Evidence of CERCLA Hazardous Substances and Potential Exposures at CERCLA §108(b) Mining and Mineral Processing Sites

Prepared by

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List of Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System database
CFR	Code of Federal Regulations
COC	contaminant of concern
COPC	contaminant of potential concern
CSF	cancer slope factor
CSM	conceptual site model
CWA	Clean Water Act
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
ERA	ecological risk assessment
FEMA	Federal Emergency Management Agency
GIS	geographic information systems
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessments
HI	hazard index
HQ	hazard quotient
ICIS	Integrated Compliance Information System
MSHA	Mine Safety and Health Administration
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NHD+	National Hydrography Dataset Plus
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
PCS	Permit Compliance System
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
ROD	Record of Decision
TRI	Toxics Release Inventory
U.S.C.	United States Code
UR	unit risk
USGS	U.S. Geological Survey

Executive Summary

This report documents Agency efforts from 2009 – 2012 to determine what mining and mineral processing practices and contamination patterns have historically caused Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, also known as Superfund) cleanups to occur. Specifically, the Agency studied the human and ecological exposures to releases of CERCLA hazardous substances identified in Superfund risk assessments, and described the extent to which those same practices, contamination patterns, releases, and exposures might occur at current and future sites.

The methodology presented in this report is two pronged: first, examine Superfund risk assessments and other CERCLA site-specific documents for risk estimates, including estimated exposures of human and ecological receptors to CERCLA hazardous substances from mining and mineral processing sites cleaned up under Superfund in the past (i.e., **Historical sites**), and second, collect available information on potential exposures of human and ecological receptors to CERCLA hazardous substances from mining and mineral processing sites that were operational in 2009 (the most current available data at the time the evaluation took place). EPA is using these **2009 Current sites** as a proxy for current and future mining and mineral processing sites that may be subject to CERCLA 108(b) regulatory requirements.

EPA compared conditions at Case Study **Historical sites** to those at **2009 Current sites**, in order to compare the potential for human or ecological exposures to CERCLA hazardous substances from mines and processors to be regulated under CERCLA 108(b) to Historical sites where Superfund cleanups had occurred. EPA used data from Historical sites for two main reasons:

- CERCLA Section 108(b)(2) requires EPA to set the level of financial responsibility based on the experience of the Superfund (42 U.S.C. 9608(b)(2)), and
- Few Superfund risk assessments have been conducted at currently operating mines and mineral processors. In addition, insufficient information is available from other CERCLA site documents regarding potential exposures of human and ecological receptors to CERCLA hazardous substances from releases at currently operating mines and mineral processors to estimate risks.

Findings for 108(b) Historical CERCLA Sites

EPA initially identified 251 sites as mining and mineral processing sites cleaned up using Superfund authority. Referred to in the report as the 108(b) Historical CERCLA Sites universe," or "Historical sites," the list included 104 National Priorities List (NPL) sites, 132 Removal sites, and 15 sites cleaned up as part of Superfund enforcement actions. Within the 108(b) Historical CERCLA Sites universe, 82 sites had operated after 1980. The report refers to this group as the "post-1980 sites." To better represent current mining and processing operations and practices, EPA randomly selected a subset of 30 post-1980 sites (including 24 NPL sites and 6 removal sites) for in-depth review. The focus on post-1980 sites was intended to strengthen the relevance of the data to 2009 Current sites, because sites operating after 1980 would be more likely to use mining and mineral processing techniques similar to those still in use today, compared with sites that had closed or been abandoned before 1980. Data collection for the 30 randomly selected sites found that insufficient Superfund risk assessment data were available for the selected

Removal and other non-NPL sites. As a result, only detailed data from the 24 NPL sites were available to use in the analysis. The report refers to these 24 NPL sites as Case Study Historical sites.

The Case Study Historical sites mined or processed various commodities, including non-precious metals such as aluminum, copper, lead, and zinc (16 sites); precious metals (10 sites); radioactive elements (2 sites); phosphorus/phosphate compounds (3 sites); and unusual commodities such as lithium (1 site). Some sites mined or processed more than one type of commodity, so the number of sites mentioned above for each commodity sums to more than 24. Typical mining and processing practices at the Case Study Historical sites included disposal of waste rock near excavation areas, use of extraction solutions such as cyanide for dissolving gold from ore, and use of high-temperature smelters and chemical processes to isolate metallic and nonmetallic mineral values from ores and/or concentrates.

To ensure that EPA's analysis included the widest possible range of conditions at mining and mineral processor sites, EPA conducted an exhaustive review of CERCLA data to identify sites missed in the original 108(b) Historical CERCLA Sites universe. As of the end of 2012, the 108(b) Historical CERCLA Sites universe had expanded to 448 sites. EPA also selected additional sites from the expanded 108(b) Historical CERCLA Sites universe for in-depth review, to better represent the range of commodities mined and/or processed at Historical sites. While Superfund risk assessment data were collected for the supplemental sites, and for completeness of documentation their collection is recorded in Appendix B, the data were not available in time to be included in the analyses. References to "Case Study Historical sites" in this report refer only to the randomly selected 24 NPL sites, and any conclusions drawn by this report are based solely on data from the 24 NPL sites and not on data from the supplemental sites.

To collect information for the Case Study Historical sites, EPA reviewed documents available in the Superfund Data Management System, including Remedial Investigation/ Feasibility Studies (RI/FS) on hazardous substances that were found to be contaminants of concern, contaminant sources, pathways of concern, human and ecological receptors, and quantitative risk estimates, when those estimates were available.

A CERCLA hazardous substance found at a concentration that a Superfund risk assessment has determined poses an unacceptable risk to human health or the environment is referred to as a Contaminant of Concern (COC). These are the substances that are addressed by cleanup actions at the site. EPA identified 86 different COCs associated with Case Study Historical sites. To focus the remainder of this analysis, EPA identified the subset of COCs that occurred most frequently at the Case Study Historical sites. COCs identified at four or more of the sites, due to either associated human health or ecological risks, were retained for further review and called Priority COCs. Priority COCs for human health risk were, in descending order of frequency: arsenic, manganese, cadmium, zinc, antimony, lead, beryllium, copper, benzo[a]pyrene, chromium, mercury, selenium, thallium, benzo[b]fluoranthene, nickel, radium-226, benz[a]anthracene, dibenz[a,h]anthracene, fluorine (as fluoride), lead-210, silver, uranium-238, polychlorinated biphenyls, radon-222, and thorium-228. Priority COCs for ecological risk were, in descending order of frequency: zinc, lead, arsenic, cadmium, copper, antimony, chromium, selenium, thallium, manganese, beryllium, silver, mercury, and nickel.

Environmental settings at the Case Study Historical sites ranged from lightly populated arid areas to densely populated urban areas, with the majority of sites located in the western United States. Exposure pathways found to occur at sites where Superfund risk assessments estimated human health risks were at or above levels of concern included surface water, ground water, soil, and food ingestion (i.e., one case study included resident ingestion of homegrown vegetables, and one case study included fisher ingestion of shrimp). Exposure pathways found to occur for ecological receptors included soil, food, and surface water exposures. Flooding, or the presence of hazardous substances in a floodplain zone with periodic rising water levels, contributed to hazardous substance releases at several of the Case Study Historical sites.

Quantitatively, the highest estimated human cancer or noncancer risks to a reasonable maximum exposure (RME) individual in Superfund risk assessments were associated with practitioners of traditional lifestyles on an Indian reservation, due to exposures from contamination resulting from an abandoned uranium mine. Other examples of high RME individual risks are associated with metals in drinking water from wells at off-site residences near an abandoned gold mine, as well as with arsenic in soil ingested by current and future residents near an abandoned gold mine and mill.

The highest Superfund risk assessment ecological risk estimates at Case Study Historical sites, for raccoons ingesting selenium-contaminated prey at a tungsten processing site, were four to five orders of magnitude higher than the benchmark for adverse effects. Other examples of ecological risks include reduced fish populations downstream from an abandoned gold mine and mill (possibly due to dam releases of contamination from the mine/mill site), and suggestive evidence of risk to the viability and functioning of omnivorous birds (robins) due to cadmium, lead, and zinc in in their prey, resulting from zinc smelting waste disposal.

EPA also compiled a list of 64 Natural Resource Damage Assessment (NRDA) settlement sites where final settlements had been reached as of the end of 2012 (i.e., the period covered by this report). Nine of the NRDA sites were also Case Study Historical sites, and data from these sites' natural resource injury assessment documents are included in this report.

Findings for 2009 Current Sites

EPA identified 491 mining and mineral processing sites operating in 2009, using data from the Department of Labor's Mine Safety and Health Administration (MSHA) and the Department of Interior's U.S. Geological Survey (USGS). These "2009 Current" sites mine or process the same commodities that were mined or processed at the Historical sites. Nine of the 2009 Current sites are also Historical sites, and six of those nine were among the Case Study Historical sites for which EPA reviewed detailed Superfund risk assessment information.

EPA searched documents for available information on mining and mineral processing practices at the 2009 Current sites. Mining and mineral processing practices at the 2009 Current sites were then compared to practices at the Case Study Historical sites to assess whether similar sources of potential hazardous substance releases could also occur at 2009 Current sites.

EPA also reviewed its databases to identify evidence of CERCLA hazardous substances present at, or released from, 2009 Current sites. EPA found that 121 (24%) of 2009 Current sites reported on-site releases of CERCLA hazardous substances to the Toxics Release Inventory (TRI). These on-site 2009 releases totaled almost 300 million pounds. The most frequently reported CERCLA hazardous substances released on site were lead compounds, followed by copper, mercury, zinc, manganese, nickel compounds, ammonia, and 58 other hazardous substances. In terms of total quantities released, five CERCLA hazardous substances (lead, zinc, copper, arsenic, and manganese, in that order) accounted for 85% of the total. Sixty-six percent of the total quantity of hazardous substances reported as released on site in 2009 were from the 10 highest reporting facilities, which included four lead/zinc ore mines, two copper smelters, one gold mine, one silver mine, one iron and steel mill, and one copper/nickel ore mine.

EPA also compiled information on the 2009 Current sites that are required by their National Pollutant Discharge Elimination System (NPDES) permits to monitor and report releases of hazardous substances to surface waters. This evaluation found that roughly 14% of the sites reported discharging CERCLA hazardous substances to surface waterbodies in quantities that exceeded their NPDES permit limits.

In addition to the data regarding the presence and release of CERCLA hazardous substances, EPA compiled data in a geographic information system (GIS) to estimate the proximity of human and ecological receptors to 2009 Current sites in the contiguous United States and Alaska. Findings include:

- Roughly half of the sites are located in moderately or densely populated areas, based on the U.S. Census Bureau's 2000 population estimates.
- An estimated 82% of the sites in the contiguous United States are within a 24-hour travel distance upstream of non-tribal drinking water sources. An estimated 45% of sites in Alaska are a similar distance upstream of non-tribal drinking water sources.
- An estimated 3% of sites in the contiguous U.S. are within a 24-hour travel distance upstream of tribal drinking water sources. (Relevant information was not available to evaluate sites in Alaska.)
- An estimated 32% of the sites (i.e., in both the contiguous United States and Alaska) are within a 24-hour travel distance upstream of river/stream segments listed as impaired waters under Section §303(d) of the Clean Water Act.
- An estimated 23% of the sites have reported TRI releases of the Priority COCs or have NPDES permits with numerical permit limits for the Priority COCs.
- An estimated 57% of the sites are within Federal Emergency Management Agency (FEMA) special flood hazard areas: in the event of a "base" flood (also known as a 100-year flood) these sites may experience hazardous substance releases associated with floodwaters contributing to hazardous substance movement.

Findings regarding potential ecological receptors at 2009 Current sites include:

- An estimated 6% of the sites are located within 3 miles of a critical habitat designated for federally listed threatened or endangered species.
- An estimated 37% of the sites are within a 24-hour travel distance upstream of dams on waterbodies that may provide habitat for aquatic receptors.
- An estimated 34% of the sites in the contiguous U.S. are within a 24-hour travel distance upstream from river/stream segments listed as impaired waters under Section §303(d) of the Clean Water Act. This does not necessarily mean that the 2009 Current sites located upstream from impaired waters are contributing to the water quality problems in those segments; rather, it is an indication of proximity to an already impacted water resource and ecological receptor habitat.

The findings for human and ecological receptor proximity to the 2009 Current sites, where exposures to CERCLA hazardous substance releases could be of concern, are uncertain. One source of uncertainty is the uncertainty regarding the exact location of each 2009 Current site. Other sources of uncertainty are information source-specific, such as uncertainty from the use of Census Bureau data to estimate residence locations, as well as the age of the data (from Census 2000). However, despite the uncertainties with the findings, they can be useful in providing context regarding the potential for future CERCLA hazardous substance exposures from mines and mineral processors.

Using Case Study Historical Sites to Predict Potential Human and Ecological Exposure to CERCLA Hazardous Substances from 2009 Current Sites

Based on the 2009-2012 data collection and analysis, EPA has concluded the following:

- **Case Study Historical Sites:** Human health and ecological risk estimates in Superfund risk assessments are site-specific and highly variable. CERCLA hazardous substances that often drive the risk estimates include several metals, radionuclides, Polychlorinated biphenyls (PCBs), and Polynuclear Aromatic Hydrocarbons (PAHs). The human receptors affected, or potentially affected, are frequently site workers, nearby residents (including children), and site trespassers. Ecological receptors are typically flora and fauna that inhabit the sites. The COCs migrate through the environment and affect human or ecological receptors, or potentially affect future receptors, via specific exposure pathways. Human exposure pathways include: surface water and ground water contamination that affects drinking water sources, and soil and food plant contamination that affects nearby residents. Ecological exposure pathways include: surface water contamination that causes fish kills or otherwise adversely affects aquatic organisms, and contamination of soil and prey that affects birds and mammals inhabiting the sites.

- **2009 Current Sites:** Many mines and mineral processors operating in 2009 release CERCLA hazardous substances that were identified as Contaminants of Concern at the Case Study Historical Sites, and are located near both human and ecological receptors that may be affected by those releases. Examples of CERCLA hazardous substances frequently reported as released are lead and manganese. Examples of nearby receptors are humans who drink water from surface water bodies downstream from the mine or mineral processor site, and endangered species with habitat near the mine or mineral processing site.

- **Considering 2009 Current Site Data in Light of the Case Study Historical Site Data:** Taken together, the data on mining and mineral processing practices, CERCLA hazardous substances, receptors, environmental settings, and exposure pathways suggest the following potential for exposure of human and ecological receptors to CERCLA hazardous substance releases from the 2009 Current sites:
  - Some of the 2009 Current sites are also in the universe of 108(b) Historical CERCLA sites.

- Mining and mineral processing practices at the Case Study Historical sites continue to be used at the 2009 Current sites, especially when comparing sites that mine or process the same range of commodities.
- There are similarities between the Priority COCs reported at the Case Study Historical sites and the CERCLA hazardous substances reported in TRI and NPDES permit reporting from 2009 Current sites;
- Human and ecological receptors at Case Study Historical sites have parallel potential receptors at 2009 Current sites.
- Environmental settings and exposure pathways at Case Study Historical sites have corresponding environmental settings and potential exposure pathways at 2009 Current sites.

The compiled information demonstrates that the 2009 Current sites share characteristics with the Case Study Historical sites, and illustrates the applicability of EPA's CERCLA experience to evaluating currently operating mines and processors.

1.0 Introduction and Problem Formulation

The purpose of this report is to document the efforts that EPA undertook, from 2009 to 2012, to 1) determine what mining and mineral processing practices and contamination patterns have historically caused Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, also known as Superfund) cleanups to occur, 2) identify the corresponding Superfund human health and environmental risk estimates, with an emphasis on the relevant CERCLA hazardous substances and human and ecological receptor exposures, and 3) describe the extent to which those same practices, contamination patterns, CERCLA hazardous substances and receptor exposures may occur at current and future mining and mineral processing sites.

1.1 Background and Purpose

The CERCLA, Section 108(b) directs the President to promulgate requirements that

> ***…****classes of facilities establish and maintain evidence of financial responsibility consistent with the degree and duration of risk associated with the production, transportation, treatment, storage, or disposal of hazardous substances.*

As authorized by the President, the EPA Administrator determined that mines and processors of metal and non-fuel, non-metallic mineral resources were those for which financial responsibility regulations would first be developed. EPA published a *Federal Register* notice in July 2009 (74 FR 37213-37219) stating that

> *...the Agency has identified classes of facilities within the hard rock mining industry as its priority for the development of financial responsibility requirements under CERCLA Section 108(b). For purposes of this notice only, hardrock mining is defined as the extraction, beneficiation or processing of metals (e.g., copper, gold, iron, lead, magnesium, molybdenum, silver, uranium, and zinc) and non-metallic, non-fuel minerals (e.g., asbestos, gypsum, phosphate rock, and sulfur).*

Note that the July 2009 *Federal Register* notice defined the phrase *hard rock mining* as encompassing several minerals that professional geologists and miners generally would not consider to be hard rock minerals. Therefore, to avoid confusion, EPA is using phrases such as *mining and mineral processing* or *mines and mineral processors* throughout this document to indicate the economic sector that is the subject of this analysis.

To further focus the list of potentially regulated mines and mineral processors to those most likely to cause risk, EPA published a memorandum to the record ("Mining Classes Not Included in Identified Hardrock Mining Classes of Facilities," June 29, 2009, document number EPA-HQ-SFUND-2009-0265-0003, U.S. EPA (2009a)) which lists 59 MSHA commodities to be excluded from 108(b) regulation.

