Final Remedial Investigation Report

Homestake Mining Company Superfund Site

Operable Unit 1: Tailings Seepage Contamination of Groundwater Aquifers

Operable Unit 2: Long-Term Tailings Stabilization, Surface Reclamation and Site Closure

Near Grants, New Mexico

March 12, 2020

90041190

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Appendices

Appendix **Title**

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Acronyms and Abbreviations

ABSd	dermal absorption factor
ACM	asbestos containing materials
ACOE	U.S. Army Corps of Engineers
ACZ	ACZ Laboratories, Inc., of Steamboat Springs, Colorado
AF	dermal adherence factor
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
AUF	Area Use Factor
bgs	below ground surface
BKG	background
°C	Degrees Celsius
CDI	cancer daily dose intake
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cm	centimeters
cm^2	centimeters squared
COC(s)	contaminant(s) of concern
COPC(s)	chemicals of potential concern
cpm	counts per minute
CR	cancer risk
Cs-137	Cesium 137
CSF	cancer slope factor
CSF_{ABS}	absorbed cancer slope factor
CSM	conceptual site model
DAD	dermally absorbed dose
DIR	Dietary Ingestion Rate
DL	detection limits
DOE	Department of Energy
DP	Discharge Permit
d/y	days per year
ED	exposure duration
EF	exposure frequency
Energy	Energy Laboratories, Inc., of Billings Montana and Casper, Wyoming

EP	Evaporation Pond
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
ERG	Environmental Restoration Group, Inc.
ERT	Electrical resistivity tomography
ESV(s)	ecological screening value(s)
ET	exposure time
˚F	Degrees Fahrenheit
ft	feet
ft/day	feet per day
ft/ft	foot per foot
gpd/ft	gallons per day per foot
GSF	Gamma Shielding Factor
GI_{ABS}	gastrointestinal absorption factor
gpm	gallon per minute
H	Henry's Law
HDPE	high-density polyethylene
HHRA	human health risk assessment
HMC	Homestake Mining Company
HPRO	high pressure reverse osmosis
HQ	hazard quotient
HSCM	Hydrogeologic Site Conceptual Model
IUR	inhalation unit risk
IRS	soil ingestion rate
IRIS	Integrated Risk Information System
K-40	potassium-40
KM	Kaplan-Meier
Kp	dermal permeability coefficients
LANL	Los Alamos National Laboratory Ecorisk Database
LOAEL	Lowest Observed Adverse Effect Levels
LPRO	low pressure reverse osmosis
LTP	Large Tailings Pile
LTA(s)	Land Treatment Area(s)
m^3/kg	cubic meters per kilogram
MCL(s)	EPA Maximum Contaminant Level(s)

MDC	minimum detectable concentration
m/sec	meter per second
MDL(s)	method detection limit(s)
µCi/ml	micro Curie per milliliter
mg/cm^2	milligram per centimeter squared
mg/kg	milligram per kilogram
mg/kg-d	milligram per kilogram body weight per day
mg/L	milligram per liter
ml/d	milliliter per day
mg/m^3	milligram chemical per cubic meter of air
mrem/yr	millirem per year
msl	mean sea level
n	number
N	No
NA	not applicable
NAREL	EPA National Air and Radiation Environmental Laboratory in Montgomery, Alabama
NAWQC	National Ambient Water Quality Criteria
ND	not detected
NHNM	Natural Heritage New Mexico
NM	New Mexico
NMED	New Mexico Environment Department
NMEID	New Mexico Environmental Improvement Division
NMSU	New Mexico State University
NOAEL	No Observed Adverse Effect Levels
NRC	Nuclear Regulatory Commission
NWS	National Weather Station
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
OSL	optically stimulated luminescence
OU	Operable Unit
Pb-212	Lead-212
pCi/g	picoCurie per gram
pCi/L	picoCurie per liter
pCi/m^2s	picoCurie per square meter per second
PEF	particulate emission factor

PRG(s)	Preliminary Remediation Goal(s)
Ra-223	Radium 223
Ra-226	Radium-226
Ra-228	Radium-228
RadPRG(s)	Radionuclide Preliminary Remediation Goal(s)
RAGS	Risk Assessment Guidance for Superfund
RAOs	Remedial Action Objectives
RESL(s)	Radioecological Screening Level(s)
RfC	reference concentration
RfD	reference dose
RFD_{ABS}	absorbed reference dose
RI	Remedial Investigation
RL(s)	reporting limit(s)
RME	reasonable maximum exposure
RMM	reformulated mixing model
Rn-222	Radon 222
RO	reverse osmosis
ROD	Record of Decision
ROPC(s)	radionuclide(s) of potential concern
RR	risk ratio
RSLs	regional screening levels
SA	skin surface area
SAG	San Andres-Glorietta
SE	stripping efficiency
SFi	cancer slope factor - inhalation
SFo	cancer slope factor – oral
Site	Homestake Mining Company Superfund Site, Cibola County, New Mexico
SLERA	Screening Level Ecological Risk Assessment
SMC	San Mateo Creek
SMDP	Scientific/Management Decision Point
spp	species
SLs	screening levels
SM	silty sand
SP-SM	poorly graded sand to silty sand
SSL(s)	soil screening level(s)

STP	Small Tailings Pile
SW	surface water
TDS	total dissolved solids
TEDE	total effective dose equivalent
Th-228	Thorium 228
Th-230	Thorium-230
Th-232	Thorium 232
Th-234	Thorium 234
Tl-208	Thallium 208
tpd	ton per day
TRV	toxicity reference value
U	uranium
U-234	Uranium 234
U-235	Uranium 235
U-238	Uranium 238
µg/kg	microgram per kilogram
µg/L	microgram per liter
U_3O_8	triuranium octoxide
UCL	upper confidence limit
UCL95(s)	upper 95th percentile confidence limit(s)
U-nat	Uranium natural
UN-HP	United Nuclear-Homestake Partners
USCB	United States Census Bureau
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USL	upper simultaneous limit
V	vanadium
WIR	Water Ingestion Rate
WRCC	Western Regional Climate Center
Y	Yes

1 Introduction

1.1 Purpose of the Report

This Remedial Investigation (RI) Report describes the nature and extent of uranium mill-related contamination in soil and groundwater at the Homestake Mining Company Superfund Site, Cibola County, New Mexico (Site). Refer to Figure 1-1 for a plan view of the Site that is the subject of this RI Report. The basis for this RI Report are the documents in the administrative record that describe prior response actions and data collection activities that have been completed at the Site.

Administratively, the Site has been divided into three Operable Units (OUs):

- OU1: Tailings seepage contamination of groundwater aquifers
- OU2: Long-term tailings stabilization, surface reclamation and Site closure
- OU3: Radon concentrations in neighboring subdivisions

OU1 and OU2 are addressed together in this RI Report. In 1989, the United States Environmental Protection Agency (EPA) issued a Record of Decision (ROD) for OU3.

1.2 Site Location and Ownership

The Site is located approximately 5.5 miles north of Milan, New Mexico, in Cibola County (refer to Figure 1-1).

Homestake Mining Company of California (HMC) opened and began operating the mill facility in 1958 under two partnerships, with HMC acting as operating partner for both. Beginning in 1981, HMC became both the sole owner and operator. In 2001, HMC merged with Barrick Gold Corporation. Currently, HMC is a wholly owned subsidiary of Barrick Gold Corporation and owns the Homestake Facility.

1.3 Site Description

The Site includes:

- The former uranium milling operation areas, tailings piles, and facilities used for on-going closure operations, including collection and evaporation ponds, water treatment plant, and support facilities. These features are fenced and included within an area licensed by the Nuclear Regulatory Commission (NRC) for uranium milling and closure activities. The license boundary includes approximately 1,085 acres (refer to Figure 1-2). This area is referred to as the Homestake Facility.
- The location of the release (or releases) of hazardous substances and CERCLA eligible pollutants and contaminants associated with the Homestake Facility and wherever those hazardous substances, pollutants and contaminants have come to be located.
- Four hay fields, referred to as land treatment areas (LTAs), which were historically irrigated with groundwater extracted as part of on-going remediation activities at the Site. Land

treatment has occurred at two fields using flood irrigation (120 and 24 acres) and two fields using center pivot units (100 and 150 acres). Locations of LTAs are shown on Figure 1-2.

1.4 Site History

The Site is located within the Grants Mineral Belt in New Mexico, which produced more uranium than any other district in the world during the period of 1951-1980 (McLemore and Chenoweth, 1989). Situated within the San Mateo Creek (SMC) Basin, more than 85 legacy uranium mines with recorded production are located upgradient of the Site (NMED 2009a). Refer to Figure 1-3 for a location of some of the mines in relation to the Site. A number of legacy uranium mines generated liquid wastes that included water produced from mine dewatering operations that were discharged to the surface.

Uranium milling operations occurred at the Homestake Facility from 1958 until 1990. Currently there are closure activities occurring at the Site, including security, groundwater remediation operations, and environmental monitoring. The following paragraphs provide an overview of Site history, including:

- Mill operation history, focusing on the deposition of tailings, which are the primary contamination source material at the Site
- Decommissioning and closure activities completed to date
- Groundwater remediation activities completed to date

1.4.1 Mill Operation History

There were originally two separate mills that operated independently: the larger mill with a nominal milling capacity of 1,750 tons per day (tpd) and a smaller mill with a nominal milling capacity of 750 tpd. Each had separate tailings piles. The smaller of the two piles is called the Small Tailings Pile (STP) and the larger is called the Large Tailings Pile (LTP). In 1961, the two milling facilities were combined and milling capacity expanded to a combined 3,400 tpd.

Originally, tailings were deposited into only one cell of the LTP. In 1966, a cell adjacent to and west of the existing cell was added. From 1966 until 1990, tailings disposal alternated between the two cells to maintain optimal operating conditions. The initial perimeter dike for the LTP was constructed by compacting 6-inch lifts of natural soils excavated from within the tailings pile area. The starter dike was constructed to a height of approximately 10 feet and a width of approximately 10 to 15 feet at the crest and 25 to 30 feet at the base. During operations, the perimeter dike was raised to add volume for deposition of tailings.

The tailings piped to the LTP were separated using hydrocyclone equipment. Hydrocycloning separated the tailings by grain size, into a coarse fraction comprised mostly of sand and a fine fraction that contained mostly silt. The coarse fraction was deposited downstream of the dike crest to raise the dike, and the fine fraction was deposited upstream of the dike crest toward the center of each cell. The tailings liquid was recovered through the use of two decant towers and the water reused in the mill process. When production rates were low during the latter stages of mill operations, hydrocyclone separation was not used. Instead, the tailings slurry was discharged directly into the tailings pond. This method of operation confined disposal to a single cell, while the other cell was used for evaporation.

Tailings deposited within the STP were contained by an embankment dike composed of compacted natural soils. The embankment dike was compacted by heavy equipment and raised to a height of 20 to 25 feet. The crest was a minimum of 10 feet wide and the base approximately 40 feet wide.

Both mills were alkaline leach-caustic precipitation processes designed to concentrate uranium oxide from ores with average grades of 0.05 to 0.30 percent triuranium octoxide (U_3O_8). A detailed summary of the milling operation, including process chemistry, tailings characteristics, and slope stability analysis for the tailings piles is provided in Appendix A to this document (HMC 2012).

1.4.2 Description of Completed Decommissioning Activities

Milling operations ceased on February 2, 1990. In January 1991, HMC submitted a proposed tailings reclamation and mill decommissioning plan to NRC (AKG et al. 1991). On October 29, 1993, HMC submitted an Updated Reclamation Plan that superseded the 1991 submittal (AKG and Jenkins 1993). Mill decommissioning and reclamation activities for soil cleanup began in 1993.

1.4.2.1 Mill Decommissioning and Burial

Demolition activities began on May 5, 1992, with removal of asbestos-containing materials (ACM) from various mill facilities prior to demolition. The New Mexico Environment Department (NMED) approved burial of the asbestos in the tailing impoundment (AKG 1996). The ACM was disposed of in a disposal pit at the toe of the original slope of the LTP (refer to Figure 1-4). Residual byproduct and scale materials were removed from milling process components before these components were demolished and buried. Byproduct materials consisting primarily of scale, sludge, and tailings in tank precipitators were removed by mechanized equipment and by hand tools and hauled to the LTP for burial. Demolition of milling facilities was accomplished using heavy equipment and was completed by March 1995 (AKG 1996). Mill decommissioning at the Site met applicable standards in 10 CFR Part 40 and applicable license conditions (HMC 2013a).

Mill debris was buried in pits located within the mill area or south of the LTP (refer to Figure 1-4). Burial pits were excavated using heavy equipment and debris was placed into pits in lifts up to 5 feet thick. Slurry grout was poured into the pit until it had filled the voids and reached a level approximately equal to the top of the debris lift. This process was repeated until each pit was filled with debris and slurry. Debris pits were capped with up to 4 feet of soil (AKG 1996).

1.4.2.2 Removal of Windblown Tailings Contamination Areas

In 1987, HMC committed to a contaminated soil cleanup effort in which soil exceeding 5 picocuries per gram (pCi/g) Radium 226 (Ra-226) above background in the top 15 centimeters (cm) of soil (HMC 1987) would be remediated in accordance with 10 CFR 40 Appendix A Criterion 6 (6). Background for Ra-226 was calculated to be 5.5 pCi/g. Thus, the cleanup level was set at 10.5 pCi/g (5.5 pCi/g background + 5 pCi/g). The cleanup of windblown contaminated soils began early in 1988 (Environmental Restoration Group, Inc. [ERG] 1995). In February 16, 1989, a plan approved by NRC as License Condition No. 19 committed HMC to remediating certain areas near the tailings piles that exceeded the 10.5 pCi/g cleanup criterion for Ra-226 (ERG 1995) in the top 15 cm of soil. At depths greater than 15 cm below the surface, the Ra-226 cleanup criterion was 20.5 pCi/g (5.5 pCi/g background + 15 pCi/g) in accordance with 10 CFR 40 Appendix A Criterion 6 (6). There was a period of inaction during soil cleanup due to decommissioning activities. After the mill decommissioning was complete, cleanup of the windblown contamination and other off-pile

contaminated materials resumed in 1993 under Licence Condition 29C, which also required the cleanup be completed in accordance with 10 CFR 40 Appendix A Criterion 6 (6).

Surface soils from approximately 1,200 acres of land were removed (refer to Figure 1-5). Most of the excavated soils were placed on the eastern side slope of the LTP, but significant quantities were placed on the southern end of the STP and the aprons of the LTP. Subsequent to placement, deposited soils were covered with soil and rock as described in the section below.

1.4.2.3 Placement of Cover Materials

Cover materials were placed on the former mill area, the LTP, and the STP as part of the mill decommissioning efforts completed in the mid-1990s:

- At the STP, 1 foot of cover material was placed in areas outside of Evaporation Pond (EP) 1.
- At the LTP, extensive regrading was completed to fill in the tailings ponds and flatten the side slopes to improve stability. Cover material was placed on the side slopes at a thickness varying from 2 to 3.8 feet, as needed to effectively buffer radon emissions. In addition, 6 to 9 inches of rock cover was placed on the side slopes for erosion protection. On the top of the LTP, HMC placed 1 foot of cover material. Since this initial placement, additional cover has been placed on the LTP to fill depressions caused by settlement, to improve drainage, and to address specific areas with elevated radon flux measurements.
- At the former mill area, located southeast of the LTP (refer to Figure 1-2), an average of 2 feet of contaminated soil (containing radium levels above the cleanup standard) was removed following completion of mill demolition. Excavated soils were transported to the east end of the LTP or the south end of the STP for burial. Areas that had been excavated were backfilled with clean alluvial soils. After backfilling, at least 2 feet of clean soil was placed over the entire mill area. The average thickness of material placed was 4.7 feet. The rock was the same crushed basalt used for erosion protection on the impoundment surfaces. During the period of November 16, 1995, to December 10, 1995, this rock was applied in a single lift of 2 to 6 inches, and then mixed with the underlying soil to a depth of not more than two times the rock lift thickness. After the mill cover material was placed, gamma surveys were conducted to verify gamma emission rates were acceptable at the cover surface.

Cover materials were obtained from borrow areas near the LTP, STP, mill area, and evaporation and collection ponds. Figure 1-5 is a plan view which shows borrow area locations.

Drainage was reestablished following soil cleanup activities, with the work being conducted in 1994 and 1995. Drainage areas within the Homestake Facility (including areas adjacent to the LTP, mill and ore storage areas, windblown soil cleanup areas, and borrow areas) were regraded and surface channels established for drainage. Constructed surface channels are shown on Figure 1-6.

1.4.3 Groundwater Remediation Activities Completed to Date

In 1975, at the request of the New Mexico Environmental Improvement Division (NMEID), EPA undertook a study of the impacts resulting from uranium mining and milling activities in the Grants Mineral Belt. EPA determined that groundwater in the alluvial aquifer, which was being used for domestic use, had elevated selenium levels. Based on these findings, a Groundwater Protection

Plan was signed in 1976 between NMEID and United Nuclear-Homestake Partners (UN-HP), which was the owner of the Homestake Facility at that time (NMEID and UN-HP 1976).

In 1976, UN-HP determined that there was a contaminant plume in the alluvial aquifer that originated from the LTP and was moving to the south and west (HMC and Hydro-Engineering 2010). UN-HP installed and operated a line of groundwater wells along the southern facility boundary between the LTP and the downgradient residential subdivisions in 1977 to create a hydraulic barrier to limit movement of the alluvial aquifer contaminant plume across the facility boundary (MFG 2006). Since 1977, HMC has continually improved and expanded the scope and operation of this remediation system. A comprehensive history of the changes made to the system is provided in the *Grants Reclamation Project Corrective Action Program* (CAP) which was submitted to NRC in 2019. The following is a brief summary of the changes and improvements made to the groundwater remediation system:

- 1977–1983—Multiple hydraulic containment and collection wells were installed in the alluvial aquifer.
- 1984—Hydraulic containment of the Upper Chinle aquifer was initiated.
- 1986—Installation of extension of the Milan water supply for Broadview Acres, Felice Acres, Murray Acres, and Pleasant Valley Estates subdivisions.
- 1990—EP-1 was constructed within the footprint of the STP to assist in the dewatering of the LTP and to hold water pumped from the collection wells. Additional hydraulic containment and collection wells were installed in the alluvial aquifer.
- 1992—Toe drains were installed around the tailings.
- 1993–2000—During this period, corrective action and monitoring well networks were revised through addition and abandonment of wells.
- 1996—Use of EP-2 began in March.
- 1999—The reverse osmosis (RO) treatment unit was added; treated water is used for hydraulic containment of the alluvial aquifer.
- 2000—Irrigation of 270 acres as a means to manage extracted groundwater was initiated.
- 2002—60 acres of irrigation area were added and RO plant capacity increased from 300 gallons per minute (gpm) (one unit) to 600 gpm (two units).
- 2002–2009—During this period, corrective action, and monitoring well networks were revised through addition and abandonment of wells.
- 2004–2005—64 acres of irrigation area were added.
- 2010—EP-3 was constructed and commissioned.
- 2012—Land Application program ceased operation
- 2012—300 Zeolite pilot treatment started operation.
- 2015—RO Plant was expanded to a maximum throughput of 1200 gpm with the addition of a 600 gpm low pressure skid, a 250 gpm high pressure skid, and two microfiltration skids to replace the existing sand filters amongst other updates.

- 2016—1200 GPM Zeolite system started operation for off-Site water treatment.

Groundwater remediation at the Site is ongoing. The current system includes multiple components that are frequently adjusted based on evaluation of monitoring data. Figure 1-7 provides a diagram of the water balance for the remediation system, based on 2018 data. Quantities displayed in Figure 1-7 vary from year to year based on operational changes, local conditions, and other factors. The following provides a brief description of the components:

- Hydraulic Containment. Water is added into the alluvial, Upper Chinle, and Middle Chinle aquifers to create a hydraulic barrier to limit the movement of contaminated groundwater. The hydraulic barrier in the alluvial aquifer is created and maintained downgradient of the LTP with dozens of wells used to introduce the water into the alluvium and more than 6,000 linear feet of infiltration lines (HMC 2012). Water added to the alluvial formation to create a hydraulic gradient is derived from several sources, including the RO plant product water, less contaminated areas of the alluvial aquifer, the Middle Chinle aquifer, and the San Andres-Glorietta (SAG) aquifer. In 2018, an average of 678 gpm was introduced into the alluvial aquifer to maintain the hydraulic barriers. In addition, an average of 21 gpm and 46 gpm was introduced into the Upper Chinle and Middle Chinle aquifers, respectively (HMC 2019a).
- Tailings Flushing. Starting in 2000 and continuing through mid-2015, water was introduced into the LTP to expedite the mass flux of contaminants from the tailings.
- RO Treatment. The RO treatment plant removes contaminant mass from groundwater extracted upgradient of the hydraulic barrier. Plant influent is composed primarily of groundwater from the alluvial, Upper Chinle, and Middle Chinle aquifers (approximately 90 percent) and collection pond water (approximately 10 percent), which receives water from the RO plant (miscellaneous overflows). In 2018, approximately 279 gpm of RO plant influent came from the alluvial aquifer collection wells, 48 gpm from the collection ponds, 130 gpm from Upper Chinle aquifer extraction wells, and 34.3 came from Middle Chinle aquifer extraction wells. As indicated on Figure 1-8, the RO plant treatment process includes lime clarification and microfiltration as pre-treatment to the RO treatment units. There are four RO treatment trains. The first is a low pressure RO #1 (LPRO#1) skid (300 gpm capacity) that also has a high pressure RO (HPRO) skid (75 gpm capacity) to treat the brine from LPRO#1. The second train, LPRO#2, only has an LPRO treatment skid (300 gpm). The third unit has a 600 gpm low-pressure RO skid and a 250 gpm high-pressure skid. The clarifier, sand filters (which has been replaced with microfiltration), LPRO#1, and HPRO treatment systems were originally designed and constructed in 1999 for 300 gpm treatment capacity. LPRO#2 was added in in 2003 and the third unit was added in 2015, bringing the maximum theoretical RO plant treatment capacity to 1,200 gpm. Accounting for scheduled maintenance, the operational capacity is about 1,000 gpm.
- Evaporation. There are three lined evaporation ponds (EP-1, EP-2, and EP-3) in use at the Homestake Facility (refer to Figure 1-2) to concentrate uranium and other contaminants. The evaporation system receives water from the extraction wells in the alluvial and Upper Chinle aquifers and brine from the RO plant. In 2018, average evaporation from the ponds was approximately 200 gpm, while receiving an average of 33 gpm from the collection

ponds, 85 gpm of brine from the RO plant, 23 gpm from the zeolite treatment plant, and 28 gpm from precipitation.

1.4.4 HMC Supply of Drinking Water to Residential Subdivision

Pursuant to the 1983 Agreement between HMC and the EPA, HMC financed the extension of the Village of Milan's municipal water supply to the residences of the subdivisions and made payments to the Village of Milan for the residents' water usage over a period of ten years. The extension of the water supply was completed in 1985 (EPA 2006). In late 2018, HMC restarted the water supply payment program for the subdivisions downgradient of the Site.

The New Mexico Environment Department and HMC entered into a Memorandum of Agreement pursuant to which HMC voluntarily agreed to connect residents within a designated area near the Site to the Village of Milan's water system on January 21, 2009 (NMED 2009b). This work has been completed.

1.5 Regulatory History and Authorities

The following paragraphs provide a summary of the regulatory history for the Site and a brief description of regulatory authorities. A complete discussion of regulatory authority at the Site is available in the *Decommissioning and Reclamation Plan Update 2013* (HMC 2013a), submitted to NRC in 2013.

Uranium milling and closure operations at the Homestake Facility have been regulated through radioactive materials licenses since milling operations began at the Homestake Facility in 1958:

- From 1958 through 1974, the Homestake Facility was regulated by the Atomic Energy Commission under License Number SUA-708.
- In 1974, regulatory authority was granted to the New Mexico Environmental Improvement Board.
- In 1986, regulatory authority over uranium milling and closure operations at the Homestake Facility was transferred to NRC from the State of New Mexico and the Homestake Facility was granted license SUA-1471, replacing license SUA-708.

In 1983, at the request of the State of New Mexico, the Site was added to EPA's Superfund National Priorities List. As a result, the Site's cleanup activities are being overseen under EPA's Superfund Program, in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). Pursuant to a 1993 memorandum of understanding between EPA and NRC, NRC is designated as the lead regulatory agency for reclamation and closure activities, while EPA has responsibility to monitor reclamation activities to assure attainment of applicable or relevant and appropriate requirements under CERCLA.

The State of New Mexico asserts regulatory authority at the Site through a number of state environmental statutes and regulations. Currently the Site maintains groundwater discharge permit DP-200, which regulates several aspects of the ongoing groundwater cleanup program and related RO water treatment system. A former Discharge Permit (DP-725) that regulated the discharge to the evaporation ponds and two existing collection ponds has been rolled into DP-200. The New

Mexico Office of State Engineer regulates construction and operation of the evaporation ponds, tailing piles, water appropriations, and well permits.

The State of New Mexico is also supporting EPA for CERCLA compliance.

1.6 Report Organization

This report is generally organized as suggested in the EPA guidance document entitled *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988). Usually RI Reports includes a section describing the field activities completed for the RI. Because this RI presents data collected from numerous field activities over a long period of time, the section describing field activities is omitted.

The RI Report is organized into the following major sections:

Section 1.0 – Introduction – This section describes the purpose of the RI and summarizes Site setting, Site history, and prior work completed at the Site.

Section 2.0 – Site Characteristics – This section provides a brief description of the environmental setting.

Section 3.0 – Nature and Extent of Contamination – This section provides a description of the contaminants present at the Site due to milling operations and the extent of the contaminants.

Section 4.0 – Contaminant Fate and Transport – This section provides a qualitative discussion of contaminant migration routes and persistence in the environment.

Section 5.0 –Risk Analyses – This section discusses human and ecological risks present at the Site.

Section 6.0 – Conclusions – This section presents general conclusions.

Section 7.0 – References – This section provides full references for all citations in the body of the report.

2 Site Characteristics

2.1 Surface Features

A brief description of the major Site surface features is provided in the following paragraphs.

- Large Tailings Pile: The LTP contains approximately 21 million tons of tailings, occupies approximately 215 acres, and is approximately 70 to 90 feet tall with side slopes of 5.0 horizontal and 1.0 vertical.
- Small Tailings Pile: The STP contains approximately 1.2 million tons of tailings, occupies approximately 40 acres, is approximately 20 to 25 feet tall, and has similar side slopes as the LTP.
- EP-1: EP-1 was constructed on top of the STP in 1990 to assist with dewatering the LTP. It has a capacity of approximately 285 acre-feet and covers 26.2 acres. It is lined with a non-woven fabric impregnated and overlain with petroleum-based asphaltic material.
- EP-2: EP-2 was designed and constructed in 1995 to increase storage and treatment capacity for contaminated groundwater. The pond is located between the STP on the east and the collection ponds on the west, has an area of 17.48 acres, and a maximum storage capacity of 317.43 acre-feet. It is lined with an upper primary liner (60 mil thick high-density polyethylene [HDPE]), an intermediate layer (the detection or geogrid layer), and a secondary liner (bottom) that is 40 mil HDPE.
- EP-3: EP-3 is located north of the LTP and was constructed in 2010. It consists of two cells—each approximately 13.3 acres (total of 26.6 acres) of water surface at maximum pool level, and a total capacity of approximately 286 acre-feet. The pond is lined with a three-part liner system consisting of two HDPE membranes (primary and secondary liners) and an HDPE geonet leak detection/drainage layer between the two membranes. The primary liner membrane is 60 mil thick, the secondary liner is 40 mil thick, and the geonet is a minimum of 0.20 inch thick.
- West and East Collection Ponds: The collection ponds are each approximately 2.5 acres and are lined with a non-woven fabric impregnated and overlain with petroleum-based asphaltic material. They are located west of the STP and were constructed in 1985 to support water treatment operations.

Other surface features at the Site include administration buildings northeast of the LTP, a water treatment building west of the collection ponds, two water towers southeast of the LTP, and a meteorological station south of EP-2.

2.2 Topography

The Site is located in a semi-circular valley defined by a series of mesas that are approximately 7,000 to 8,000 feet above mean sea level (msl). The Site elevation is approximately 6,600 feet above msl. Local topography in the valley is generally flat with some low, rolling hills and shallow arroyos. The Site is located near the confluence of the ephemeral Lobo Creek and SMC drainages, both tributaries of the Rio San Jose.

2.3 Climate

The climate of western New Mexico and the Site is generally a mild, arid to semi-arid, continental climate characterized by low precipitation, abundant sunshine, low relative humidity, and a large annual and diurnal (day and night) temperature range. Temperature and precipitation are largely controlled by elevation and slope aspect. Summer precipitation generally falls due to southeasterly circulation from the Gulf of Mexico, whereas winter precipitation is generally associated with fronts moving eastward from the Pacific Ocean (New Mexico State University [NMSU] 2013). Most precipitation falls in the form of rain during the late summer and early autumn. Severe thunderstorms are not common in the area, but short-lived cloudbursts during the summer can produce flash flood conditions in nearby drainages and may be accompanied by significant lightning and hail events.

Climate data was collected from the following sources:

- The National Weather Station (NWS) at Grants Airport, located approximately 5.5 miles south of the Site at an elevation of approximately 6,530 feet above msl.
- An on-Site meteorological station maintained by HMC located south of EP-2 (refer to Figure 1-2) and equipped to measure horizontal wind speed and wind direction at 10 meters, temperature at 9.5 meters, solar radiation at 9.5 meters, relative humidity at 9.5 meters, precipitation at 0.4 meter, and barometric pressure at 8.8 meters.

2.3.1 Temperature

Long-term historical average monthly maximum and minimum temperatures measured at the Grants Airport NWS are presented in Table 2-1.

Table 2-1 Average Monthly Max. and Min. Temperatures at Grants, NM

Month	Grants, NM[1] °F		Month	Grants, NM[1] °F	
January	Max	56.1	July	Max	89.5
	Min	17.9		Min	52.3
February	Max	58.3	August	Max	85.5
	Min	20.9		Min	50.4
March	Max	66.2	September	Max	81.2
	Min	25.0		Min	44.2
April	Max	71.7	October	Max	73.5
	Min	30.4		Min	34.3
May	Max	80.5	November	Max	63.9
	Min	38.0		Min	25.0
June	Max	89.6	December	Max	56.9
	Min	47.4		Min	18.3
Period of Record	January 1986 to December 2018		Annual Average	Max	73.1
				Min	33.9

Source: WRCC 2019
1. Grants Airport NWS
°F = degrees Fahrenheit

2.3.2 Precipitation

Long-term historical average monthly precipitation and annual precipitation are summarized for the Grants Airport NWS in Table 2-2.

Table 2-2 Average Monthly Precipitation

Month	Grants, NM[1] inches	Month	Grants, NM[1] inches
Period of Record: January 1986 to December 2018			
January	0.65	August	2.63
February	0.70	September	1.47
March	0.76	October	1.11
April	0.85	November	0.69
May	0.75	December	0.70
June	0.66	Average Annual Precipitation Total	13.6
July	2.62		

Source: WRCC 2019
1. Grants Airport NWS

Precipitation in the area averages approximately 14 inches per year. The majority of annual precipitation typically occurs during July, August, and September. Summer precipitation is typically associated with thunderstorms, which form with the arrival of warm, moist air from the Gulf of Mexico. Evaporation is highest in May, June, and early July; the onset of the rainy season, usually in mid-July, reduces evaporation in the latter summer months. Winter precipitation in the form of

snowfall usually occurs when storms move eastward from the Pacific Ocean or northeast from the Gulf of California (NRC 2008).

2.3.3 Wind

The prevailing wind direction at the Grants Airport, located 5.5 miles south of the Site, is from the northwest (WRCC 2013). Surface wind speeds at the Grants Airport are highest in the spring, with a maximum monthly average of 14 miles per hour during April (New Mexico Climate Center 2013).

Wind speed and wind direction are measured hourly at the on-Site meteorological station. Wind roses for daytime and nighttime from 2009-2012 are shown on Figures 2-1 and 2-2, respectively. The hourly average wind speed exceeded 8.8 meters per second (m/sec) and 11.1 m/sec 4.25 percent and 1.34 percent of the time, respectively (HMC 2013a).

Historic data indicates that dominant (strongest) winds are from the west and southwest and are associated with frontal systems moving from the Pacific Ocean. High spring winds in the area are known to create periods of dusty conditions, which may occur for several days during the months of March, April, and May. Moderate winds from the south-southeast are common and typically associated with summer storms sourced in the Gulf of Mexico. Most of the light northeasterly breezes occur at night. Nighttime is relatively calm compared to daytime hours (HMC 2013a).

2.4 Soils

Surface soils at the Site are composed of San Mateo alluvium with lesser amounts of aeolian deposits (NRC 2008). Alluvial sediments beyond the Site boundaries consist of the Lobo Canyon alluvium to the east and the Rio San Jose alluvium to the west. Alluvial sediments at and in the vicinity of the Site were deposited on an uneven bedrock surface composed of the Chinle Formation.

2.5 Geology

The Site is located in the southeastern part of the Colorado Plateau physiographic province and is mostly on the south flank of the San Juan Basin. Figure 2-3 presents a portion of the geologic map of the Grants quadrangle (Dillinger 1990). The region experienced minor structural deformation (regional folding and block uplift) associated with formation of the Zuni Uplift, which is characterized by a northwest-trending anticline composed of Precambrian crystalline basement rocks overlain by Permian to Jurassic sedimentary rocks. Regional structural features are shown on Figure 2-4. Sedimentary rocks were uplifted during the Laramide Orogeny near the end of the Late Cretaceous through the Eocene, approximately 40 million to 80 million years before present (Cooley et al. 1969; Anderson et al. 2003; Lorenz and Cooper 2003). Bedrock units at the Site consist of the Glorietta Sandstone (Early Permian), San Andres Limestone (Early Permian), and Chinle Formation (Late Triassic). As a result of Laramide deformation, these bedrock units have a shallow northeastern dip direction of approximately 3 to 10 degrees (Kelley 1967).

The development of more recent northeast-trending, high-angle normal faulting associated with the Rio Grande Rift resulted in minor fault displacements in this part of New Mexico. The large northeast-striking San Mateo normal fault located northeast of the Site has a vertical displacement of as much as 450 feet (Santos 1970). Two small-scale normal faults near the Site (referred to as the West Fault and the East Fault) are shown on Figure 2-3. The West Fault and East Fault are part of

the San Mateo fault zone or may be part of the San Mateo fault zone (Thaden et. al., 1967). These two faults are approximately vertical, exhibit an east-side-down sense of shear, and act as impermeable barriers to groundwater flow within the permeable units of the Chinle Formation near the Site. However, the East Fault entirely loses slip displacement immediately south of the Felice Acres subdivision (that is, aquifer units are not vertically offset) (HMC and Hydro-Engineering 2010). With the exception of the southern terminus of the East Fault, structural offset within the Chinle Formation has resulted in the juxtaposition of permeable sandstones with impermeable mudstones and siltstones across the two faults. The magnitude of structural offset of the underlying SAG regional aquifer is much lower than the vertical thickness of the unit and does not appear to significantly affect groundwater flow.

In general, progressively older units of Cretaceous through Permian bedrock outcrop from northeast to southwest as a result of regional deformation and subsequent erosion. The overlying Tertiary units consist predominantly of widely scattered Middle Tertiary (Pliocene and Miocene) andesite and basalt surficial flows related to the Mount Taylor volcanic field cap. The Quaternary units consist of localized andesite and basalt flows and widespread alluvium, which is composed of eroded bedrock materials in the vicinity.

The Quaternary alluvium directly overlies the Chinle Formation and San Andres Limestone above a pronounced angular unconformity. As a result, sandstone units within the underlying Chinle Formation are abruptly truncated at the base of the alluvium. The Chinle Formation sandstone units are laterally continuous and separated by thick sections of low permeability shale. The Quaternary alluvial materials at the Site were partly derived from the erosion of ore-bearing bedrock. As a result, the alluvium contains significant concentrations of naturally occurring uranium, as well as selenium and molybdenum, which are typically present in uranium deposits (HMC 2012). Widespread Quaternary andesite and basalt flows are interbedded with the alluvial deposits. These localized volcanic flows were encountered during drilling investigations to the west of the Large Tailings Pile (LTP) and are limited to the area west of the Pleasant Valley Estates neighborhood. The thickness of the basalt encountered during drilling has a maximum thickness of 109 feet (average 49 feet).

Depictions of the three-dimensional geology and hydrogeology at the Site are illustrated on Figure 2-5, and detailed hydrogeological cross-sections A-A' through D-D' are depicted in Figures 2-6 through 2-10.

2.6 Hydrogeology

The Site is underlain by unconsolidated alluvial materials resting on the incised surface of the Late Triassic Chinle Formation. The alluvial materials are a heterogeneous mixture of sand, silt, clay, and gravel and comprise an aquifer with estimated hydraulic conductivities ranging from 10 to over 200 feet per day (ft/day) (HMC and Hydro-Engineering 2010). Depth to groundwater is 40 to 60 feet below ground surface at the Site. The thickness and extent of the saturated portion of the alluvial aquifer is shown on Figure 2-11 (HMC 2012).

Though the Chinle Formation is largely comprised of shale, there are three water-bearing units within the Chinle, including the Upper and Middle Chinle sandstone aquifer, and the Lower Chinle aquifer consisting of a zone of enhanced water yield within the shale formation. The extent of the Upper, Middle, and Lower Chinle aquifers are presented on Figure 2-12, Figure 2-13, and Figure 2-

14, respectively. A regional aquifer, the Permian-age San Andres Formation, exists at depth below the Site, and predominantly consists of limestone with subsidiary sandstones and shale. The extent of the SAG aquifer is shown in Figure 2-15.

Bedrock units have tilted and faulted near the Site. As a result, all three Chinle aquifers subcrop with the overlying alluvial aquifer. Water exchange occurs between the alluvial aquifer and the Chinle aquifers creating mixing zones. In the mixing zones, there is hydraulic communication between aquifers (U.S. Army Corps of Engineers [ACOE] 2010).

The following paragraphs describe Site aquifers.

2.6.1 Alluvial Aquifer System

The shallow unconfined aquifer in the area, the alluvial aquifer, includes the Quaternary Alluvium and surficial and interbedded volcanic flows. The alluvial aquifer near the Site consists of three distinct but connected alluvial systems: the San Mateo, Rio San Jose, and Rio Lobo alluvial systems, which represent the uppermost aquifer in the local groundwater system. The alluvial aquifer extends from northeast of the Site to the south and southwest, eventually joining with the more extensive Rio San Jose alluvial system (Figure 2-11).

Recent revisions were made to the interpreted extent of the Rio Lobo alluvial system. Due primarily to the ephemeral nature of the Lobo Creek, which was responsible for the deposition of the fluvial sediments that compose the Rio Lobo alluvial system, the saturated extent of this portion of the alluvial aquifer is limited to the east (Figure 2-11), where groundwater in the Rio Lobo alluvial system is directed to the southwest into a narrow alluvial channel.

Geologic information for the depth to the top of bedrock was obtained for historic borehole locations advanced in 1995 through the Rio Lobo alluvium along Lobo Creek, located more than one mile east of the Broadview Acres subdivision. The supplemental depth to bedrock information was integrated into the same 3-D geologic model that was used to model the extent of the saturated alluvium presented in the CAP submitted in 2012. The boundaries of the alluvial aquifer are defined by the intersection of the base of the alluvium (i.e., top of bedrock) with the groundwater surface. The 3-D groundwater surface (Feb 2010) that was used to bound the upper surface of the saturated portion of the alluvium presented in the 2012 CAP, was similarly used to revise the interpreted extent of the Rio Lobo alluvial system. The revised thickness and lateral extent of the saturated portion of the alluvial aquifer is shown on Figure 2-11.

2.6.1.1 San Mateo Alluvial Aquifer

The San Mateo alluvial aquifer occurs as an alluvial valley extending through the Site generally from north to south. Figure 2-4 presents the regional drainage basins including the San Mateo basin and the regional geology for the drainage areas contributing to the Site. The alluvial aquifer in and around the Site has been characterized by extensive drilling and well installation. Figure 2-16 provides the current alluvial well locations. Figures 2-17 through 2-20 are provided to present the well information in areas where data is too dense for scale of Figure 2-16. The locations of the additional maps are shown on Figure 2-16

Appendix B includes representative well logs for San Mateo alluvial aquifer. Well logs indicate the alluvial material is a very fine to coarse sand with relatively small and discontinuous silt and clay lenses. The characterization of the alluvial aquifer materials was extensive for the near up-gradient

wells with sieve analysis of drill cuttings. The well logs for wells to the south and west of the LTP indicate that materials in the alluvial aquifer throughout the Site are generally similar. The base of the alluvial aquifer for the majority of the Site occurs as a contact with the Chinle shale. Refer to Figure 2-21 for contours that represent the base of the alluvium across the Site.

Groundwater flow in the San Mateo alluvial aquifer is generally north to the south upgradient the LTP and to the southwest in the area of the LTP. Refer to Figures 2-22 through 2-26 for interpretation of alluvial groundwater flow directions based on data collected during 2014. An artificial hydraulic barrier that is part of the current remediation system creates a zone on the southern and western sides of the LTP area where the natural gradient is artificially interrupted by a combination of collection and injection operations.

The San Mateo alluvial system at the northern portion of the site along County Road 63 is characterized by a deeper paleochannel under the western portion of the LTP with a gradual slope to the east and a bedrock ridge creating a discontinuity in the alluvial sediments to the west. These features are shown in the base of alluvium mapping depicted on Figure 2-21 and in cross sections interpreted from geophysics on Figures 2-47 and 2-48. The bedrock ridge, which trends roughly north-south, was encountered in a number of borings, including SX, SW, S12, S and, most recently, BK4. Refer to Figure 2-46 for the location of the borings. At boring BK4 a sandstone unit was encountered at 35 feet bgs. The sandstone is permeable and saturated at 43 feet bgs. However, at historical water levels and likely future water levels, the ridge may have some effect on alluvial ground water flow coming into the site from the north, especially when considering that historic water levels of the alluvial aquifer were significantly lower than they are today. The lower water levels measured in 1960 by Chavez indicate that the ridge would have been a more pronounced barrier to ground water flow than it is today, possibly resulting in local braiding of the alluvial aquifer at the northwest corner of the LTP. See cross-section shown on Figure 2-30.

At “steady state” conditions, an area of high bedrock southwest and downgradient of the LTP results in a local branching of the San Mateo alluvial aquifer downgradient of the LTP. A branch extends to the west to a confluence with the Rio San Jose alluvial aquifer, and a branch extends to the south to a confluence with the Lobo alluvium, which eventually leads to a confluence with the Rio San Jose alluvial aquifer.

Since the inception of monitoring by HMC, saturation of the San Mateo alluvium has increased both upgradient and downgradient of the LTP. Increased saturation upgradient of the LTP is thought to be primarily attributable to recharge from the surface discharge of fluids from upgradient mines (refer to Figure 1-3. Below and downgradient of the LTP, mill operation is likely a large contribution to increased saturation.

The San Mateo alluvial aquifer generally behaves as an unconfined aquifer with specific yields ranging from 0.038 to 0.28. A specific yield of 0.1 is assumed to best represent the alluvial aquifer at the Site (HMC 2019d). Measured hydraulic conductivity values range from less than 1 to more than 200 ft/day. Figure 2-27 presents the hydraulic conductivities measured for the alluvial aquifer from pump tests. These values are, in general, locally consistent and are likely derived from the depositional environment. Specific examples of this consistency are areas where basalt is interbedded within the alluvium and generates high hydraulic conductivities in the Rio San Jose alluvium and the western extents of the San Mateo Creek alluvium, and low values found in areas adjacent to the historical streambed during deposition that likely received finer grained material such as the area due west of the LTP. This area of low hydraulic conductivity is also downgradient of the

bedrock ridge described in the preceding paragraph. Low hydraulic conductivity found in this area support the interpretation of fine grained deposition in areas beyond the extent of the paleochannel. Groundwater elevations within the alluvial aquifer ranged from approximately 6,427 to 6,604 feet above msl during December 2010. Groundwater flows in the alluvial aquifer at the Site generally follow topography to the southwest (HMC 2012).

2.6.1.2 Lobo Alluvium

The Lobo Creek drainage area is depicted on Figure 2-4. The area is approximately 56 square miles while the drainage area of SMC to the tailings is 240 square miles. The Lobo alluvium is typically a sandy material with minor clay and silt layers of limited continuity. The parent materials for the Lobo alluvium and San Mateo alluvium are generally similar and thus the physical characteristics of the alluvium are expected to be similar for the two drainage basins.

Nine test holes were drilled across the Lobo Creek alluvium to define saturation in the Lobo alluvium in 1995. Figure 2-28 presents the locations of these test holes and the elevation of the base of the alluvium in each of these drill holes. No saturation was found in any of these test holes with the lowest base of alluvium elevation of 6563 ft-MSL. The boring logs for these holes are presented in Appendix B. Based on this investigation, it is estimated that while some saturation may exist in the Lobo alluvium southeast of the LTP, it is likely confined to narrow sections where the alluvium was deposited within incised channels that have not been discovered by test hole drilling done to date. It may also be that a subcrop of pervious bedrock drains the alluvial aquifer upgradient of the confluence with the San Mateo. Alluvial saturation further to the north has also not been encountered, as evidenced by Chinle wells 929 through 934 located east of the LTP (refer to Figures 2-32, 2-37, and 2-42 for Chinle well locations) and alluvial wells 1N, 1I and 1O. Given the differences identified in water type in well ND as well as the differences identified in borehole BK3 in comparison to the rest of the background wells in the San Mateo Creek alluvium, it is possible that the confluence of the Lobo Creek and San Mateo Creek alluviums is in the vicinity of well ND and thus farther north than previous borehole attempts to intercept it (HMC 2019b). Based on the lack of alluvial saturation encountered in the Lobo drainage basin, the quantity of Lobo alluvial water entering the Site, if any, is thought to be only a small fraction of the quantity from the San Mateo alluvial aquifer.

2.6.1.3 Rio San Jose Alluvial Aquifer

Rio San Jose alluvium is generally sand and gravel with a wide range of transmissivity. Groundwater in the Rio San Jose alluvium flows southeast from the Bluewater site and merges with SMC alluvial groundwater. The combined flow continues southeast toward Milan (DOE 2014). A depiction of the groundwater flow is provided in Figure 2-29 (DOE 2014). Detailed description of San Jose alluvium and its origin is presented in *Groundwater Flow and Contaminant Transport in the Vicinity of the Bluewater, New Mexico, Disposal Site*, published by the DOE in November 2014.

2.6.2 Upper Chinle Aquifer

The Upper Chinle aquifer, one of three aquifers in the Chinle Formation, is a northeast-dipping, confined aquifer composed of a laterally continuous sandstone unit. Structural elevation contours of the top of the Upper Chinle aquifer indicate minor variations in the steepness of the northeasterly dip, particularly in the area immediately south of the LTP. The aquifer unit is hydraulically bounded from other Chinle Formation aquifer units by competent overlying and underlying shale that has

been structurally offset by the West and East Faults at the Site. The average thickness of the sandstone is approximately 35 feet (HMC 2012).

The Upper Chinle aquifer subcrops at the base of the alluvium on both sides of the East Fault, most notably at the base of the western side of the LTP. However, the sandstone subcrop does not occur west of the West Fault, rather, the subcrop was offset farther north as a result of the most recent high-angle normal faulting and northeast-dipping bed surface. The sandstone encountered in borehole BK4 is likely the same standstone as what makes up the Upper Chinle, but appears to be eroded between the ridge and the Upper Chinle subcrop as depicted in the cross section shown in Figure 2-30. The location of the wells used in this cross-section are best discplayed on Figure 2-46.

The water quality of the Upper Chinle aquifer is influenced by the water quality of the alluvial aquifer as a result of the alluvial aquifer discharging to the Upper Chinle east of the East Fault and in the vicinity near and north of the LTP (HMC 2012).

Aquifer properties vary significantly within the bedrock units due to the effects of secondary permeability; specifically, fracturing of the sandstone related to faulting. As a result, a narrow band (several hundred feet wide) of elevated transmissivity exists on both sides of the East Fault. Estimated transmissivity values along the western side of the East Fault exceed 10,000 gallons per day per foot (gpd/ft). Estimated transmissivity values on the eastern side of the East Fault exceeds 2,000 gpd/ft, but generally ranges between approximately 100 to 2,000 gpd/ft (HMC and Hydro-Engineering 2010). In contrast, estimated transmissivity values are much lower in the region between the West and East Faults, where the aquifer unit is not fractured and finer grain size was noted. Figure 2-31 provides a plan view showing Upper Chinle aquifer transmissivities. The hydraulic conductivity of the Upper Chinle ranges from less than 0.1 ft/day to more than 100 ft/day (HMC and Hydro-Engineering 2010).

HMC wells in the Upper Chinle aquifer are shown on Figures 2-32 and 2-33. The saturated thickness of the aquifer ranges from 15 to 65 feet thick with an average thickness of approximately 35 feet near the Site.

Groundwater flow direction in the Upper Chinle aquifer based on measurements completed in 2014 are provided on Figures 2-34 and 2-35. Flow directions are greatly influenced by remedial actions that are ongoing to remediate groundwater including fresh-water injection into the Upper Chinle at wells CW4R, CW5, CW13 and CW25 and collection from wells CE2, CE5, CE6, CE11 and CE12.

Well CW13, an injection well on the east side of the East Fault, is in the high permeability zone of the Upper Chinle aquifer that parallels the East Fault. This high permeability zone extends to a distance of at least 1000 feet parallel and adjacent to the East Fault near well CW18. Injection of fresh water has created a piezometric-surface mound along the east side of the East Fault. The permeability is much smaller at greater distances to the east of the East Fault and, therefore, an easterly gradient occurs in the Upper Chinle away from the East Fault near injection well CW13. The CW13 injection affects water levels on the west side of the East Fault in the area of Upper Chinle well CW53 in Felice Acres. Water level changes in well CW53 respond quickly to change in levels in well CW13 showing that a good connection exists in the Upper Chinle where the East Fault pinches out south of well CW53.

Injection of fresh water into Upper Chinle well CW5 is causing ground water flow to the north and south of this area. The flow that moves to the south discharges to the alluvial aquifer in the subcrop

area of the Upper Chinle, and the flow that moves to the north converge toward collection wells CE2, CE5, CE6, CE11 or CE12.

Injection into Upper Chinle well CW25 was started in 2000, and this injection are causing ground water to flow from this well back toward these collection wells. The naturally occurring flow direction in the Upper Chinle aquifer west of the East Fault is from the north.

2.6.3 Middle Chinle Aquifer

The Middle Chinle aquifer is an east to northeast-dipping, confined aquifer composed of laterally continuous sandstone. The aquifer unit is similar to the Upper Chinle aquifer and is hydraulically bounded from other Chinle Formation aquifer units by competent overlying and underlying shale. The Middle Chinle aquifer is generally the thickest of the sandstone units in the Chinle Formation and has a saturated thickness ranging from 10 to 80 feet with an average thickness of approximately 44 feet near the Site (HMC 2012).

The Middle Chinle aquifer exists as three fault-bound groundwater systems separated by the West and East Faults (HMC and Hydro-Engineering 2010). All three systems for the Middle Chinle aquifer subcrop at the base of the alluvium. The subcrops on either side of the West Fault have been laterally offset by approximately 5,400 feet due to fault slip along the West Fault. Hydraulic connectivity with the overlying alluvial aquifer exists on the west side of the West Fault. Hydraulic connectivity also exists with the alluvial aquifer between the West and East Faults at an isolated subcrop location within a confined alluvial channel south of the Felice Acres subdivision (HMC 2012).

Hydraulic properties of the Middle Chinle aquifer vary significantly due to the effects of reduced permeability associated with faulting, groundwater pumping, and containment measures (HMC and Hydro-Engineering 2010). Adjacent to the east side of the East Fault, Middle Chinle aquifer transmissivity is approximately 500 gpd/ft but decreases to less than 100 gal/day/ft east of this area. Areas of transmissivity above 5,000 gpd/ft have been observed in the Middle Chinle aquifer west of the East Fault in the western portion of the LTP, eastern Murray Acres and western Broadview and Felice Acres. Figure 2-36 provides a plan view showing Middle Chinle aquifer transmissivities.

The head in the Middle Chinle aquifer on each side of the two faults is significantly different from the head between the two faults, which demonstrates that the groundwater is not readily connected across fault boundaries. The West Fault represents a significant barrier to groundwater flow within the Middle Chinle aquifer, with up to 110 feet of hydraulic head difference across the fault in the area west of the LTP.

HMC wells in the Middle Chinle aquifer are shown on Figures 2-37 and 2-38 and the inferred direction of groundwater flow in the Middle Chinle is shown on Figures 2-39 and 2-40. The hydraulic gradient in the Middle Chinle aquifer is steeper in its alluvial subcrop area in the southern portion of Felice Acres near wells 498, CW45 and CW46.

Pumping of Middle Chinle South Collection wells Y7 and Y23 developed a depression in the Middle Chinle water surface that extends nearly 500 feet to the northeast and southwest of well Y7. This depression intercepts flow in the Middle Chinle that flowing in this portion of South Felice Acres. A steep gradient was developed to the southeast of collection well Y7 due to changes in transmissivity in this area. This increase in gradient is due to an influx of water to the Middle Chinle aquifer from the alluvial aquifer.

Flow on the east side of the East Fault is mainly toward well CW28.

Ground water flow west of the West Fault in the Middle Chinle aquifer is historically to the southwest, and it discharges into the alluvial aquifer. This prevented the impacted alluvial aquifer from affecting the water quality of the Middle Chinle aquifer on the west side of the West Fault. Middle Chinle water flows from upgradient of the Site into the area west of the LTP. The hydraulic contact that allows for alluvial recharge upgradient of the site is likely relatively close to the site given that the major ion water quality of the Middle Chinle wells west of the west fault is similar to that of the alluvial water rather than the non-mixing zone wells east of the west fault in the Chinle aquifers that becomes prevalent a certain distance beyond the subcrop. Alluvial injection in the northern portion of Section 27 temporarily reversed the gradient in the Middle Chinle during 2006 through 2014. Collection in well CW62 started in 2016 has created a depression in the water level surface that draws water from the Middle Chinle to the north and from the alluvial aquifer through the subcrop to the south.

The remainder of the Middle Chinle aquifer is recharged by the alluvial aquifer south of Felice Acres. The injection of fresh water into wells CW14 (north of Broadview Acres) and CW30 (west of Felice Acres) has created ground water mounds in their respective areas. These mounds cause the ground water to flow both north and south from these two wells. The head in the Middle Chinle aquifer on each side of the two faults is significantly different from the head between the two faults, which demonstrates that the ground water is not readily connected on each side of these faults.

2.6.4 Lower Chinle Aquifer

The confined Lower Chinle aquifer is the deepest permeable zone within the Chinle Formation and is generally located approximately 200 feet above the geologic contact with the San Andres limestone. The aquifer is hydraulically isolated from the overlying Middle Chinle aquifer and underlying SAG regional aquifer. In contrast with the overlying Chinle aquifers, the Lower Chinle aquifer is composed of shale with enough developed secondary permeability to behave as a limited aquifer (HMC and Hydro-Engineering 2010). The permeability of the aquifer is not consistently high enough to serve as a viable aquifer, and areas exist where the aquifer is effectively absent.

The Lower Chinle aquifer subcrops at the base of the alluvium on either side of the West Fault, which has been laterally offset by approximately 3,000 feet due to slip displacement along the West Fault. Direct hydraulic connectivity with the overlying alluvial aquifer exists in the area between the West and East Faults southwest of the Felice Acres subdivision and immediately west of the Valley Verde and Pleasant Valley subdivisions on the west side of the West Fault. The Lower Chinle aquifer is presumed to be laterally continuous immediately south of the terminus of the East Fault, where the aquifer functions as a single hydrologic unit (HMC 2012).

The hydraulic properties of the Lower Chinle aquifer are highly variable and largely depend on secondary permeability within the shale. The ability of the Lower Chinle aquifer to produce water is much lower and less consistent than overlying Chinle sandstone aquifers. Hydraulic conductivity ranges from 0.1 to more than 50 ft/day (HMC and Hydro-Engineering 2010). Estimated transmissivity values for the aquifer are generally higher than 100 gpd/ft near subcrop locations (HMC and Hydro-Engineering 2010). However, selected areas near subcrop locations exceed 1,000 gpd/ft. Figure 2-41 provides a plan view showing Lower Chinle aquifer transmissivities.

HMC wells in the Lower Chinle aquifer are shown on Figures 2-42 and the inferred direction of groundwater flow in the Lower Chinle is shown on Figures 2-43. Groundwater elevations for the aquifer ranged from approximately 6,426 to 6,488 feet above msl during December 2010 (HMC and Hydro-Engineering 2010). Flow west of the West Fault in the Lower Chinle is mainly to the northeast. Flow between the two faults is to the northeast in the area of the tailings. The flow is to the northwest in the southern portion of the Lower Chinle aquifer between the faults. The northwesterly flow direction in this area indicates that the Lower Chinle water moves across the West Fault in the area west of Broadview Acres. Hydraulic head is higher in the alluvial aquifer than in the Lower Chinle aquifer with the exception of the subcrop locations, where the hydraulic communication occurs.

In general, the Lower Chinle aquifer is only viable as a water resource near the subcrop locations in connection with the alluvial aquifer, where adequate secondary permeability has likely resulted from weathering and faulting (HMC 2012).

2.6.5 San Andres-Glorietta Regional Aquifer

The SAG aquifer is the most important regional aquifer in the Site area, consisting of the San Andres Limestone and Glorietta Sandstone with a total thickness that exceeds 200 feet (HMC and Hydro-Engineering 2010). Similar to the Chinle Formation aquifers, the regional aquifer is mildly folded and dips to the east and northeast as a result of regional tectonic deformation. Refer to Figure 2-44 for a plan view of the Site area showing well locations, measured ground water elevations and inferred contours from 2014 measurements. The aquifer has been used by HMC as the source of unimpacted clean water used for hydraulic containment of the alluvial aquifer and Chinle Formation aquifers. Thus, some of the water level elevations shown on Figure 2-44 are depressed due to pumping (wells 951R 943 #1 and #2). The contours shown are based in part on wells that are not shown on Figure 2-44, including well 951 and DOE wells further upgradient.

Groundwater elevations near the Site ranged from 6,420 to 6,433 feet above msl during December 2010 (HMC and Hydro-Engineering 2010). Flow direction is to the east-southeast. The water-level elevations measured during 2014 show a very flat piezometric surface. The continuity of the gradient across the Site indicates that the East and West Faults do not significantly affect the ground water flow in the SAG aquifer. It is believed that the displacement at the faults is not large enough to completely displace the entire thickness of this aquifer system. The increase in gradient across the Site also indicates a decrease in transmissivity in the area of the steeper gradient. The faults may cause a decrease in the transmitting ability of the SAG aquifer.

The U.S. Geological Survey (USGS) suggested an average transmissivity of 374,000 gpd/ft (Baldwin and Anderholm 1992; Frenzel 1992). An average groundwater velocity of 4 ft/day is estimated based on a hydraulic conductivity of 615 ft/day, a gradient of 0.00086 foot per foot (ft/ft), and an assumed effective porosity of 0.1 (HMC and Hydro-Engineering 2010). The groundwater velocity is likely to vary greatly in this type of aquifer due to a very wide variation of hydraulic conductivity and effective porosity.

The SAG regional aquifer and the alluvial aquifer are separated by the Chinle formation that acts as an aquitard (approximately 800 feet) at the Site. Refer to Figure 2-45 for a cross-section showing the bedrock formations across a portion of the Site. The plan location of the cross-section is shown on Figure 2-44. Interpretation of the piezometric head for the alluvial and SAG aquifers is shown on Figure 2-45. Difference in the head between the two aquifers confirms that the Chinle formation is

acting as an aquitard. As shown on Figure 2-44, the SAG aquifer subcrops the alluvial aquifer in Sections 5 and 32 west of the Site.

2.7 Historic Mining Impact to the San Mateo Creek Alluvium

As described in Section 1.4 and shown on Figure 1-3, the Site is located within the Grants Mineral Belt, where significant uranium mining and milling occurred starting in the early 1950s. Over many years, studies have evaluated the impact of historic mining and milling within the SMC Basin, with emphasis on groundwater impacts. Figure 1-3 provides a view of the SMC Basin, and the location of mines and mills within the basin. The potential impacts to the SMC alluvial aquifer are relevant to the Site given that it is the upgradient groundwater quality has changed over the period of monitoring and may continue to change in the future. The source and extent of these water quality changes lacks characterization.

2.7.1 Phase 2 Ground-Water Investigation Report for the San Mateo Creek Basin

The *Phase 2 Ground-Water Investigation Report for the San Mateo Creek Basin Legacy Uranium Mines Site Cibola and McKinley Counties, New Mexico* (Phase 2 Report) was completed by EPA to further the characterization of shallow ground-water quality and assess potential impacts from legacy uranium mining industry activities within the SMC Basin (EPA 2018). A brief summary of the evaluations and conclusions EPA developed relevant to the Site is presented in the bullets below.

- Alluvial Saturation: The Phase 2 Report uses alluvial saturation isopach maps from three time periods to demonstrate that discharge from approximately 30 mines during the late 1950s to the late-1970s was substantial and led to a rise in the static water level of approximately 45 to 55 feet in alluvial wells located near the junction of State Highways 605 and 509 (known locally as the “Crossroads”) and the northern part of the SMC floodplain. By 2015, saturation in alluvial wells in the Crossroads area and northern part of the Lower Basin SMC floodplain have returned to near pre-mine discharge levels.

  In the southern part of the floodplain, north of the Site, there was little rise in static water levels of alluvial wells (approximately 1-2 feet) by 1976-77. Since that time, static water levels increased by approximately ten feet by 2015.

- Alluvial Water Quality Assessment: EPA review of historic and recent water quality data suggest that plumes of uranium and selenium groundwater migrated to the south SMC floodplain of the lower basin in the early 1980s and 1990s (EPA 2018). However, a concentration that indicates the presence of mine discharge water in the Lower Basin Alluvium could not be established based on the data (EPA 2018). It is also important to note that pre-mining background water quality for uranium and selenium are not available, which makes it difficult to establish that the plumes are the result of a release without using other lines of evidence.

- Geochemical Analysis: Major ion concentration comparisons including total dissolved solids (TDS), sulfate, chloride, and uranium were evaluated to identify the chemical character of mine discharge water recharge. Indicator values were established for the SMC Upper Basin groundwater, but the data did not support the use of the values for Lower Basin groundwater

(EPA 2018). EPA's examination of the light sulfur isotope ratio ($\delta^{34}S$) suggests the presence of mine discharge water in both Upper and Lower Basin groundwater, but the conclusion was not definitive (EPA 2018).

2.7.2 Controls on Groundwater Background Constituent Concentrations due to Mineralogy Local to Monitoring Wells

In 2018 a white paper entitled *Controls on Groundwater Background Constituent Concentrations due to Mineralogy Local to Monitoring Wells: Grants, New Mexico* was developed. The white paper evaluated the water quality in the SMC Lower Basin through field and laboratory evaluation of geology, mineralogy and geochemistry of sediments and groundwater local to a set of groundwater monitoring wells (HMC 2018a). The wells evaluated have historically been used to measure background water quality for the Site. For a discussion of these wells and the development of background concentrations for the SMC alluvium, refer to Section 3.2.1. The study included the following elements:

- Sediment sampling and analysis: Two boreholes were completed in 2018 adjacent to existing upgradient wells DD and DD2 in the background area at the Site and samples from these boreholes were collected for analyses. Sample analyses included metal concentrations, leachability, grain size distribution, optical evaluation of mineralogy, and x-ray diffraction.

- Geophysical assessment: Geophysical data collected from the two borings described above, and from six monitoring wells completed in the alluvial aquifer (near DD, DD2, MV, ND, Q, T-11) by the USGS in 2016. Geophysical techniques used by USGS on the six wells included measurement of well construction and integrity (caliper, optical televiewer), groundwater/aquifer physical characteristics (induction, electromagnetic flowmeter, fluid temperature, and conductivity), and radioactivity of the material surrounding the well (natural gamma ray and natural gamma ray spectroscopy). Geophysical methods employed on two borings completed in 2018 included natural gamma ray, natural gamma ray spectroscopy, and induction conductivity.

The following conclusions were drawn from the study:

- Sediment cores lithologically logged from the two boreholes (DD-BK and DD2-BK) indicate significant vertical heterogeneity including an alternating sequence of clays, silts, silty-sands, sandy-silts, sands with various amounts of gravel, and occasional gravel layers. Previous drilling logs based on lower-resolution sampling and visual soil descriptions suggest that the alluvium was uniform with very low variability in lithology.

- Heterogeneity is also noted in the variable levels of gamma radiation measured at different lithological layers throughout each borehole. Zones of fine-grained material correlate with elevated uranium based on spectral gamma analysis.

- Mineralogical analyses suggested that materials encountered at DD-BK and DD2-BK are associated with source rock that contains unaltered feldspars, claystones that include kaolinite, and arkosic sandstones. These materials are also found at the upgradient northern boundary of the basin in the Westwater Canyon and Brushy Basin Members of the Morrison Formation, each of which contain uranium in concentrations of economic value (ore-grade).

This provides evidence that local bedrock is likely the source of uranium deposited into SMC alluvial sediments, rather than from groundwater impacted from historic mining.

- Geochemical testing, both total metal and leachability analyses, show that uranium and other constituents are primarily associated with fine-grained materials (clay and silt). Thus, the material in which a well is screened may affect the well chemistry.

2.7.3 Supplemental Background Soil and Groundwater Investigation Report

In 2019 additional field investigations were conducted by HMC to expand the extent of characterization of the soils east of wells DD and DD2, across the alluvial channel. The field investigation was documented in the report entitled, *Draft Supplemental Background Soil and Groundwater Investigation Report Grants Reclamation Project, Cibola County, New Mexico*. The investigation included:

- Installation of two well pairs and two boreholes. Refer to Figure 2-46 for a plan view of the well pairs and boreholes. Wells and boreholes were advanced using rotosonic drilling, which allowed for detailed geological logging.
- Soil sampling over a wide range of lithologies and mineralogical characteristics and analyzed for uranium and other metals, water quality parameters, mineralogical analysis, and isotope analysis.
- Groundwater sampling from each of the new wells and analysis for total and filtered metals, anions, nitrate, ammonia, isotopic uranium, total organic carbon, dissolved organic carbon, phosphate, and stable sulfur isotope analysis.
- Electrical resistivity tomography (ERT) assessment to map the alluvial channel geometry and internal variations within the alluvium. Two transect alignments of ERT were performed to provide a continuous image of the alluvial channel geometry and resistivity data on the sediments. Refer to Figure 2-46 for the transect locations.
- Borehole geophysical logging.