Current and future sites are represented in this analysis by sites operational in 2009. Considerable information is available on current mining and mineral processing practices, the types of associated contamination, and the cost of consequent cleanup activities. However, relatively few Superfund risk assessments have been conducted at currently operating sites. For the majority of sites operational in 2009, EPA could not locate Superfund risk assessments or public health assessment. The sites operational in 2009 for which EPA located Superfund risk assessments or public health assessments are listed in **Appendix A**.

Stated specifically, the purpose of this report is to summarize data on

- the presence of CERCLA hazardous substances at Superfund cleanup sites where mining and mineral processing occurred and for which Superfund risk assessments have found human health or ecological risks at or above levels of concern;
- the presence of those same CERCLA hazardous substances at mining and mineral processing sites operating in 2009;
- the known current, or potential future, human and ecological exposures at Superfund cleanup sites where mining or mineral processing occurred; and
- evidence of potential for similar human and ecological exposures to CERCLA hazardous substances from current mining and mineral processing sites.

Taken together, this set of information comprises evidence for estimating potential human and ecological exposures to CERCLA hazardous substances released from mining and mineral processing sites for which no Superfund risk assessments have yet been conducted.

1.2 Scope

The scope of this document is limited to human health and ecological risks resulting from exposure, or potential exposure, to CERCLA hazardous substances, as defined in CERCLA Section 101 (42 U.S.C. 9601(14)). In all, EPA has designated more than 800 substances as CERCLA hazardous, along with approximately 760 individually listed radionuclides, according to the statutory definition.[1] Physical safety hazards such as electrocution, ground subsidence, or trips/falls/entrapment hazards are not within the scope of this analysis because the scope of the National Contingency Plan (NCP) does not include physical safety hazards.[2] The NCP is the federal government's organizational structure and procedures for preparing for and responding to, among other things, hazardous substance releases.

In this document, EPA has collected Superfund risk estimates, as well as data regarding human and ecological exposure to CERCLA hazardous substances, for two groups of mining and mineral processing sites:

<u>108(b) Historical CERCLA sites</u>: Sites where CERCLA authority has been used for hazardous substance remediation. This includes NPL sites, Removal sites, and sites cleaned up as part of a CERCLA enforcement action. This report refers to the universe of these sites as the 108(b) Historical CERCLA Sites universe, to individual members as Historical sites, and to the subset of this universe selected for in-depth data collection and analysis as Case Study Historical sites; and

<u>2009 Current sites</u>: Sites that mined or processed commodities of interest and were operational, to varying extents, during calendar year 2009. For the purposes of this analysis,

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[1] The full list of CERCLA hazardous substances, as well as their reportable quantities, is in Title 40 of the Code of Federal Regulations in Section 302.4 (40 CFR 302.4).

[2] See 40 CFR 300.3 for the scope statement of the NCP.

these sites represent the current (and future) sites to be regulated under the CERCLA section 108(b) proposal. This report refers to these sites as 2009 Current sites.

The two groups (i.e., Historical sites and 2009 Current sites) overlap to a limited extent. As described in detail in Appendix B, roughly 5 percent of the 2009 Current sites have been previously addressed under Superfund.

1.3 Methodology and Data Sources

The following provides an overview of the methodology employed to identify known risks at Historical sites and the potential for similar human and ecological exposures to CERCLA hazardous substances at the 2009 Current sites. **Appendix B** presents an in-depth description of the methodology and data sources used.

1.3.1 Defining the Universes of Sites Evaluated in this Study

Historical Sites

EPA began with the EPA National Mining Team's list of abandoned mine lands: those lands, waters and surrounding watersheds where extraction, beneficiation or processing of ores and minerals has occurred. This list was filtered to include only mines and mineral processors of the metal and non-fuel, non-metallic mineral resources identified in the July 2009 FR notice (74 FR 37213-37219), and to exclude mines and mineral processors of commodities listed in EPA (2009a). The following criteria were used to select relevant CERCLA sites:

- Mining or mineral processing occurred at the site (either alone, together, or in combination with other activities).
- For mineral processing, CERCLA site documents describing site activities mention processing of *primary* (i.e., earthen) mineral resources rather than only secondary mineral resources (i.e., already circulating within the economy and returned for recovery).
- The site is or had been addressed by EPA under CERCLA as an NPL site, a removal site, a site cleaned up as part of a CERCLA enforcement action, or some combination of these.
- Site contamination resulted at least in part from mining or mineral processing activities that occurred *at the site*, rather than solely from mining or mineral processing wastes transported to the site from a different location or from other non-mining, non-mineral processing activities.
- The commodity or commodities mined or processed at the site were metal and non-fuel, non-metallic, mineral resources identified in the July 2009 FR notice. and
- The commodity or commodities mined or processed at the site excluded from the rule per EPA (2009a).

Operations at some of the qualifying Historical sites ceased many years ago, however, and might not represent practices at current or future sites. Therefore, EPA identified the portion of Historical sites where mining or mineral processing activities had occurred during or after 1980 and where risk assessments were available. This "post-1980" subset would represent sites where practices resulting in contamination are confirmed, are expected to be similar to current-day practices, and where risks have been characterized. From those sites, EPA randomly selected sites for detailed evaluation. The sites chosen for detailed evaluation are called “Case Study Historical sites” throughout this document and are listed in **Appendix B, Table B-2**.

2009 Current Sites

EPA initially identified relevant mining and/or processing sites in operation during the 2007–2009 calendar years based on two data sources:

- **The U.S. Department of Labor’s Mine Safety and Health Administration (MSHA) Mine Data Retrieval System:** The Mine Data Retrieval System provides mine-by-mine data for metal/non-metal mines and their contractors in the United States, Puerto Rico, and the Virgin Islands. It contains data related to accidents, injuries, inspections, violations, assessments, and field samples, as well as employment and production reports.
- **U.S. Geological Survey (USGS) Minerals Yearbooks:** The Minerals Yearbooks are published annually and provide reviews of the mineral and material industries of the United States and foreign countries, including statistical data on materials and minerals, as well as information on economic and technical trends and development.

There is a significant amount of overlap between the MSHA commodities and the USGS commodities, and in many instances the commodity names are identical. After merging the two commodity lists, EPA filtered for metal and non-metallic, non-fuel minerals identified in the July 2009 FR notice, and excluded those identified in EPA (2009a).

The degree to which a site was in active operation during the 2009 time frame could vary substantially from site to site. For the purpose of this analysis, sites were considered operational as long as they had the potential to resume active operations during the 2007–2009 calendar years.[3]

The methodology for identifying the universe of 2009 Current sites, the resulting list, and overlap of the 2009 Current sites and Historical sites, are discussed in detail in **Appendix B, Section B.3**.

1.3.2 Mining and Mineral Processing Practices Responsible or Potentially Responsible for CERCLA Hazardous Substance Releases

Historical Sites

For the Case Study Historical sites, EPA reviewed Records of Decision (RODs), Superfund risk assessments, and other CERCLA site documents to identify the site histories. These data include dates of active operation, mining and mineral processing practices, and waste disposal practices that were identified as contributing to or resulting in the hazardous substance releases found to present risks at or above levels of concern. **Section 2** describes the summary-level findings at the Case Study Historical sites.

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[3] At the time the lists were constructed, the USGS Minerals Yearbooks were available only for 2007 and 2008, and the processors listed might or might not have still been operating in 2009. This does raise some uncertainty about 2009 operating status; however, these sites are referred to throughout this report as “2009 Current sites” for simplicity.

2009 Current Sites

EPA reviewed information in *Identification and Description of Mineral Processing Sectors and Waste Streams* (U.S. EPA, 1995a) to determine whether mining, mineral processing, and waste disposal practices at 2009 Current sites were similar to the practices at the Case Study Historical sites. **Section 2** describes the summary-level findings. **Appendix C** presents more detailed data on specific site practices.

1.3.3 Hazardous Substance Release Mechanisms

Historical Sites

At Case Study Historical sites, a wide range of mining, mineral processing, and waste management practices were used. The probability of a CERCLA hazardous substance release occurring is also influenced by site characteristics, as well as by physical phenomena such as the rate of the release and its magnitude. Site characteristics such as climate, soil types, geological settings, topography, and hydrology can play a major role in influencing CERCLA hazardous substance releases. **Section 2** presents additional information for the site characteristics that affected CERCLA hazardous substance releases at the Case Study Historical sites.

2009 Current Sites

The scope of this analysis included some analysis of topography and hydrology, including whether the 2009 Current sites were located within a 24-hour time of travel downstream to a 100-year floodplain area designated by the Federal Emergency Management Agency (FEMA) as a special flood hazard area. The scope of this analysis did not include site-specific determinations of site characteristics such as climate, soil types, or geological settings that can affect rates or magnitudes of hazardous substance releases. **Section 2** presents summary-level information on the proximity of the 2009 Current sites to special flood hazard areas.

1.3.4 Hazardous Substances of Concern

Historical Sites

To identify the CERCLA hazardous substances found to pose human health or ecological risks above levels of concern, EPA reviewed detailed site data from Superfund risk assessments and Records of Decision (RODs) for the Case Study Historical sites. For each site, EPA identified the contaminants of concern (COCs) found to cause reasonable maximum exposure (RME) risks at or above levels of concern. From these identified COCs, EPA selected a subset of the COCs most frequently found to be risk drivers at the Case Study Historical sites. The COCs identified as risk drivers at four or more sites were retained in the study for further evaluation. These frequent COCs are referred to throughout the rest of this report as Priority COCs. **Section 2** identifies the COCs found at the Case Study Historical sites, as well as the subset of Priority COCs. See **Appendix D** for more details about the identification of COCs and selection of Priority COCs at Case Study Historical sites.

2009 Current Sites

EPA reviewed existing data sources containing records of the release and onsite presence or management of CERCLA hazardous substances at 2009 Current sites. **Appendix F** describes the data and data sources reviewed, including those sources found to contain insufficient data to develop evidence for this analysis. Two EPA databases were found to contain the most useful information for the purposes of this analysis:

- **The Toxic Release Inventory (TRI):** A database of reported releases of certain toxic chemicals. Contains data on various types of releases, including but not limited to, release to onsite facilities for treatment, disposal (e.g., in a landfill or injection well), or recycling, as well as uncontrolled or other emissions (e.g., fugitive emissions to air). Data also cover transfers offsite for treatment, disposal or recycling. Data are collected for over 600 toxic chemicals from thousands of U.S. facilities.
- **Discharge Monitoring Reports (DMRs) from the National Pollutant Discharge Elimination System (NPDES):** Publicly available periodic reports on point source discharges to surface water bodies. Both the Integrated Compliance Information System (ICIS) and Permit Compliance System (PCS) databases were used to identify relevant DMR data.

Because most 2009 Current sites are not Superfund sites, data on the presence of CERCLA hazardous substances at 2009 Current sites were collected from other programs. This report used data obtained from the TRI and NPDES EPA databases to characterize primarily the types and secondarily, when available, estimate amounts of CERCLA hazardous substances present at the 2009 Current sites. **Section 2** presents the summary-level information from both of these data sources, while **Appendix F** presents complete tables of CERCLA hazardous substance release data for the 2009 Current sites.

1.3.5 Exposures to Hazardous Substances: Receptors

Historical Sites

The Superfund risk assessment conducted for each Historical site generally identifies current and future potential land uses to define likely human and ecological receptors at or near the site. Each Superfund risk assessment identifies the receptor types for which risks are assessed. Examples of common receptor types assessed include current or future nearby residents, current or future trespassers onto the site, and flora/fauna inhabiting the site itself either currently or in the future. Distances to receptors are not usually directly measured as part of the Superfund risk assessment; instead, at most sites field samples of soil, surface water, sediment, or well-water samples, and sometimes plant or animal tissues, are taken in order to determine exposure point concentrations that are used in the site-specific risk calculations. **Section 3** presents summary-level information of receptor types assessed at the Case Study Historical sites.

2009 Current Sites

For the 2009 Current sites, EPA attempted to identify the specific locations (latitude and longitude) for each site, using publicly available data. EPA assigned a three-tiered code to reflect confidence in the quality of the site location assumption. **Appendix E** provides a detailed discussion of the development of the geographic data and confidence codes and a description of the entire geographic information system (GIS) analysis used to support this document.

In this report, EPA assumed that all residents near the sites are receptors of potential concern. EPA compiled U.S. Census Bureau data on distances from the identified site latitudes/longitudes to nearby residences within various buffer zones extending up to 20 miles from the identified site locations. In addition, EPA analyzed information on the proximity of drinking water source protection areas to the 2009 Current sites, in order to develop general knowledge of potential impacts of mining or mineral processing sites on drinking water supplies. **Section 3** presents the summary-level information developed for nearby human receptors of potential concern and proximity to drinking water supply locations, while **Appendix G** presents the more detailed data tables for selected buffer distances to nearby residences.

EPA considered all federally designated threatened or endangered species with critical habitat designated within 20 miles of the identified site latitude/longitude as ecological receptors of potential concern. To do so, EPA used the "Final Critical Habitat" dataset produced by the U.S. Fish and Wildlife Service. These data identify the areas where final critical habitat exist for species listed as endangered or threatened. The Final Critical Habitat data were downloaded from the U.S. Fish and Wildlife Service in May 2010. For the 2009 Current sites, EPA did not attempt to define any species besides federally designated threatened or endangered species as being receptors of potential concern, because data at the level of resolution needed was not available. However, EPA recognizes that substantial impacts on non-federally listed species could occur, especially in situations where acidic mine drainage could adversely affect populations of aquatic organisms in surface water bodies down-gradient from mining or mineral processing operations. **Section 3** presents the summary-level information developed for nearby federally designated critical habitat, for federally listed threatened or endangered species, while **Appendix H** presents more detailed data tables related to ecological receptors.

1.3.6 Exposure Pathways/Routes

Historical Sites

Superfund risk assessments identify complete exposure *pathways*, meaning a sequence of environmental media through which CERCLA hazardous substances move when migrating from the site to a receptor. These risk assessments also identify potential exposure pathways when future receptors are assessed or when inadequate information exists to definitively confirm a complete exposure pathway. Exposure *routes* are the avenues by which the CERCLA hazardous substance comes into contact with an organism, such as ingestion by humans or animals, inhalation by humans or animals, or dermal contact by humans or animals, including aquatic organisms living in surface water bodies affected by CERCLA hazardous substance releases. **Section 3** presents summary-level information on the exposure pathways and exposure routes found at the Case Study Historical sites.

2009 Current Sites

Because relatively few Superfund risk assessments have been conducted for the 2009 Current sites, EPA currently lacks data on specific complete exposure pathways at most of these sites. **Section 3** presents the data that are available from Superfund risk assessments of the 2009 Current sites, presents the data from the GIS analysis that suggests potential exposure pathways, and compares them with exposure pathways evaluated in Superfund risk assessments of the Case Study Historical sites.

1.3.7 Discussion of Findings, and Public Health Assessments

EPA utilized multiple information sources to determine the potential for human and/or ecological exposure to CERCLA hazardous substances from mining and mineral processing sites operating in 2009. **Section 4** reviews the summary-level information that EPA has compiled for similarities between the Case Study Historical sites and 2009 Current sites; comparing mining, mineral processing, and waste management practices, CERCLA hazardous substance releases, release mechanisms, receptor types, and exposure pathways and routes. **Section 4** also reviews the major sources of uncertainty in this report.

Public Health Assessments (PHAs) and Health Consultations (HCs) conducted by the federal Agency for Toxic Substances and Disease Registry (ATSDR) address public health impacts of mining and mineral processing sites; **Section 4** describes those findings, where available, for the Case Study Historical sites, the broader universe of 108(b) Historical CERCLA Sites and, in a few instances, 2009 Current sites that have not been addressed by CERCLA cleanup authority. Finally, EPA briefly reviews some of the data from other countries that documented human health and ecological impacts from mining and mineral processing activities.

2.0 Hazard Identification

To identify potential hazards warranting regulation under CERCLA Section 108(b), this section first describes the universes of 108(b) Historical CERCLA sites and 2009 Current sites (**Section 2.1**). Sections then describe the mining and mineral processing practices responsible for CERCLA hazardous substance releases (**Section 2.2**), the release mechanisms (**Section 2.3**), and the CERCLA Contaminants of Concern (COCs, **Section 2.4**) associated with each Historical or 2009 Current site.

2.1 Universes of Sites Reviewed in this Study

Using the methodology described in **Section 1.3.1**, EPA identified a universe of 108(b) Historical CERCLA Sites to represent Superfund estimated risks associated with mining and mineral processing activities cleaned up using CERCLA authority, and a universe of sites operating in 2009 (i.e., 2009 Current sites) to represent current and future mining and mineral processing sites. How these two universes were identified is described below.

2.1.1 Historical Sites

This report reviewed CERCLA experience related to human health and ecological risks associated with past mining and mineral processing activities. To obtain Superfund risk estimates and information on human and ecological exposures to CERCLA hazardous substances, EPA used the methodology summarized in **Section 1.3** (above), and described in detail in **Appendix B**, to identify the universe of mining and mineral processing sites (i.e., sites relevant to the 108(b) hard-rock mining rule) that have been subject to cleanup actions under CERCLA authority. This effort identified a universe of 251 sites, referred to in this report as the 108(b) Historical CERCLA Sites universe. See Appendix B, **Attachment B1**, for a complete listing of the 108(b) Historical CERCLA Sites universe.

A detailed review of Superfund risk assessments and other CERCLA site documents for all sites in the 108(b) Historical CERCLA Sites universe was not possible within time and funding constraints. Therefore, EPA selected a subset of these sites for more in-depth review. To better represent current mining and processing operations and practices, EPA randomly selected 30 sites (including 24 NPL sites and 6 removal sites) that had operated after 1980. CERCLA site documents were reviewed to identify numerical risk estimates, as well as contextual information for those estimates, such as specific hazardous substances; the contaminated media; exposure pathways and routes; and, for ecological receptors, the species, if available. While collecting data for the randomly selected sites, EPA found that insufficient data were available for the sample of Removal and other non-NPL sites. As a result, only detailed data from the 24 NPL sites were available to use in the report. The report refers to these 24 NPL sites as Case Study Historical sites.

Based on ongoing QA/QC of the 108(b) Historical CERCLA Sites list, EPA decided to continue developing the 108(b) Historical CERCLA Sites universe. As described in detail in Appendix B **Section B.2** (“Expanded List of Historical Sites and Supplemental Sampling”), the continued development culminated in a universe of 448 sites.

EPA also found that the range of commodities mined or processed at Case Study Historical sites was limited when compared to the entire 108(b) Historical CERCLA Sites universe. EPA therefore conducted a supplemental selection and data collection for additional historical sites. However, while this report describes the selection and data collection for these supplemental sites in order to completely document EPA's 2009 – 2012 research efforts, the data were not available in time to be included in the comparisons to 2009 Current site data. References to "Case Study Historical sites" in the remainder of this report refer only to the original, randomly selected 24 NPL sites, and any conclusions drawn by this evaluation are based solely on data from the 24 NPL sites and not on data from the supplemental sites.

Appendix B describes in detail the original development and subsequent expansion of the 108(b) Historical CERCLA Sites universe. Appendix B also describes the process used to randomly select and collect data for the initial Case Study Historical sites, as well as the process used to select and collect data for the supplemental sites.

2.1.2 2009 Current Sites

A set of sites representative of current and future mining and mineral processing sites potentially subject to CERCLA 108(b) requirements was also needed. Two federal agencies monitor the existence and activities of U.S. mines and mineral processors: the Department of Interior's U.S. Geological Survey (USGS), which conducts annual surveys to determine production rates and commodity prices, and the Department of Labor's Mine Safety and Health Administration (MSHA), which collects mine safety compliance and employment information. EPA used data from both agencies to construct a list of mining or mineral processing sites in operation during calendar year 2009.

Each agency uses different nomenclature to identify specific mineral commodities, so EPA combined mineral commodities that were named similarly by both USGS and MSHA. EPA then compiled mining and mineral processing site information for the subset of commodities that were not excluded from consideration in the CERCLA 108(b) rule, per U.S. EPA (2009a). **Appendix B** also contains the list of commodities that EPA used to compile mining and mineral processing sites.

Defining whether a mining or mineral processing site is "in operation" is complicated somewhat by the tendency of mines and mineral processors to limit or shut down their operations because of external pressures such as commodity price fluctuations. Such shutdowns affect the probability of hazardous substance releases occurring. Because the proposed rule aims to internalize costs associated with cleanups of CERCLA hazardous substance releases, EPA needed to identify sites with an operating status similar to those that would be subject to the proposed rule. Therefore, EPA chose to develop a list of mines and mineral processors that were operating—interpreted broadly as not abandoned—at some point during calendar year 2009. For example, the MSHA database contains five mine status codes: active, intermittent, non-producing, new, and abandoned. EPA included sites with any of these codes except abandoned. From the USGS data, EPA included any additional mines and mineral processors that were not identified in the MSHA database but were mentioned in a published USGS Minerals Yearbook for 2009. Thus, the degree to which a site was in active operation during 2009 may vary substantially from site to site, from mines or mineral processors that actively produced commodities throughout the entire year, to mines or mineral processors that were essentially inactive for much or all of the year but that had not notified MSHA to change their mine status to "abandoned."

Using the methodology described above resulted in a universe of 491 sites in the contiguous United States and Alaska, referred to in the remainder of this report as the 2009 Current Sites universe, and individual members as 2009 Current sites. **Appendix B Attachment B5** lists the 2009 Current Sites universe. The locations for 74 of the 2009 Current sites could not be identified with confidence (e.g., location-related information, such as address, were for a corporate office and not the location of the facility itself). The locations of the remaining 417 sites, including 22 sites in Alaska, could be verified and were presumed to be accurate. Therefore, analyses that were based on spatial relations (for example, populations within a certain distance of a site) were only performed on the 417 sites with verifiable locations.

In addition, some analyses could not be run for sites in Alaska because of lack of data. In such cases, the total number of valid sites is 395. Where the number 417 is used in the text, it is referring to all sites with verifiable locations; where the number 395 is used, it is referring to those sites with verifiable locations in the contiguous United States.

2.2 Mining and Mineral Processing Practices

Five general methods are used to extract metal and nonmetallic resources in the United States; the method used depends on characteristics of the ore body or brine/water resource, its position within the earth, and economic considerations:

- **Brine/surface water/ground water extraction** removes compounds such as boron, bromine, iodine, lithium, and magnesium compounds from the brine or water supply.
- **Solution mining** extracts metals in ores by injecting and circulating chemical solutions through ore and recovering those solutions for processing.
- **Surface mining** removes ores at the surface by removing overburden.
- **Underground mining** remove ores underground, where miners access ore bodies via adits, mine shafts, and tunnels.
- **Placer mining** removes target metals from placer deposits located in sand, gravel, or rock, typically deposited by flowing water (and thus usually located in or adjacent to surface water bodies).[4]

For the purposes of this report EPA considers all of these types of mining except surface water extraction as potentially subject to the 108(b) requirements.

Processing non-fuel minerals includes a range of activities that depend on ore or brine/water characteristics and typically occur in a stepwise manner to increase the concentration of the target material within the medium being processed. The entire range of processing activities spans a continuum between the initial manipulation of the ore or brine/water upon removal from the earth and highly specialized steps that produce the final target material to a customer’s exact specifications. Some mineral processing is categorized as chemical manufacturing and, thus, would be outside the scope of the proposed 108(b) regulations for mining and mineral processing.

MSHA defines a coal or other mine as

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[4] Currently, most of the placer mining sites (except those using CERCLA hazardous substances) are not included in the 2016 proposed CERCLA 108(b) rule.

> *(a) an area of land from which minerals are extracted in nonliquid form or, if in liquid form, are extracted with workers underground, (b) private ways and roads appurtenant to such area, and (c) lands, excavations, underground passageways, shafts, slopes, tunnels and workings, structures, facilities, equipment, machines, tools, or other property including impoundments, retention dams, and tailings ponds, on the surface or underground, used in, or to be used in, or resulting from, the work of extracting such minerals from their natural deposits in nonliquid form, or if in liquid form, with workers underground, or used in, or to be used in, the milling of such minerals, or the work of preparing coal or other minerals, and includes custom coal preparation facilities. In making a determination of what constitutes mineral milling for purposes of this act, the Secretary shall give due consideration to the convenience of administration resulting from the delegation to one Assistant Secretary of all authority with respect to the health and safety of miners employed at one physical establishment. (*30 CFR 41.1(c))

The MSHA regulations apply to facilities that mine and mill minerals, but as the final sentence in this definition indicates, the worker safety requirements at mineral processing sites are sometimes handled by a different agency within the Department of Labor. Thus, MSHA records include all mines known to MSHA to extract minerals from the earth, according to the definition of mine in 30 CFR 41.1(c), including those that also process minerals at or near the mine site and some, but not all, mineral processing sites.

In contrast to this definition, USGS uses slightly different criteria for identifying mines and mineral processors for which it publishes statistics for mineral production:

> *Although crude mineral production may be measured at any of several stages of extraction and processing, the stage of measurement used in this annual report is what is termed "mine output." This term refers to minerals or ores in the form in which they are first extracted from the ground, but customarily may include the output from auxiliary processing at or near the mines.* (USGS, 2011)

In practice, there are differences between whether a given facility would be considered a "mine" under the MSHA regulations and whether USGS would report its production in its Minerals Yearbooks. For example, MSHA's limitation for liquid extraction operations where workers are underground means that MSHA might not consider sites extracting minerals from surface waters, ground water, or in-situ solution mining to be mines, while USGS does consider them to be mines because they are producing minerals.

2.2.1 Historical Sites

EPA grouped the Case Study Historical sites into 6 categories, based on the type of commodity mined or processed at each site, and then assessed the specific mining and mineral processing practices used at each site:

- **Aluminum:** Three of the Case Study Historical sites were aluminum smelters, and all used the Hall-Heroult production process. CERCLA site documents for all three of these sites list a common waste management practice -- on-site disposal of a waste referred to as “potliners,” which is generated from the Hall-Heroult process -- as the source of site-related contamination.

- **Iron and steel:** One of the Case Study Historical sites was a ferrochromium alloy manufacturer that smelted chromium ore in an electric arc furnace. CERCLA site documents indicate that calculated risks are related to on-site disposal of waste generated at the site.
- **Phosphates:** Three of the Case Study Historical sites processed phosphate. CERCLA site documents for all three sites indicate that on-site waste disposal was the source of site contamination. One waste stream identified in common among the three sites was slag from processing of phosphate ore.
- **Primary metals:** Twelve of the Case Study Historical sites mined or processed primary metals. CERCLA site documents indicate three general types of mining or processing practices that resulted in hazardous substance contamination requiring cleanup at these sites: high-temperature smelting (5 sites), cyanide leaching and/or mercury amalgamation of precious metals ore (4 sites), and exposure of sulfide-bearing rock resulting in acidic mine drainage or tailings/waste rock drainage (7 sites). Some sites reported more than one of these practices; hence, the number of sites sums to more than 12. On-site waste disposal was reported for 11 of the 12 sites.
- **Radioactive metals:** Two of the Case Study Historical sites mined radioactive metals. CERCLA site documents indicated acidic mine drainage from onsite disposal as a condition common to both sites that resulted in hazardous substance releases.
- **Other metals:** Three of the Case Study Historical sites processed other metals. CERCLA site documents indicated on-site disposal of mineral processing waste as the practice in common at all three that resulted in hazardous substance releases.

Appendix C presents more detailed information on the mining and mineral processing wastes documented for the Case Study Historical sites.

2.2.2 2009 Current Sites

Using the same categories described above for the Case Study Historical sites, EPA reviewed the mining and mineral processing and waste management techniques used at the 2009 Current sites.

- **Aluminum:** Two of the three aluminum smelters in the set of Case Study Historical sites were still operating in 2009. It appears that all aluminum smelters operating in 2009 use the same Hall-Heroult process that was used at the three Historical sites. However, an important difference between the three Historical sites and the aluminum smelters operational in 2009 is that the hazardous waste regulations under the Resource Conservation and Recovery Act (RCRA) have now been in effect for a number of years; those regulations modify the waste management practices substantially compared with the practices that resulted in contamination at the three Historical sites.
- **Iron and steel:** The single Case Study Historical site was a chromite ore processor that produced ferrochromium alloys using electric arc furnaces. The single ferrochromium alloy producer operational in 2009 produced ferrochromium via an electrolytic process.
- **Phosphates:** Two of the three phosphate-related Case Study Historical sites were still operating in 2009, and an additional 26 sites mined or processed phosphates in 2009.

Similar processes were used at the two Case Study Historical sites. The general processes used at these sites are similar to those used today; however, the specific methodologies used may differ among sites and over time.

- **Primary metals:** Three of the 12 primary metal-related Case Study Historical sites were still operating in 2009, and an additional 207 sites mined or processed primary metals in 2009. However, mining and processing practices have changed somewhat from those used at the Case Study Historical sites. Specifically:
  - High-temperature smelting practices have changed substantially, both in terms of reductions in the absolute number of high-temperature smelters operating in the United States and in terms of additional air emissions controls (and ensuing contaminant release reductions) instituted in response to regulations (primarily Clean Air Act regulations).
  - While cyanide leaching of precious and certain base metals still occurs, voluntary and state-mandated changes in practices, such as impermeable liners installed underneath leaching areas to collect more of the leaching solution, have changed the potential for releases of hazardous substances at certain sites. At other sites that either have not voluntarily changed practices or are not mandated to change by state requirements, there may be relatively few changes compared with the practices that occurred at the Historical sites. At many, if not most, sites, changes may have occurred for the actual leaching areas, while waste disposal area practices may have changed very little.
  - EPA is not aware of mercury amalgamation occurring in the United States in 2009, and EPA issued final regulations controlling mercury emissions from gold ore processing operations in December 2010.
  - Exposure of sulfide-bearing rock resulting in acidic mine drainage or tailings/waste rock drainage can still occur at certain sites.
- **Radioactive metals:** Neither of the two radioactive metals-related Case Study Historical sites were still operating in 2009. However, eight of the 2009 Current sites mined or processed uranium or thorium. At these sites, exposure of sulfide-bearing rock resulting in acidic mine drainage or tailings/waste rock drainage remains a potential cause of CERCLA hazardous substance releases, unless state requirements or voluntary practices mitigate the conditions that lead to releases. However, because the development of acidic mine drainage is a very long-term threat, even state-required or voluntary practices in effect in the early 21st century may not mitigate conditions over the centuries during which the threat may persist.
- **Other metals:** One of the three Case Study Historical sites associated with *other metals* was still operating in 2009, and an additional 49 sites mined or processed other metals or non-metallic, non-fuel minerals in 2009. These sites include a wide range of practices due to the widely varying nature of the ores and earthen materials being processed into a wide range of products.

Appendix C describes in more detail the information that EPA found for mining and mineral processing wastes documented for the 2009 Current sites.

2.3 Release Mechanisms

Environmental characteristics such as meteorological conditions (e.g., precipitation, temperature, wind direction and speed), topography, and other site-specific factors play roles in the potential for, and rate of, the movement of hazardous substances through the environment. For example:

- Higher temperatures can increase the rate at which mercury or other volatile compounds move from rock, soil or water into the air.
- Dusty conditions are more prevalent in dry climates than in wet climates, potentially causing air to be a more important movement conduit than water.
- Steep slopes increase precipitation runoff rates and resulting erosion into surface water bodies.
- Sites located in floodplains have an increased probability of hazardous substance dispersion via flooding relative to sites not located in floodplains.
- Clay soils often adsorb metal contaminants to a much greater degree than silty or sandy soils, thus slowing the environmental transport relative to silty/sandy soils.

Superfund risk assessments often refer to these mechanisms as environmental fate and transport processes. Fate and transport processes influence the types of environmental media (air, soil, ground water, or surface water) that serve either as reservoirs of, or directional movement conduits for, CERCLA hazardous substances.

2.3.1 Historical Sites

This analysis did not consider weather conditions, soil types, or geological settings at the Case Study Historical sites. However, topography was considered to the extent that many of the CERCLA site documents mentioned flooding as playing a role in dispersing CERCLA hazardous substances from mining and mineral processing sites. In particular:

- Past flood events or erosion due to water played a role in contamination.
- At least part of the site was located within a 100-year floodplain at 10 sites (42%).
- Flooding was a potential contaminant dispersion mechanism at 13 sites (54%).

Appendix I presents the flood scenarios found at the Case Study Historical sites.

2.3.2 2009 Current Sites

Site-specific analyses required verifiable locations for each 2009 Current site. As introduced in Section 1.3 and described in detail in Appendix E, EPA attempted to identify the specific location of each site and assign a three-tiered code to reflect confidence in the quality of the site location information. EPA was able to map 417 of the 491 sites in the 2009 Current Sites universe.

A GIS analysis determined which surface waterbodies receive runoff from 2009 Current sites, and estimated if flooding of those waterbodies could affect the 2009 Current sites. FEMA flood maps were overlain with the National Hydrography Dataset Plus (NHDplus) data layer to perform this analysis. The analysis estimated that 236 out of 417 (57%) of the mining/mineral processing sites in the continental U.S. and Alaska are within the 100-year floodplain of a river or stream catchment. These sites have approximately a 1% annual chance of being inundated during a flood event. If floodplain waters rise sufficiently, CERCLA hazardous substances present at the sites may be released to surrounding media similar to scenarios that occurred at the Case Study Historical sites.

Appendix I presents a list of the 2009 Current Sites located within 100-year flood zones.

2.4 CERCLA Contaminants of Concern (COCs)

2.4.1 Historical Sites

As specified in the NCP, 40 CFR 300.430(e)(2)(i), and introduced in Section 1.3.4, a CERCLA hazardous substance estimated to cause risks at or above levels of concern is referred to as a COC. Based on a review of Superfund risk assessments of the Case Study Historical sites, EPA identified 86 unique COCs associated with those sites. **Table 2-1** presents the list of the 86 COCs associated with the Case Study Historical sites. Superfund risk assessments of some sites identified only general categories of hazardous substances (e.g., “radionuclides”).

To focus the remainder of this analysis, EPA identified the subset of COCs that occurred most frequently at the Case Study Historical sites. COCs identified at four or more of the Case Study Historical sites, due to either human health or ecological risks, were retained for further evaluation and called Priority COCs.[5] This selection was modeled after the ATSDR Priority List (found at http://www.atsdr.cdc.gov/spl/). **Table 2-1** also identifies the 27 Priority COCs and their frequency at the Case Study Historical sites.

The toxicity of the Priority COCs is described in **Section 2.5**. **Appendix D** provides more detail on the selection of the COCs and Priority COCs.