The investigation completed in 2019 reinforced the findings of the 2018 report and white paper, and added the following conclusions (HMC 2019b):

- A sandstone bedrock ridge is located northwest of the LTP, at borehole location BK4, which extends above the water table. There is evidence that the sandstone is permeable.
- The highest uranium concentrations encountered are in the unsaturated zone, indicating that uranium in alluvial soils is naturally occurring due to transport and deposition of naturally uranium-rich materials throughout geologic time, not from deposition from uranium-bearing groundwater.
- Geochemical analyses indicate that uranium and vanadium are generally correlated with each other.
- ERT data revealed higher resistivity alluvium, which is typical of coarse-grained materials, between the center and the western edge of the alluvial channel. Coarse-

grained sediments may conduct groundwater more effectively through the center-west portion of the alluvium compared to the eastern side of the basin. Figures 2-47 and 2-48 are vertical cross-sectional portrayals of modelled electrical resistivity roughly from the ground surface.

- The variability and heterogeneity of the alluvial system is therefore captured by the current upgradient (background) well network situated across the basin and represents the range of natural uranium concentration variation in groundwater prior to the alluvial system moving on-Site. The location of the monitoring points established to develop the Site background groundwater standards is therefore appropriate, as is the numerical approach as it included all of the groundwater quality data at these monitoring points distributed across the alluvial valley.

2.8 Surface Water

The natural land surface gradients of the Site are usually less than 1 percent; the average grade is 0.1 percent. Surface drainage across the Site is predominately directed to the southwest, although there are generally no established drainage courses or signs of active erosion. Ponding may occur after significant precipitation events, but this water either evaporates or infiltrates the alluvium (HMC 2012).

San Mateo Creek and Lobo Creek basins both drain onto the Homestake Facility. Two Lobo Creek drainage paths enter the east side of the Homestake Facility (refer to Figure 1-1). A diversion levee was constructed to the north of the mill area to divert surface water discharges from the northern branch of Lobo Creek (refer to Figure 1-6). During flood events, the levee diverts Lobo Creek water to the North Diversion Channel located north of the LTP, preventing discharges from flowing across the mill area. The levee was constructed of uncontaminated soils from the North Borrow Area and generally consists of clayey sands and sandy clays. The slopes of the levee are protected against erosion using the same cover specified for the tailings pile top surfaces (HMC 2013a). San Mateo Creek drainage enters the Homestake Facility from the north, and is diverted by the North Diversion Channel west around the LTP.

2.9 Demographics and Land Use

The Site is situated in Cibola County, which encompasses a land area of 4,539 square miles (City-Data 2019a). Cibola County was created by a division of Valencia County in 1981; therefore, population data for the new county before 1981 are estimated. In 1970, the county's population was 20,125, rising to 30,109 in 1980 and falling to 20,794 in 1990. The population changes were mainly related to uranium mining activity in the area. The population was estimated at 27,351 in 2016 with a population density of six people per square mile (City-Data 2019a).

The average household size in the county in 2016 was 2.0 people compared to 3 people for the State of New Mexico (City-Data 2019a). The estimated median household income in 2016 was $37,010, compared to the state median income of $46,748 (City-Data 2019a). Industries providing employment in Cibola County as of 2016 were: educational, health, and social services (36.7%); professional, scientific, management, administrative, and waste management services (11.9%); agriculture, forestry, fishing and hunting, and mining (11.4%); and public administration (14.1 percent) (City-Data 2019a).

The most common industries for males are (City-Data 2019a):

- Health care and social assistance (23%)
- Educational services (13%)
- Retail trade (12%)
- Accommodation and food services (10%)
- Arts, entertainment, and recreation (9%)
- Public administration (8%)
- Other services, except public administration (3%)

The most common industries for females are (City-Data 2019a):

- Health care and social assistance (25%)
- Educational services (14%)
- Retail trade (13%)
- Accommodation and food services (10%)
- Arts, entertainment, and recreation (10%)
- Public administration (9%)
- Other services, except public administration (4%))

Ethnicity (by percentage) in Cibola County for the year 2016 is displayed in Table 2-3 (City-Data 2019a).

Table 2-3 Cibola County, New Mexico Ethnicities

Ethnicity	Percentage[1]
White Non-Hispanic Alone	19.9%
Hispanic or Latino	38.4%
American Indian and Alaska Native Alone	38.1%
Persons reporting two or more races	1.8%
Black Non-Hispanic Alone	0.9%
Asian Alone	0.6%

Source: City-Data 2019a

The median resident age is 36.3 years, compared to the state median age of 37.7 years (City-Data 2019a).

A mix of rural and industrial activities has characterized the Cibola County economy. Uranium mining has been the biggest factor in the boom cycles of the 1950s, 1960s, and 1970s and the bust cycle in the 1980s. The location of the federal and state prisons in the county has helped buffer some of the past economic downturn.

The City of Grants is the largest incorporated area near the Site and is the county seat of Cibola County. The City of Grants began as a railroad camp in the 1880s and now encompasses a land area of approximately 14.86 square miles with a population of 9,241 in 2014 (City-Data 2019b). The

estimated median household income for the City of Grants in 2016 was $36,606, compared to $30,652 in 2000 (City-Data 2019b). The Village of Milan is a suburb of the City of Grants and had a population of 3,255 as of 2014 (City-Data 2019c).

Current major land uses south and southwest of the Site consist of residential development, agriculture, and livestock raising (EPA 2011). Five residential subdivisions near the Site include Felice Acres, Broadview Acres, Murray Acres, Pleasant Valley Estates, and Valle Verde. There are large areas north, east, and west of the Site that are mostly unused except for livestock grazing (ACOE 2010). According to the United States Department of Agriculture (USDA), cattle are the main livestock produced in Cibola County, followed by sheep (USDA 2007).

2.10 Ecology

2.10.1 Regional Setting

The Site is located within the Semiarid Tablelands ecoregion of the Arizona and New Mexico plateau that contains areas of high relief and some low relief plains (EPA 2010a). It is characterized by canyons, valleys, mesas, and plateaus formed primarily from flat to gently sloping sedimentary rocks, and areas of Tertiary and Quaternary volcanic fields. Bedrock exposures are common features in this ecoregion. The tablelands are vegetated with woodland, shrubs, and grass. Shallow, stony soils supporting scattered to dense stands of junipers (*Juniperus species [spp.]*), and pinyon-juniper woodland is common in some areas. Other characteristic vegetation includes saltbush (*Atriplex spp.*), alkali sacaton (*Sporobolus airoides*), sand dropseed (*Sporobolus cryptandrus*), and mixed grama grasses (*Bouteloua spp.*). Vegetation is not as sparse as in the San Juan/Chaco Tablelands and Mesas ecoregion to the north or the Albuquerque Basin ecoregion to the east. The Semiarid Table lands ecoregion lacks the dense pine forests typical of the higher-elevation Arizona and New Mexico Mountains ecoregion (EPA 2010a).

2.10.2 Vegetation

The Site and surrounding area generally consists of desert and semi-desert habitat. Vegetation communities are predominately Inter-Mountain Basins Mixed Salt Desert Scrub and Inter-Mountain Basins Semi-Desert Grasslands, with smaller, patchy areas of Inter-Mountain Basins Semi-Desert Shrub Steppe (HMC 2018b).

Vegetation types within the Site and immediate vicinity consist largely of semi-desert grassland, mixed salt desert scrub, and greasewood flat (Southwest Regional Gap Analysis Project 2004). The Site has been subject to human disturbance for more than 50 years. In 1995, much of the Homestake Facility was bladed and reseeded with a seed mixture consisting of western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), sand dropseed (*Sporobolus cryptandrus*), Indian ricegrass (*Achnatherum hymenoides*), alkali sacaton (*Sporobolus airoides*), and fourwing saltbush (*Atriplex canescens*) (NRC 1993). Groundcover varies from 79 percent to 99 percent.

Other common plant species found within the Homestake Facility include kochia (*Kochia spp.*), bottlebrush squirreltail (*Elymus elymoides*), Russian thistle (*Salsola tragus*), broom snakeweed (*Gutierrezia sarothrae*), three-awn (*Aristida spp.*), spike dropseed (*Sporobolus contractus*), galleta grasses (*Pleuraphis spp.*), greasewood (*Sarcobatus vermiculatus*), sand sage (*Artemisia filifolia*),

and narrowleaf yucca (*Yucca angustissima*). Limited areas of saltcedar (*Tamarix ramosissima*) are present along the ephemeral San Mateo Creek (HMC 1982; Bridges and Meyer 2007; NRC 2008).

2.10.3 Wildlife

Characteristic species include desert cottontails, jack rabbits, pocket gophers, meadowlarks, and western rattlesnakes. Table 2-4 lists species known to occur within the Site or immediate vicinity. Results of bird surveys conducted in 2018 in the Site area are included in Table 2-4. In addition to the species in Table 2-4, various species of shorebirds and waterfowl have been observed using the evaporation ponds at the Site during spring and fall migration (HMC 1982; Bridges and Meyer 2007).

Table 2-4 Wildlife Species Known to Occur in the HMC Superfund Site Area

Common Name	Scientific Name
Mammals	
Desert cottontail	*Sylvilagus audubonii*
Black-tailed jackrabbit	*Lepus californicus*
Silky pocket mouse	*Perognathus flavus*
Botta's pocket gopher	*Thomomys bottae*
Deer mouse	*Peromyscus maniculatus*
Ord's kangaroo rat	*Dipodomys ordii*
White-throated woodrat	*Neotoma albigula*
Mexican woodrat	*Neotoma mexicana*
Spotted ground squirrel	*Spermophilus spilosoma*
Rock squirrel	*Spermophilus variegatus*
Black-tailed prairie dog	*Cynomys ludovicianus*
Coyote	*Canis latrans*
Mule deer	*Odocoileus hemionus*
Birds	
American robin	*Turdus migratorius*
American kestrel	*Falco sparverius*
Barn swallow	*Hirundo rustica*
Bewick's wren	*Thryomanes bewickii*
Brewer's sparrow	*Spizella breweri*
Brown-headed cowbird	*Molothrus ater*
Bullock's oriole	*Icterus bullockii*
Burrowing owl	*Athene cunicularia*
Common raven	*Corvus corax*
Eastern meadowlark	*Sturnella magna*
Eurasian collared-dove	*Streptopelia decaocto*
European starling	*Sturnus vulgaris*
Ferruginous hawk	*Buteo regalis*
Golden eagle	*Aquila chrysaetos*
Great blue heron	*Ardea herodias*
Hermit thrush	*Catharus guttatus*
Horned lark	*Eremophila alpestris*
House finch	*Haemorhous mexicanus*

Table 2-4 Wildlife Species Known to Occur in the HMC Superfund Site Area (Con't)

Common Name	Scientific Name
House sparrow	*Passer domesticus*
Loggerhead shrike	*Lanius ludovicianus*
Mourning dove	*Zenaida macroura*
Northern mockingbird	*Mimus polyglottos*
Olive-sided flycatcher	*Contopus cooperi*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Sage thrasher	*Oreoscoptes montanus*
Sagebrush sparrow	*Artemisiospiza nevadensis*
Say's phoebe	*Sayornis saya*
Scaled quail	*Callipepla squamata*
Turkey vulture	*Cathartes aura*
Vesper sparrow	*Pooecetes gramineus*
Violet-green swallow	*Tachycineta thalassina*
Western kingbird	*Tyrannus verticalis*
Western meadowlark	*Sturnella neglecta*
White-crowned sparrow	*Zonotrichia leucophrys*
Yellow-rumped warbler	*Setophaga coronata*
Reptiles	
Western rattlesnake	*Crotalus oreganus*
Lesser earless lizard	*Holbrookia maculata*
Horned lizard	*Phrynosoma* spp.

Sources: HMC 2013a; HMC 1982; Salter 1990; Bridges 2007, HMC 2018b

2.10.4 Aquatic Ecology

The ephemeral San Mateo Creek exists within the Site, but flows infrequently and only after heavy precipitation events or snowmelt. There is no distinct channel for this drainage within the Site (Bridges and Meyer 2007).

The evaporation ponds are man-made, engineered structures designed to concentrate Site contaminants. Therefore, they do not have a natural aquatic ecosystem, and are not suitable for aquatic habitats for community-level receptor groups such as fish or invertebrates.

The significant aquatic habitat nearest to the Site is Bluewater Lake, a man-made impoundment of Bluewater Creek, located about 14 miles to the west.

2.10.5 Threatened and Endangered Species and Species of Concern

Threatened and endangered species and species of concern known to occur in Cibola County are listed in Table 2-5 with a description of their potential for occurrence near the Site (HMC 2013a).

No species currently listed as endangered by the federal government or the State of New Mexico are expected near the Site. The majority of listed species and species of concern have no potential to

occur in the project area due to a lack of suitable habitat. A survey by biologist Louis Bridges, who has extensive experience with western threatened and endangered species evaluations, confirmed the lack of suitable habitat for listed plant and animal species (Bridges and Meyer 2007). The exceptions are American peregrine falcons, arctic peregrine falcons, and bald eagles, which may occasionally pass through the project area during migration; cinder phacelia, mountain plovers, and western burrowing owls, which can inhabit disturbed areas and areas near people; and spotted bats, which may occasionally forage at the Site (HMC 2013a).

Table 2-5 Known or Suspected Threatened, Endangered, and Candidate Species

Common Name	Scientific Name	Federal Status	State Status	Preferred Habitat	Potential for Occurrence
Acoma fleabane	Erigeron acomanus	Species of Concern	None	Sandy slopes and benches beneath sandstone cliffs of the Entrada Sandstone Formation in piñon-juniper woodland; 2,100-2,170 m (msl)	None; there is no suitable habitat in the project area and the project area is located below the elevational range for this species.
American peregrine falcon	Falco peregrinus anatum	Species of Concern	Threatened	Cliffs in forested or wooded habitats	Low; there is no suitable nesting habitat in or near the project area. Individuals may pass through when migrating or foraging.
Arctic peregrine falcon	Falco peregrinus tundrius	Species of Concern	Threatened	Forested or wooded montane habitats	Low; individuals may pass through when migrating.
Bald Eagle	Haliaeetus leucocephalus alascanus	None	Threatened	Timbered areas along coasts, rivers, and large lakes	Low; there is no suitable nesting or roosting habitat in or near the project area. Individuals may pass through when migrating.
Black- footed ferret	Mustela nigripes	Endangered	None	Large prairie dog colonies (more than 40 hectares in size)	None; the prairie dog colonies in and near the project area are small (<40 hectares) and therefore not suitable for this species.
Cebolleta southern pocket gopher	Thomomys umbrinus paguatae	Species of Concern	None	Sycamore, cottonwood, and rabbitbrush riparian habitats	None; there is no suitable habitat in or near the project area.
Cinder phacelia	Phacelia serrate	Species of Concern	None	Volcanic cinders; also roadcuts and abandoned quarries in open, sunny locations; near ponderosa pine and piñon-juniper woodlands; 1,800-2,200 m	Low; there is some potential for this species to be found within disturbed areas, but the habitat is not ideal.
Gray vireo	Vireo vicinior	None	Threatened	Open woodlands and shrublands	None; there is no suitable habitat in or near the project area.
Gypsum phacelia	Phacelia sp. nov.	Species of Concern	None	Weathered gypsum outcrops and gypsiferous and pure gypsum soils in woodland and desert scrub at elevations of 1,600-2,300 m (msl)	None; there is no suitable habitat in or near the project area.

Table 2-5 Known or Suspected Threatened, Endangered, and Candidate Species (Con't)

Common Name	Scientific Name	Federal Status	State Status	Preferred Habitat	Potential for Occurrence
Mountain plover	Charadrius montanus	None	Sensitive	Shortgrass prairie, barren ground, disturbed areas, especially areas of flat topography and with no nearby surface water	Low; there is some potential for nesting in disturbed areas in and around the project area, but the habitat is not ideal.
New Mexico silverspot butterfly	Speyeria nokomis nitocris	Species of Concern	None	Alpine meadows	None; there is no suitable habitat in or near the project area.
Northern goshawk	Accipiter gentilis	Species of Concern	None	Various forest types, especially mature, closed-canopy forest	None; there is no suitable habitat in or near the project area.
Parish's alkali grass	Puccinellia parishii	None	Endangered	Alkaline springs, seeps, and seasonally wet areas that occur at the heads of drainages or on gentle slopes at 800-2,200 m	None; there is no suitable habitat in the project area.
Pecos sunflower	Helianthus paradoxus	Threatened	Endangered	Saturated saline soils of desert wetlands. Usually associated with desert springs (cienegas) or the wetlands created from modifying desert springs; 1,000-2,000 m	None; there is no suitable habitat in or near the project area.
Rio Grande sucker	Catostomus plebeius	Species of Concern	None	Pools, runs, and riffles of small to moderately large streams	None; this species is believed to be extirpated from the Rio San Jose watershed and there are no suitable aquatic habitats in the project area.
Southwestern willow flycatcher	Empidonax traillii extimus	Endangere d	Endangered	Riparian habitats	None; there is no suitable habitat in or near the project area.
Spotted bat	Euderma maculatum	None	Threatened	Subalpine coniferous forest, montane forest, pinyon-juniper woodland, open semi- desert shrubland. Roosts in crevices in cliffs and canyons.	Low; there is some potential for this species to forage in the project area although there are no suitable roosting sites.

Table 2-5 Known or Suspected Threatened, Endangered, and Candidate Species (Con't)

Common Name	Scientific Name	Federal Status	State Status	Preferred Habitat	Potential for Occurrence
Western burrowing owl	Athene cunicularia hypugaea	Species of Concern	None	Open land with small mammal burrows, especially prairie dog burrows	Moderate; there is some potential for this species to use prairie dog or ground squirrel burrows within the project area. Few individuals would be expected based on the lack of extensive prairie dog colonies.
Yellow- billed cuckoo	Coccyzus americanus	Candidate	None	Lowland riparian woodlands	None; there is no suitable habitat in or near the project area.
Zuni bluehead sucker	Catostomus discobolus yarrow	Candidate	Endangered	Headwater streams to large rivers with moderate to fast flowing water above a rubble-rock substrate	None; there are no known occurrences of this species in the Rio San Jose watershed where this project is located, and there are no suitable aquatic habitats in the project area.
Zuni fleabane	Erigeron rhizomatus	Threatened	None	Nearly barren detrital clay hillsides with soils derived from shales of the Chinle or Baca formations; most often on north or east-facing slopes in open piñon-juniper woodlands at 2,200-2,400 m	None; there is no suitable habitat in the project area and the project area is located below the elevational range for this species.

Sources: HMC 2013a; Natural Heritage New Mexico (NHNM) 2011; NatureServe 2010; U.S. Fish and Wildlife Service 2010; Biota Information System of New Mexico 2009; New Mexico Rare Plant Technical Council 1999.

3 Nature and Extent of Contamination

Nature and extent of contamination is described for two areas: the Homestake Facility and the LTAs. These areas are evaluated separately because they are not contiguous and the direct source of the contamination is dissimilar, as described in the following subsection.

3.1 Source Material

3.1.1 Primary Sources

The primary sources of contaminants at the Site are the two tailings piles referred to as the LTP and STP. As described in Section 2.2, the LTP and STP contain approximately 21 million tons and 1.2 million tons of uranium mill tailings, respectively. Throughout most of the mill operations, tailings were deposited after particle size separation by a cyclone operation. Tailings were deposited hydraulically, with progressively finer particles being deposited further away from the cyclone, which was moved along the crest of the embankment, creating overlapping fields of deposition. Thus, no distinct interface existed between the coarse and fine tailings (HMC 1982).

The finer fraction, which generally consisted of silt and clay particles, made up approximately 30 percent of the tailings deposited. The coarse fraction, generally consisting of sand, made up the remaining 70 percent of the tailings (HMC 1982). On the Unified Soil Classification System, the finer tailings are classified as silty sand (SM) with 13 – 50 percent silt by weight. The coarser tailings are classified as poorly graded sand to silty sand (SP-SM) with 5 to 12 percent silt by weight (HMC 2012).

Finer fraction tailings exhibited a higher concentration of radioactive elements than coarser tailings, as displayed in Table 3-1 below.

Table 3-1 Nuclide Concentrations in Deposited Tailings

Contaminant	Fine Tailings	Coarse Tailings
Radium 226	630 pCi/g	65 pCi/g
Thorium 230	0.081 pCi/g	0.0116 pCi/g
Lead 210	840 pCi/g	99 pCi/g
Triuranium octoxide (U3O8)	0.011%	0.004%

Source: HMC 1982
pCi/g = picocuries per gram

Debris from the mill operating facilities, which is buried south of the tailings piles (refer to Figure 1-4) is also a primary source of potential contamination. Comparatively, the buried debris pits are much smaller than the tailings piles.

3.1.2 Homestake Facility Secondary Sources

Secondary sources are media or physical features impacted by the primary sources and can serve as sources of contamination to media and ultimately receptors. Homestake Facility secondary sources include:

- Radon-222 gas and dust, can be transported through the movement of wind

- Surface and subsurface soils, which are a source to plants and animals, and can transfer contaminants to other media, such as precipitation
- Two collection ponds, three evaporation ponds, and the RO groundwater treatment system, which can spread contaminants if containment measures are compromised
- Groundwater/aquifers, which can spread contaminants and potentially be used as potable or nonpotable water sources in the future

3.1.3 Land Treatment Area Secondary Sources

In the LTAs, while the primary sources of the contamination for the Site are the tailings pile and contaminated debris, the fields are being included as part of this RI Report because of the application of irrigation water that contained low concentrations of uranium and other contaminants. During the period of 2000 to 2012, approximately 9,551 acre-feet of water was used for irrigation. Land application was part of the Site remediation system that was approved by the New Mexico Environment Department (NMED), NRC, and EPA. HMC elected to discontinue the land treatment program after the 2012 irrigation season. Following HMC suspension of the land application program, NMED withdrew regulatory support for the program. Table 3-2 summarizes the yearly quantity of water used, the total area irrigated, and the fields irrigated.

Two pipelines were used to supply irrigation water; one for the flood irrigation fields and the 150-acre center pivot (Section 33/34 Pipeline) and one for the 100-acre center pivot irrigation field (Section 28 Pipeline). Each of the pipelines drew water from various wells. A plan view of each of the Section 33/34 Pipeline and the Section 28 Pipeline are shown on Figures 3-1 and 3-2, respectively. The figures include the location and identifying number of the wells used in 2012 for water supply. During the course of the irrigation period (2000 to 2012) the number and locations of wells used have varied. Generally, wells used for water supply are screened in the alluvium, though some are screened in the Chinle aquifers.

Table 3-2 Land Treatment Locations and Quantities, by Year

Year	Water Applied (acre-feet)	Irrigated Area (acre)	Fields Irrigated
2000	715	270	150-Acre Center Pivot 120-Acre Flood Irrigation
2001	695	270	150-Acre Center Pivot 120-Acre Flood Irrigation
2002	995	330	150-Acre Center Pivot 120-Acre Flood Irrigation 100-Acre Center Pivot
2003	949	330	150-Acre Center Pivot 120-Acre Flood Irrigation 100-Acre Center Pivot
2004	1,028	354	150-Acre Center Pivot 24-Acre Flood Irrigation 120-Acre Flood Irrigation 100-Acre Center Pivot
2005	1,034	394	150-Acre Center Pivot 24-Acre Flood Irrigation 120-Acre Flood Irrigation 100-Acre Center Pivot
2006	837	370	150-Acre Center Pivot 120-Acre Flood Irrigation 100-Acre Center Pivot
2007	789	370	150-Acre Center Pivot 120-Acre Flood Irrigation 100-Acre Center Pivot
2008	1,054	394	150-Acre Center Pivot 24-Acre Flood Irrigation 120-Acre Flood Irrigation 100-Acre Center Pivot
2009	731	394	150-Acre Center Pivot 24-Acre Flood Irrigation 120-Acre Flood Irrigation 100-Acre Center Pivot
2010	201	120	120-Acre Flood Irrigation
2011	213	100	100-Acre Center Pivot
2012	310	220	100-Acre Center Pivot 120-Acre Flood Irrigation
2013	0	0	None

Source: HMC 2014

Tables 3-3 and 3-5 present the concentrations of uranium, selenium, TDS, sulfate, molybdenum, and chloride in the 2000 to 2012 irrigation water from the Section 33/34 Pipeline and the Section 28 Pipeline, respectively. Yearly averages are also presented in the tables. In addition, concentrations of Ra-226, Radium 228 (Ra-228), vanadium (V) and Thorium 230 (Th-230) were measured for Section 33/34 irrigation water in 2010 and 2012 and for Section 33/34 irrigation water in 2011 and 2012. Concentrations of these elements and isotopes are included in Tables 3-4 and 3-6.

Based on the quantities of water applied during irrigation (Table 3-2) and the average concentrations shown in Tables 3-3 through 3-5, the mass of uranium, selenium, and sulfate applied to the irrigation fields is estimated in Table 3-7.

Table 3-3 Sections 33/34 Irrigation Water: Average Concentrations 2000 – 2010, 2012

Year	Parameter (mg/L)					
	Uranium	Selenium	TDS	Sulfate	Chloride	Molybdenum
2000	0.27	0.12	1549	624	107	<0.03
2001	0.26	0.1	1570	642	113	0.04
2002	0.23	0.1	1564	705	126	<0.03
2003	0.22	0.08	1600	732		
2004	0.26	0.09	1553	679	131	<0.03
2005	0.27	0.06	1546	732	162	<0.03
2006	0.29	0.07	1650	716	151	0.04
2007	0.28	0.06	1584	666	134	<0.03
2008	0.24	0.05	1550	702	137	<0.03
2009	0.24	0.05	1673	709	161	<0.03
2010	0.14	0.045	1711	739	167	<0.03
2012	0.12	0.06	1690	689	162	<0.03

Source: HMC 2014
mg/L = milligrams per liter

Table 3-4 Sections 33/34 Irrigation Water: Average Concentrations of Ra-226, Ra-228, V, and Th-230 in 2010, 2012

Year	Date	Ra-226 (pCi/L)	Ra-228 (pCi/L)	V (mg/L)	Th-230 (pCi/L)
2010	November 1, 2010	-0.02	0.07	<0.01	0.04
2012	October 11, 2012	0.38	1.4	<0.01	0.03

Source: HMC 2014
pCi/L = picocuries per liter
mg/L = milligrams per liter

Table 3-5 Section 28 Irrigation Water: Average Concentrations 2000 – 2009, 2011, 2012

Year	Sampling Date	Parameter (mg/L)					
		Uranium	Selenium	TDS	Sulfate	Chloride	Molybdenum
2002	October 2, 2002	0.23	0.08	2070	881		
2003	May 14, 2003	0.24	<1.005	2070	936	184	<0.03
2004	Average	0.27	0.07	2115	919	185	<0.03
2005	Average	0.35	0.08	2109	927	180	0.040
2006	Average	0.35	0.08	1986	882	175	0.04
2007	Average	0.36	0.08	2122	921	171	0.04
2008	Average	0.36	0.07	1917	927	133	0.04
2009	Average	0.38	0.07	2029	894	174	0.05
2011	Average	0.14	0.03	1409	608	121	<0.03
2012	Average	0.14	0.036	1846	756	189	<0.03

Source: HMC 2014
mg/L = milligrams per liter

Table 3-6 Section 28 Irrigation Water: Average Concentrations of Ra-226, Ra-228, V, and Th-230 in 2011, 2012

Year	Date	Ra-226 (pCi/L)	Ra-228 (pCi/L)	V (mg/L)	Th-230 (pCi/L)
2011	October 12, 2011	0.39	-0.40	<0.01	0.05
2012	October 2, 2012	0.08	0.1	<0.01	0.05

Source: HMC 2014
pCi/L = picocuries per liter
mg/L = milligrams per liter

Table 3-7 Estimated Mass of Uranium, Selenium, and Sulfate Applied During Irrigation

Year	System	Uranium Mass (lbs)	Selenium Mass (lbs)	Sulfate Mass (lbs)
2000	Section 28			
	Sections 33 and 34	525.4	233.5	1,214,286
2001	Section 28			
	Sections 33 and 34	491.1	188.9	1,212,646
2002	Section 28	82.6	28.7	316,284
	Sections 33 and 34	538.6	234.2	1,650,893
2003	Section 28	100.7	1	392,543
	Sections 33 and 34	475	172.7	1,580,334
2004	Section 28	133.9	34.7	455,897
	Sections 33 and 34	597.8	206.9	1,561,090
2005	Section 28	226.6	51.8	600,044
	Sections 33 and 34	584.7	129.9	1,585,232
2006	Section 28	221.8	50.7	558,922
	Sections 33 and 34	476.5	115	1,176,577
2007	Section 28	236.9	52.7	606,180
	Sections 33 and 34	416.3	89.2	990,081
2008	Section 28	270.2	52.5	695,850
	Sections 33 and 34	510.2	106.3	1,492,312
2009	Section 28	196.2	35.2	449,817
	Sections 33 and 34	355.9	74.1	1,051,344
2010	Section 28			
	Sections 33 and 34	74.1	24.5	402,781
2011	Section 28	81.1	17.4	345,844
	Sections 33 and 34			
2012	Section 28	60.9	17.4	329,007
	Sections 33 and 34	47.3	16.3	280,778

Other LTA secondary sources include:

- Dust, which can transport contaminants through wind erosion
- Surface and subsurface soils, which are a source to plants and animals, and can transfer contaminants to other media, such as irrigated water or precipitation
- Vegetation, which can uptake contaminants and serve as a source to herbivores

3.2 Nature and Extent of Contamination from the Homestake Facility

The following subsections describe the nature and extent of contamination based on data collected by HMC at the Site and information collected by the EPA for its Human Health Risk Assessment (HHRA) (EPA 2014a). Available data relevant to the nature and extent has been carried forward to the risk assessment.

3.2.1 Groundwater Impacts from the Homestake Facility

Seepage from the tailings piles has resulted in the contamination of groundwater at the Site. Beginning in 1977, HMC has operated a remediation system to mitigate the impact of seepage from tailings to groundwater. Groundwater impacts from mill tailing operations have been identified in the alluvial, Upper, Middle, and Lower Chinle aquifers. Nature and extent of impact to each of the aquifers is described in this section. The description is not geographically limited to the Homestake Facility.

The EPA and NMED have collected and analyzed samples from domestic wells located in the subdivisions on multiple occasions, leading to interim actions to provide water from the City of Milan drinking water system as described in Section 1.4. Domestic wells are not used to characterize the nature and extent of groundwater contamination since well logs and well construction diagrams are not available for many of these wells.

Groundwater data is compared to standards established for Site's NRC license, most of which are based on upgradient background concentrations that were calculated from historic data. A summary of the background calculations and the establishment of groundwater cleanup standards for the NRC license are provided in this section.

3.2.1.1 Chemicals and Radionuclides of Potential Concern and Cleanup Levels Developed for NRC License

NRC, EPA, and NMED agreed upon the chemicals of potential concern (COPCs) and radionuclides of potential concern (ROPCs) and cleanup levels for groundwater in 2006. Specifically, NRC approved these cleanup levels in 2006 in License Condition 35.B; EPA approved the levels via letter to NRC dated September 27, 2005; and the NMED approved these levels in DP-200.

The COPCs/ ROPCs and cleanup levels established for the Site by NRC are listed in Table 3-8.

Table 3-8 NRC Site Cleanup Levels

Constituent	Alluvial Aquifer	Chinle Mixing Zone	Upper Chinle Non-Mixing Zone	Middle Chinle Non-Mixing Zone	Lower Chinle Non-Mixing Zone
Selenium (mg/L)	0.32	0.14	0.06	0.07	0.32
Uranium (mg/L)	0.16	0.18	0.09	0.07	0.03
Molybdenum (mg/L)	0.10	0.10	0.10	0.10	0.10
Sulfate (mg/L)	1,500	1,750	914	857	2,000
Chloride (mg/L)	250	250	412	250	634
Total Dissolved Solids (mg/L)	2,734	3,140	2,010	1,560	4,140
Nitrate (mg/L)	12	15	*	*	*
Vanadium (mg/L)	0.02	0.01	0.01	*	*
Thorium-230 (pCi/L)	0.3	*	*	*	*
Radium-226 and Radium-228 (pCi/L)	5	*	*	*	*

Source: HMC 2012
* No standard for the constituent in the indicated zone
mg/L = milligrams per liter
pCi/L = picocuries per liter

NRC Site Cleanup Levels represent the culmination of previous work conducted to characterize contamination at the Site and establish background concentrations. As explained in detail below, the majority of these NRC Site Cleanup Levels are based on the background levels of contaminants in the various environmental media at the Site. Others represent levels of contaminants in environmental media that have been deemed acceptable through previous study and regulatory action. NRC Site Cleanup Levels provide a benchmark against which sampling can be judged to determine where contaminants are present at unacceptable levels.

NRC Site Cleanup Levels for each of the aquifers impacted by the Site were finalized in 2006 after background water quality was evaluated. Background concentrations were calculated at the 95 percent upper tolerance limit using data from 1995 through 2004. The uranium, selenium, sulfate, TDS, and nitrate cleanup levels were set at the calculated background concentration. Vanadium was set at the analytical detection limit (DL), since it had not been detected from 1995 through 2004. The molybdenum standard was adopted from 40 Code of Federal Regulations (CFR) Part 192 - Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites. For chloride, the NRC Site Cleanup Levels for the alluvial aquifer, Middle Chinle non-mixing zone, and Chinle mixing zone, were set at the secondary drinking water standard (40 CFR Part 143). In the Upper Chinle non- mixing zone and the Lower Chinle non-mixing zone, the NRC Site Cleanup Levels for chloride were set at the calculated background.

Background concentrations for the SMC alluvial aquifer were developed using nine near up-gradient wells: DD, ND, P, P1, P2, P3, P4, Q, and R. Refer to Figure 2-20 for a view of the well locations. Statistical methodology used in evaluating background concentration data complies with EPA guidance for calculating background concentrations (EPA 1992). Although water-quality data is available from as early as 1976, NMED directed that the period of record for the alluvial aquifer background analysis be limited to data from years 1995 through 2004. .

Mixing zones occur in Chinle aquifers from the intrusion of alluvial ground water into the Chinle aquifer at subcrop locations. Alluvial ground water typically has a much higher calcium concentration than the Chinle aquifers' ground water. A calcium concentration of greater than 30 mg/l is generally used to define which wells are in the mixing zone. Therefore, mixing zone ground water within the Chinle aquifers is characterized by an elevated calcium concentration, and for the purposes of defining background water quality, the mixing zone is considered a separate hydrologic system. Areas of the Chinle aquifers where the water quality has not been affected by the intrusion of alluvial ground water are referred to as the "non-mixing" zones.

These standards are assessed at five point of compliance wells (three are screened in the alluvial aquifer and two in the Upper Chinle aquifer). In addition, HMC regularly monitors additional wells to comply with federal and state licenses and permits. Table 3-9 provides a list of compliance monitoring wells that are routinely monitored. Analyses performed for the compliance monitoring are provided in Table 3-10.

Table 3-9 Summary of Groundwater Compliance Monitoring Program

Well	Parameter List Code[1]	Frequency of Monitoring
Alluvial Background Wells		
Background Wells P, Q, 921	B, F	Annual
Operational Monitoring		
Collection system wells	Total Volume	Monthly
Injection system wells	Total Volume	Monthly
Reversal wells B, BA, KZ, DZ, SM, SN, S2, S5	Water Level	Weekly
San Andres Wells		
Deep #1R, Deep #2R, 943M, 951R	B, F H	Annual Semiannual
Alluvial Compliance Monitoring Wells		
On-Site Monitoring Wells (Evap. Ponds) DD, DD2, X	B, F plus Mn H	Annual Quarterly
Additonal On-Site Monitoring Wells 1A, 1K, 639, 802, B11, D1, F, FB, GH, GN, L, L5, K9, M3, MX, MB, MQ, NC, S4, SUB3, T2, T19, T23, T41, T54	B, F	Annual
South Off-Site Wells 490, 497, 540, 631, 643#, 644, 864, 869, Q5, R3, SUB2	B, F	Annual
Section 34 Land application wells 555, 556, 557, 844, 845, 846	B, F	Annual
North Off-Site Wells(includes Section 28 Land application wells) 688, 881, 882, 883, 884, 886, 888, 893, 659, H2A, MR, H55, MO	B, F	Annual
Western Portion of North Off-Site Wells (Includes Section 33 Land application wells) 541, 551, 647, 649, 654, 899, 996	B, F	Annual
Chinle Wells		
Upper Chinle Wells 494, CE2, CE8, CE9, CE15, CF4, CW3, CW13#, CW18, CW25#	B, F	Annual
Middle Chinle Wells 493, ACW, CW17, CW2, CW28, CW45, CW55, CW62, CW76, R3, Y7	B, F	Annual
Lower Chinle Wells CW29, CW32, CW41, CW42, CW43, V6	B, F	Annual

Source: HMC 2019d

1. Refer to Table 3-10 for parameters associated with list codes

= Monitoring will start after well ceasing to be used for injection

Table 3-10 Summary of Groundwater Compliance Monitoring Program

Parameter List Code	Included Parameters (Dissolved)	Method	Reporting Limits	Units
B	Water level			
	pH	A4500-HB	0.01	s.u.
	TDS	A2540 C	20	mg/L
	Sulfate (SO4)	E300.0	4	mg/L
	Chloride (Cl)	E300.0	1	mg/L
	Bicarbonate (HCO3)	A2320 B	5	mg/L
	Carbonate (CO3)	A2320 B	5	mg/L
	Sodium (Na)	E200.7	0.9	mg/L
	Calcium (Ca)	E200.7	0.5	mg/L
	Magnesium (Mg)	E200.7	0.5	mg/L
	Potassium (K)	E200.7	0.5	mg/L
	Nitrate (NO3)	E353.2	0.1	mg/L
	Uranium (U)	E200.8	0.0003	mg/L
	Selenium (Se)	E200.8	0.005	mg/L
	Molybdenum (Mo)	E200.8	0.03	mg/L
	Radium-226 (Ra-226)	E903.0	Precision Variable	pCi/L
F	Vanadium	E200.8	0.01	mg/L
	Radium-228	RA-05	Precision Variable	pCi/L
	Thorium-230	E908.0	Precision Variable	pCi/L
H	Water Level			
	TDS	A2540 C	20	mg/L
	SO4	E300.0	4	mg/L
	U	E200.8	0.0003	mg/L
	Se	E200.8	0.005	mg/L
	Mo	E200.8	0.03	mg/L
	Cl	E300.0	1	mg/L

Source: HMC 2019d

For the purposes of this RI, the NRC Site Cleanup Levels will be considered preliminary remediation goals (PRGs).

3.2.1.2 Groundwater COPCs/ROPCs and Preliminary Remediation Goals for Remedial Investigation

As part of the CERCLA process, COPC/ROPCs are identified in the RI and preliminary remediation goals (PRGs) for the COPCs/ROPCs are developed based on screening levels established by applicable or relevant and appropriate requirements (ARARs) or by risk-based information or criteria. At this stage, PRGs are preliminary and are finalized at the end of the CERCLA process, which is the signing of the ROD.

Table 3-11 lists other potential PRGs for the COPC/ROPCs that are the most stringent of potential chemical-specific ARARs. A complete list of chemical-specific ARARs will be included and discussed in the Feasibility Study. Note that chloride and TDS, which are regulated in the NRC license, are not considered contaminants by EPA; however, they are regulated by the State of New Mexico pursuant to the Clean Water Act.

Table 3-11 Groundwater COPCs/ROPCs and Potential ARARs

Constituent	Other Potential PRGs	Source
Selenium (mg/L)	0.05	NMAC 20.6.2.3103A/EPA Primary Maximum Contaminant Level
Uranium (mg/L)	0.03	NMAC 20.6.2.3103A/EPA Primary Maximum Contaminant Level
Molybdenum (mg/L)	0.08	EPA risk-based value selected in the Molycorp Inc. ROD (EPA 2010b)
Sulfate (mg/L)	600	NMAC 20.6.2.3103B
Nitrate (mg/L)	10	NMAC 20.6.2.3103A/EPA Primary Maximum Contaminant Level
Vanadium (mg/L)	-	No applicable chemical specific ARARs are available for vanadium
Thorium-230 (pCi/L)	15	EPA Primary Maximum Contaminant Level for alpha emitters
Radium-226 and Radium-228 (pCi/L)	5	EPA Primary Maximum Contaminant Level
Chloride (mg/L)	250	NMED, DP-200 permit.
TDS (mg/L)	2,734	NMED, DP-200 permit.

When appropriate, background levels for environmental media are established and compared to PRGs. Where background levels exceed the PRG, it is EPA's policy to clean up sites to background levels. At the Site, remediation is ongoing based on cleanup levels established in the NRC license that has been issued. As described in the previous subsection of this Report, many of the cleanup levels are based on background concentrations that have been scientifically calculated based on data and methodologies that met regulatory guidance and was approved by the applicable regulatory agencies, including NRC, NMED, and EPA.

Table 3-12 provides a summary of the groundwater COPCs/ROPCs cleanup levels in the NRC license and the basis of the cleanup level.

Table 3-12 Comparison of NRC License Cleanup Level (Alluvial Aquifer) and Other Potential PRGs

Constituent	Other Potential PRGs	NRC License Cleanup Level	Basis of NRC Cleanup Level
Selenium (mg/L)	0.05	0.32	Background
Uranium (mg/L)	0.03	0.16	Background
Molybdenum (mg/L)	0.08	0.10	40 CFR Part 192 – Standards for Control of Residual Radioactive Materials from Inactive Uranium Processing Sites
Sulfate (mg/L)	600	1,500	Background
Nitrate (mg/L)	10	12	Background
Vanadium (mg/L)	-	0.02	Analytical Detection Limit
Thorium-230 (pCi/L)	15	0. 3	Analytical Detection Limit
Radium-226 and Radium-228 (pCi/L)	5	5	40 CFR Part 192 – Standards for Control of Residual Radioactive Materials from Inactive Uranium Processing Sites

Based on the comparison in Table 3-12, molybdenum is the only COPC/ROPC where other potential PRGs are more stringent than the NRC License Cleanup Levels, excluding those where the NRC License Cleanup Levels was set to background.

For the nature and extent description of COPCs/ROPCs in groundwater, the NRC License Cleanup Levels are used for comparison to measured levels.

3.2.2 Alluvial Aquifer Impacts from the Homestake Facility

Nature and extent of groundwater impacts to the alluvial aquifer from milling operations are presented in this section. A more detailed presentation of the nature extent of alluvial groundwater impacts and contaminant trends is presented in *2018 Annual Monitoring Report / Performance Review for Homestake's Grants Project Pursuant to NRC License SUA-1471 and Discharge Plan DP-200,* which is the source for this abbreviated description (HMC 2019a).

3.2.2.1 COPCs/ROPCs in the Alluvial Aquifer

Figure 3-3 presents uranium data and contours collected in 2018. The light yellow/green pattern on Figure 3-3 shows areas where uranium concentrations are elevated, which includes the LTP, the STP, and the area to the west extending into Section 28. Additional areas where uranium concentrations in the alluvium were greater than the NRC Site Cleanup Levels in 2018 exist south of the STP along Highway 605, and in Felice Acres. The area of elevated concentrations in Felice Acres extends southwest approximately 2,600 feet from the southwest corner of Felice Acres. Figures 3-4 through 3-6 are detail maps showing uranium concentrations in the alluvial aquifer.

A closer look at the uranium concentrations in the Rio San Jose is provided in Figure 3-7 which presents the 2017 uranium concentrations measured for the Rio San Jose alluvial aquifer and the San Mateo alluvial aquifer in an area extending from the confluence of the alluvial aquifers to the south. Higher uranium concentrations exist in the Rio San Jose alluvial aquifer to the northwest of the San Mateo confluence.

Selenium concentrations throughout the Site in 2018 are presented in Figure 3-8. Concentrations of selenium in the alluvial aquifer above the NRC Site Cleanup Levels are located with the Homestake Facility, with the exception of an area east of Highway 605 located southeast of the LTP. Selenium concentrations in the nearby subdivisions are below the NRC Site Cleanup Levels. Figures 3-9 through 3-11 are detail maps showing selenium concentrations in the alluvial aquifer.

Figure 3-12 presents data and contours of molybdenum concentrations in the alluvial aquifer during 2018. The NRC Site Cleanup Levels for molybdenum is 0.10 mg/l. Significant molybdenum concentrations extend approximately ¼ mile west of the LTP and to the southeast of the STP along Highway 605. A 10 mg/l contour extends around the LTP and to the west side of the STP. Figures 3-13 through 3-15 are detail maps showing molybdenum concentrations in the alluvial aquifer.

Figures 3-16 and 3-17 present Ra-226 and Ra-228 concentrations for the alluvial groundwater near the Site. Ra-226 and Ra-228 concentrations above the NRC Site Cleanup Levels in the alluvial aquifer are limited to areas directly underneath the LTP. Vanadium and Th-230 concentrations are presented on Figures 3-18 and 3-19, respectively. Vanadium concentrations were above or equal to the NRC Site Cleanup Level of 0.02 mg/L in four of the seven alluvial wells located within the footprint of the LTP, one well near the southwest corner of the LTP and three wells located near the perimeter of STP. Thorium-230 was present above the NRC Site Cleanup Level of 0.3 pCi/L in three of the five alluvial wells sampled within the footprint of the LTP. In addition three wells near the perimeter of the LTP also exhibited Th-230 concentrations above the 0.3 pCi/L: one to the north, one to the east and one near the southwest corner.

Sulfate concentration contours for the alluvial aquifer during 2018 are presented on Figure 3-20. Areas where sulfate exceed the NRC Site Cleanup Levels include below the LTP, approximately 0.25 mile west of the LTP, within the 120-acre flood irrigation field, and south of the Murray Acres subdivision. Figures 3-21 through 3-23 are detail maps showing sulfate concentrations in the alluvial aquifer.

Nitrate concentrations measured in the alluvial aquifer in 2018 near the Site are presented in Figures 3-24, 3-25 and 3-26. Areas where the nitrate concentrations exceeded the NRC Site Cleanup Level of 12 mg/L include within the footprint of the LTP (6 out of 30 wells), between the LTP and STP (three wells), and in one well located within the 120-acre flood irrigation field. Nitrate concentrations in all of the alluvial subdivision wells were below 12 mg/L.

3.2.3 Upper Chinle Aquifer Impacts from the Homestake Facility

Nature and extent of groundwater impacts to the Upper Chinle aquifer from milling operations are presented in this section. A more detail presentation of the nature extent of groundwater impacts to the Upper Chinle aquifer and contaminant trends is presented in *2018 Annual Monitoring Report / Performance Review for Homestake's Grants Project Pursuant to NRC License SUA-1471 and Discharge Plan DP-200,* which is the source for this abbreviated description (HMC 2019a).

NRC Site Cleanup Levels for the Upper Chinle aquifer have been established for the mixing zone and the non-mixing zone, as shown in Table 3-8. The mixing zone is defined as the area of the aquifer adjacent to subcrop locations where the alluvial aquifer has had an impact on water quality in the Chinle aquifer. Non-mixing zone areas are where the alluvial aquifer has not had an impact on water quality in the Chinle aquifer. Figure 3-27 displays the extent of the Upper Chinle Mixing Zone impacts.

3.2.3.1 COPCs in the in Upper Chinle Aquifer

Figures 3-28 and 3-29 present contours of uranium concentrations in the Upper Chinle aquifer for 2018. Uranium concentrations exceed the corresponding mixing or non-mixing zone NRC Site Cleanup Level in the LTP area extending down to the south of the Collection Ponds in the Upper Chinle aquifer in 2018. One uranium value exceeds the mixing zone NRC Site Cleanup Level of 0.18 mg/l just north of Broadview Acres and two values in Felice Acres also exceed this NRC Site Cleanup Level.

Selenium concentrations in the Upper Chinle aquifer are presented on Figures 3-30 and 3-31. In 2018, the selenium concentrations are less than the mixing-zone NRC Site Cleanup Level of 0.14 mg/l with the exception of wells in and near the subcrop area near the LTP and extending down to the Collection Ponds. The non-mixing zone NRC Site Cleanup Level of 0.06 mg/l is not exceeded in 2018.

Figures 3-32 and 3-33 present the molybdenum concentrations in the Upper Chinle aquifer during 2018. Molybdenum concentrations near and underlying the LTP exceeded both the mixing and non-mixing zone NRC Site Cleanup Levels of 0.1 mg/L. Concentrations greater than 1.0 mg/L were observed in a region extending from the Upper Chinle-alluvium subcrop area, below the LTP, toward the east side of the LTP and to the south of Evaporation Pond 2 and the Collection Ponds. The NRC Site Cleanup Levels is exceeded in one well north of Broadview Acres. Molybdenum concentrations from Broadview Acres to the south and east of the East Fault were equal or below NRC Site Cleanup Levels in 2018.

Vanadium concentrations measured in 2018 are presented in Figure 3-34. A vanadium concentration of 0.02 mg/L, which is above the NRC Site Cleanup Level of 0.01 mg/L, was detected in well CW3. Well CW3 is located northwest of the HMC office. Remaining measurements were equal to or less than the NRC Site Cleanup Levels.

Figures 3-35 and 3-36 present the radium-226 (Ra-226) and the radium-228 (Ra-228) values measured in 2018. None of the values exceed the EPA Maximum Contaminant Level (MCL). The largest Ra-226 concentration measured in the Upper Chinle wells in 2018 was 3.7 pCi/l in well CW3. The largest Ra-228value was 2.9 pCi/l in well CW18.

Sulfate concentrations in the Upper Chinle aquifer during 2018 are presented in Figures 3-37 and 3-38. Only wells below and near the LTP area exceeded the NRC Site Cleanup Level for the mixing zone of 1750 mg/l. The non-mixing zone NRC Site Cleanup Level of 914 mg/l in the Upper Chinle in 2018 is also exceeded in the eastern portion of the LTP.

Nitrate concentrations in the Upper Chinle aquifer measured in 2018 are presented in Figures 3-39 and 40. All measured nitrate concentrations in the Upper Chinle aquifer in 2018 are less than the NRC Site Cleanup Level except for well T32 at 18.7 mg/l.

3.2.4 Middle Chinle Aquifer Impacts from the Homestake Facility

Nature and extent of groundwater impacts to the Middle Chinle aquifer from milling operations are presented in this section. A more detailed presentation of the nature extent of groundwater impacts to the Middle Chinle aquifer and contaminant trends is presented in *2018 Annual Monitoring Report / Performance Review for Homestake's Grants Project Pursuant to NRC License SUA-1471 and Discharge Plan DP-200,* which is the source for this abbreviated description (HMC, 2019a).

NRC Site Cleanup Levels for the Middle Chinle aquifer have been established for the mixing zone and the non-mixing zone. Figure 3-41 displays the extent of the Middle Chinle Mixing Zone. In the area west of the West Fault, it is believed the Middle Chinle subcrops an alluvial aquifer further to the north, based on the geochemistry (calcium concentrations). The Middle Chinle mixing zone is created by alluvial water entering the Middle Chinle north of the area shown on the figure and flowing to the subcrop area to the southwest.

3.2.4.1 COPCs in the Middle Chinle Aquifer

Figures 3-42 and 3-43 presents contours of uranium concentrations in the Middle Chinle aquifer during 2018. Areas in the southern portion of Felice Acres, extending into Section 3, west and northwest of the LTP exhibited concentrations greater than the mixing-zone NRC Site Cleanup Levels. Uranium concentrations in the Middle Chinle aquifer exceeded non-mixing zone NRC Site Cleanup Levels in Broadview Acres and Felice Acres.

Selenium concentrations were measured in 2018 in the Middle Chinle aquifer and are presented on Figures 3-44 and 3-45. An area northwest of the LTP exceeded the mixing zone NRC Site Cleanup Levels in 2018. The higher selenium concentrations in these wells are caused by downward movement of alluvial water into the Middle Chinle aquifer subcrop. An area located in Felice Acres exceeded the non-mixing zone NRC Site Cleanup Levels in two wells.

The 2018 molybdenum concentrations in the Middle Chinle aquifer are presented on Figures 3-46 and 3-47. Molybdenum concentrations greater than the NRC Site Cleanup Levels of 0.10 mg/L can be found west of the West Fault, northwest of the LTP.

Sulfate concentration contours for the Middle Chinle aquifer for 2018 are presented in Figures 3-48 and 3-49. Concentrations ranged from 459 to a high of 2,200 mg/L in 2018. Mixing-zone sulfate concentrations in the Middle Chinle aquifer were above the NRC Site Cleanup Levels of 1,750 mg/L in four wells west of the West Fault. Sulfate concentrations in the non-mixing zone of the Middle Chinle were below the NRC Site Cleanup Levels of 867 mg/L.

Figure 3-50 presents the nitrate concentrations in the Middle Chinle aquifer wells from samples collected in 2018. There is an area west of the West Fault where the mixing zone NRC Site Cleanup Levels was exceeded.

3.2.5 Lower Chinle Aquifer Impacts from the Homestake Facility

Nature and extent of groundwater impacts to the Lower Chinle aquifer from milling operations are presented in this section. A more detailed presentation of the nature extent of groundwater impacts to the Lower Chinle aquifer is presented in *2018 Annual Monitoring Report / Performance Review for Homestake's Grants Project Pursuant to NRC License SUA-1471 and Discharge Plan DP-200,* which is the source for this abbreviated description (HMC, 2019a).

NRC Site Cleanup Levels for the Lower Chinle aquifer have been established for the mixing zone and the non-mixing zone, as shown in Table 3-8. Figure 3-51 displays the location of the Lower Chinle Mixing Zone.

3.2.5.1 COPCs in the Lower Chinle Aquifer

Figures 3-52 and 3-53 present uranium concentrations in the Lower Chinle aquifer collected in 2018. Uranium concentrations observed in 2018 in the Lower Chinle aquifer exceeded the mixing-zone

NRC Site Cleanup Levels southwest of Felice Acres in Section 3. The non-mixing zone adjacent and northeast of the mixing zone also exceeded the NRC Site Cleanup Levels.

Selenium concentrations in the Lower Chinle aquifer for 2018 are presented on Figures 3-54 and 3-55. None of the selenium concentrations obtained in 2018 from the Lower Chinle wells exceeded the NRC Site Cleanup Levels.

The 2018 molybdenum concentrations obtained from the Lower Chinle wells were at levels near the DL. These measurements were consistent with historic measurements of molybdenum in the Lower Chinle aquifer.

Sulfate concentrations in the Lower Chinle aquifer during 2018 are presented in Figures 3-56 and 3-57. None of the Lower Chinle concentrations of sulfate or nitrate exceeded NRC Site Cleanup Levels in the mixing zone. Areas west of the West Fault and north of the LTP have sulfate concentrations greater than NRC Site Cleanup Levels in the non-mixing zone, which are thought to be naturally occurring levels.

Nitrate concentrations measured in 2018 are all significantly below the site standard.

3.2.6 San Andres-Glorietta Aquifer

As described in Section 2.6.5, the San Mateo alluvial and SAG aquifers are separated by the Chinle formation, preventing the direct communication between the aquifers. A subcrop of the SAG to the San Jose alluvial aquifer occurs about 2 miles southwest of the LTP. As can be seen by comparing Figure 2-44 with Figures 3-3 through 3-26, the subcrop occurs in a location that has not been impacted by releases from the Site.

Figures 3-58 and 3-59 provide concentrations versus time plots for uranium from SAG wells that are routinely monitored by HMC. The location of these wells is shown on Figure 2-44. Highest uranium concentrations in the SAG wells monitored during 2018 were 0.088 and 0.03 mg/l in wells 943 and 951R respectively. The 2017 uranium value of 0.11 mg/l from well 806R appears to be an outlier. Uranium concentrations in well 943 are much greater than those in well 943M because leakage into well 943 from an overlying aquifer had affected the concentration in well 943 prior to its abandonment.

Selenium concentrations in the San Andres aquifer vary from <0.005 to 0.011 mg/l except for the effected concentration in well 943 of 0.047 mg/l. All measured molybdenum concentrations are less than 0.03 mg/l.

Uranium milling operations at the Bluewater Mill Site, which is located approximately 4 miles west north-west (directly upgradient) of the LTP released uranium to the SAG aquifer. Refer to Figure 3-60 for an isoconcentration contour map for uranium in the SAG aquifer. Based on this information, the increase in uranium concentration experienced in Well 951R is probably the result of uranium releases from the Bluewater Mill Site.

3.2.7 Nature and Extent of Soil Contamination from the Homestake Facility

As described in Section 1.4.2.2 of this report, areas around the tailings piles, shown on Figure 1-5, were remediated to the soil cleanup levels prescribed by NRC in 10 CFR 40 Appendix A (NRC 1999). Characterization and verification methods used, and the data collected were documented in

Completion Report for Reclamation of Off-Pile Areas at the Homestake Mining Company of California Uranium Mill (ERG 1995). For reference, this report is provided in Appendix C.

Described in this section are results of recent Homestake Facility soils investigations to characterize the nature and extent of soil contamination.

3.2.7.1 Chemicals and Radionuclides of Potential Concern and PRGs

In 2011, EPA completed a background study for surface soils (EPA 2014a). Samples for the background study were collected approximately 2 miles southwest of the Site (refer to Figure 3-61). Electronic data for the soil data set is provided in Appendix D. A statistical summary of select radionuclides and metals is presented in Table 3-13. Based on the results of the background study, as well as Site history and results from the extensive environmental studies and activities completed at the Site, the following soil ROPCs were retained:

- Uranium-234/238
- Th-230
- Ra-226 and Ra-228

40 CFR 192 establishes soil cleanup values of 5 pCi/g above background in surface soils (>15 centimeters) and 15 pCi/g above background in subsurface soils for Ra-226, Ra-228, and Th-230 at UMTRA Title I sites. The surface value is a health-based standard based on gamma radiation exposure. Since the Homestake Facility will remain under federal control following completion of remediation, these standards are relevant and appropriate. Other PRGs for soil are developed for the HHRA (see Section 5) using EPA's PRG Calculator (EPA 2019b).

Table 3-13 Background Descriptive Statistics for Metals and Radionuclides in Soil

Chemical	n	Mean	Median	Minimum	Maximum	Standard Deviation
Metals (mg/kg)						
Arsenic	12	4.80	4.68	4.25	5.52	0.40
Lead	12	11.13	10.55	9.46	14.20	1.56
Molybdenum	12	0.41	0.39	0.34	0.62	0.08
Selenium	12	0.55	0.40	0.35	2.03	0.47
Vanadium	12	27.55	28.05	20.40	36.50	4.47
Radionuclides (pCi/g)						
Ra-226	12	1.70	1.74	1.29	2.00	0.21
Ra-228	12	1.08	1.11	0.91	1.26	0.11
Th-230	5	1.10	1.05	0.70	1.56	0.31
U-234	5	0.91	0.88	0.60	1.22	0.24
U-235	12	0.10	0.10	0.06	0.12	0.02
U-235	5	0.06	0.06	0.00	0.12	0.05
U-238	5	0.95	0.89	0.73	1.21	0.21

Source: EPA 2014a
mg/kg = milligram per kilogram
pCi/g = picocurie per gram

3.2.7.2 EPA Soil Sampling for 2013 Human Health Risk Assessment

EPA completed an investigation of soils within and near the Homestake Facility boundaries for developing a baseline risk assessment for off-Site residential receptors. Surface soil samples were collected from banks of evaporation ponds, near the fence line at the southwest boundary of the Homestake Facility, and areas between the fence line and the evaporation ponds. Refer to Figure 3-61 for the sample locations.

Table 3-14 and 3-15 provide the descriptive statistics for samples collected within the Homestake Facility and at the fence line, respectively.

As shown on Figure 3-61, two samples were collected from near the banks of EP-1. According to information from EPA, these samples were collected from “white residue” at the banks of EP-1. It is believed that the white residue is salts that evaporate from the ponds. Since the salts do not represent soil, data from these samples is evaluated qualitatively.

Table 3-14 Descriptive Statistics for Metals and Radionuclides in Surface Soil (0-6 inches bgs) Collected Between the Evaporation Ponds and Fenceline

Chemical	n	Mean	Median	Minimum	Maximum	Standard Deviation
Metals (mg/kg)						
Arsenic	26	5.89	6.32	2.68	9.58	1.68
Lead	26	14.28	16.15	3.88	19.70	4.79
Molybdenum	26	6.93	1.81	0.62	126.00	24.33
Selenium	26	1.37	0.75	0.37	11.10	2.09
Vanadium	26	36.29	40.05	11.70	60.70	12.46
Radionuclides (pCi/g)						
Ra-226	26	3.50	3.06	1.48	8.90	1.78
Ra-228	25	1.32	1.47	0.48	1.71	0.37
Th-230	24	2.13	1.83	0.51	5.85	1.40
U-234	24	3.39	2.47	0.58	18.30	3.48
U-235	26	0.25	0.22	0.07	0.70	0.14
U-235	24	0.19	0.14	0.03	0.99	0.19
U-238	24	3.43	2.68	0.83	19.00	3.61

Source: EPA 2014a
mg/kg = milligram per kilogram
pCi/g = picocurie per gram

Table 3-15 Descriptive Statistics for Metals and Radionuclides in Soil Collected Near the Fenceline

Chemical	n	Mean	Median	Minimum	Maximum	Standard Deviation
Metals (mg/kg)						
Arsenic	4	3.72	3.76	2.67	4.71	0.95
Lead	4	9.31	8.74	6.45	13.30	3.33
Molybdenum	4	0.94	1.01	0.35	1.41	0.50
Selenium	4	0.48	0.50	0.23	0.68	0.22
Vanadium	4	20.58	19.85	15.10	27.50	6.38
Radionuclides (pCi/g)						
Ra-226	4	2.41	2.39	1.20	3.64	1.00
Ra-228	4	0.87	0.89	0.61	1.09	0.23
Th-230	4	1.56	1.50	0.66	2.58	0.80
U-234	4	1.17	1.13	0.49	1.95	0.62
U-235	4	0.15	0.15	0.08	0.22	0.06
U-235	4	0.12	0.12	0.08	0.17	0.05
U-238	4	1.14	1.07	0.52	1.90	0.57

Source: EPA 2014a
mg/kg = milligram per kilogram
pCi/g = picocurie per gram

3.2.7.3 Soil Sampling Near Evaporation Ponds

In 2009, HMC collected soil samples around the evaporation ponds (EP-1, EP-2, and EP-3). The objective of the soil sampling was to characterize pre-construction soil conditions near EP-3 and provide general indicators of soil quality near EP-1 and EP-2. The location of the soil samples collected is displayed on Figure 3-62. Soil samples were collected from the surface (0 inch to 6 inches) around EP-1 and EP-2 (17 locations) and EP-3 (10 locations). Subsurface samples (depths greater than 6 inches) were collected at 11 of the 17 EP-1 and EP-2 locations and at all EP-3 locations.

The samples obtained in the vicinity of EP-1, EP-2, and EP-3 were analyzed for radionuclides (Ra-226, Th-230, and uranium), molybdenum, selenium and a number of soil quality parameters that are not relevant to the RI Report and are therefore not included in this report. Analytical methods used for the analysis are provided in Table 3-16.

Table 3-16 Analytical Methods for Soil Analysis

Parameter	Method Number	Method
Soil digestion	EPA Method 3052[1]	Microwave digestion
Radium-226	EPA Method 903.1[2]	Radon emanation
Thorium-230	ESM 4506/4108[3]	Alpha spectroscopy
Total Uranium	EPA 6020[1]	EPA 6020[1]
Total Molybdenum	EPA 6020[1]	EPA 6020[1]
Total Selenium		

Source: HMC 2014
1. EPA 2007a
2. EPA 2008
3. Instrument manufacturer procedure: Alpha Spectrometer Counting Procedure (4108), Determination of Thorium in Soil and Water

Results from the analysis of samples collected near EP-1 and EP-2 for molybdenum and selenium are provided in Table 3-17.

Table 3-17 Analytical Results: Molybdenum and Selenium Concentrations Near EP-1 and EP-2.

Sample ID	Molybdenum mg/kg	Selenium mg/kg	Sample ID	Molybdenum mg/kg	Selenium mg/kg
EP-1 0-6"	13[1]	1[2]	EP-9 12-18"	6[2]	1[2]
EP-1 6-12"	11[1]	1[2]	EP-10 0-6"	8[1]	1[2]
EP-2 0-6"	6[2]	1[2]	EP-10 6-12"	6[2]	1[2]
EP-3 0-6"	26[1]	1[2]	EP-11 0-6"	7[2]	1[2]
EP-3 6-12"	9[1]	1[2]	EP-12 0-6"	7[2]	1[2]
EP-3 12-18"	6[2]	1[2]	EP-13 0-6"	20[1]	3[1]
EP-4 0-6"	6[2]	1[2]	EP-13 6-12"	18[1]	4[1]
EP-4 6-12"	6[2]	1[2]	EP-13 12-18"	6[2]	1[2]
EP-5 0-6"	6[2]	1[2]	EP-14 0-6"	12[1]	2[1]
EP-6 0-6"	6[2]	1[2]	EP-14 6-12"	7[1]	2[1]
EP-6 6-12"	6[2]	1[2]	EP-15 0-6"	7[2]	1[2]
EP-6 12-18"	6[2]	1[2]	EP-16 0-6"	20[1]	3[1]
EP-7 0-6"	6[2]	1[2]	EP-16 6-12"	12[1]	3[1]
EP-7 6-12"	6[2]	1[2]	EP-16 12-18"	6[2]	3[1]
EP-8 0-6"	6[2]	1[2]	EP-17 0-6"	6[2]	1[2]
EP-9 0-6"	11[1]	1[2]	EP-17 6-12"	6[2]	1[2]
EP-9 6-12"	6[2]	1[2]			

Source: HMC 2014
1. Sample result qualified as B; i.e., analyte concentration detected at a value between method and practical quantitation limits. The associated value is an estimated quantity.
2. Sample result qualified as U; i.e., the material was analyzed for, but was not detected above the level of the associated value. The associated value is the sample quantitation or detection limit.
mg/kg = milligram per kilogram

Table 3-18 lists the concentrations of Ra-226, Th-230, and uranium from samples collected near EP-1 and EP-2. Concentrations of molybdenum and selenium from samples collected near EP-3 are listed in Table 3-19 and Table 3-20 lists radionuclide concentrations from samples collected near EP-3.