Table 2-1. CERCLA Hazardous Substances Identified in Superfund Risk Assessments of Case Study Historical Sites

CAS	COC	No. of Sites with Risks of Concern		CAS	COC	No. of Sites with Risks of Concern	
		Human	Eco			Human	Eco
Priority Contaminants of Concern				Other Contaminants of Concern (continued)			
7440-38-2	Arsenic & compounds	22	8	NA	Polynuclear aromatic hydrocarbons	1	2
7439-96-5	Manganese & compounds	14	5				
7440-66-6	Zinc & compounds	13	9	12674-11-2	Aroclor 1016	1	1
7440-43-9	Cadmium & compounds	13	8	11104-28-2	Aroclor 1221	1	1
7440-36-0	Antimony & compounds	11	6	11141-16-5	Aroclor 1232	1	1
7440-41-7	Beryllium & compounds	9	4	207-08-9	Benzo[k]fluoranthene	1	1
7440-50-8	Copper & compounds	7	8	67-66-3	Chloroform	1	1
7439-97-6	Mercury & compounds	7	3	014952-40-0	Actinium-227	1	0
7439-92-1	Lead & compounds	6	10	111-44-4	Bis(2-chloroethyl)ether	1	0
7440-28-0	Thallium & compounds	6	7	75-25-2	Bromoform	1	0
7440-02-0	Nickel & compounds	6	3	56-23-5	Carbon tetrachloride	1	0
50-32-8	Benzo[a]pyrene	6	2	108-90-7	Chlorobenzene	1	0
205-99-2	Benzo[b]fluoranthene	6	2	106-46-7	Dichlorobenzene, 1,4-	1	0

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[5] Chemicals qualify as COC's (and therefore possibly as Priority COC’s) because they have a toxicity value and can therefore be quantitatively evaluated. Section 4.6 (Uncertainty) discusses chemicals that are not quantitatively evaluated.

		No. of Sites with Risks of Concern	
CAS	COC	Human	Eco
NA	Radionuclides	6	0
13982-63-3	Radium-226	6	0
7440-47-3	Chromium & compounds	5	6
7782-41-4	Fluorine (as fluoride)	5	3
56-55-3	Benz[a]anthracene	5	2
53-70-3	Dibenz[a,h]anthracene	5	1
7440-61-1	Uranium-238	5	1
14255-04-0	Lead-210	5	0
1336-36-3	Polychlorinated biphenyls	4	2
14859-67-7	Radon-222	4	0
14274-82-9	Thorium-228	4	0
7440-22-4	Silver & compounds	3	4
7440-48-4	Cobalt compounds	3	3
7782-49-2	Selenium & compounds	2	6
Other Contaminants of Concern			
193-39-5	Indeno[1,2 3-cd]pyrene	3	1
79-01-6	Trichloroethylene	3	1
18540-29-9	Chromium (VI)	3	0
15262-20-1	Radium-228	3	0
127-18-4	Tetrachloroethylene	3	0
14269-63-7	Thorium-230	3	0
13966-29-5	Uranium-234	3	0
53469-21-9	Aroclor 1242	2	2
12672-29-6	Aroclor 1248	2	2
57-12-5	Cyanides	2	2
11096-82-5	Aroclor 1260	2	1
71-43-2	Benzene	2	0
107-06-2	Dichloroethane, 1,2-	2	0
10043-92-2	Radon	2	0
79-34-5	Tetrachloroethane,1,1,2,2-	2	0
11097-69-1	Aroclor 1254	1	2
75-35-4	Dichloroethylene, 1,1-	1	0
156-60-5	Dichloroethylene, 1,2-	1	0
75-09-2	Methylene chloride	1	0
13981-52-7	Polonium-210	1	0
13966-00-2	Potassium-40	1	0
7440-14-4	Radium	1	0
7440-29-1	Thorium-232	1	0
71-55-6	Trichloroethane, 1,1,1-	1	0
7440-61-1	Uranium	1	0
7440-61-1	Uranium-230	1	0
15117-96-1	Uranium-235	1	0
75-01-4	Vinyl Chloride	1	0
129-00-0	Pyrene	0	3
83-32-9	Acenaphthene	0	2
208-96-8	Acenaphthylene	0	2
191-24-2	Benzo(g,h,i)perylene	0	2
117-81-7	Bis(2-ethylhexyl) phthalate	0	2
218-01-9	Chrysene	0	2
85-01-8	Phenanthrene	0	2
67-64-1	Acetone	0	1
120-12-7	Anthracene	0	1
85-68-7	Butyl benzyl phthlate	0	1
57-74-9	Chlordane, alpha isomer	0	1
106-44-5	Cresol, p-	0	1
72-54-8	DDD	0	1
72-55-9	DDE, 4,4’-	0	1
50-29-3	DDT	0	1
72-20-8	Endrin	0	1
206-44-0	Fluoranthene	0	1
72-43-5	Methoxychlor	0	1
7440-23-5	Sodium	0	1

2.4.2 2009 Current Sites

To evaluate the potential for release of the Priority COCs from the 2009 Current sites, EPA used two data sources: The Toxics Release Inventory (TRI, available at http://www2.epa.gov/toxics-release-inventory-tri-program) and Discharge Monitoring Reports (DMRs, available at http://cfpub.epa.gov/dmr/) required under the National Pollutant Discharge Elimination System (NPDES).

EPA reviewed TRI on-site release data for the reporting year 2009 for the 2009 Current sites. These data indicate that 103 (21%) of the sites reported on-site releases of the Priority COCs. In terms of quantity released, the top five Priority COCs released were, in order, lead, zinc, copper, arsenic, and manganese. Together, these five substances accounted for 85% of the total quantity of all the Priority COCs reported as released in TRI. Mercury accounted for less than 1% of the total releases. The 10 facilities reporting the highest quantities released (four lead/zinc mines, two copper smelters, one gold mine, one silver mine, one iron and steel mill, and one copper/nickel mine) accounted for 66% of the total quantity of Priority COCs reported in TRI as released on site in 2009. The Priority COCs *most frequently* reported as released on site were lead compounds, followed by copper, mercury, zinc, manganese, nickel compounds, ammonia, and 58 other hazardous substances.

Not all of the 27 Priority COCs listed in Table 2-1 were represented among the reported TRI chemicals. EPA grouped the Priority COCs into four broad categories:

- **Non-radioactive metals:** arsenic, manganese, cadmium, zinc, antimony, lead, beryllium, copper, chromium, mercury, selenium, thallium, nickel, and silver, together with their compounds
- **Radionuclides:** the general category "radionuclides" and the specific radionuclides radium-226, lead-210, uranium-238, radon-222, and thorium-228
- **Organics:** benzo[a]pyrene, benzo[b]fluoranthene, benz[a]anthracene, dibenz[a,h]anthracene, and polychlorinated biphenyls
- **Other:** fluorine (as flouride).

Of these categories, only the members of the non-radioactive metals category and fluorine were required to be reported in TRI reporting year 2009. None of the radionuclides were required to be reported in 2009, and only one of the five organic compounds (polychlorinated biphenyls) was required to be reported in 2009. Thus, the TRI release data are best used as an information source on quantities of non-radionuclide metals and fluorine released on site at mines and mineral processors.

It is important to note that the TRI may also under-report Priority COC releases. Because of a court order stating that naturally occurring ores *in situ* have not been manufactured within the meaning of the legislation authorizing TRI reporting, and some mining companies may interpret the TRI reporting requirements as not applying to movement of rock materials and their naturally occurring hazardous substance content as a result of mining practices. This may explain why fewer than half of the 2009 Current mines appear to have reported to the 2009 TRI.

Submitted by NPDES permit holders, DMRs are another source of data regarding Priority COC releases from 2009 Current sites. NPDES permits are required for direct discharges of pollutants (as that term is defined in the Clean Water Act [CWA]) to the waters of the United States. By definition in the CERCLA statute, all CWA pollutants are considered CERCLA hazardous substances. Under the national NPDES program, permits for industrial facilities are only issued for point sources of process wastewater, non-process wastewater, or site storm water runoff that discharges *directly* into regulated surface waters, while industrial discharges from on-site treatment facilities that are *indirect* discharges (i.e., flows conveyed through treatment facilities prior to discharge) are regulated by the National Pretreatment Program and do not require an NPDES permit. Discharges to groundwater are also typically not regulated under the NPDES program unless hydrogeologic conditions allow an interaction with surface waters. Data regarding monitored releases of hazardous substances from mining and mineral processing sites into surface water bodies are documented in DMRs submitted to EPA by some, but not all, NPDES permit holders.

Some, but not all NPDES direct point source discharge permits stipulate that the permit holder monitor certain CWA pollutants and report the levels found to their state environmental agency. The data are entered into one of two EPA databases: the Permit Compliance System (PCS) or the Integrated Compliance Information System (ICIS).

For this evaluation EPA used data from both of these databases to define CERCLA releases of Priority COCs. In CERCLA, hazardous substance "releases" do not include federally permitted releases such as those allowed by an NPDES permit. Rather, CERCLA releases include only releases that exceed the permit limit, and are therefore a subset of all CERCLA hazardous substance discharges recorded in the PCS and ICIS databases.

Of the 2009 Current sites with verifiable locations (i.e., 417 sites), an estimated 57 (14%) reported Priority COC releases to surface water bodies through permitted NPDES discharges that exceeded the permitted discharge limit.

See **Appendix F** for more information on how the TRI and DMR data were extracted and compiled, and tables showing the CERCLA hazardous substance and Priority COC releases to surface water data for the 2009 Current sites.

The EPA's Effluent Guidelines program has conducted a detailed review of TRI data from 2007 and DMR data for mines and mineral processors, among other industries (U.S. EPA, 2009b). Although these data do not match the 2009 time frame examined in this report, they do provide similar findings regarding the number of sites and the quantities of toxic chemicals released that corroborate the findings reported here.

Under Section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop Total Maximum Daily Loads (TMDLs) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. A TMDL has been established along many of the streams that were evaluated using a constructed Aquatic Area of Review (AqAoR – see Appendix H for a detailed discussion of how AqAoRs were constructed and used). The streams identified in **Appendix F** by mine or processor site represent only the principal waterbody of the aquatic area of review. Tributaries of the principal stream may also have their own established TMDLs, and would be part of the aquatic area of review, but are not identified; these streams may also be the source of the TMDL at some distance downstream of the mine or processor site. Limitations of the original data sources only allow inclusion of streams within the conterminous United States. A total of 134 streams are listed in **Appendix F**; however, the cause of the impairment has not been determined for each stream. It should be noted that the identified mine or processor may not be the cause of the impairment, but a release from the identified mine or processor could further deteriorate an already stressed aquatic ecosystem or degrade stream quality to affect associated uses of the stream (e.g., drinking water source or recreation). Appendix F also includes maps showing the distribution of mines and facilities located along streams with established TMDLs.

2.5 Toxicity of Priority COCs

This section describes the toxicity of each Priority COC. The toxicity of a Priority COC varies depending on the receptor and the route of exposure (i.e., inhalation, ingestion, or dermal), as well as information from toxicity and/or epidemiology studies. The descriptions below, therefore, present the toxicity information for likely receptors and exposure pathways and exposure routes.

The human health toxicity descriptions below are from ATSDR's ToxFAQs™ (ATSDR, 2011) and the EPA's Integrated Risk Information System (IRIS) database (U.S. EPA, 2011b) during the period of this analysis (i.e., 2009 - 2012). The ecological toxicity descriptions are from the EPA's ECOTOX database (U.S. EPA, 2011c) and National Oceanic and Atmospheric Administration's (NOAA) Screening Quick Reference Tables (NOAA, 2008). EPA identified general classes of sensitive receptors from a literature search of EPA's ECOTOX database. Because ecological toxicity studies have been conducted only on a limited number of species, in general, EPA presents the toxicity for aquatic organisms (sediment and surface water biota).

Antimony

Antimony is a silvery white metal found in small quantities in the earth's crust. Antimony ores are mined and then either processed into antimony metal or combined with oxygen to form antimony oxide. Antimony enters the environment during the mining and processing of its ores and in the production of antimony metal, alloys, antimony oxide, and the combination of antimony with other substances.

Human Health Toxicity: The primary exposure route of concern for antimony is ingestion of contaminated media. The non-cancer endpoint for ingestion of antimony is hematological effects. Available studies indicate chronic ingestion of antimony may result in altered blood glucose and cholesterol levels. EPA has not classified the carcinogenicity of antimony. (U.S. EPA, 2011b; ATSDR, 2011)

Ecological Toxicity: Based on available toxicological data, screening benchmarks have been developed for terrestrial, aquatic, and sediment receptors. Mammals are the most sensitive terrestrial receptors to antimony exposure. Sediment and surface water biota are sensitive aquatic receptors to antimony exposure. Antimony is not known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Arsenic

The main use of metallic arsenic is for strengthening alloys of copper and lead.

Human Health Toxicity: The main exposure routes of concern for arsenic are ingestion and inhalation of contaminated media. The main non-cancer endpoints for ingestion of arsenic are cardiovascular and dermal effects. Exposure to lower levels can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of "pins and needles" in hands and feet. Ingesting or breathing low levels of inorganic arsenic for a long time can cause a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso. Skin contact with inorganic arsenic may cause redness and swelling. (U.S. EPA, 2011b; ATSDR, 2011)

EPA classifies arsenic as a known human carcinogen through ingestion and inhalation. Ingestion of inorganic arsenic can increase the risk of skin cancer and cancer in the liver, bladder, and lungs. Inhalation of inorganic arsenic can cause increased risk of lung cancer. (U.S. EPA, 2011c)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to arsenic exposure in soil. Invertebrates are the most sensitive aquatic receptors to arsenic exposure. Arsenic is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Beryllium

Human Health Toxicity: The primary exposure routes identified for beryllium are ingestion or inhalation of contaminated media. The associated non-cancer endpoints are gastrointestinal and pulmonary effects, respectively. Ingestion of beryllium may result in ulcers. Inhalation of high concentrations of beryllium may result in acute beryllium disease, resembling pneumonia. Exposure at lower concentrations may result in heightened sensitivity to beryllium and inflammation of the respiratory tract, weakness, and difficulty breathing. (U.S. EPA, 2011b; ATSDR, 2011)

Beryllium is classified as a probable human carcinogen. The primary cancer exposure route identified for beryllium is inhalation of contaminated media, causing lung cancer. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to beryllium exposure in soil. Invertebrates are the most sensitive aquatic receptors to beryllium exposure. Beryllium is not known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Cadmium

Human Health Toxicity: Cadmium's primary exposure route is ingestion of contaminated media, leading to renal effects. Available studies indicate chronic ingestion of cadmium may result in proteinuria, the excretion of essential proteins in urine that would otherwise be retained by the body, and kidney disease. (U.S. EPA, 2011b; ATSDR, 2011)

Cadmium is classified as a probable human carcinogen. The primary exposure route of concern for cadmium is inhalation of contaminated media, leading to lung cancer. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to cadmium exposure in soil. Invertebrates and fish are the most sensitive aquatic receptors to cadmium exposure. Cadmium is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Chromium

Human Health Toxicity: The primary exposure routes for chromium are ingestion and inhalation of contaminated media. The associated non-cancer endpoints are gastrointestinal and pulmonary effects, respectively. Available studies indicate chronic ingestion of chromium may result in irritation and ulcers in the stomach and small intestine, while inhalation may result in irritation to the lining of the nose, nose ulcers, and breathing problems such as asthma. (U.S. EPA, 2011b; ATSDR, 2011)

When chromium is in the hexavalent oxidation state, EPA classifies it as a known human carcinogen. The primary exposure routes of concern for hexavalent chromium are ingestion and inhalation of contaminated media, leading to gastrointestinal and pulmonary cancers, respectively. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, invertebrates are the most sensitive terrestrial ecological receptors to chromium exposure in soil. Invertebrates are also the most sensitive aquatic receptors to chromium exposure. Chromium is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Copper

Human Health Toxicity: The primary exposure route for copper is ingestion of contaminated media. The associated non-cancer endpoint is gastrointestinal effects. Available studies indicate chronic ingestion of copper may result in gastrointestinal disturbances, such as nausea and diarrhea. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of copper. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to copper exposure. Invertebrates are the most sensitive aquatic receptors to copper exposure. Copper is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Fluorine

Human Health Toxicity: The primary exposure route for fluorine is ingestion of contaminated media. The associated non-cancer endpoint is hematological effects. Available studies indicate chronic ingestion of fluorine may result in decreased count for red blood cells, packed cell volume, and hemoglobin. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of fluorine. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, microbes are the most sensitive terrestrial ecological receptors to fluorine exposure. Invertebrates are the most sensitive aquatic receptors to fluorine exposure. Fluorine is not known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Lead

Human Health Toxicity: The primary exposure routes for lead are ingestion of and inhalation of contaminated media. The associated non-cancer endpoint for both exposure pathways is neurological effects. Available studies indicate chronic exposure to lead may result in changes to neurobehavioral development in children or brain damage. (U.S. EPA, 2011b; ATSDR, 2011)

EPA classifies lead as a potential human carcinogen. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to lead exposure. Amphibians are the most sensitive aquatic receptors to lead exposure. Lead is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Manganese

Human Health Toxicity: The primary exposure routes for manganese are ingestion of and inhalation of contaminated media. The associated non-cancer endpoint for both exposure pathways is neurological. Available studies indicate chronic exposure to manganese may result in weakness and fatigue, gait disturbances, tremors, dystonia, or impairment of neurobehavioral function. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of manganese. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, invertebrates are the most sensitive terrestrial ecological receptors to manganese exposure. Fish are the most sensitive aquatic receptors to manganese exposure. Manganese is not known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Mercury

Human Health Toxicity: The primary exposure route for mercury is ingestion of contaminated media. The associated non-cancer endpoint is neurological effects. Available studies indicate chronic exposure to mercury may result in hand tremor, increases in memory disturbances, autonomic dysfunction, and developmental neurotoxicity. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of mercury. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to mercury exposure. Invertebrates and fish are the most sensitive aquatic receptors to mercury exposure. Mercury is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Nickel

Human Health Toxicity: The primary exposure routes for nickel are ingestion and inhalation of contaminated media. The associated non-cancer endpoints are body weight and pulmonary effects, respectively. Available studies indicate chronic ingestion of nickel may result in decreased weight of the body and select organs, while chronic inhalation may result in bronchitis and reduced lung function. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of nickel. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to nickel exposure. Fish are the most sensitive aquatic receptors to nickel exposure (Nanda et al., 2000). Nickel is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a class of structurally similar chemical compounds characterized by the presence of fused aromatic rings. PAHs are typically formed during the incomplete burning of organic material including coal, oil, gasoline, and garbage. Benzo[a]pyrene, benzo[b]fluoranthene, benz[a]anthracene, and dibenz[a,h]anthracene were the individual PAHs identified as Priority COCs. (U.S. EPA, 2011b; ATSDR, 2011)

Human Health Toxicity: EPA classifies some individual PAHs as probable human carcinogens. All PAHs identified as Priority COCs are classified as probable carcinogens. The primary exposure routes for PAHs are ingestion and inhalation of contaminated media, with associated endpoints of gastrointestinal and pulmonary cancers, respectively. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to PAH exposure. Invertebrates are the most sensitive aquatic receptors to PAH exposure. PAHs are known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Polychlorinated Biphenyls (PCBs)

PCBs are a class of organic compounds with 2 to 10 chlorine atoms attached to a biphenyl molecule composed of two benzene rings. Each type of PCB with a given number of chlorine atoms and a given structure is known as a congener, and each congener is usually identified with the word “Aroclor” and a number. PCB production was banned by the U.S. Congress in 1979.