Table 3-18 Analytical Results: Radionuclide Concentrations Near EP-1 and EP-2.

Sample ID	Radium-226		Thorium-230		Uranium	
	Concentration	MDC	Concentration	MDC	Concentration	
	pCi/g	pCi/g	pCi/g	pCi/g	mg/kg	pCi/g
EP-1 0-6"	0.7	1.1	-0.1	1.6	13	9
EP-1 6-12"	9.9	1.6	1.4	1.5	5	3
EP-2 0-6"	1.1	1.5	0.53	1.4	6	4
EP-3 0-6"	3.6	0.78	2.7	1.5	29	20
EP-3 6-12"	1.5	0.92	0.43	1.6	6	4
EP-3 12-18"	0.84	0.82	-0.24	1.6	4[1]	3[1]
EP-4 0-6"	9	1.1	1.7	1.8	8	5
EP-4 6-12"	1.3	0.99	0.14	1.6	2[1]	1[1]
EP-5 0-6"	0.92	1.2	0.57	1.6	5[1]	3[1]
EP-6 0-6"	1.1	1.2	0.66	2	6[1]	4[1]
EP-6 6-12"	0.91	0.99	-0.07	1.7	2[1]	1[1]
EP-6 12-18"	6.2	1.3	0.28	1.7	1[1]	1[1]
EP-7 0-6"	0.65	0.44	0.44	1.5	4[1]	3[1]
EP-7 6-12"	0.79	1.1	0.02	1.5	2[1]	1[1]
EP-8 0-6"	1.2	1.1	3	1.5	2[1]	1[1]
EP-9 0-6"	1.3	0.91	0.88	1.8	9	6
EP-9 6-12"	1	1.1	0.39	1.5	3[1]	2[1]
EP-9 12-18"	0.05	0.95	0.47	1.6	2[1]	1[1]
EP-10 0-6"	4.1	1.2	1.5	1.6	15	10
EP-10 6-12"	3.6	1.1	1.5	1.6	11	7
EP-11 0-6"	3	1.3	2	1.6	8	5
EP-12 0-6"	2.6	1.2	1.4	1.5	6[1]	4[1]
EP-13 0-6"	2.3	1.1	1.3	1.6	24	16
EP-13 6-12"	3.1	1.3	1.9	1.6	13	9
EP-13 12-18"	1.5	1.2	0.68	1.6	4[1]	3[1]
EP-14 0-6"	2	0.88	2.8	1.5	11	7
EP-14 6-12"	1.7	0.97	0.61	1.6	6	4
EP-15 0-6"	6.1	0.82	2.5	1.7	7[1]	5[1]
EP-16 0-6"	4	1.1	2.3	1.6	16	11
EP-16 6-12"	4.6	1.1	1.9	1.7	9	6
EP-16 12-18"	1.8	0.81	1	1.7	5[1]	3[1]
EP-17 0-6"	2.1	0.74	1.6	1.5	5[1]	3[1]
EP-17 6-12"	2.2	0.81	2.9	1.5	30	20

Source: HMC 2014

1. Sample result qualified as B; i.e., analyte concentration detected at a value between method and practical quantitation limits. The associated value is an estimated quantity.

pCi/g = picocurie per gram

mg/kg = milligram per kilogram

Table 3-19 Analytical Results: Molybdenum and Selenium Near EP-3.

Sample ID	Molybdenum mg/kg	Selenium mg/kg	Sample ID	Molybdenum mg/kg	Selenium mg/kg
EP3-1 0-6"	6[2]	2[1]	EP3-5 0-6"	6[2]	1[2]
EP3-1 6-18"	6[2]	1[2]	EP3-5 6-18"	6[2]	1[2]
EP3-2 0-6"	49	2[1]	EP3-6 0-6"	6[2]	1[2]
EP3-2 6-18"	28[2]	1	EP3-6 6-18"	6[2]	1[2]
EP3-3 0-6"	6[2]	3[1]	EP3-7 0-6"	6[2]	1[2]
EP3-3 6-18"	6[2]	1[2]	EP3-7 6-18"	6[2]	1[2]
EP3-4 0-6"	6[2]	1[2]	EP3-8 0-6"	6[2]	1[2]
EP3-4 6-18"	6[2]	1[2]	EP3-8 6-18"	6[2]	1[2]

Source: HMC 2014
1. Sample result qualified as B; i.e., analyte concentration detected at a value between method and practical quantitation limits. The associated value is an estimated quantity.
2. Sample result qualified as U; i.e., the material was analyzed for, but was not detected above the level of the associated value. The associated value is the sample quantitation or detection limit.
mg/kg = milligram per kilogram

Table 3-20 Analytical Results: Radionuclide Concentrations Near EP-3.

Sample ID	Radium-226		Thorium-230		Uranium, total	
	Concentration	MDC	Concentration	MDC	Concentration	
	pCi/g	pCi/g	pCi/g	pCi/g	mg/kg	pCi/g
EP3-1 0-6"	14	1	2.9	1.4	6	4
EP3-1 6-18"	3.8	1.1	1.9	1.5	3[1]	2[1]
EP3-2 0-6"	2.8	0.77	1.3	1.5	44	30
EP3-2 6-18"	2.6	1	1.3	1.5	24	16
EP3-3 0-6"	8.3	1	7.4	1.5	6[1]	4[1]
EP3-3 6-18"	2.9	1.1	1.6	1.5	8	5
EP3-4 0-6"	5.9	0.86	2	1.7	3[1]	2[1]
EP3-4 6-18"	1.5	0.95	0.77	1.4	3[1]	2[1]
EP3-5 0-6"	2.8	0.75	2.4	1.4	3[1]	2[1]
EP3-5 6-18"	1.9	0.95	1.8	1.5	3[1]	2[1]
EP3-6 0-6"	5.5	1.2	3	1.4	6[1]	3[1]
EP3-6 6-18"	1.3	0.8	0.85	1.7	3[1]	2[1]
EP3-7 0-6"	5.6	0.73	7.1	1.6	5[1]	3[1]
EP3-7 6-18"	3	0.8	2.3	1.3	3[1]	2[1]
EP3-8 0-6"	3.3	1	2.3	1.5	4[1]	3[1]
EP3-8 6-18"	1.4	1.1	0.91	1.4	2[1]	1[1]
EP3-9 0-6"	1.7	0.83	2.2	1.9	3[1]	2[1]
EP3-9 6-18"	1.1	0.83	0.98	1.6	2[1]	1[1]
EP3-10 0-6"	1	0.82	1.1	1.4	3[1]	2[1]
EP3-10 6-18"	0.04	1.1	0.12	1.7	2[1]	1[1]

Source: HMC 2014
Sample result qualified as B; i.e., analyte concentration detected at a value between method and practical quantitation limits. The associated value is an estimated quantity.
pCi/g = picocurie per gram
mg/kg = milligram per kilogram

3.2.7.4 Windblown Contamination Remediation Outside the Homestake Facility

As described in Section 1.4.2.2, soil remediation was conducted as part of the facility decommissioning to remediate soil impacted by dust generated during mill operations. The remediation occurred both within and outside the license boundary, as shown in Figure 1.5.

Remediation of the windblown areas outside license boundaries were remediated as required by NRC License Condition 29C and in accordance with 10 CFR 40 Appendix A Criterion 6 (6). Specifically, the soil cleanup criteria was:

- 10.5 piC/g in the upper 15 cm of soil
- 20.5 piC/g below 15 cm the ground surface

See Section 1.4.2.2 for further discussion of the soil cleanup criteria.

Confirmation sampling of the areas outside the license boundary consisted of both field gamma readings and confirmation sampling and analysis. In addition, the density of confirmation sampling varied for the “inner zone” and the “outer zone”. Refer to Figure 1-5 for the extent of the zones. Areas outside the license boundary were within the outer zone. The confirmation sampling for the outer zone was performed as follows:

- Grid blocks measuring 500 feet by 500 feet were established.
- The grid blocks were futher divided into 100 square meter blocks (roughly 33 feet by 33 feet). Areas were remediated until the average gamma reading for any area of 100 square meter size was 21,000 counts per minute (cpm) or less.
- For the first 52 500 foot by 500 foot grid blocks, the 100 square meters with the highest average gamma reading within each grid block was sampled and analyzed for Ra-226.
- Statictics were calculated for the 52 samples and compared to the cleanup criteria of 10.5 piC/g for Ra-226. The mean concentration was 2.51 pCi/g and the 95% confidence level using the student t test was 2.6 piC/g, which is much less that the cleanup criteria (ERG 1995).
- Based on passing the statistical test, the remaining outer zone was divided into 1,000 foot by 1,000 foot grid blocks. One sample from the 100 square meter block within each 1,000 foot by 1,000 fot grid block with the highest average gamma reading was sampled and analyzed for Ra-226. A total of 78 samples was collected using the larger grid blocks.
- Statistics for the set of 78 samples indicated that the mean concentration was 2.95 pCi/g (ERG 1995) and the 95% confidence level using the student t test was 3.5 piC/g, which is much less that the cleanup criteria (ERG 1995).

Confirmation samples collected were analyzed using an on-site lab and approximately ten percent of the samples were analyzed at an off-site laboratory for quality control.

Gamma scans and confirmation scanning extended beyond the extent of soil remediation to verify that the extent of windblown contaminants had been remediated. In the report documenting the

remediation, the area beyond what was remediated was referred to as the “off-set” area. Generally, the offset area extended 100 - 200 feet beyond the remediation limits.

As described in Section 1.4.2.2, the objective of the windblown cleanup was to remediate the top 15 cm of soil to less than 10.5 pCi/g. This cleanup objective was met. Details of the remediation results, including the plates showing the gamma scan results, are available in Appendix C. Documentation of NRC approval of the remediation is also available in Appendix C.

The mean concentrations of Ra-226 were based on a sampling methodology that was biased high. For each 500 foot by 500 foot grid blocks, there were 225 100 square meters blocks that were scanned. On average there were between 8 and 9 gamma readings recorded within each 100 square meters block. The block with the highest average gamma reading was sampled. For the 1,000 foot by 1,000 foot grid blocks, there were 900 100 square meters blocks and the one with the highest average gamma reading was sampled. As a result, the mean Ra-226 concentrations do not represent the average Ra-226 concentration in the surface soil after remediation, but a concentration that is higher.

Two relatively recent activities provide relevant information that can be compared to the confirmation data from the windblown remediation:

- In 2013, the EPA completed a Time Critical Removal Action which included soil remediation in the nearby subdivisions. For the Removal Action, an action level of 3.5 pCi/g was used, which is higher than the confirmation sample averages (EPA 2013).
- In 2019, Homestake conducted a gamma survey of a portion of the San Mateo alluvial flood plain upgradient of the Homestake Facility. See Figure 3-63 for the location and a graphic display of the gamma survey results. The average of the upgradient gamma data was calculated to be 14,337 cpm (ERG 2019). The 52 500 foot by 500 foot grid blocks recorded an average gamma reading of 16,629 cpm. Although the average gamma confirmation data is higher, the confirmation sampling methodology was biased high.

Preliminary analyses indicate that potential health risks within the windblown remediation area outside facility license boundaries are within EPA’s risk management range. The analysis included using the RadPRG calculator to compute a PRG range for Ra-226 for a trespasser scenario. The PRG range for $1x10^{-4}$ to $1x10^{-6}$ cancer risk was 0.98 – 98 pCi/g. Confirmation sampling completed within the outer zone found the average concentration of Ra-226 in the 100 square meters blocks with the highest gamma reading to be 2.51 pCi/g and 2.95 pCi/g. Compared to the trespasser risk range computed with the RadPRG calculator, these concentrations would represent a cancer risk within $1x10^{-5}$ to $1x10^{-6}$.

3.2.8 Nature and Extent of Air Contamination from the Homestake Facility

HMC operates an air-monitoring program for the Homestake Facility. Monitoring data is used to assess the impact on nearby residences and the environment using monitors placed along the perimeter of the Homestake Facility. Potential exposures from the Homestake Facility include:

- Air particulates
- Radon 222

- Direct gamma radiation

Monitors for the above parameters at the Homestake Facility are summarized in Table 3-21. Figure 3-64 shows the locations of these monitors.

Table 3-21 Summary of Air Monitoring Locations

Station	Sampling Unit	Location Notes
HMC-1	Hi-Volume Particulate (Air) Track Etch Cup (Radon) OSL Badge (Gamma)	Located to have the highest concentrations of radioactive airborne particulates
HMC-1A	Hi-Volume Particulate (Air) Track Etch Cup (Radon) OSL Badge (Gamma)	In sectors to have the highest concentrations of radioactive airborne particulates Added in 1st Quarter 2010
HMC-2	Hi-Volume Particulate (Air) Track Etch Cup (Radon) OSL Badge (Gamma)	Located to have the highest concentrations of radioactive airborne particulates
HMC-3	Hi-Volume Particulate (Air) Track Etch Cup (Radon) OSL Badge (Gamma)	Located to have the highest concentrations of radioactive airborne particulates
HMC-4	Hi-Volume Particulate (Air) Track Etch Cup (Radon) OSL Badge (Gamma)	At facility boundary nearest occupied residences
HMC-5	Hi-Volume Particulate (Air) Track Etch Cup (Radon) OSL Badge (Gamma)	At facility boundary nearest occupied residences
HMC-6	Hi-Volume Particulate (Air) Track Etch Cup (Radon) OSL Badge (Gamma)	Background for airborne particulate
HMC-7	Particulate Blank Track Etch Cup (Radon)	At facility boundary, south of the LTP, along Highway 605
HMC-16	Track Etch Cup (Radon) OSL Badge (Gamma)	Background for Radon and Direct Gamma Radiation

Source: HMC 2013a
OSL = optically stimulated luminescence detector

HMC-16 is the NRC approved air monitoring location for radon background at the Homestake Facility and HMC-6 is the NRC approved location for airborne particulates at the Homestake Facility.

These background locations were selected when the Homestake Facility was licensed in 1958 and a basis for the selection of these locations is not documented in the record.

For particulates, the most appropriate location for a background station would be upwind. As stated in Section 2.3.2, the most dominant (strongest) winds are from the west and southwest. HMC-6's location to the west would seem appropriate, but a study into the most appropriate location has not been conducted.

In 2013, HMC conducted an evaluation of radon background to evaluate whether HMC-16 is appropriate and if not, to select a more appropriate location. A key consideration in selecting the appropriate background is the conceptual model for radon transport from the Homestake Facility and other sources. Based on evaluation of collected data and air modeling completed by HMC, the highest radon concentrations in air occur during calm or near-calm conditions. During calm

conditions radon transport is driven predominantly by topography, moving principally downgradient (HMC 2013b). Thus, an appropriate location for background is topographically upgradient from the Homestake Facility and situated in a similar topographic position. Other key considerations for selecting an appropriate location include:

- Within an area that has similar geologic formations; and
- Within an area that is far enough from the Homestake Facility to not be significantly affected by Homestake Facility off-gassing of radon.

HMC-16 is topographically higher than nearby drainages and isolated from San Mateo Creek. For these reasons, HMC has concluded that it is likely underestimating background radon concentrations (HMC 2013b).

3.2.8.1 Radionuclides of Potential Concern

ROPCs at the Homestake Facility are monitored by HMC and include:

- Uranium, Th-230, Ra-226
- Radon-222
- Gamma radiation

3.2.8.2 Uranium, Radium-226, and Thorium-230

Particulate samplers are analyzed for natural uranium, Ra-226, and Th-230. Monitoring station HMC-6 is considered background for airborne particulates.

Semiannual reports submitted to NRC summarize radionuclide concentrations. Table 3-22 summarizes the average quarterly results of radionuclide concentrations in micro Curies per milliliter (µCi/ml) for the high volume samplers for calendar years 2015 and 2018.

Table 3-22 Radionuclide Concentrations (µCi/ml) 2015 through 2018

Monitor Location	Radionuclide	Average	Max	Min
HMC-1	Uranium	2.79E-16	4.73E-16	1.25E-16
	Th-230	1.58E-17	2.50E-17	6.75E-18
	Ra-226	2.53E-17	3.00E-17	1.60E-17
HMC-1A[2]	Uranium	1.72E-16	2.85E-16	9.25E-17
	Th-230	1.86E-17	2.60E-17	1.08E-17
	Ra-226	2.68E-17	3.50E-17	1.25E-17
HMC-2	Uranium	2.59E-16	4.58E-16	1.45E-16
	Th-230	1.99E-17	3.50E-17	1.10E-17
	Ra-226	3.03E-17	3.75E-17	1.85E-17
HMC-3	Uranium	6.33E-16	1.12E-15	4.23E-16
	Th-230	2.00E-17	3.00E-17	1.38E-17
	Ra-226	3.32E-17	4.00E-17	2.03E-17
HMC-4	Uranium	8.56E-16	1.50E-15	4.63E-16
	Th-230	4.01E-17	6.50E-17	2.13E-17
	Ra-226	5.63E-17	9.25E-17	2.78E-17
HMC-5	Uranium	1.82E-15	2.58E-15	1.04E-15
	Th-230	2.34E-17	4.25E-17	1.25E-17
	Ra-226	3.58E-17	4.25E-17	2.58E-17
HMC-6 (Background)	Uranium	3.24E-16	4.63E-16	1.93E-16
	Th-230	2.14E-17	3.75E-17	1.20E-17
	Ra-226	3.56E-17	4.25E-17	2.23E-17

Source: HMC 2013a; HMC 2019c

3.2.8.3 Radon-222/220

Semiannual reports submitted to NRC summarize radon gas concentrations. Table 3-23 summarizes the average semiannual results of radon concentrations (µCi/ml) for the track etch samplers for calendar years 2015 through 2018. HMC-16 is considered background for radon and direct gamma radiation.

Table 3-23 Summary of Annual Radon Gas Monitoring Results 2015 through 2018 (pCi/L)

Monitor Location	2015	2016	2017	2018
HMC-1	1.13	0.91	0.73	0.80
HMC-1A	1.18	0.94	0.62	0.73
HMC-2	1.21	0.97	0.72	0.93
HMC-3	0.92	0.72	0.57	0.71
HMC-4	1.37	1.10	0.71	0.89
HMC-5	1.37	0.91	0.68	0.84
HMC-6	0.98	0.92	0.69	0.69
HMC-7	0.84	0.85	0.69	0.81
HMC-16 (Background)	0.65	0.49	0.32	0.35

Source: HMC 2013a; HMC 2019c
NA = Not available, data set incomplete
µCi/mL = microCurie per milliliter

A NRC License amendment in 2002 requires HMC to collect radon flux measurements annually. Radon flux is measured with radon canisters placed on the LTP and STP. Radon flux from the mill tailings pile is limited to 20 pCi/m^{2}s in accordance with National Emission Standards for Hazardous Air Pollutants Subpart W: Standards for Radon Emissions from Operating Uranium Mill Tailings.

Through 2016, 100 canisters distributed over the interim covers on the LTP and STP were used to measure the radon flux. Starting in 2017, 200 canisters, 100 on the LTP and 100 on the STP, were used. Figure 3-65 shows the locations of these canisters.

Prior to 2017, the average radon flux from the LTP was calculated using the area-weighted average of the flux measured annually from the top of the LTP and the flux measured on the side slopes and aprons in 1994 and 1995. The area of the aprons and side slopes constitutes 65 percent of the total area with the top of the pile being 35 percent. In 2017, NRC determined average flux of the LTP could no longer include the side slope. At the STP, because the evaporation pond (EP-1) that sits atop the STP is an operational facility, flux calculations using an area-weighted average is appropriate.

Table 3-24 summarizes the radon flux measurements for the LTP and the STP since 2003. As can be seen, the regulatory limit of 20 pCi/m^{2}s was exceeded in 2016-2018. In 2017, Homestake requested a variance from the flux standard for the top of the LTP as existing groundwater treatment and monitoring wells prevent placement of final radon barrier. Discussions with NRC on the path forward are ongoing and resolution is expected in 2020. In addition, dose assessment based on site measurements indicates the limit exceedance doesnot result in exceedances of public dose limits (HMC 2019c).

Table 3-24 Radon Flux Measurements for Large and Small Tailings Pile

Year	Total Number of Canisters	Total Number of Readings	Number of Measurements Location		Average Measured Flux[1] (Average) pCi/m^{2}s	
			LTP	STP	LTP	STP
2003	89	97	52	46	14.1	5.58
2004	89	99	66	33	20.3	7.7
2005	97	101	61	36	15.3	8.21
2006	97	102	61	36	20.6	6.9
2007	97	97	61	36	14.1	12.05
2008	97	103	64	36	9.73	4.67
2009	96	102	64	35	16.8	5.6
2010	97	103	65	35	17.5	6.59
2011	100	100	65	36	18.8	9.14
2012	100	99	63	36	15.67	4.12
2013	100	100	64	36	18.93	8.28
2014	100	100	64	36	19.7	6.84
2015	100	100	64	36	19.64	7.22
2016	204	200	100	100	21.73	7.88
2017	200	200	100	100	46.6	3.5
2018	200	200	100	100	51.3	12.7

Source: HMC 2013a, HMC 2019c
1 Individual canister measurements are presented in annual monitoring reports
pCi/m^{2}s = picocurie per square meter per second
LTP = Large Tailings Pile
STP = Small Tailings Pile

Measured average flux values for the LTP slightly exceeded the 20 pCi/m^{2}s standard in 2004, 2006, 2010, 2011, and 2015 - 2018. In 2004, additional interim cover was placed on the top of the LTP and new measurements were collected at canister locations that were affected by the new cover. A new average was calculated for the LTP, which brought the pile into compliance. For the year 2006, the measurements could not be made until September. Because of inclement weather, interim cover could not be added until early 2007 where the new measurements indicated an average flux of 18.1 pCi/m2 (Cox 2007). Values reported in Table 3-24 are final measurements.

In 2011, EPA collected radon data from locations on HMC property. Monitoring stations were established at 12 locations along the fenceline between the Homestake Facility and the subdivisions (Murray Acres and Broadview Acres) and at 9 locations either upgradient or downgradient of the former mill facilities. Figures 3-66 and 3-67 show the monitoring station locations. At each of the locations, detectors were in place for approximately 3 months. Monitoring continued for 1 year. Two detectors were placed each quarter at fenceline monitoring stations: one approximately 5 feet above the ground surface and one approximately 6 inches above the ground surface. At the nine stations upgradient or downgradient of the former mill facilities, three detectors were placed 5 feet above the ground surface. At 10 percent of the detectors, an additional, co-located detector was installed for data quality assurance.

During the third and fourth quarters of radon data collection, two passive track-etch detectors were placed side by side at some of the radon monitoring stations, with one of the detectors having a thoron proof filter and the second that detects both radon 222 and thoron (radon-220). Thoron gas is then calculated based on equations and procedures provided by Department of Energy (Pearson, et al. 1991). It is important to note that the correction factors and the calculation of radon (222 and 220) were based on the direct relationship between measured values of the two detectors, one with thoron filter and the other without thoron filter. Table 3-25 summarizes EPA's corrected results.

Table 3-25 Annual HMC Radon Results adjusted for Thoron (Radon-220) in pCi/L

Location	Annual HMC Radon Results adjusted for Thoron	Sub-Location
HMC01	0.91	Upgradient North of Facility
HMC02	1.37	Upgradient North of Facility
HMC03	1	Upgradient North of Facility
HMC04	1.12	Upgradient North of Facility
HMC05	2.1	Downgradient South of Facility
HMC06	2.36	Downgradient South of Facility
HMC07	2.36	Downgradient South of Facility
HMC08	1.2	West of the Facility
HMC09	0.54	North West of the Facility

Source: EPA 2014a
pCi/L = picocurie per Liter

3.2.8.4 Gamma Radiation

Semiannual reports submitted to NRC summarize direct gamma radiation results. Table 3-26 summarizes the average semiannual results of direct gamma radiation results (millirems per year [mrem/yr]) for the optically stimulated luminescence samplers for calendar years 2009 through 2012.

Table 3-26 Net Annual Gamma-Ray Exposure Rate at Nearest Neighbor Locations[1] (mrem/yr)

Year	HMC-1	HMC-2	HMC-3	HMC-4[2]	HMC-5[2]
2012	3	12	6	15	17
2011	3.5	17	0	15	15.5
2010	0	14	8	17	22
2009	1	13	36	11	9

Source: HMC 2013a
1. Values assume 10 percent occupancy.
2. Location used to demonstrate compliance with public dose limits.

3.3 Impacts to Environmental Media at the Land Treatment Areas

The LTAs were irrigated with groundwater that contained uranium, selenium, and other chemicals. This section will describe soil and groundwater impacts to LTAs from irrigation activities. Comparison of pre-irrigation and post-irrigation sampling and analysis of groundwater and soil will be used as the basis for the impacts.

3.3.1 Nature and Extent of Groundwater Contamination at Land Treatment Areas

Impacts to the underlying aquifers resulting from irrigation using Site groundwater are presented for the 120-acre flood irrigation field (located in Section 34), the 150-acre center pivot irrigation field (located in Section 33), the 24-acre flood irrigation field (located in Section 33), and the 100-acre center pivot irrigation field (located in Section 28). Information regarding the geology and hydrogeology as well as concentrations of chemicals monitored is provided the LTAs.

3.3.1.1 Chemicals of Potential Concern at Land Treatment Areas

Based on the chemistry of the groundwater applied to the LTAs, uranium, selenium, and molybdenum are the COPCs for groundwater below the LTAs. Other parameters including sulfate, TDS, chloride, and nitrate are also monitored to evaluate impacts to water quality.

3.3.1.2 Groundwater Impacts at the 120-Acre Flood Irrigation Field

Figure 3-68 provides a plan view of the 120-acre flood irrigation field and Figure 3-69 provides a geologic cross-section of the area. As shown on the cross-section, the San Mateo alluvial aquifer exists throughout the extent of the 120-acre flood irrigation field (HMC 2014). Table 3-27 provides data from monitoring wells used to collect groundwater samples. As shown on Figure 3-68, wells 555, 556, and 557 are located on the western edge of the 120-acre flood irrigation field and wells 844 and 845 are located on the north and south boundaries of the 120-acre flood irrigation field, respectively. Well 846 is located approximately 0.25 mile west of the 120-acre flood irrigation field.

Table 3-27 Well Data for 120-Acre Flood Irrigation Field

Well	Well Depth (ft-bgs)	Casing Diameter (inch)	Water Level		
			Date	Depth (ft-bgs)	Elevation (ft-msl)
555	80	5	2/6/2018	47.52	6509.62
556	80	5	2/6/2018	54	6502.02
557	70	5	2/10/2016	41.55	6512.22
844	75	4	2/6/2018	41.56	6514.57
845	65	4	2/6/2018	39.62	6517.43
846	75	4	12/3/2018	43.82	6505.1

Well	Pipe stickup Above Ground Surface (ft)	Well Elevation Top of Pipe (ft-msl)	Base of Alluvium (ft-bgs)	Base of Alluvium (ft-msl)	Well Screen Interval (ft bgs)	Alluvium Saturated Thickness (ft)
555	2	6557	80	6477	60-80	32.62
556	2	6556	78	6478	60-80	24.02
557	2	6556	70	6486	50-70	26.22
844	1.2	6556.13	70	6484.9	35-75	29.67
845	1.7	6557.05	55	6500.4	45-65	17.03
846	0.8	6548.92	65	6483.1	40-65	22.00

Source: HMC 2014, HMC 2019c
bgs = below ground surface
ft = feet
msl = mean sea level

Figures 3-70 through 3-76 present COPC concentrations over time for wells 555, 556, 557, 844, 845, and 846. These wells are used to monitor the 120-acre flood irrigation field. There has not been a discernable change trend in uranium concentration with the exception of well 844, which appears to be trending slightly upward from 2005 to 2012. Subsequently, the well has been trending downward with uranium concentrations below the established and approved alluvial background concentration of 0.16 mg/L. Well 555 has been monitored since 2011 and the uranium concentration may be trending up slightly. The relatively short monitoring period for this well makes trend analysis less certain than the other wells with all uranium concentrations continuing to be well below the established and approved alluvial background concentration.

Selenium concentrations in well 846 appear to be trending upward since 1995. Since this trend begins prior to the start of the irrigation, the rise is not likely associated with the land treatment program. Wells 844 and 845 both experienced a rise in selenium concentrations, occurring in 2002 in the former and between 2003 and 2005 in the latter. Since those events, selenium concentrations in both wells appear to have stabilized at a concentration well below the established and approved alluvial background of 0.32 mg/L. Well 557, which has been monitored since 2010, appears to be trending upward but remains well below the alluvial background concentration. A trend is not noted in wells 555 and 556.

Molybdenum concentrations in all wells appear stable since 1997.

Sulfate concentrations in wells 844 and 845 have exhibited a general increase during the period of irrigation, but their concentrations are slightly less than concentrations that were observed prior to the mid-1990s. Sulfate concentrations in monitoring well 846 have shown an increasing trend since the early 1990s. Wells 555, 556, and 557, which have been monitored since 2010, show varied trends: well 555 appears to be trending upward: well 556 appears stable: and well 557 appears to be trending downward. It is unclear from the data whether any of the wells are reacting in response to land irrigation. The TDS and chloride trends over time have shown similar patterns to those of sulfate.

In wells 844 and 845, nitrate concentrations have dropped from 2004 to 2012, then rose in 2013, while well 846 rose steadily from 1996 through 2012, and then dropped in 2013. Wells 555 and 557 appear to be trending upward since 2011 and well 556 is trending slightly downward.

3.3.1.3 Groundwater Impacts at the 150-Acre Center Pivot and 24-Acre Flood Irrigation Land Treatment Areas

Figure 3-77 provides a plan view of the 150-acre center pivot irrigation field and 24-acre flood irrigation fields. The 150-acre center pivot irrigation field is underlain by the Rio San Jose alluvium (HMC 2014) as shown on the geologic cross-section displayed on Figure 3-78. A geologic cross-section of the 24-acre flood irrigation field is shown on Figure 3-69. Alluvium also underlies the 24-acre flood irrigation field; however, bedrock elevation is greater than the groundwater surface elevation below much of this field, thus, the alluvial aquifer is not present. Table 3-28 presents the monitoring well data.

Table 3-28 Well Data for 150-Acre Center Pivot Irrigation and 24-Acre Flood Irrigation Land Treatment Areas

Well	Well Depth (ft-bgs)	Casing Diameter (inch)	Water Level		
			Date	Depth (ft-bgs)	Elevation (ft-msl)
551	130	5	12/26/2018	99	6448.3
553	120	5	12/26/2018	104.1	6443.38
554	140	5	12/26/2018	106.7	6440.47
647	140	4.5	12/26/2018	104.9	6447.01
649	124	4.5	12/26/2018	102.9	6440.39
650	109	4.5	12/26/2018	81.73	6465.38
658	130	6	12/26/2018	107.5	6442.68

Well	Pipe Stickup Above Ground Surface (ft)	Well Elevation Top of Pipe (ft-msl)	Base of Alluvium (ft-bgs)	Base of Alluvium (ft-msl)	Well Screen Interval (ft bgs)	Alluvium Saturated Thickness (ft)
551	2	6547.3	120	6433	90-130	15.30
553	2	6547.48	110	6433	80-120	10.38
554	2	6547.17	130	6411	100-140	29.47
647	1.4	6551.91	132	6418.5	80-140	28.51
649	0.3	6543.29	115	6428	84-124	12.39
650	2.2	6547.11	103	6441.9	89-109	23.48
658	0.4	6550.18	129	6420.8	89-130	21.88

Source: HMC 2014, HMC 2019c
bgs = below ground surface
ft = feet
msl = mean sea level

Figures 3-79 through 3-85 present COPC concentrations over time for wells 551, 553, 554, 647, 649, 650, and 658. Each of these wells (with the exception of well 650) is used to monitor the 150-acre center pivot irrigation field, which was irrigated from 2000 through 2009. There has not been a discernable change in uranium or selenium concentrations over the monitoring period (1997 to 2014). Uranium and selenium concentrations remain well below the approved alluvial background standard. Very few data points exhibit concentrations above the DL for molybdenum.

Sulfate concentrations in the wells appear to be trending up slightly since 2009, with the exception of well 658, which appears to be trending flat to slightly lower, and well 649, which has been trending slightly upward since 2007. The trend may have flattened for several wells since 2012, including wells 551, 553, and 647. All wells, however, remain well below the approved alluvial background standard for sulfate of 1,500 mg/L. Much like the other irrigation fields, TDS trends are similar to sulfate and they also are below the approved alluvial background for TDS of 2,734 mg/L. Concentrations of TDS recorded in wells 551, 553, and 554 have a slight upward trend since monitoring began in these wells in 2009. TDS in wells 647 and 650 has been stable since 2010. Chloride concentrations in wells 553 and 554 have a slight upward trend since monitoring began in

these wells in 2009, while well 551 has been generally stable since 2010. In wells 647 and 650, concentrations trended upward from 2009 to 2011 and have been stable since. Wells 649 and 658 appear to trend up slightly since 2012 with all these well below the approved background standard within the alluvial aquifer for chloride of 250 mg/L. Nitrate concentrations have fluctuated in many of the wells since monitoring began in 1995, but no significant trends are apparent with all wells below the approved nitrate standard for the alluvial aquifer of 12 mg/L.

Well 650 is used to monitor the 24-acre flood irrigation field, which was irrigated in 2004, 2005, 2008, and 2009. Figures 3-79 through 3-85 present COPC concentrations over time for this well. There has not been a discernable change in uranium, selenium, or molybdenum concentrations over the monitoring period (1997 to 2014). Sulfate, TDS, and chloride concentrations appear to be trending up since 2010. Nitrate concentrations over time do not indicate a trend. All COPC concentrations continue to be well below the approved NRC Site Cleanup Levels for the alluvium.

3.3.1.4 Groundwater Impacts at the 100-Acre Center Pivot Irrigation Field

Figure 3-86 provides a plan view of the 100-acre center pivot irrigation field and Figure 3-87 provides a geologic cross-section of the area. This area has consisted of 60 acres of center pivot irrigation from 2002 through 2004, and, after expansion of the center pivot area, 100 irrigated acres from 2005 through 2009 and in 2011 and 2012. The 100-acre center pivot irrigation field exists over the San Mateo alluvial aquifer that extends to the western portion of Section 28 (HMC 2014).

Table 3-29 provides data from monitoring wells 634, 881, 886, and 888, which are used to collect groundwater samples. As shown on Figure 3-86, wells 881, 886, and 893 are located within the 100-acre center pivot irrigation field and wells 634, 888, and 890 are located west of the 100-acre center pivot irrigation field.

Table 3-29 Well Data for 100-Acre Center Pivot Irrigation Field

Well	Well Depth (ft-bgs)	Casing Diameter (inch)	Water Level		
			Date	Depth (ft-bgs)	Elevation (ft-msl)
634	103	4.5	12/26/2018	71.14	6488.93
881	96	4.5	12/26/2018	69.17	6495.87
886	90	5	12/26/2018	65.78	6498.77
888	105	5	12/26/2018	77.57	6479.76
890	101	5	8/28/2018	74.33	6484.1
893	98	4.5	12/26/2018	66.11	6497.86

Well	Well Elevation Top of Pipe (ft-msl)	Pipe Stickup Above Ground Surface (ft)	Base of Alluvium (ft-bgs)	Base of Alluvium (ft-msl)	Well Screen Interval (ft bgs)	Alluvium Saturated Thicknes s (ft)
634	6560.07	2.8	95	6462.3	80-100	28.77
881	6565.04	2	103	6460.0	Jun-96	34.41
886	6564.55	1.5	87	6476.1	60-90	23.97
888	6557.33	1.1	90	6466.2	75-105	16.7
890	6558.43	1.7	93	6463.7	81-101	18.3
893	6563.97	2.1	93	6468.9	78-98	25.5

Source: HMC 2014, HMC 2019c
bgs = below ground surface
ft = feet
msl = mean sea level

Figures 3-88 through 3-94 present the COPC concentrations over time for wells 634, 881, 886, 888, 890, and 893. Uranium concentrations in well 881 trended downward from 2002 to late 2005, but have been variable with trending upward through 2010 and downward since that time. In well 886, the trend from 2001 to 2013 was variable but generally downward until the last reading that was up sharply. Well 893 was stable from 2002 through 2008, and has been variable since 2009. In the downgradient wells (634, 888, and 890) there is no discernable trend. Selenium concentrations have been generally stable with no discernable trends. Molybdenum concentrations in the wells are mostly below DLs, though concentrations slightly higher than the DLs have been observed in wells 881 (since 2008) and 886 (since 2010).

Sulfate concentrations are variable, but there appears to be a slight upward trend for all wells between 2007 and 2012 with downward trends since that time. The TDS and chloride trends have shown similar patterns to those of sulfate. There do not appear to be any meaningful trends in the nitrate concentrations.

3.3.2 Nature and Extent of Soil Contamination at Land Treatment Areas

Soil samples have been collected from within and near the irrigation fields from 1999 through 2013. Composite samples were prepared from locations within each irrigation area. In 2000, samples

were collected from 0- to 6-inch, 6- to 18-inch, and 18- to 36-inch depth intervals. Sampling depths during 2001 through 2013 were 0 to 1 foot, 1 to 2 feet, and 2 to 3 feet, respectively. For simplicity, this variation is not noted further in the data presentation or evaluation. Depths greater than 3 feet were first sampled in 2009.

ACZ Laboratories, Inc., of Steamboat Springs, Colorado, performed the analyses on the soil samples from 1998 through 2012. Energy Laboratories, Inc., of Billings, Montana, performed the analyses on the soil samples in 2013. Samples were analyzed for uranium, selenium, molybdenum, calcium, magnesium, sodium, chloride, and sulfate and occurred following completion of irrigation. Results from uranium and selenium are presented.

In 1998, HMC characterized uranium and selenium concentrations in soils, prior to selecting fields for land treatment of groundwater. Refer to Figure 3-95 for the location of the samples collected in 1998. HMC also collected and analyzed soil samples outside the irrigated fields from 1999 through 2010. These results, along with the 1998 data, are used to calculate background concentrations for uranium and selenium in soil. Background data is presented and discussed for each of the irrigation fields. Tables summarizing analytical results for uranium and selenium from each sample used to calculate background are provided in Appendix E.

3.3.2.1 Soil Chemicals of Potential Concern at Land Treatment Areas

Based on the chemistry of the groundwater applied to the LTAs, uranium and selenium are the COPCs for soil within the LTAs. Other parameters including molybdenum, calcium, magnesium, sodium, chloride, and sulfate are also monitored to evaluate impacts on water quality.

3.3.2.2 Soil Impacts at the Flood Irrigation Fields

Figures 3-96 through 3-109 display the locations of the soil samples collected each year from the flood irrigations fields and surrounding (background) locations. The following information summarizes the number of samples collected within the irrigation fields by year:

- 1999 and 2000: Nine locations within the 120-acre flood irrigation field
- 2001: 30 samples from 3 depths at 10 locations within the 120-acre flood irrigation field
- 2002: 36 samples from 3 depths at 12 locations within the 120-acre flood irrigation field
- 2003: 33 samples from 3 depths at 11 locations within the 120-acre flood irrigation field
- 2004, 2005, 2006, 2007, and 2008: 36 samples from 3 depths at 12 locations within the 120-acre flood irrigation field and 3 locations within the 24-acre flood irrigation field
- 2009: Samples were collected from three lysimeters and five soil sampling locations within the 120-acre flood irrigation field and one lysimeter and one soil sampling location within the 24-acre flood irrigation field
- 2010: Seven sample locations within the 120-acre flood irrigation field and one location within the 24-acre flood irrigation field
- 2011: Five sample locations within the 120-acre flood irrigation field and one location within the 24-acre flood irrigation field
- 2012 and 2013: Five samples within the 120-acre flood irrigation field

Background concentrations for uranium and selenium are summarized in Table 3-30. Values contained in the table are the average calculated from sample locations outside the irrigated area (refer to Figures 3-96 through 3-107) and from samples collected in 1998 (refer to Figure 3-95).

Table 3-30 Statistics for Uranium and Selenium Background Concentrations for Flood Irrigation Fields

Metal	Interval (feet)	n	Mean	Median	Minimum	Maximum
Uranium (mg/kg)	0-1[1]	29	2.14	2.31	0.45	3.60
	1-2	17	1.81	1.60	0.53	3.93
	2-3	18	1.19	1.15	0.40	2.29
	3-4	2	0.75	0.75	0.56	0.94
	4-5	2	0.55	0.55	0.52	0.58
	5-6	4	0.44	0.47	0.31	0.52
	6-8	4	0.61	0.58	0.33	0.93
	8-10	4	0.68	0.68	0.27	1.11
	10-12	4	1.12	1.25	0.65	1.33
	12-14	1	0.96	0.96	0.96	0.96
	14-16	1	0.97	0.97	0.97	0.97
Selenium (mg/kg)	0-1[2]	28	0.43	0.40	0.10	0.80
	1-2	16	0.45	0.37	0.20	0.87
	2-3	17	0.31	0.34	0.10	0.54
	3-4	2	0.17	0.17	0.16	0.17
	4-5[3]	2	0.07	0.07	0.03	0.11
	5-6	4	0.05	0.05	0.03	0.09
	6-8	4	0.07	0.06	0.03	0.12
	8-10	4	0.09	0.09	0.03	0.17
	10-12	4	0.42	0.14	0.07	1.31
	12-14	1	0.53	0.53	0.53	0.53
	14-16	1	0.27	0.27	0.27	0.27

Source: HMC 2014
mg/kg = milligram per kilogram
Notes:
1. 17 samples collected from 0-12", 11 from 0-6", and one from 0-14"
2. 16 samples collected from 0-12", 11 from 0-6", and one from 0-14"

Figure 3-110 presents a plot of the uranium concentrations over time from the Section 33 and 34 flood areas and compares them to average background. Uranium concentrations have gradually increased in the 0- to 1-foot interval (referred to as Upper in Figure 3-110) for the previous 8 years and were steady in 2013, when irrigation did not occur. The concentrations have had steady levels in the 1- to 2-foot interval for the last 6 years. From 2001 to 2011, uranium concentrations in the 120-acre flood irrigation field increased in the 0- to 1-foot layer from 2.72 mg/kg to a maximum of 5.15 mg/kg in 2011, and were at 4.67 mg/kg and 4.70 mg/kg in 2012 and 2013, respectively.

Overall, the average uranium concentration in the upper 3 feet of soil increased from 1.91 mg/kg to 3.07 mg/kg, or by a factor of 1.61.

Figure 3-111 presents the uranium concentrations with depth for the treated and background concentrations. The distance between these two lines is the increase in uranium concentration. The green shaded area shows where uranium concentrations increased in the 120-acre flood irrigation field to a depth of 4 feet. The increase is primarily in the upper 2 feet with a lesser increase in the 2- to 4-foot interval. The black pattern on this figure shows an increase in 2012 within the 9- to 13-foot interval; however, the increase is small and is likely attributable to variation in the laboratory analyses.

The 2013 selenium level in the upper interval was similar to the 2012 concentration, but slightly higher (refer to Figure 3-112). A comparison of sample results from 2001 through 2013 indicates that selenium concentrations have increased in the treated areas of Section 34. Figure 3-113 shows that this increase has mainly been in the upper interval of the soil.

3.3.2.3 Soil Impacts at the 100-Acre Center Pivot Irrigation Field

Irrigation at the 100-acre center pivot irrigation field in Section 28 began in 2002. Figures 3-114 through 3-125 display the locations of the soil samples collected each year from the 100-acre center pivot irrigation field and surrounding (background) locations. The following summarizes the number of samples collected within the irrigation fields by year:

- 2002 through 2008: Twelve locations, each sampled at three depths (0 to 1 foot, 1 to 2 feet, and 2 to 3 feet)
- 2009: Samples were collected from three lysimeter and five soil sampling locations
- 2010: Samples were collected from one lysimeter and five soil sampling locations
- 2011, 2012, and 2013: Samples were collected from one lysimeter and four soil sampling locations

Background concentrations for uranium and selenium are summarized in Table 3-31. These values are the average calculated from sample locations outside of the irrigated area (refer to Figures 3-114 through 3-125) and from samples collected in 1998 (refer to Figure 3-95).

Table 3-31 Statistics for Uranium and Selenium Background Concentrations in the 100-Acre Center Pivot Irrigation Field

Metal	Interval (feet)	n	Mean	Median	Minimum	Maximum
Uranium (mg/kg)	0-1[1]	14	0.80	0.64	0.19	2.99
	1-2[2]	11	0.64	0.51	0.34	1.62
	2-3	9	0.70	0.56	0.45	1.45
	3-4	2	0.46	0.46	0.39	0.52
	4-5	2	0.41	0.41	0.36	0.45
	5-6	2	0.53	0.53	0.43	0.62
	6-8	2	0.62	0.62	0.44	0.79
	8-10	2	0.50	0.50	0.48	0.52
	10-12	2	0.81	0.81	0.65	0.97
	12-14	2	0.64	0.64	0.60	0.68
	14-16	2	0.69	0.69	0.54	0.84
Selenium (mg/kg)	0-1[3]	13	0.13	0.15	0.03	0.23
	1-2[4]	10	0.11	0.10	0.03	0.24
	2-3	8	0.14	0.13	0.06	0.25
	3-4	2	0.08	0.08	0.07	0.09
	4-5	2	0.06	0.06	0.06	0.07
	5-6	2	0.08	0.08	0.08	0.08
	6-8	2	0.09	0.09	0.08	0.09
	8-10	2	0.09	0.09	0.09	0.09
	10-12	2	0.12	0.12	0.12	0.12
	12-14	2	0.11	0.11	0.08	0.13
	14-16	2	0.10	0.10	0.09	0.10

Source: HMC 2014

Notes:

1. Ten samples collected from 0-12", two from 0-6", and two from 0-8"
2. Nine samples collected from 12"-24", one from 8"-28", and one from 8"-24"
3. Nine samples collected from 0-12", two from 0-6", and two from 0-8"
4. Eight samples collected from 12"-24", one from 8"-28", and one from 8"-24"

Figure 3-126 presents a plot of the uranium concentrations over time from the 100-acre center pivot irrigation field. For comparison, the concentrations are compared on the graph to the average concentrations of samples collected to represent background. Upper, middle and lower are soil results for the 0-1, 1-2 and 2-3 foot intervals respectively. The concentrations are from a composite sample from the several sample locations in each irrigation area. Uranium concentrations in composite samples collected from the treated and background areas in 2002 were, with one exception, at concentrations above pre-operational levels.

Uranium concentrations in the treated area in the 2- to 3-foot interval increased in 2012 and 2013 from the levels observed in 2011. The uranium concentrations in the 0- to 1-foot and 1- to 2-foot intervals were less than the DL in 2013. Figure 3-127 presents the uranium concentrations with

depth for the treated and background concentrations. The most recent (that is, 2013) concentrations of uranium observed in the treated area produced uranium gains of less than 0.40 mg/kg (at 0 to 1 foot), less than 0.48 mg/kg (at 1 to 2 feet), and 0.79 mg/kg (at 2 to 3 feet).

Figure 3-128 presents a plot of the selenium concentrations over time from the 100-acre center pivot irrigation field. For comparison, the concentrations are compared on the graph to the average concentrations of samples collected to represent background. Upper, middle and lower are soil results for the 0-1, 1-2 and 2-3 foot intervals respectively. The concentrations are from a composite sample from the several sample locations in each irrigation area. A comparison of the results obtained from 2001 through 2013 indicates that selenium concentrations increased in the 100-acre center pivot irrigation field. Figure 3-129 indicates that this increase has mainly been in the upper 1 foot of the soil.

3.3.2.4 Soil Impacts at the 150-Acre Center Pivot Irrigation Field

Irrigation at the 150-acre center pivot irrigation field in Section 33 began in 2000. Figures 3-96 through 3-107 display the locations of the soil samples collected each year from the 150-acre center pivot irrigation field and surrounding (background) locations. The following summarizes the number of samples collected within the irrigation fields by year:

- 1999 and 2000: Three locations
- 2001-2008: Twelve locations, each sampled at three depths (0 to 1 foot, 1 to 2 feet, and 2 to 3 feet)
- 2009: Samples were collected from five lysimeter and five soil sampling locations
- 2010: Samples were collected from one lysimeter and five soil sampling locations
- 2011, 2012, and 2013: Samples were collected from five soil sampling locations

Background concentrations for uranium and selenium are summarized in Table 3-32. These values are the average calculated from sample locations outside the irrigated area (refer to Figures 3-96 through 3-108) and from samples collected in 1998 (refer to Figure 3-95).

Table 3-32 Statistics for Uranium and Selenium Background Concentrations for 150-Acre Center Pivot Irrigation Field

Metal	Interval (feet)	n	Mean	Median	Minimum	Maximum
Uranium (mg/kg)	0-1[1]	17	0.83	0.85	0.36	1.14
	1-2	10	0.72	0.74	0.52	0.89
	2-3	10	0.81	0.82	0.66	1.09
	3-4	2	1.02	1.02	1.01	1.03
	4-5	2	0.92	0.92	0.90	0.94
	5-6	2	0.60	0.60	0.52	0.68
	6-8	2	0.90	0.90	0.80	0.99
	8-10	2	0.86	0.86	0.72	0.99
	10-12	2	0.66	0.66	0.56	0.76
	12-14	2	0.55	0.55	0.42	0.68
	14-16	2	0.72	0.72	0.45	0.99
Selenium (mg/kg)	0-1[2]	16	0.16	0.18	0.03	0.39
	1-2	9	0.20	0.16	0.12	0.44
	2-3	9	0.20	0.19	0.12	0.30
	3-4	2	0.17	0.17	0.15	0.18
	4-5	2	0.15	0.15	0.12	0.17
	5-6	2	0.10	0.10	0.08	0.11
	6-8	2	0.12	0.12	0.09	0.14
	8-10	2	0.08	0.08	0.05	0.11
	10-12	2	0.04	0.04	0.03	0.06
	12-14	2	0.08	0.08	0.06	0.10
	14-16	2	0.12	0.12	0.09	0.14

Source: HMC 2014
Notes:
mg/kg = milligram per kilogram
1. 11 samples collected from 0-12", 6 from 0-6"
Analytical results below detection limits were set at 1/2 the detection limit

Figure 3-130 presents a plot of the uranium concentrations over time from the 150-acre center pivot irrigation field and compares the concentrations to calculated background. The most recent (that is, 2013) concentrations observed in the treated area were 2.20 mg/kg (at 0 to 1 foot), 1.60 mg/kg (at 1 to 2 feet), and 1.20 mg/kg (at 2 to 3 feet). This compares to the corresponding mean background values of 0.80 mg/kg (at 0 to 1 foot), 0.69 mg/kg (at 1 to 2 feet), and 0.73 mg/kg (2 to 3 feet). Uranium concentrations increased in the upper two feet of soil at a relatively constant rate until 2004, when concentrations reached a steady state, then increased in 2009 and 2010 and declined in 2011. The 2012 and 2013 data returned to values similar to those found in 2009 and 2010. Figure 3-131 shows the 2012 and 2013 increase in uranium concentrations in Section 33. The increase in the upper 5 feet in 2012 is supported by the 2013 data.

Figure 3-132 presents a plot of the selenium concentrations over time from the 150-acre center pivot irrigation field and compares the concentrations to calculated background. In all three intervals, a variable, but a slightly upward trend is observed. Selenium concentrations in 2012 for the top three feet of treated soil exceeded the mean background by factors of 2.67 (at 0 to 1 foot), 2.27 (at 1 to 2 feet), and 1.85 (at 2 to 3 feet). The 150-acre center pivot irrigation field selenium concentration profile is presented in Figure 3-133 using 2012 data concentrations (2013 selenium analytical results were unusable due to high DLs). The majority of the increase is in the upper 7 feet with some increase observed in two of the four lower intervals.

3.3.2.5 EPA Soil Data from Irrigation Fields

In 2009 and 2010, EPA collected soil samples (0-6") within the four irrigation fields. Table 3-33 displays descriptive statistics of analytical results for uranium and selenium.

Table 3-33 Statistics for Uranium and Selenium in Irrigation Fields (mg/kg)[1]

Location	Chemical	n	Mean	Median	Minimum	Maximum
Center Pivot Fields	Selenium	13	0.48	0.46	0.29	0.71
	Total Uranium [2, 4]	12	2.04	2.07	1.57	2.68
Irrigation Fields	Selenium	6	0.85	0.75	0.50	1.31
	Total Uranium [3, 4]	6	5.30	4.90	3.05	8.01

Source: EPA 2014a
1. Uranium data converted from pCi/g to mg/kg using conversion factor of 1.48.
2. Two sets of U-235 data were included for the center pivot irrigation fields. The data set that reported the same number of data points was used for this table.
3. Two sets of U-235 data were included for the center pivot irrigation fields. The data set that reported the higher value was used for this table.
4. Total Uranium is the sum of U-234, U-235, U-238.

3.3.2.6 HMC Soil Data Collected from Irrigation Fields 2017-2018

Comprehensive soil sampling and analysis at each of the four irrigation fields was completed in 2017 and 2018. The objective of the sampling and analysis program was to evaluate whether concentration of constituents of potential concern met the proposed criteria for unrestricted release from NRC Radioactive Materials License SUA-1471 (ERG 2018).

Soil surveys at each land application area included comprehensive gamma radiation surveys, and statistically-based soil sampling. Gamma survey data was used to evaluate areas of elevated terrestrial gamma radiation and select biased soil sampling locations. The sampling interval was from the ground surface to a depth of 15 cm. Analysis of the samples included selenium, uranium, and Ra-226. Descriptive statistics of the analytical results from the soil sampling, including duplicates, is provided in Table 3-34. The following is a brief summary of the activities completed at each of the irrigation fields (ERG 2018).

- 100-Acre Center Pivot Irrigation Field: Twenty samples plus two biased samples were collected. Refer to Figure 1-134 for sampling locations. In one of the bias sample locations, Ra-226 concentration was 80.8 pCi/g, which is above the NRC-approved 10.5 pCi/g cleanup criterion. Based on this result, excavation was conducted until gamma scan readings approached local background levels. A composite soil sample, centered on the location where the Ra-226 concentration was found to be 80.8 pCi/g, was collected after removal of

contaminated soil. The results reported in Table 3-34 exclude the results from the sample which triggered the excavation activities. Excavated soils were disposed at the solid waste trench disposal area on the southern portion of the STP (ERG 2018).

- 150-Acre Center Pivot Irrigation Field: Twenty samples plus four biased samples were collected. Refer to Figure 1-135 for sampling locations.
- 24-Acre Flood Irrigation Field: Twenty samples plus two biased samples were collected. Refer to Figure 1-136 for sampling locations.
- 120-Acre Flood Irrigation Field: Twenty samples plus seven biased samples were collected. Refer to Figure 1-137 for sampling locations.

Table 3-34 Statistics for 2017-2018 Soil Data from Irrigation Fields

Location	Chemical	n	Mean	Median	Minimum	Maximum
100 Acre CP Section 28	Selenium (mg/kg)	23	0.4	0.4	0.3	0.5
	Uranium Nat (mg/kg)	23	0.8	0.7	0.5	2.8
	Ra-226 (pCi/g)	23	0.9	0.9	0.5	1.8
150 Acre CP Section 33	Selenium (mg/kg)	25	0.6	0.6	0.3	1.2
	Uranium Nat (mg/kg)	25	1.4	1.3	0.6	3.3
	Ra-226 (pCi/g)	25	1.2	1.3	0.7	2.1
24 Acre Irrigation Section 33	Selenium (mg/kg)	24	0.5	0.5	0.4	0.7
	Uranium Nat (mg/kg)	24	1.6	1.6	1.3	2.0
	Ra-226 (pCi/g)	24	1.8	1.7	1.2	3.9
120 Acre Irrigation Section 34	Selenium (mg/kg)	29	1.3	1.3	0.7	2.6
	Uranium Nat (mg/kg)	29	4.1	4.1	1.8	7.2
	Ra-226 (pCi/g)	29	2.0	2.0	1.5	2.9

Source: ERG 2018

3.3.2.7 Oak Ridge Soil Data Collected from Irrigation Fields 2018

At the request of NRC, the Oak Ridge Institute for Science and Education (ORISE) performed confirmatory survey activities at the four irrigation fields. Activities included gamma radiation surface soil scans, surface and subsurface soil sampling, and limited alpha-plus-beta scans and surface activity measurements on irrigation equipment (ORISE 2019).

Gamma radiation scans were performed over a randomly selected population of confirmatory investigation areas that consisted of 400 square meter blocks. The scan objective was to determine if anomalous areas of elevated direct radiation indicative of residual contamination were present. None were identified (ORISE 2019).

Alpha-plus-beta scans of the irrigation equipment identified uniform, elevated count rates commonly encountered on metal surfaces and indicative of natural radon long-lived progeny build-up. Although elevated, the total surface activity levels measured were less than NRC guidance limits (ORISE 2019).

Soil samples were collected from the center of each of the 400 square meter blocks. At each location, a sample was collected from 0 to 30 cm below the ground surface. At some of the locations, a second sample was collected from 30 cm to 60 cm below the ground surface. The number of subsurface locations sampled was dependent upon physical boundary limitations—specifically, the composition and density of the soil. In total, 103 soil samples were collected from 41 locations at the following depths:

- 41 samples from 0–15 cm
- 39 samples from 15–30 cm
- 23 samples from 30–60 cm

The sample locations are shown on Figure 3-138 through 3-141. Each was analyzed for Ra-226, Th-230, and uranium. Table 3-35 provides a summary of the data.

Table 3-35 Statistics for ORISE Soil Data from Irrigation Fields

Radionuclide	Minimum	Maximum	Mean	Standard Deviation
Ra-226 (pCi/g)	0.22	1.49	0.68	0.32
Th-230 (pCi/g)	-7.7	3.4	0.18	1.93
U-total (mg/kg)	1.42	7.47	3.33	1.59

Source: ORISE 2019

4 Contaminant Fate and Transport

Migration and persistence of COPCs and ROPCs in the environment will be discussed in this section. Understanding contaminant fate and transport at a site provides an important basis for assessing human health and ecological risks from exposure. The COPCs and ROPCs for the Site are limited to inorganic chemicals and radionuclides.

4.1 Routes of Migration

4.1.1 Groundwater Transport Pathway

As described in Section 1.4, the LTP and STP were deposited above grade, the majority in the form of slurry. Downward migration of pore water from the tailings piles is a primary source of groundwater contamination at the Site. Introduction of water from wells as part of the current remediation system is intended to accelerate the drawdown of pore water and COPCs/ROPCs from the tailings. Percolation of precipitation through the vadose zone may also drive COPCs/ROPCs to groundwater, though this pathway is limited due to the arid climate. Once COPCs/ROPCs reach the groundwater, movement is governed by groundwater flow within the alluvial and Chinle Formation aquifers and geochemical conditions.

HMC has developed a Groundwater Flow and Transport model that includes the Site and also the SMC Basin. The framework for the model is the Hydrogeologic Site Conceptual Model (HSCM). A HSCM is a summary of available knowledge related to groundwater flow and water quality of the principal hydrostratigraphic units at a certain location and scale. Key HSCM elements specific to the Site include:

- Aquifers of Quaternary, Triassic, and Permian age are present at the Site.
- Principal aquifers with groundwater flow at the Site include the alluvium; Upper, Middle, and Lower transmissive units of the Chinle Formation; and SAG aquifer.
- Local groundwater flow in the alluvium generally flows parallel to downgradient surface flows in SMC, the Rio Lobo, and the Rio San Jose, but bifurcates around a bedrock high located south of the LTP.
- Groundwater flow in the Chinle Formation aquifer units is generally to the north-northeast, except where influenced by faulting, subcrop locations, or ongoing restoration operations.
- Groundwater flow in the underlying SAG aquifer is to the east and southeast.
- Site remedial activities have included groundwater extraction and injection in both the alluvium and Chinle sandstones, affecting local groundwater flow conditions.
- The presence of fault zones has restricted and redirected local groundwater flow in the Chinle aquifers under the Site.
- Local groundwater flow conditions have been well characterized through data collected from hundreds of monitoring wells on the Site.

As an initial step toward creating a groundwater flow and transport model, a 3-D geologic model was developed that captures stratigraphy and faulting at both the site scale around the Site and regionally within the SMC Basin. The geologic model was then used to create appropriate hydrostratigraphic layer structure. The geologic model was developed using Leapfrog™, a geologic modeling software that provides for enhanced interpretation and visualization of regional stratigraphy and geology. Development of the regional Leapfrog 3-D geologic included the incorporation of an existing site-scale geologic model's interpretations of surface outcrops, stratigraphic layer thicknesses, fault structures, dip directions, and dip angles to produce "layer cake" representation of the primary stratigraphic units in the SMC Basin in the vicinity of the Site. Information from 1,437 geologic logs from the Site, along with regional well information (well depths and units penetrated) and 14 geologic maps for the region were added and localized changes were made to stratigraphic thicknesses and depths (HMC 2019d).

Table 4-1 summarizes the hydraulic parameters used in the model.

Table 4-1 Hydraulic Properties of Site Stratigraphy

Model Layer Number	Hydrostratigraphy	Horizontal Hydraulic Conductivity (ft/d)	Specific Yield	Specific Storage (1/ft)
1	Alluvium	2.0 - 215	0.1	0.0001
2	Bedrock above the Chinle	0.04	0.01	0.00001
3	Chinle Shale	0.25 – 0.0005	0.005	1E-07
4	Upper Chinle Aquifer	1.0 - 10	0.01	0.00001
5	Chinle Shale	0.25 – 0.0002	0.005	1E-07
6	Middle Chinle Aquifer	1.0 - 10	0.01	0.00001
7	Chinle Shale	0.0009	0.005	1E-07
8	Lower Chinle Aquifer	0.5 - 10	0.01	0.00001
9	Chinle Shale	0.004	0.01	0.00001
10	SAG	10 - 500	0.2	0.0001

Source: (HMC 2019d)

To understand COC transport through the LTP, STP, and the alluvial aquifer a conceptual geochemical model has been developed – refer to Figure 4-1 (WME 2019). A fundamental description of the model is summarized in the following statements:

- The source of groundwater contamination is contained within the mound of tailings water within the LTP. After flushing of the LTP ceased in 2015, mounding in the LTP has continued to dissipate.
- As a result of the alkaline leaching process, the source is an alkaline (pH ≈ 10) sodium-sulfate type water, with elevated concentrations of TDS, uranium, selenium, molybdenum, and indicator constituents, such as chloride and sulfate. Redox conditions are moderately oxidizing and therefore uranium, selenium, and molybdenum exist in solution as oxyanions (e.g., MoO42-, SeO42-, UO2 (CO3)34).
- As LTP seepage migrates into the alluvial aquifer, it becomes partially diluted as it mixes with moderately-oxidizing water from upgradient in the San Mateo alluvial aquifer.

- As the impacted groundwater moves downgradient, the concentrations of predominantly indicator constituents (chloride, sulfate) are primarily controlled by dilution and dispersion. The oxyanionic forms of uranium (UO2 (CO3)34-), molybdenum (MoO42-), and selenium (SeO42- and/or SeO32-) are partially adsorbed to hydrous ferric hydroxide, but the majority remain mobile and are transported downgradient.
- Some areas of the groundwater are slightly reducing, such that selenium exists as selenium (IV) (SeO32-), with the potential for precipitation as amorphous elemental selenium.
- Within the LTP, solid forms of uranium, selenium, and molybdenum remain in the tailing, which could be released upon long-term leaching or weathering. Historical information suggests that uranium, selenium, and molybdenum may exist as oxide and/or sulfide minerals, associated with clays, or adsorbed to iron oxides.

Data collection and evaluation to advance the conceptual geochemical model is ongoing.

Movement of contaminants into and within groundwater has been modeled by HMC using MODFLOW-NWT and MT3D-USGS (collectively referred to as the SMC Basin model). MODFLOW-NWT is a publically available model created and maintained by U.S. Geological Survey, includes the Newton-Raphson solution formulation that enables improved unconfined groundwater flow simulations, and incorporates code changes that better simulate drying and rewetting, which may occur within the GRP and SMC Basin if sufficient water table declines and increases are predicted (Niswonger et al., 2011). MT3D-USGS simulates contaminant transport ((Bedekar et al. 2016).

A separate seepage model (the reformulated mixing model [RMM]) was previously developed to assess long-term changes in both seepage flow rates and constituent mass loading. Assessments of past LTP seepage rates, along with predictions of future seepage rates, were developed based on vadose modeling using the VADOSE/W code (HMC 2012). The RMM was recently replaced by a Drain Down Model (DDM) that incorporates the Brooks and Corey method to estimate seepage and toe drain rates (Brooks and Corey 1964). The revised seepage estimates developed from the DDM model were incorporated into this SMC Basin model update to simulate seepage from the LTP into the underlying local groundwater system (HMC 2019d).

In the land treatment fields, irrigating with water containing inorganics is a pathway for contaminants to potentially impact groundwater quality. Recharge from rainfall, can also drive contaminants through the vadose zone into groundwater, though recharge rates are low due to the arid climate.

The release of contaminants from the LTP has impacted residential wells in the nearby subdivisions. As described in Section 1, through agreements with EPA in 1983 and NMED in 2009, HMC has extended the Village of Milan's municipal water supply to the residences of the subdivisions and provided connection.

4.1.2 Air Transport Pathways

Under current Site conditions, releases of COPCs/ROPCs to air from dust and generation of radon-222 through radioactive decay of Ra-226 is inhibited by the cap that was placed on the tailings piles in the mid-1990s. During historical mill operations, dust generation and transport by wind was likely because operations involved intensive milling, earth-moving, and ore-hauling activities. Significant deposition of dust primarily downwind of the tailings piles was remediated in the mid-1990s (refer to Figure 1-5) after milling operations ceased. Mine tailings and the mill operation areas were capped

with imported materials. Quarterly radon monitoring suggests that migration of radon from the Homestake Facility does not exceed background levels.

EPA completed a RI that studied the transport of radon from the Homestake Facility in 1989. The evaluation included 59 residential houses and 28 outdoor monitoring stations and was conducted over a fifteen-month period. At the houses, the average annual indoor radon concentration was 2.7 pCi/1 and the average annual outdoor concentration was 1.9 pCi/1. Based on the results of the RI, EPA determined that the uranium mill and tailing embankments at the Homestake Facility, though a potential source of radon, were not contributing significantly to subdivision radon concentrations. This determination resulted in a “no action” decision that was formalized in a ROD (EPA 2014a).

In 2010, EPA undertook a second investigation of the radon near the Site. The study included:

- Selection of a “background” community
- Collection and analysis of 885 indoor radon samples from 79 houses in the five subdivisions and 28 houses in the background community.
- Collection and analysis of 751 outdoor long term annual (4 quarters) radon samples were collected from several areas around the Homestake Facility, the Five Subdivisions and the background community.

The study concluded the following:

- For indoor air, statistical tests did not show significant difference between the subdivisions and the background community.
- Outdoor radon levels in the subdivisions were statistically higher than outdoor radon levels at the background community.
- Radon levels collected from monitors placed 6 inches above the ground surface were statistically higher than levels from corresponding monitors 5 feet above the ground surface along the fence line separating the Homestake Facility and the subdivisions.
- The upgradient air monitors did not show a trend in the level of radon flowing from the north towards the Homestake Facility.
- Air monitors downgradient from the Homestake Facility showed higher radon levels than upgradient radon levels.
- The impact of radon/thoron gas that was seen at the HMC downgradient monitors and near the Homestake Facility was not seen at the fence line air monitors or at the community at large.

Using information from the study, EPA conducted a HHRA that concluded outdoor radon in the area of the Five Subdivisions presents excess cancer risk greater than EPA’s acceptable risk range. The HHRA calculates the source of the excess cancer risk as 13×10^{-4} from background sources and 5×10^{-4} (EPA 2014a).

Based on the results of the indoor radon study, EPA took removal action at ten properties in the subdivision. EPA installed radon mitigation systems in homes where indoor radon exceeded the EPA mitigation action level of 4 pCi/L. The source of the indoor radon was not determined (EPA 2015c).

4.1.3 Runoff, Overland Flow Pathways

Surface water and runoff can be a means of transporting inorganic contaminants. As described in Section 2.7, the Site is generally flat and natural surface drainages no longer exist at the Homestake Facility. Artificially made surface channels have been constructed to transport flood water (refer to Figure 1-7). Due to the capping that has occurred at the Homestake Facility and the climate conditions, surface water and runoff pathways are not significant factors of contaminant transport at the Site, though possible in an extreme weather event.

The top perimeter of the Large Tailings Pile is graded and a berm erected to prevent stormwater from flowing from the top and down the sides, which could result in erosion of the side slope radon barrier. The stormwater collected on the top of the pile is transported down the side slopes of the tailing pile through 12-inch diameter pipe downdrains.

In 2010, because of high rainfall events, runoff from the top of the pile was preferentially directed to three areas on the top of the south side of the large tailings pile. The pooled water spilled over berms that direct runoff to the downdrains. Three areas of the radon barrier were eroded; however, uranium mill tailings were not exposed. The erosion areas were repaired and drainage improvements completed to prevent similar occurrences (DBE 2010).

4.2 Contaminant Persistence

Persistence is one of the key factors considered in assessing the risk associated with a chemical in the environment. Metals, which are elemental, are infinitely persistent, though can change oxidation state or combine with other elements to form compounds. Radionuclides undergo natural radioactive decay that, for some compounds, may significantly reduce potential risks over relatively short time periods. However, for other radionuclides, half-lives are very long, meaning that risks posed by the presence of these compounds will persist for a very long time. Table 4-2 summarizes the half-lives of radionuclides commonly found at the Site.

Table 4-2 Half-Life of Common Site Radionuclides

Nuclide	Half-life	Decay Mode	Daughter
Uranium-238	$4.47*10^8$ years	alpha	Thorium-234
Uranium-235	$7.04*10^8$ years	alpha	Thorium-231
Uranium-234	$2.46*10^5$ years	alpha	Thorium-230
Thorium-230	$7.54*10^4$ years	alpha	Radium-226
Thorium-234	24 days	beta	Protactinium-234
Radon-222	3.82 days	alpha	Polonium -218

Source: Vanderbilt 2013

5 Risk Analyses

5.1 Data Evaluation

Data collected by EPA for use in its human health risk assessment (HHRA) for the Site (EPA 2014a) and data collected by HMC for yearly monitoring reports completed for the Site since 2014 are the primary inputs for the risk assessments performed for this RI Report. Other reports completed by HMC for the Site were reviewed and applicable data collected for use in the risk assessments.

Selection of data for the risk assessments was based on several factors:

1. The newest data, where available at the time of this report, were considered preferable to older data to reflect current Site conditions. Older data were included only if a data gap was identified with use of the new data only.

2. Radon data collected by HMC and EPA were included for specific stations (Figure 3-64). Background radon concentrations were evaluated at HMC-16. HMC-6 was used as the background location for particulate analytes in air.

3. Current indoor air radon data were evaluated; however, personnel monitoring data and lysimetry data were not included.

4. No data qualified as rejected or unusable were used.

The analytical results along with the screening for contaminants are presented as summary statistics (minimum and maximum detected results, arithmetic mean, number of samples, number of detected results, and frequency of detection) in Appendix F. The data presented include:

1. HMC and EPA soil data from 2017 and earlier for the Homestake Facility, and soil data from 2017 to 2018 for the LTAs

2. EPA surface soil data to represent background

3. Evaporation pond sediment and water quality data from 2015 to 2018

4. Radon data (indoor and outdoor) (HMC quarterly data from 2014 to 2018)

Table 5-1 provides a summary of reports and data sources evaluated for use in the HHRA.

There were three soil samples (EP-2, EP-5, and EP3-9) that were not included in the final soil data set since they were located outside the Homestake Facility and not within a LTA. In addition, the Ra-226 results from one sample were rejected based on the data usability review and statistical analysis.

Refer to Appendix G for the data usability report.

Table 5-1 Data Sets Evaluated

Item	Data Set Description	Data Owner	Location	Medium	Year	Laboratory	Reference	Information Provided
1	Background	EPA-Region 6 (R6)	South of Homestake Mill	Soil	2011	NAREL	EPA 2014a	
2	Evaporation Pond Sediment	HMC	Homestake Facility	Sediment	2015	Energy	ERG 2017	Report
3	Evaporation Pond Water	HMC	Homestake Facility	Water	2015-2018	Energy	ERG 2017	Report
4	EP-1 & EP-2	HMC	Homestake Facility	Soil	2009	ACZ	ERG 2014	Sample Results
5	EP- 3	HMC	Homestake Facility	Soil	2009	ACZ	ERG 2014	Sample Results
6	EP-1 & EP-2	HMC	Homestake Facility	Soil	2009	ACZ	ERG 2014	Sample Results
7	Radon and Air Particulate Data	HMC	HMC-1, HMC-16 (BKG), HMC-1A, HMC-2, HMC-3, HMC-4, HMC-5, HMC-6, HMC-6 (BKG), HMC-7, Office, RO Plant (See Figure 3-64)	Indoor and Outdoor Air	2014-2018 (Radon) 2015-2018 (Particulate)	Energy	HMC 2019c	Sample Results
8	Soil Data for LTAs - ORISE	HMC	LTAs	Soil	August 27-20, 2018	Radiological and Environmental Analytical Laboratory in Oak Ridge, Tennessee	ORISE 2019	Sample Results
9	Soil Data for LTAs – Final Status Survey	HMC	LTAs	Soil	2017-2018	Energy	ERG 2018	Sample Results

Notes:
BKG = Background
EDD = electronic data deliverable
EPA = U.S. Environmental Protection Agency
ERG = Environmental Restoration Group, Inc.
HMC = Homestake Mining Company
LTA = Land Treatment Area
NAREL = EPA National Air and Radiation Environmental Laboratory in Montgomery, Alabama
ACZ = ACZ Laboratories, Inc. of Steamboat Springs, Colorado
Energy = Energy Laboratories, Inc. of Billings, Montana and Casper, Wyoming
R6 = Region 6
ORISE = Oak Ridge Institute for Science and Education

5.2 Human Health Risk Assessment

The HHRA consists of a conceptual site model, a screening level analysis, and the baseline or forward risk analysis. The baseline or forward risk analysis includes an exposure assessment, toxicity assessment, and risk characterization. Uncertainty is addressed, and a comparison made to background, in the risk characterization.

Risk Assessment Guidance for Superfund (RAGS) Part D Planning Tables are provided in Appendix H.

5.2.1 Conceptual Site Model

The conceptual site model (CSM) is a description of the Site and its environment based on existing knowledge of Site conditions. It describes contamination sources and possible receptors, and the interactions that link them. The CSM typically addresses both current and future land use scenarios, and is developed and used as a planning tool to integrate information from a variety of resources and to evaluate the information with respect to project objectives and data needs. The HHRA CSM describes the ways that COPCs and ROPCs can be released to or transported within the environment, and the exposure routes that could lead to human receptors. Exposure pathways are shown on the CSM. Complete exposure pathways consist of five components: 1) source, 2) exposure medium, 3) release mechanism, 4) exposure route, and 5) receptor.

HHRA CSMs have been prepared for the Homestake Facility and the LTAs and are included as Tables 5-2 and 5-3. EPA also developed its own CSM for human access and exposure to COPCs and ROPCs representing the potential chemical and radiological hazards for nearby residential receptors (EPA 2014a). EPA's CSM served as a basis for developing the HHRA CSMs for this RI Report.

The sources of COPCs and ROPCs at the Site above background concentrations result from historical uranium milling and mining activities in the region. Residual chemical and radionuclide contamination potentially remains in the Homestake Facility and LTAs following cessation of mill activities, demolition of the mill, and subsequent remedial actions discussed in Section 1.4.

5.2.1.1 Current and Future Land Use

The current primary land uses for the Homestake Facility area are groundwater remediation and associated maintenance activities and general property maintenance such as cap monitoring, fence repair, equipment and road repairs, facility administration, and weed control. The Homestake Facility area totals 1,085 acres. There are four LTAs in Sections 28, 33, and 34: two flood irrigated fields (24 acres and 120 acres), and two center pivot irrigated fields (100 acres and 150 acres). Spray and flood irrigation that occurred in the LTAs ceased in 2012 (refer to Figure 1-2). Currently, the LTAs are not used for Site-related activities.

Upon completion of Homestake Facility decommissioning, the Homestake Facility will be turned over to the Department of Energy (DOE) for legacy management. There are no planned changes in the existing land uses known at this time for the Homestake Facility. It will continue under an industrial use scenario.

Trespassing could occur in this area. It is not expected that trespassers would access the area frequently because there is other open space in the area. The property is also fenced.

Currently, a Declaration of Restrictive Covenants is being developed by HMC that, upon recording, will prohibit residential and agricultural use of the LTAs and use of groundwater beneath the LTAs for drinking water purposes.

5.2.1.2 Contaminant Sources

The primary sources of ROPCs and COPCs for both the Homestake Facility and the LTAs are the two tailings piles (refer to Figure 1-2) remaining from the historical uranium milling operations. Secondary sources are materials contaminated by release and transport from primary sources.

In the Homestake Facility, surface and subsurface soils, groundwater, fugitive dusts, two collection and three evaporation ponds, and the RO equipment could act as potential secondary sources.

Secondary sources at the LTAs include soils and fugitive dust. Wind could have carried contaminants from the Homestake Facility, and irrigation water could have introduced contamination to soils.

Groundwater is approximately 40 feet below grade at the Site. HMC provided communities south of the Homestake Facility with a potable water system as an extension of the Village of Milan water supply in the 1980s to address a concern over the quality of groundwater used for domestic purposes. HMC, through a Memorandum of Agreement with NMED, provided residents of these communities connection to the Village of Milan water at HMC's expense (NMED 2009b). The community continues to be served by this alternate water supply. In addition, remedial efforts are underway to treat groundwater that has migrated from the Homestake Facility. Within the Homestake Facility, HMC uses bottled water for drinking and water from a SAG well for other domestic and sanitary uses. For these reasons, groundwater is not considered to be a current complete pathway in this HHRA. Potential groundwater risks were evaluated only for future receptors exposed to post-remedy groundwater concentrations.

5.2.1.3 Release and Transport Mechanisms

Tailings produced during the mill's operation were placed in the tailings piles within the Homestake Facility. From there, the potential primary release and transport mechanisms included:

- Air dispersion/volatilization (for example, windblown fugitive dust or radon gas generation)
- Percolation of water, vertical migration
- Runoff, overland flow

5.2.1.4 Potential Routes of Migration

Potential routes of migration are described in Section 4.1. Routes of migration as they pertain to the risk assessment CSM are summarized in this section.

COPCs and ROPCs released from the tailings could be transported by surface water runoff to other areas down gradient from the source. Surface soil concentrations collected downgradient from the tailing piles also reflect contamination transported by surface water in addition to contamination transported by air. Erosion occurring on the tailings piles is not considered a reasonably expected event as the in-place erosion protection is designed to protect the impoundment for a Probable Maximum Precipitation event and to last a minimum of at least 1,000 years.

Windblown dust, especially in arid regions, represents a potential migration pathway for contaminants in surface soils due to generation of fugitive dust. In addition, radon gas migrates through air. Contaminants deposited onto surface soils can migrate through vertical and horizontal migration or mechanical disturbance.

Groundwater is another potential route of migration for COPCs and ROPCs from the tailings pile. Leaching to groundwater followed by groundwater flow can carry contaminants in the plume away from the primary source. Groundwater is currently undergoing remediation, and is being addressed and monitored under a separate EPA-led initiative.

Contaminants can also potentially migrate through uptake via the food chain. EPA measured concentrations of COPCs and ROPCs in produce (EPA 2014a) and evaluated residential exposure south of the Homestake Facility. Because of a deed restriction proposed in 2019, residential and agricultural uses will be prohibited within the LTAs, if the deed restriction is selected as part of a remedial alternative by EPA. Specifically, the deed restriction will prohibit residential, agricultural (animal grazing or using the land to grow food for animal or human consumption) uses within the LTAs. These land uses are also not envisioned for the Homestake Facility since it will be returned to DOE for legacy purposes. Therefore, food chain contamination due to contaminated irrigation water or alluvial groundwater will not be further addressed in this HHRA.

The draft deed restriction also prohibits use of groundwater except in compliance with a permit or applicable law (this would address groundwater-related pathways). In addition, groundwater remedies approved and monitored by EPA will reduce contamination from groundwater at the LTAs. The remedies will be designed to remove contamination to Site specific background levels; however, these background levels could be higher than the MCL value of some chemicals and/or radionuclides.

Potential Human Receptors

Human receptors potentially exposed to COPCs and ROPCs for this RI Report differ by exposure area. Current workers within the Homestake Facility operate under approved health and safety programs and are not considered receptors in this HHRA. Although other human receptors could possibly be in the vicinity of the Site and come in contact with environmental media, these categories identified below are intended to address those humans most likely exposed at the highest (that is, reasonable maximum exposure (RME)) rates. Access to the Homestake Facility is controlled and the area is fenced; however, trespassing remains a possibility and is considered in this analysis.

In the Homestake Facility, potential current and hypothetical future receptors evaluated for the HHRA include the following (refer to Table 5-2):

- Future Commercial/Industrial Indoor/Outdoor Worker (adult) (note: this scenario could only occur as part of the DOE legacy program). This is also referred to as “composite worker”.
- Future Construction Worker (adult) (note: construction could only occur as part of the DOE legacy program)
- Current and Future Trespasser (adult)

The LTA receptors are:

- Future Composite Worker (adult)

- Future Construction Worker (adult)
- Current and future trespassers (adult)

Note that a hypothetical future residential receptor is not modeled in the risk assessment. EPA has modeled risks to local residents near the LTAs and so current and future potential risks are identified and understood. Any risks to a resident would be higher than those for a worker due to longer exposure durations and higher exposure frequency. Because of the proposed deed restriction, residential use is not an expected land use for this area.

5.2.1.5 Exposure Media and Exposure Routes

The following exposure media and exposure routes are addressed in this risk assessment.

- Soil (surface and subsurface) - Exposure routes include incidental ingestion (for COPCs), dermal or direct contact (for COPCs), outdoor only fugitive dust inhalation of COPCs and ROPCs, inhalation of volatile ROPCs, and external radiation (submersion or immersion in a radiation field) from ROPCs (beta and gamma emitters).
    - All exposure routes in the Homestake Facility or LTAs for surface soil contact are considered potentially complete for all receptors.
    - Contact with subsurface soils is considered possible for the future construction worker engaged in excavation, and the future composite worker in the Homestake Facility in the event that excavated subsurface soils are left at the surface.
- Evaporation Pond Water – The evaporation ponds contain water or brine and may be a source of intermittent exposure due to accidental contact resulting in incidental ingestion of COPCs or ROPCs, dermal contact for COPCs, and immersion for ROPCs. Contact with pond water or brine is considered potentially complete for a hypothetical current trespasser. Accidental exposure is considered a rare event and was conservatively modeled at 6 days per year (d/y) for 10 years. Closure of the ponds will eliminate evaporation pond pathways for future trespassers.
- Evaporation Pond Sediments – Pond sediments are the solids at the bottom of the Evaporation Ponds and not the white residue or evaporites surrounding the ponds. Sediment samples have been collected and the sediment data is provided in the risk assessment.
- Evaporites or Brine Lining the Evaporation Ponds - An accidental immersion into the brine or sludge surrounding the ponds was considered a possibility. However, review of EPA data indicated many constituents were lower in evaporites or white residue than in surface soils, likely because the ponds contain relatively clean water that has been treated in the RO unit (EPA 2014a). If included in an exposure model, part of the typical total allotted soil ingestion rate would have to be reallocated to this brine/sludge material, which would then reduce predicted soil exposure. Given that the areal extent of the brine/sludge is very small relative to the soil areal extent and that humans would rarely contact it; it was not included in the quantitative evaluation.
- Groundwater –Groundwater is not a current exposure medium in the HHRA. For future land use; however, ground water is evaluated as a complete exposure pathway for the future indoor worker with the NRC Site Cleanup Levels used to quantify potential exposures.

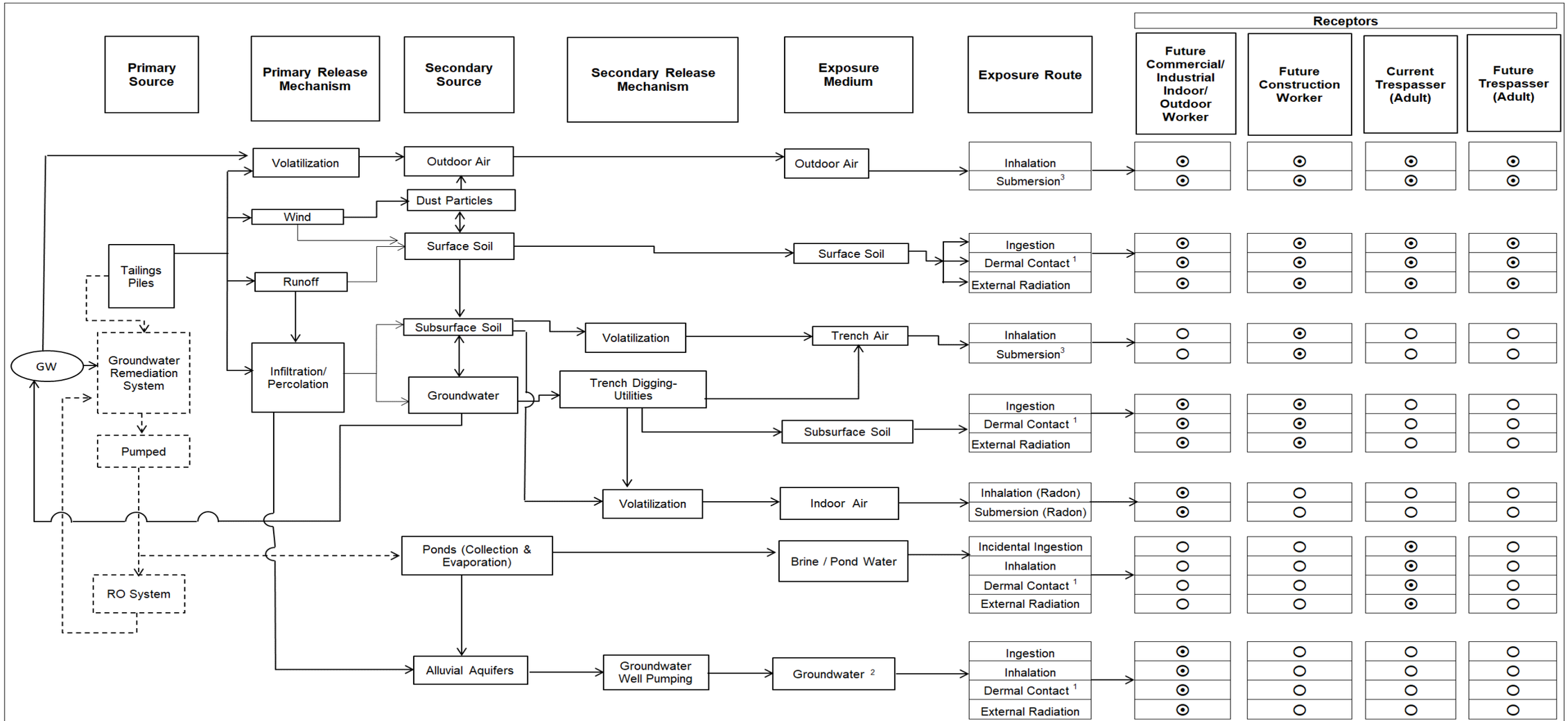
Groundwater is encountered at a depth of roughly 40 ft bgs and is undergoing remediation. Groundwater that passes through the reverse osmosis system may enter the evaporation ponds, at which point any exposure is addressed as pond water. Section 5.2.5.2.7 discusses post-remediation groundwater exposure.

- Irrigation Water – Irrigation is not occurring in the Homestake Facility or LTAs. Irrigation in the LTAs was terminated in 2012.
- Air – Air can be an exposure medium. Measured indoor and outdoor air data for radon gas and outdoor air data for particulates were included in the HHRA. The results of modeling particulate exposure from soil dust emissions and measured particulate data are compared. This is discussed in the uncertainty analysis.
- Trench Air – Air in deep trenches is a potential exposure medium for construction workers. However, only radon gas is a ROPC for this medium as it is the only volatile in the Homestake Facility or LTA. There is no radon gas data for surface or subsurface soils, and therefore trench air was not modeled quantitatively for those media. Exposure to trench air is quantified with measured indoor and outdoor air data, and addressed in the uncertainty analysis.

Access to the Homestake Facility is restricted by fencing and HMC personnel. There are no natural and permanent surface water features on the Site. Surface water that may be associated with evaporation ponds has been included in this CSM for current trespassers. Natural sediment is not evaluated.

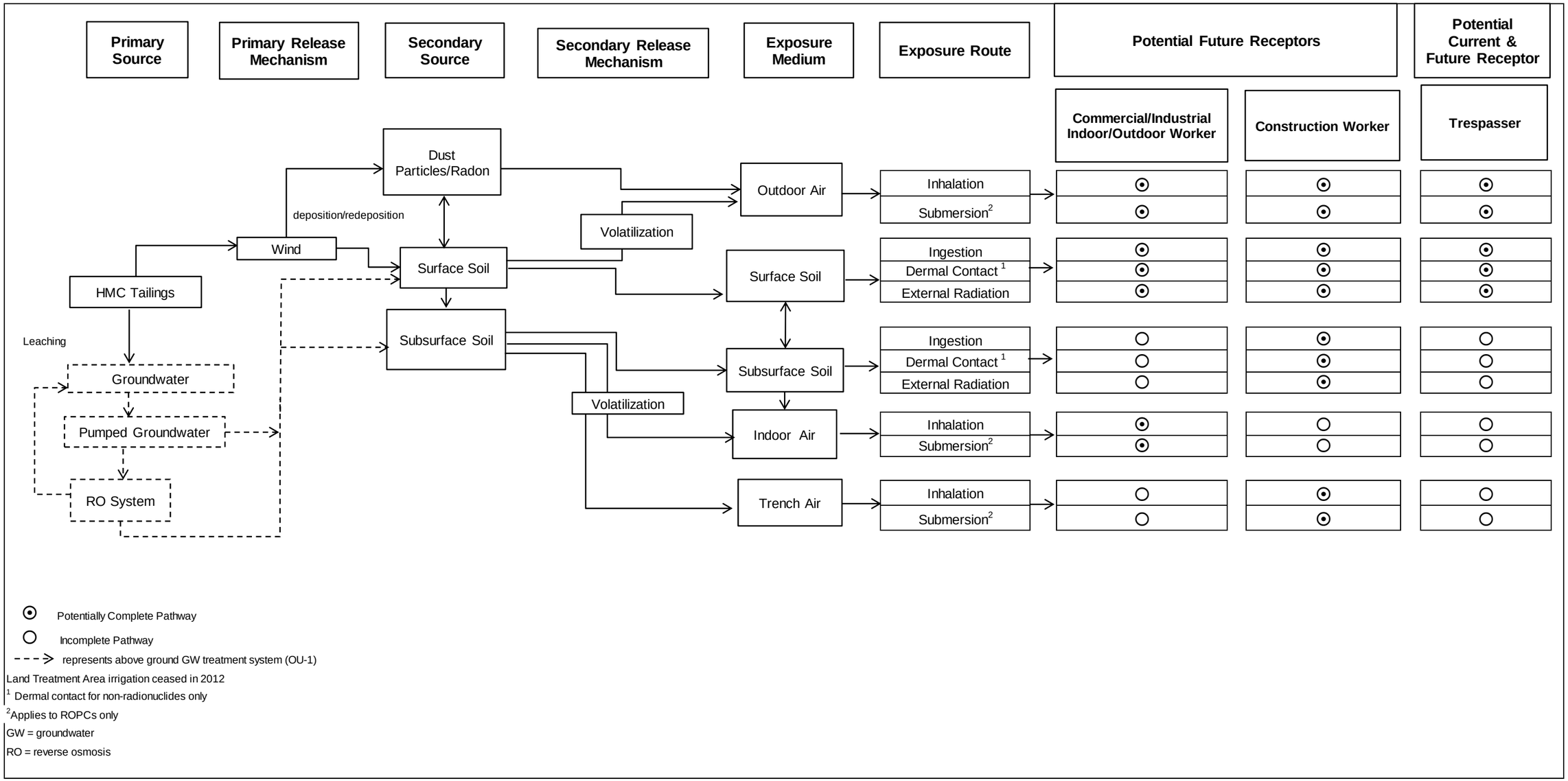
Indoor air exposure to volatile compounds was evaluated based on the future composite worker, although it is expected that future buildings would have mitigation for radon as part of best construction practices. Inhalation of fugitive dust was assessed for the future composite worker, and inhalation of trench air for the future construction worker.

Table 5-2 Conceptual Site Model for Human Receptors within Homestake Facility



○ Likely Incomplete Pathway
⊙ Potentially Complete Pathway
Shading denotes potential exposure is de minimus; not quantitatively evaluated
RO = reverse osmosis
- - - - - -> Represents above ground GW treatment system (OU-1)
Current facility operators and site workers are covered under the Occupation Safety and Health Administration standards.
[1] Dermal contact for non-radionuclides only
[2] Groundwater (OU-1) is under remediation; evaluated for future indoor worker in the HHRA.
[3] - Applies to ROPCs only

Table 5-3 Conceptual Site Model for Human Receptors within Land Treatment Areas



5.2.2 HHRA Screening for Chemicals of Potential Concern and Radionuclides of Potential Concern

The source documents referenced in Table 5-1 were reviewed to compile a primary list of analytes for the quantitative HHRA. HMC and EPA soil data were segregated into Homestake Facility, LTAs, or background.

EPA provides default regional screening level (RSLs) tables for workers and residents, and a calculator that estimates remediation goals or risks for chemicals in soil, air, and water for receptors potentially associated with the Site including recreational visitors or trespassers, indoor and outdoor workers, construction workers, and composite workers which are inclusive of both indoor and outdoor exposure pathways (EPA, 2019a). For initial soil COPC screening, workers as a group were addressed using the default RSLs for industrial soil (EPA 2019a) which are based on the composite worker exposure scenario.

In addition, the EPA and the Oak Ridge National Laboratory (ORNL) provide screening values for radionuclides or radiological preliminary remediation goals (RadPRGs) in various environmental media. RadPRGs are provided as defaults or can be calculated as Site-specific values whereby the user may input different exposure parameters and Site conditions. The human receptors addressed by the RadPRGs include composite workers, construction workers, and recreational visitors or trespassers. For the HMC HHRA, the default RadPRGs for the composite worker in all available environmental media were selected as most applicable for the initial ROPC screening based on the CSMs in Section 5.2.1.

The metals and radionuclides in the Homestake Facility and LTA data sets were compared record by record to these conservative, default screening levels based on EPA's "composite worker" and if the ratio for the maximum concentration or activity exceeded a screening level the analyte was considered to carry forward into the Baseline HHRA. Therefore, if the COPC and ROPC concentrations exceeded the screening values, those COPCs and ROPCs were retained for further evaluation in the HHRA Screening values for the composite worker are provided in Tables 5-4 through 5-7. This receptor has long-term, high rates of exposure to multiple pathways and is typically considered protective of other industrial receptors.

5.2.2.1 Inorganics

Inorganic chemicals evaluated in the screening level risk assessment were arsenic, lead, molybdenum, selenium, vanadium, and uranium as a metal. The screening methods and results are described in the following sections. All screening levels are conservative default values and have not been adjusted to reflect Site-specific conditions. The results and raw data are presented by location (i.e. LTAs or Homestake Facility) in Appendix F.

5.2.2.1.1 Soil

EPA RSLs for the composite worker exposed to industrial soil were used as the screening levels for metals for identifying COPCs (EPA 2019a). Site surface and subsurface soil concentrations were combined and compared to the 2019 EPA industrial soil RSLs for the composite worker (EPA 2019a) (refer to Table 5-4). Metals that exceeded the industrial soil RSLs are carried forward for further evaluation. The results are presented in Section 5.2.2.4. Appendix F also contains a summary of soil screening levels used in the HHRA.

Table 5-4 Summary of Soil Screening Values for All Analytes Evaluated in the HHRA

Analyte Name	Chemical Symbol	CASRN	Effect Basis	Composite Worker RSL (TCR=1E-06 THQ=0.1) (mg/kg)	Composite Worker RadPRG - Composite Worker (pCi/g)
Inorganics (mg/kg)					
Arsenic	As	7440-38-2	c*R	3.0	NA
Lead	Pb	7439-92-1	nc	800	NA
Molybdenum	Mo	7439-98-7	nc	580	NA
Selenium	Se	7782-49-2	nc	580	NA
Uranium (soluble salts)	U	--	nc	23	NA
Vanadium	V	7440-62-2	nc	580	NA
Radionuclides					
Gross Alpha	Gross Alpha	12587-46-1	c	NA	NA
Barium-140	Ba-140	14798-08-4	c	NA	0.0143
Gross Beta	Gross Beta	12587-47-2	c	NA	NA
Bismuth-212	Bi-212	--	c	NA	0.0258
Bismuth-214	Bi-214	--	c	NA	0.0231
Cobalt-60	Co-60	10198-40-0	c	NA	0.0142
Cesium-137	Cs-137	--	c	NA	0.069
Iodine-131	I-131	10043-66-0	c	NA	0.109
Potassium-40	K-40	13966-00-2	c	NA	0.219
Protactinium-234 Metastable	Pa-234m	15100-28-4	c	NA	0.02
Lead-212	Pb-212	15092-94-1	c	NA	0.024
Lead-214	Pb-214	15067-28-4	c	NA	0.0204
Radium-223	Ra-223	15623-45-7	c	NA	0.146
Radium-226	Ra-226	--	c	NA	0.0203
Radium-228	Ra-228	--	c	NA	0.0153

Table 5-4 Summary of Soil Screening Values for All Analytes Evaluated in the HHRA (Con't)

Analyte Name	Chemical Symbol	CASRN	Effect Basis	Composite Worker RSL (TCR=1E-06 THQ=0.1) (mg/kg)	Composite Worker RadPRG -Composite Worker (pCi/g)
Radon-219	Rn-219		c	NA	0.239
Radon-222	Rn-222	--	c	NA	0.0204
Thorium-227	Th-227	15623-47-9	c	NA	0.106
Thorium-228	Th-228	14274-82-9	c	NA	0.0238
Thorium-230	Th-230	14269-63-7	c	NA	0.0203
Thorium-232	Th-232	--	c	NA	0.0153
Thorium-234	Th-234	--	c	NA	0.02
Thallium-208	Tl-208	14913-50-9	c	NA	0.01
Uranium-234	U-234	13966-29-5	c	NA	0.0203
Uranium-235	U-235	--	c	NA	0.0731
Uranium-238	U-238	--	c	NA	0.02
U-natural	U-nat	--	c	23	0.02015

Sources: EPA 2019a.

Notes:

COPC = chemical of potential concern;
ROPC = radionuclide of potential concern

c = cancer
c*R = RBA applied (See User Guide for Arsenic notice) (EPA 2019a)
CASRN = Chemical Abstracts Service Registry Number
EPA = U.S. Environmental Protection Agency
HMC = Homestake Mining Company
mg/kg = milligram per kilogram
NA = not applicable
nc = non-cancer
ORNL = Oak Ridge National Laboratory
pCi/g = picoCurie per gram
RadPRG = radionuclide preliminary remediation goal assuming secular equilibrium
RBA = relative bioavailability factor
RSL = regional screening level
TCR = total cancer risk
THQ = total hazard quotient

5.2.2.1.2 Water

EPA RSLs (EPA 2019a) for residential use of tapwater were used to conservatively assess potential water exposures because there are no tapwater RSLs for industrial use, but the residential RSLs represent long-term exposure to a higher contact rate than would be expected under an industrial use scenario, and are therefore considered conservative for the screening evaluation. Tapwater RSLs for metals were used to screen the evaporation and collection ponds water data for dissolved and total metals (refer to Table 5-5). Where both dissolved and total data were available, the total concentrations were used as the basis of the exposure point concentrations (EPCs). Metals that exceeded the residential tapwater RSLs are carried forward for further evaluation. The results are presented in Section 5.2.2.4. All residential tapwater RSLs are also provided in Appendix F.

5.2.2.2 Radionuclides

RadPRGs were obtained from the EPA-Oak Ridge National Laboratory (ORNL). Screening values assume secular equilibrium with daughter products (progeny) throughout the chain, including the assumption of no decay. EPA provides RadPRGs for various media for composite workers and other receptors using both default and Site-specific exposure parameters. For consistency and in accordance with the CSMs in Section 5.2.1, default RadPRGs for the composite worker were selected for ROPC screening. All screening levels and raw data are provided in Appendix F.

5.2.2.2.1 Soil

Soil screening levels for radionuclides were the default RadPRGs for the composite worker (refer to Table 5-4). This is expected to be protective of other industrial exposure scenarios (e.g., construction workers) because this is a long-term worker with moderately high contact rates, and is the basis of default screening values used by EPA. The Site surface and subsurface soil data for radionuclides were combined and compared to the RadPRGs. If concentrations exceeded the RadPRG for the composite worker, the radionuclide was carried forward for further evaluation. The results are presented in Section 5.2.2.4. All RadPRGs are also provided in Appendix F.

5.2.2.2.2 Water

Residential tapwater RadPRGs were used to screen the evaporation and collection pond water data (refer to Table 5-6) because industrial SLs are not available for tapwater. This is conservative because receptors would not be expected to use any of the evaporation or collection ponds as a primary drinking water source. Evaporation pond data for radionuclides were compared to the RadPRGs for residential use. If concentrations exceeded the RadPRG for residential use of tapwater, the radionuclide was carried forward for further evaluation. The results are presented in Section 5.2.2.4. All RadPRGs are also provided in Appendix F.

5.2.2.2.3 Sediment

There are sediment data from two samples. One sample was collected from the West Collection Pond and was analyzed for uranium natural (U-nat) and Th-230. The other sample was collected at EP1 and analyzed for Ra-226. Soil RadPRGs (Table 5-4) were used to initially screen sediments. The sediment samples evaluated in the risk assessment were collected on September 24, 2015 (ERG 2017).

There are no residential or industrial screening levels for sediment. Therefore, sediment data were compared to industrial soil screening levels (Table 5-4).

There is a salt crust around the edges of the evaporation ponds. The primary constituents found in this grey or white crust were calcium carbonate, magnesium, sodium and silicon. Silicon indicates the presence of soil or rock. The crust does not represent true sediments; however, as it is formed by evaporation. Receptors are not expected to contact the evaporite for any length of time due to the limited areal extent, and data from the salt crust are not used to develop the sediment EPCs.

Table 5-5 Tapwater Regional Screening Levels (RSLs) for Chemicals in Evaporation & Collection Pond Water

Analyte Name	CAS Number	Residential Tapwater RSL (µg/L)
Manganese	7439-96-5	43 nc
Molybdenum	7439-98-7	10 nc
Nitrate	14797-55-8	3200 nc
Selenium	7782-49-2	10 nc
Uranium (Soluble Salts)	NA	0.4 nc
Vanadium and Compounds	7440-62-2	8.6 nc

Notes:
Tap water regional screening levels (RSLs) obtained from EPA 2019a: HQ=0.1
nc = non-cancer
µg/L = microgram per liter

Table 5-6 Tapwater RadPRGs for Radionuclides in Evaporation and Collection Pond Water

Isotope	Residential Tapwater RadPRG (pCi/L)
Ra-226	0.000397
Ra-228	0.000966
Th-230	0.000396

Notes:
Residential tapwater RadPRGs obtained from EPA 2019b
RadPRG = radiological preliminary remediation goal
pCi/L = picoCurie per liter

5.2.2.2.4 Air

For outdoor air, radon gas and particulate data for U-nat, Ra-226, and Th-230 data were available for ROPC screening (refer to Table 5-7). The data are based on radon track etch and high volume particulate samples (HMC 2019c). Ambient air RadPRGs for the composite worker were obtained from EPA ORNL (EPA 2019b). Homestake Facility air data were used for screening. The air data for radionuclides were compared to the RadPRGs. If concentrations exceeded the RadPRG for air for composite workers, the radionuclide is carried forward for further evaluation. The results are presented in Section 5.2.2.4. All RadPRGs are also provided in Appendix F.

For indoor air, the data from the office and RO plant were utilized to predict air concentrations of Rn-222 in an indoor environment. Only data from the second quarter of 2015 through 2018 were

utilized for indoor air because the ventilation system was improved. Thus, previously measured air concentrations of radon are not reflective of current conditions.

Table 5-7 Composite Worker RadPRGs for Ambient Air

Isotope	Composite Worker Air PRG (no decay) (pCi/m^3)
Ra-226	0.000135
Rn-222	0.000258
Th-230	0.000086
U-234	0.0000661
U-235	0.000025
U-238	0.0000553

Notes:
Composite Worker Air RadPRGs obtained from ORNL/EPA, July 2019 including inhalation and external exposure risk components
pCi/m^3 = picoCurie per cubic meter
RadPRG = radionuclide preliminary remediation goal

5.2.2.3 Evaluation of Detection Limits Relative to Contaminant Screening Levels

Detection limits represented by method detection limits (MDLs), minimum detectable concentration (MDC), or reporting limits (RLs) were available. The vast majority of the data were detected results thus minimizing any uncertainty introduced by missing detection limits. For non-detected analytes, if the maximum detection limit exceeded a screening value, it was retained in that medium for further evaluation.

5.2.2.4 Screening Results

The MDCs were compared to the RSLs and the RadPRGs for each data set and by environmental sampling medium for the Homestake Facility and LTA s. If the MDC exceeded the screening value, the chemical was retained for further evaluation in Section 5.2.3.

Soil

Surface and subsurface soil were combined for this analysis. Contaminants that carried forward for further quantitative analysis in the baseline or forward risk analysis component of the HHRA are summarized in Table 5-8. The comparison of the HHRA data to the screening levels and identification of ROPCs and COPCs is presented in detail in Appendix F.

Table 5-9 identifies the EPCs for use in the baseline HHRA. Where there were a minimum required number of samples, upper 95th percentile confidence limits (UCL95s) on the arithmetic mean were estimated with ProUCL version 5.1 (EPA 2016). ProUCL supporting information is provided in Appendix F. If there were no detections, a UCL was not calculated. If there were fewer than six detections, a median was used as a robust estimate of the UCL. Otherwise, the highest UCL recommended by ProUCL (EPA 2016) was selected as the EPC.

Background soil data are used in the uncertainty analysis portion of the HHRA and are not used to remove analytes from evaluation as COPCs or ROPCs. The background raw data reported in Appendix F were used in hypothesis tests with ProUCL (EPA 2016) to determine if the site significantly exceeded background or not.

Table 5-8 Screening Level Results for Soil by Location

Analyte	Units	n	Maximum RL[1]	Minimum Detected Result	Maximum Detected Result	Number of Detected Values	RSL or PRG	Industrial Ratio
Homestake Facility								
As	mg/kg	26	NA	1.91	9.58	26	3	3E+00
Ba-140	pCi/g	27	11.8	NA	NA	0	0.0143	8E+02
Bi-212	pCi/g	27	NA	0.39	2.04	27	0.0258	8E+01
Bi-214	pCi/g	27	NA	0.504	5.79	27	0.0231	3E+02
Co-60	pCi/g	27	0.0345	NA	NA	0	0.0142	2E+00
Cs-137	pCi/g	27	0.027	0.0105	0.151	20	0.069	2E+00
I-131	pCi/g	27	27.2	NA	NA	0	0.109	2E+02
K-40	pCi/g	27	NA	12.9	21.2	27	0.219	1E+02
Mo	mg/kg	61	7	0.619	126	38	580	2E-01
Pa-234m	pCi/g	26	NA	1.2	18.9	26	0.02	9E+02
Pb	mg/kg	26	NA	3.88	19.7	26	800	2E-02
Pb-212	pCi/g	27	NA	0.425	1.67	27	0.024	7E+01
Pb-214	pCi/g	27	NA	0.54	6.13	27	0.0204	3E+02
Ra-223	pCi/g	20	NA	0.097	0.67	20	0.146	5E+00
Ra-226	pCi/g	75	NA	0.04	9.9	75	0.0203	5E+02
Ra-228	pCi/g	27	NA	0.483	1.71	27	0.0153	1E+02
Rn-219	pCi/g	3	NA	0.124	0.29	3	0.239	1E+00
Se	mg/kg	61	1	0.283	11.1	34	580	2E-02
Th-227	pCi/g	8	NA	0.047	0.227	8	0.106	2E+00
Th-228	pCi/g	27	NA	0.47	2.34	27	0.0238	1E+02
Th-230	pCi/g	76	-0.1	0.02	7.4	73	0.0203	4E+02
Th-232	pCi/g	27	NA	0.39	1.81	27	0.0153	1E+02
Th-234	pCi/g	20	NA	0.28	11.2	20	0.02	6E+02
Tl-208	pCi/g	27	NA	0.138	0.527	27	0.01	5E+01
U natural	pCi/g	49	NA	1	30	49	0.02015	1E+03
U total	mg/kg	49	NA	1	44	49	23	2E+00
U-234	pCi/g	27	NA	0.58	18.3	27	0.0203	9E+02

Table 5-8 Screening-Level Results For Soil by Location (Con't)

Analyte	Units	n	Maximum RL[1]	Minimum Detected Result	Maximum Detected Result	Number of Detected Values	RSL or PRG	Industrial Ratio
Homestake Facility								
U-235	pCi/g	27	NA	0.071	0.697	27	0.0731	1E+01
U-238	pCi/g	27	NA	0.79	19	27	0.02	1E+03
U-nat	mg/kg	NA	NA	NA	NA	NA	NA	NA
V	mg/kg	26	NA	11.7	60.7	26	580	1E-01
Land Treatment Areas								

As	mg/kg	19	NA	2.04	6.79	19	3	2E+00
Ba-140	pCi/g	21	5.25	NA	NA	0	0.0143	4E+02
Bi-212	pCi/g	21	NA	0.45	1.71	21	0.0258	7E+01
Bi-214	pCi/g	21	NA	0.43	1.44	21	0.0231	6E+01
Co-60	pCi/g	21	0.0293	NA	NA	0	0.0142	2E+00
Cs-137	pCi/g	21	NA	0.016	0.114	21	0.069	2E+00
I-131	pCi/g	21	17.3	NA	NA	0	0.109	2E+02
K-40	pCi/g	21	NA	11.5	20.3	21	0.219	9E+01
Mo	mg/kg	134	1	0.283	4	51	580	7E-03
Pa-234m	pCi/g	13	NA	0.66	3.3	13	0.02	2E+02
Pb	mg/kg	19	NA	3.47	18	19	800	2E-02
Pb-212	pCi/g	21	NA	0.419	1.52	21	0.024	6E+01
Pb-214	pCi/g	21	NA	0.485	1.55	21	0.0204	8E+01
Ra-223	pCi/g	17	NA	0.093	0.364	17	0.146	2E+00
Ra-226	pCi/g	309	NA	0.218	3.9	309	0.0203	2E+02
Ra-228	pCi/g	21	NA	0.453	1.66	21	0.0153	1E+02
Rn-219	pCi/g	NA	NA	NA	NA	NA	NA	NA
Se	mg/kg	319	0.5	0.06	2.6	244	580	4E-03
Th-227	pCi/g	1	NA	0.087	0.087	1	0.106	8E-01
Th-228	pCi/g	6	NA	1.02	1.84	6	0.0238	8E+01
Th-230	pCi/g	109	-0.1	0.1	3.4	65	0.0203	2E+02
Th-232	pCi/g	6	NA	1.04	1.92	6	0.0153	1E+02
Th-234	pCi/g	15	NA	0.27	2.09	15	0.02	1E+02
Tl-208	pCi/g	21	NA	0.134	0.5	21	0.01	5E+01
U natural (pCi/g)	pCi/g	NA	NA	NA	NA	NA	NA	NA
U total	mg/kg	218	1	0.19	7.47	192	23	3E-01
U-234	pCi/g	6	NA	0.88	2.73	6	0.0203	1E+02
U-235	pCi/g	15	NA	0.059	0.193	15	0.0731	3E+00
U-238	pCi/g	6	NA	1.06	2.49	6	0.02	1E+02
U-nat	mg/kg	185	NA	0.5	7.2	185	23	3E-01
V	mg/kg	19	NA	9.16	39.6	19	580	7E-02

Table 5-8 Screening-Level Results For Soil by Location (Con't)

Analyte	Units	n	Maximum RL[1]	Minimum Detected Result	Maximum Detected Result	Number of Detected Values	RSL or PRG	Industrial Ratio
Background								
As	mg/kg	12	5.52	4.25	5.52	12	3	2E+00
Ba-140	pCi/g	13	3.69	NA	NA	0	0.0143	3E+02
Bi-212	pCi/g	13	1.34	0.87	1.34	13	0.0258	5E+01
Bi-214	pCi/g	13	1.05	0.806	1.05	13	0.0231	5E+01
Co-60	pCi/g	13	0.0294	NA	NA	0	0.0142	2E+00

Cs-137	pCi/g	13	0.093	0.053	0.093	13	0.069	1E+00
I-131	pCi/g	13	9.7	NA	NA	0	0.109	9E+01
K-40	pCi/g	13	19.9	16.6	19.9	13	0.219	9E+01
Mo	mg/kg	12	0.623	0.343	0.623	12	580	1E-03
Pa-234m	pCi/g	4	1.6	0.9	1.6	4	0.02	8E+01
Pb	mg/kg	12	14.2	9.46	14.2	12	800	2E-02
Pb-212	pCi/g	13	1.22	0.89	1.22	13	0.024	5E+01
Pb-214	pCi/g	13	1.1	0.84	1.1	13	0.0204	5E+01
Ra-223	pCi/g	10	0.344	0.224	0.344	10	0.146	2E+00
Ra-226	pCi/g	13	2	1.29	2	13	0.0203	1E+02
Ra-228	pCi/g	13	1.26	0.91	1.26	13	0.0153	8E+01
Rn-219	pCi/g	NA	NA	NA	NA	NA	NA	NA
Se	mg/kg	12	2.03	0.349	2.03	12	580	4E-03
Th-227	pCi/g	5	0.14	0.061	0.14	5	0.106	1E+00
Th-228	pCi/g	5	1.44	0.98	1.44	5	0.0238	6E+01
Th-230	pCi/g	5	1.56	0.7	1.56	5	0.0203	8E+01
Th-232	pCi/g	5	1.12	0.87	1.12	5	0.0153	7E+01
Th-234	pCi/g	10	0.88	0.32	0.88	10	0.02	4E+01
Tl-208	pCi/g	13	0.394	0.285	0.394	13	0.01	4E+01
U natural (pCi/g)	pCi/g	NA	NA	NA	NA	NA	NA	NA
U total	mg/kg	NA	NA	NA	NA	NA	NA	NA
U-234	pCi/g	5	1.22	0.6	1.22	5	0.0203	6E+01
U-235	pCi/g	18	0.123	0.03	0.123	17	0.0731	2E+00
U-238	pCi/g	5	1.21	0.73	1.21	5	0.02	6E+01
U-nat	mg/kg	NA	NA	NA	NA	NA	NA	NA
V	mg/kg	12	36.5	20.4	36.5	12	580	6E-02

Notes:
[1] - the maximum RL is the highest reporting limit for nondetected samples
Shaded cells indicate the analyte is an ROPC or COPC and carries forward to the Baseline HHRA
Abbreviations:
NA – Not applicable, RL – Reporting limit
RSL – Regional screening level for non-radioactive inorganics
PRG – Preliminary remedial goal for radionuclides

Table 5-9 Soil Exposure Point Concentrations for Baseline Risk Assessment

Homestake Facility Exposure Point Concentrations				
Parameter	**Units**	**Distribution**	**Statistic**	**Value**
As	mg/kg	Approx. Normal	95% Student's-t UCL	6.328
Bi-212	pCi/g	No Dist	95% Student's-t UCL	1.498
Bi-214	pCi/g	Approx. Gamma	95% Adjusted Gamma UCL	2.333
Cs-137	pCi/g	Normal	95% KM (t) UCL	0.0672
K-40	pCi/g	Approx. Normal	95% Student's-t UCL	18.1
Mo	mg/kg	No Dist	99% KM (Chebyshev) UCL	36.53
Pa-234m	pCi/g	Approx. Gamma	95% Adjusted Gamma UCL	4.603

Pb-212	pCi/g	No Dist	95% Student's-t UCL	1.348
Pb-214	pCi/g	Approx. Gamma	95% Adjusted Gamma UCL	2.468
Ra-223	pCi/g	Normal	95% Student's-t UCL	0.414
Ra-226	pCi/g	Gamma	95% Adjusted Gamma UCL	4.027
Ra-228	pCi/g	No Dist	95% Student's-t UCL	1.422
Se	mg/kg	No Dist	99% KM (Chebyshev) UCL	3.797
Th-227	pCi/g	Normal	95% Student's-t UCL	0.174
Th-228	pCi/g	Approx. Normal	95% Student's-t UCL	1.604
Th-230	pCi/g	Gamma	95% KM Approximate Gamma UCL	2.596
Th-232	pCi/g	No Dist	95% Student's-t UCL	1.372
Th-234	pCi/g	Gamma	95% Adjusted Gamma UCL	3.26
Tl-208	pCi/g	No Dist	95% Student's-t UCL	0.434
U total	mg/kg	Lognormal	95% H-UCL	14.2
U-234	pCi/g	Approx. Gamma	95% Adjusted Gamma UCL	4.287
U-235	pCi/g	Gamma	95% Adjusted Gamma UCL	0.307
U-238	pCi/g	Lognormal	95% H-UCL	4.323

Table 5-9 Soil Exposure Point Concentrations for Baseline Risk Assessment (Con't)

Homestake Facility Exposure Point Concentrations				
Parameter	**Units**	**Distribution**	**Statistic**	**Value**
Land Treatment Area Exposure Point Concentrations				
As	mg/kg	Approx. Gamma	95% Adjusted Gamma UCL	4.693
Bi-212	pCi/g	No Dist	95% Student's-t UCL	1.015
Bi-214	pCi/g	No Dist	95% Modified-t UCL	0.87
Cs-137	pCi/g	Normal	95% Student's-t UCL	0.0711
K-40	pCi/g	Normal	95% Student's-t UCL	15.92
Mo	mg/kg	No Dist	95% Student's-t UCL	0.623
Pa-234m	pCi/g	Gamma	95% Adjusted Gamma UCL	1.844
Pb-212	pCi/g	No Dist	95% Modified-t UCL	0.938
Pb-214	pCi/g	No Dist	95% Modified-t UCL	0.942
Ra-223	pCi/g	Approx. Lognormal	95% H-UCL	0.253
Ra-226	pCi/g	Gamma	95% Approximate Gamma UCL	1.41
Ra-228	pCi/g	No Dist	95% Modified-t UCL	0.982
Se	mg/kg	No Dist	99% KM (Chebyshev) UCL	1.12
Th-228	pCi/g	Normal	95% Student's-t UCL	1.763
Th-230	pCi/g	Normal	95% KM (t) UCL	1.164
Th-232	pCi/g	Normal	95% Student's-t UCL	1.74
Th-234	pCi/g	Gamma	95% Adjusted Gamma UCL	0.892
Tl-208	pCi/g	No Dist.	95% Modified-t UCL	0.295
U total	mg/kg	No Dist.	95% Modified-t UCL	3.987
U-234	pCi/g	Normal	95% Student's-t UCL	2.23
U-235	pCi/g	No Dist	95% Student's-t UCL	0.131
U-238	pCi/g	Normal	95% Student's-t UCL	2.21

Table 5-9 Soil Exposure Point Concentrations for Baseline Risk Assessment (Con't)

Homestake Facility Exposure Point Concentrations				
Parameter	**Units**	**Distribution**	**Statistic**	**Value**
Background				
As	mg/kg	Normal	95% Student's-t UCL	5.01
Bi-212	pCi/g	Normal	95% Student's-t UCL	1.195
Bi-214	pCi/g	Normal	95% Student's-t UCL	0.948
Cs-137	pCi/g	Normal	95% Student's-t UCL	0.0731
K-40	pCi/g	Normal	95% Student's-t UCL	18.35
Mo	mg/kg	Approx. Normal	95% Student's-t UCL	0.447
Pa-234m	pCi/g	Normal	95% Student's-t UCL	1.515
Pb	mg/kg	Normal	95% Student's-t UCL	11.94
Pb-212	pCi/g	Normal	95% Student's-t UCL	1.104
Pb-214	pCi/g	Normal	95% Student's-t UCL	1.017
Ra-223	pCi/g	Normal	95% Student's-t UCL	0.296
Ra-226	pCi/g	Normal	95% Student's-t UCL	1.81
Ra-228	pCi/g	Normal	95% Student's-t UCL	1.14
Se	mg/kg	No Discernable Distribution	95% Student's-t UCL	0.799
Th-227	pCi/g	Normal	95% Student's-t UCL	0.13
Th-228	pCi/g	Normal	95% Student's-t UCL	1.412
Th-230	pCi/g	Normal	95% Student's-t UCL	1.393
Th-232	pCi/g	Normal	95% Student's-t UCL	1.135
Th-234	pCi/g	Normal	95% Student's-t UCL	0.703
Tl-208	pCi/g	Normal	95% Student's-t UCL	0.357
U total	mg/kg	Mean of U-234 and U-238	Multiply by 1.48 to get concentration	1.69
U-234	pCi/g	Normal	95% Student's-t UCL	1.141
U-235	pCi/g	Normal	95% Student's-t UCL	0.112
U-238	pCi/g	Normal	95% Student's-t UCL	1.147
V	mg/kg	Normal	95% Student's-t UCL	29.87

Notes: U-natural or U-total activities are not used as EPCs in the EPA/ORNL calculator and so are not shown in this table. The calculator predicts radiation risk on individual isotope measurements and estimated activity throughout the decay chain.
KM – Kaplan-Meier
mg/kg – milligram per kilogram, pCi/g – picocuries per gram
No Dist – Data do not follow a known distribution
UCL – Upper confidence limit on the mean

The screening level analysis of the Homestake Facility data reduced the analytes to two COPCs (arsenic and U-total) and 25 ROPCs in soil. Molybdenum and selenium were retained at the request of EPA although maximum concentrations were below screening levels. Only Ba-140, Co-60, I-131, lead, Rn-219, and vanadium were screened out.

The screening level analysis of the LTA data reduced the analytes to one COPC (arsenic) and 18 ROPCs in the combined surface and subsurface soil. Molybdenum and selenium were retained at the request of EPA although maximum concentrations were orders of magnitude below screening levels. Only Ba-140, Co-60, I-131, lead, Th-227, U-total (as a metal), U-nat (as a metal), and vanadium were removed from soil for the LTAs. U-total was carried forward as a metal since the uranium isotopes carried forward although it was well below screening levels.

Surface Water

Surface water data from the monitoring program were available for 2015 to 2018. Maximum concentrations of each analyte were compared to the residential tapwater RSL or a radionuclide PRG if available. Tapwater SLs are not available for the industrial scenario. These screening levels assume a lifetime ingestion rate of 2.5 L/d as an adult and 0.78 L/d as a child up through age 6. This is overly conservative for the evaporation ponds, where only infrequent, incidental ingestion of a few milliliters (ml) at most is expected to occur. Every analyte exceeded its screening level (Table 5-10).

Sediment

There are two sludge samples evaluated in the risk assessment (Table 5-10). All analytes in sediment/sludge carry forward because they exceeded industrial screening levels for soils.

Outdoor Air

No particulates were retained in air as all maximum concentrations were well below screening levels (Table 5-11). These measured results were compared to the results of the soil inhalation pathway for which the PEF is used to model inhalation exposure to predict risk of exposure to fugitive dusts. The inhalation risk was less than 1×10^{-6} for all radionuclides based on maximum concentrations, similar to the results of the measured particulate data. Radon-222 in outdoor air was retained for further evaluation for the Homestake Facility and LTAs based on a combined of outdoor air samples. Radon-222 was retained for trench air based on a proxy data set of the indoor air measurements from the office and RO plant. The outdoor air and trench air data were used to estimate representative concentrations across the Site. Radon-222 was retained in indoor air from the Homestake Facility based on data from the RO building.

Screening Level Uncertainty Analysis

One identified uncertainty in the screening analysis is associated with data for molybdenum and selenium analyzed by HMC contract laboratories where the RLs were elevated compared to RLs from EPA's laboratories. However, the number of detected values associated with the EPA 2011 data suggests that selenium and molybdenum concentrations are not elevated across the Site, and both metals were below screening levels (Table 5-8). Because they are COPC, selenium and molybdenum are retained for further evaluation.

Another identified uncertainty is the evaluation of the uranium isotopes. PRGs are available only for individual isotopes and not uranium mixtures. U-nat is predominantly U-238 (i.e., approximately 99%) with lesser amounts of other isotopes. The NRC states U-nat contains the relative

concentrations of isotopes found in nature of 0.7 percent uranium-235, 99.3 percent uranium-238, and a trace amount of uranium-234 by mass. In terms of radioactivity, however, the radiation emitted by natural uranium comes approximately 2.2 percent from uranium-235, 48.6 percent from uranium-238, and 49.2 percent from uranium-234 (NRC 2019). To represent the toxicity of U-nat, the mean of the screening level activity of U-238 and U-234 was used. This uncertainty is not likely to bias results of the evaluation.

Table 5-10 Summary of Screening Results and EPCs for Air, Pond Sludge/Sediment, and Pond Water

Analyte Name	Units	Sample Size (n)	Minimum Result	Maximum Result	Number of Detected Results	Industrial SL	Industrial SL Ratio	UCL95	Basis
Sludge									
Ra226	pCi/g	1	32.5	32.5	1	0.0203	2E+03	NA	n<8-10, Use Maximum
Th230	pCi/g	1	0.5	0.5	1	0.0203	2E+01	NA	n<8-10, Use Maximum
U-nat	pCi/g	1	2566	2566	1	0.02015	1E+05	NA	n<8-10, Use Maximum
Water									
Manganese (total)	mg/L	43	0.001	1.4	42	0.043	3E+01	0.302	No Dist @ 5% - Use 95% KM (Chebyshev) UCL
Molybdenum (total)	mg/L	80	3.82	4760	80	0.01	5E+05	864.4	Lognormal - Use 95% H-UCL
Nitrate	mg/L	25	0.1	9	15	3.2	3E+00	2.135	Approx. Normal - Use 95% KM (t) UCL
Ra-226	pCi/L	24	0.06	130	24	0.000397	3E+05	45.75	Gamma - 95% Adjusted Gamma UCL
Ra228	pCi/L	24	-0.5	140	21	0.000966	1E+05	71.01	No Dist @ 5% - Use 99% KM (Chebyshev) UCL
Selenium (total)	mg/L	64	0.11	5.98	63	0.01	6E+02	0.733	Approx. Lognormal - Use KM H-UCL
Th230	pCi/L	24	0.006	2210	24	0.000396	6E+06	1200	Lognormal - Use 99% Chebyshev (Mean, Sd) UCL
U-natural (total)	mg/L	80	2	2940	80	0.0004	7E+06	548.8	Lognormal - Use 95% H-UCL
Vanadium	mg/L	24	0.01	0.32	16	0.0086	4E+01	0.107	Gamma - 95% KM Adjusted Gamma UCL

Table 5-10 Summary of Screening Results and EPCs for Air, Pond Sludge/Sediment, and Pond Water (Con't)

Analyte Name	Units	Sample Size (n)	Minimum Result	Maximum Result	Number of Detected Results	Industrial SL	Industrial SL Ratio	UCL95	Basis
Outdoor Air									
Ra-226	pCi/L	120	2E-12	2E-10	120	1.35E-07	1E-03	NA	Not a ROPC
Rn-222	pCi/L	160	0.37	1.77	160	2.58E-07	7E+07	0.949	Approx. Gamma – Use 95% Approx. Gamma UCL
Th-230	pCi/L	120	3E-12	3E-10	120	8.58E-08	3E-03	NA	Not a ROPC
U-Nat	pCi/L	120	1.9E-13	6.7E-09	120	6.07E-08	3E-01	NA	Not a ROPC
Indoor Air									
Rn-222	pCi/L	29	0.75	2.9	29	2.58E-07	1E+07	1.837	Approx. Normal – Use 95% Student's-t UCL

Notes:
Approx. - approximate
n = number of samples
Dist - distribution
pCi/m^3 = picoCurie per cubic meter
KM = Kaplan-Meier
mg/L = milligram per liter
pCi/g = picoCurie per gram
pCi/L = picoCurie per liter
ROPC = radionuclide of potential concern
UCL = upper confidence limit
* UCL95 = 95% upper confidence limit; UCL95s calculated by ProUCL V5.1 (EPA 2016)

Table 5-11. Comparison of Modeled Fugitive Dust and Measured Particulate Inhalation Risks

Radionuclide	Soil Activity (pCi/g)	Fugitive Dust Inhalation Risk (unitless)	Particulate Activity (pCi/L)	Particulate Activity (pCi/m^3)	Particulate Inhalation Risk (unitless)
Ra-226	9.9	1E-08	2.0E-10	2.00E-07	1E-09
Th-230	7.4	1E-08	3.0E-10	3.00E-07	4E-09
U-234	18.3	4E-08	3.35E-09	3.35E-06	5E-08
U-238	19	5E-08	3.35E-09	3.35E-06	6E-08
U-natural	NA	NA	6.70E-09	6.70E-06	

Notes: Half the U-natural activity maximum was assigned equally to U-234 and U-238 to compare risks to modeled fugitve dust

5.2.3 Baseline Human Health Exposure Assessment

This Exposure Assessment uses available information to provide numeric estimates of exposure for each of the identified receptors in Tables 5-2 and 5-3 for each of the COPCs and ROPCs identified in Tables 5-8 and 5-10. Only COPCs or ROPCs that exceeded screening levels (Appendix F) are further addressed in the Baseline HHRA.

5.2.3.1 Media of Potential Concern

5.2.3.1.1 Soil

The following COPCs exceeded one or more screening level in surface or subsurface soil media in the Homestake Facility and are further evaluated:

- Arsenic – exceeded surface soil only. There are no subsurface data for arsenic.
- U-total (as a metal)
- Selenium and Molybdenum were retained at the request of EPA although they were below screening levels.

Nearly all radioisotopes were identified as ROPCs that exceeded screening levels for soil at the Homestake Facility (see Table 5-8). These are addressed in the baseline HHRA.

Arsenic was the only COPC that exceeded screening levels in LTA surface soil, and nearly all ROPCs exceeded screening levels in surface soils in the LTAs (Table 5-8).

It is known that U-nat is 99% U-238, and in terms of radioactivity it is approximately half U-234 and half U-238. Therefore, retaining all uranium analytes in the baseline risk assessment, which culminates with summation of cancer risks across all ROPCs and COPCs, would lead to overestimating the EPC and thus double counting the risks due to exposure to uranium isotope activity. The EPA RadPRG calculator only predicts exposure to individual uranium isotopes, and therefore the U-nat or U-total activity data were not utilized.

5.2.3.1.2 Surface Water

All of the analytes exceeded tapwater screening levels (Table 5-10). The following analytes in the evaporation pond water are further addressed for the Homestake Facility:

- Manganese
- Molybdenum
- Nitrate
- Selenium
- Uranium-natural (reported in units of mg/L)
- Vanadium
- Ra-226

- Ra-228
- Th-230

5.2.3.1.3 Air

Radon is the only ROPC identified for indoor or outdoor air. Levels in indoor air were higher than in outdoor air.

5.2.3.1.4 Sediments

There were three radionuclides evaluated in sediments and all carried forward into the baseline HHRA:

- Ra-226
- Th-230
- U-nat

5.2.3.2 Current and Future Potential Receptors

Current and future receptors were identified and described in Section 5.2.1.5 and are shown in Tables 5-2 and 5-3. Included are receptors that could potentially occur currently, or may be expected to occur in the future. Current receptors are modeled as exposed to conditions at the current time. The same data were used to represent future conditions, although once the Homestake Facility is closed, certain pathways will become incomplete (for example, contact with the evaporation ponds would be incomplete because the ponds would be removed). Therefore, the future scenario analyses may be overestimating risks for that time frame. Furthermore, future workers will not be onsite 8 hours per day, 250 days per year, but would spend at most two weeks per year conducting sampling under the legacy program. Workers currently engaged in remediation activities may enter the area, but they are not considered under this HHRA because they have received appropriate training and are covered under the Occupational Safety and Health Administration 1910.120 standards which requires air monitoring, employing use of personal protective equipment or other engineering controls, etc.