Human Health Toxicity: Non-cancer health data are available for select PCB congeners. The primary exposure route for Aroclor-1016 is ingestion of contaminated media, resulting in reproductive effects. Available studies indicate chronic ingestion of Aroclor-1016 may result in reduced birth weight and neurological impairment of infants. The primary exposure pathway for Aroclor-1254 is ingestion of contaminated media, which is associated with ocular, hair, and immunological effects. Available studies indicate chronic ingestion of Aroclor-1254 may result in inflammation of the eyes, distorted nails, and reduced antibody function. (U.S. EPA, 2011b; ATSDR, 2011)

EPA classifies all PCBs as probable human carcinogens. The primary exposure pathways of concern for PCBs are ingestion and inhalation of contaminated media, which are associated with liver cancer. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to PCB exposure. Fish are the most sensitive aquatic receptors to PCB exposure. PCBs are known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Radionuclides

Radionuclides are any atoms with unstable nuclei that will eventually decay toward a more stable configuration by releasing excess energy to the surrounding environment in the form of radiation. Naturally occurring radionuclides are ubiquitous in nature but can be concentrated during mining and processing activities. The individual radionuclides identified as Priority COCs at Case Study Historical sites were radium-226, radon-222, lead-210, uranium-238, and thorium-228.

Human Health Toxicity: Radionuclides are chemically identical to their stable counterparts. Therefore, they share the same toxicological endpoints and health effects.

EPA classifies all radionuclides as known human carcinogens. The primary exposure routes of concern for radionuclides are ingestion and inhalation of contaminated media, as well as external exposure to radiation. The associated cancer endpoints vary by radionuclide and exposure route; however, exposure of any organ system to elevated levels of radiation increases the likelihood of cancer. (U.S. EPA, 2011b)

Ecological Toxicity: Little information is available to establish a dose-response relationship between ecological receptors and radionuclide exposure. (U.S. EPA 2011c)

Selenium

Human Health Toxicity: The primary exposure routes for selenium are ingestion and inhalation of contaminated media, which are associated with dermal, neurological, hepatic and pulmonary effects, respectively. Available studies indicate chronic ingestion of selenium may result in clinical selenosis, resulting in hair loss, sloughing of nails, fatigue, irritability, and neurological damage. Extreme cases of selenosis can result in cirrhosis of the liver, pulmonary edema, and death. Chronic inhalation of selenium may result in respiratory irritation, bronchial spasms, and coughing. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of selenium. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, plants and birds are the most sensitive terrestrial ecological receptors to selenium exposure. Egg laying vertebrates (i.e., fish) are the most sensitive aquatic receptors to selenium exposure. Selenium is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Silver

Human Health Toxicity: The primary exposure route for silver is ingestion of contaminated media, which is associated with dermal effects. Available studies indicate chronic ingestion of silver may result in argyra, a permanent blue-gray discoloration of the skin and other body tissues. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of silver. (U.S. EPA, 2011c)

Ecological Toxicity: Based on available data, plants are the most sensitive terrestrial ecological receptors to silver exposure. Invertebrates are the most sensitive aquatic receptors to silver exposure. Silver is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Thallium

Human Health Toxicity: The primary exposure route for thallium is ingestion of contaminated media. The associated non-cancer endpoints are dermal, neurological, and reproductive effects. Available studies indicate chronic ingestion of thallium may result in hair loss, as well as damage to the nervous and reproductive systems. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of thallium. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available data, mammals are the most sensitive terrestrial ecological receptors to thallium exposure. Invertebrates are the most sensitive aquatic receptors to thallium exposure. Thallium is not known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

Zinc

Human Health Toxicity: The primary exposure route for zinc is ingestion of contaminated media. The associated non-cancer endpoints are dermal, neurological, and reproductive effects. Available studies indicate chronic ingestion of zinc may result in hair loss, damage to the nervous and reproductive systems, and decreases in erythrocyte Cu, Zn-superoxide dismutase (ESOD) activity in healthy adults. (U.S. EPA, 2011b; ATSDR, 2011)

EPA has not classified the carcinogenicity of zinc. (U.S. EPA, 2011b)

Ecological Toxicity: Based on available literature, invertebrates are the most sensitive terrestrial ecological receptors to zinc exposure. Invertebrates and fish are the most sensitive aquatic receptors to zinc exposure. Zinc is known to bioaccumulate in animals. (U.S. EPA 2011c; NOAA, 2008)

In summary, each of the Priority COCs has certain toxic effects on either humans, ecological receptors, or both.

3.0 Exposure Analysis

Superfund exposure assessments estimate the magnitude of current and possible future human and ecological exposures, the frequency and duration of these exposures, and the pathways by which receptors are potentially exposed. Reasonable maximum exposures are developed for past, present, and possible future exposures to CERCLA hazardous substances. The Superfund exposure assessment process includes the following tasks:

- Characterizing exposure setting, including the receptors that may be impacted by the CERCLA hazardous substances being evaluated;
- Identifying exposure pathways and the specific routes by which the receptors may come into contact with the CERCLA hazardous substances; and
- Quantifying exposure.

When evaluating potential human health risk, The EPA's Risk Assessment Guidance for Superfund, or RAGS, Part A, directs that the exposure assessment consider both current and future land uses and corresponding exposures (U.S. EPA, 1989a, page 6-4). Guidance for evaluating ecological risks at Superfund sites suggests that a qualitative and, if data allow, quantitative appraisal of the actual or potential impacts of contaminants from a hazardous waste site on plants and animals be performed (U.S. EPA, 1997). Additionally, ecological assessments should consider exposure to especially sensitive habitats and critical habitats of federally classified threatened or endangered species.

Some concepts related to exposure assessments are described here. Please refer to EPA's RAGS, Part A (U.S. EPA, 1989a) for further explanation of exposure analysis in the Superfund program.

- A **stressor** is "any physical, chemical, or biological entity that can induce an adverse response. Stressors may adversely affect specific natural resources or entire ecosystems, including plants and animals, as well as the environment with which they interact" (U.S. EPA, 2011a). In the context of the Superfund clean ups described in this report, stressors are limited to CERCLA hazardous substances.
- A **receptor** is an organism exposed to the stressor. Examples of human receptors are occupational workers, current and future residential adults and children, and trespassers. Examples of ecological receptors include birds, mammals, fish, benthic invertebrates, and plants.
- Environmental **fate and transport** evaluates how contaminants might move through or be transformed physically, chemically, and biologically in the environment; how contaminants are taken up by plants and animals; and how they are transferred among plants and animals (i.e., through animals eating plants or other animals) (U.S. EPA, 1997).
- EPA has defined an **exposure pathway** as "[t]he course a chemical or physical agent takes from a [contamination] source to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, a transport/exposure medium (e.g., air) or media (in cases of intermedia transfer) also is included" (U.S. EPA, 1989a, p. 6-2).

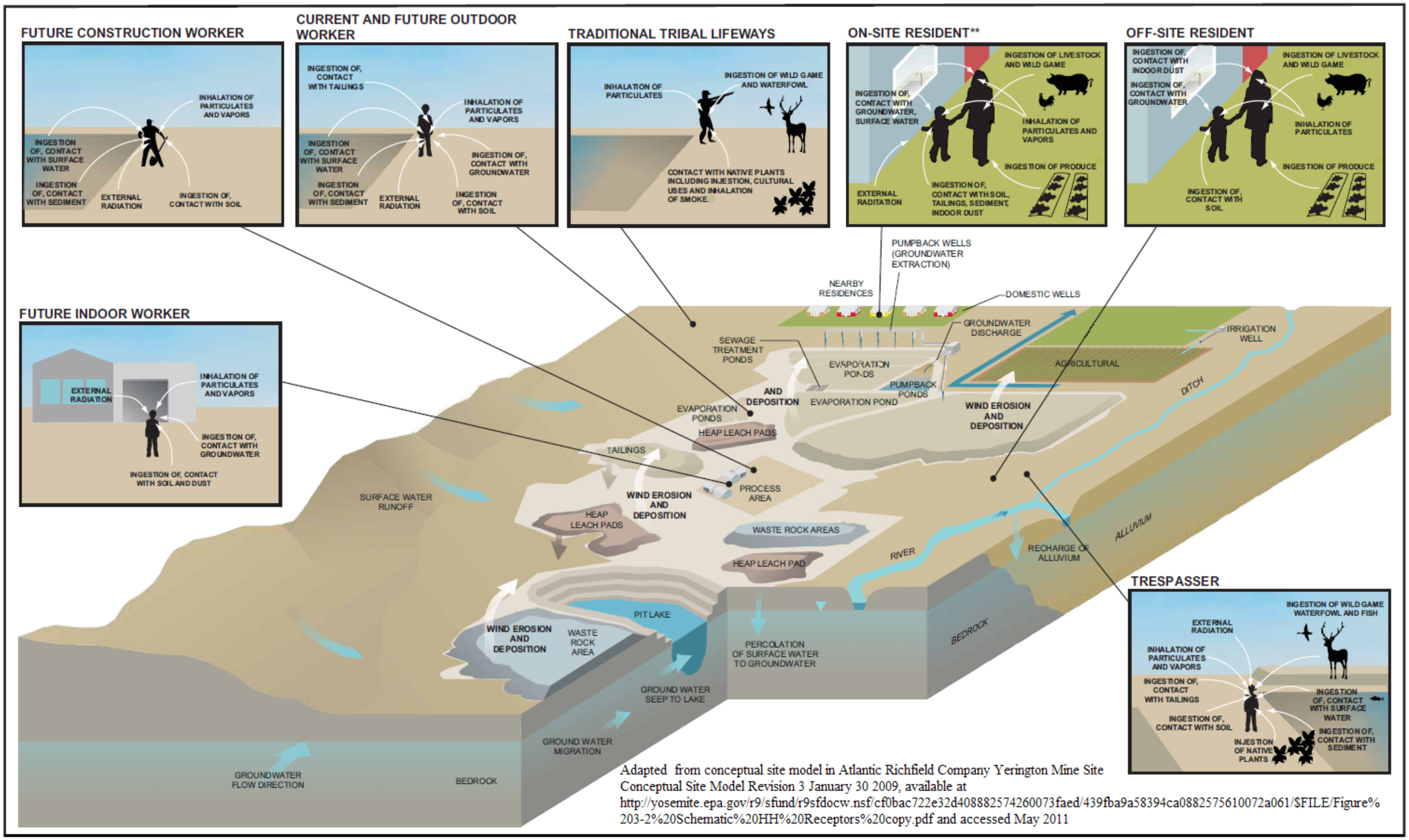
- EPA has defined **exposure route** as "[t]he way a chemical or physical agent comes in contact with an organism (e.g., by ingestion, inhalation, dermal contact)" (U.S. EPA, 1989a, p. 6-2). Exposure occurs when there are complete pathways between a chemical or physical agent and receptors.

3.1 Conceptual Site Models for Superfund Human Health and Ecological Risk Assessments

The purpose of a conceptual site model (CSM) is to identify potential receptors, exposure pathways, and exposure routes based on the potential release, transport, and fate of CERCLA hazardous substances (contaminants of potential concern) at a mine or processor site. The CSM describes specific contaminant sources, contaminant release mechanisms, pathways for contaminant transport, and the resulting potential for human and ecological exposure.

The example CSM provided in **Figure 3-1**, adapted from a CSM prepared for a mining NPL site in Nevada, shows a mining and ore processing site of nonspecific location, climate, and physical setting. Although this model may not capture every possible combination of receptor and pathway that could occur at a site (e.g., recreational users of surface waters are excluded), it is generally consistent with what was seen at the Case Study Historical sites. Thus, it is likely to be generally consistent with the exposure pathways that can be expected at the 2009 Current sites that are the surrogate for the current and future population of sites. The current and future receptors and their corresponding exposure pathways depicted in Figure 3-1 are summarized below. More detailed information about the CSM can be found in **Appendix K**.

- **Future Construction Worker:** This represents an adult who would likely be exposed to on-site contamination at a point in the future when the land is being redeveloped. The future construction worker could potentially be exposed to contamination through the following pathways:
  - Surface water, via ingestion or direct contact
  - Sediment, via ingestion or direct contact
  - Particulates and vapors in the air, via inhalation
  - Soil, via ingestion or direct contact
  - External radiation.
- **Current and Future Outdoor Worker:** This represents an adult who is either currently working on site and in direct contact with environmental media (e.g., a guard or a remediation worker) or a future adult working on site and in direct contact with environmental media (e.g., landscaper, gardener, guard). This person could potentially be exposed to contamination through the following pathways:
  - Tailings, via ingestion or direct contact
  - Surface water, via ingestion or direct contact
  - Sediment, via ingestion or direct contact
  - Particulates and vapors in the air, via inhalation
  - Ground water, via ingestion or direct contact
  - Soil, via ingestion or direct contact
  - External radiation.



Adapted from conceptual site model in Atlantic Richfield Company Yerington Mine Site Conceptual Site Model Revision 3 January 30 2009, available at http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/cf0bac722e32d408882574260073faed/439fba9a58394ca0882575610072a061/$FILE/Figure%203-2%20Schematic%20HH%20Receptors%20copy.pdf and accessed May 2011

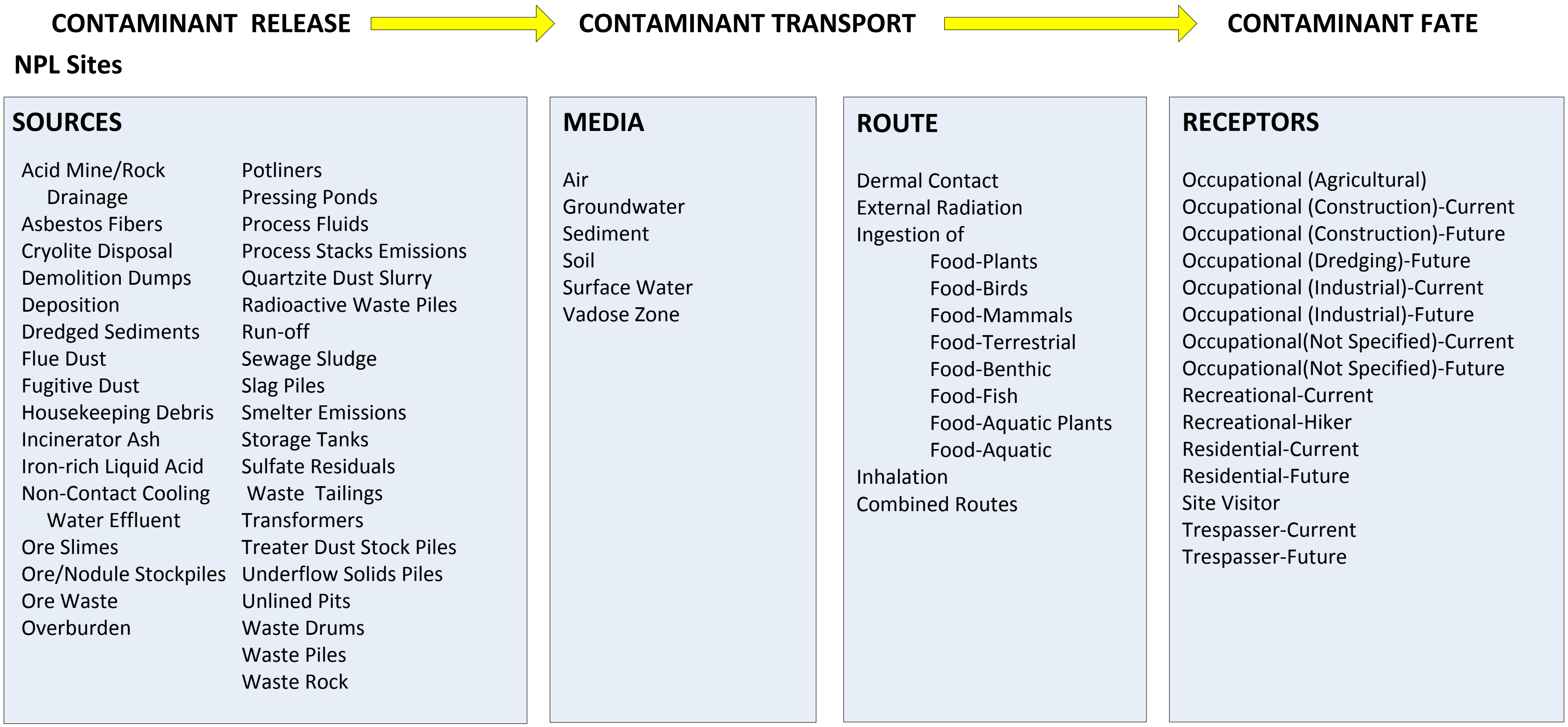
Figure 3-1. Generic mine site conceptual site model and exposure pathways for a Superfund human health risk assessment.