The receptors that are quantitatively addressed in this HHRA are:

- Future composite workers
- Future construction workers
- Current and future trespassers

5.2.3.3 Potentially Complete Exposure Pathways

A complete exposure pathway is one where chemical contaminants or radionuclides can be traced from a source to a target organ within a receptor where an adverse health effect can occur. Potential pathways were considered complete unless there was sound justification for designating them as incomplete. The potentially complete exposure pathways vary by receptor. Exposure pathways may be potentially complete, incomplete due to a missing pathway component, or potentially complete but likely insignificant.

Dermal exposure is not evaluated for ROPCs, for which external or submersion exposure in a radiation field is evaluated (EPA 2019b). For COPCs, external or submersion exposure is not evaluated, but dermal exposure is.

Some pathways may be complete but exposure cannot be quantified due to lack of data, at least for some constituents. This adds to the uncertainty, but does not infer that these pathways are either incomplete or insignificant. This can occur when critical exposure parameters are lacking for exposure modeling or risk evaluation, such as dermal permeability coefficients (Kp) or dermal absorption factors (ABSd), or toxicity values.

5.2.3.4 Receptor-Specific Exposure Parameters

The exposure parameters for the receptors identified above are summarized in Table 5-12. Receptor-specific parameters vary with the exposure assumptions for each receptor. The parameters that are applied to each receptor are discussed below.

5.2.3.4.1 Future Composite Worker

Site knowledge indicates that it is unlikely that any worker would be at the Homestake Facility full time in the future, and therefore, this is a hypothetical future scenario. This worker is conservatively modeled as present within the Homestake Facility for a full day (exposure time [ET] of 8 hours), for an exposure frequency (EF) of 250 days per year. It is more realistic to expect that workers at the facility in the future will be there on an infrequent, intermittent basis, but this receptor is protective of other future workers.

The default composite worker represents a long-term exposure duration (ED) of 25 years doing security, fence or building repairs, office or commercial work, or landscape maintenance work. This worker could breathe radon gas or particulates in air, and contact surface soils. The particulate emission factor (PEF) for both COPCs and ROPCs was based on the EPA (2019a; 2019b) calculators for Albuquerque, New Mexico (NM). The risk assessment evaluates the default worker, but actual risks to workers will be much lower. A Site-specific composite worker is one that is on-Site for 10 years full time until the property is relinquished to DOE, and another who is on-Site at most 2 weeks per year indefinitely under the DOE legacy program. The default worker spends 50,000 hours over a 25 year period, whereas the 10 year worker would be exposed 20,000 hours, and the legacy worker 2,800 hours over the working life.

The soil ingestion rate (IRS) of 100 mg/d (EPA 2019a; 2019b) applied to this receptor is a standard value for workers that may be outdoors. A skin surface area (SA) of 3,527 centimeters squared (cm^2) for workers for evaluating COPC dermal exposure to hands, forearms, and head (EPA 2019a) was applied. This is a weighted average of mean values for head, hands, and forearms for males and females of 21 or more years of age. The dermal adherence factor (AF) of 0.12 milligrams per centimeter squared (mg/cm^2 - event) applied to evaluate dermal exposure for the COPCs is the currently recommended value for commercial/industrial outdoor workers (EPA 2019a). Table 5-12 presents the exposure parameters for the future composite worker, and Table 5-13 presents chemical-specific parameters.

Table 5-12 Receptor – Specific Exposure Factors Used in the HMC Remedial Investigation HHRA

Parameter Name and Abbreviation	Units	Future Composite Worker		Future Construction Worker		Current Trespasser		Future Trespasser	
Absorption Factor, Dermal (ABSd)	unitless	CS	a	CS	a	CS	a	CS	a
Adherence Factor (AF)	mg/cm^2-d	0.12	a	0.3	a	0.12	a	0.12	a
Averaging Time, non-cancer (ATnc)	d	9125	a	365	a	3650	c	3650	c
Averaging Time, cancer (ATc)	d	25550	a	25550	a	25550	a	25550	a
Body Weight (BW)	kg	80	a,b	80	a,b	80	a,b	80	a,b
Correction Factor, mass (CF_m)	kg/mg	1×10^{-6}	a	1×10^{-6}	a	1×10^{-6}	a	1×10^{-6}	a
Correction Factor, time (CF_{time})	1 d/24 hr	0.042		0.042		0.042		0.042	
Event (EV)	event/day	1	a	1	a	1	a	1	a
Exposure Duration (ED)	y	25	a,b	1	a,b	10	c	10	c
Exposure Frequency, soil (EFs)	d/y	250	a,b	250	a,b	48	c	48	c
Exposure Frequency, water (EFw)	d/y	NA		NA		6	c	NA	
Exposure Time(ET)	h/d	4 indoor 4 outdoor	c	8	a,b	2	c	2	c
Exposure Time, water (event)	h/event	NA				0.2	c	NA	
Gamma Shielding Factor GSF	unitless	1	b	1	b	1	b	1	b
Inhalation Rate, IRA	m^3/d	60	b	60	b	20	b	20	b
Particulate Emission Factor (PEF), Albuquerque, NM	m^3/kg	6.61E+09	a	7.31E+07	a,d	6.61E+09	a	6.61E+09	a
Soil Ingestion Rate (IRSow)	mg/d	100	a,b	330	a,b	100	c	100	c
Surface Area (SA)	cm^2	3527	a,d	3527	a	3527	a	3527	a
Time of exposure (tw)	y	25	a,b	1	a,b	10	c	10	c
Water Ingestion Rate (IRW)	L/d	NA		NA		0.005	c	NA	
Water-Air Transfer Factor (Kp)	L/m^3	NA		NA		CS	a	NA	

a - EPA 2019a
b - EPA 2019b
c - Professional judgment
d –PEF from calculator for other construction activity
e - Weighted average of mean values for head, hands, and forearms (male and female, 21+years)(EPA 2019a)
CS - Chemical-specific; refer to Table 5-13
ATnc - Calculated as ED * 365 d/y
ETw - Based on assumed 12 minutes incidental contact time

Table 5-13 Chemical Specific Parameters Used in the Exposure Assessment for COPCs

Analyte	Kp	GI_{ABS}	ABSd
Arsenic, Inorganic	0.001	1	0.03
Lead Compounds	0.0001	NV	NV
Molybdenum	0.001	1	NV
Selenium	0.001	1	NV
Uranium (Soluble Salts)	0.001	1	NV
Vanadium and Compounds	0.001	0.026	NV

Source: EPA 2019a; 2004

5.2.3.4.2 Future Construction Worker

This receptor represents a short-term worker (1-year exposure duration) engaged in excavation such as pipeline or utility work. This receptor could reroute piping, put up buildings, and move equipment. This receptor is potentially exposed to surface and subsurface soil, fugitive dust from soils, and radon gas in trench or outdoor air. This receptor was modeled as short-term (1 year), 250 days per year, for 8 hours per day (refer to Table 5-12). Exposure to surface or subsurface soil is possible, and the potential for high soil contact is reflected in the value of 330 mg/d as the soil ingestion rate (EPA 2019a; 2019b).

The PEF for construction workers includes exposure to dust generated by Site construction activities including wind erosion (Other Than Standard Vehicle Traffic equations in the EPA [2019b] calculator). For this analysis, it was assumed 30 acres total, with 10 acres of tilling, 10 acres of grading, 10 acres of bulldozing, fraction of vegetative cover of 0.25, bulldozer or grading blade length of 2 m, bulldozing and grading of Site one time, to 1 m depth, and 10 m^2 for area of excavation at any given time would generate dust. A Site-specific PEF of 7.31 $x10^7$ cubic meters per kilogram (m^3/kg) was derived using these inputs for the future construction worker.

The dermal surface area contacting bulk solids of 3,527 cm^2 is a standard value for a construction worker and is based on the weighted average mean values for head, hands, and forearms (male and female), 21 years and older (EPA 2019a). This surface area assumes that a short-sleeved shirt, long pants, and shoes are worn. The dermal adherence factor that predicts soil remaining on skin for the construction worker for COPC dermal contact was obtained from EPA RSL calculator and Soil Screening Guidance (EPA 2019a; EPA 2002). Body weight is estimated to be 80 kg (EPA 2019a; 2019b). Table 5-12 presents the exposure parameters for the future construction worker.

5.2.3.4.3 Current and Future Trespasser

This receptor is assumed an older adolescent or young adult and represents an adult or older juvenile who walks or otherwise uses the Homestake Facility or LTAs for infrequent recreational purposes. This receptor was not expected to trespass in the Homestake Facility for the entire duration of local residence, only for an exposure duration of 10 years during young adulthood. The trespasser may contact surface soils or breathe fugitive dust from surface soils or radon gas in air. The PEF of $6.61x10^9$ for both COPCs and ROPCs was based on the EPA (2019a; 2019b) calculators for Albuquerque, NM.

It is unlikely that this receptor would contact subsurface soils. This receptor was modeled as currently contacting water incidentally from the evaporation ponds (i.e., an incidental ingestion rate of 5 milliliters each incidence, or 5 milliliters per day [ml/d]) although not using it as a drinking water source. This could occur if the receptor splashed in the pond(s). In the future, the evaporation ponds will be closed, and so a future trespasser would not have access to surface water in the Homestake Facility. It is assumed that this receptor, currently or in the future, would be on-Site infrequently (1 time per week, 4 weeks per month, for twelve months per year for a total exposure frequency of 48 days per year), but only contact the ponds six times per year for a period of 10 years. It is assumed that the ponds will be decommissioned after this period. There is no reason to suspect frequent contact as there are no fish in the ponds and therefore they would not present a source of interest. The soil ingestion rate of 100 mg/d for outdoor workers and residential adult (EPA 2019a; 2019b) was assumed applicable to this receptor based on presumed activity patterns. The standard skin surface area of 3,527 cm^2 for adult workers from EPA (2014c) was applied, assuming head, hands, and forearms are exposed. The dermal adherence factor for the outdoor worker for COPC exposure (EPA 2019a) was applied to the trespasser as well. Table 5-12 presents the exposure parameters for the current and future trespasser.

5.2.3.5 Site-Specific Exposure Parameters

Site-specific exposure parameters are ones that are dependent on-Site conditions or assumptions. The following Site-specific exposure parameters were incorporated into the HHRA:

- PEF (m^3/kg) – The value for Albuquerque, NM from the EPA RSL calculator of 6.61×10^9 m^3/kg was applied to the future composite worker and the current and future trespassers for COPCs and ROPCs. A value of 7.31×10^7 m^3/kg was applied to the future construction worker, which was developed with the EPA (2019a) calculator as described above.
- Gamma Shielding Factor (GSF) (unitless) – Set to the default value of 1.
- The radionuclide-specific Area Correction Factor (ACF) for the external radiation equations was conservatively based on a 0 cm soil cover and a 1,000 m^2 (infinite) slab. This is considered to represent baseline conditions.

5.2.3.6 Exposure Point Concentrations

The EPC is the concentration to which a receptor is presumed exposed for the purposes of the risk assessment. EPCs (Tables 5-9 and 5-10) are different for each medium and between exposure areas, or area where receptors are potentially exposed. Two general exposure areas were identified at the Site based on potential current and future land use and contaminant levels:

- Homestake Facility – this area includes the evaporation ponds, RO unit, and tailings piles.
- LTAs – this area includes the center pivot and flood irrigation LTAs.

Protective clothing and respiratory protection was assumed to be absent for all current and future receptors evaluated in the HHRA. For evaluating potential exposure, surface and subsurface soil data were combined for the construction worker. Evaporation pond water, radon gas in air, and sediment samples were used. The UCL95 value was used as a conservative representation of the RME EPC (EPA 1989) for each COPC in each exposure area if there were eight or more samples with six or more detected values. ProUCL Version 5.00.00 (EPA 2016) was used to calculate the UCL95. ProUCL estimates a reliable and stable UCL95 of the population mean using both the

detected and non-detected data. The UCL95 provides an RME estimate for the unknown population mean where there is 95 percent confidence that the true mean is below the UCL95. ProUCL may recommend more than one value that can be used as the UCL95 for a given data set, in which case, the maximum recommended UCL95 value that was lower than the maximum detected value was used in the risk assessment. The UCL95 recommended by ProUCL V5.0 was the primary value unless greater than the maximum detected concentration.

Small sample size or low numbers of detected values in a dataset can preclude calculation of the UCL95 statistic. If a UCL95 could not be calculated, a proxy value was applied per EPA guidance (EPA 2016) and consistent with the USEPA human health risk assessment for this site (USEPA 2014). UCL95s were used for all analytes except Pa-234m, for which there were only 4 samples. A mean was used as the EPC for this radionuclide.

The soil EPCs were presented in Table 5-9 for analytes that exceeded screening levels and so were identified as COPCs or ROPCs. Each of the COPCs and ROPCs is addressed in further detail in this risk assessment.

Air concentrations due to generation of fugitive dust were modeled from soil data by use of particulate emission factors (PEFs) and also from measured particulate data (Table 5-11). This information was used to predict risk due to inhalation exposure. No COPCs were measured in air, so this represents the only inhalation pathway for inorganics. ROPCs were measured in outdoor air, although particulate radionuclides and fugitive dusts were all below screening levels.

Rn-222 was measured in outdoor air samples from the Homestake Facility and at the fenceline, and these data were used as the basis of the EPC for the LTAs and Homestake Facility. The EPC for outdoor air was 949 pCi/m^3 based on an approximate gamma UCL95. This was considered to represent a Site-wide outdoor air radon concentration based on evaluation of the wind rose for the Site (Figures 2-1 and 2-2). Rn-222 was measured from indoor air from buildings on the Homestake Facility. Trench air data were not available. The indoor air value was a 95% Student's-t UCL of 1837 pCi/m^3 and was also considered representative of trench air, and the combined indoor and outdoor air concentrations resulted in an EPC of 1074 pCi/m^3. The combined indoor and outdoor air EPC was used to represent exposure by all commercial/industrial receptors (i.e., composite worker and construction worker).

The data sets used to develop the EPCs were presented in Table 5-1 and the EPCs are shown in Tables 5-9 and 5-10.

5.2.3.7 Fate and Transport Modeling

Fate and transport modeling was performed to provide estimates of COPC or ROPC concentrations in potential exposure media that were not sampled as part of the RI activities. These media include fugitive dust associated with surface soil emissions. Air particulate data were available which likely represent dust emissions from surface soil, but data for all of the surface soil COPCs or ROPCs were not available. Therefore, the standard PEF model in the EPA calculator was set to Albuquerque, NM, and used to predict fugitive dust from soil exposure for all surface soil ROPCs. The PEF is not chemical-specific, but is based on Site-specific conditions and assumptions such as wind speed and vegetative cover, and can be receptor specific. The construction worker generates dust by construction activities and this is reflected in the PEF for this receptor. This PEF for each receptor is reported in Table 5-12.

Volatile chemicals such as radon (Rn-222) that behave according to Henry's Law can emanate from water or soil into air, and can then be inhaled. Radon emitted from the ponds would be captured in the air samples collected from around the site.

5.2.3.8 Exposure Intake Equations

Exposure intakes are receptor-specific estimates of daily exposure made by applying the exposure parameters defined in Table 5-12 to equations for each receptor. The exposure intake is a measure of exposure expressed as the mass of a substance per unit body weight per unit time (for example, milligrams per kilogram body weight per day [mg/kg-d]) (EPA 1989). For COPCs, these equations were derived by rearranging the equations used by EPA (2019) to estimate screening levels for each medium to solve for target cancer risk or non-cancer hazard. The COPC intake equations are shown in Table 5-14 and the ROPC equations (EPA 2019b) are presented in Table 5-15. These equations demonstrate the relationship between abiotic media concentrations and predictions of exposure.

The RadPRG calculator was used to provide risk estimates by substituting receptor and Site-specific exposure parameters from Table 5-12 into the calculator.

Table 5-14 Exposure Equations for Cancer and Non-Cancer Endpoints by Receptor - COPCs

FUTURE COMPOSITE WORKER – CANCER
Surface Soil Pathways (Incidental Ingestion, Dermal Contact, Fugitive Dust)
CDIs-ing = (Cs * IRS * CFm * EF * ED) / (BW * ATc)
CDIs-derm = (Cs * SA * ABSd * AF * CFm *EV* EF * ED) / (BW * ATc)
ECs-fg[1] = (Cs * EF * ED * ET * 1 d/24 h*1000 ug/mg * 1/PEF) / (ATc)
Air Pathways (Inhalation, Submersion)
(ROPCs Only)
FUTURE COMPOSITE WORKER - NON-CANCER
Surface Soil Pathways (Incidental Ingestion, Dermal Contact, Fugitive Dust)
CDIsi-ing = (Csi * IRS * CFm * EF * ED) / (BW * ATnc)
CDIsi-derm = (Csi * SA * ABSd * AF * CFm * EV* EF * ED) / (BW * ATnc)
ECs-fg[2] = (Cs * EF * ED * ET * 1 d/24 h * 1/PEF) / (ATnc)
Air Pathways (Inhalation, Submersion)
(ROPCs Only)
FUTURE CONSTRUCTION WORKER – CANCER
Surface and Subsurface Soil Pathways (Incidental Ingestion, Dermal Contact, Fugitive Dust)
CDIs-ing = (Cs * IRS * CFm * EF * ED) / (BW * ATc)
CDIs-derm = (Cs * SA * ABSd * AF * CFm * EF * ED) / (BW * ATc)
ECs-fg[1,3] = (Cs * EF * ED * ET * 1 d/24 h*1000 ug/mg * 1/PEF) / (ATc)
Air Pathways (Inhalation, Submersion)
(ROPCs Only)
FUTURE CONSTRUCTION WORKER - NON-CANCER
Surface and Subsurface Soil Pathways (Incidental Ingestion, Dermal Contact, Fugitive Dust)
CDIs-ing = (Cs * IRS * CFm * EF * ED) / (BW * ATnc)
CDIs-derm = (Cs * SA * ABSd * AF * CFm * EF * ED) / (BW * ATnc)
ECs-fg[2,3] = (Cs * EF * ED * ET * 1 d/24 h * 1/PEF)/ (ATnc)
Air Pathways (Inhalation, Submersion)
(ROPCs Only)
CURRENT AND FUTURE TRESSPASSER – CANCER[4]
Surface Soil Pathways (Incidental Ingestion, Dermal Contact, Fugitive Dust)
CDIs-ing = (Cs * IRS * CFm * EF * ED) / (BW * ATc)
CDIs-derm = (Cs * SA * ABSd * AF * CFm * EV * EF * ED) / (BW * ATc)
ECs-fg = (Cs * EF * ED * ET * 1 d/24 h*1000 ug/mg * 1/PEF)/ (ATc)
Air Pathways (Inhalation, Submersion)
(ROPCs Only)

Table 5-14 Exposure Equations for Cancer and Non-Cancer Endpoints by Receptor – COPCs (Con't)

CURRENT AND FUTURE TRESSPASSER - NON-CANCER
Surface Soil Pathways (Incidental Ingestion, Dermal Contact, Fugitive Dust)
CDIs-ing = (Cs * IRS * CFm * EF * ED) / (BW * ATnc)
CDIs-derm = (Cs * SA * ABSd * AF * CF* EV * EF * ED) / (BW * ATnc)
ECs-fg = (Cs * EF * ED * ET * 1 d/24 h * 1/PEF)/ (ATnc)
Air Inhalation Pathway
(ROPCs Only)
CURRENT TRESSPASSER ONLY – CANCER[4]
Evaporation Pond Water Pathways (Incidental Ingestion, Dermal Contact, Inhalation of Volatiles)
CDIw-ing = (Cw * IRW * EF * ED) / (BW * ATc)
DAD = (Cw* Kp * ETw * EV * EF*ED *SA * 1L/1000 cm^3) / (BW*ATc)
ECw-inh= ROPCs Only
CURRENT TRESPASSER ONLY – NON-CANCER
Evaporation Pond Water Pathways (Incidental Ingestion, Dermal Contact, Inhalation of Volatiles)
CDIw-ing = (Cw * IRW * EF * ED) / (BW * ATnc)
DAD = Cw* Kp * ETw * EV * EF*ED *SA * 1L/1000 cm^3) / (BW*ATnc)
ECsw-inh= ROPCs Only

Notes:
1. EC in units of ug/m3 to be consistent with cancer inhalation unit risk (IUR) factor
2. EC in units of mg/m3 to be consistent with non-cancer reference concentration (RfC)
3. PEF is based on other than standard vehicular traffic, Refer to Section 5.2.3.4.2
4. Pond water exposure only pertains to current trespassers
5. Pond water exposure only pertains to current receptors

Variable Definitions and Units:
CDI*i*–chronic daily intake (mg/kg-d) for contact with medium *i*
EC–exposure concentration (cancer = $\mu g/m^3$, non-cancer = mg/m^3)
DAD–Contaminant dermally absorbed dose (mg/kg-d) (EPA 2004)
C*i* – Concentration in medium *i*

Media Abbreviations–Surface or subsurface soil
ing–Ingestion; derm–Dermal; fg–Air particulates or fugitive dust; w- Evaporation pond water

Parameter Definitions:
ABSd – Absorption factor, chemical-specific (Table 5-13)
AF –Adherence factor, receptor-specific (Table 5-12)
ATc –Averaging time, cancer, receptor-specific (Table 5-12)
ATnc –Averaging time, noncancer, receptor-specific (Table 5-12)
BW – Body weight, receptor-specific (Table 5-12)
CFm –Conversion factor for mass (Table 5-12)
GI_{ABS} – Gastrointestinal absorption, chemical-specific (Table 5-13)
ED – Exposure duration, receptor-specific (Table 5-12)
EF – Exposure frequency, receptor-specific (Table 5-12)
ET –Exposure time, receptor-specific (Table 5-12)
EV – Number of events per day, receptor-specific (Table 5-12)
IRS –Soil ingestion rate, receptor-specific (Table 5-12)
IRW – Water ingestion rate, receptor-specific (Table 5-12)
Kp – Partition coefficient, chemical-specific (Table 5-13)
PEF – Particulate emission factor, Site-specific (Table 5-12)
SA – Surface area, receptor-specific (Table 5-12)

Table 5-15 Exposure Equations for Cancer and Non-Cancer Endpoints by Receptor - ROPCs

FUTURE COMPOSITE WORKER – CANCER
Surface Soil Pathways (Incidental Ingestion, External Radiation, Inhalation of Fugitive Dust or Particulates from Soil)[1]
CEs-ing = (Cs* (1-$e^{-\lambda tw}$) * IRS * EF * ED * g/1000 mg)/ (tw * λ)
CEs-ext = (Cs* (1-$e^{-\lambda tw}$) * ACF * EF *1 yr/365 d* ED * ET *1 d/24 h *GSF)/ (tw * λ)
CEs-fg = (Cs* (1-$e^{-\lambda tw}$) * IRA * EF * ED * 1/PEF *ET *1 d/24h *1000g/kg)/ (tw * λ)
Air Inhalation Pathway (No Decay)
CEair-inh = Cair * ET * 1 d/24 h * EF * ED * IRA
CEair-ext/sub = Cair * ET * 1 d/24 h * EF * ED * 1 y/365 d * GSF
FUTURE CONSTRUCTION WORKER – CANCER[2]
Surface Soil Pathways (Incidental Ingestion, External Radiation, Inhalation of Fugitive Dust or Particulates from Soil)
CEs-ing = (Cs* (1-$e^{-\lambda tw}$) * IRS * EF * ED * g/1000 mg)/ (tw * λ)
CEs-ext = (Cs* (1-$e^{-\lambda tw}$) * ACF * EF *1 yr/365 d* ED * ET *1 d/24 h *GSF)/ (tw * λ)
CEs-fg = (Cs* (1-$e^{-\lambda tw}$) * IRA * EF * ED * 1/PEF *ET *1 d/24h *1000g/kg)/ (tw * λ)
Air Inhalation Pathway (No Decay)
CEair-inh = Cair * ET * 1 d/24 h * EF * ED * IRA
CEair-ext/sub = Cair * ET * 1 d/24 h * EF * ED * 1 y/365 d * GSF
CURRENT AND FUTURE TRESPASSER - CANCER
Surface Soil Pathways (Incidental Ingestion, External Radiation, Inhalation of Fugitive Dust)
CEs-ing = (Cs* (1-$e^{-\lambda tw}$) * IRS * EF * ED * g/1000 mg)/ (tw * λ)
CEs-ext = (Cs* (1-$e^{-\lambda tw}$) * ACF * EF *1 yr/365 d* ED * ET *1 d/24 h *GSF)/ (tw * λ)
CEs-fg = (Cs* (1-$e^{-\lambda tw}$) * IRA * EF * ED * 1/PEF *ET *1 d/24h *1000g/kg)/ (tw * λ)
Air Inhalation Pathway (No Decay)
CEair-inh = Cair * ET * 1 d/24 h * EF * ED * IRA
CEair-ext/sub = Cair * ET * 1 d/24 h * EF * ED * 1 y/365 d
CURRENT TRESPASSER ONLY- CANCER
Evaporation Pond Water[3]
CEw-ing = Cw* EF * ED * IRW
CEw-ext = Cw *1 yr/8760 h* EF * ED * EV * tevent

Table 5-15 Exposure Equations for Cancer and Non-Cancer Endpoints by Receptor - ROPCs (con't)

Notes:
1. The risk for each pathway was calculated with RadPRG Calculator using default exposure parameters to obtain screening levels (.e, RadPRGs) for the screening level analysis). The calculator results were used with Site-specific exposure parameters in the Baseline HHRA. Cancer risks were then summed to obtain total cancer risk across all pathways.
2. The RSL calculator was used with nonradioactive inorganic data and results used for each receptor. Default exposure parameters were used for SLs, and Site-specific parameters for the baseline HHRA.

Variable Definitions and Units:
CE–chronic exposure (pCi)
DAD–Contaminant dermally absorbed dose (mg/kg-d) (EPA 2004)
Ci – Concentration in medium i

Media Abbreviations:
air–Air
s–Surface or subsurface soil
ing–Ingestion
derm–Dermal
fg–Air particulates or fugitive dust
w- Evaporation pond water
ext/sub–External exposure or submersion to air
ext–External exposure to soil

Parameter Definitions:
λ–Decay constant; 0.693/half-life (EPA 2019b)
ACF – Area correction factor, isotope-specific (Table 5-16)
ED – Exposure duration, receptor-specific (Table 5-12)
EF – Exposure frequency, receptor-specific (Table 5-12)
ET –Exposure time, receptor-specific (Table 5-12)
EV – Number of events per day, receptor-specific (Table 5-12)
GSF- Gamma shielding factor (Table 5-12)
IRA –Inhalation rate, receptor-specific (Table 5-12)
IRS –Soil ingestion rate, receptor-specific (Table 5-12)
IRW – Water ingestion rate, receptor-specific (Table 5-12)
PEF – Particulate emission factor, Site-specific (Table 5-12)
tw – Time for exposure, receptor-specific (Table 5-12)
tevent –Exposure time for water, receptor-specific (Table 5-12)

5.2.4 Toxicity Assessment

The toxicity assessment presents the toxicity values for individual COPCs and ROPCs. These are used to determine if predicted exposure to COPCs and ROPCs exceeds levels associated with no adverse effects on human health. Just as cancer and non-cancer intakes are tracked separately, there are separate toxicity values for cancer and non-cancer health effects.

Inhalation and fugitive dust exposure is addressed with concentration-based toxicity values as opposed to the dose-based values applied to evaluation of bulk solid media ingestion or dermal exposure. The most current EPA toxicity values, as summarized by EPA (EPA 2019a) and the Integrated Risk Information System (IRIS) (EPA 2014c), were applied in this HHRA (refer to Table 5-13).

Uranium was evaluated as a COPC with mass concentration data, and also evaluated as a ROPC using specific activity levels as described in Section 5.2.4.3. The non-cancer effects of uranium as a COPC are addressed in Section 5.2.4.2.

The EPA/ORNL calculator evaluates risks for individual isotopes, and predicts exposure for all progeny as well along the decay chain to the last stable isotope. For Rn-222, the progeny are solids that bind to aerosols or dusts, and historically the calculator only performed decay chain calculations for Po-218 – Pb-214 – Bi-214 –Po-214, and any progeny after Po-214 were assumed to be on the ground. Pb-210 has a long half-life, and the assumption was that Pb-210, Bi-210, Po-210, Hg-206, and Tl-206 would settle to the ground. The revised calculator assesses radon daughters down the decay chain to the stable isotope Pb-206 in air, although this is not realistic. Particulate measurements were made in air at the Site, and there are no elevated risks due to particulates including all progeny modeled from parent radionuclide assuming secular equilibrium. Therefore, it was deemed reasonable to stop the evaluation of radon in air at nuclides lower than Po-214.

5.2.4.1 Carcinogenic Toxicity Values

The toxicity value used to predict the potential for carcinogenic risk for dermal and ingestion exposure to water or soils is the oral cancer slope factor (CSF). The CSF converts estimated daily intakes averaged over a lifetime of exposure to incremental risk of an individual developing cancer. The CSF is expressed in units of the inverse of milligrams chemical per kilogram body weight per day, or 1/mg/kg-d, also written as $(mg/kg\text{-}d)^{-1}$.

The inhalation unit risk (IUR) factor is used to predict carcinogenic risk for inhalation exposure for fugitive dust or vapor emissions from bulk solid media, as well as risk due to inhalation of outdoor air. The units for the IUR are the inverse of micrograms chemical per cubic meter of air, or $1/ug/m^3$, also written as $(ug/m^3)^{-1}$. The toxicity values for evaluating cancer risk for COPCs are summarized in Table 5-16.

Table 5-16 Toxicity Values for COPCs

Analyte	CSF (mg/kg-day)$^{-1}$	IUR (ug/m^3)$^{-1}$	RfD (mg/kg-day)	RfC (mg/m^3)	GI_{ABS}	ABS	RBA
Arsenic, Inorganic	1.5E+00 I,R	4.3E-03 I	3.0E-04 I	1.5E-05 C	1	0.03	0.6
Lead Compounds	NV	NV	NV	NV	1	--	--
Molybdenum	NV	NV	5.0E-03 I	NV	1	--	--
Selenium	NV	NV	5.0E-03 I	2.0E-02 C	1	--	--
Uranium (Soluble Salts)	NV	NV	2.0E-04 A	4.0E-05 A	1	--	--
Vanadium and Compounds	NV	NV	5.0E-03 G	1.0E-04 A	1	0.03	0.6

A – Agency for Toxic Substances and Disease Registry (ATSDR)
C – California EPA
G – EPA (2019a) User's Guide, Section 5, stating RfD derived from IRIS oral RfD for vanadium pentoxide by factoring out molecular weight of oxide ion.
NV - No value
I – EPA Integrated Risk Information System (IRIS)
R- Relative bioavailability factor of 0.6 is applied to arsenic solid media ingestion
ABS – Dermal absorption factor
GIABS – Gastrointestinal absorption factor
RBA – Relative bioavailability factor

5.2.4.2 Noncarcinogenic Toxicity Values

The toxicity value used to predict the potential for noncarcinogenic hazard for dermal and ingestion exposure is the oral reference dose (RfD) (refer to Table 5-16). The RfD is an estimate, with uncertainty of approximately an order of magnitude (inclusive of sensitive subgroups), that is based on the assumption that there is a threshold for noncarcinogenic responses, below which there is little risk of adverse effect(s) during the course of a lifetime (EPA 2019c). The RfD can be derived from various types of toxicity endpoints (i.e., a no observed adverse effect level (NOAEL), a lowest observed adverse effect level (LOAEL), or a benchmark concentration, to which uncertainty factors are applied to reflect limitations of the data used. The units for the RfD are milligrams chemical per kilogram body weight per day (mg/kg-d).

The reference concentration (RfC) is used to predict non-cancer hazard for inhalation exposure; the units are milligrams chemical per cubic meter of air (mg/m^3). It can be derived from a NOAEL, LOAEL, or benchmark concentration, to which uncertainty factors are applied to reflect limitations of the data used. The RfC (refer to Table 5-16) is applied to evaluate the non-cancer hazard due to inhalation exposure to suspended particulates or vapors in air.

5.2.4.3 Radionuclide Toxicity Values

Radionuclide toxicity values are based on a cancer endpoint and are referred to as slope factors (SF) to distinguish them from cancer slope factors for COPCs. ROPC slope factors differ by medium and receptor as well as by constituent. The EPA-ORNL calculator was used to obtain the radionuclide toxicity values for each receptor and medium combination. Only SFs for adults were

utilized in the risk assessment. SFs were only calculated for adult receptors because all current and future receptors at this Site are considered older adolescents or adults.

Tables 5-17, 5-18, and 5-19 provide the radionuclide SFs for each receptor and exposure route. Soil SFs are presented for inhalation, ingestion, and external contact for each receptor that is modeled as having soil contact. The exposure parameters used to assess potential risk to these receptors were reported in Table 5-12.

Table 5-17 Slope Factors for the ROPCs for Soil and Air Exposure Pathways

Composite and Construction Worker							
Isotope	**ICRP Lung Absorption Type**	**Inhalation Slope Factor (risk/pCi)**	**External Exposure Slope Factor (risk/yr per pCi/g)**	**Adult Soil Ingestion Slope Factor (risk/pCi)**	**Lambda (1/yr)**	**Half-life (yr)**	**1000 m^2 Soil Volume Area Correction Factor**
**Secular Equilibrium Risk for Bi-212*							
Bi-212	S	1.13E-10	4.96E-07	4.44E-13	6.02E+03	1.15E-04	8.05E-01
Po-212	-	0.00E+00	0.00E+00	0.00E+00	7.31E+13	9.48E-15	9.00E-01
Tl-208	-	0.00E+00	1.75E-05	0.00E+00	1.19E+05	5.81E-06	8.71E-01
**Secular Equilibrium Risk for Bi-214*							
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	5.05E+01	1.37E-02	7.28E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	4.47E+04	1.55E-05	7.49E-01
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	3.12E-02	2.22E+01	8.75E-01
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1.83E+00	3.79E-01	8.02E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	8.67E+04	7.99E-06	7.69E-01
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	2.80E+05	2.47E-06	8.23E-01
**Secular Equilibrium Risk for Cs-137*							
Ba-137m	-	0.00E+00	2.69E-06	0.00E+00	1.43E+05	4.86E-06	7.63E-01
Cs-137	S	1.12E-10	5.52E-10	3.18E-11	2.30E-02	3.02E+01	7.22E-01
**Secular Equilibrium Risk for K-40*							
K-40	S	2.22E-10	7.99E-07	1.51E-11	5.54E-10	1.25E+09	8.32E-01
**Secular Equilibrium Risk for Pa-234m*							
At-218	-	0.00E+00	2.74E-11	0.00E+00	1.46E+07	4.76E-08	9.00E-01
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	5.05E+01	1.37E-02	7.28E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	4.47E+04	1.55E-05	7.49E-01
Pa-234	S	1.20E-12	6.62E-06	9.66E-13	9.06E+02	7.65E-04	8.02E-01
Pa-234m	-	0.00E+00	9.06E-08	0.00E+00	3.11E+05	2.23E-06	8.23E-01
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	3.12E-02	2.22E+01	8.75E-01
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1.36E+04	5.10E-05	7.68E-01
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1.83E+00	3.79E-01	8.02E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1.17E+05	5.90E-06	9.00E-01
Ra-226	S	2.82E-08	2.50E-08	2.95E-10	4.33E-04	1.60E+03	6.85E-01
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	6.24E+08	1.11E-09	7.57E-01

Table 5-17 Slope Factors for the ROPCs for Soil and Air Exposure Pathways (Con't)

Composite and Construction Worker							
Isotope	**ICRP Lung Absorption Type**	**Inhalation Slope Factor (risk/pCi)**	**External Exposure Slope Factor (risk/yr per pCi/g)**	**Adult Soil Ingestion Slope Factor (risk/pCi)**	**Lambda (1/yr)**	**Half-life (yr)**	**1000 m^2 Soil Volume Area Correction Factor**
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	6.62E+01	1.05E-02	7.84E-01
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	8.67E+04	7.99E-06	7.69E-01
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	2.80E+05	2.47E-06	8.23E-01
U-234	S	2.78E-08	2.53E-10	5.11E-11	2.82E-06	2.46E+05	1.00E+00
**Secular Equilibrium Risk for Pb-212*							
Bi-212	S	1.13E-10	4.96E-07	4.44E-13	6.02E+03	1.15E-04	8.05E-01
Pb-212	S	6.29E-10	4.96E-07	1.31E-11	5.71E+02	1.21E-03	6.98E-01
Po-212	-	0.00E+00	0.00E+00	0.00E+00	7.31E+13	9.48E-15	9.00E-01
Tl-208	-	0.00E+00	1.75E-05	0.00E+00	1.19E+05	5.81E-06	8.71E-01
**Secular Equilibrium Risk for Pb-214*							
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	5.05E+01	1.37E-02	7.28E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	4.47E+04	1.55E-05	7.49E-01
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	3.12E-02	2.22E+01	8.75E-01
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1.36E+04	5.10E-05	7.68E-01
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1.83E+00	3.79E-01	8.02E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	8.67E+04	7.99E-06	7.69E-01
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	2.80E+05	2.47E-06	8.23E-01
**Secular Equilibrium Risk for Ra-223*							
Bi-211	-	0.00E+00	1.90E-07	0.00E+00	1.70E+05	4.07E-06	7.90E-01
Pb-211	S	4.03E-11	2.91E-07	2.63E-13	1.01E+04	6.87E-05	8.11E-01
Po-211	-	0.00E+00	3.76E-08	0.00E+00	4.24E+07	1.64E-08	8.02E-01
Po-215	-	0.00E+00	7.48E-10	0.00E+00	1.23E+10	5.65E-11	8.12E-01
Ra-223	S	2.92E-08	4.55E-07	1.23E-10	2.21E+01	3.13E-02	7.31E-01
Rn-219	-	0.00E+00	2.35E-07	0.00E+00	5.52E+06	1.26E-07	7.62E-01
Tl-207	-	0.00E+00	1.59E-08	0.00E+00	7.64E+04	9.08E-06	8.21E-01
**Secular Equilibrium Risk for Ra-226*							
At-218	-	0.00E+00	2.74E-11	0.00E+00	1.46E+07	4.76E-08	9.00E-01
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	5.05E+01	1.37E-02	7.28E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	4.47E+04	1.55E-05	7.49E-01
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	3.12E-02	2.22E+01	8.75E-01
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1.36E+04	5.10E-05	7.68E-01
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1.83E+00	3.79E-01	8.02E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1.17E+05	5.90E-06	9.00E-01
Ra-226	S	2.82E-08	2.50E-08	2.95E-10	4.33E-04	1.60E+03	6.85E-01
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	6.24E+08	1.11E-09	7.57E-01
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	6.62E+01	1.05E-02	7.84E-01

Table 5-17 Slope Factors for the ROPCs for Soil and Air Exposure Pathways (Con't)

Composite and Construction Worker							
Isotope	**ICRP Lung Absorption Type**	**Inhalation Slope Factor (risk/pCi)**	**External Exposure Slope Factor (risk/yr per pCi/g)**	**Adult Soil Ingestion Slope Factor (risk/pCi)**	**Lambda (1/yr)**	**Half-life (yr)**	**1000 m^2 Soil Volume Area Correction Factor**
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	8.67E+04	7.99E-06	7.69E-01
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	2.80E+05	2.47E-06	8.23E-01
**Secular Equilibrium Risk for Ra-228*							
Ac-228	S	4.92E-11	4.04E-06	8.58E-13	9.87E+02	7.02E-04	8.18E-01
Bi-212	S	1.13E-10	4.96E-07	4.44E-13	6.02E+03	1.15E-04	8.05E-01
Pb-212	S	6.29E-10	4.96E-07	1.31E-11	5.71E+02	1.21E-03	6.98E-01
Po-212	-	0.00E+00	0.00E+00	0.00E+00	7.31E+13	9.48E-15	9.00E-01
Po-216	-	0.00E+00	7.10E-11	0.00E+00	1.51E+08	4.60E-09	8.03E-01
Ra-224	S	1.13E-08	3.91E-08	8.47E-11	6.91E+01	1.00E-02	6.86E-01
Ra-228	S	4.37E-08	3.43E-11	6.70E-10	1.21E-01	5.75E+00	1.00E+00
Rn-220	-	1.15E-12	2.77E-09	0.00E+00	3.93E+05	1.76E-06	7.72E-01
Th-228	S	1.32E-07	5.64E-09	6.40E-11	3.63E-01	1.91E+00	7.95E-01
Tl-208	-	0.00E+00	1.75E-05	0.00E+00	1.19E+05	5.81E-06	8.71E-01
**Secular Equilibrium Risk for Rn-219*							
Bi-211	-	0.00E+00	1.90E-07	0.00E+00	1.70E+05	4.07E-06	7.90E-01
Pb-211	S	4.03E-11	2.91E-07	2.63E-13	1.01E+04	6.87E-05	8.11E-01
Po-211	-	0.00E+00	3.76E-08	0.00E+00	4.24E+07	1.64E-08	8.02E-01
Po-215	-	0.00E+00	7.48E-10	0.00E+00	1.23E+10	5.65E-11	8.12E-01
Rn-219	-	0.00E+00	2.35E-07	0.00E+00	5.52E+06	1.26E-07	7.62E-01
Tl-207	-	0.00E+00	1.59E-08	0.00E+00	7.64E+04	9.08E-06	8.21E-01
**Secular Equilibrium Risk for Rn-222*							
At-218	-	0.00E+00	2.74E-11	0.00E+00	1.46E+07	4.76E-08	9.00E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1.36E+04	5.10E-05	7.68E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1.17E+05	5.90E-06	9.00E-01
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	6.24E+08	1.11E-09	7.57E-01
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	6.62E+01	1.05E-02	7.84E-01
**Secular Equilibrium Risk for Th-227*							
Bi-211	-	0.00E+00	1.90E-07	0.00E+00	1.70E+05	4.07E-06	7.90E-01
Pb-211	S	4.03E-11	2.91E-07	2.63E-13	1.01E+04	6.87E-05	8.11E-01
Po-211	-	0.00E+00	3.76E-08	0.00E+00	4.24E+07	1.64E-08	8.02E-01
Po-215	-	0.00E+00	7.48E-10	0.00E+00	1.23E+10	5.65E-11	8.12E-01
Ra-223	S	2.92E-08	4.55E-07	1.23E-10	2.21E+01	3.13E-02	7.31E-01
Rn-219	-	0.00E+00	2.35E-07	0.00E+00	5.52E+06	1.26E-07	7.62E-01
Th-227	S	3.50E-08	4.45E-07	2.06E-11	1.35E+01	5.12E-02	7.25E-01
Tl-207	-	0.00E+00	1.59E-08	0.00E+00	7.64E+04	9.08E-06	8.21E-01
**Secular Equilibrium Risk for Th-228*							
Bi-212	S	1.13E-10	4.96E-07	4.44E-13	6.02E+03	1.15E-04	8.05E-01
Pb-212	S	6.29E-10	4.96E-07	1.31E-11	5.71E+02	1.21E-03	6.98E-01

Table 5-17 Slope Factors for the ROPCs for Soil and Air Exposure Pathways (Con't)

Composite and Construction Worker							
Isotope	**ICRP Lung Absorption Type**	**Inhalation Slope Factor (risk/pCi)**	**External Exposure Slope Factor (risk/yr per pCi/g)**	**Adult Soil Ingestion Slope Factor (risk/pCi)**	**Lambda (1/yr)**	**Half-life (yr)**	**1000 m^2 Soil Volume Area Correction Factor**
Po-212	-	0.00E+00	0.00E+00	0.00E+00	7.31E+13	9.48E-15	9.00E-01
Po-216	-	0.00E+00	7.10E-11	0.00E+00	1.51E+08	4.60E-09	8.03E-01
Ra-224	S	1.13E-08	3.91E-08	8.47E-11	6.91E+01	1.00E-02	6.86E-01
Rn-220	-	1.15E-12	2.77E-09	0.00E+00	3.93E+05	1.76E-06	7.72E-01
Th-228	S	1.32E-07	5.64E-09	6.40E-11	3.63E-01	1.91E+00	7.95E-01
Tl-208	-	0.00E+00	1.75E-05	0.00E+00	1.19E+05	5.81E-06	8.71E-01
**Secular Equilibrium Risk for Th-230*							
At-218	-	0.00E+00	2.74E-11	0.00E+00	1.46E+07	4.76E-08	9.00E-01
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	5.05E+01	1.37E-02	7.28E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	4.47E+04	1.55E-05	7.49E-01
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	3.12E-02	2.22E+01	8.75E-01
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1.36E+04	5.10E-05	7.68E-01
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1.83E+00	3.79E-01	8.02E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1.17E+05	5.90E-06	9.00E-01
Ra-226	S	2.82E-08	2.50E-08	2.95E-10	4.33E-04	1.60E+03	6.85E-01
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	6.24E+08	1.11E-09	7.57E-01
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	6.62E+01	1.05E-02	7.84E-01
Th-230	F	3.41E-08	8.45E-10	7.73E-11	9.19E-06	7.54E+04	9.34E-01
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	8.67E+04	7.99E-06	7.69E-01
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	2.80E+05	2.47E-06	8.23E-01
**Secular Equilibrium Risk for Th-232*							
Ac-228	S	4.92E-11	4.04E-06	8.58E-13	9.87E+02	7.02E-04	8.18E-01
Bi-212	S	1.13E-10	4.96E-07	4.44E-13	6.02E+03	1.15E-04	8.05E-01
Pb-212	S	6.29E-10	4.96E-07	1.31E-11	5.71E+02	1.21E-03	6.98E-01
Po-212	-	0.00E+00	0.00E+00	0.00E+00	7.31E+13	9.48E-15	9.00E-01
Po-216	-	0.00E+00	7.10E-11	0.00E+00	1.51E+08	4.60E-09	8.03E-01
Ra-224	S	1.13E-08	3.91E-08	8.47E-11	6.91E+01	1.00E-02	6.86E-01
Ra-228	S	4.37E-08	3.43E-11	6.70E-10	1.21E-01	5.75E+00	1.00E+00
Rn-220	-	1.15E-12	2.77E-09	0.00E+00	3.93E+05	1.76E-06	7.72E-01
Th-228	S	1.32E-07	5.64E-09	6.40E-11	3.63E-01	1.91E+00	7.95E-01
Th-232	S	4.33E-08	3.58E-10	8.47E-11	4.93E-11	1.41E+10	9.79E-01
Tl-208	-	0.00E+00	1.75E-05	0.00E+00	1.19E+05	5.81E-06	8.71E-01
**Secular Equilibrium Risk for Th-234*							
At-218	-	0.00E+00	2.74E-11	0.00E+00	1.46E+07	4.76E-08	9.00E-01
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	5.05E+01	1.37E-02	7.28E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	4.47E+04	1.55E-05	7.49E-01
Pa-234	S	1.20E-12	6.62E-06	9.66E-13	9.06E+02	7.65E-04	8.02E-01

Table 5-17 Slope Factors for the ROPCs for Soil and Air Exposure Pathways (Con't)

Composite and Construction Worker							
Isotope	**ICRP Lung Absorption Type**	**Inhalation Slope Factor (risk/pCi)**	**External Exposure Slope Factor (risk/yr per pCi/g)**	**Adult Soil Ingestion Slope Factor (risk/pCi)**	**Lambda (1/yr)**	**Half-life (yr)**	**1000 m^2 Soil Volume Area Correction Factor**
Pa-234m	-	0.00E+00	9.06E-08	0.00E+00	3.11E+05	2.23E-06	8.23E-01
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	3.12E-02	2.22E+01	8.75E-01
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1.36E+04	5.10E-05	7.68E-01
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1.83E+00	3.79E-01	8.02E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1.17E+05	5.90E-06	9.00E-01
Ra-226	S	2.82E-08	2.50E-08	2.95E-10	4.33E-04	1.60E+03	6.85E-01
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	6.24E+08	1.11E-09	7.57E-01
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	6.62E+01	1.05E-02	7.84E-01
Th-230	F	3.41E-08	8.45E-10	7.73E-11	9.19E-06	7.54E+04	9.34E-01
Th-234	S	3.08E-11	1.77E-08	9.51E-12	1.05E+01	6.60E-02	7.64E-01
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	8.67E+04	7.99E-06	7.69E-01
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	2.80E+05	2.47E-06	8.23E-01
U-234	S	2.78E-08	2.53E-10	5.11E-11	2.82E-06	2.46E+05	1.00E+00
**Secular Equilibrium Risk for Tl-208*							
Tl-208	-	0.00E+00	1.75E-05	0.00E+00	1.19E+05	5.81E-06	8.71E-01
**Secular Equilibrium Risk for U-234*							
At-218	-	0.00E+00	2.74E-11	0.00E+00	1.46E+07	4.76E-08	9.00E-01
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	5.05E+01	1.37E-02	7.28E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	4.47E+04	1.55E-05	7.49E-01
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	3.12E-02	2.22E+01	8.75E-01
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1.36E+04	5.10E-05	7.68E-01
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1.83E+00	3.79E-01	8.02E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1.17E+05	5.90E-06	9.00E-01
Ra-226	S	2.82E-08	2.50E-08	2.95E-10	4.33E-04	1.60E+03	6.85E-01
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	6.24E+08	1.11E-09	7.57E-01
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	6.62E+01	1.05E-02	7.84E-01
Th-230	F	3.41E-08	8.45E-10	7.73E-11	9.19E-06	7.54E+04	9.34E-01
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	8.67E+04	7.99E-06	7.69E-01
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	2.80E+05	2.47E-06	8.23E-01
U-234	S	2.78E-08	2.53E-10	5.11E-11	2.82E-06	2.46E+05	1.00E+00
**Secular Equilibrium Risk for U-235*							
Ac-227	S	1.49E-07	1.98E-10	2.01E-10	3.18E-02	2.18E+01	9.60E-01
At-219	-	0.00E+00	0.00E+00	0.00E+00	3.90E+05	1.78E-06	9.00E-01
Bi-211	-	0.00E+00	1.90E-07	0.00E+00	1.70E+05	4.07E-06	7.90E-01
Bi-215	-	0.00E+00	1.08E-06	0.00E+00	4.79E+04	1.45E-05	7.74E-01
Fr-223	S	4.07E-11	1.35E-07	4.88E-12	1.66E+04	4.19E-05	7.64E-01
Pa-231	F	7.62E-08	1.27E-07	1.54E-10	2.12E-05	3.28E+04	7.85E-01

Table 5-17 Slope Factors for the ROPCs for Soil and Air Exposure Pathways (Con't)

Composite and Construction Worker							
Isotope	**ICRP Lung Absorption Type**	**Inhalation Slope Factor (risk/pCi)**	**External Exposure Slope Factor (risk/yr per pCi/g)**	**Adult Soil Ingestion Slope Factor (risk/pCi)**	**Lambda (1/yr)**	**Half-life (yr)**	**1000 m^2 Soil Volume Area Correction Factor**
Pb-211	S	4.03E-11	2.91E-07	2.63E-13	1.01E+04	6.87E-05	8.11E-01
Po-211	-	0.00E+00	3.76E-08	0.00E+00	4.24E+07	1.64E-08	8.02E-01
Po-215	-	0.00E+00	7.48E-10	0.00E+00	1.23E+10	5.65E-11	8.12E-01
Ra-223	S	2.92E-08	4.55E-07	1.23E-10	2.21E+01	3.13E-02	7.31E-01
Rn-219	-	0.00E+00	2.35E-07	0.00E+00	5.52E+06	1.26E-07	7.62E-01
Th-227	S	3.50E-08	4.45E-07	2.06E-11	1.35E+01	5.12E-02	7.25E-01
Th-231	S	1.50E-12	2.49E-08	9.07E-13	2.38E+02	2.91E-03	8.49E-01
Tl-207	-	0.00E+00	1.59E-08	0.00E+00	7.64E+04	9.08E-06	8.21E-01
U-235	S	2.50E-08	5.51E-07	4.92E-11	9.84E-10	7.04E+08	6.88E-01
**Secular Equilibrium Risk for U-238*							
At-218	-	0.00E+00	2.74E-11	0.00E+00	1.46E+07	4.76E-08	9.00E-01
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	5.05E+01	1.37E-02	7.28E-01
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1.83E+04	3.79E-05	8.27E-01
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	4.47E+04	1.55E-05	7.49E-01
Pa-234	S	1.20E-12	6.62E-06	9.66E-13	9.06E+02	7.65E-04	8.02E-01
Pa-234m	-	0.00E+00	9.06E-08	0.00E+00	3.11E+05	2.23E-06	8.23E-01
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	3.12E-02	2.22E+01	8.75E-01
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1.36E+04	5.10E-05	7.68E-01
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1.83E+00	3.79E-01	8.02E-01
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1.33E+11	5.21E-12	8.02E-01
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1.17E+05	5.90E-06	9.00E-01
Ra-226	S	2.82E-08	2.50E-08	2.95E-10	4.33E-04	1.60E+03	6.85E-01
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	6.24E+08	1.11E-09	7.57E-01
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	6.62E+01	1.05E-02	7.84E-01
Th-230	F	3.41E-08	8.45E-10	7.73E-11	9.19E-06	7.54E+04	9.34E-01
Th-234	S	3.08E-11	1.77E-08	9.51E-12	1.05E+01	6.60E-02	7.64E-01
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	8.67E+04	7.99E-06	7.69E-01
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	2.80E+05	2.47E-06	8.23E-01
U-234	S	2.78E-08	2.53E-10	5.11E-11	2.82E-06	2.46E+05	1.00E+00
U-238	S	2.36E-08	1.24E-10	4.66E-11	1.55E-10	4.47E+09	1.00E+00

Notes:
ICRP - International Commission on Radiological Protection
pCi - pico Curies
yr - year
g - gram
m2 – meters squared

Table 5-18 Air Slope Factors (SFs) for Composite Worker, Construction Worker, and Trespasser for ROPCs in Radon Decay Chain

Isotope	Inhalation Slope Factor (risk/pCi)	Submersion External Exposure Slope Factor (risk/yr per pCi/m^3)
At-218	0.00E+00	3.08E-14
Bi-210	4.55E-10	5.29E-12
Bi-214	6.18E-11	6.69E-09
Pb-214	7.77E-11	1.02E-09
Po-214	0.00E+00	3.57E-13
Po-218	1.39E-11	3.95E-17
Rn-218	0.00E+00	3.19E-12
Rn-222	2.28E-12	1.62E-12

Source: EPA 2019b. Composite_rprg_table_run_pCi_25NOV14.xlsx

Table 5-19 Water Slope Factors (SFs) for the Trespasser for ROPCs

Isotope	Water Ingestion Slope Factor (risk/pCi)	Immersion Slope Factor (risk/yr per pCi/L)
**Secular Equilibrium Risk for Ra-226*	-	-
At-218	0.00E+00	5.13E-17
Bi-210	8.92E-12	7.82E-15
Bi-214	1.92E-13	1.45E-11
Hg-206	0.00E+00	1.08E-12
Pb-210	8.84E-10	9.08E-15
Pb-214	3.44E-13	2.23E-12
Po-210	1.78E-09	9.07E-17
Po-214	0.00E+00	7.74E-16
Po-218	0.00E+00	5.06E-20
Ra-226	3.85E-10	6.27E-14
Rn-218	0.00E+00	6.92E-15
Rn-222	0.00E+00	3.51E-15
Tl-206	0.00E+00	1.47E-14
Tl-210	0.00E+00	2.69E-11
**Secular Equilibrium Risk for Ra-228*	-	-
Ac-228	1.88E-12	8.15E-12
Bi-212	7.18E-13	9.91E-13
Pb-212	2.52E-11	1.23E-12
Po-212	0.00E+00	0.00E+00
Po-216	0.00E+00	1.42E-16
Ra-224	1.67E-10	9.12E-14
Ra-228	1.04E-09	5.02E-16
Rn-220	0.00E+00	5.71E-15
Th-228	1.08E-10	1.66E-14
Tl-208	0.00E+00	3.46E-11
**Secular Equilibrium Risk for Th-230*	-	-
At-218	0.00E+00	5.13E-17
Bi-210	8.92E-12	7.82E-15
Bi-214	1.92E-13	1.45E-11
Hg-206	0.00E+00	1.08E-12
Pb-210	8.84E-10	9.08E-15
Pb-214	3.44E-13	2.23E-12
Po-210	1.78E-09	9.07E-17
Po-214	0.00E+00	7.74E-16
Po-218	0.00E+00	5.06E-20
Ra-226	3.85E-10	6.27E-14
Rn-218	0.00E+00	6.92E-15
Rn-222	0.00E+00	3.51E-15
Th-230	9.14E-11	3.01E-15
Tl-206	0.00E+00	1.47E-14
Tl-210	0.00E+00	2.69E-11

Source: EPA 2019b. EPA 2019b. Output generated 22AUG2019:19:30:14

Slope factors for water exposures (refer to Table 5-19) were obtained from the recreational receptor for exposure to tap water in the EPA-ORNL calculator (EPA 2019b). The Site-specific exposure parameters in Table 5-12 were used in the calculator in lieu of standard residential values to

represent the Site-specific current and future trespasser receptor and generate trespasser-specific radionuclide SFs and risk model outputs.

5.2.4.4 Derivation of Toxicity Values for the Dermal Exposure Pathway

Oral toxicity factors are applied to evaluate risk for the ingestion pathways, and dermal toxicity factors derived from the oral values are applied to estimate risk due to the dermal exposure pathways. Oral toxicity factors represent an administered or external dose, whereas dermal toxicity is typically due to the fraction of the dose that is absorbed (that is, molecules of contaminant crossing the skin to circulate in the bloodstream). The dermal exposure intake equations convert the concentration applied to the skin (that is, the concentration of chemical in soil in mg/kg) into an absorbed or internal dose, or the concentration of chemical at the target organ normalized to body weight (mg/kg-d). The toxicity values require a similar conversion from applied or administered to an absorbed basis. When gastrointestinal absorption of a compound in the critical study from which the toxicity value (that is, RfD or CSF) was derived is high (that is, 100 percent), the absorbed dose is equivalent to the administered dose, that is, the dose at the target organ that triggers the response is the same as that provided to the receptor. Therefore, no adjustment of the toxicity values is necessary.

For chemicals for which gastrointestinal absorption is low (that is, less than 50 percent), the absorbed dose is much smaller than the administered dose, and the chemical is more toxic in effect than what it would appear from the administered dose. For example, the absorption of a chemical is 10 percent, toxic effects are not due to an administered dose of 10 mg/kd-d but to this absorbed fraction of 1 mg/kg-d. An adjustment is made with the gastrointestinal absorption factor (GI_{ABS}) to the toxicity values to account for the difference in the absorbed dose relative to the administered dose (EPA 2004). Vanadium is the only COPC that is adjusted for dermal exposure, but while it is a COPC in water it is not a COPC in soils and therefore the gastrointestinal absorption factor dermal adjustment is not applied.

A higher CSF is indicative of higher carcinogenic potential, and the GI_{ABS} adjusts the slope factor accordingly. The GI_{ABS} value converts the oral slope factors to dermal slope factors by factoring out the proportion that is not absorbed into blood. These adjustments only apply to the dermal exposure pathways. For the derivation of the cancer slope factor for an absorbed dose (CSF_{ABS}) from the oral administered dose (CSF), the following equation was used:

$$CSF_{ABS} = \frac{CSF}{GI_{ABS}}$$

Where:

CSF_{ABS} -Absorbed cancer slope factor; chemical-specific, inverse of milligram per kilogram per body weight per day $(mg/kg\text{-}d)^{-1}$

CSF - Oral cancer slope factor; chemical-specific $(mg/kg\text{-}d)^{-1}$

GI_{ABS} - Gastrointestinal absorption factor; the fraction of contaminant absorbed in the gastrointestinal tract in the critical toxicity study (dimensionless); chemical-specific

A lower RfD is indicative of greater toxicity, and GI_{ABS} adjusts the oral RfD accordingly. For the derivation of the absorbed reference dose (RfD_{ABS}) from the orally administered RfD, the following equation was used:

$$RfD_{ABS} = RfD \times GI_{ABS}$$

Where:

RfD_{ABS} - Oral reference dose absorbed; chemical-specific (mg/kg-d)

RfD - Oral reference dose; chemical-specific (mg/kg-d)

GI_{ABS} - Fraction of contaminant absorbed in the gastrointestinal tract in the critical toxicity study (dimensionless); chemical-specific

If a value is lacking, EPA recommends assuming that absorption is 100 percent (that is, a value of 1 is used for GI_{ABS}) (EPA 2004). The adjustment factors for the COPCs are shown in Table 5-16.

5.2.5 Risk Characterization

Risk characterization is the step in the risk assessment process where the toxicity data are combined with the exposure intakes in order to produce estimates of potential cancer and non-cancer health effects (EPA 1989). Toxicity values (Section 5.2.4) are compared to the estimated intakes ECs, or CEs (Section 5.2.3.7) for each receptor in the baseline risk assessment. Uncertainty is described, and background conditions are addressed in the risk estimates. Cumulative cancer risks and non-cancer hazard indices (HIs) are also estimated. The risk characterization process is explained in detail below.

5.2.5.1 Risk Estimation

Risk estimation is the process of developing quantitative or numeric cancer and non-cancer risk estimates. A cancer risk was estimated for each receptor and media combination to reflect the contribution made by each complete exposure pathway. The cancer risk management range is considered to be 1×10^{-6} to 1×10^{-4}, or 1 in 1,000,000 to 1 in 10,000 excess cancers per exposed people (EPA 1989). COPCs or ROPCs that produce cancer risks that fall within or below this range may be acceptable under EPA guidelines, with no further evaluation or risk management typically required. COPCs or ROPCs that produce excess cancer risks above the upper bound of 1×10^{-4} are considered a COC for further evaluation or risk management, and require further evaluation or other action.

A non-cancer hazard is also estimated for each receptor and media combination to reflect the contribution made by each complete exposure pathway, but the target value is always 1 or less. If the HQ for a COPC is greater than 1, the COPC becomes a COC and must undergo further evaluation or risk management.

5.2.5.1.1 ROPC Cancer Risk Estimation

Cancer risks are related to intakes and toxicity values as follows for each ROPC, by receptor, for each exposure area:

Cancer Risk (CR) = Chronic Radiation Exposure (CDI) x SFi

Where:

Cancer risk (CR) – the probability of contracting cancer due to exposure to ROPCs over the course of a 70-year lifetime (unitless)

Radiation Exposure– the daily dose or exposure *i* (CDI) based on the assumptions used in the exposure model averaged over 70 years (pCi),

SFi– the radionuclide slope factor for radionuclide *i* (risk/pCi)

5.2.5.1.2 COPC Cancer Risk Estimation

Cancer risks due to chemical exposure are related to intakes and toxicity values as follows for each COPC, by receptor, for each exposure area:

Cancer Risk (CR) = Chronic Daily Cancer Intake (CDI) x CSFi

Where:

Cancer risk (CR) – the probability of contracting cancer over the course of a 70-year lifetime (unitless)

Cancer Intake– the daily dose or exposure intake (CDI) based on the assumptions used in the exposure model (mg/kg-d), averaged over 70 years

CSFi– the oral or dermal cancer slope factor for chemical *i (*mg/kg-d)$^{-1}$

For inhalation exposures, cancer risk was estimated as follows:

Cancer Risk (CR) = Chronic Cancer Air Concentration (ECair) x IURi

Where:

Cancer risk (CR) – the probability of contracting cancer over the course of a 70-year lifetime (unitless)

ECair– the air EPC (mg/m^3) weighted by receptor-specific exposure parameters (Table 5-11)

IURi– the inhalation unit risk factor for chemical *i (*mg/m^3)$^{-1}$

The cancer risks for each COPC in each pathway were summed to obtain a total pathway risk. Cumulative cancer risks for each receptor were then estimated by summing risks across multiple chemicals and pathways to derive the total cancer risks for receptors of interest. Care must be taken to avoid double counting exposure when combining exposure pathway risk estimates.

- A receptor with both surface soil and subsurface soil exposure would have doubled exposure if risks were directly summed for each media separately. Therefore, both soil media were combined and analyzed as one medium. For most constituents there was not a great difference in concentration between surface and subsurface media. The UCL95 was based on the combined dataset and therefore there is not expected to be an underestimate of risk.
- The composite worker was modeled with both indoor and outdoor air exposures and would have double exposure if both were counted at 8 hours per day, resulting in a 16-hour daily exposure. The EPA/ORNL calculator addresses this type of exposure without designating indoor or outdoor. Therefore, the indoor and outdoor air data were combined for one EPC for radon.
- The construction worker can be exposed to both outdoor and trench air. This receptor would have double exposure if both media were counted at 8 hours per day, resulting in a 16-hour

daily exposure. Indoor air was considered appropriate to predict exposure in a trench. Therefore, the indoor and outdoor air data were combined for one EPC for radon.

Given the uncertainty in the risk estimates, cancer risks are considered accurate to only one significant figure (EPA 1989). This means that a cancer risk value between 0.5 $x10^{-6}$ and 1.49 $x10^{-6}$ cannot be mathematically distinguished from $1x10^{-6}$, and any values between 1.5 $x10^{-6}$ to 2.49 $x10^{-6}$ are not distinguishable from the number 2 $x10^{-6}$.

5.2.5.1.3 COPC Non-Cancer Hazard

Non-cancer hazards for COPCs are not probabilities and the magnitude of the hazard quotient (HQ) cannot be used to state the likelihood of occurrence of adverse effects or be used to predict the severity of effects with any accuracy. The HQ is simply an indicator of whether the estimated daily dose exceeds a dose predicted to be reasonably safe or not. Generally, the higher the HQ, the greater is the level of concern (EPA 1989). The HQ is estimated as follows:

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

Where:

HQ– The ratio of a single substance exposure intake over a specified time period (e.g., chronic or subchronic) to a reference dose for that substance derived from a similar exposure period (unitless)

Non-cancer Intake – The daily non-cancer exposure intake based on the assumptions used in the exposure model (mg/kg-d)

RfD– The oral or dermal reference dose (mg/kg-d)

For inhalation exposures, noncancer hazard was estimated as follows:

Noncancer Hazard Quotient (HQ) = Chronic Noncancer Air Concentration (ECair) / RfC

Where:

HQ – indicator that exposure exceeds the expected acceptable level. HQs greater than one require further evaluation or risk management (unitless)

ECair– the air EPC (mg/m3) weighted by receptor-specific exposure parameters (Table 5-10)

RfC – the inhalation reference concentration for chemical i (mg/m3)

The non-cancer HQs for each pathway was summed to obtain a Total HQ for each COPC. Total non-cancer hazards across multiple chemicals are estimated for noncarcinogens by summing the Total HQs to obtain a Hazard Index (EPA 1989).

Where HQs for any individual COPC exceed 1, the Site should proceed forward into further evaluation or risk management. If the HQs are less than 1, the COPC may be dropped from further evaluation. Where the HI is above 1 but the HQs are not, the mechanisms of toxic action may be evaluated to determine if the toxic effects would be less than additive. This could occur if the mechanism of toxic action for each analyte occurred on different target organs.

Given the uncertainty in the risk estimates, HQs are considered accurate to only one significant figure (EPA 1989). This means that a HQ between 0.5 and 1.49 cannot be mathematically

distinguished from 1, and any values between 1.5 and 2.49 are not mathematically distinguishable from the number 2.

5.2.5.1.4 Comparison to Background

Soil

The soil data for the site were compared to surface soil background data for COPCs and ROPCs. The Wilcoxon-Mann-Whitney Test in ProUCL (EPA 2015) was used to test the hypothesis that the site mean or median was less than background. Gehan's test was used when there were multiple detection limits to verify the results. Table 5-20 presents this comparison for the Homestake Facility, and Table 5-21 presents the comparison for the LTAs.

The ROPCs Cs-137, K-40, Pb-212, Th-227, Th-228, Th-232, and U-235 soil concentrations were statistically similar to or less than background soil for the Homestake Facility; the remaining ROPCs were statistically higher than background (Table 5-20).

The ROPCs at the LTAs were statistically equal to or below background with the exception of Th-232, U-234, and U-238 (Table 5-21). Maximum acitivities of Th-232, U-234, and U-238 exceeded screening levels as well.

The maximum concentrations of the COPCs molybdenum, selenium, and vanadium were below screening levels at the Homestake Facility. Only arsenic both exceeded screening levels and exceeded background. Molybdenum is statistically significantly elevated at a 5% significance level at both the Homestake Facility and the LTAs. There was one outlier of 126 mg/kg in the Homestake Facility dataset; this outlier was nearly 5 times higher than the next highest value of 26 mg/kg.

The COPCs arsenic, molybdenum, lead, and vanadium were statistically less than background at the LTAs. Only selenium exceeded background, and this analyte was below screening levels.

Air

EPA prefers the use of HMC-16 as a background location for radon in air. HMC has disagreed with this because HMC-16 is elevated out of the valley and would not be expected to have concentrations as high as those found in an area of topographic similarity as the Site. EPA considers that HMC-1OFF is located too close to the LTP to provide an accurate estimate of background.

Radon concentrations from air data collected at HMC-16 were used to calculate a BTV similar to the statistic used for the EPCs for addressing exposure. HMC-16 is the NRC approved air monitoring location for background at the Homestake Facility.

Using data collected from HMC-16, a UCL95 for outdoor air was estimated as 551 pCi/m^3 for Rn-222 based on data collected from 2014 to 2019 (Table 5-22). The background UCL is lower than the UCL95 radon concentrations calculated from data collected for the Homestake Facility which is 949 pCi/m^3 for outdoor air.

Table 5-20 Background and Homestake Facility Soil Comparisons

Analyte	Homestake Facility Soil Detection Frequency	Homestake Facility UCL95	Homestake Facility UCL95 Basis	Background Surface Soil Detection Frequency	Background UCL95	Wilcoxon-Mann-Whitney Test	Conclusion	Retain COPC or ROPC?
Inorganics, mg/kg								
Arsenic	26/26	6.328	95% Student's-t	12/12	5.01	$p < 0.05$	>BKG	Y, RR>1
Molybdenum	33/43	36.53	99% KM (Chebyshev) UCL	12/12	0.447	$p < 0.05$	>BKG	N, RR<1*
Lead	26/26	15.53	95% Student's-t UCL	12/12	11.94	$p < 0.05$	>BKG	N,RR<1
Selenium	30/43	3.869	99% KM (Chebyshev) UCL	12/12	0.799	$p \geq 0.05$	<=BKG	N, RR<1,<BKG*
Uranium (total)	24/24	15.53	95% Adjusted Gamma UCL	No Data	1.69 (mean of U-234 and U-238)	$p < 0.05$	>BKG	Y, RR>1
Vanadium	26/26	39.47	95% Student's-t UCL	12/12	29.87	$p < 0.05$	>BKG	N,RR<1
Radionuclides, pCi/g								
Ba-140	0/27	--	NA - All ND	0/13	NA	NA	NA	N, All ND
Bi-212	26/26	1.498	95% Student's-t UCL	12/12	1.195	$p < 0.05$	>BKG	Y, RR>1
Bi-214	26/26	2.333	95% Adjusted Gamma UCL	12/12	0.948	$p < 0.05$	>BKG	Y, RR>1
Co-60	0/27	--	NA - All ND	0/12	NA	NA	NA	N, All ND
Cs-137	19/27	0.0672	95% KM (t) UCL	12/12	0.0731	$p \geq 0.05$	<=BKG	Y, RR>1
I-131	0/27	--	NA- All ND	0/12	NA	NA	NA	N, All ND
K-40	26/26	18.1	95% Student's-t UCL	12/12	18.35	$p \geq 0.05$	<=BKG	Y, RR>1
Pa-234m	25/25	4.603	95% Adjusted Gamma UCL	4/4	1.515	$p < 0.05$	>BKG	Y, RR>1
Pb-212	26/26	1.348	95% Student's-t UCL	12/12	1.104	$p < 0.05$	>BKG	Y, RR>1

Table 5-20 Surface Soil Background and Homestake Facility Soil Comparisons (Con't)

Analyte	Homestake Facility Soil Detection Frequency	Homestake Facility UCL95	Homestake Facility UCL95 Basis	Background Surface Soil Detection Frequency	Background UCL95	Wilcoxon -Mann-Whitney Test	Conclusion	Retain COPC or ROPC?
Pb-214	26/26	2.468	95% Adjusted Gamma UCL	12/12	1.017	$p < 0.05$	>BKG	Y, RR>1
Ra-223	20/20	0.414	95% Student's-t UCL	9/9	0.296	$p < 0.05$	>BKG	Y, RR>1
Ra-226	50/50	4.348	95% Adjusted Gamma UCL	12/12	1.81	$p < 0.05$	>BKG	Y, RR>1
Ra-228	26/26	1.422	95% Student's-t UCL	12/12	1.14	$p < 0.05$	>BKG	Y, RR>1
Rn-219	NA – Not an ROPC							N, HQ≤1
Th-227	8/8	0.174	95% Student's-t UCL	5/5	0.13	$p \geq 0.05$	<=BKG	Y, RR>1
Th-228	26/26	1.604	95% Student's-t UCL	5/5	1.412	$p \geq 0.05$	<=BKG	Y, RR>1
Th-230	50/50	2.607	95% KM Approximate Gamma UCL	5/5	1.393	$p < 0.05$	>BKG	Y, RR>1
Th-232	26/26	1.372	95% Student's-t UCL	5/5	1.135	$p \geq 0.05$	<=BKG	Y, RR>1
Th-234	20/20	3.26	95% Adjusted Gamma UCL	9/90	0.703	$p < 0.05$	>BKG	Y, RR>1
Tl-208	26/26	0.434	95% Student's-t UCL	12/12	0.357	$p < 0.05$	>BKG	Y, RR>1
U natural (pCi/g)	24/24	11.29	95% H-UCL	No Data; use mean of U-234 and U-238	1.14	$p < 0.05$	>BKG	Y, RR>1
U-234	26/26	4.287	95% Adjusted Gamma UCL	5/5	1.141	$p < 0.05$	>BKG	Y, RR>1

Table 5-20 Surface Soil Background and Homestake Facility Soil Comparisons (Con't)

Analyte	Homestake Facility Soil Detection Frequency	Homestake Facility UCL95	Homestake Facility UCL95 Basis	Background Surface Soil Detection Frequency	Background UCL95	Wilcoxon -Mann-Whitney Test	Conclusion	Retain COPC or ROPC?
U-235	26/26	0.307	95% Adjusted Gamma UCL	11/12	0.112	$p \geq 0.05$	<=BKG	Y, RR>1
U-238	26/26	4.323	95% H-UCL	5/5	1.147	$p < 0.05$	>BKG	Y, RR>1

Notes:
BKG – Background
HHRA = human health risk assessment
KM = Kaplan Meier
mg/kg = milligram per kilogram
n = number of samples
N = no
NA = not available or not applicable
pCi/g = picoCurie per gram
RR = maximum divided by screening level is termed the risk ratio
Sd = standard deviation
UCL95 = 95th percentile upper confidence limit on the arithmetic mean
Y = yes
U-total background estimated from the mean of U-234 and U-238 multiplied by 1.48 (USDOE 2011) to convert activity to concentration
Background Data Source EPA 2014a

Table 5-21 Surface Soil Background and Land Treatment Areas Soil Comparisons for the RI HHRA

Analyte	LTAs Soil Detection Frequency	LTAs UCL95	LTAs UCL95 Basis	Background Surface Soil Detection Frequency	Background UCL95	Wilcoxon -Mann-Whitney Test	Conclusion	Retain as COPC or ROPC?
Inorganics, mg/kg								
Arsenic	18/18	4.693	95% Adjusted Gamma UCL	12/12	5.01	p > 0.05	LTAs<=BKG	Y, RR>1
Molybdenum	39/49	2.452	99% KM (Chebyshev) UCL	12/12	0.447	p ≥ 0.05	LTAs<=BKG	N, RR<1, <BKG*
Lead	18/18	13.4	95% Chebyshev (Mean, Sd) UCL	12/12	11.94	p ≥ 0.05	LTAs<=BKG	N,RR<1, <BKG
Selenium	134/150	0.975	99% KM (Chebyshev) UCL	12/12	0.799	p < 0.05	LTAs > BKG	N,RR<1*
Uranium (total)	133/134	4.329	99% KM (Chebyshev) UCL	No Data	No Data	p ≥ 0.05	LTAs<=BKG	N, RR<1, <BKG
Vanadium	18/18	25.15	95% H-UCL	12/12	29.87	p ≥ 0.05	LTAs<=BKG	N,RR<1, <BKG
Radionuclides, pCi/g								
Ba-140	0/20	--	NA- All ND	0/13	NA – all ND	NA	NA	N, All ND
Bi-212	20/20	1.015	95% Student's-t UCL	13/13	1.195	p ≥ 0.05	LTAs<=BKG	Y, RR>1
Bi-214	20/20	0.87	95% Modified-t UCL	13/13	0.948	p ≥ 0.05	LTAs<=BKG	Y, RR>1
Co-60	0/20	--	NA-All ND	0/13	NA	NA	NA	N, All ND
Cs-137	20/20	0.0711	95% Student's-t UCL	13/13	0.0731	p ≥ 0.05	LTAs<=BKG	Y, RR>1
I-131	0/20	--	NA-All ND	0/13	NA	NA	NA	N, All ND
K-40	20/20	15.92	95% Student's-t UCL	13/13	18.35	p ≥ 0.05	LTAs<=BKG	Y, RR>1
Pa-234m	13/13	1.844	95% Adjusted Gamma UCL	4/4	1.515	p ≥ 0.05	LTAs<=BKG	Y, RR>1
Pb-212	20/20	0.935	95% Student's-t UCL	13/13	1.104	p ≥ 0.05	LTAs<=BKG	Y, RR>1

Table 5-21 Surface Soil Background and Land Treatment Areas Soil Comparisons for the RI HHRA (Con't)

Analyte	LTAs Soil Detection Frequency	LTAs UCL95	LTAs UCL95 Basis	Background Surface Soil Detection Frequency	Background UCL95	Wilcoxon-Mann-Whitney Test	Conclusion	Retain as COPC or ROPC?
Pb-214	20/20	0.938	95% Student's-t UCL	13/13	1.017	$p \geq 0.05$	LTAs<=BKG	Y, RR>1
Ra-223	16/16	0.244	95% Modified-t UCL	10/10	0.296	$p \geq 0.05$	LTAs<=BKG	Y, RR>1
Ra-226	224/224	1.325	95% Chebyshev (Mean, Sd) UCL	13/13	1.81	$p \geq 0.05$	LTAs<=BKG	Y, RR>1
Ra-228	20/20	0.978	95% Student's-t UCL	13/13	1.14	$p \geq 0.05$	LTAs<=BKG	Y, RR>1
Rn-219	No Data	NA						
Th-227	1/1	0.087	Maximum	5/5	0.13	NA	NA	N, RR<1
Th-228	6/6	1.763	95% Student's-t UCL	5/5	1.412	$p \geq 0.05$	LTAs<=BKG	Y, RR>1
Th-230	65/109	1.032	95% KM (t) UCL	5/5	1.393	$p \geq 0.05$	LTAs<=BKG	Y, RR>1
Th-232	6/6	1.74	95% Student's-t UCL	5/5	1.135	$p < 0.05$	LTAs > BKG	Y, RR>1
Th-234	14/14	0.892	95% Adjusted Gamma UCL	10/10	0.703	$p \geq 0.05$	LTAs<=BKG	Y, RR>1
Tl-208	20/20	0.294	95% Student's-t UCL	13/13	0.357	$p \geq 0.05$	LTAs<=BKG	Y, RR>1
U natural (pCi/g)	No Data	2.22	Mean of U-234 and U-238 UCLs	No Data – Mean of U-234 and U-238	1.1	$p < 0.05$	LTAs > BKG	Y, RR>1
U-234	6/6	2.23	95% Student's-t UCL	5/5	1.141	$p < 0.05$	LTAs>BKG	Y, RR>1
U-235	15/15	0.131	95% Student's-t UCL	17/18	0.112	$p \geq 0.05$	LTAs <= BKG	Y, RR>1
U-238	6/6	2.21	95% Student's-t UCL	5/5	1.147	$p < 0.05$	LTAs > BKG	Y, RR>1

Table 5-21 Surface Soil Background and Land Treatment Areas Soil Comparisons for the RI HHRA (Con't)

Notes:
*Indicates the COPC retained at request of EPA
Detection frequency is shown as the number of detections divided by the number of samples for the analyte
BKG - Background
RR – Risk ratio of maximum to screening level
KM = Kaplan Meier
LTA = land treatment area
mg/kg = milligram per kilogram
n = number of samples
N = no
pCi/g = picocurie per gram
Sd = standard deviation
UCL95 = 95th percentile upper confidence limit on the arithmetic mean
UPL = upper prediction limit
Y = yes
Background Data Source: EPA 2014a

Table 5-22. UCL95 Values for Radon in Air Background Compared to Site Activity

Data Set	Indoor Air (pCi/m^3)	UCL Basis	Outdoor Air (pCi/m^3)	UCL Basis	Combined Indoor and Outdoor Air (pCi/m^3)	UCL Basis
Site Data	1837	95% Student's-t UCL	949	95% Approximate Gamma UCL	1074	95% Approximate Gamma UCL
HMC-16 BKG	--	--	551	95% Student's-t UCL	--	
Bluewater	2000	USEPA (2014)				
Indoor BKG[1]	2000	NA	--	--	--	

Notes:
All data in pCi/m^3
-- = No value
1 – Indoor background for Cibola County, NM ranges from 2000 to 4000 pCi/m^3 (EPA 2019d)

5.2.5.2 Risk Description

This section discusses the numeric risk estimates for each receptor. It also identifies how exposure pathways were combined to determine aggregate risk. Tables 5-23 through 5-30 present the numerical risk estimates, including estimated inherent background risks, for the COPCs and ROPCs that were identified as exceeding background for the Homestake Facility, and Tables 5-31 through 5-36 present the numerical risk estimates for the LTAs.

The inherent risks due to background exposure, and the amount of risk potentially attributable to the Site once background is accounted for by subtracting the background UCL95 from the site UCL95, are shown by receptor and location in Tables 5-23 through 5-36. The inherent background risk presented in these tables is based on the background surface soil concentrations and soil exposure pathways of ingestion, inhalation as estimated from PEF, and dermal exposure for COPCs or external exposure for ROPCs.

The column labeled “Excess Risk Attributable to Site” is the difference between the sum of the soil pathways and the “Inherent Background Soil Risk” column. This applies to COPCs and ROPCs.

5.2.5.2.1 Future Composite Worker - Homestake Facility

Tables 5-23 and 5-24 present the ROPC and COPC cancer risks and non-cancer HQs for each analyte evaluated for each exposure pathway for this receptor. The initial results suggest that cancer risks for arsenic, and soil radionuclides are elevated for surface soils. However, arsenic cancer risks are not elevated above background cancer risk for soils (Table 5-23) and there is no excess risk at the Site due to arsenic once background is accounted for. There are no non-cancer HQs above 1 (Table 5-24).

The major contributor to risk is due to radon inhalation. Rn-222 risks are elevated for exposure to the EPC based on combined outdoor and indoor air data. The total cumulative cancer risk based on the combined indoor and outdoor air EPC of 1074 pCi/m^3 is 2 x 10^{-2}, which is above the upper bound of the risk management range.

Note that radon is, however, not greatly elevated above background for outdoor air, being elevated at the Site by less than a factor of 2. The Site outdoor air EPC is 949 pCi/m^3 which is 1.7 times above the background outdoor air UCL95 of 551 pCi/m^3. Risks due to radon are 2 x 10^{-2}, and, once background is accounted for, are 1 x 10^{-2}, which is above the risk management range. The Site indoor air concentration of 1837 pCi/m^3 is less than the reported background for both Bluewater and Cibola County identified by EPA’s radon map of 2-4 pCi/L (2000 to 4000 pCi/m^3). The radon indoor air concentration for Bluewater developed by EPA (2014) is 2 pCi/L (2000 pCi/m3), which is at the low end of the Cibola County Range.

Consultation with EPA indicated that risk cannot exceed 1, and the RadPRG calculator defaults to a different model above 1 x10^{-2}. There may be a discrepancy in risk estimates due to use of different models simply because background risks for radon, even after daughter progeny below Po-214 are removed, are so high.

Major contributors for soil exposure risk are Pa-234m, Ra-226, U-234, and U-238, all of which had cancer risk estimates above 1 x 10^{-4}. However, a significant part of the cancer risk is related to Site background levels for soils (refer to Table 5-23). EPCs for Pa-234m, U-234, and U-238 are approximately 3 to 4 times higher in the Site soils than background, but other risk driving radionuclides in soil are only 1 to 2 times higher than background. The Site cumulative cancer risk

for soils is 8 x 10^{-4}, and excess risk attributable to the Site soils after accounting for background is 9x10^{-4}. This is above the upper bound of the cancer risk management range.

5.2.5.2.2 Future Construction Worker - Homestake Facility

Table 5-25 presents the cancer risks for COPCs and ROPCs. Table 5-26 presents the non-cancer hazards.

There are no excess cancer risks for chemicals (Table 5-25). There are no non-cancer hazard quotients (refer to Table 5-26) above 1 for COPCs.

The results indicate that while over half the isotopes in soils have cancer risks above 1x10^{-6}, that there are no elevated cancer risks above 1x10^{-4} for soils. Total cancer risk for the construction worker exposed to surface and subsurface soils is 7 x10^{-5}. This includes consideration of soil ingestion, particulate inhalation during construction activities, and external exposure. When inherent risks due to background exposure are factored out, the excess risk attributable to the Site is 4 x10^{-5}.

Rn-222 risks are elevated for exposure to air. The air EPC of 1074 pCi/m^3 was based on indoor air samples from second quarter of 2015 through 2018 from the HMC office and RO plant, and outdoor air based on all data combined from 2014 through 2018 from the Homestake Facility. The indoor/outdoor air EPC of 1074 pCi/m^3 was used to represent both the Homestake Facility and LTAs. The indoor/outdoor air EPC was used to represent potential trench air radon levels. The total cumulative cancer risk at the Homestake Facility for air is 8 x 10^{-4}, which is above the upper bound of the risk management range. When inherent background is subtracted out of the total risk, the cancer risk attributable to the Site is 4 x 10^{-4}, which also exceeds the upper bound of the risk management range.

External exposure is the only exposure pathway with elevated risks for soil contact pathways for this receptor. The ingestion and inhalation of fugitive dust pathways have lower radiation risks. The major risk driver is radon in air for risks estimated for the inhalation pathways from measured air concentrations; all other estimated cancer risks fall below the upper bound of the risk management range.

A significant part of the cancer risk is related to Site background radon levels (refer to Table 5-25). Radon activity in outdoor air (949 pCi/m3) at the Homestake Facility is higher by a factor of 1.7 than outdoor background concentrations of 551 pCi/m^3 based on a UCL95 from the data from HMC-16. Radon risks are higher than soil exposure pathway risks.

5.2.5.2.3 Current and Future Trespasser -Homestake Facility

Table 5-27 presents the cancer risks for COPCs and ROPCs for exposure to soil and air in the Homestake Facility for the current trespasser, and Table 5-28 presents the cancer risks for exposure to surface water and sediments. Table 5-29 presents the non-cancer hazards for exposure to soils, surface water, sediment, and air for the Homestake Facility for the current trespasser. Remediation efforts will remove the evaporation ponds, and thereby remove pond water and sediments as a potential exposure medium for future receptors. The future trespasser in the Homestake Facility therefore has only soil and air exposure pathways compared to the current trespasser who is potentially exposed infrequently to sediments and surface water as well as to soil and air. Cancer risks for the future trespasser are shown in Table 5-30 and non-cancer hazards are shown in Table 5-31.

There are no excess cancer risks for chemicals for soil and air (Table 5-27 and 5-30) for the current or future trespasser. There are no non-cancer hazard quotients (refer to Table 5-29) above 1 for COPCs in soil and air. There is an HQ of 2 for uranium for exposure to surface water for the current trespasser; the HI for exposure to surface water in the evaporation ponds is 3 (Table 5-29). The HI for exposure to sediment is less than 1 (Table 5-29).

The results indicate that while over half the isotopes have cancer risks above $1x10^{-6}$, that there are no elevated cancer risks above $1x10^{-4}$ for soils. Total cancer risk for the current trespasser exposed to soils is $4x10^{-5}$. This includes consideration of soil ingestion, particulate inhalation, and external exposure. When inherent risks due to background exposure are factored out, the excess risk attributable to the Site is $2x10^{-5}$.

The major risk driver for current trespassers is radon activity in air for risks estimated for the inhalation pathway from measured air concentrations. Cancer risk is $1x10^{-4}$ for total Site risk for air. After subtracting background activity the excess risk attributable to the Site is $6x10^{-5}$, which falls within the risk management range.For future trespassers within the Homestake Facility, the exposure pathways are the same as for current trespassers for soil and air. Risks and hazards are the same as for the current trespasser for soil and air.

Table 5-28 shows cancer risks for incidental exposure to surface water or sediment. Background data were not available for surface water or sediment and Site risks cannot be adjusted to reflect amounts expected to be naturally occurring. Cancer risks for radionuclides are $7x10^{-5}$ for surface water, in sediment potential risk estimates are $6x10^{-5}$ for U-234 and U-238, and total cancer risk is $1x10^{-4}$. Pond water and sediment pathways are removed for future trespassers (refer to Tables 5-30 and 5-31).

Table 5-28 suggests potential risk to trespassers at the ponds for contact with sediment. Exposure parameters used to predict sediment exposure (0.2 hours/day, 6 days/year for 10 years) are considered conservative because it is unlikely someone would fall into the ponds on a regular basis. Albuquerque was used as a location for the PEF to model if sediments dried and became wind-blown. A sediment ingestion rate of 100 mg/day was used to predict sediment exposure which is also considered conservative as humans would not spend as much time in contact with sediments as they do with soils. Neither soil, air, surface water or sediment exposure estimates result in cancer risks above $1x10^{-4}$.

5.2.5.2.4 Future Composite Worker - Land Treatment Areas

Tables 5-32 and 5-33 present the ROPC and COPC cancer risks and non-cancer HQs for each analyte evaluated for each exposure pathway for this receptor. There is no cancer risk above $2x10^{-6}$ for chemicals for exposure within the LTAs (Table 5-32). There are no non-cancer hazards above 1. Total cancer risk for exposure to radionuclides in soil is $8x10^{-4}$. After accounting for background, the cancer risk due to radionuclides is $1x10^{-4}$. The major contributor to risk is due to radon inhalation in air. Rn-222 risks are elevated for exposure to an EPC based on outdoor and indoor air data (Table 5-32).

There are no indoor or outdoor air measurements for the LTAs. Data from monitoring stations around the LTP were used as the basis of the LTA air EPC, which is conservative. Data from these monitors are collected quarterly. Indoor air monitoring data used is from the second quarter of 2015, after a modification to the air circulation system, through 2018. The predicted indoor/outdoor air concentration for the LTAs of 1074 pCi/m^3 is lower than the indoor air background of 2000 pCi/m^3 at

Bluewater, and below the lower end of the average indoor air concentrations predicted for Cibola County (EPA 2019d) of 2000 - 4000 pCi/m^3.

A significant part of the cancer risk is related to Site background levels for soils as well as air (refer to Table 5-32), and many isotopes are not elevated at the LTAs. However, U-234 and U-238 risks for soil exposure pathways are nearly 2 times higher at the LTAs than background. Radon risks for air are two orders of magnitude higher than soil risks and exceed the upper bound of the cancer risk management range (Table 5-32).

5.2.5.2.5 Future Construction Worker - Land Treatment Areas

Table 5-34 presents the cancer risks for COPCs and ROPCs. Table 5-35 presents the non-cancer hazards. There are no cancer risks above 1x10^{-6} for COPCs (refer to Table 5-34) and no non-cancer hazard quotients (refer to Table 5-35) above 1 for COPCs.

The total cumulative cancer risk for the soil exposure pathways for radionuclides is 1x10^{-5}. This is estimated as the sum of the surface and subsurface soil pathways at exposure times of 8 hours per day and soil ingestion rates of 330 mg/d plus the sum of the fugitive dust air pathway and external exposure. External exposure is the only exposure pathway with elevated risks for the soil contact pathways for this receptor. Excess risk (Table 5-34) attributable to the LTAs based on the soil pathways is 4x10^{-5}. Once background is factored out, the overall inherent site risk is 1x10^{-5}.

The major risk driver is radon for risks estimated for the inhalation pathway from measured air concentrations; all other estimated cancer risks fall below the upper bound of the risk management range. Rn-222 risks are elevated for exposure to the Site-wide outdoor and indoor air concentration of 1,074 pCi/m^3. This concentration was used to represent exposure to outdoor and trench air concentration. Total risk is 8x10-4, but once background is factored out, excess risk (Table 5-34) attributable to the LTAs based on the air pathways is 4x10^{-4}. The Site-wide radon concentration in combined indoor and outdoor air of 1,074 pCi/m^3 is higher than the outdoor background UCL95 of 551 pCi/m^3 based upon data from HMC-16, and below average indoor air concentrations predicted by background for Bluewater (USEPA 2014) of 2000 pCi/m^3, or for Cibola County of 2000 – 4000 pCi/m^3 (EPA 2019d).

5.2.5.2.6 Current and Future Trespasser - Land Treatment Areas

Cancer risk and non-cancer hazard for the LTA trespasser is similar under current or future scenarios and the exposure pathways are also similar (Tables 5-36 and 5-37). There is no cancer risk above 1x10^{-6} for chemicals for exposure within the LTAs. There are no non-cancer hazard quotients above 1 for COPCs (refer to Table 5-37).

The cumulative cancer risk for soil exposure pathways for Site radionuclides and background are 2x10^{-5} and 1x10^{-5}, respectively. Excess cancer risk attributable to the Site is 1x10^{-5}, which is within the risk management range.

Radon risks were evaluated for exposure to outdoor air. The cumulative cancer risk for the current and future LTA trespasser is 1x10^{-4} for the Site and 7x10^{-5} for the UCL95 of 551 pCi/m^3 based on HMC-16 data. The excess cancer risk is 3x10^{-5}, or within the cancer risk management range.

The excess risk for both current and future trespassers attributable to the LTAs' surface soils and air is within the cancer risk management range. Outdoor radon concentrations in air are modeled as higher than background, but since the data were all collected on the Homestake Facility, outdoor air

risks may be biased high. A large component of risk for radon exposure is due to ambient conditions.

Table 5-23 Cancer Risk for Future Composite Workers in the Homestake Facility

COPC	Homestake Facility Soil EPC (mg/kg)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	Dermal Exposure Risk	Total Homestake Facility Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site from Soil	Excess Site Risk >1E-06?	Excess Site Risk >1E-04?
Arsenic	6.328	2E-06	3E-10	4E-07	2E-06	2E-06	0E+00	No	No
Molybdenum	36.53	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	3.87	NA	NA	NA	NA	NA	NA	NA	NA
Uranium (total)	15.53	NA	NA	NA	NA	NA	NA	NA	NA
Cumulative Cancer Risk		2E-06	3E-10	4E-07	2E-06	2E-06	0E+00	No	No

Isotope	Homestake Facility Soil EPC (pCi/g)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	External Exposure Risk	Total Homestake Facility Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site from Soil	Site Air EPC (pCi/m3)	Inhalation Risk (no decay)	External Exposure Risk (no decay)	Total Risk (no decay)	Inherent Background Air Risk	Excess Risk Attributable to Site[1]	Excess Site Risk > 1E-06?	Excess Site Risk >1E-04?
*Secular Equilibrium Risk for Bi-212	1.498	4E-10	3E-12	5E-05	5E-05	5E-05	0E+00	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Bi-214	2.333	3E-06	1E-09	8E-05	8E-05	4E-05	4E-05	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Cs-137	0.0672	1E-09	1E-13	7E-07	7E-07	8E-07	0E+00								
*Secular Equilibrium Risk for K-40	18.1	2E-07	8E-11	7E-05	7E-05	7E-05	0E+00								
*Secular Equilibrium Risk for Pa-234m	4.603	7E-06	1E-08	2E-04	2E-04	5E-05	2E-04	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Pb-212	1.35	1E-08	2E-11	5E-05	5E-05	5E-05	0E+00	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Pb-214	2.468	3E-06	1E-09	1E-04	1E-04	5E-05	5E-05	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Ra-223	0.414	3E-08	2E-10	2E-06	2E-06	2E-06	0E+00	--	--	--	--	--	--	No	No
Secular Equilibrium Risk for Ra-226	4.00	6E-06	4E-09	2E-04	2E-04	7E-05	1E-04	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Ra-228	1.422	7E-07	5E-09	8E-05	8E-05	7E-05	1E-05	--	--	--	--	--	--	Yes	No
Secular Equilibrium Risk for Rn-222	--	--	--	--	--		--	1074	2E-02	5E-05	2E-02	1E-02	1E-02	Yes	Yes*
*Secular Equilibrium Risk for Th-227	0.174	2E-08	2E-10	1E-06	1E-06										
*Secular Equilibrium Risk for Th-228	1.604	2E-07	4E-09	6E-05	6E-05										
Secular Equilibrium Risk for Th-230	2.593	4E-06	5E-09	1E-04	1E-04	6E-05	4E-05	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Th-232	1.372	8E-07	6E-09	7E-05	8E-05										
*Secular Equilibrium Risk for Th-234	3.26	5E-06	7E-09	1E-04	1E-04	4E-05	6E-05	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Tl-208	0.434	0E+00	0E+00	4E-05	4E-05	4E-05	0E+00	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for U-234	4.287	7E-06	1E-08	2E-04	2E-04	5E-05	2E-04	--	--	--	--	--	--	Yes	Yes
*Secular Equilibrium Risk for U-235	0.307	1E-07	2E-09	3E-06	3E-06										
*Secular Equilibrium Risk for U-238	4.323	7E-06	1E-08	2E-04	2E-04	5E-05	2E-04	--	--	--	--	--	--	Yes	Yes
Total Risk	--	4E-05	5E-08	1E-03	1E-03	7E-04	3E-04	--	2E-02	5E-05	2E-02	1E-02	1E-02	Yes--	Yes

Note: EPA RSL and RadPRG calculators used to determine risk estimates. If risk does exceed $1x10^{-2}$, the calculator defaults to a different model. This represents modeling uncertainty.
* Rn-222 air risk calculated with progeny down decay chain to Po-214 only, at which point radon daughters are not expected to be airborne.
1 – Excess risk is the Total Risk (Site) – Inherent Background Air Risk estimated with the UCL95 of 551 pCi/m3 derived from data from HMC-16 as the EPC
EPCs - 95th percentile upper confidence limit on the mean (UCL95); bold values are maxima
Highlighted cells indicate the cancer risk > 1E-6, red shading for Site, blue shading for background; red text indicates result is above $1x10^{-4}$
NA = not applicable
-- = No value
pCi/g = picocurie per gram
Arsenic risks were corrected for the RBA of 0.6
NA = Not applicable, no cancer slope factor
EPC = Exposure point concentration
ROPC = Radionuclide of potential concern
There are no metals in air data shown because particulates in air screened out. Particulates generated from soils are predicted with PEF and presented as fugitive dust inhalation risk.

Table 5-24 Non-Cancer Risk for Future Composite Workers in the Homestake Facility

COPC	Homestake Facility Soil EPC (mg/kg)	Soil Ingestion HQ	Fugitive Dust Inhalation HQ	Dermal Exposure HQ	Total Homestake Facility Soil HQ	Inherent Soil Background HQ	Excess Hazard Attributable to Site	Excess Site HQ>1?
Arsenic	6.328	1E-02	1E-05	2E-03	1E-02	1E-02	0E+00	No
Molybdenum	36.53	6E-03	No RfC	No ABS	6E-03	8E-05	6E-03	No
Selenium	3.869	7E-04	7E-09	No ABS	7E-04	1E-04	6E-04	No
Uranium	15.53	6E-02	1E-05	No ABS	6E-02	7E-03	5E-02	No
Hazard Index (HI)		Hazard Index (HI)	8E-02	3E-05	2E-03	8E-02	2E-02	6E-02

Notes:
EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
ABS = Dermal absorption factor
COPC = Contaminant of potential concern
EPC = Exposure point concentration
HQ = Hazard quotient
mg/kg = milligram per kilogram
RfC = Reference concentration
-- = No value
Arsenic risks were corrected for the RBA of 0.6
Background values for uranium were estimated by averaging the activity for U-234 and U-238, then multiplying by 1.48 ug/pCi to convert to mass units per DOE (2011)
HQ>1 represent elevated hazard; indicated with red text
EPCs = 95th percentile upper confidence limit on the mean (UCL95)
Excess hazard is calculated as the sum of the Site surface soil pathway hazards or Total HQ minus the background hazard for that constituent

Table 5-25 Cancer Risk for Future Construction Workers Within the Homestake Facility

COPC	Homestake Facility Soil EPC (mg/kg)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	Dermal Exposure Risk	Total Homestake Facility Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Excess Site Risk >1E-06?	Excess Site Risk >1E-04?
Arsenic	6.328	2E-07	1E-09	4E-08	3E-07	2E-07	1E-07	No	No
Molybdenum	36.53	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	3.869	NA	NA	NA	NA	NA	NA	NA	NA
Uranium (total)	15.53	NA	NA	NA	NA	NA	NA	NA	NA
Cumulative Cancer Risk		2E-07	1E-09	4E-08	3E-07	2E-07	1E-07	No	No

Isotope	Homestake Facility Soil EPC (pCi/g)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	External Exposure Risk	Total Homestake Facility Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site from Soil	Site Air EPC (pCi/m^3)	Inhalation Risk (no decay)	External Exposure Risk (no decay)	Total Site Risk (no decay)	Inherent Background Air Risk	Excess Risk Attributable to Site[1]	Excess Site Risk>1E-06?	Excess Site Risk >1E-04?
*Secular Equilibrium Risk for Bi-212	1.498	5E-11	1E-11	2E-06	2E-06	2E-06	0E+00	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Bi-214	2.333	4E-07	5E-09	3E-06	4E-06	1E-06	3E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Cs-137	0.0672	2E-10	5E-13	3E-08	3E-08	3E-08	0E+00								
*Secular Equilibrium Risk for K-40	18.1	2E-08	3E-10	3E-06	3E-06	3E-06	0E+00								
*Secular Equilibrium Risk for Pa-234m	4.603	9E-07	4E-08	7E-06	8E-06	2E-06	6E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Pb-212	1.35	2E-09	7E-11	2E-06	2E-06	2E-06	0E+00	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Pb-214	2.468	4E-07	5E-09	4E-06	4E-06	2E-06	2E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Ra-223	0.414	4E-09	8E-10	9E-08	9E-08	7E-08	2E-08	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Ra-226	4.348	8E-07	2E-08	7E-06	8E-06	3E-06	5E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Ra-228	1.422	1E-07	2E-08	3E-06	3E-06	3E-06	0E+00	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Rn-222	--	-	-	-	-	-	--	1074	8E-04	2E-06	8E-04	4E-04	4E-04	Yes	Yes*
*Secular Equilibrium Risk for Th-227	0.174	2E-09	8E-10	5E-08	5E-08	4E-08	1E-08								
*Secular Equilibrium Risk for Th-228	1.604	2E-08	2E-08	2E-06	2E-06	2E-06	0E+00								
*Secular Equilibrium Risk for Th-230	2.607	5E-07	2E-08	4E-06	5E-06	2E-06	3E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Th-232	1.372	1E-07	2E-08	3E-06	3E-06	3E-06	0E+00								
*Secular Equilibrium Risk for Th-234	3.26	7E-07	3E-08	5E-06	6E-06	1E-06	5E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Tl-208	0.434	0E+00	0E+00	2E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for U-234	4.287	9E-07	4E-08	7E-06	8E-06	2E-06	6E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for U-235	0.307	1E-08	7E-09	1E-07	1E-07	5E-08	5E-08								
*Secular Equilibrium Risk for U-238	4.323	9E-07	4E-08	7E-06	8E-06	2E-06	6E-06	--	--	--	--	--	--	Yes	No
Total Risk	--	6E-06	2E-07	5E-05	6E-05	3E-05	4E-05	--	8E-04	2E-06	8E-04	4E-04	4E-04	Yes	No

Notes: EPA RSL and RadPRG calculators used to determine risk estimates. If risk does exceed 1x10^{-2}, the calculator defaults to a different model. This represents modeling uncertainty.
* Rn-222 air risk calculated with progeny down decay chain to Po-214 only, at which point radon daughters are not expected to be airborne.
1 – Excess risk is the Total Risk (Site) – Inherent Background Air Risk estimated with the UCL95 of 551 pCi/m^3 derived from data from HMC-16 as the EPC
Arsenic risks were corrected for the RBA of 0.6
EPCs - 95th percentile upper confidence limit on the mean (UCL95); bold values are maxima
Highlighted cells indicate the cancer risk >1x10^{-6}, red shading for Site, blue shading for background; red text indicates result is above 1x10^{-4}
NA = not applicable
-- = No value
pCi/g = picocurie per gram
NA = Not applicable, no cancer slope factor
EPC = Exposure point concentration
ROPC = Radionuclide of potential concern
-- = No value
pCi/g = picoCurie per gram
-- = No value
pCi/g = picoCurie per gram

Table 5-26 Non-Cancer Risk for Future Construction Workers Within the Homestake Facility

COPC	Homestake Facility Soil EPC (mg/kg)	Soil Ingestion HQ	Fugitive Dust Inhalation HQ	Dermal Exposure HQ	Total Homestake Facility Soil HQ	Inherent Soil Background HQ	Excess Hazard Attributable to Site	Excess Site HQ>1?
Arsenic	6.328	4E-02	1E-03	6E-03	4E-02	4E-02	0E+00	No
Molybdenum	36.53	2E-02	No RfC	No ABS	2E-02	3E-04	2E-02	No
Selenium	3.87	2E-03	6E-07	No ABS	2E-03	5E-04	2E-03	No
Uranium (total)	15.53	2E-01	5E-04	No ABS	2E-01	3E-02	2E-01	No
Hazard Index (HI)		3E-01	2E-03	6E-03	3E-01	6E-02	2E-01	No

Notes: EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
ABS = Dermal absorption factor
COPC = Contaminant of potential concern
EPC = Exposure point concentration
HQ = Hazard quotient
mg/kg = milligram per kilogram
RfC = Reference concentration
-- = No value

Arsenic risks were corrected for the RBA of 0.6
Background values for U-total were estimated by averaging the activity for U-234 and U-238, then multiplying by 1.49 ug/pCi
Particulates in air screened out and fugitive dusts are modeled from soil concentrations
HQs > 1 represent elevated risk, indicated with red text
EPCs = 95th percentile upper confidence limit on the mean (UCL95)
Uranium (total) in Background (1.69 mg/kg) is the mean of U-234 and U238 activity multiplied by 1.48 to convert to a mass (DOE 2011)
Excess hazard is calculated as the sum of the Site surface soil pathway hazards or Total HQ minus the background hazard for that constituent

Table 5-27 Cancer Risks for Current Trespassers within the Homestake Facility

COPC	Homestake Facility Soil EPC (mg/kg)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	Dermal Exposure Risk	Total Homestake Facility Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Excess Site Risk >1E-06?	Excess Site Risk >1E-04?
Arsenic	6.328	3E-07	1E-11	6E-08	3E-07	1E-07	2E-07	No	No
Molybdenum	36.53	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	3.87	NA	NA	NA	NA	NA	NA	NA	NA
Uranium (total)	15.53	NA	NA	NA	NA	NA	NA	NA	NA
Cumulative Cancer Risk	--	3E-07	1E-11	6E-08	3E-07	1E-07	2E-07	No	No

Isotope	Homestake Facility Soil EPC (pCi/g)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	External Exposure Risk	Total Homestake Facility Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Site Outdoor Air EPC (pCi/m^3)	Inhalation Risk (no decay)	External Exposure Risk (no decay)	Total Site Risk (no decay)	Inherent Background Air Risk	Excess Risk Attributable to Site[1]	Excess Site Risk > 1E-06?	Excess Site Risk > 1E-04?
*Secular Equilibrium Risk for Bi-212	1.498	1E-10	2E-14	1E-06	1E-06	8E-07	2E-07	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Bi-214	2.333	6E-07	9E-12	2E-06	2E-06	9E-07	1E-06	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Cs-137	0.0672	1E-10	9E-16	1E-08	1E-08	2E-08	0E+00								
*Secular Equilibrium Risk for K-40	18.1	5E-08	5E-13	1E-06	1E-06	1E-06	0E+00								
*Secular Equilibrium Risk for Pa-234m	4.603	1E-06	7E-11	4E-06	5E-06	1E-06	4E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Pb-212	1.35	4E-09	1E-13	9E-07	9E-07	8E-07	1E-07	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Pb-214	2.468	6E-07	9E-12	2E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Ra-223	0.414	1E-08	1E-12	4E-08	5E-08	4E-08	1E-08	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Ra-226	4.00	1E-06	3E-11	3E-06	4E-06	2E-06	2E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Ra-228	1.422	2E-07	3E-11	1E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Rn-222	--	--	--	--	--	--	--	949	1E-04	8E-07	1E-04	7E-05	3E-05	Yes	No
*Secular Equilibrium Risk for Th-227	0.174	6E-09	1E-12	2E-08	3E-08	2E-08	1E-08								
*Secular Equilibrium Risk for Th-228	1.604	6E-08	3E-11	1E-06	1E-06	1E-06	0E+00								
*Secular Equilibrium Risk for Th-230	2. 593	7E-07	3E-11	2E-06	3E-06	1E-06	2E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Th-232	1.372	2E-07	4E-11	1E-06	2E-06	1E-06	1E-06								
*Secular Equilibrium Risk for Th-234	3.26	1E-06	5E-11	2E-06	3E-06	7E-07	2E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Tl-208	0.434	0E+00	0E+00	7E-07	7E-07	6E-07	1E-07	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for U-234	4.287	1E-06	6E-11	3E-06	4E-06	1E-06	3E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for U-235	0.307	2E-08	1E-11	6E-08	8E-08	3E-08	5E-08								
*Secular Equilibrium Risk for U-238	4.323	1E-06	8E-11	3E-06	5E-06	1E-06	4E-06	--	--	--	--	--	--	Yes	No
Total Risk	--	8E-06	4E-10	3E-05	4E-05	2E-05	2E-05	--	1E-04	8E-07	1E-04	7E-05	3E-05	Yes	No

Notes: EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
* Rn-222 air risk calculated with progeny down decay chain to Po-214 only, at which point radon daughters are not expected to be airborne.
1 – Excess risk is the Total Risk (Site) – Inherent Background Air Risk estimated with the UCL95 of 551 pCi/m^3 derived from data from HMC-16 as the EPC
NA = Not applicable, no cancer slope factor
EPC = Exposure point concentration
ROPC = Radionuclide of potential concern
-- = No value
pCi/g = picoCurie per gram
Arsenic risks were corrected for the RBA of 0.6
Background data were not available for surface water or sediment
There are no metals in air data shown because particulates in air screened out. Particulates generated from soils are predicted with PEF and presented.
EPCs - 95th percentile upper confidence limit on the mean (UCL95); bold values are maxima
Highlighted cells indicate the cancer risk > 1x10^{-6}, red shading for Site, blue shading for background, red text indicates risk>1x10^{-4}

Table 5-28 Cancer Risks for Current Trespassers Exposed to Sediment and Surface Water in the Evaporation Ponds within the Homestake Facility

Surface Water And Sediment Cancer Risk											
Isotope	**Homestake Facility Pond Surface Water EPC (pCi/L)**	**Ingestion Risk**	**Immersion Risk**	**Total Surface Water Risk**	**Homestake Facility Pond Sediment EPC (pCi/g)**	**Ingestion Risk**	**Inhalation Risk**	**External Exposure Risk**	**Total Sediment Risk**	**Excess Site Risk >1E-06?**	**Excess Site Risk >1E-04?**
*Secular Equilibrium Risk for Ra-226	45.75	8E-09	1E-12	8E-09	**32.5**	1E-06	3E-12	3E-07	1E-06	No	No
*Secular Equilibrium Risk for Ra-228	71.01	6E-09	2E-12	6E-09	**--**	--	--	--	--	No	No
*Secular Equilibrium Risk for Th-230	1200	2E-07	3E-11	2E-07	**0.5**	2E-08	7E-14	5E-09	2E-08	No	No
*Secular Equilibrium Risk for U-234	185357.2	4E-05	4E-09	4E-05	**1283**	5E-05	2E-10	1E-05	6E-05	Yes	No
*Secular Equilibrium Risk for U-238	185357.2	4E-05	4E-09	4E-05	**1283**	5E-05	3E-10	1E-05	6E-05	Yes	No
*Total Risk		7E-05	9E-09	7E-05	**--**	1E-04	5E-10	2E-05	1E-04	Yes	No

Notes: EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
U-234 and U-238 actiivity estimated from Utotal mass concentration. Calculated from UCL95 for Utotal (548.8 mg/L) *1000 (ug/mg)* 0.67 pCi/ug = 367696 pCi/L divided by 2 = 185357.2 pCi/L for U-234 and 185357.2 for U-238

EPC = Exposure point concentration
pCi/g = picoCurie per gram
pCi/L = picoCurie per liter
-- = No value
Background data were not available for surface water or sediment in the evaporation ponds
EPCs - 95th percentile upper confidence limit on the mean (UCL95); bold values are maxima
Highlighted cells indicate the cancer risk > $1X10^{-6}$, red shading for Site, red text for cancer risk>$1x10^{-4}$
Measured activity of U-natural in sediment was used to estimate EPCs for U-234 and U-238 EPCs in the absence of isotopic-specific data by assigning half the U-natural activity to each isotope.
Exposure parameters used to predict sediment exposure were those for surface water exposure (0.2 hours/day, 6 days/year for 10 years), with Albuquerque as a location for PEF in the event dried sediments were wind-blown, and a sediment ingestion rate of 100 mg/day as per soils

Table 5-29 Non-Cancer Hazard for Current Trespassers Within the Homestake Facility

COPC	Homestake Facility Soil EPC (mg/kg)	Soil Ingestion HQ	Fugitive Dust Inhalation HQ	Dermal Exposure HQ	Total Homestake Facility Soil HQ	Inherent Soil Background Hazard	Excess Hazard Attributable to Site	Excess Site HQ>1?
Arsenic	6.328	2E-03	7E-07	4E-04	3E-03	2E-03	1E-03	No
Molybdenum	36.5	1E-03	No RfC	No ABS	1E-03	1E-05	1E-03	No
Selenium	3.8	1E-04	3E-10	No ABS	1E-04	3E-05	7E-05	No
Uranium (total)	14.3	1E-02	6E-07	No ABS	1E-02	1E-03	9E-03	No
Hazard Index (HI)		2E-02	1E-06	4E-04	1E-02	3E-03	1E-02	No

Surface Water and Sediment Non-Cancer Hazard										
COPC	Homestake Facility Surface Water EPC (mg/L)	Surface Water Ingestion HQ	Dermal Exposure HQ	Total Homestake Facility Surface Water HQ	Pond Sediment EPC (mg/kg)	Ingestion HQ	Inhalation HQ	Dermal HQ	Total Sediment HQ	Excess Site HQ>1?
Manganese	0.302	3E-06	3E-04	3E-04	--	--	--	--	--	No
Molybdenum (total)	864.4	4E-02	1E-01	2E-01	--	--	--	--	--	No
Nitrate	2.135	3E-07	1E-06	1E-06	--	--	--	--	--	No
Selenium (total)	0.572	3E-05	1E-04	1E-04	--	--	--	--	--	No
Uranium (total)	548.8	6E-01	2E+00	3E+00	**2566**	3E-01	1E-06	No ABS	3E-01	No
Vanadium	0.107	4E-06	7E-04	7E-04	--	--	--	--	--	No
Hazard Index (HI)		6E-04	6E-01	2E+00	3E+00	--	3E-01	1E-06	-	3E-01

Notes: EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
ABS = Dermal absorption factor
COPC = Contaminant of potential concern
EPCs = 95th percentile upper confidence limit on the mean (UCL95)
HQ = Hazard quotient
mg/kg = milligram per kilogram
mg/L = milligram per liter
-- = No value
Arsenic risks were corrected for the RBA of 0.6
Background data were not available for surface water or sediment in the evaporation ponds
EPCs - 95th percentile upper confidence limit on the mean (UCL95); bold values are maxima
Uranium (total) in Background soil (1.69 mg/kg) is the mean of U-234 and U238 activity multiplied by 1.48 ug/pCi to convert to a mass (DOE 2011)
Excess hazard is calculated as the sum of the Site surface soil pathway hazards or Total HQ minus the background hazard for that constituent
Exposure parameters used to predict surface water exposure (0.2 hours/day, 6 days/year for 10 years), Albuquerque as a location for PEF, and a sediment ingestion rate of 100 mg/day were used to predict sediment exposure
Molybdenum and selenium were below SLs but retained at request of EPA
HQs > 1 represent elevated non-cancer hazard as indicated with red text

Table 5-30 Cancer Risk for Future Trespassers within the Homestake Facility

COPC	Homestake Facility Soil EPC (mg/kg)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	Dermal Exposure Risk	Total Homestake Facility Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Excess Site Risk >1E-06?	Excess Site Risk >1E-04?
Arsenic	6.328	3E-07	1E-11	6E-08	3E-07	1E-07	2E-07	No	No
Molybdenum	36.53	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	3.87	NA	NA	NA	NA	NA	NA	NA	NA
Uranium (total)	15.53	NA	NA	NA	NA	NA	NA	NA	NA
Cumulative Cancer Risk	--	3E-07	1E-11	6E-08	3E-07	1E-07	2E-07	No	No

Isotope	Homestake Facility Soil EPC (pCi/g)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	External Exposure Risk	Total Homestake Facility Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Site Outdoor Air EPC (pCi/m3)	Inhalation Risk (no decay)	External Exposure Risk (no decay)	Total Site Risk (no decay)	Inherent Background Air Risk	Excess Risk Attributable to Site[1]	Excess Site Risk >1E-06?	Excess Site Risk >1E-04?
*Secular Equilibrium Risk for Bi-212	1.498	1E-10	2E-14	1E-06	1E-06	8E-07	2E-07	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Bi-214	2.333	6E-07	9E-12	2E-06	2E-06	9E-07	1E-06	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Cs-137	0.0672	1E-10	9E-16	1E-08	1E-08	2E-08	0E+00								
*Secular Equilibrium Risk for K-40	18.1	5E-08	5E-13	1E-06	1E-06	1E-06	0E+00								
*Secular Equilibrium Risk for Pa-234m	4.603	1E-06	7E-11	4E-06	5E-06	1E-06	4E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Pb-212	1.35	4E-09	1E-13	9E-07	9E-07	8E-07	1E-07								
*Secular Equilibrium Risk for Pb-214	2.468	6E-07	9E-12	2E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Ra-223	0.414	1E-08	1E-12	4E-08	5E-08	4E-08	1E-08	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Ra-226	4.00	1E-06	3E-11	3E-06	4E-06	2E-06	2E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Ra-228	1.422	2E-07	3E-11	1E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for Rn-222	--	--	--	--	--	--	--	949	1E-04	8E-07	1E-04	7E-05	3E-05	Yes	Yes*
*Secular Equilibrium Risk for Th-227	0.174	6E-09	1E-12	2E-08	3E-08	2E-08	1E-08								
*Secular Equilibrium Risk for Th-228	1.604	6E-08	3E-11	1E-06	1E-06	1E-06	0E+00								
*Secular Equilibrium Risk for Th-230	2. 593	7E-07	3E-11	2E-06	3E-06	1E-06	2E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Th-232	1.372	2E-07	4E-11	1E-06	2E-06	1E-06	1E-06								
*Secular Equilibrium Risk for Th-234	3.26	1E-06	5E-11	2E-06	3E-06	7E-07	2E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Tl-208	0.434	0E+00	0E+00	7E-07	7E-07	6E-07	1E-07	--	--	--	--	--	--	No	No
*Secular Equilibrium Risk for U-234	4.287	1E-06	6E-11	3E-06	4E-06	1E-06	3E-06	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for U-235	0.307	2E-08	1E-11	6E-08	8E-08	3E-08	5E-08								
*Secular Equilibrium Risk for U-238	4.323	1E-06	8E-11	3E-06	5E-06	1E-06	4E-06	--	--	--	--	--	--	Yes	No
Total Risk	--	8E-06	4E-10	3E-05	4E-05	1E-05	3E-05	--	1E-04	8E-07	1E-04	7E-05	3E-05	Yes	Yes

Notes: EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
* Rn-222 air risk calculated with progeny down decay chain to Po-214 only, at which point radon daughters are not expected to be airborne.
1 – Excess risk is the Total Risk (Site) – Inherent Background Air Risk estimated with the UCL95 of 551 pCi/m^3 derived from data from HMC-16 as the EPC
COPC = Contaminant of potential concern
EPC = Exposure point concentration
NA = not applicable, no cancer slope factor
pCi/g = picoCurie per gram
pCi/m^3 = picoCurie per cubic meter
ROPC = Radionuclide of potential concern
-- = No value
Arsenic risks were corrected for the RBA of 0.6
EPCs - 95th percentile upper confidence limit on the mean (UCL95); bold values are maxima
Highlighted cells indicate the cancer risk > 1x10^{-6}, red shading for Site, blue shading for background, and red text indicates risk > 1x10^{-4}

Table 5-31 Non-Cancer Hazard for Future Trespassers Within the Homestake Facility

COPC	Homestake Facility Soil EPC (mg/kg)	Soil Ingestion HQ	Fugitive Dust Inhalation HQ	Dermal Exposure HQ	Total Homestake Facility Soil HQ	Inherent Soil Background HQ	Excess Hazard Attributable to Site	Excess Site HQ>1?
Arsenic	6.328	2E-03	7E-07	4E-04	3E-03	2E-03	1E-03	No
Molybdenum	36.53	1E-03	No RfC	No ABS	1E-03	1E-05	1E-03	No
Selenium	3.87	1E-04	3E-10	No ABS	1E-04	3E-05	7E-05	No
Uranium (total)	15.53	1E-02	6E-07	No ABS	1E-02	1E-03	9E-03	No
Hazard Index (HI)		2E-02	1E-06	4E-04	1E-02	3E-03	1E-02	No

Notes: EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
ABS = Dermal absorption factor
COPC = Contaminant of potential concern
EPC = Exposure point concentration
HQ = Hazard quotient
mg/kg = milligram per kilogram
RfC = Reference concentration
-- = No value
Arsenic risks were corrected for the RBA of 0.6
Background data were not available for surface water or sediment in the evaporation ponds
HQs >1 represent elevated hazard and are indicated by red text
Uranium (total) in Background is the mean of U-234 and U238 activity multiplied by 1.48 ug/pCi to convert to a mass (DOE 2011)
EPCs = 95th percentile upper confidence limit on the mean (UCL95)
Molybdenum and selenium were below SLs but retained at request of EPA; uranium also retained as conservative assumption since related to Site
Excess hazard is calculated as the sum of the Site surface soil pathway hazards or Total HQ minus the background hazard for that constituent

Table 5-32 Cancer Risks for Future Composite Worker in the Land Treatment Areas

COPC	LTAs Soil EPC (mg/kg)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	Dermal Exposure Risk	Total LTAs Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Excess Site Risk >1E-04?
Arsenic	4.69	1.3E-06	2E-10	3E-07	2E-06	2E-06	None	No
Molybdenum	0.628	NA	NA	NA	NA	NA	NA	NA
Selenium	1.12	NA	NA	NA	NA	NA	NA	NA
Uranium (total)	3.99	NA	NA	NA	NA	NA	NA	NA
Cumulative Cancer Risk		--	--	--	--	--	--	--

Isotope	LTAs Soil EPC (pCi/g)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	External Exposure Risk	Total LTAs Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Site Air EPC (pCi/m^3)	Inhalation Risk (no decay)	External Exposure Risk (no decay)	Total Risk (no decay)	Inherent Background Air Risk	Excess Risk Attributable to Site[1]	Excess Site Risk > 1E-06?	Excess Site Risk > 1E-04?
*Secular Equilibrium Risk for Bi-212	1.015	3E-10	2E-12	3E-05	3E-05	4E-05	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Bi-214	0.87	1E-06	5E-10	3E-05	3E-05	3E-05	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Cs-137	0.0711	1E-09	2E-13	8E-07	8E-07	8E-07	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for K-40	15.92	2E-07	7E-11	6E-05	6E-05	7E-05	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pa-234m	1.45	3E-06	4E-09	7E-05	8E-05	5E-05	3E-05	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pb-212	0.935	8E-09	1E-11	3E-05	3E-05	4E-05	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pb-214	0.942	1E-06	5E-10	4E-05	4E-05	4E-05	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-223	0.253	2E-08	1E-10	1E-06	1E-06	2E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-226	1.41	2E-06	2E-09	6E-05	6E-05	7E-05	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-228	0.978	5E-07	3E-09	5E-05	5E-05	6E-05	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Rn-222	-	-	-	-	-	--	-	1074	2E-02	5E-05	2E-02	1E-02	1E-02	Yes	Yes*
*Secular Equilibrium Risk for Th-228	1.763	2E-07	5E-09	6E-05	6E-05	5E-05	1E-05								
*Secular Equilibrium Risk for Th-230	1.164	2E-06	2E-09	5E-05	5E-05	6E-05	0E+00								
*Secular Equilibrium Risk for Th-232	1.74	1E-06	8E-09	1E-04	1E-04	6E-05	3E-05	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for Th-234	0.892	1E-06	2E-09	4E-05	4E-05	3E-05	8E-06								
*Secular Equilibrium Risk for Tl-208	0.294	0E+00	0E+00	3E-05	3E-05	3E-05	0E+00								
*Secular Equilibrium Risk for U-234	2.23	3E-06	5E-09	9E-05	9E-05	5E-05	4E-05	--	--	--	--	--	--	Yes	No
*Secular Equilibrium Risk for U-235	0.131	5E-08	8E-10	1E-06	1E-06	1E-06	0E+00								
*Secular Equilibrium Risk for U-238	2.21	3E-06	6E-09	9E-05	9E-05	5E-05	4E-05	--	--	--	--	--	--	Yes	No
Total Risk		7E-06	2E-08	8E-04	8E-04	7E-04	1E-04	--	2E-02	5E-05	2E-02	1E-02	1E-02	Yes	Yes

Notes: * EPA RSL and RadPRG calculators used to determine risk estimates. If risk does exceed $1x10^{-2}$, the calculator defaults to a different model. This represents modeling uncertainty.
* Rn-222 air risk calculated with progeny down decay chain to Po-214 only, at which point radon daughters are not expected to be airborne.
1 – Excess risk is the Total Risk (Site) – Inherent Background Air Risk estimated with the UCL95 of 551 pCi/m^3 derived from data from HMC-16 as the EPC
COPC – Contaminant of potential concern
EPC = Exposure point concentration
LTA = Land Treatment Area
NA = not applicable, no cancer slope factor
-- = No value
pCi/g = picoCurie per gram
pCi/m^3 = picoCurie per cubic meter
The Site soil risks are for surface soil; for background only surface soil data were available. The Site radon air EPC is for indoor and outdoor air combined; for background only outdoor air data were used.
EPCs - 95th percentile upper confidence limit on the mean (UCL95)
Excess risk for soils calculated as the sum of the Site surface soil pathway hazards minus the background risk or hazard for that constituent
Highlighted cells show cancer risk > $1x10^{-6}$, red shading for Site, blue shading for background; red text indicates result is >$1x10^{-4}$
Risks based on default exposure parameters for the composite worker
Uranium (total) in Background is the mean of U-234 and U238 activity multiplied by 1.48 ug/pCi to convert to a mass (DOE 2011)

Table 5-33 Non-Cancer Hazard Quotients for Future Composite Workers in the Land Treatment Areas

COPC	LTAs Soil EPC (mg/kg)	Soil Ingestion HQ	Fugitive Dust Inhalation HQ	Dermal Exposure HQ	Total LTAs Soil HQ	Inherent Soil Background HQ	Excess Hazard Attributable to Site	Excess Site HQ >1?
Arsenic	4.69	8E-03	1E-05	2E-03	1E-02	1E-02	None	No
Molybdenum	0.628	1E-04	No RfC	No ABS	1E-04	8E-05	2E-05	No
Selenium	1.12	2E-04	2E-09	No ABS	2E-04	1E-04	1E-04	No
Uranium (total)		3.99	2E-02	3E-06	No ABS	2E-02	7E-03	1E-02

Notes:
ABS = Dermal absorption factor
COPC – Contaminant of potential concern EPC = Exposure point concentration
HQ = Hazard quotient
LTA = Land Treatment Area
mg/kg = milligram per kilogram
RfC = Inhalation reference concentration
-- = No value

The Site soil risks are for surface and subsurface soil combined; for background only surface soil data were available
The Site radon air EPC is for indoor and outdoor air combined; for background only outdoor air data were used.
EPCs - 95th percentile upper confidence limit on the mean (UCL95)
Excess risk calculated as the sum of the Site surface soil pathway hazards minus the background risk or hazard for that constituent
Highlighted cells show HQs >1, red shading for Site, blue shading for background; red text indicates result is >1
Risks based on default exposure parameters for the composite worker
Uranium (total) in Background is the mean of U-234 and U238 activity multiplied by 1.49 ug/pCi to convert to a mass
Background risk is for background soil ingestion, dermal contact, and inhalation pathways based on background soil EPC.
Molybdenum and selenium were below SLs but retained at request of EPA; uranium also retained as conservative assumption since related to Site
Excess hazard is calculated as the sum of the Site surface soil pathway hazards or Total HQ minus the background hazard for that constituent

Table 5-34 Cancer Risk for Future Construction Workers in the Land Treatment Areas

COPC	LTAs Soil EPC (mg/kg)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	Dermal Exposure Risk	Total LTAs Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Excess Site Risk >1E-04?
Arsenic	4.69	2E-07	3E-08	9E-10	2E-07	2E-07	None	No
Molybdenum	2.452	NA	NA	NA	NA	NA	NA	NA
Selenium	0.975	NA	NA	NA	NA	NA	NA	NA
Uranium (total)	4.329	NA	NA	NA	NA	NA	NA	NA
Cumulative Cancer Risk		--	--	--	--	--	--	--

Isotope	LTAs Soil EPC (pCi/g)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	External Exposure Risk	Total LTAs Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Site Air EPC (pCi/m^3)	Inhalation Risk (no decay)	External Exposure Risk (no decay)	Total Risk (no decay)	Inherent Background Air Risk	Excess Risk Attributable to Site[1]	Excess Site Risk >1E-06?	Excess Site Risk >1E-04?
*Secular Equilibrium Risk for Bi-212	1.015	4E-11	8E-12	1E-06	1E-06	2E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Bi-214	0.87	1E-07	2E-09	1E-06	1E-06	1E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Cs-137	0.0711	2E-10	5E-13	3E-08	3E-08	3E-08	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for K-40	15.92	2E-08	2E-10	2E-06	2E-06	3E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pa-234m	1.45	4E-07	2E-08	3E-06	3E-06	2E-06	1E-06	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pb-212	0.935	1E-09	5E-11	1E-06	1E-06	2E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pb-214	0.942	2E-07	2E-09	1E-06	2E-06	2E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-223	0.253	2E-09	5E-10	5E-08	5E-08	7E-08	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-226	1.41	3E-07	5E-09	2E-06	2E-06	3E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-228	0.978	7E-08	1E-08	2E-06	2E-06	3E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Rn-222	-	-	-	-	-	--	--	1074	8E-04	2E-06	8E-04	4E-04	4E-04	Yes	Yes*
*Secular Equilibrium Risk for Th-228	1.763	2E-08	2E-08	3E-06	3E-06	2E-06	1E-06	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Th-230	1.164	2E-07	7E-09	2E-06	2E-06	2E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Th-232	1.74	1E-07	3E-08	4E-06	4E-06	3E-06	1E-06	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Th-234	0.892	2E-07	7E-09	1E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Tl-208	0.294	0E+00	0E+00	1E-06	1E-06	1E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for U-234	2.23	5E-07	2E-08	3E-06	4E-06	2E-06	2E-06	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for U-235	0.131	6E-09	3E-09	5E-08	6E-08	5E-08	1E-08	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for U-238	2.21	5E-07	2E-08	4E-06	4E-06	2E-06	2E-06	--	--	--	--	--	--	Yes	No
Total Risk		2E-06	1E-07	3E-05	3E-05	3E-05	0E+00	--	8E-04	2E-06	8E-04	4E-04	4E-04	Yes	Yes- Air

Notes: * EPA RSL and RadPRG calculators used to determine risk estimates. If risk does exceed $1x10^{-2}$, the calculator defaults to a different model. This represents modeling uncertainty.
* Rn-222 air risk calculated with progeny down decay chain to Po-214 only, at which point radon daughters are not expected to be airborne.
1 – Excess risk is the Total Risk (Site) – Inherent Background Air Risk estimated with the UCL95 of 551 pCi/m^3 derived from data from HMC-16 as the EPC
COPC – Contaminant of potential concern
EPC = Exposure point concentration
LTA = Land Treatment Area
NA = not applicable, no cancer slope factor
-- = No value; pCi/g = picoCurie per gram; pCi/m^3 = picoCurie per cubic meter
The Site soil risks are for surface and subsurface soil combined; for background only surface soil data were available
The Site radon air EPC is for indoor and outdoor air combined; for background only outdoor air data were used.
EPCs - 95th percentile upper confidence limit on the mean (UCL95)
Excess risk for soils calculated as the sum of the Site surface soil pathway hazards minus the background risk or hazard for that constituent
Highlighted cells show cancer risk > $1x10^{-6}$, red shading for Site, blue shading for background; red text indicates result is >$1x10^{-4}$
Risks based on default exposure parameters for the composite worker
Uranium (total) in Background is the mean of U-234 and U238 activity multiplied by 1.48 ug/pCi to convert to a mass (DOE 2011)
Background risk is for background soil ingestion, dermal contact, and inhalation pathways based on background soil EPC.