- **Traditional Tribal Lifeways:** This represents a person who is partially or fully living a traditional tribal lifestyle that involves hunting wild game and/or collecting wild plants/berries for sustenance. This person would likely be spending time outdoors and could potentially be exposed to contamination through the following pathways:
  - Particulates in the air, via inhalation
  - Wild game and waterfowl, via ingestion
  - Fish, or shellfish , via ingestion
  - Contact with native plants, via ingestion, cultural uses, and/or inhalation of smoke.
- **On-Site Resident:** This represents current and future adults and children who live on site. Except for temporary on-site living facilities for workers at more remote mines, the probability of residents living on site is low; however, if this does occur, the potential exposures are high. These residents could potentially be exposed to contamination through the following pathways:
  - Ground water, via ingestion or direct contact
  - Surface water, via ingestion or direct contact
  - Livestock and wild game, via ingestion
  - Produce, via ingestion
  - Particulates and vapors in the air, via inhalation
  - Soil, via ingestion or direct contact
  - Tailings, via ingestion or direct contact
  - Sediment, via ingestion or direct contact
  - Indoor dust, via ingestion or direct contact
  - External radiation.
- **Off-Site Resident:** This represents current and future adults and children who live off site but within the buffer zone of potential exposures (i.e., 3 miles). Exposures will vary depending on several factors (e.g., whether the residential area is down-gradient or up-gradient from the site). These residents could potentially be exposed to contamination through the following pathways:
  - Indoor dust, via ingestion or direct contact
  - Ground water, via ingestion or direct contact
  - Livestock and wild game, via ingestion
  - Product, via ingestion
  - Particulates, via inhalation
  - Soil, via ingestion or direct contact.
- **Future Indoor Worker:** This represents a person who would be working indoors, on site, at a point in the future after the land has been redeveloped (e.g., a librarian). It is unlikely that this person would come into direct contact with the land because the assumption is that the ground where they walk is paved (i.e., parking lot, sidewalks). However, this person could potentially be exposed to contamination through the following pathways:
  - Particulates and vapors in the air, via inhalation
  - Ground water, via ingestion or direct contact
  - Soil and dust, via ingestion or direct contact

  - External radiation.
- **Trespasser/Hunter:** This represents a current or future adult or adolescent who is exposed to environmental media on site, even though the site may be fenced, guarded, or otherwise prohibited from public access. This person could potentially be exposed to contamination through the following pathways:
  - Tailings, via ingestion or direct contact
  - Soil, via ingestion or direct contact
  - Native plants, via ingestion
  - Sediment, via ingestion or direct contact
  - Surface water, via ingestion or direct contact
  - Wild game, waterfowl, and fish, via ingestion
  - Particulates and vapors, via inhalation
  - External radiation.

The collected data indicate that mineral processing operations that do not occur at or near mining sites frequently take place in a more urban or densely populated setting. A CSM for a mineral processing operation in an urban setting would show site features, sources for hazardous substance releases, receptors, and likely transport pathways from source to receptor. Mineral processing that takes place within enclosed buildings may present a different (lower) potential for hazardous substance transport than mining operations taking place outdoors. Outdoor waste management practices could occur at both mine and processor sites.

Based on a review of Superfund risk assessments and other CERCLA site documents, EPA compiled a list of contaminant sources, affected environmental media, human exposure routes, and human and ecological receptors at Case Study Historical sites. **Figure 3-2** is a detailed chart displaying the contaminant sources, affected environmental media, human exposure routes, and human receptors for the Case Study Historical sites. **Figure 3-3** shows the same information for ecological receptors.



CONTAMINANT RELEASE → **CONTAMINANT TRANSPORT** → **CONTAMINANT FATE**

NPL Sites

SOURCES

- Acid Mine/Rock Drainage
- Asbestos Fibers
- Cryolite Disposal
- Demolition Dumps
- Deposition
- Dredged Sediments
- Flue Dust
- Fugitive Dust
- Housekeeping Debris
- Incinerator Ash
- Iron-rich Liquid Acid
- Non-Contact Cooling Water Effluent
- Ore Slimes
- Ore/Nodule Stockpiles
- Ore Waste
- Overburden
- Potliners
- Pressing Ponds
- Process Fluids
- Process Stacks Emissions
- Quartzite Dust Slurry
- Radioactive Waste Piles
- Run-off
- Sewage Sludge
- Slag Piles
- Smelter Emissions
- Storage Tanks
- Sulfate Residuals
- Waste Tailings
- Transformers
- Treater Dust Stock Piles
- Underflow Solids Piles
- Unlined Pits
- Waste Drums
- Waste Piles
- Waste Rock

MEDIA

- Air
- Groundwater
- Sediment
- Soil
- Surface Water
- Vadose Zone

ROUTE

- Dermal Contact
- External Radiation
- Ingestion of
  - Food-Plants
  - Food-Birds
  - Food-Mammals
  - Food-Terrestrial
  - Food-Benthic
  - Food-Fish
  - Food-Aquatic Plants
  - Food-Aquatic
- Inhalation
- Combined Routes

RECEPTORS

- Occupational (Agricultural)
- Occupational (Construction)-Current
- Occupational (Construction)-Future
- Occupational (Dredging)-Future
- Occupational (Industrial)-Current
- Occupational (Industrial)-Future
- Occupational(Not Specified)-Current
- Occupational(Not Specified)-Future
- Recreational-Current
- Recreational-Hiker
- Residential-Current
- Residential-Future
- Site Visitor
- Trespasser-Current
- Trespasser-Future

Figure 3-2. Contaminant sources, exposure pathways, exposure routes, and human receptors at Case Study Historical sites.

CONTAMINANT RELEASE → **EXPOSURE PATHWAYS** → **WILDLIFE SPECIES**

SOURCES

- Airborne Emissions
- ARD
- Calcium Silicate Slag Piles
- Coke Dust Slurry
- Coke Stockpiles
- Cryolite Disposal
- Debris
- Exposed Mineralized Bedrock
- Fuel/Oil
- Fugitive Dust
- Leachate
- Manual/Aerial Deposition
- Municipal Waste
- Nodule Stockpiles
- Non-Contact Cooling Water Effluent
- Ore Stockpiles
- Overburden
- Phossy Water
- Potliners
- Process Residues
- Process Stacks Air Emissions
- Quartzite Dust Slurry
- Run-off
- Slag
- Slag Piles
- Sludge
- Spent Mineral Waste
- Spent Ore
- Tailings
- Treater Dust Stock Piles
- Underflow Solids Piles
- Waste Drums
- Waste Piles
- Waste Rock
- Wastewater

EXPOSURE PATHWAYS

- Groundwater
- Sediment
- Soil
- Subsurface Soil
- Surface Soil
- Surface water
- Water

COMPARTMENTS

- Aquatic Invertebrates
- Aquatic Plants
- Benthic Invertebrates
- Birds
- Fish
- Mammals
- Plants
- Terrestrial Invertebrates
- Terrestrial Plants
- Plants
- Soil Invertebrates

ROUTES

- Dermal Contact
- Ingestion
- Inhalation
- Combined Routes

Birds

- American Dipper
- American Kestrel
- American Robbin
- Barn Owl
- Belted Kingfisher
- Bobwhite Quail
- Carnivorous Birds
- Cliff Swallow
- Great blue heron
- Horned Lark
- King Fisher
- Mallard
- Mountain Chickadee
- Northern Harrier
- Omnivorous Birds
- Pine Grosbeak
- Red-tailed Hawk
- Sage Grouse
- song sparrow
- spotted sandpiper
- Waterfowl
- Woodcock

Mammals

- Carnivorous Mammals
- Coyote
- Deer
- Deer Mouse
- Field Mice
- Herbivorous Mammals
- Long-tailed Weasel
- Masked Shrew
- Meadow Vole
- Mink
- Montane Vole
- Omnivorous Mammals
- Piscivorous Mammals
- Rabbits
- Raccoon
- Red Fox
- Small mammals
- Soil Invertebrate-feeding Mammals
- White-tailed Deer

Other-Terrestrial

- Benthic Invertebrates
- Benthic macroinvertebrates
- Benthic Organisms
- Deepwater Habitats
- Fish
- Future-Aquatic Organisms
- Future-Wetland Invertebrates
- Periphyton Community
- Predatory Fish
- Rainbow Trout

Other-Aquatic

- Sagebrush
- Soil invertebrates
- Terrestrial Invertebrates
- Terrestrial Organisms
- Terrestrial Plant Community
- Terrestrial Soil Community
- Thickspike Wheatgrass

Other-Generic

- Amphibians
- Future-Wildlife
- Herbivores
- Plants
- Vegetation

* Receptors are considered current unless otherwise stated.

Figure 3-3. Contaminant sources, exposure pathways, exposure routes, and ecological receptors at Case Study Historical sites.

3.2 Receptors

3.2.1 Case Study Historical Sites: Human Receptors

Superfund risk assessments of Case Study Historical sites included a wide range of human habitation settings, from very sparsely populated sites to densely populated urban metal smelting sites, and also included one Indian reservation. The most common human receptor to be exposed to CERCLA hazardous substances at levels of concern (i.e., >1E-06 cancer risk or >1.0 hazard quotient/hazard index, discussed further in **Section 4.0**) at the Case Study Historical sites is the residential receptor (22 sites), followed by occupational receptors (18 sites). Of the highest hazard quotients (i.e., HQs > 100) for human receptors, 9 of 11 (or 82%) are attributed to residential receptors; of the highest cancer risk values (i.e., >1E-02) for human receptors, 18 of 25 (72%) are attributed to residential receptors.

3.2.2 Case Study Historical Sites: Ecological Receptors

Superfund risk assessments of the Case Study Historical sites also evaluated a range of ecological receptor habitat settings, including aquatic habitats, especially streams near mines, as well as habitat for terrestrial and avian receptors, including some federally designated threatened and endangered species. Ecological receptors at the Case Study Historical sites included species identified as federally designated threatened or endangered species at the time the site was investigated, as well as state-designated threatened or endangered and federal or state-designated species of concern. The federally designated threatened/endangered species identified at the Case Study Historical sites included mammals, birds, aquatic organisms, plants, invertebrates, fish, amphibians, and one reptile species, in descending order of frequency. **Appendix H, Attachment H1** shows the federally listed threatened/endangered species mentioned in the CERCLA site documents for the Case Study Historical sites, and the species' status listed in the table reflects what their status was at the time the CERCLA site documents were prepared. The Superfund ecological risk assessments of the Case Study Historical sites also evaluated species that are not specifically identified as federally designated threatened or endangered species. In several cases the ecological risk assessments identified major groupings of ecological receptors, for example, benthic invertebrates (e.g., crayfish or mussels) or omnivorous birds, rather than individual species.

3.2.3 2009 Current Sites: Documented Human Receptors

Human and ecological exposure analyses have been conducted at a very limited number of the 2009 Current sites. For example, a lead smelter in Herculaneum, Missouri, has undergone a public health exposure investigation by ATSDR and the state of Missouri (ATSDR, 2005); a copper smelter in Arizona has undergone a public health assessment that included an exposure evaluation (ATSDR, 2002); a phosphate mining area has undergone a risk assessment that included an exposure analysis (NewFields, 2005); a licensed uranium processing site has undergone a Superfund risk assessment (U.S. EPA, 2002); and a currently operating manganese processing site has undergone an exposure assessment (ATSDR, 2009). At these sites, known human receptors have been identified. For example, the lead smelter's and copper smelter's receptors of concern are residents living in the vicinity of those two smelters, including pregnant women and children, while the phosphate mining area's receptors are Native American children and children living a subsistence lifestyle. **Appendix A** provides more details on the exposure analyses that EPA located for the 2009 Current sites.

Residents within the 3-mile buffer zone of a site or other, varying buffer distances depending on the hazardous substances being evaluated, could be exposed to contamination via several pathways. These pathways include ingestion of ground water, surface water, soil, sediment, and dust; dermal contact with ground water, surface water, soil, sediment, and dust; inhalation of particulates; and ingestion of animals and produce. Pregnant women and children may be more vulnerable to the harmful effects that can occur as a result of exposure to contaminated media, and are therefore given special consideration when determining their exposure potential.

3.2.4 2009 Current Sites: Potential Human Receptors

Information on the presence of human receptors was gathered for most of the 2009 Current sites, from a spatial dataset that EPA developed as part of this analysis. See **Appendix E** for the GIS methodology and documentation and **Appendix L** for detailed GIS data.

For potential human receptors, EPA developed an area-apportionment method to analyze the 2009 Current sites using 2000 Census population data to estimate the human residential populations within several specified distances from each site. EPA created buffer zones of selected distances around each site and then overlaid each buffer zone with census block group boundaries to estimate total population. The numbers of sites with different populations of potential human receptors living within 3 miles of each site are shown in **Figure 3-4**. EPA chose the 3-mile distance for this analysis because a few mines are as large as 1 to 2 miles or more across (e.g., a molybdenum mine in New Mexico; an iron ore mine and processor in Minnesota), and humans typically would not be living inside or next to a mine pit or directly on top of disturbed land while the mine is active. As shown in Figure 3-4, of the 2009 Current sites with verifiable locations (i.e., 417 sites), 227 sites (i.e., 54%) have fewer than 1,000 people living within 3 miles.

Examples of sites with estimated populations within 3 miles are presented below. These are intended to show the range of population densities that occur within a 3-mile radius of currently active mines or processors in the United States. In general, the denser the population surrounding a site, the higher the potential for human exposure to and subsequent health impacts from contamination from that site. However, each site will have a site-specific potential to expose the surrounding population, depending on various factors such as site activities (release rates, types of CERCLA hazardous substances present), the number of people living down-gradient vs. up-gradient from the site, and the lifestyle of those exposed (e.g., subsistence farming vs. urban setting).

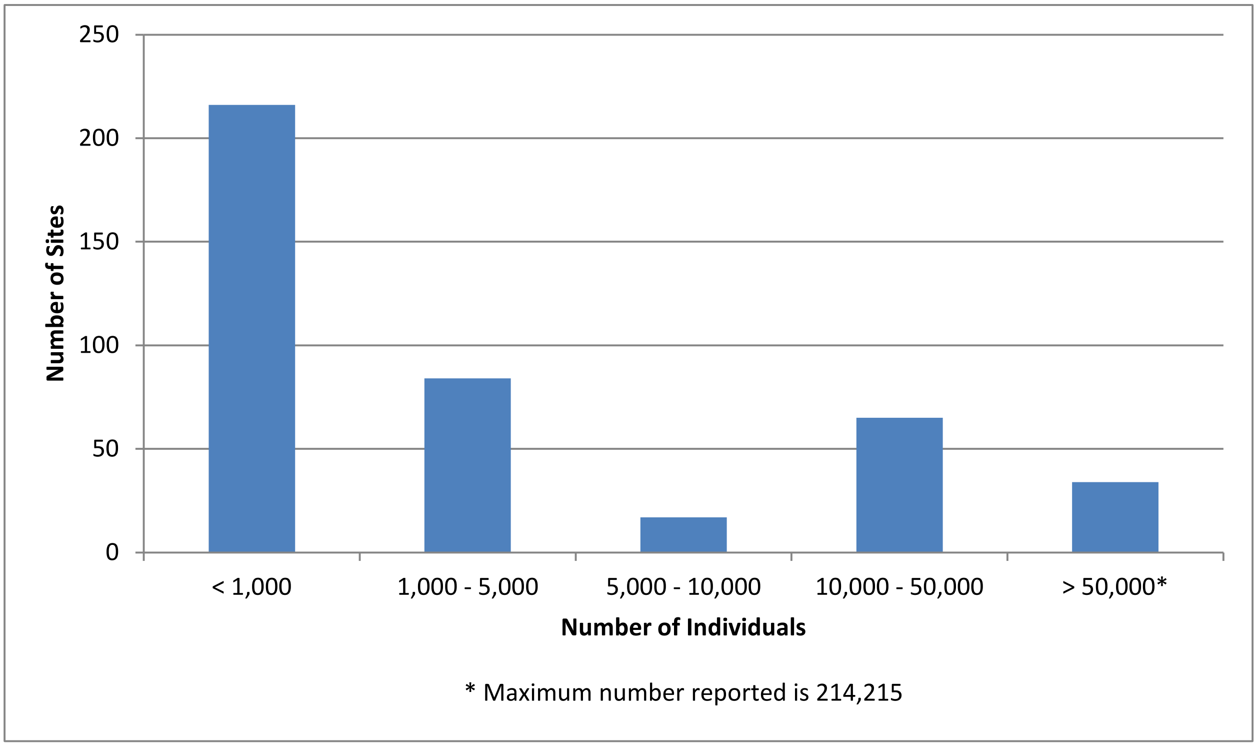


Figure 3-4. Number of 2009 Current sites, by estimated population within 3 miles.