Table 5-35 Non-Cancer Hazard Quotients for Future Construction Worker in the Land Treatment Areas

COPC	LTAs Soil EPC (mg/kg)	Soil Ingestion HQ	Fugitive Dust Inhalation HQ	Dermal Exposure HQ	Total LTAs Soil HQ	Inherent Soil Background Hazard	Excess Hazard Attributable to Site	Excess HQ>1?
Arsenic	4.69	3E-02	1E-03	4E-03	3E-02	4E-02	None	No
Molybdenum	2.452	1E-03	No RfC	No ABS	1E-03	3E-04	7E-04	No
Selenium	0.975	6E-04	2E-07	No ABS	6E-04	5E-04	1E-04	No
Uranium	4.329	6E-02	1E-04	No ABS	6E-02	3E-02	3E-02	No
Hazard Index (HI)		9E-02	1E-03	4E-03	1E-01	6E-02	4E-02	No

Notes: EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
ABS = Dermal absorption factor
COPC = Contaminant of potential concern
EPC = Exposure point concentration
HQ = Hazard quotient
LTA – Land Treatment Area
mg/kg = milligram per kilogram
RfC = Reference concentration
-- = No value
Background values for uranium were estimated by averaging the activity for U-234 and U-238, then multiplying by 1.49 ug/pCi to convert to mass units
HQs >1 represent elevated hazard, indicated with red text
Molybdenum and selenium were below SLs but retained at request of EPA; uranium also retained as conservative assumption since related to Site
EPCs = 95th percentile upper confidence limit on the mean (UCL95)
Excess hazard is calculated as the sum of the Site surface and subsurface soil pathway hazards or Total HQ minus the background hazard for that constituent

Table 5-36 Cancer Risk for Current and Future Trespasser in the Land Treatment Areas

COPC	LTAs Soil EPC (mg/kg)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	Dermal Exposure Risk	Total LTAs Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Excess Site Risk >1E-04?
Arsenic	4.69	1E-07	1E-08	5E-12	1E-07	1E-07	0E+00	No
Molybdenum	0.628	-	-	-	-	-	-	-
Selenium	1.12	-	-	-	-	-	-	-
Uranium (total)	3.99	-	-	-	-	-	-	-
Cumulative Cancer Risk	-	1E-07	1E-08	5E-12	1E-07	1E-07	0E+00	No

Isotope	LTAs Soil EPC (pCi/g)	Soil Ingestion Risk	Fugitive Dust Inhalation Risk	External Exposure Risk	Total LTAs Soil Risk	Inherent Soil Background Risk	Excess Risk Attributable to Site	Site Outdoor Air EPC (pCi/m^3)	Inhalation Risk (no decay)	External Exposure Risk (no decay)	Total Site Risk (no decay)	Inherent Background Air Risk	Excess Risk Attributable to Site[1]	Excess Site Risk > 1E-06?	Excess Site Risk > 1E-04?
*Secular Equilibrium Risk for Bi-212	1.015	8E-11	1E-14	7E-07	7E-07	8E-07	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Bi-214	0.87	2E-07	3E-12	6E-07	8E-07	9E-07	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Cs-137	0.0711	1E-10	1E-15	2E-08	2E-08	2E-08	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for K-40	15.92	4E-08	4E-13	1E-06	1E-06	1E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pa-234m	1.45	5E-07	3E-11	1E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pb-212	0.935	3E-09	8E-14	6E-07	6E-07	8E-07	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Pb-214	0.942	2E-07	4E-12	7E-07	9E-07	1E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-223	0.253	7E-09	9E-13	2E-08	3E-08	4E-08	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-226	1.41	4E-07	9E-12	1E-06	1E-06	2E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Ra-228	0.978	1E-07	2E-11	1E-06	1E-06	1E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Rn-222	-	-	-	-	-	-	-	949	1E-04	8E-07	1E-04	7E-05	3E-05	Yes	No*
*Secular Equilibrium Risk for Th-228	1.763	6E-08	3E-11	1E-06	1E-06	1E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Th-230	1.164	3E-07	1E-11	8E-07	1E-06	1E-06	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Th-232	1.74	2E-07	5E-11	2E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Th-234	0.892	3E-07	1E-11	7E-07	9E-07	7E-07	2E-07	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for Tl-208	0.294	0E+00	0E+00	5E-07	5E-07	6E-07	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for U-234	2.23	6E-07	3E-11	2E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for U-235	0.131	9E-09	5E-12	2E-08	3E-08	3E-08	0E+00	--	--	--	--	--	--	--	--
*Secular Equilibrium Risk for U-238	2.21	7E-07	4E-11	2E-06	2E-06	1E-06	1E-06	--	--	--	--	--	--	--	--
Total Risk	--	4E-06	2E-10	2E-05	2E-05	1E-05	4E-06	--	1E-04	8E-07	1E-04	7E-05	3E-05	Yes	No

Notes: EPA RSL and RadPRG calculators used to determine risk estimates. If risk does exceed $1x10^{-2}$, the calculator defaults to a different model. This represents modeling uncertainty.
* Rn-222 air risk calculated with progeny down decay chain to Po-214 only, at which point radon daughters are not expected to be airborne.
1 – Excess risk is the Total Risk (Site) – Inherent Background Air Risk estimated with the UCL95 of 551 pCi/m^3 derived from data from HMC-16 as the EPC
COPC = Contaminant of potential concern
EPC = Exposure point concentration
LTA = Land Treatment Area
NA = not applicable, no cancer slope factor
pCi/g = picoCurie per gram
pCi/m^3 = picoCurie per cubic meter
ROPC = Radionuclide of potential concern
-- = No value
The Site soil risks are for surface soil; for background only surface soil data were available
Arsenic risks were corrected for the RBA of 0.6
EPCs - 95th percentile upper confidence limit on the mean (UCL95); bold values are maxima
Highlighted cells indicate the cancer risk > $1x10^{-6}$, red shading for Site, blue shading for background, and red text indicates risk > $1x10^{-4}$

Table 5-37 Non-Cancer Hazard Quotients for Current and Future Trespasser in the Land Treatment Areas

COPC	LTAs Soil EPC (mg/kg)	Soil Ingestion HQ	Fugitive Dust Inhalation HQ	Dermal Exposure HQ	Total LTAs Soil HQ	Inherent Soil Background Hazard	Excess Hazard Attributable to Site	Excess HQ>1?
Arsenic	4.69	2E-03	5E-07	2E-04	2E-03	2E-03	0E+00	No
Molybdenum	0.628	2E-05	No RfC	No ABS	2E-05	1E-05	1E-05	No
Selenium	1.12	4E-05	9E-11	No ABS	4E-05	3E-05	1E-05	No
Uranium	3.99	3E-03	2E-07	No ABS	3E-03	1E-03	2E-03	No
Hazard Index (HI)		4E-03	5E-03	7E-07	2E-04	3E-03	2E-03	No

Notes: EPA RSL (EPA 2019a) and RadPRG (EPA 2019b) calculators used to determine risk estimates.
ABS = Dermal absorption factor
COPC = Contaminant of potential concern
EPC = Exposure point concentration
HQ = Hazard quotient
LTA – Land Treatment Area
mg/kg = milligram per kilogram
RfC = Reference concentration
-- = No value
Background values for uranium were estimated by averaging the activity for U-234 and U-238, then multiplying by 1.48 ug/pCi to convert to mass units (DOE 2011)
HQs >1 represent elevated hazard, indicated with red text
Molybdenum and selenium were below SLs but retained at request of EPA; uranium also retained as conservative assumption since related to Site
EPCs = 95th percentile upper confidence limit on the mean (UCL95)
Excess hazard is calculated as the sum of the Site surface soil pathway hazards or Total HQ minus the background hazard for that constituent

5.2.5.2.7 Potential Risk Estimates for Post-Remedy Groundwater

Groundwater is approximately 40 feet below grade at the Site. It is currently undergoing remedy as OU1, and therefore was not addressed in detail in this HHRA. NRC has designated Site Cleanup Level for groundwater - see Table 3-8.

Risk estimates have been developed to estimate potential risks to future use of remediated groundwater as a potable water supply. Specifically, the estimates evaluate exposure to COPCs or ROPCs with NRC Site Cleanup Levels which are greater than MCL. This scenario is unlikely since potable water is supplied to the area and the State Engineer has prohibited the installation of potables wells in the area. For ingestion of groundwater, potential risks of using the remediated groundwater as a total potable source are as shown in Table 5-38. Noncancer hazard is elevated due to uranium and selenium (Table 5-39).

Table 5-38 Cancer Risk Estimates for Groundwater for NRC Site Cleanup Levels

Isotope	NRC Site Cleanup Levels (pCi/L)	Ingestion Risk	Inhalation Risk	Immersion Risk	Produce Consumption Risk	Total Tapwater Risk
*Secular Equilibrium Risk for U-234	107.2#	7E-03	6E-01	1E-09	2E-02	7E-01

Risk Estimate Exposure Parameters				
Default Residential Tapwater Exposure Parameters	**Abbreviation**	**Units**	**Adult Value**	**Child Value**
Exposure Frequency	EF	d/yr	350	350
Exposure Duration	ED	yr	20	6
Exposure Time (washing)	ETw	hr/event	0.71	0.54
Exposure Time	ET	hr/d	24	24
Number of Events	EV	event/d	1	1
Body Weight	BW	kg	80	15
Water Ingestion Rate	IRW	L/d	2.5	0.78
K (Andelman volatilization factor) L/m^3	K	L/m^3	0.5	0.5
Surface Area	SA	cm^2	19652	6365

Notes:
Shading indicates risk is above target of $1x10^{-6}$, red text indicates risk is above $1x10^{-4}$

Table 5-39 Non-Cancer Hazard Quotients for Groundwater for NRC Action Levels

Chemical	Action Level (ug/L)	Ingestion Child HQ	Dermal Child HQ	Inhalation Child HQ	Noncancer Child Total HI	Ingestion Adult HQ	Dermal Adult HQ	Inhalation Adult HQ	Noncancer Adult Total H
Nitrate (measured as nitrogen)	12000	4E-01	2E-03	-	4E-01	2E-01	1E-03	-	2E-01
Selenium	320	3E+00	1E-02	-	3E+00	2E+00	1E-02	-	2E+00
Uranium (Soluble Salts)	160	4E+01	2E-01	-	4E+01	2E+01	1E-01	-	2E+01
*Total Risk/HI	-	4E+01	2E-01	-	4E+01	3E+01	2E-01	-	3E+01

Risk Estimate Exposure Parameters

Default Residential Tapwater Exposure Parameters	Abbreviation	Units	Adult Value	Child Value
Exposure Frequency	EF	d/yr	350	350
Exposure Duration	ED	yr	205	6
Exposure Time (washing)	ETw	hr/event	0.715	0.54
Exposure Time	ET	hr/d	248	24
Number of Events	EV	event/d	1	1
Body Weight	BW	kg	80	15
Water Ingestion Rate	IRW	L/d	2.5	0.78
K (Andelman volatilization factor) L/m^3	K	L/m^3	0.5	0.5
Surface Area	SA	cm^2	19652	6365

Shading indicates hazard is above target of 1

5.2.5.3 Uncertainty Analysis

The baseline HHRA uncertainty analysis describes the known and suspected uncertainties and their impacts on the baseline HHRA results. It is not the goal of the uncertainty analysis to eliminate all uncertainty or variability, merely to understand how uncertainty or variability in underlying assumptions or data may affect the risk assessment HHRA results.

5.2.5.3.1 Uncertainty in the Toxicity Values

The toxicity values represent currently accepted regulatory values proposed for this purpose. However, some of the EPA RSL toxicity values are not based on IRIS information. These are considered more uncertain than those that have an IRIS value because they may not have undergone the same level of peer-review.

There is conservatism built into the toxicity estimates. This is because each slope factor is the upper 95th percentile estimate of cancer potency (EPA 1989). According to EPA, upper 95th percentiles of probability distributions are not strictly additive, and the cumulative or total cancer risk estimate can become artificially more conservative as the cancer risks from multiple carcinogens are summed (EPA 1989).

The toxicity for the ROPCs was addressed with values incorporating exposure to progeny. For every parent ROPC measurement, the complete decay chain was evaluated under the assumption of no decay and secular equilibrium. However, due to air movement its uncertain if secular equilibrium would occur in the environment. This may bias the risk assessment results high.

In addition, for radon all progeny are solids and not gases. The daughters are expected to adhere to particulates or aerosols and settle out of the atmosphere, particularly from Pb-210 (which has a 22 year half-life) down the decay chain. This complicates the assumption of secular equilibrium, since the aerosols don't remain suspended and Po-210 cannot reach equilibrium with Pb-210, and data indicate Po-210 air concentrations are lower by a factor of 10 to 20 (Marley et al. 2000). The Agency for Toxic Substances and Disease Registry states that Pb-210, Bi-210, and Po-210 are not considered to contribute to respiratory tract toxicity (ATSDR 2012). Previous versions of the EPA/ORNL RadPRG calculator did not evaluate radon toxicity below Po-214. This approach is also used by the NAS (1991), which states decay chain calculations can be truncated at Pb-210. Thus, risks for Bi-210, Hg-206, Pb-210, Po-210, and Tl-2016 could be realistically removed from the total radon chain risk estimate, and current radon risk estimates are biased high. The remaining radon risk would be approximately 2% of the modeled amount shown in the risk characterization tables.

5.2.5.3.2 Uncertainty in the Site Data

The Site data may contain uncertainties due to analytical methodology, sample location, seasonal fluctuations in concentrations, or matrix interferences that produce false positives or negatives. Data validation also reduces uncertainty in the analytical results. There is variability inherent in the Site data, which adds to uncertainty in the risk estimates based on the data.

There were more analytes sampled in surface than subsurface soils. Many EPCs were higher in surface soils, suggesting lack of subsurface soil data does not underestimate risk. The locations of samples collected were intended to represent Site conditions.

Detection limits represented by MDLs, MDCs, or RLs were available for some of the data only. It is not likely to bias the risk assessment results low or high.

Background air data were based on outdoor air samples from HMC-16. Background was compared to the EPC based on combined data for indoor and outdoor air for the worker receptors. Indoor air has much higher radon concentrations than outdoor air, where dispersal reduces concentrations. The Site EPCs for workers are higher than background in part for this reason, biasing risk estimates high.

The measured site radon outdoor air UCL95 is 1.7 times higher than outdoor air from HMC-16. This conservatively reflects the difference between the Site and background because the HMC-16 is at a location that experiences lower radon concentrations based on its location above the alluvial floodplain and its position on a bedrock outcrop. HMC-16 as a background location is currently under review with NRC. Refer to Section 3.2.8 for discussion of the radon background location..

5.2.5.3.3 Uncertainty in the Exposure Modeling

There are numerous exposure pathways quantified for the receptors. While this allows for identification of potentially significant pathways, summing conservative estimates of risk across multiple pathways creates a total risk estimate that is biased high and potentially leads to double counting. This is the result of propagating the error of biasing risk estimates high over and over again. Each of the exposure parameters was at least 50th percentile measures of central tendency, and some were higher. Multiplying them produces intakes that would be higher than a 50th percentile estimate.

Groundwater was not modeled because it is undergoing remedy. It is assumed that trenching would not be performed by employees not covered by OSHA until the remedy is complete. Air monitoring is recommended if excavation is performed.

Only the current trespasser was modeled as being exposed to pond water or sediments at the evaporation ponds. It is possible that radon could be emitted from the pond water and inhalation of this radon could occur. The radon air measurements are expected to capture all radon sources. However, use of the pond area is expected to be minimal, as well as temporary. Therefore, this uncertainty is not expected to bias or underestimate true risk low.

5.2.5.3.4 Cross Media Transport Modeling

Fugitive dusts generated from outdoor soils were quantified by modeling cross-media transport with the PEF. The PEF was adjusted by using climatic information from Albuquerque, NM. This is not expected to bias risk estimates. The future construction worker PEF accounts for Site activity including excavation and grading. If the area undergoing activity is larger than that modeled, dust exposure could be underestimated. If it is smaller, dust exposure would be overestimated. The measured air data provide a higher estimate of risk than estimates modeled from surface soil data. This could be because air data sample locations were targeted around the tailings pile. The measured air data included radon gas and high volume particulate samples. Particulates screened out based on measured data, and are not expected to add significant exposure levels to the assessment.

5.2.5.3.5 Uncertainty in Receptor Selection

Receptors were selected that reflect the current and realistic future uses at the Site. All these receptors were older adolescents or adults. Residents, including children and infants, are not anticipated to be present because of land use restrictions. This may bias risk estimates low since

exposure and therefore risk estimates are higher for residential scenarios. There are no current residents within the LTAs or Homestake Facility, and the remedy at the Site is already underway. Current remediation efforts include a remediation system intended to drive contaminated groundwater back to the Homestake Facility boundary. The Homestake Facility is designated to be returned to DOE, and no residential use is envisioned in that area either. Therefore, the lack of evaluation of a residential use scenario does not bias the risk assessment results low under realistic exposure scenarios.

5.2.6 Conclusions

Risks to human receptors within the LTAs are within the cancer risk management range for soils. The air data indicate radon inhalation risks may exceed the upper bound of the risk management range. Radon is similar to background levels, suggesting risks in the LTAs are acceptable for the receptors and exposure conditions evaluated. Risks due to radon in air are above the upper bound of the cancer risk management range for workers, but the majority of this is due to ambient conditions. That the LTAs do not present an elevated risk to human health under the assumptions in this report is further supported by the soil EPCs being less than or similar to background. In addition, measured radon data were below Site background concentrations.

Risk to long-term composite workers within the Homestake Facility is above the cancer risk management range. For the composite workers, this is primarily due to concentrations of Pa-234m, Ra-226, U-234, and U-238 in soils when evaluated for external exposure. Note that while statistically significantly different from background, EPCs for Ra-226 within the Homestake Facility are only 2 times higher than background, and the other three risk drivers are 3 times higher than background.

For construction workers, risk is due primarily to measured concentrations of radon in potential trench air concentrations. However, radon within the Site is similar to background concentrations, suggesting that the bulk of exposure is due to naturally occurring radon gas in air. Cancer risks to all other receptors for the Homestake Facility are within the risk management range.

There are no non-cancer hazard quotients above 1 associated with exposure to media at the LTA or Homestake Facility under the assumptions made in this HHRA.

5.3 Baseline Ecological Risk Assessment

This section presents the Screening Level Ecological Risk Assessment (SLERA) and Baseline Ecological Risk Assessment (BERA) completed for the areas of concern, which are defined as the Homestake Facility and the LTAs (refer to Figure 1-1).

EPA procedures (1997, 1998) for conducting an ecological risk assessment recommend a tiered approach for risk evaluation. The SLERA is considered the first tier of the process and is designed to serve as Steps 1 and 2 of EPA's eight-step process (EPA 1997). Step 1 consists of evaluating relevant information, formulating problems and evaluating toxicity. Step 2 consists of developing exposure estimates and risk calculations.

At the end of Step 2, a scientific/management decision point (SMDP) is reached where it may be concluded that:

- There is adequate information to conclude that ecological risks are negligible and therefore there is no need for remediation on the basis of ecological risk;
- The information is not adequate to make a decision at this point, and the ecological risk assessment process will continue to Step 3a; or
- The information indicates a potential for adverse ecological effects, and a more thorough assessment is warranted.

If the decision is made that further evaluation is warranted for any specific receptors/pathways, a BERA is conducted (EPA 2001). The BERA serves to refine the conservative risk analysis conducted in the SLERA by considering additional Site specific factors.

Data quality objectives for the BERA are summarized as follows:

Problem Statement: Potential ecological impacts due to operations at the HMC uranium mill have not previously been evaluated and quantified. The BERA will be conducted with historical data collected by HMC and EPA using EPA procedures (EPA 1997; 1998).

BERA Goal: The goal of the BERA is to determine if metals, radionuclides, and ionizing radiation associated with HMC activities pose an unacceptable risk to the environment.

BERA Information Inputs: Data used in the evaluation include historical soil and evaporation pond sampling data from the areas of concern in conjunction with ecological screening levels developed primarily by EPA and the New Mexico Environment Department.

Study Boundaries: The spatial boundaries of the areas of concern are shown in Figure 1-1. There are no temporal boundaries for soils data. For the evaporation ponds, the most recent sampling data available were used. An additional temporal boundary is that the evaporation ponds will be removed when the remedy effort is complete.[1]

Information Synthesis Strategy: The following decision rules were applied to the data used in the BERA:

- Historical sampling data were evaluated and validity for use in the BERA was confirmed.
- All rejected data were assumed to have been removed from the datasets prior to providing them for use in the BERA. If there are unknown but rejected data in the dataset, then there is additional uncertainty in the BERA results.
- If the maximum concentration for a constituent exceeded its respective ecological screening level, the constituent was further evaluated in the BERA.

[1] Once the HMC groundwater restoration program is complete, the evaporation ponds will be removed.

- If historical data were collected from areas that have not undergone remediation, and could be predicted to be reflective of current Site conditions, they were used in the BERA. All available post-remedy data were used in the BERA.

Plan for Obtaining Data: Historical Site documents and reports were reviewed. HMC and EPA were contacted to provide electronic versions of data from past sampling events. The data were organized in Microsoft Excel for evaluation and quantification of risk.

5.3.1 Screening-Level Risk Assessment

5.3.1.1 Screening-Level Problem Formulation

The screening-level problem formulation serves to define the reasons for the SLERA and BERA, and to define the methods for analyzing/characterizing risks. The specific goal of this effort is a conservative evaluation of the likelihood for adverse effects, and the ecological significance of any such predicted effects, to receptors that may be exposed to Site related constituents.

Problem formulation produces three outputs: (1) assessment endpoints that adequately reflect management goals and the ecosystem the goals are meant to protect, (2) a Site Conceptual Exposure Model (SCEM) that describes the relationships between stressors and the assessment endpoints, and (3) a plan for analyzing the potential risks to the assessment endpoints.

5.3.1.1.1 Environmental Setting

Site characteristics, including Site features, soils, geology, hydrogeology, current and future land use, and ecology, are described in Section 2.0. Information for Site conditions and characterization of ecological habitats and resources is based on a review of observations and findings from the following surveys and reports:

- **Salter, 1990.** Baseline ecology data were collected in 1990 for a proposed tailings disposal area at the Site. A wildlife biologist walked regular north-south transects at 300-foot intervals throughout the tailings basin, recorded wildlife observations, and mapped habitat types. No sensitive ecological resources (e.g., threatened and endangered species or their habitats) were observed in this baseline study.
- **Byszewski, B., 2006.** A cultural resources inventory of 350 acres was conducted within the vicinity of the areas of concern and included observations of the environmental setting and ecological species.
- **Bridges and Meyer 2007, NRC 2008.** A biologist collected baseline data at the Site in 2006 for an environmental assessment of the construction of EP-3. No sensitive ecological resources (e.g., threatened and endangered species or their habitats) were observed in this study.
- **USFWS and NMED**. The websites of the U.S. Fish and Wildlife Service (USFWS), New Mexico Ecological Services Field Office and Natural Heritage New Mexico (NHNM) were queried for lists of threatened and endangered species and species of concern known to occur in Cibola County (HMC, 2013a). The species identified from these queries are summarized in Table 2-5.

No species currently listed as endangered by the Federal government or the State of New Mexico are expected in the areas of concern included in this BERA due to a lack of suitable habitat. A survey by biologist Louis Bridges, who has extensive experience with western threatened and endangered species evaluations, confirmed the lack of suitable habitat for listed plant and animal species (Bridges and Meyer 2007). Species of concern that may occasionally pass through the Site when migrating are American peregrine falcons, arctic peregrine falcons, and bald eagles.

Homestake Facility. Much of the Homestake Facility was remediated in 1995 and re-seeded with shrubs, forbs, and grasses. No aquatic species are present on or near the Site and there are no native aquatic habitats, riparian areas, or wetlands. The only features containing open water within the Homestake Facility are the manmade collection ponds and evaporation ponds, which will be reclaimed as part of final closure of the Homestake Facility.

Wildlife is generally limited to small mammals and bird species that are common in desert landscapes and relatively tolerant of human disturbance. During a cultural resource inventory survey in June 2006, cottontail rabbits and black tailed jackrabbits, ravens, rattlesnakes, horned lizards, blackbirds, and prairie dogs were observed (Byszewski, 2006). Table 2-4 lists species potentially expected to occur at the Site based on past observations.

Land Treatment Areas. Plant and wildlife communities in the LTAs are expected to be similar to those at the Homestake Facility.

Evaporation Ponds. There are three lined evaporation ponds and two collection ponds in use at the Homestake Facility (Figure 1-2). The evaporation system receives water from the extraction wells in the alluvial and Upper Chinle aquifers and brine from the RO plant. The evaporation ponds are engineered structures designed to concentrate Site contaminants and do not provide true aquatic habitat. There is no vegetation in or along the banks of the ponds and there are no fish present. Various species of shorebirds and waterfowl have been observed using the evaporation ponds during spring and fall migration (HMC 1982; Bridges and Meyer 2007). The evaporation ponds are within the fenced area of the Homestake Facility.

5.3.1.1.2 Contaminants at the Site

As discussed in Section 3.1, sources of inorganic and radionuclide constituents within the areas of concern (Homestake Facility and LTAs) are the HMC tailings piles and groundwater pumped from the remediation system into on-Site evaporation ponds. Historically, there was pumping to off-Site irrigation fields/LTAs, but this ceased in 2012.

5.3.1.1.3 Site Conceptual Exposure Model

Table 5-40 presents the SCEM. Exposure pathways for several groups of ecological receptors were identified as potentially relevant. Each exposure pathway includes a potential source of chemicals of potential concern (COPCs) and radionuclides of potential concern (ROPCs), an environmental medium, and a potential exposure route. Surface soil and evaporation/collection pond surface water are the primary media of potential ecological concern due to the presence of inorganic and radionuclide constituents from past milling activities.

5.3.1.1.4 Contaminant Fate and Transport

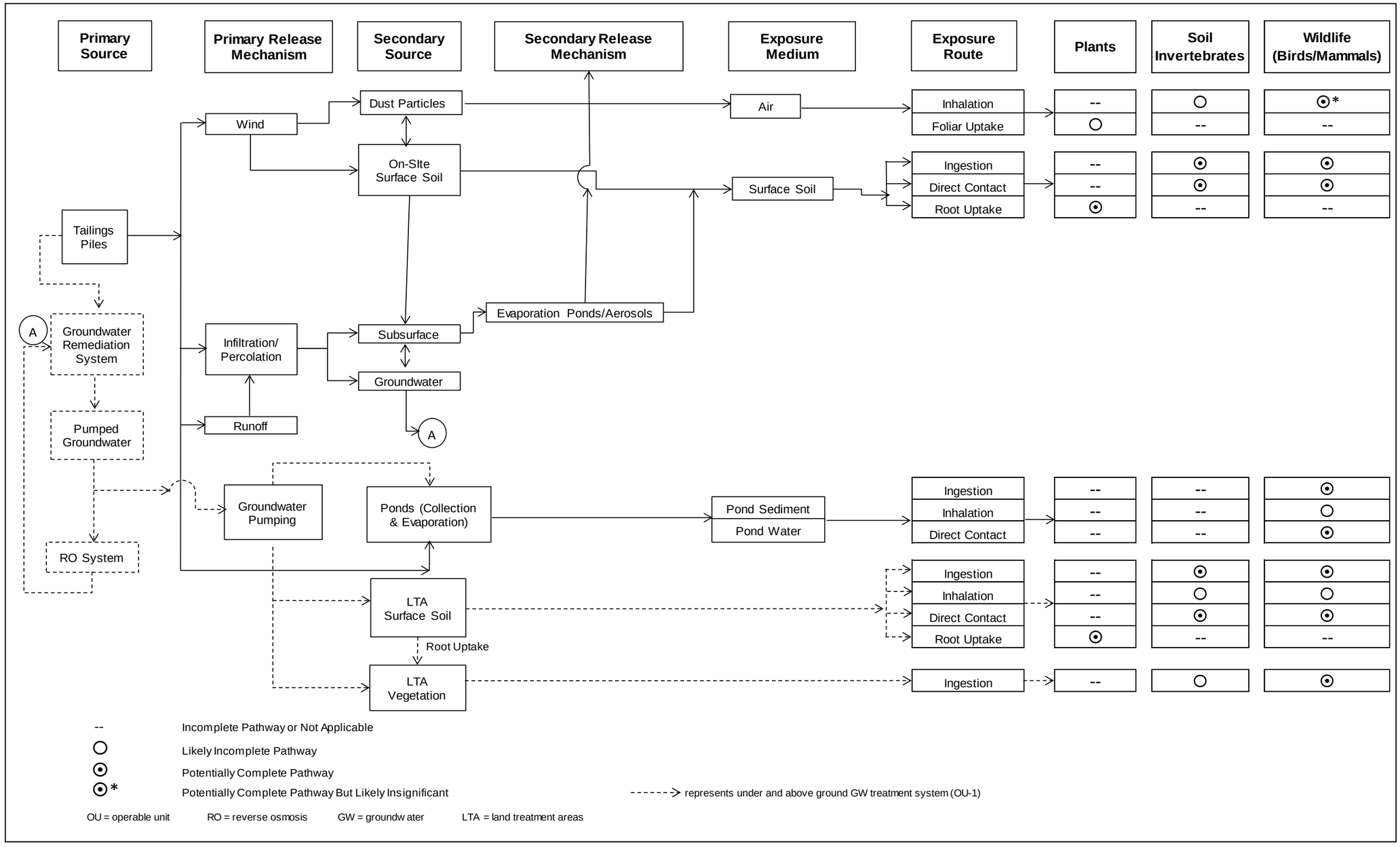
The potential for constituents to be released and transported from the sources to points of contact with ecological receptors depends on their physicochemical properties, concentrations, and their spatial distribution. As shown on the SCEM in Table 5-40, potential fate and transport process of constituents from the tailings piles include:

- Suspension and windblown transport of particulates in ambient air
- Groundwater pumping to Site collection and evaporation ponds
- Historical application of pumped groundwater to LTAs

5.3.1.1.5 Ecotoxicity

The potential ecotoxicity for constituents related to the Site vary depending on a wide range of factors, such as constituent concentrations, the receptor species exposed, the exposure route (e.g., ingestion or direct contact), and physical factors (e.g., soil pH, temperature, moisture content). Some of the effects that could be observed in wildlife are mortality, reduced reproductive ability, decreased fertility, decreased offspring survival, alteration of immune and behavioral function, and retarded growth.

Table 5-40 Ecological Risk Assessment Site Conceptual Exposure Model



The following paragraphs describe the potential ecotoxicity for the types of constituents detected in the areas of concern (Homestake Facility and LTAs). These descriptions of constituent mechanisms of toxicity are presented without consideration of constituent concentrations, as the descriptions are intended to convey an understanding of possible effects, rather than to describe the concentrations at which these effects might occur.

Metals. Toxicity and effects of trace metals may be greatly influenced by biotic and abiotic factors, including pH, organic carbon content, and the presence of sulfides in the matrix in which they occur. These factors affect the nature of the inorganic and organic complexes formed by the metal and its bioavailability. Imbalances in the essential trace metals may cause a decrease in photosynthetic ability, teratogenesis, susceptibility to predation and disease, reduced growth, mortality, histopathological changes, organ dysfunction of the liver or kidneys, neurological defects, changes in respiration and osmoregulation, and anemia. However, some of the metals (e.g., molybdenum) at the Site are known to be nutrients required by birds and mammals. If in large excess, nutrients can also have adverse effects.

Radionuclides. In general, organisms that are more primitive are the most radioresistant taxonomic groups, and more advanced complex organisms, such as mammals, are the most radiosensitive. The early effects of exposure to ionizing radiation result primarily from cell death; cells that frequently undergo mitosis are the most radiosensitive, and cells that do not divide are the least. Thus, embryos and fetuses are particularly susceptible to ionizing radiation and very young animals are consistently more radiosensitive than adults.

5.3.1.1.6 Potential Receptors

Ecological receptors located in the Homestake Facility and LTAs were selected to represent communities and species in the major consumer trophic levels. The categories of receptors are intentionally generic at the SLERA stage of the assessment process. Ecological receptors potentially at risk consist of terrestrial plants, soil invertebrates, and wildlife (birds and mammals).[2] These receptors were selected based on the habitat provided in the Homestake Facility and LTAs and their likelihood for exposure to potential contaminants. Consideration of these species provides a measure of protection to species of concern that may occasionally pass through the Site when migrating.

2 Although potential exposure pathways may exist for reptiles, there is a lack of herpetofauna-specific toxicological data for most environmental contaminants. Reptiles are indirectly assessed via the bird and mammals evaluations since they are not likely to be more sensitive than the receptors evaluated (Hall and Henry, 1992).

5.3.1.1.7 Exposure Pathways

A complete exposure pathway is one in which the constituent can be traced or expected to travel from the source to a receptor that can be affected by the chemicals. Therefore, a constituent, its migration from the source, a receptor, and the mechanisms of toxicity of that constituent must be demonstrated before a complete exposure pathway can be identified.

The ecological SCEM for the Site is shown in Table 5-40 and integrates the potential sources of concern, the media in which they are present, the exposure routes by which they interact with ecological receptors, and the various types of potentially exposed ecological receptors.

The relevant potential exposure pathways identified in the ecological SCEM include:

- Potential exposure of vegetation and soil invertebrates from direct contact with constituents in surface soils Homestake Facility and in the LTAs;
- Potential exposure of terrestrial avian and mammalian receptors from ingestion of constituents in surface soil at the Homestake Facility and in the LTAs and through uptake in the food chain from terrestrial prey resources; and
- Potential exposure of avian and mammalian receptors from contact with constituents in the on-Site evaporation ponds.

The soil and water ingestion pathways are the primary routes of potential exposure for wildlife. In addition, sediment ingestion may be a route of exposure for ecological receptors. Dietary exposure pathways are also a major route of potential exposure and bioaccumulation is incorporated into the screening levels for exposure to soils.

Although inhalation is listed as a possible exposure route, under most exposure conditions inhalation pathways do not represent a significant contribution to ecological receptor risk (EPA 2005a). In addition, while dermal exposure is listed as a possible exposure route, under most exposure conditions dermal pathways do not represent a significant contribution to ecological receptor risk. Feathers of birds, fur on mammals, and scales on reptiles are thought to reduce potential dermal exposure by limiting the contact of the skin surface with the contaminated media (EPA 2005a). The dermal and inhalation pathways are usually minor exposure pathways (Sample et al. 1997) and are not evaluated in this SLERA.

5.3.1.1.8 Assessment and Measurement Endpoints

Based on the identification of potentially complete exposure pathways, assessment endpoints and measures of effect were identified. Assessment endpoints contain an entity (e.g., avian population) and an attribute of that entity (e.g., survival rate). Because assessment endpoints often cannot be measured directly, a set of surrogate endpoints (measures of effect) are generally selected for ecological risk assessment that relate to the assessment endpoints and have measurable attributes (e.g., comparison of media concentrations to screening benchmarks, results of food web models) (EPA 1997; 1998). These measures of effect provide a quantitative metric for evaluating potential effects of constituents on the ecosystem components potentially at risk.

The following assessment endpoints and measures of effect were selected for the SLERA:

Soil Assessment Endpoint 1 – Survival, growth, and reproduction of terrestrial plant and soil invertebrate communities in Homestake Facility and LTA upland habitat areas.

Soil Measure of Effect 1 – Comparison of maximum concentrations of constituents in soil to soil screening values derived for the protection of plants and soil invertebrates.

Soil Assessment Endpoint 2 –Survival, growth, and reproduction of terrestrial wildlife receptors within the Homestake Facility and LTA upland habitat areas.

Soil Measure of Effect 2 – Comparison of maximum concentrations of constituents in soil to soil screening values derived for the protection of avian and mammalian receptors exposed to soil or to bioaccumulating analytes in prey species.

Evaporation Pond Assessment Endpoint 1 –Survival, growth, and reproduction of wildlife receptors that may occasionally ingest water from the evaporation ponds.

Evaporation Pond Measure of Effect 1 – Comparison of maximum concentrations of constituents in evaporation pond surface water and sediment to screening values derived for protection of aquatic life.

5.3.1.2 Screening-Level Ecological Effects Evaluation

In the screening-level ecological effects evaluation, data were evaluated to characterize potential ecological exposures and corresponding effects. Risk estimates developed in this evaluation were intended to serve as a means to identify COPCs/ROPCs to be carried forward into Step 3a (BERA). The outcome of Step 2 is an initial identification of COPCs/ROPCs based on conservative screening level risk estimates. Following Step 2 screening, refining COPCs/ROPCs in Step 3a of the process enables identification of screening level risk estimates with more appropriate Site-specific significance.

5.3.1.2.1 Exposure Point Concentrations

Data from past sampling at the Site were used for this SLERA and were considered adequate for identifying COPCs and ROPCs from historical milling operations. A significant amount of soil cleanup was completed in 1995. Only post-remediation data were considered in this evaluation.

A full summary of the data used in the SLERA (including the number of samples collected in each media, number of detections, and minimum and maximum detections) is provided in Appendix F. Soil sample locations are shown on Figures 3-39 and 3-40. Sample analyses included radionuclides and inorganics although not all media and locations were analyzed for all of these constituents in each sampling event.

EPCs were selected based on maximum detected concentrations for each COPC from the areas of concern for each media.

- **Soil - Homestake Facility and Soil - LTAs.** Refer to Appendix F. Data were obtained from EPA (EPA 2014a), ORISE (ORISE 2019), and ERG (ERG 2014; 2018) and include Homestake Facility samples and LTA samples. Older as well as newer soil data were included to adequately represent current conditions at the Site and avoid introducing data gaps. It was assumed that soil concentrations were not likely to change as much seasonally or over time as air and pond water concentrations would, and so using older data would not introduce excessive uncertainty.
- **Evaporation Pond Surface Water.** Refer to Appendix F. Data were obtained from HMC Semi-Annual Monitoring Reports (HMC 2019c) and included samples from EP-1, EP-2, EP-

3-A, EP-3-B, the East Collection Pond, and the West Collection Pond. Only the most recent surface water data were used to adequately reflect current conditions at the Site.

- **Evaporation Pond Sediments.** Data were obtained for a limited subset of analytes for pond sediments or sludge from the West Collection Pond and EP1 (ERG 2017). This is not the white crust, which is a saline evaporite lining the banks, but sediments in the pond.

5.3.1.2.2 ESV/RESL Selection

Ecological screening values (ESVs) and radioecological screening levels (RESLs) used in the screening-level ecological effects characterization are summarized in Tables 5-41 and 5-42, respectively for all chemical constituents for which soil, surface water or sediment data are available and relevant radionuclides (See Section 5.3.2.3). ESVs (also called ecotoxicity values or benchmark values) represent conservative thresholds for adverse ecological effects. RESLs correspond to the No Observed Radiological Effect Level (NOREL) for virtually any nonhuman organism or any ecosystem.

In selecting ESVs and RESLs for soil, preference was given to sources from EPA, other federal governmental agencies, and the NMED. For evaluating wildlife that may occasionally ingest water from the evaporation ponds, acute ESVs are not available for bird and mammals. ESVs based on acute National Ambient Water Quality Criteria (NAWQC) for aquatic life were selected as a surrogate. This approach is overly conservative for this evaluation and will overestimate the potential for risk as aquatic life are typically much more sensitive to water-borne constituents than terrestrial life since gill membranes allow for rapid and efficient transport of water-soluble constituents directly into the blood stream.

The soil RESLs were considered representative of sediments since the intent is not to protect a benthic invertebrate community but to protect terrestrial animals that may incidentally and infrequently contact sediments in the evaporation ponds. The soil RESLs should be adequately conservative since terrestrial animals are not expected to remain in constant contact with sediments due to lack of prey or cover in the evaporation pond area.

5.3.1.2.3 COPCs/ROPCs with no ESVs/RESLs

Table 5-43 summarizes constituents that were included in historical data but for which ecological screening values do not exist. None of the constituents listed in Table 5-43 are identified as a concern in any of the historical evaluations reviewed for this SLERA. Most have short half-lives and are daughter products of parent compounds that are included in this SLERA. As such, these constituents were not evaluated quantitatively in this SLERA (see Section 5.3.9):

- Pb-214 (half-life 27 minutes) and Bi-214 (half-life 20 minutes) are daughters of Ra-226.
- Pb-212 (half-life 11 hours), Bi-212 (half-life 61 minutes), and Tl-208 (half-life 3 minutes) are daughters of Th-228.
- Th-234 (half-life 24 days) and Pa-234m (half-life 1 minute) are daughters of U-238.
- Th-227 (half-life 19 days) and Ra-223 (half-life 11 days) are daughters of U-235.
- Tl-208 (half-life 3 minutes) is a daughter of Ra-228

Table 5-41 Ecological Screening Values for Site Media

Chemical	Soil ESVs					Evaporation Pond ESVs
	Plants (mg/kg)	Invertebrates (mg/kg)	Avian (mg/kg)	Mammals (mg/kg)	ESV (mg/kg)	Surface Water (mg/L)
Arsenic	18 [a]	60 [b]	43 [a]	46 [a]	18 [c]	0.34 [d]
Lead	120 [a]	1,700 [a]	11 [a]	56 [a]	11 [c]	0.065 [d]
Manganese	NA	NA	NA	NA	NA	0.120[d]
Molybdenum	2 [b]	Not Established	15	Not Established	2 [c]	160 [e]
Nitrate	NA	NA	NA	NA	NA	3[g]
Selenium	0.52 [a]	4.1 [a]	1.2 [a]	0.63 [a]	0.52 [c]	0.0015 [f]
Uranium	5 [b]	Not Established	1,100 [h]	480 [h]	5 [c]	0.046 [e]
Vanadium	2 [b]	Not Established	7.8 [a]	280 [a]	2 [c]	0.28 [e]

[a] EPA EcoSSL, ECOTOX Database (www.epa.gov/ecotox) (EPA, 2010).
[b] No EPA EcoSSL available; value from Oak Ridge National Laboratory (ORNL) (Sample et al. 1997).
[c] Selected ESV for initial screening in this SLERA. Lowest plant, soil invertebrate, avian, and mammalian ESV selected.
[d] EPA National Recommended Water Quality Criteria, Aquatic Life, Freshwater Acute (assumed hardness of 100 mg/L in the absence of Site-specific data).
[e] Suter and Tsao, 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota (Freshwater, Tier II Acute)
[f] Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater. EPA 822-P-15-001. July 2015).
[g] Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, and Ammonia). Water Stewardship Division Ministry of Environment, Province of British Columbia (Nordin and Pommen, 2009)
[h] LANL 2019. QrESLss. 03/13/19.
NA – Not applicable

Table 5-42 Radioecological Screening Levels for Site Media

Radionuclide	Soil or Sediment RESLs					Evaporation Pond RESLs
	Plants (pCi/g)	Burrowing Animals (pCi/g)	Deer (pCi/g)	Mountain Lion (pCi/g)	ESV (pCi/g)	Surface Water (pCi/L)
Cesium-137	2,460 [a]	3,180 [a]	254 [a]	1,000 [a]	254 [b]	6,190 [c]
Radium-226	21.2 [a]	985 [a]	61.5 [a]	575 [a]	21.2 [b]	160 [c]
Radium-228	1430 [a]	1,700 [a]	57.3 [a]	584 [a]	57.3 [b]	0.9[e]
Thorium-228	16.1 [a]	1,190 [a]	180 [a]	1,030 [a]	16.1 [b]	60 [d]
Thorium-230	112 [a]	39,600 [a]	280 [a]	2,120 [a]	112 [b]	413 [d]
Thorium-232	131 [a]	8,070 [a]	56.2 [a]	425 [a]	56.2 [b]	477 [d]
Uranium-234	110 [a]	63,200 [a]	442 [a]	4,070 [a]	110 [b]	400,000 [c]
Uranium-235	117 [a]	9,520 [a]	464 [a]	3,960 [a]	117 [b]	416,000 [c]
Uranium-238	118 [a]	36,700 [a]	466 [a]	4,230 [a]	118 [b]	455,000 [c]
U-natural	114[f]	49950[f]	454[f]	4150[f]	114[f]	--

[a] Radioecological Screen Level (RESL) (NMED 2000). Radiological screening involves sum of fractions when multiple radionuclides present.
[b] Selected ESV for initial screening in this SLERA. Lowest plant, borrowing animal, deer, and mountain lion RESL selected.
[c] NMED RESLs and DOE Benchmarks for surface water (NMED 2000, Tables 3-6 and 3-10).
[d] No NMED RESL available, value from Oak Ridge National Laboratory Radiological Benchmarks (Bechtel Jacobs Company, 1998).
[e] Ecorisk Database, Version 4.1. March 13, 2019. Minimum LANL ESL for algae (LANL 2019)
[f] U-natural is only evaluated for sediments because individual isotopic data are not available. Value is the average of U-234 and U-238 RESLs.

Table 5-43 Constituents Not Evaluated Quantitatively for Ecological Risk (No RESL)

Constituent	Minimum Detection (pCi/L)	Maximum Detection (pCi/L)	Constituent	Minimum Detection (pCi/L)	Maximum Detection (pCi/L)
Bi-212			**Pb-212**		
LTA Soil	0.45	1.71	LTA Soil	0.419	1.52
Homestake Facility Soil	0.39	2.04	Homestake Facility Soil	0.425	1.67
Bi-214			**Pb-214**		
LTA Soil	0.43	1.44	LTA Soil	0.485	1.55
Homestake Facility Soil	0.504	5.79	Homestake Facility Soil	0.54	6.13
Co-60			**Ra-223**		
LTA Soil	ND	ND	LTA Soil	0.093	0.364
Homestake Facility Soil	ND	ND	Homestake Facility Soil	0.097	0.67
I-131			**Th-227**		
LTA Soil	ND	ND	LTA Soil	0.087	0.087
Homestake Facility Soil	ND	ND	Homestake Facility Soil	0.047	0.227
K-40			**Th-234**		
LTA Soil	11.5	20.3	LTA Soil	0.27	2.09
Homestake Facility Soil	12.9	21.2	Homestake Facility Soil	0.28	11.2
Pa-234m			**Tl-208**		
LTA Soil	0.66	3.3	LTA Soil	0.134	0.5
Homestake Facility Soil	1.2	18.9	Homestake Facility Soil	0.138	0.527

5.3.1.3 Screening-Level Exposure Estimates and Risk Calculations

This step of the SLERA is comprised of the estimation of ecological intakes, risk estimation, risk characterization, and the evaluation of uncertainties. These form the foundation of evidence to support the scientific management decision point.

5.3.1.3.1 Risk Calculation Method for Inorganics

To estimate risk in the SLERA, HQs were used to calculate the screening level risk estimate for each COPC in each medium. An HQ is the unitless ratio of a constituent concentration in media to the ESV for that constituent in that medium considered protective of ecological receptors.

$$\text{Hazard Quotient} = \frac{\text{Exposure Point Concentration}}{\text{Ecological Screening Value}} \qquad \text{(Equation 1)}$$

An HQ less than or equal to 1 in the SLERA indicates that the constituent alone is unlikely to cause adverse ecological effects. However, an HQ > 1 does not in itself represent an unacceptable risk; but instead indicates that additional evaluation is needed to better determine the risk potential.

Maximum detected soil concentrations were used as the EPCs for soil (Homestake Facility and LTAs) and maximum detected surface water and sediment concentrations were used as the EPCs for the evaporation ponds. The lowest available soil ESVs for plants, soil invertebrates, and avian and mammalian wildlife were used in the calculations.

5.3.1.3.2 Risk Calculation Method for Radionuclides

Default RESLs were used to evaluate radioactive materials in soils, sediment, and surface water. The default RESLs are based on a set of mathematical models and modeling assumptions and use input parameters representative of the most sensitive species. As such, they provide a large margin of safety and a high level of assurance that concentrations below these values have a very low likelihood of having adverse radioecological effects. When multiple radionuclides are present, a Site will pass the radioecological screening process if the following equation is satisfied (referred to as the sum of fractions rule):

$$\left[SUF = \sum {}^{Ci}/_{RESLi}\right] < 1.0$$

where:

SUF = sum of fractions (Equation 2)

Ci = concentration or radionuclide i in soil (pCi/g)

RESLi = limiting RESL for radionuclide i in soil

5.3.1.4 Initial Screening Level Results

The following subsections summarize results of the initial screening (refer to Table 5-44 through 5-50). Note that there were no inorganic analytes in the sediment samples, thus a table for inorganics is not presented. For each constituent screened with an HQ exceeding 1, an initial SMDP was reached that information was not adequate to make a decision regarding adverse ecological effects and the constituent was carried forward for evaluation in Step 3a.

Table 5-44 Soil Screening – Inorganics Homestake Facility

Chemical	Max Conc. (mg/kg)	Sample Location	ESV (mg/kg)	HQ	COPC Selection
Arsenic	9.58	6F	18	0.5	No
Lead	19.7	10E	11	2	Yes – HQ > 1
Molybdenum	126	3A	2	63	Yes – HQ > 1
Selenium	11.1	6F	0.52	21	Yes – HQ > 1
Uranium (total)	44	EP3-2	5	9	Yes – HQ > 1
Vanadium	60.7	6F	2	30	Yes – HQ > 1

Shading indicates COPC retained for further evaluation.

Table 5-45 Soil Screening – Radionuclides Homestake Facility

Radionuclide	Max Conc. (pCi/g)	Sample Location	RESL (pCi/g)	HQ	COPC Selection
Cesium-137	0.15	10C	254	0.0	No
Radium-226	9	EP3-1	21.2	0.4	No
Radium-228	1.71	6F	57.3	0.0	No
Thorium-228	2.34	6B	16.1	0.1	No
Thorium-230	7.4	EP3-3	112	0.1	No
Thorium-232	1.81	6C	56.2	0.0	No
Uranium-234	18.3	3A	110	0.2	No
Uranium-235	0.697	3A	117	0.0	No
Uranium-238	19	3A	118	0.2	No
Sum of Fractions (SUF)				**1**	

Shading indicates COPC retained for further evaluation.

Table 5-46 Soil Screening – Inorganics Land Treatment Areas

Chemical	Max Conc. (mg/kg)	Sample Location	ESV (mg/kg)	HQ	COPC Selection
Arsenic	6.79	FIA2-1	18	0.4	No
Lead	18.0	FIA2-1	11	2	Yes – HQ > 1
Molybdenum	4	FIA2-1	2	2	Yes – HQ > 1
Selenium	2.6	34F-B1	0.52	5	Yes – HQ > 1
Uranium (total)	7.47	5328S0033A	5	1	No
Vanadium	39.6	FIA2-1	2	20	Yes – HQ > 1

Shading indicates COPC retained for further evaluation.

[a] Maximum uranium concentration estimated by converting maximum U-238 concentration to mg/kg.

Table 5-47 Soil Screening – Radionuclides Land Treatment Areas

Radionuclide	Max Conc. (pCi/g)	Sample Location	RESL (pCi/g)	HQ	COPC Selection
Cesium-137	0.114	P2-1	254	0.0004	No
Radium-226	3.9	33F-S-11-0015-121238	21.2	0.2	No
Radium-228	1.66	FIA2-1	57.3	0.03	No
Thorium-228	1.84	FIA3-2	16.1	0.1	No
Thorium-230	3.4	5328S0013A	112	0.03	No
Thorium-232	1.92	FIA3-2	56.2	0.03	No
Uranium-234	2.73	FIA2-1	110	0.02	No
Uranium-235	0.193	FIA2-1	117	0.002	No
Uranium-238	2.49	FIA2-1	118	0.02	No
Sum of Fractions				**0.4**	

Table 5-48 Evaporation Pond Surface Water Screening – Inorganics

Chemical	Max Conc. (mg/L)	ESV (mg/L)	HQ	COPC Selection
Manganese	1.4	0.120	12	Yes – HQ>1
Molybdenum	760	160	30	Yes – HQ > 1
Nitrate	9	3	3	Yes – HQ >1
Selenium	5.98	0.0015	3,987	Yes – HQ > 1
Uranium –natural (total)	2,940	0.046	63,913	Yes – HQ > 1
Vanadium	0.32	0.28	1	No

Shading indicates COPC retained for further evaluation.

Table 5-49 Evaporation Pond Surface Water Screening – Radionuclides

Radionuclide	Max Conc. (pCi/L)	RESL (pCi/L)	HQ	COPC Selection
Radium-226	130	160	0.8	No
Radium-228	140	0.9	156	Yes – HQ >1
Thorium-230	2,210	413	5	Yes – HQ > 1
Sum of Fractions			**162**	

All ROPCs retained for further evaluation; shading indicates the HQ>1

Table 5-50 Evaporation Pond Sediment Screening – Radionuclides

Radionuclide	Max Conc. (pCi/L)	RESL (pCi/g)	HQ	COPC Selection
Radium-226	32.5	21.2	2	Yes – HQ >1
Thorium-230	0.5	112	0.004	No
Uranium-natural	2566	114[a]	23	Yes – HQ >1
Sum of Fractions			**25**	

[a] Use average of ESVs of major components of U-natural, which are U-234 and U238.
All ROPCs retained for further evaluation; shading indicates the HQ>

5.3.1.4.1 Soil (Homestake Facility) Initial Screening Level Results

Soil assessment endpoint 1 (protection of plants and soil invertebrates) and soil assessment endpoint 2 (protection of terrestrial wildlife) were evaluated by calculating HQs from maximum detected soil concentrations divided by the lowest available soil ESV/RESL for plants, soil invertebrates, and avian and mammalian wildlife.

As shown in Table 5-44, an HQ of 1 was exceeded for the following inorganics: lead, molybdenum, selenium, uranium, and vanadium. As shown in Table 5-45, no individual radionuclides exceeded an HQ of 1 and the sum of fractions for all detected radionuclides does not exceed 1.

5.3.1.4.2 Soil (Land Treatment Areas) Initial Screening Results

Soil assessment endpoint 1 (protection of plants and soil invertebrates) and soil assessment endpoint 2 (protection of terrestrial wildlife) were evaluated by calculating HQs from maximum detected soil concentrations divided by the lowest available soil ESV/RESL for plants, soil invertebrates, and avian and mammalian wildlife.

As shown in Table 5-46, an HQ of 1 was exceeded for the following inorganics: lead, selenium, and vanadium. As shown in Table 5-47, no individual radionuclides exceeded an HQ of 1 and the sum of fractions for all detected radionuclides was below 1.

5.3.1.4.3 Evaporation Pond Surface Water and Sediment Initial Screening Results

Evaporation pond assessment endpoint 1 (protection of wildlife that may occasionally drink water from the evaporation ponds) was evaluated by calculating HQs from maximum detected surface water concentrations divided by the lowest calculated Site specific ESV for avian and mammalian wildlife and RESLs for aquatic environments.

As shown in Table 5-48, an HQ of 1 was exceeded for the following inorganics in evaporation pond surface water: manganese, molybdenum, nitrate, selenium, vanadium, and uranium. As shown in Table 5-49, individual radionuclides exceeded an HQ of 1 for Ra-228, and thorium-230. Individual HQs for radium -226 do not exceed 1 but contribute to the sum of fractions exceeding 1.

Sediment HQs are reported in Table 5-50. Radium-226 and uranium exceeded RESLs.

5.3.1.5 Step 3a - COPC/ROPC Refinement for BERA

The assumptions made in Steps 1 and 2 of the screening level risk analysis were designed to provide a conservative evaluation of potential risk based on the maximum detected constituent concentrations and maximized exposure scenarios. COPCs and ROPCs identified for further evaluation following the initial screening are summarized in Table 5-51.

Table 5-51 COPC/ROPC Identification Following Initial Screening

Chemical	Soil Homestake Facility	Soil Land Treatment Areas	Surface Water	Sediment
Arsenic	--	--	--	NV
Lead	HQ = 2	HQ = 2	--	NV
Manganese	NV	NV	HQ=12	NV
Molybdenum	HQ = 63	HQ = 2	HQ = 30	NV
Nitrate	NV	NV	HQ=3	NV
Selenium	HQ = 21	HQ = 5	HQ = 3987	NV
Uranium	HQ = 9	--	HQ = 63913	NV
Vanadium	HQ = 30	HQ = 20	--	NV
Radionuclide	**Soil Homestake Facility**	**Soil Land Treatment Areas**	**Surface Water**	**Sediment**
Radium-226	--	--	--	HQ = 2
Radium-228	--	--	HQ = 156	NV
Thorium-230	--	--	HQ = 5	--
Uranium-natural	--	--	--	HQ = 23

NV – No value because data unavailable

-- Not identified as a COPC/ROPC in the initial screening.

The presence of constituents in environmental media at concentrations above ESVs/RESLs does not necessarily constitute ecological risk or indicate that ecological risk is present under actual Site specific conditions. The maximum detected concentration is an over-estimate of the potential

average exposure level and constituents may not be absorbed into an organism's system following ingestion, or may not be absorbed through direct contact due to the chemical form of the constituent.

The objective of a Step 3a evaluation is to refine the list of COPCs/ROPCs identified Steps 1 and 2 of the BERA and determine if there are COPCs/ROPCs that warrant evaluation in additional steps of the ecological risk assessment process. The refinement of COPCs/ROPCs allows for the identification and characterization of potential ecological risks using more Site specific assumptions than were considered in the screening level evaluation.

COPCs that could not be eliminated based on maximum EPC and maximum exposure-based assumptions were further evaluated based on the following factors:

- Consideration of more realistic EPCs.
- Consideration of receptor-specific exposure.

In the refined COPC/ROPC selection, an EPC based on the 95 percent upper confidence limit (UCL95) of the mean for each chemical or radionuclide carried forward was calculated. The UCL95 is based on surface soil data only, and is generally regarded as an appropriately conservative estimator of the upper-bound, central tendency EPC that receptors foraging randomly throughout an exposure area would be expected to encounter.

With the exception of burrowing animals, ecological receptors only contact surface soils. In the Homestake Facility, maximum concentrations were higher in surface than subsurface soils for molybdenum, selenium, and uranium. In the LTAs, maximum concentrations of selenium and uranium were higher in surface than subsurface samples, and molybdenum does not carry forward as a COPC. Therefore, use of only surface soil data was considered a conservative assumption.

EPA's ProUCL Version 5.00.00 software (EPA 2016) was used to calculate the UCL95. The ProUCL recommended UCL95 was selected as the reasonable maximum EPC unless the recommended UCL was higher than the maximum detected concentration. In these instances, the lower of the selected UCL and the maximum detected concentration was used as the reasonable maximum EPC. Appendix F provides the output from ProUCL.

The resultant UCL95 EPC values were compared to the same ESVs used in the initial screening (see tables 5-52 through 5-56).

Table 5-52 Refined Soil Screening – Inorganics Homestake Facility

Chemical	UCL95 (mg/kg)	ESV (mg/kg)	HQ (UCL95)	COPC Refinement
Lead	15.53	11	1	No
Molybdenum	36.53	2	18	Yes – HQ > 1
Selenium	3.87	0.52	7	Yes – HQ > 1
Uranium	15.53	5	3	Yes – HQ > 1
Vanadium	39.47	2	20	Yes – HQ > 1

Shading indicates COPC retained for further evaluation.

Table 5-53 Refined Soil Screening – Inorganics Land Treatment Areas

Chemical	UCL95 (mg/kg)	ESV (mg/kg)	HQ (UCL95)	COPC Refinement
Lead	13.4	11	1	No
Molybdenum	2.45	2	1	No
Selenium	0.975	0.52	2	Yes – HQ > 1
Vanadium	25.15	2	13	Yes – HQ > 1

Shading indicates COPC retained for further evaluation.

Table 5-54 Refined Evaporation Pond Surface Water Screening – Inorganics

Chemical	UCL95 (mg/L)	ESV (mg/L)	HQ	COPC Refinement
Manganese	0.302	0.12	3	Yes – HQ > 1
Molybdenum	864.4	160	5	Yes – HQ > 1
Nitrate	2.135	3	0.7	No
Selenium	0.733	0.0015	488	Yes – HQ > 1
Uranium	548.8	0.046	11,930	Yes – HQ > 1
Vanadium	--	--	--	--

Concentrations are for total inorganics when both dissolved and total concentrations provided by laboratory.
Shading indicates COPC retained for further evaluation.

Table 5-55 Refined Evaporation Pond Surface Water Screening – Radionuclides

Radionuclide	UCL95 (pCi/L)	RESL (pCi/L)	HQ	ROPC Refinement
Radium-226	45.75	21.2	2	Yes –HQ > 1
Radium-228	71.01	0.9	79	Yes – HQ > 1
Thorium-230	1,200	413	3	Yes – HQ > 1
Sum of Fractions			**84**	

Shading indicates ROPC retained for further evaluation.

Table 5-56 Refined Evaporation Pond Sediment Screening – Radionuclides

Radionuclide	UCL95 (pCi/g)	RESL (pCi/g)	HQ	ROPC Refinement
Radium-226	32.5	21.2	2	Yes – HQ > 1
U-natural	2566	114	23	Yes – HQ > 1
Sum of Fractions			**25**	

Shading indicates ROPC retained for further evaluation.
The average of the RESLs for U-234 and U-238 was used to represent the RESL for U-natural

5.3.1.5.1 Soil (Homestake Facility) Refined Screening Results

As shown in Table 5-52 for Homestake Facility soil, UCL95 concentrations result in an HQ of greater than one for molybdenum, selenium, uranium, and vanadium.

5.3.1.5.2 Soil (Land Treatment Areas) Refined Screening Results

As shown in Table 5-53 for LTA soil, the UCL95 concentration results in an HQ greater than one for selenium and vanadium.

5.3.1.5.3 Evaporation Pond Surface Water and Sediment Refined Screening Results

As shown in Table 5-54 for evaporation pond surface water, UCL95 concentrations exceed an HQ of 1 for manganese, molybdenum, selenium, and uranium. As shown in Table 5-55 for evaporation pond surface water, Ra-226, Ra-228, and Th-230 UCL95 concentrations exceed an HQ of 1.

Table 5-56 shows the screening results for sediment based on maximum measured concentrations. These results cannot be refined with a UCL95 due to the small sample size.

5.3.1.6 SLERA Uncertainty Analysis

The SLERA by definition is a highly conservative analysis. The evaluation is intended to separate those media or constituents that are not a potential threat to the environment from those that are. In order to make this distinction, the following assumptions are used:

- The maximum measured concentration is utilized in the evaluation for each analyte. This is expected to bias risk results high.
- The minimum screening levels for any receptor is used. In combination with the maximum EPC, the maximum HQ is obtained. In selecting ESVs and RESLs for soil, preference was given to sources from EPA, other federal governmental agencies, and the NMED. This is not expected to bias risk results high or low.
- ESVs were not available for some constituents. A reasonable surrogate was used were applicable (i.e., the average of ESVs for U-234 and U-238 to represent U-natural).
- Radionuclides with very short half-lives without ESVs were not evaluated because they would not provide chronic exposure. This is not expected to bias risk results low.
- For evaluating wildlife that may occasionally ingest water from the evaporation ponds, ESVs based on acute NAWQC for aquatic life were selected as a surrogate. This approach is overly conservative for this evaluation and will overestimate the potential for risk as aquatic life are typically much more sensitive to water-borne constituents than terrestrial life since gill membranes allow for rapid and efficient transport of water-soluble constituents directly into the blood stream. There are no aquatic life in the ponds as they are artificial impoundments receiving water from the RO plant. Aquatic life are typically more sensitive because they are continually immersed in water than are birds and mammals that briefly contact water for drinking. The ESVs and RESLs are expected to bias risk results high.
- There are also uncertainties with respect to the analytical data. If there are unknown but rejected data in the dataset, then there is additional uncertainty in the risk results. There is also a mixture of older and newer data, because it was assumed that soil concentrations were not likely to change as much seasonally or over time as air and pond water concentrations would, and so using older data would not introduce excessive uncertainty. This is not expected to bias risk results high or low.

5.3.2 Baseline Ecological Risk Assessment (BERA)

The following sections describe the BERA. Exposure assumptions are further refined to reflect Site-specific conditions. Risk estimates are therefore also more representative of Site-specific

conditions. Table 5-57 indicates the locations and analytes evaluated in each medium in the BERA:

Table 5-57 COPC/ROPC Identification Following Refined Screening

Chemical	Soil Homestake Facility	Soil Land Treatment Areas	Surface Water	Sediment
Manganese	--	--	HQ = 3	--
Molybdenum	HQ = 10	--	HQ = 5	--
Selenium	HQ = 3	HQ = 2	HQ = .833	--
Uranium	HQ = 3	--	HQ = 11,930	--
Vanadium	HQ = 20	HQ = 13	--	--
Radionuclide	**Soil Homestake Facility**	**Soil Land Treatment Areas**	**Surface Water**	**Sediment**
Radium-226	--	--	HQ = .2	2
Radium-228	--	--	HQ = 792	--
Thorium-230	--	--	HQ = 3	--
Uranium-natural	--	--	--	22

-- Not identified as a COPC/ROPC in the refined screening.

5.3.2.1 Exposure Assessment

COPCs and ROPCs identified following the refined screening with UCL95 EPCs are summarized in Table 5-57.

Birds and mammals were further evaluated in the BERA. Because plants and invertebrates are immobile, application of exposure assessment refinements does not alter HQs predicted for these taxa. To further evaluate the assessment endpoints identified in Section 5.3.1.8 for avian and mammalian receptors, a food web model was used and receptor-specific exposures were estimated. Food chain modeling was applied to the non-radionuclide COPCs, whereas surface water and sediment ROPC concentrations were compared against the Los Alamos National Laboratory Ecorisk Database (LANL) RESLs because food chain modeling is already incorporated into the LANL values.

- **Soil Assessment Endpoint 2 –** Protection and maintenance of terrestrial wildlife receptors within the Homestake Facility and LTA upland habitat areas.
- **Evaporation Pond Assessment Endpoint 1 –** Protection and maintenance of wildlife receptors that may occasionally ingest water from the evaporation ponds.

The calculation of chemical constituent doses provides the means, when compared to toxicity, reference values for drawing inferences regarding the protection of avian and mammalian receptors. Exposure was modeled using the methods described in the EPA's *Wildlife Exposure Factors Handbook* (EPA 1993). The approach and the parameters are described in detail in the following sections.

$$HQ_j = \frac{\left(\left(Soil_j * P_s * DIR\right) + \left(SW_j * WIR\right) + \left(\sum_{i=1}^{N} B_i * P_i * DIR\right)\right) * AUF}{TRV_j} \quad \text{(Equation 3)}$$

where:

HQ_j = Hazard quotient for contaminant (j) (unitless)

$Soil_j$ = Concentration of contaminant (j) in soil (mg/kg dry weight)

P_s = Soil ingestion as proportion of diet

DIR = Dietary ingestion rate (kg food [dry weight (dw)]/kg body weight/day)

SW_j = Concentration of contaminant (j) in surface water (mg/L)

WIR = Water ingestion rate (L/day)

B_i = Concentration of contaminant in biota type (i) (mg/kg dw)

P_i = Proportion of biota type (i) in diet

TRV_j = Toxicity reference value for contaminant (j) (mg/kg-d)

AUF = Area use factor (set equal to 1 for screening)

5.3.2.1.1 Representative Receptors

It is not feasible to evaluate exposures and risks for each avian and mammalian species potentially present at the Site. For this reason, several species were selected to serve as representative species (surrogates) of several different feeding guilds. Risk to protected species that may occasionally pass through the Site can be indirectly determined or implied within the selections of the species models and input parameters for assessment endpoints appropriate to the protected species. In the case of protected species (i.e., migratory birds, bald eagles), adverse effects to individual organisms could have population-level consequences.

Representative wildlife receptors selected for the Site are summarized in Table 5-58. Selection was based on receptors representing key feeding guilds and ecological communities known and/or expected to be present in the Site vicinity (see Table 2-4) for which adequate life history data are available.

Table 5-58 Representative Receptors

Feeding Guild	Representative Receptor	Ecological Attributes
Avian herbivore	Scaled Quail (*Callipepla squamata*)	Herbivorous birds are an important prey item for many higher trophic level predators. They are important in seed dispersal for many plants in both terrestrial and aquatic ecosystems.
Avian invertivore	American Robin (*Turdus migratorius*)	Invertivorous birds are an important prey item for higher trophic level predators. Also, they consume insects and other soil invertebrates, which may have taken up Site-related constituents in their tissues.
Avian carnivore	American Kestrel (*Falco sparverious*)	Carnivorous birds provide an important functional role to the environment by regulating lower trophic-level prey populations. The kestrel is also selected as a surrogate for the bald eagle (*Haliaeetus leucocephalus*).[3] American kestrel is the most common falcon species in open and semi-open areas throughout North America. Compared to other birds of prey, the smaller body weight of the American kestrel yields a higher body weight-normalized ingestion rate and, therefore, a more conservative exposure assessment.
Mammalian herbivore	Ord's Kangaroo Rat (*Dipodomys ordi*)	Herbivorous mammals are an important prey item for many higher trophic level predators. They provide an important link for energy transfer between primary and higher trophic-level consumers. In addition, these organisms generally comprise the majority of the terrestrial tissue biomass, and are important in seed dispersal and pollination for many plant species. They are the direct link in the terrestrial food chain between plants and higher trophic-level organisms.
Mammalian omnivore	Deer Mouse (*Peromyscus maniculatus*)	Omnivorous mammals are an important prey item for higher trophic level predators, and influence lower trophic level populations through predation. They are the direct link in the terrestrial food chain between plants and higher trophic-level organisms.
Mammalian carnivore	Kit Fox (*Vulpes macrotis*	Carnivorous mammals provide an important functional role to the environment by regulating lower trophic-level prey populations.

5.3.2.1.2 Estimates of Exposure

Exposure to wildlife receptors was estimated for ingestion of soil and food chain exposure for soil in the Homestake Facility and in the LTAs and for ingestion of surface water from the evaporation ponds. There were no COPCs in sediment and therefore food chain modeling was not performed for this medium. Exposure assumptions (e.g., body weights, ingestion rates, etc.) are provided in Table

[3] As noted in Section 5.3.1.1, the bald eagle has been reported to potentially pass through the Site on occasion during migration. The American kestrel was selected to serve as a surrogate for this and other larger birds of prey potentially passing through the area.

5-59. Data were generally obtained from the EPA's Wildlife Exposure Factors Handbook (EPA 1993). Alternate sources were only used when the handbook did not provide sufficient information. Allometric equations (as cited in EPA 1993) were used to estimate the 90th percentile ingestion rate. The potential food chain exposure was conservatively modeled assuming receptors eat only prey items from the Site.

Simplified and conservative assumptions were used in the food chain modeling since it is difficult to mimic a complete diet. With the exception of the deer mouse, all other receptors were assumed to consume a single food type at the UCL95 concentration 100% of the time. Contaminant concentrations in biota types (the term for "B_i" in Equation 3 above) composing the wildlife diets were estimated by assuming that the concentration of the contaminant in the food type could be predicted from the concentration of the contaminant in the soil (Soilj) by using a bioaccumulation factor (see Table 5-60).

Table 5-59 Receptor-Specific Exposure Parameters

Parameter	Scaled Quail	Western Kingbird	American Kestrel	Ord's Kangaroo Rat	Deer Mouse	Kit Fox
Scientific Name	*Callipepla squamata*	*(Tyrannus verticalis)*	*Falco sparverious*	*Dipodomys ordi*	*Peromyscus maniculatus*	*Vulpes macrotis*
Habitat	Upland	Upland	Upland	Upland	Upland	Upland
Feeding Guild	Avian Herbivore	Avian Invertivore	Avian Carnivore	Mammalian Herbivore	Mammalian Omnivore	Mammalian Carnivore
Dietary Ingestion Rate (DIR) (kg/kg/d)						
DIR (min BW)	0.1831	0.2316	0.1011	0.1109	0.1918	0.0647
DIR (max BW)	0.1810	0.2241	0.0844	0.0849	0.1604	0.0565
Allometric Equation	=0.398*BW^0.850/BW	=0.398*BW^0.850/BW	=0.301*BW^0.751/BW	=0.621BW^0.564/BW	=0.621BW^0.564/BW	=0.235BW^0.822/ BW
Equation for	passerine	passerine	nonpasserine	rodent	rodent	all mammals
Soil Fraction in Diet (P)	0.1	0.1	0.028	0.02	0.02	0.028
Source	Beyer et al, 1994 woodcock	Beyer et al, 1994 woodcock	Beyer et al, 1994 red fox	Beyer et al, 1994 white footed mouse	Beyer et al, 1994 white footed mouse	Beyer et al, 1994 red fox
Diet (Pi)	100% plants	100% terrestrial Invertebrates	100% small mammals	100% plants	50% plants; 50% terrestrial invertebrates	100% small mammals
Water Ingestion Rate (WIR) (L/kg/d)						
WIR (min BW)	0.104	0.175	0.136	0.133	0.151	0.096
WIR (max BW)	0.102	0.163	0.107	0.125	0.145	0.089
Allometric Equation	=0.059BW^0.67 /BW	=0.059BW^0.67 /BW	=0.059BW^0.67 /BW	=0.099BW^0.9/BW	=0.099BW^0.9/BW	=0.099BW^0.9/BW
Body Weight (BW) (g for birds; kg for mammals)						
BW Minimum	177	37	80	0.052	0.0148	1.4
BW Maximum	191	46	165	0.096	0.0223	3
Source	Schemnitz, 1994	EPA, 1993	EPA, 1993	Smithsonian, 2009	EPA, 1993	Meyer, 2009

Notes: All data from EPA, 1993 unless otherwise stated.
Shaded cells indicate parameter estimated with algometric equations from EPA, 1993

Table 5-60 Equations to Estimate Contaminant Concentration in Different Biota Types

COPC	Herbivore Uptake Equation for Plants (mg/kg dw)	Invertivore Uptake Equation for Earthworms (mg/kg dw)	Carnivore Uptake Equation for Small Mammals (mg/kg dw)
Arsenic	$B_i = 0.03752*(Soilj)$	$B_i = e^{0.76*\ln(Soilj) -1.421}$	$B_i = e^{0.8188*\ln(Soilj) -4.8471}$
Lead	$B_i = e^{0.561*\ln(Soilj) -1.328}$	$B_i = e^{0.807*\ln(Soilj) -0.218}$	$B_i = e^{0.4422*\ln(Soilj) + 0.0761}$
Molybdenum	$B_i = 0.085*(Soilj)$	$B_i = 0.209*(Soilj)$	$B_i = 0.01*(Soilj)$
Selenium	$B_i = e^{1.104*\ln(Soilj) -0.677}$	$B_i = e^{0.733*\ln(Soilj) -0.075}$	$B_i = e^{0.3764*\ln(Soilj) -0.4158}$
Uranium	$B_i = 0.002*(Soilj)$	$B_i = 0.063*(Soilj)$	Not Available
Vanadium	$B_i = 0.00485*(Soilj)$	$B_i = 0.042*(Soilj)$	$B_i = 0.0123*(Soilj)$

Sources:
Values for arsenic, lead, selenium, and vanadium from EPA Ecological Soil Screening Level (Eco-SSL) Table 4a, EcoSSL Attachment 4-1 (2007 Update)
Values for molybdenum and uranium from Sample et al., 1996b and Efroymson, 1997.

5.3.2.2 Toxicity Assessment

Once exposure is estimated with the food chain model described above, the estimated exposure is compared to a toxicity reference value (TRV). TRVs for terrestrial wildlife that could ingest soil, sediments, and evaporation pond surface water are provided in Table 5-61. Chronic NOAELs and chronic LOAELs were used as measures of effect. In addition, acute TRV values were considered for surface water COPCs exceeding an LOAEL HQ of 1.

Due to human disturbance and a lack of quality habitat and cover, evaporation pond exposure is limited in duration compared to the basis of chronic NOAEL/LOAEL TRVs. The evaporation ponds have no naturally occurring aquatic or benthic life and have no discharge point other than evaporation. They will be removed following completion of the groundwater restoration program (thereby eliminating potential exposure pathways for ecological receptors). They are fenced and access is limited. As such, the acute TRVs are considered appropriate for evaluating measures of effect.

TRVs were not available for the ROPCs, some of which carried forward in surface water and sediment. New Mexico Environment Department presents normalized dose rates that can be multiplied by the measured activity and then divided by a no effect activity for birds or mammals of 0.1 rem/d (NMED 2000). Alternatively, LANL has RESLs for various avian and mammalian species that have already accounted for the normalized internal and external dose rates due to soil, water and food ingestion (LANL 2019). The LANL No Effect ESL values (Table 5-62) were applied in this step of the risk assessment. Values for soils were applied to sediments as well, even though sediments might be less frequently contacted.

Table 5-61 Wildlife TRVs

COPC	Avian TRVs (mg/kg-day)			Mammalian TRVs (mg/kg-day)		
	NOAEL	LOAEL	Acute	NOAEL	LOAEL	Acute
Manganese	179[f]	348[f]	435 [f]--	51.5[f]	65[f]	136[f]
Molybdenum	3.50 [b]	35.3 [b]	[c]	0.26 [b]	2.60 [b]	40 [d]
Selenium	0.29 [a]	0.606 [a]	--	0.143 [a]	0.437 [a]	--
Uranium	16.00 [b]	160 [b]	1,600 [b]	3.07 [b]	6.13 [b]	118 [e]
Vanadium	0.344 [a]	1.19 [a]	--	4.16 [a]	5.92 [a]	--

-- TRV not needed as calculated LOAEL and/or NOAEL HQs were below 1 for all receptors in all media.
[a] EPA Ecological Soil Screening Level (Eco-SSL) documents (*www.epa.gov/ecotox/ecossl*).
[b] Toxicological Benchmarks for Wildlife (Sample et al., 1996a).
[c] TRV not found in literature.
[d] Acute NOAEL dose for developmental toxicity to Spraque Dawley rats, Reproductive Toxicology 49 (2014) 202-208 (Murray, et al., 2014).
[e] Acute NOAEL dose for hepatic or renal toxicity to Spraque Dawley rats, Toxicological Profile for Uranium (ATSDR, 2013).
[f] EcoSSL for Manganese (EPA 2007b) – TRV for EcoSSL and lowest bounded LOAEL for the categories growth, reproduction, and mortality. Acute avian dose is a 14 day NOAEL for chicken, number 34, Appendix 5.1. Acute mammalian dose is a 1 day NOAEL for hamster, study number 96, Appendix 6.1.

Table 5-62 Receptor-Specific RESLs for Surface Water and Sediment

Receptor	Feeding Guild	Surface Water (pCi/L)			
		Ra-228 NE ESL	Ra-228 LE ESL	Th-230 NE ESL	Th-230 LE ESL
American Kestrel	Avian insectivore/carnivore	1.0E06	1.00E07	4.2E07	4.20E08
American Robin	Avian herbivore/omnivore/ insectivore	9.9E05	9.90E06	4.2E07	4.20E08
Deer Mouse	Mammalian omnivore	1.1E07	1.10E08	7.8E08	7.80E09
Gray Fox	Mammalian carnivore	6.4E04	6.40E05	3.2E06	3.20E07
Receptor	**Feeding Guild**	**Soil/Sediment (pCi/g)**			
		Ra-226 NE ESL	**Ra-226 LE ESL**	**U-natural NE ESL**	**U-natural LE ESL**
American Kestrel	Avian insectivore/carnivore	6.1E01	6.1E02	1.4E04	1.4E05
American Robin	Avian herbivore/omnivore/ insectivore	8.2E00	8.2E01	1.1E03	1.1E04
Deer Mouse	Mammalian omnivore	3.8E02	3.8E03	7.4E02	1.8E03
Gray Fox	Mammalian carnivore	3.7E02	3.7E03	4.8E03	1.2E04

NE ESL – no effect ESL

LE ESL – lowest effect ESL

Source: LANL (2019). Lowest ESL value used as the NE ESL and LE ESL if animals were assigned to multiple feeding categories.

5.3.2.3 Risk Characterization

COPCs exceeding the refined screening in any media were carried forward into the BERA for receptor-specific evaluation (see Tables 5-63 through 5-69). ROPCs that exceeded the refined screening in any media are further evaluated in Tables 5-70.

A 90th percentile of the dietary ingestion rate (DIR) (Table 5-53) as estimated from the minimum and maximum DIR based on body weight was used to represent dietary intake and calculate soil and food dose. A 90th percentile water ingestion rate (WIR) (Table 5-53) estimated from the minimum and maximum body weight range was used to determine surface water exposure.

Table 5-63 Scaled Quail Risk Calculations – Soil Homestake Facility and Land Treatment Areas

COPC	Soil Homestake Facility					Soil Land Treatment Areas				
	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ
Molybdenum	0.67	0.16	1.24	0.4	--	--	--	--	--	--
Selenium	0.069	1.43	0.48	2	0.8	0.02	0.09	0.11	0.4	--
Uranium	0.26	0.0004	0.29	0.02	--	--	--	--	--	--
Vanadium	0.72	0.10	0.76	2	0.6	0.46	0.02	0.48	1	--

[a] Soil Dose = (Soil Concentration)*(90th percentile Dietary Ingestion Rate)*(Soil Fraction in Diet) (see Table 5-58)

[b] Food Dose calculated using herbivore uptake equation for plants presented in Table 5-59.

Shading indicates HQ exceeding 1.

-- Not calculated as NOAEL HQ does not exceed 1.

Table 5-64 Western Kingbird Risk Calculations – Soil Homestake Facility and Land Treatment Areas

COPC	Soil Homestake Facility					Soil Land Treatment Areas				
	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ
Molybdenum	0.84	1.76	2.6	0.7	--	--	--	--	--	--
Selenium	0.088	0.58	0.67	2	1	0.02	0.21	0.23	0.8	--
Uranium	0.33	0.23	0.58	0.04	--	--	--	--	--	--
Vanadium	0.91	0.38	1.3	4	1	0.58	0.24	0.82	2	0.7

[a] Soil Dose = (Soil Concentration)*(90th percentile Dietary Ingestion Rate)*(Soil Fraction in Diet) (see Table 5-58)

[b] Food Dose calculated using insectivore uptake equation for earthworms presented in Table 5-59.

Shading indicates HQ exceeding 1.

-- Not calculated as NOAEL HQ does not exceed 1.

Table 5-65 American Kestrel Risk Calculations – Soil Homestake Facility and Land Treatment Areas

COPC	Soil Homestake Facility					Soil Land Treatment Areas				
	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ
Molybdenum	0.10	0.04	0.14	0.04	--	--	--	--	--	--
Selenium	0.01	0.11	0.12	0.4	--	0.003	0.065	0.068	0.2	--
Uranium	0.04	No UF	0.04	0.003	--	--	--	--	--	--
Vanadium	0.11	0.05	0.16	0.5	--	0.070	0.031	0.101	0.3	--

[a] Soil Dose = (Soil Concentration)*(90th percentile Dietary Ingestion Rate)*(Soil Fraction in Diet) (see Table 5-58)

[b] Food Dose calculated using carnivore uptake equation for small mammals presented in Table 5-59. "No UF" indicates an uptake factor for prey is not available and dose cannot be calculated.

Shading indicates HQ exceeding 1.

-- Not calculated as NOAEL HQ does not exceed 1.

Table 5-66 Ord's Kangaroo Rat Risk Calculations – Soil Homestake Facility and Land Treatment Areas

COPC	Soil Homestake Facility					Soil Land Treatment Areas				
	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ
Molybdenum	0.13	0.34	0.47	2	0.2	--	--	--	--	--
Selenium	0.01	0.25	0.26	2	0.6	0.004	0.05	0.06	0.4	--
Uranium	0.06	0.003	0.06	0.02	--	--	--	--	--	--
Vanadium	0.14	0.02	0.17	0.04	--	0.092	0.01	0.11	0.03	--

[a] Soil Dose = (Soil Concentration)*(90th percentile Dietary Ingestion Rate)*(Soil Fraction in Diet) (see Table 5-58)

[b] Food Dose calculated using herbivore uptake equation for plants presented in Table 5-59.

Shading indicates HQ exceeding 1.

-- Not calculated as NOAEL HQ does not exceed 1.

Table 5-67 Deer Mouse Risk Calculations – Soil Homestake Facility and Land Treatment Areas

COPC	Soil Homestake Facility					Soil Land Treatment Areas				
	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ
Molybdenum	0.17	1.01	1.18	5	0.5	--	--	--	--	--
Selenium	0.018	0.45	0.47	3	1	0.005	0.133	0.137	1	0.7
Uranium	0.072	0.095	0.17	0.1	--	--	--	--	--	--
Vanadium	0.182	0.17	0.36	0.1	--	0.116	0.111	0.227	0.1	--

[a] Soil Dose = (Soil Concentration)*(90th percentile Dietary Ingestion Rate)*(Soil Fraction in Diet) (see Table 5-58)
[b] Food Dose calculated using herbivore uptake equation for plants (50%) and insectivore uptake equation for earthworms (50%) presented in Table 5-59.
Shading indicates HQ exceeding 1.
-- Not calculated as NOAEL HQ does not exceed 1.

Table 5-68 Kit Fox Risk Calculations – Soil Homestake Facility and Land Treatment Areas

COPC	Soil Homestake Facility					Soil Land Treatment Areas				
	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ	Soil Dose[a] (mg/kg-d)	Food Dose[b] (mg/kg-d)	Total Dose (mg/kg-d)	NOAEL HQ	LOAEL HQ
Molybdenum	0.102	0.023	0.125	0.5	--	--	--	--	--	--
Selenium	0.011	0.070	0.081	0.6	--	0.003	0.042	0.044	0.3	--
Uranium	0.043	No UF	0.043	0.01	--	--	--	--	--	--
Vanadium	0.11	0.031	0.141	0.03	--	0.070	0.020	0.090	0.02	--

[a] Soil Dose = (Soil Concentration)*(90th percentile Dietary Ingestion Rate)*(Soil Fraction in Diet) (see Table 5-58)
[b] Food Dose calculated using carnivore uptake equation for small mammals presented in Table 5-59. "No UF" indicates an uptake factor for prey is not available and dose cannot be calculated.
Shading indicates HQ exceeding 1.
-- Not calculated as NOAEL HQ does not exceed 1.

Table 5-69 Receptor-Specific Risk Calculations – Evaporation Pond Surface Water

COPC	TRVs		EPC	HQs					
	Birds (mg/kg-d)	Mammals (mg/kg-d)	Surface Water UCL95 (mg/L)	Scaled Quail	American Robin	American Kestrel	Ord's Kangaroo Rat	Deer Mouse	Kit Fox
	NOAEL TRVs			NOAEL HQs					
Manganese	179	51.5	0.302	0.0002	0.0003	0.0002	0.0008	0.0009	0.0006
Molybdenum	3.53	0.26	864.4	26	43	33	440	500	316
Selenium	0.29	0.143	0.733	0.3	0.4	0.3	1	1	0.5
Uranium-natural	16	3.07	548.8	4	6	5	24	27	17
	LOAEL TRVs			LOAEL HQs					
Manganese	179	51.5	0.302	--	--	--	--	--	--
Molybdenum	35.3	2.6	864.4	3	4	3	44	50	32
Selenium	0.606	0.437	0.733	--	--	--	--	--	--
Uranium-natural	160	6.13	548.8	0.4	0.6	0.5	12	13	9
	Acute TRVs			Acute HQs					
Manganese	435	136	0.302						
Molybdenum	[b]	40	864.4	[b]	[b]	[b]	2	2	1
Uranium-natural	1600	118	548.8	0.04	0.1	0.05	0.6	0.7	0.4

Shading indicates HQ exceeding 1.
[a] No LOAEL TRV found in literature.
[b] No acute TRV found in literature.
Concentrations shown are on a total basis.

Table 5-70 Evaporation Pond Surface Water and Sediment Receptor-Specific Evaluation

ROPC	Surface Water UCL95 (pCi/L)	Receptor-Specific No Effect RESLs (pCi/g) American Kestrel	American Robin	Deer Mouse	Gray Fox	No Effect HQs American Kestrel	American Robin	Deer Mouse	Gray Fox
Ra-228	71.01	1000000	990000	11000000	64000	0.00007	0.0001	0.00001	0.001
Th-230	1200	42000000	42000000	780000000	3200000	0.00003	0.00003	0.000002	0.0004
ROPC	**Sediment Maximum (pCi/g)**	**Receptor-Specific No Effect RESLs (pCi/g) American Kestrel**	**American Robin**	**Deer Mouse**	**Gray Fox**	**No Effect HQs American Kestrel**	**American Robin**	**Deer Mouse**	**Gray Fox**
Ra-226	32.5	61	8.2	380	370	0.5	4	0.08	0.08
U-nat	2566	14,000	1,100	740	4800	0.2	2	3	0.5
Sum of Fractions (SUF)						0.7	6	3	0.6
ROPC	**Sediment Maximum (pCi/g)**	**Low Effect RESLs (pCi/g) American Kestrel**	**American Robin**	**Deer Mouse**	**Gray Fox**	**Low Effect HQs American Kestrel**	**American Robin**	**Deer Mouse**	**Gray Fox**
Ra-226	32.5	--	82	--	--	--	0.4	--	--
U-nat	2566	--	11,000	1,800	--	--	0.2	1	--
Sum of Fractions (SUF)							0.6	1	

ROPC RESLS from LANL 2019

Shading indicates HQ exceeding 1

5.3.2.3.1 Soil- Homestake Facility

5.3.2.3.1.1 COPCs

COPCs were evaluated for receptor-specific exposure in a food web model. As shown in Tables 5-63 through 5-69, NOAEL HQs exceed 1 for the following receptors:

- Scaled quail – selenium and vanadium
- Western kingbird – selenium and vanadium
- Kangaroo rat - molybdenum and selenium
- Deer mouse - molybdenum and selenium

As shown in Tables 5-63 through 5-69, no LOAEL HQs exceed 1. The American kestrel was selected as a surrogate for protected species (migratory birds, bald eagles) potentially passing through the area. As shown in Table 5-65, NOAEL HQs do not exceed 1 for any COPCs for the American kestrel. Based on these findings, exposure to soil at the Homestake Facility is not expected to result in unacceptable risks to terrestrial receptors.

5.3.2.3.1.2 ROPCs

No ROPCs were identified in soil following the initial screening (see Table 5-52).

5.3.2.3.2 Soil - Land Treatment Areas

5.3.2.3.2.1 COPCs

COPCs were evaluated for receptor-specific exposure in a food web model. As shown in Tables 5-63 through 5-69, NOAEL HQs exceed 1 for the following receptors:

- Western kingbird – vanadium
- Kangaroo rat - selenium
- Deer mouse - selenium

As shown in Tables 5-62 through 5-67, no LOAEL HQs exceed 1. The American kestrel was selected as a surrogate for protected species (migratory birds, bald eagles) potentially passing through the area. As shown in Table 5-65, NOAEL HQs do not exceed 1 for any COPCs for the American kestrel. Based on these findings, exposure to soil in the LTAs is not expected to result in unacceptable risks to terrestrial receptors.

5.3.2.3.2.2 ROPCs

No ROPCs were identified in soil following the initial screening (see Table 5-52).

5.3.2.3.3 Evaporation Ponds

5.3.2.3.3.1 COPCs

COPCs were evaluated for receptor-specific exposure. As shown in Table 5-69, manganese and selenium in evaporation pond surface water had HQs below 1 for all species and are not expected to result in unacceptable risks to terrestrial receptors.

As shown in Table 5-69, NOAEL HQs exceed 1 for all receptors for molybdenum and uranium. As shown in Table 5-69, LOAEL HQs exceed 1 for the following receptors.

- Scaled quail – molybdenum
- American robin –molybdenum
- American kestrel – molybdenum
- Ord's-Kangaroo rat - molybdenum, uranium
- Deer mouse – molybdenum, uranium
- Kit fox - molybdenum, uranium

As shown in Table 5-69, acute HQs exceed 1 for the following receptors.

- Ord's-Kangaroo rat - molybdenum
- Deer mouse – molybdenum

Because the acute HQ is below 1, uranium in evaporation pond surface water is not expected to result in unacceptable risks to terrestrial receptors. Additional evaluation of the uncertainties and assumptions is needed prior to making a conclusion regarding ecological effects from evaporation pond exposure to molybdenum.

5.3.2.3.3.2 ROPCs

As shown in Table 5-69, the UCL95 EPCs for Ra-226, Ra-228, and Th-230 in evaporation pond surface water are below receptor-specific no effect RESLs, and the sum of fractions is less than 1.

Table 5-69 also reports HQs for comparison to maximum sediment concentrations as EPCs, because a UCL95 could not be calculated due to low sample size. HQs are greater than 1 for the American robin (representing herbivorous, omnivorous, and insectivorous birds) for Ra-226 and uranium as represented by U-natural activity. HQs for uranium for the deer mouse also exceed 1. LANL has low effect RESLs, and all HQs based on dividing maximum concentrations by low effect RESLs were 1 or less (LANL 2019).

5.3.3 Evaluation of Uncertainties

This BERA has many sources of uncertainty that are associated with the conservative assumptions characteristic of any screening assessment.

Use of Generic ESVs/RESLs. The ESVs used in the screening evaluation are generic values developed using a variety of test species and experimental conditions that may not be representative of the receptors and Site specific environmental conditions. Therefore, application of these generic values adds uncertainty to the risk assessment because these values may not be directly relevant to environmental conditions at the Site (e.g., acclimation of ecological receptors over time to Site specific factors, differences in bioavailability of COPCs, heterogeneous soil matrices, etc.). In general, these values are developed using highly conservative assumptions and tend to incorporate significant margins of error. As such, the likelihood of adverse ecological effects could be overestimated for COPCs exceeding the ESV benchmarks.

The RESLs used to calculate HQs for ROPCs in the evaporation ponds are based on protection of aquatic life. The ERA used EPA's NAWQC to assess risk to birds and mammals even though the AWQC are not designed to protect these two receptor groups from toxicity due to ingestion of contaminated surface water. However, wildlife receptors are not expected to receive the same level of exposure via surface water ingestion compared to aquatic community-level receptor groups (e.g., algae, invertebrates, fish, larval amphibians) which are in constant direct and continuous contact with dissolved constituents. Use of the NAWQC as a screening tool was overly protective of avian and mammalian receptors that may ingest water from the ponds as a drinking water source. This conservative approach carried more analytes from the SLERA into the BERA than would have been the case if wildlife surface water ingestion criteria had been used in the analysis.

Analysis of Only Constituents with Established ESVs. Data gaps that exist in this BERA include a lack of available toxicity benchmarks for some COPCs/ROPCs. Toxicity benchmarks have been developed for the contaminants that are relatively toxic to wildlife, bioaccumulate, and are typically detected in the environment. Therefore, the COPCs/ROPCs that could not be assessed because of a data gap are less likely to pose significant risk than those for which adequate toxicity data exist.

Conservative Assumptions in Risk Calculations. Conservative assumptions regarding body weight, ingestion rates, area of use, etc. were used in the food web model. COPCs were assumed to be 100 percent available to receptors. This is a highly unlikely circumstance based on soil chemistry. Under many circumstances, both inorganic and organic compounds are chemically bound in the soil matrix and are not available for uptake by receptors.

Selection of Receptors for BERA. Receptors were selected that are likely to occur within the Site. Avian and mammalian receptors were evaluated for exposure to all media. The SLERA evaluated plants and invertebrates, but BERA did not evaluate them in any depth because the screening values are the only data for these taxa. The following evaluation helps reduce this uncertainty:

- Arsenic - Plants were the most sensitive taxa for arsenic in soils, and the ESV in the analysis was based on plants. Maximum arsenic concentrations were below the plant ESV.
- Lead - Plants and invertebrates were not the most sensitive taxa to lead by an order of magnitude or more. Lead screened out of the analysis.
- Molybdenum - Plants were the most sensitive taxa for molybdenum, and invertebrate toxicity data were lacking. Molybdenum UCL95 values in the Homestake Facility were 18 times higher than the plant ESV based on data from ORNL, but in the LTAs molybdenum did not carry forward as a COPC.
- Selenium - Plants were the most sensitive taxa for selenium, and invertebrate toxicity data were higher by about an order of magnitude. UCL95 values in the Homestake Facility were seven times higher than the plant EcoSSL used as the ESV, but in the LTAs selenium was only two times higher than the ESV.
- Uranium - Plants were the most sensitive taxa for uranium, and invertebrate toxicity data were not available. UCL95 values in the Homestake Facility were three times higher than the plant ESV from ORNL, but in the LTAs uranium did not carry forward as a COPC.
- Vanadium - Plants were the most sensitive taxa for vanadium, and invertebrate toxicity data were not available. UCL95 values in the Homestake Facility were 20 times higher than the

plant ESV from ORNL, and in the LTAs vanadium was 13 times higher than the ESV based on plants.

- Radionuclides – Plants were often the most sensitive taxa for radionuclide exposure. Radionuclides did not carry forward in soils at the Homestake Facility or LTAs. Therefore, plants have been evaluated for this stressor.

Comparison to Soil Background. With the exception of molybdenum and uranium, the Site does not appear to have elevated soil concentrations:

- Arsenic - Arsenic was at or below background in soils from the Homestake Facility and LTAs, and therefore the Site does not present an excess hazard.
- Lead - Lead was at or below background in soils from the Homestake Facility and LTAs, and therefore the Site does not present an excess hazard.
- Molybdenum – Molybdenum was above background in the Homestake Facility and LTAs.
- Selenium - Selenium was two times background in soils from the Homestake Facility, and below background in the LTAs.
- Uranium – Uranium was eight times higher than background in the Homestake Facility, but only two times higher than background in the LTAs.
- Vanadium - Vanadium was at or below background in soils from the Homestake Facility and LTAs
- Radionuclides – All the radionuclides were similar to or lower than background in the LTAs. Most of the radionuclide activities were only one to two times higher than background in the Homestake Facility, with the exception of U-natural.

Uncertainty in the Site Data. There is variability inherent in the Site data, which adds to uncertainty in the risk estimates based on the data. Soil samples collected from the Homestake Facility include a mix of samples that were collected from within areas that were remediated in 1995 and samples that were collected from areas that were not remediated in 1995. HMC sorted the soil analytical data and statically evaluated these two datasets. The evaluation concluded that datasets representing samples collected from remediated areas and samples collected outside remediated areas are not statistically unique. The Site data may also contain uncertainties due to analytical methodology, sample location, seasonal fluctuations in concentrations, or matrix interferences that produce false positives or negatives. Another uncertainty in the Site data is a lack of data for total uranium.

5.3.3.1 Conclusions

The results of the ecological risk analysis were analyzed and interpreted to determine the potential for adverse ecological effects and to determine whether or not a conclusion of no significant risk can be reached for each assessment endpoint evaluated. The ecological risk characterization summarizes the results of the risk analysis phase of work and provides interpretation of the ecological significance of the findings.

The outcome of the Step 2 screening level evaluation provided an initial identification of COPCs/ROPCs based on conservative screening level risk estimates and Step 3a refined the

COPC/ROPC selection process using more Site specific assumptions for exposure concentrations and ecological effects.

There are three possible decisions at this point in the BERA process:

- There is adequate information to conclude that ecological risks are negligible and therefore no need for remediation on the basis of ecological risk;
- The information is not adequate to make a decision at this point, and the ecological risk assessment process will continue; or
- The information indicates a potential for adverse ecological effects, and a more thorough assessment is warranted.

Homestake Facility and Land Treatment Area Soil. As discussed in Section 5.3.8, exposure to soil is not expected to result in unacceptable risks to terrestrial wildlife receptors. Some inorganics are elevated with respect to plants, but most of this is in the Homestake Facility area where more human disturbance occurs. No additional risk evaluation is warranted and remedial decision-making on the basis of ecological risk for these two areas is not recommended.

Evaporation Ponds. Evaporation pond surface water appears to provide limited potential for ecological risk to avian receptors given low chronic LOAEL and acute HQs (see Table 5-68). There is some uncertainty associated with risk from exposure to molybdenum in surface water because acute TRVs could not be determined for avian receptors.

For mammals, NOAEL and LOAEL HQs above one for molybdenum and uranium may indicate the potential for risk when using the evaporation ponds as a source of water. However, as discussed in Section 5.3.9, the HQ calculations used very conservative assumptions (receptors were assumed to eat and drink only from the Site even though the Site provides no quality habitat) that likely overestimate actual risk.

The RESLs used to calculate HQs for ROPCs in surface water are based on protection of aquatic life. Because there is no aquatic life in the ponds, the RESLs are overly conservative for the avian and mammalian receptors at the Site. Continual observations since the start of pond operations do not indicate any adverse effects to avian or mammalian receptors. Site operation crews inspect the ponds daily for wildlife in and around them and no mortality or other indicators have been reported since operation of the first pond began in 1990. Current permit provisions require no measures for mitigation to keep wildlife away from the ponds.

Given that the evaporation ponds will be removed following completion of the groundwater restoration program (thereby eliminating potential exposure pathways for ecological receptors) and there is no indication that pond operations to date have resulted in adverse ecological effects, it is concluded that additional assessment is not warranted.

SMDP: There is adequate information to conclude that, despite some uncertainties, ecological risks are negligible overall for plant and invertebrate and vertebrate wildlife receptors that may come into contact with Site-related constituents in soil and surface water. Therefore, remediation on the basis of ecological risk is not recommended.

6 Summary and Conclusions

6.1 Summary

6.1.1 Nature and Extent of Contamination from the Homestake Facility

6.1.1.1 Groundwater

Nature and extent of impacts on the groundwater aquifers from milling operations are not limited to the Homestake Facility. Groundwater quality standards have been established for the Homestake Facility and are listed in Table 6-1.

Table 6-1 Comparison of NRC License Cleanup Level (Alluvial Aquifer) and Other Potential PRGs

Constituent	Other Potential PRGs	NRC License Cleanup Level	Basis of NRC Cleanup Level
Selenium (mg/L)	0.05[1,2]	0.32	Background
Uranium (mg/L)	0.03[1,2]	0.16	Background
Molybdenum (mg/L)	0.08[3]	0.10	40 CFR Part 192 – Standards for Control of Residual Radioactive Materials from Inactive Uranium Processing Sites
Sulfate (mg/L)	600[2]	1,500	Background
Nitrate (mg/L)	10[1,2]	12	Background
Vanadium (mg/L)	-	0.02	Analytical Detection Limit
Thorium-230 (pCi/L)	15[1]	0.3	Analytical Detection Limit
Radium-226 and Radium-228 (pCi/L)	5[1]	5	40 CFR Part 192 – Standards for Control of Residual Radioactive Materials from Inactive Uranium Processing Sites

1. EPA Primary Maximum Contaminant Level
2. NMAC 20.6.2.3103A
3. EPA risk-based value selected in the Molycorp Inc. ROD (EPA 2010b)

Based on the comparison in Table 6-1, molybdenum is the only COPC/ROPC where other potential PRGs are more stringent than the NRC License Cleanup Levels, excluding those where the NRC License Cleanup Levels was set to background.

6.1.1.1.1 Alluvial Aquifer

Groundwater in the alluvial aquifer has been impacted by historic milling operations. Remediation of the alluvial aquifer was initiated in 1977 with significant progress to date; however, significant contamination still exists. Uranium, selenium, molybdenum, sulfate, TDS, chloride and nitrate concentrations exceed the groundwater quality standards established for the Homestake Facility. The extent of groundwater impacts from these chemicals is beyond the LTP. Thorium and Ra-

226/228 have impacted the alluvial aquifer below the LTP. Figures 3-3 through 3-26 display the extent of groundwater impacts in the alluvial aquifer.

6.1.1.1.2 Upper Chinle Aquifer

Uranium, selenium, molybdenum, vanadium, sulfate, TDS, and chloride concentrations in the Upper Chinle aquifer exceed mixing zone NRC Site Cleanup Levels below and south of the LTP. In addition, non-mixing zone NRC Site Cleanup Levels for uranium, selenium, molybdenum, sulfate, TDS, and chloride were exceeded in the Upper Chinle aquifer. Figures 3-28 through 3-40 display the extent of groundwater impacts in the Upper Chinle aquifer.

6.1.1.1.3 Middle Chinle Aquifer

In the Middle Chinle mixing zone west of the LTP, uranium, selenium, molybdenum, sulfate, TDS, and nitrate exceed NRC Site Cleanup Levels. In addition, uranium, selenium, and TDS exceed the non-mixing zone NRC Site Cleanup Levels south of the license boundaries, with uranium also exceeding mixing zone standards in this area. Figures 3-42 through 3-50 display the extent of groundwater impacts in the Middle Chinle aquifer.

6.1.1.1.4 Lower Chinle Aquifer

Uranium has impacted groundwater in the mixing zone and non-mixing zone of the Lower Chinle aquifer south of the LTP. Refer to Figures 3-52 through 3-57 for the extent of uranium above NRC Site Cleanup Levels in the Lower Chinle aquifer.

6.1.1.1.5 San Andres-Glorietta Aquifer

Uranium milling operations at the Bluewater Mill Site, which is located approximately 4 miles west north-west (directly upgradient) of the LTP released uranium to the SAG aquifer. Refer to Figure 3-60 for an isoconcentration contour map for uranium in the SAG aquifer.

Because the SAG aquifer has been used as a source of fresh water by HMC, ten SAG wells are routinely monitored by HMC. The location of these wells is shown on Figure 2-43. With no areas of direct communication within the area where the alluvial aquifer is impacted by the Homestake tailings seepage, and only very limited hydraulic communication through the Chinle shale, the SAG aquifer is not affected by Site releases (HMC 2019a).

6.1.1.2 Soil

The ROPCs identified for soils at Homestake Facility include Ra-226, Ra-228, Th-232, and U-238. Radionuclides that exceeded screening levels, produced risk in forward risk calculations, and exceeded background for the most sensitive human receptor are considered ROPCs. Table 6-2 summarizes the statistics for each of these ROPCs based on risk estimates for the default composite worker. Note that this receptor is identified as unlikely, and that the long-term worker for the DOE legacy effort would have an exposure level nearly 20 times lower.

Table 6-2 Summary of Soil ROPCs Homestake Facility (pCi/g)

ROPC	n	Minimum	Maximum	UCL95	Background UCL95
Surface Soil					
Bi-212	27	0.39	2.04	1.498	1.195
Bi-214	27	0.504	5.79	2.333	0.948
Cs-137	27	0.0105	0.151	0.0672	0.0731
K-40	27	12.9	21.2	18.1	18.35
Pa-234m	26	1.2	18.9	4.603	1.515
Pb-212	27	0.425	1.67	1.348	1.104
Pb-214	27	0.54	6.13	2.468	1.017
Ra-223	20	0.097	0.67	0.414	0.296
Ra-226	50	0.65	9.0	4.027	1.81
Ra-228	27	0.483	1.71	1.422	1.14
Th-227	8	0.047	0.227	0.174	0.13
Th-228	27	0.47	2.34	1.604	1.412
Th-230	51	0.44	7.4	2.596	1.393
Th-232	27	0.39	1.81	1.372	1.135
Th-234	20	0.28	11.2	3.260	0.703
Tl-208	27	0.138	0.527	0.434	0.357
U-natural	24	1	30	9.706	1.14
U-234	27	0.58	18.3	4.287	1.141
U-235	27	0.071	0.697	0.307	0.112
U-238	27	0.79	19	4.323	1.147
Surface and Subsurface Soil Combined*					
Ra226	25	0.04	9.9	4.348	1.81
Th230	25	0.02	2.9	2.607	1.393
U-natural	25	1	20	11.29	1.14

Notes:
* = These are the only ROPCs sampled in both surface and subsurface soil.
n = number of observations
UCL = upper confidence limit
ROC – radionuclide of concern

Based on comparison to background, surface soil concentrations of U-234, U-238 and Ra-226 are elevated. Pa-234m, Pb-214, and Ra-226 are also elevated above background. Spatially, there does not appear to be a discernable pattern to the concentrations of these constituents. Soil remediation of much of the Homestake Facility was completed in the early and mid-1990s (refer to Figure 1-5 for the extent of the remediation area). The surface soil action level for the remediation was 10.5 pCi/g of Ra-226, which is above the highest concentration detected at the Site in 2009 (ERG 2014). The current UCL95 is less than half of the action level. Other COPCs were not analyzed during the remediation that took place during the 1990s.

6.1.1.3 Air

Air particulates are continuously monitored at seven locations around the Homestake Facility (refer to Figure 3-64). The location identified as HMC-6 in Figure 3-64 represents background conditions,

and is located due west of the LTP at the westernmost side of the property boundary. Locations HMC-4 and HMC-5 are proximal to the nearest residences and are used to evaluate the equivalent radiation dose received by the public. The evaluation uses quarterly monitoring data for four radionuclides (uranium-238, uranium-234, thorium-230, and radium-226) and is published in Semiannual Environmental Monitoring Reports (HMC 2019c). The equivalent radiation dose at HMC-4 and HMC-5 from Homestake Facility emissions is estimated by subtracting the dose from background concentrations measured at HMC-6. Based on these calculations, the annual radiation dose from particulates ranged from 0.2 to 2.4 mrem over the last 4 years. Compared to the NRC limit for the public of 10 mrem/yr (refer to 10 CFR 20.1101), the equivalent radiation dose attributable to air particulates is relatively small. Particulates in air were below screening levels and are not considered a source of elevated cancer risk.

Radon in air was the major risk driver for the human health risk assessment; however, background concentrations of radon are a major contributor to radon risk estimates. The average radon concentration for 2018 at HMC-4 and HMC-5 was 0.89 and 0.84 pCi/L respectively. The average annual concentration at the background location (HMC-16) was 0.35 pCi/L. Subtracting the background concentration from the measured concentrations at HMC-4 and HMC-5 results in net radon concentrations of 0.54 and 0.49 pCi/L, respectively. Based on these concentrations, the equivalent calculated radiation dose at locations HMC-4 and HMC-5 is 41 and 37 mrem/yr respectively.

An estimate of the radiation dose from direct exposure to radiation sources at the Homestake Facility is obtained from optically stimulated luminescence (OSL) dosimeters placed at each monitoring station. The average annual dose in 2018 was calculated at HMC-4 and HMC-5 to be 130 and 131 mrem/yr, respectively. The average annual dose at the background location (HMC-16) was calculated to be 115 mrem/yr. Using a 75 percent occupancy factor, the net annual dose for HMC-4 and HMC-5 was calculated to be 15 and 16 mrem/yr for HMC-4 and HMC-5 respectively.

Total Effective Dose Equivalent (TEDE) to the nearest resident is calculated by adding net doses from inhalation of airborne particulate, from the exposure to radon, and from direct gamma radiation. The 2018 TEDE at HMC-4 was 52 mrem/yr and at HMC-5 was 50 mrem/yr. These are below the NRC limit of 100 mrem/yr (refer to 10 CFR 20.1301) for public exposure.

6.1.2 Nature and Extent of Contamination Within Land Treatment Areas

6.1.2.1 Groundwater

Impacts to the underlying aquifers resulting from irrigation using Site groundwater were evaluated for each of the LTA fields. Refer to Figure 1-2 for a plan view of the Site showing the location of the LTA fields.

Based on the chemistry of the water applied to the LTAs, uranium, selenium, and molybdenum are the COPCs for groundwater below the LTAs. Other parameters including sulfate, TDS, chloride, and nitrate are also monitored to evaluate impacts on water quality.

6.1.2.1.1 Groundwater Impacts at the 120-Acre Flood Irrigation Field

Figures 3-67 through 3-73 present groundwater COPC concentrations over time using data collected from 6 groundwater monitoring wells located within and around the 120-acre flood irrigation field. A

few concentrations appear to be increasing over time, but the data is either inconsistent, the period of increase does not reasonably coincide with the start of irrigation activities, and/or is not supported by similar increases in nearby wells. For instance, uranium concentrations appear to be increasing in Well 844; however, the increase began in 1994 (6 years prior to the start of irrigation) and there is no evidence of similar increases in other monitoring wells. Based on review of the monitoring well data collected in this field, there do not appear to be data trends that point to groundwater impact from the historical irrigation activities.

6.1.2.1.2 Groundwater Impacts at the 150-Acre Center Pivot and 24 Acre Flood Irrigation Fields

Figures 3-76 through 3-82 present groundwater COPC concentrations over time using data collected from 6 groundwater monitoring wells located within and around the 150-acre center pivot and 24 acre flood irrigation fields. Based on review of the monitoring well data collected in this field, there do not appear to be data trends that point to groundwater impact from the historical irrigation activities.

6.1.2.1.3 Groundwater Impacts at the 100-Acre Center Pivot Irrigation Field

Figures 3-85 through 3-91 present groundwater COPC concentrations over time using data collected from 6 groundwater monitoring wells located within and around the 100-acre center pivot fields. Based on review of the monitoring well data collected in this field, there do not appear to be data trends that point to groundwater impact from the historical irrigation activities.

6.1.2.2 Soil

Impacts to soil resulting from irrigation using Site groundwater were evaluated for each of the LTA fields. Soil samples have been collected from within and near the irrigation fields from 1999 through 2013. In 2017 and 2018, comprehensive soil sampling and analysis at each of the four irrigation fields was completed (Final Status Survey). The objective of the sampling and analysis program was to evaluate whether concentration of constituents of potential concern met the proposed criteria for unrestricted release from NRC Radioactive Materials License SUA-1471. Over one hundred samples were collected and analyzed for selenium, uranium and Ra-226. Based on the results, it was concluded that the criteria for unrestricted release had been met. In 2018, to confirm these results, HMC funded a study by ORISE to independently sample the four LTA fields and confirm or deny the conclusions of the previous study. This study consisted of gamma surveys as well as soil sampling and analysis. Results of the ORIS study were consistent with the Final Status Survey.

6.1.3 Human Health Risk Assessment

6.1.3.1 Human Health Risk Assessment for the Homestake Facility

An evaluation of risks to human health from environmental media Homestake Facility was conducted for the RI. Receptors were selected which conservatively represent current land uses and future land uses which are reasonably expected. Tables 6-3 and 6-4 summarize the cumulative cancer and non-cancer risks, for chemicals and radionuclides.

Table 6-3 Cancer Risks Homestake Facility

Receptor	Media	Total Cancer Risk	Inherent Background Risk[1]	Excess Risk Attributable to Site[2]
Future Composite Worker	Soil	2E-03	7E-04	8E-04
	Air	2E-02	1E-02	1E-02
	Total	**2E-02**	**1E-02**	**1E-02**
Future Construction Worker	Soil	7E-05	3E-05	4E-05
	Air	8E-04	4E-04	4E-04
	Total	**9E-04**	**4E-04**	**4E-04**
Current Trespasser	Soil	4E-05	2E-05	2E-05
	Air	1E-04	7E-05	5E-05
	Total	**1E-04**	**9E-05**	**7E-05**
Future Trespasser	Soil	4E-05	2E-05	2E-05
	Air	1E-04	7E-05	5E-05
	Total	**1E-04**	**9E-05**	**7E-05**

Notes:
1. Background risk is for background soil ingestion, dermal contact, and inhalation pathways based on background soil EPC. Air background risk is for inhalation and immersion to Rn-222. Does not include pond media exposure.
2. Excess risk is the sum of the Site surface soil pathway risks or hazards minus the background risk or hazard for that constituent. If less than zero, the value is set to zero.

Table 6-4 Non-Cancer Risks Homestake Facility

Receptor	Media	Total Non-Cancer Risk	Inherent Background Risk[1]	Excess Risk Attributable to Site[2]
Future Composite Worker	Soil	8E-02	2E-02	6E-02
	Air	NA	NA	NA
	Total	**8E-02**	**2E-02**	**6E-02**
Future Construction Worker	Soil	3E-01	6E-02	2E-01
	Air	NA	NA	NA
	Total	**3E-01**	**6E-02**	**2E-01**
Current Trespasser	Soil	2E-02	3E-03	2E-02
	Air	NA	NA	NA
	Total	**2E-02**	**3E-03**	**2E-02**
Future Trespasser	Soil	2E-02	3E-03	2E-02
	Air	NA	NA	NA
	Total	**2E-02**	**3E-03**	**2E-02**

Notes:
1. Background risk is for background soil ingestion, dermal contact, and inhalation pathways based on background soil EPC.
2. Excess risk is the sum of the Site surface soil pathway risks or hazards minus the background risk or hazard for that constituent.
NA – there are no noncancer risks for air

Risk to construction workers within the Homestake Facility is above the cancer risk management range. This is primarily due to radon in air.

Cancer risks to current and future trespassers for the Homestake Facility are within the risk management range.

Non-cancer hazard quotients associated with exposure to media from the Homestake Facility under the assumptions made in this HHRA are all below 1.

6.1.3.2 Human Health Risk Assessment Within Land Treatment Areas

An evaluation of risks to human health from environmental media at the LTAs was conducted for the RI. Receptors were selected which represent current land uses and future land uses which are reasonably expected. Tables 6-5 and 6-6 summarize the calculated cancer and non-cancer risks for the selected receptors.

Table 6-5 Cancer Risks Within Land Treatment Areas

Receptor	Media	Total Cancer Risk	Inherent Background Risk[1]	Excess Risk Attributable to Site [2]
Future Composite Worker	Soil	8E-04	7E-04	1E-04
	Air	2E-02	1E-02	1E-02
	Total	**2E-02**	**1E-02**	**1E-02**
Future Construction Worker	Soil	4E-05	3E-05	4E-06
	Air	8E-04	4E-04	4E-04
	Total	**8E-04**	**4E-04**	**4E-04**
Current and Future Trespasser	Soil	2E-05	2E-05	3E-06
	Air	1E-04	7E-05	5E-05
	Total	**1E-04**	**9E-05**	**5E-05**

Notes:
1. Background risk is for background soil ingestion, dermal contact, and inhalation pathways based on background soil EPC. Air background risk is for inhalation and immersion to Rn-222.
2. Excess risk is the sum of the Site surface soil pathway risks or hazards minus the background risk or hazard for that constituent. If less than zero, the value is set to zero.

Table 6-6 Non-Cancer Risks Within Land Treatment Areas

Receptor	Media	Total Non-Cancer Risk	Inherent Background Risk[1]	Excess Risk Attributable to Site[2]
Future Composite Worker	Soil	3E-02	2E-02	1E-02
	Air	NA	NA	NA
	Total	**3E-02**	**2E-02**	**1E-02**
Future Construction Worker	Soil	1E-01	6E-02	4E-02
	Air	NA	NA	NA
	Total	**1E-01**	**6E-02**	**4E-02**
Current and Future Trespasser	Soil	5E-03	3E-03	2E-03
	Air	NA	NA	NA
	Total	**5E-03**	**3E-03**	**2E-03**

Notes:
1. Background risk is for background soil ingestion, dermal contact, and inhalation pathways based on background soil EPC.
2. Excess risk is the sum of the Site surface soil pathway risks or hazards minus the background risk or hazard for that constituent. If less than zero, the value is set to zero.
NA – there are no noncancer risks for air

For construction workers, risk is less than $1x10^{-4}$ in soil, but above this for air. Risk is largely due to measured concentrations of radon in indoor air selected as representative of potential trench air concentrations.

There are no non-cancer hazard quotients above 1 associated with exposure to media at the LTA under the assumptions made in this HHRA.

6.1.4 EPA Human Health Risk Assessment for the Subdivisions

The EPA completed HHRA for receptors living in the subdivisions located southwest of the Homestake Facility (refer to Figure 1-2). Prior to completing the HHRA, EPA performed field investigation. Elements of the field investigation included:

- **Gamma Radiation Scanning**: Performance of a walking, gamma scan (2-3 feet per second; 15 inches above ground surface) at 90 properties in the subdivisions south of the Homestake Facility. Gamma radiation scanning was also conducted around each home up to a maximum of one-acre surface area throughout the yard. In addition, scanning occurred on approximately 250 acres of HMC property, between the evaporation ponds and the fenceline separating HMC property and residential subdivisions. EPA conducted the gamma scan on HMC property to investigate whether:
    - spraying uranium contaminated water high into the air results in contaminants being deposited in the area down gradient from the evaporation ponds, and
    - heavy rains could have resulted in contaminants being carried from the uranium mill tailing piles and evaporation ponds into adjacent residential neighborhoods.

  The conclusion from the gamma scan was "…there was no definitive pattern leading away from the evaporation ponds" (EPA 2014).

- **Soil Sampling and Analysis**: A total of 640 soil samples were collected from private properties, at various locations on Homestake's property, and from an area south of the residential properties to evaluate background conditions. The location of the soil samples collected on HMC property and background soil sampling locations are shown on Figure 3-58.
- **Ambient and Indoor Air Sampling and Radon Analysis**: The EPA's year-long radon sampling began in September 2010 and was completed it in November 2011. Four quarters of sampling were completed in homes, both indoors and outdoors, in the five subdivisions south of the Homestake Facility, on Homestake's property and north of the large tailings pile, and in Bluewater Village, the location EPA selected to represent background. Approximately 1,500 radon samples were collected and analyzed.

Two land use exposure scenarios were evaluated by EPA:

- residential
- subsistence farming

The subsistence farmer scenario assumed duration is 40 years. Subsistence farming also assumes that 100% of the residences food is produced on the property within the subdivisions for this duration, which is extremely conservative and highly unlikely assumption, for the following reasons:

- Subsistence farming is extremely rare in the United States, especially in the arid west, where soil and climate is not conducive to growing a variety of fruits and vegetables.
- None of the properties appear large enough to support the production of the variety of fruits, vegetables, and grains assumed in the model, as well as provide 100% of the foodstuff for milk cows, beef cattle, chickens for consumption, and chickens for egg production. To support this assertion, HMC researched the size, lot sizes, and property ownership within the subdivision using the Cibola County Assessor's Office – refer to Table 6-7 (Cibola County, 2015). HMC also researched available on the acreage needed to support cows and estimates that at a minimum, 36 acres of grazing pasture would be needed to support one head of cattle (Sprinkle and Bailey 2004). When comparing this information, it is apparent that the subsistence farmer scenario is a highly unlikely and extremely conservative exposure scenario.

Table 6-7 Adjacent Subdivision Lot and Property Sizes

Subdivision Name	Subdivision Size (acres)	Number of Lots	Average Lot Size (acres)	Largest Property Size (acres)
Valley Verde Estates	122	100	1.2	1.6
Pleasant Valley	54	17	3.2	9.2
Murray Acres	132	30	4.4	17.1
Broadview Acres	68	54	1.3	4.6
Felice Acres	68	14	4.9	6.6

Included in both the residential and subsistence farmer exposure scenario is the risk to the use of groundwater for drinking water and other domestic purposes. Significantly, all homes within the subdivisions near the Homestake Facility are currently receiving domestic water from the Milan

municipal water system, with the exception of one Valle Verde residence. Costs to hookup the subdivision residential structures were funded by HMC. Based on the reality of the drinking water source for the residential properties, calculating the risks based on 100% of domestic water being derived from untreated groundwater is extremely conservative.

Table 6-8 presents RME cancer risks from radionuclides for current and future residents.

Table 6-8 RME Cancer Risks from Radionuclides: Current/Future Residents

Medium	Exposure Pathway	Radionuclides Of Primary Concern	Total Cancer Risk	Inherent Background Risk	Risk Attributable to Site
Soil	Ingestion, external, inhalation and produce consumption	Ra-226+D (external exposure)	2.4×10^{-4}	1.8×10^{-4}	6.0×10^{-5}
Air	Inhalation of Ambient Air	Rn-222 +D (inhalation)	1.8×10^{-3}	1.3×10^{-3}	5.0×10^{-4}
Total			2.0×10^{-3}	1.5×10^{-3}	5.6×10^{-4}
Goundwater[1]	Ingestion and inhalation	Rn-222+D & Ra-226 +D (inhalation) Ra-228+D (ingestion)	2.2×10^{-3}	See Note 2	See Note 2

Notes:
1. Risk is from exposure to radionuclides in well water in the event that a well is dug and used for domestic purposes sometime in the future.
2. Radionuclide background concentrations in groundwater were not determined.

Based on EPA's analysis, residential cancer risk from reasonable maximum exposure to radionuclides in soil is above EPA's cancer risk management range; however, when risk attributable to background are factored out, cancer risks from exposure to radionuclides in soils are within the cancer risk management range.

Based on EPA's analysis, residential cancer risk from reasonable maximum exposure to radionuclides in ambient (outdoor) air is above EPA's cancer risk management range. The analysis shows that most of this risk is attributable to background concentrations of radon. After factoring our background risks, the risk from reasonable maximum exposure to radionuclides in outdoor air is above the cancer risk management range.

Based on EPA's analysis, residential cancer risk from reasonable maximum exposure to radionuclides in untreated groundwater used for domestic purposes is above the cancer risk management range.

Table 6-9 presents RME cancer risks from radionuclides for current and future subsidence farmers.

Table 6-9 RME Cancer Risks From Radionuclides: Current/Future Subsistence Farmer

Medium	Exposure Pathway	Radionuclides Of Primary Concern	Total Cancer Risk	Inherent Background Risk	Risk Attributable to Site
Soil	Ingestion, external, inhalation, produce consumption, beef, milk, poultry, and egg consumption	Ra-226+D (external exposure) and Ra- 226+D, U-234 and U238 in milk	1.1×10^{-3}	8.8×10^{-4}	2.2×10^{-4}
Air	Inhalation of Ambient Air	Rn-222 +D (inhalation)	1.8×10^{-3}	1.3×10^{-3}	5.0×10^{-4}
Total			2.9×10^{-3}	2.18×10^{-3}	7.2×10^{-4}
Goundwater[1]	Ingestion and inhalation	Rn-222+D & Ra-226 +D (inhalation) Ra-228+D (ingestion)	2.2×10^{-3}	See Note 2	See Note 2

Notes:
1. Risk is from exposure to radionuclides in well water in the event that a well is dug and used for domestic purposes sometime in the future.
2. Radionuclide background concentrations in groundwater were not determined.

Based on EPA's analysis, residential cancer risk from reasonable maximum exposure to radionuclides in soil is above EPA's cancer risk management range; however, when risk attributable to background are factored out, cancer risks from exposure to radionuclides in soils are within the cancer risk management range.

Based on EPA's analysis, residential cancer risk from reasonable maximum exposure to radionuclides in ambient (outdoor) air is above EPA's cancer risk management range. The analysis shows that most of this risk is attributable to background concentrations of radon. After factoring our background risks, the risk from reasonable maximum exposure to radionuclides in outdoor air is above the cancer risk management range.

Based on EPA's analysis, residential cancer risk from reasonable maximum exposure to radionuclides in untreated groundwater used for domestic purposes is above the cancer risk management range.

6.1.5 Screening Level Ecological Risk Assessment

The results of the ecological risk analysis were analyzed and interpreted to evaluate the potential for adverse ecological effects and conclude whether or not significant risk exists for each assessment endpoint evaluated. Based on the development of an ecological CSM for the Site the following relevant potential exposure pathways were identified:

- Potential exposure of vegetation and soil invertebrates by direct contact to constituents in terrestrial habitat Homestake Facility and in the LTAs;

- Potential exposure of terrestrial avian and mammalian receptors from foraging and through uptake in the food chain to constituents in terrestrial habitat Homestake Facility and in the LTAs; and
- Potential exposure of avian and mammalian receptors by contact to constituents in the on-Site evaporation ponds (Homestake Facility).

Based on the identification of potentially complete exposure pathways, assessment endpoints and measures of effect were identified. Assessment endpoints contain an entity (e.g., avian population) and an attribute of that entity (e.g., survival rate). The following assessment endpoints and measures of effect were selected for the BERA:

Soil Assessment Endpoint 1 – Survival, growth, and reproduction of terrestrial plant and soil invertebrate communities in Homestake Facility and LTA upland habitat areas.

Soil Measure of Effect 1 – Comparison of maximum concentrations of constituents in soil-to-soil screening values derived for the protection of plants and soil invertebrates.

Soil Assessment Endpoint 2 – Survival, growth, and reproduction of terrestrial wildlife receptors within the Homestake Facility and LTA upland habitat areas.

Soil Measure of Effect 2 – Comparison of maximum concentrations of constituents in soil-to-soil screening values derived for the protection of avian and mammalian receptors exposed to soil or to dietary items bioaccumulating analytes from soil.

Evaporation Pond Assessment Endpoint 1 – Survival, growth, and reproduction of wildlife receptors that may occasionally ingest water from the evaporation ponds.

Surface Water Measure of Effect 1 – Comparison of maximum concentrations of constituents in evaporation pond surface water to screening values derived for protection of aquatic receptors.

An initial screening level evaluation (Step 2) identified COPCs/ROPCs based on conservative screening level risk estimates.

For soils Homestake Facility, soil assessment endpoint 1 (survival, growth, and reproduction of plants and soil invertebrates) and soil assessment endpoint 2 (protection of terrestrial wildlife) were evaluated and the following COPCs were identified: lead, molybdenum, selenium, uranium, and vanadium. No ROPCs were identified.

For soils within the LTAs, soil assessment endpoint 1 (survival, growth, and reproduction of plants and soil invertebrates) and soil assessment endpoint 2 (protection of terrestrial wildlife) were evaluated and the following COPCs were identified: lead, selenium, and vanadium. No ROPCs were identified.

Evaporation pond assessment endpoint 1 (survival, growth, and reproduction of wildlife that may occasionally drink water from the evaporation ponds) was evaluated and the following COPCs in surface water were identified: arsenic, molybdenum, selenium, uranium, and vanadium, radium-226, thorium-228, and thorium-230.

For this BERA, further evaluation (Step 3a) refined the COPC/ROPC selection process using more Site-specific assumptions for exposure concentrations and food web modeling.

Homestake Facility and Land Treatment Area Soil. As discussed in Section 5.3.8, exposure to soil is not expected to result in unacceptable risks to terrestrial receptors. No additional risk

evaluation is warranted and remedial decision-making on the basis of ecological risk for these two areas is not recommended.

Evaporation Ponds. Evaporation pond surface water appears to provide limited potential for ecological risk to avian receptors given low chronic LOAEL and acute HQs (see Table 5-58). There is some uncertainty associated with risk from exposure to molybdenum in surface water because acute TRVs could not be determined.

For mammals, NOAEL and LOAEL HQs above one for molybdenum and uranium may indicate the potential for risk when using the evaporation ponds as a source of water. However, as discussed in Section 5.3.9, the HQ calculations used very conservative assumptions (receptors were assumed to eat and drink only from the Site even though the Site provides no quality habitat) that likely overestimate actual risk.

The RESLs used to calculate HQs for ROPCs are based on protection of aquatic life. Because there is no aquatic life in the ponds, the RESLs are overly conservative. Continual observations since the start of pond operations do not indicate any adverse effects to avian or mammalian receptors. HMC operation crews inspect the ponds daily for wildlife in and around them and no mortality or other indicators have been reported since operation of the first pond began in 1990. Current permit provisions require no measures for mitigation to keep wildlife away from the ponds.

Given that the evaporation ponds will be removed following completion of the groundwater restoration program (thereby eliminating potential exposure pathways for ecological receptors), and there is no indication that pond operations to date have resulted in adverse ecological effects, it is concluded that additional assessment is not warranted.

SMDP: There is adequate information to conclude that, despite some uncertainties, ecological risks are negligible overall for plant and invertebrate and vertebrate wildlife receptors that may come into contact with Site-related constituents in soil and surface water. Therefore, remediation on the basis of ecological risk is not recommended.

6.2 Preliminary Remedial Action Objectives

Under the National Contingency Plan, Remedial Action Objectives (RAOs) are established to specify “contaminants and media of concern, potential exposure pathways, and remediation goals” (40 CFR §300.430(e)(2)(i)). RAOs provide a foundational consideration in the process of comparing remedial alternatives and help to focus the development and evaluation of alternatives. Preliminary RAOs are described below. RAOs typically evolve over the course of the RI/FS process and become final only when the ROD is signed.

RAO1 – Protect future workers and potential downgradient receptors from ingestion of groundwater from the alluvial, Upper Chinle, Middle Chinle, and Lower Chinle aquifers containing COPCs and ROPCs above NRC Site Cleanup Levels established in NRC License SUA-1471, DP-200, and agreed upon by EPA in correspondence to NRC dated September 27, 2005.

RAO2 – Protect human receptors from inhalation of Rn-222 emissions from the Homestake Facility by limiting average radon flux from the LPT and SPT to 20 pCi/m^{2}s.

7 References

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