- In *sparsely* populated areas (fewer than 1,000 people within 3 miles):
  - an active gold mine in Humboldt County, Nevada, 6 people
  - an intermittently active wollastonite mine in Essex County, New York, 395 people
  - an intermittently active rare earth ore mine and processor in San Bernardino County, California, 7 people
- In *moderately* populated areas (1,000 – 50,000 people within 3 miles):
  - an iron and steel slag processor in Butler County, Ohio, 31,923 people
  - a silicomanganese producer in Mason County, West Virginia, 26,548 people
  - a tungsten processor in Madison County, Alabama, 18,548 people
- In *densely* populated areas (more than 50,000 people within 3 miles):
  - a vermiculite processor in Maricopa County, Arizona, 210,332 people
  - an iron and steel slag processor in Cuyahoga County, Ohio, 140,164 people
  - a vermiculite processor in Middlesex County, New Jersey, 95,550 people

3.2.5 2009 Current Sites: Documented Ecological Receptors

Information on known ecological receptors was available for only a limited number of the 2009 Current sites. For example, studies are performed as part of the National Environmental Policy Act (NEPA) process at mines or mineral processors located on federal lands, and these studies sometimes identify the presence of threatened or endangered species or other ecological receptors (e.g., Kanouse, 2011). At sites regulated under Resource Conservation and Recovery Act (RCRA) hazardous waste regulations, or the state's equivalent requirements, site owners or operators are sometimes required to perform ecological risk assessments as part of their permit requirements (e.g., Oklahoma DEQ, 2008). The risk assessment of one phosphate mine evaluated livestock, wildlife, fish, and aquatic invertebrates (NewFields, 2005). At a copper mine, ecological receptors included specific birds, mammals, and reptiles (Golder and Associates Inc., 2005).

3.2.6 2009 Current Sites: Potential Ecological Receptors

EPA searched multiple data sources to identify the existence of critical habitat for federally designated threatened and endangered species and the presence and proximity of aquatic habitat inhabited by aquatic species. For federally designated threatened and endangered species, 24 (i.e., 6%) of the estimated 417 sites with verifiable locations are located within 3 miles of federally designated "critical habitat" according to data that were current as of the download date of May 5, 2010. At a distance of 3 miles, the federally designated threatened and endangered species included certain birds, mammals, fish, reptiles, and amphibians. As the distance from the sites increases, the number of sites near critical habitat increases; an estimated 22% (92 of 417 sites) of the 2009 Current sites are within 20 miles of critical habitat. Depending on the species and the extent of the range that it uses for habitat and acquiring food, either a 3-mile or a 20-mile distance (or more) may be relevant. **Appendix H** shows the species identified in this analysis.

Perennial streams were detected within a 24-hour downstream travel distance from 371 (i.e., 94%) of the 395 sites in the contiguous United States with verifiable locations.[6] These streams would therefore receive precipitation runoff from these sites, unless an engineered diversion has been constructed. Aquatic receptors could be expected to be present in many surface water bodies with perennial flow. Even some streams with only intermittent flow support aquatic life when flow is present. Eight percent of the 395 sites are located in such arid climates that there is no perennial stream nearby.

An estimated 151 (i.e., 38%) of the 395 sites are estimated to be within a 24-hour downstream travel distance of a dam that provides a beneficial use for fish and wildlife.

3.3 Exposure Pathways and Routes

Exposure pathways include the sequence of environmental media, such as air, water, soil, or sediments, through which CERCLA hazardous substances move from the source to the receptor. Exposure routes are the points of contact into the receptor organism (inhalation; ingestion; direct contact with plant tissue, skin or exterior membranes). Figure 3-2 identifies environmental media, exposure pathways, and exposure routes found in the Superfund human health and ecological risk assessments performed at the Case Study Historical sites.

3.3.1 Case Study Historical Sites: Human Exposure Pathways and Routes

As noted above, the most common human receptors for the Case Study Historical sites were residential and occupational. For both residential and occupational receptors at Case Study Historical sites, the most common exposure medium was ground water (at 18 of 22 sites with residential receptors and 8 of 14 sites with occupational receptors), followed by soil (at 9 of 22 sites with residential receptors and 5 of 14 sites with occupational receptors). The most common

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[6] As discussed in Section 2.1.3, the 2009 Current Sites universe includes 417 sites with verifiable locations. Some analyses could not be run for sites in Alaska because of lack of data. The remaining 395 sites with verifiable locations are all in the contiguous United States.

exposure route was ingestion (at 21of 22 sites with residential receptors and all 14 sites with occupational receptors), followed by inhalation (at 14 of 22 sites with residential receptors and 8 of 14 sites with occupational receptors). Note that all values are for CERCLA hazardous substances found to be above a level of concern. Also, a single site could report more than one medium or route; thus, the numbers sum to more than the total number of sites.

Examples of human exposure pathways and exposure routes evaluated for specific CERCLA hazardous substances found to be of concern at the Case Study Historical sites include the following:

- Antimony in surface soil ingested by current and future residents (Colorado DPHE, 2008, Table 8-54)
- Uranium found in food plants ingested by people (U.S. EPA, 2005a, p. 97)
- Thorium in creek sediment contacted by adolescent recreational users of the creek (U.S. EPA, 2005b, Table 11).

The Superfund risk assessments of other Case Study Historical sites include similar examples of human exposure pathways and exposure routes shown in Figure 3-2.

3.3.2 Case Study Historical Sites: Ecological Exposure Pathways and Routes

The most common exposure media for ecological receptors at Case Study Historical sites were sediment and surface water (at 13 and 11 sites, respectively). The most common ecological exposure routes were ingestion and dermal contact (at 9 and 8 sites, respectively). Again, all counts are for CERCLA hazardous substances present above a level of concern.

Examples of ecological exposure pathways and exposure routes evaluated at the Case Study Historical sites include the following:

- Lead and zinc in food items ingested by terrestrial invertebrates and subsequently eaten by birds (Colorado DPHE, 2008, p. 9-111);
- Lead in soil, surface water, and food items ingested by robins (U.S. EPA, 2001, Table 65);
- Selenium, aluminum, antimony, and arsenic in food items ingested by red fox (U.S. EPA, 1998, Appendix 7B-3).

The Superfund risk assessments of other Case Study Historical sites include similar examples of exposure pathways and exposure routes for ecological receptors.

The species near the Case Study Historical sites that were classified as federally endangered or threatened at the time of the source document include the following:

- Endangered:
  - Birds: Bald eagle, peregrine falcon, whooping crane
  - Mammals: Gray wolf
  - Reptiles: Bog turtle

- Threatened:
  - Birds: Bald eagle
  - Fish: Bull trout

- Mammals: [Canada] lynx, grizzly bear
- Plants: Ute ladies'-tresses.

A table showing the full list of both federal- and state-designated threatened and endangered species, by site, can be found in **Appendix H, Attachment H1**.

At the dozen Case Study Historical sites that also had final NRD settlements, most involved natural resource injuries caused by contamination of surface water bodies. Migratory birds, anadromous fish species and threatened/endangered species were affected.

3.3.3 2009 Current Sites: Documented Human Exposure Pathways and Routes

Examples of exposure pathways and exposure routes for specific CERCLA hazardous substances found to be of concern in human health risk assessments of 2009 Current sites include the following:

- Selenium from a phosphate mining area, both soil ingestion and fish consumption, by people following subsistence lifestyles (NewFields, 2005, page 10-1)
- Radionuclides from a uranium processor, external radiation exposure to nearby residents (U.S. EPA, 2002, page 7-4)
- Arsenic, copper, and lead from a copper smelter, direct soil contact and air inhalation exposures to residential soil and ambient air by residents (U.S. EPA, 2008).

These examples of exposure pathways and exposure routes are consistent with exposure pathways and exposure routes shown in Figure 3-2 that were found at the Case Study Historical sites.

3.3.4 2009 Current Sites: Potential Human Exposure Pathways and Routes

On-site workers can be exposed through incidental ingestion of contaminated soil, air inhalation, drinking water ingestion, or external radiation exposure. Nearby residents may come into contact with soil contaminated by mining or mineral processing activities; the probability may increase in more densely populated areas relative to sparsely populated areas. Trespassers and recreational users of less densely populated sites can have exposures such as incidental ingestion of contaminated soils, surface water, or sediment or external radiation exposure from their presence near radiation sources such as tailings disposal areas, where tailings have elevated levels of radionuclides relative to the background soil and rock.

The GIS analysis (see **Appendix E**) illustrates the population densities near 2009 Current sites and describes the potential for drinking water supplies to be affected by CERCLA hazardous substance releases from 2009 Current sites. Drinking water source protection areas for both surface and ground water supplies are located within a 24-hour downstream travel distance of 324 (i.e., 82%) of the 395 sites within the contiguous United States with verifiable locations.

3.3.5 2009 Current Sites: Documented Ecological Exposure Pathways and Routes

Examples of known ecological exposure pathways and exposure routes either evaluated or disclosed at the 2009 Current sites include the following:

- Direct contact of aquatic organisms to contaminated water from an Alaskan lead, silver, and zinc mine on Forest Service land (habitat degradation monitoring described in Kanouse, 2011)
- Direct contact of aquatic organisms to selenium in surface water bodies down-gradient from a phosphate mining area (NewFields, 2005)
- Direct contact of birds with mineral processing wastes in inactive tailings impoundments (Phelps Dodge, 2005).

3.3.6 2009 Current Sites: Potential Ecological Exposure Pathways and Routes

Aquatic organisms inhabiting surface waterbodies down-stream from a 2009 Current site could be exposed to CERCLA hazardous substances through direct contact with contaminated surface water or sediment. Birds and terrestrial mammals with habitats that include a 2009 Current site may be exposed through ingestion of contaminated soil or prey, or from direct contact with mining or mineral processing wastes (such as birds attracted to cyanide-containing surface impoundments). Plants in the vicinity of a 2009 Current site could also be adversely affected by CERCLA hazardous substance releases from the site.

The GIS analysis evaluated the potential for federally listed threatened and endangered species to be exposed to CERCLA hazardous substances from 2009 Current sites with verifiable locations, when critical habitats for those species are located near the sites.

The GIS analysis illustrates the potential for surface water organisms to be adversely affected by hazardous substance releases from mining and mineral processing sites, where those releases impact surface water bodies. For example:

- Spatial analysis identified dams within a 24-hour downstream travel distance of 153 (approximately 37%) of the 417 sites with verifiable locations. These dams suggest that aquatic habitat is present within the stream, and could have beneficial uses for fish and wildlife.
- Approximately 5% of the sites (19 of 417 sites) are adjacent to or upstream of National Wild and Scenic Rivers that are generally considered outstanding resource waters and typically provide ecological services.

Terrestrial receptors (e.g., mammals, birds) can be adversely affected by CERCLA hazardous substance releases from 2009 Current sites, where those releases impact lands that provide habitat. For example:

- Approximately 8% of the sites (32 of 417 sites) are within 3-miles of lands managed by the U.S. Fish and Wildlife Service (U.S. FWS) and characterized by FWS as Approved; also, 3% of the sites (13 of 417 sites) are located within 3 miles of U.S. FWS Interest Areas that are also managed by the FWS. Some of these U.S. FWS lands may be maintained or managed as habitat.

- Over half of the sites (230 of 417 sites) are located on, adjacent to, or within a 24-hour travel distance upstream from Federal Lands. Federally owned and managed public lands include National Parks, National Forests, and National Wildlife Refuges.
- Approximately 70% of the sites (294 of 417 sites) are within, adjacent to, or within a 24-hour travel distance upstream of lands designated as protected areas. These "protected areas" are lands dedicated to the preservation of biological diversity and to other natural, recreation, and cultural uses and managed for these purposes through legal or other effective means.
- Approximately 6% of the sites (24 of 417 sites) are within 3 miles of areas that are designated as critical habitat.

4.0 Discussion of Findings

The objective of this section is to integrate the information on known and potential exposures discussed in the exposure analysis (**Section 3.0**), with known toxicity information for the COCs and risks from Superfund risk assessments, into an evaluation of the current and possible future human health and ecological impacts associated with CERCLA hazardous substance releases at 2009 Current sites.

The paucity of available Superfund risk assessments of the 2009 Current sites led EPA to compare CERCLA hazardous substance release, human and ecological receptor, and exposure information from 2009 Current sites to similar information collected during assessments of Case Study Historical sites. This report therefore presents information for both Case Study Historical and 2009 Current sites.

Section 4.1 presents an overview of Superfund risk assessment methodology. **Section 4.2** summarizes the results of data collection from CERCLA site documents for the Case Study Historical sites, and **Section 4.3** summarizes the data collection results for the 2009 Current sites. **Section 4.4** compares the information about the CERCLA hazardous substances and exposure potential associated with Case Study Historical and 2009 Current sites. **Section 4.5** discusses information from other data sources (e.g., ATSDR Public Health Assessments) regarding Case study Historical sites and 2009 Current sites. **Section 4.6** discusses the uncertainties inherent in this report. **Section 4.7** summarizes the results. Lastly, **Section 4.8** presents the findings of this report, taking into account both the comparison results and the uncertainties.

4.1 Overview of Superfund Risk Assessment

Superfund risk assessments are site-specific and therefore may vary in both detail and the extent to which qualitative and quantitative analyses are used. As EPA (1989a) describes in detail, there are four steps in the Superfund baseline risk assessment process: data collection and analysis; exposure assessment; toxicity assessment; and risk characterization.

Data collection and evaluation (also known as hazard identification) involves gathering and analyzing the site data relevant to the human health or ecological evaluation and identifying the CERCLA hazardous substances present at the site that are the focus of the risk assessment process.

The exposure assessment estimates the magnitude of current and possible future human or ecological exposures, the frequency and duration of those exposures, and the pathways by which human or ecological receptors are exposed. The exposure assessment estimates reasonable maximum exposures for both current and possible future land-uses. Estimates of current exposures are used to determine whether a threat exists based on existing site conditions. Estimates of future exposures provide decision-makers with an understanding of potential future exposures and threats and include a qualitative estimate of the likelihood of such exposures occurring.

The toxicity assessment considers: (1) the types of adverse health effects associated with exposure to the CERCLA hazardous substances identified during hazard identification; (2) the relationship between magnitude of exposure and adverse effects; and (3) related uncertainties such as the weight of evidence of a particular CERCLA hazardous substance's carcinogenicity in humans.

In risk characterization, the information from hazard identification, exposure assessment, and toxicity assessment are summarized and integrated into quantitative and qualitative expressions of risk. To estimate potential noncarcinogenic effects, intakes of CERCLA hazardous substances are compared to toxicity values; to estimate potential carcinogenic effects, probabilities that an individual will develop cancer over a lifetime of exposure are determined from intakes and chemical-specific dose-response information. Major assumptions, scientific judgments, and to the extent possible, estimates of the uncertainties embodied in the assessment are also presented.

Superfund ecological risk assessments use various parameters (e.g., area use, food ingestion rates, bioaccumulation rates, bioavailability, life-stage, body weight, and dietary composition) to estimate the exposure of plant or animal receptors to a CERCLA hazardous substance. Estimation of risk involves the calculation of hazard quotients (the ratio of chemical contaminant concentration to a selected screening benchmark).[7]

4.2 Case Study Historical Site Data Collection Results

EPA compiled data for the Case Study Historical sites from Superfund risk assessments and other CERCLA site documents (e.g., remedial investigations (RIs) and feasibility studies (FSs), and records of decision (RODs)). The information was used to characterize exposures of human and ecological receptors to CERCLA hazardous substance releases from Case Study Historical mining and mineral processing operations. EPA identified CERCLA hazardous substances, contaminated media, and exposure pathways that contributed to the human health and ecological risks associated with these activities in the Superfund risk assessments and other CERCLA site documents.

EPA compiled human cancer and noncancer risks and ecological hazards from Superfund risk assessments of Case Study Historical sites (see **Section 2**, **Table 2-1**). Further review of the risk estimates was conducted for those CERCLA hazardous substances most frequently identified as contaminants of concern (COCs) at Case Study Historical sites.

4.2.1 Human Health

EPA's experience with cleaning up the Case Study Historical sites reveals certain consistencies in CERCLA hazardous substance releases, complete exposure pathways and receptor types, and estimated risks that are at or above levels of concern in Superfund risk assessments.

In-depth review of the Case Study Historical sites identified a consistent pattern in the COCs found to pose human health risks of concern (i.e., >1E-06 cancer risk or >1 HQ) in Superfund risk assessments. In descending order of frequency, these Priority COCs for human health risks of concern include arsenic, manganese, cadmium, zinc, and antimony. The releases generally occur in a pattern of three broad categories: either as air emissions from smelters or other processing activities, as contamination of surface waters from acidic mine drainage, or as contamination from on-site waste disposal practices.

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[7] See EPA (1997): "Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments," available at http://semspub.epa.gov/work/11/157941.pdf

Complete site-specific exposure pathways in Superfund risk assessments are more variable across sites, possibly reflecting the range of different mining and mineral processing techniques used at the Case Study Historical sites. The exposure scenarios that present the greatest number of exposure routes are the on-site resident (evaluated at 22 sites), the current and future outdoor worker (occupational worker – evaluated at 14 sites), and the trespasser. For the on-site resident, the exposure routes that most often lead to risks exceeding benchmarks in Superfund risk assessments include ingestion (which exceeded at 21 of the 22 sites that evaluated residential exposures) and inhalation (which exceeded at 14 of the 22 sites). The media through which residential exposures most often exceeded benchmarks are groundwater (exceeded at 18 out of 22 sites) and soil (exceeded at 9 out of 22 sites). Similarly, the occupational worker is most commonly exposed to contamination via the ingestion route (14 out of 14 sites) and through groundwater (8 out of 14 sites). The on-site resident is of particular concern because of the potential presence of children and elderly, who may be more susceptible to the effects of hazardous substances.

Reported major sources of uncertainty in Superfund risk assessments of Case Study Historical sites include future land use patterns, uncertainties about the toxicity assessments of COCs, limited data on contamination levels at some sites, and lack of overall knowledge of specific human behaviors that affect the magnitude of exposures and resulting risks. Uncertainties are discussed further in **Section 4.7**.

4.2.2 Ecological Impacts

EPA identifies any federally listed threatened or endangered species with critical habitat in the vicinity of Superfund sites (in order to ensure that the selection of a cleanup strategy does not adversely affect federally protected species) (U.S. EPA, 1989b). EPA conducts these threatened/endangered species identifications at all CERCLA cleanup sites. EPA found that there were federally designated threatened or endangered species at most of the Case Study Historical sites. The federally designated threatened and endangered species found most often were mammals and birds.

Screening level, or in some cases in-depth, ecological risk assessments have also been conducted at many sites. The COCs found most frequently to cause ecological risks of concern in Superfund risk assessments of the Case Study Historical sites follow a pattern that is similar to those that cause human health risks of concern. This overlapping but slightly different set of metals reflects differences in toxicity between humans and other organisms. These Priority COCs for ecological risks of concern include lead, zinc, arsenic, cadmium, and copper. Of these, lead, arsenic, and cadmium (in descending order of frequency) are also Priority COCs for human health risks.

The sources of Priority COCs for ecological exposures are frequently acidic mine drainage and on-site waste disposal practices. Complete exposure pathways for ecological receptors generally do not include the ground water pathway (except in cases where groundwater intersects with surface waters), but include direct contact with contaminated surface waters, sediments, soils, and food (prey) items.

The Superfund ecological risk assessments found high exposures of birds and raccoons – orders of magnitude higher than benchmarks – to arsenic, lead, and zinc. For aquatic ecological receptors, there is no consistent CERCLA hazardous substance responsible for risk estimates above levels of concern.

Sources of uncertainty in Superfund ecological risk assessments of Case Study Historical sites include uncertainties regarding the toxicity of substances to species inhabiting the site (often, data are only available for similar surrogate species, rather than data for the specific species at the site); uncertainties due to limited data regarding environmental media concentrations to which ecological receptors might be exposed; and uncertainties due to lack of knowledge about specific receptor behaviors that could affect exposures and resulting risks. Overall uncertainties found in Superfund ecological risk assessments of Case Study Historical sites are discussed further in **Section 4.7**.

4.3 2009 Current Site Data Collection Results

4.3.1 Human Health

Only a small number of exposure assessments have been performed at 2009 Current sites, either for nearby residents, workers, or others potentially affected by CERCLA hazardous substance releases. Exposure assessments performed as part of Superfund risk assessments of two sites, found complete exposure pathways and corresponding estimated human health risks that exceeded benchmarks (U.S. EPA 2008), or situations in which “sole use of a site-specific location over extended periods of time could result in elevated risks” (NewFields, 2005).

The potential for human exposure to CERCLA hazardous substance releases at the 2009 Current sites is associated with a combination of factors. These factors include 1) the quantity of CERCLA hazardous substances released; 2) the toxicity of the CERCLA hazardous substances; 3) the proximity of people; and 4) the site’s environmental conditions or settings. Typically, these factors must be present to create a situation in which humans might be exposed to one or more CERCLA hazardous substances at or above a level of concern. Children living on-site (which has been documented for at least one 2009 Current site) could be exposed at especially high levels because of behaviors such as playing outside close to the ground, where they would be likely to ingest soil from their hands, or playing in nearby streams where they may be potentially exposed to contaminated surface waters through ingestion and dermal contact.

Given the mechanisms of CERCLA hazardous substance releases at 2009 Current sites, it is possible to identify trends regarding current conditions and the potential for human exposures of concern:

- Sites that are located in areas with a higher population density, that are located in floodplains, and that release (or could release) highly toxic CERCLA hazardous substances due either to on-site waste disposal practices or flooding, would have an increased potential to adversely affect human health.
- Sites that are located in areas with a higher population density and that release air emissions from smelting or other processing activities would have an increased potential to adversely affect human health.
- Sites that are located in areas with a lower population density, that are not located in floodplains, and that release less toxic CERCLA hazardous substances (or lower quantities of CERCLA hazardous substances) than other sites, or have other site or environmental conditions that would tend to mitigate or reduce the possibility of

CERCLA hazardous substance releases, would have a lower potential to adversely affect human health.

It is also possible to identify trends regarding future conditions and the potential for future human exposures of concern, although projections regarding future conditions are inherently more uncertain than known current conditions:

- Sites that are located where future residents are likely to settle, that release (or could release) highly toxic CERCLA hazardous substances due either to on-site waste disposal practices or flooding, have higher potential to adversely affect human health.
- Sites that are located where future residents are likely to settle, and that release air emissions from smelting or other processing activities, have higher potential to adversely affect human health.
- Sites that are located where future residents are less likely to settle, are not in floodplains, and would release less toxic CERCLA hazardous substances (or lower quantities of CERCLA hazardous substances) than other sites, or have other site or environmental conditions that would tend to minimize or reduce the possibility of CERCLA hazardous substance releases, would have lower potential to adversely affect human health.

4.3.2 Ecological Impacts

EPA assessed the potential for 2009 Current sites to adversely impact endangered species by identifying the proximity of each 2009 Current site to designated critical habitat for federally listed threatened/endangered species. Based on the assumption that site-specific activities could affect critical habitat located up to 20 miles from the site, 22% of the 2009 Current sites could adversely impact the habitat of endangered species. Reducing the assumed impact distance to three miles, 6% of the sites could adversely impact the habitat of endangered species.

The biological surveys or ecological studies of several 2009 Current sites studied ecosystem health both prior to, and during active mining or mineral processing operations (e.g., Kanouse, 2010; Ott and Morris, 2010, NewFields, 2005). Unfortunately, there was insufficient information available to make general statements regarding potential exposures of ecological receptors at 2009 Current sites based solely on information from 2009 Current sites. Using information from the Case Study Historical sites, it is reasonable to expect that acidic mine drainage problems might pose morbidity and mortality threats to aquatic organisms in surface water bodies downgradient from 2009 Current sites with sulfide-bearing host rock or overburden, and at which CERCLA hazardous substances are released. It is also reasonable to expect that 2009 Current sites with soil, sediment, and surface water contamination patterns that are similar to those observed at Case Study Historical sites could present similar exposures to ecological receptors. At some of the 2009 Current sites, investigators have found CERCLA hazardous substance releases that have, or likely have, adversely impacted ecological receptors (e.g., NewFields, 2005; U.S. FWS, 2003). This suggests that some of the CERCLA hazardous substance releases and resulting environmental contaminations at 2009 Current sites are the same as those found at the Case Study Historical sites.

In addition to the evidence from the Case Study Historical sites, several studies published in the English-language peer-reviewed scientific literature provide evidence of ecological effects from CERCLA hazardous substance releases from mining and mineral processing activities (e.g., Park et al., 2011; Peplow and Edmonds, 2005).

4.4 Comparisons of Data from Historical and 2009 Current Sites

4.4.1 Overview

Quantitative human health and ecological risk estimates from Superfund risk assessments of the Case Study Historical sites are highly variable and site-specific. Certain COCs released at the Case Study Historical sites drive the risk estimates; primarily several common metals, radionuclides, and two categories of organic compounds. Human receptors are typically site workers, nearby residents, and site trespassers. Ecological receptors are typically flora and fauna that inhabit the sites. The COCs migrate through the environment in specific ways and come into contact with, or potentially come into contact with, receptors via specific exposure pathways: soil and food plant contamination that affects nearby residents, ground water contamination that affects water supply wells, surface water contamination that causes fish kills or otherwise adversely affects aquatic organisms, and contamination of soil and prey that affects birds and mammals inhabiting the sites.

Evidence collected from analysis of EPA databases show many 2009 Current sites release CERCLA hazardous substances to the air and to surface waterbodies, and are located near both human and ecological receptors that could be affected by those releases. Examples of CERCLA hazardous substances frequently reported as released are lead and manganese; examples of nearby receptors are humans who drink water obtained from surface water bodies downstream from the 2009 Current site, or an endangered species with critical habitat near the 2009 Current site.

Taken together, the data on CERCLA hazardous substances, environmental settings, potential receptors and exposure pathways suggest the following potential exposures of human and ecological receptors at 2009 Current sites, which represent the mining and mineral processing sites that could be regulated under CERCLA 108(b):

- The Priority COCs, and their sources, found at Case Study Historical sites are also present at the 2009 Current sites; therefore, the Priority COCs identified at Case Study Historical sites can be considered at least contaminants of potential concern (COPCs) at 2009 Current sites (and by extension, at future sites).
- Human and ecological receptors at Case Study Historical sites have parallel potential receptors at 2009 Current sites.
- Environmental settings and exposure pathways at Case Study Historical sites correspond to environmental settings and potential exposure pathways at some 2009 Current sites.

These correlations suggest that the exposures at Case Study Historical sites are similar to the potential exposures at 2009 Current sites (and thus, current and future sites). Therefore, risks estimated in Superfund risk assessments of Case Study Historical sites may be relevant for current or future releases of CERCLA hazardous substances at the 2009 Current sites that have similar environmental settings, COCs, receptors and exposure pathways.

4.4.2 Similar CERCLA Hazardous Substances are Present

Table 4-2 illustrates the identification of Priority COCs at the Case Study Historical sites that are also released at 2009 Current sites (from TRI, DMR, and NEI data sets; see **Appendix F**

for further discussion of the NEI data extraction and analysis, which was not described earlier in this report due to the limited information obtained from NEI. Please note that the NEI data set was limited to sites reporting Priority COC releases exceeding 10 tons annually.)

Table 4-2. Priority COCs Identified at Case Study Historical and 2009 Current Sites

CASRN	Priority COCs Identified at Case Study Historical Sites	2009 Current Site Data		
		TRI	DMR	NEI
7440-36-0	Antimony and compounds	●	●	
7440-38-2	Arsenic and compounds	●	●	
56-55-3	Benz[a]anthracene			
50-32-8	Benzo[a]pyrene			
205-99-2	Benzo[b]fluoranthene			
7440-41-7	Beryllium and compounds	●		
7440-43-9	Cadmium and compounds	●	●	
7440-47-3	Chromium and compounds			
7440-48-4	Cobalt compounds	●		
7440-50-8	Copper and compounds	●	●	
53-70-3	Dibenz[a,h]anthracene			
7782-41-4	Fluorine (as fluoride)			
7439-92-1	Lead and compounds	●	●	
14255-04-0	Lead-210			
7439-96-5	Manganese and compounds	●		●
7439-97-6	Mercury and compounds	●	●	
7440-02-0	Nickel and compounds	●		
1336-36-3	Polychlorinated biphenyls	●		
NA	Radionuclides			
13982-63-3	Radium-226			
14859-67-7	Radon-222			
7782-49-2	Selenium and compounds	●	●	
7440-22-4	Silver and compounds	●		
7440-28-0	Thallium and compounds	●		
14274-82-9	Thorium-228			
7440-61-1	Uranium-238			
7440-66-6	Zinc and compounds	●	●	

4.4.3 Similar Exposure Pathways

Based on the information presented in **Section 3.0** ("Exposure Analysis"), for 2009 Current sites that have undergone an exposure assessment, many of the human and ecological exposures taking place at 2009 Current sites are similar to those that have been documented at Case Study Historical sites. For example, the contamination of nearby residential areas from high-temperature smelting operations at the East Helena and Omaha Lead Case Study Historical sites are mirrored in contamination of nearby residential areas documented at the Herculaneum lead smelter 2009 Current site, and the Hayden, Arizona copper smelter 2009 Current site.

The current operating practices at 2009 Current sites may be similar or identical to those that took place under previous owners or operators. Certain waste management practices may be technically difficult to change, such as the placement of a series of gravity-flow wastewater treatment ponds relative to nearby surface water. To the extent that these practices are similar to Case Study Historical sites' practices, and other variables are also similar (e.g., proximity of receptors, CERCLA hazardous substances released), human or ecological exposures could be expected to occur at 2009 Current sites that are similar to those that have occurred at Case Study Historical sites.

Therefore, some 2009 Current sites may cause similar exposures to similar receptors, as Case Study Historical sites. Unless specific site variables that affect CERCLA hazardous substance release, movement, and transport toward receptors are fundamentally different, or there are changes in the way that receptors behave, exposures will continue to be similar to those found at Case Study Historical sites. Potentially contaminated media will continue to include air, surface water, groundwater, sediment, and soil; potential routes of exposure will continue to include dermal, inhalation, and ingestion. However, as mining and mineral processing technologies change, and regulations cause practices to change, those changes may also affect exposure potential at 2009 Current sites.

4.5 Other Analyses

4.5.1 Public Health Hazards

The federal Agency for Toxic Substances and Disease Registry (ATSDR) is tasked with evaluating each NPL site for public health hazards, in a public health assessment (PHA) process that is mandated by CERCLA Section 104(i)(6)(A). In addition, CERCLA Section 104(i)(4) authorizes ATSDR to perform Health Consultations (HCs) to provide advice on public health issues related to actual or potential human exposure to a toxic material, regardless of site status (i.e., from sites that might not be proposed for the NPL). Thus, ATSDR may investigate CERCLA removal sites, enforcement cleanup sites, or sites that are not CERCLA cleanup sites but simply are of concern to a community.

Within the overall PHA and HC process, ATSDR has established five distinct descriptive conclusion categories to help ensure a consistent approach in drawing conclusions across sites.[8] These five categories are:

1) <u>Urgent Public Health Hazard</u>: The site has certain physical hazards or evidence of short-term (less than 1 year), site-related *exposure to hazardous substances that could result in adverse health effects and require <u>quick</u> intervention to stop people from being exposed*.
2) <u>Public Health Hazard</u>: The site has certain physical hazards or evidence of chronic (more than 1 year), site-related *exposure to hazardous substances that could result in adverse health effects.*

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[8] SOURCE: ATSDR Public Health Assessment Guidance Manual, Table 9-1 ("Summary of Conclusion Categories"), available at http://www.atsdr.cdc.gov/HAC/PHAManual/ch9.html.

3) Indeterminate Public Health Hazard: *critical information is lacking* (missing or has not yet been gathered) to support a judgment regarding the level of public health hazard.
4) No Apparent Public Health Hazard: Exposure to site-related chemicals might have occurred in the past or is still occurring, *but the exposures are not at levels likely to cause adverse health effects*.
5) No Public Health Hazard: No exposure to site-related hazardous substances exists.

Known Public Health Hazards from Historical Sites

EPA queried ATSDR databases for information on any sites in the 108(b) Historical CERCLA Sites universe, and then reviewed the PHAs and HCs conducted at the Case Study Historical sites. ATSDR categorized 16 of the sites (i.e., 67%) as Public Health Hazards. There was insufficient information to draw conclusions for six sites (i.e., 25%), which ATSDR therefore categorized as Indeterminate Public Health Hazards. One site was categorized as No Apparent Public Health Hazard; and a PHA was performed at one site, but as of this report EPA and ATSDR have not yet released the information. **Appendix M** contains more detailed information on the PHAs and HCs conducted at sites in the 108(b) Historical CERCLA Sites universe.

Known and Potential Public Health Hazards from 2009 Current Sites

Some of the 2009 Current sites are also NPL sites for which ATSDR performed a PHA. At these sites, ATSDR found at least one at which human exposures to hazardous substances are occurring (i.e., the Herculaneum Lead Smelter site (ATSDR, 2005)), and at least three at which ATSDR has determined that a public health hazard exists, or may exist (i.e., Smokey Canyon Mine (ATSDR, 2003); the Southeast Idaho Phosphate Mining Resource Area (ATSDR, 2006); and the Elkem Eramet mine site (ATSDR, 2009)). **Appendix A** contains more information on the PHAs and HCs conducted at 2009 Current sites.

4.5.2 Documented Human Health Impacts in Other Countries

In an attempt to look more broadly for relevant data, EPA searched the English language peer-reviewed literature for studies of human health and ecological adverse effects from mining and mineral processing sites in other countries. We identified studies of sites in China, Korea, Norway, Mexico and Slovakia, as well as examples of low-probability, high-consequence releases of CERCLA hazardous substances from mining and mineral processing sites in Hungary and China.

Rapant et al. (2009) conducted a human biomonitoring study of residents in a heavily contaminated mining area in Slovakia, in which they compared selected residents' hair, nail, blood and urinary levels of arsenic and antimony (both identified as 108(b) Priority COCs). Epidemiological data, though not age-adjusted, indicated a substantially elevated crude death rate, cardiovascular disease mortality, and neoplasm mortality for members of both genders living in the mining area, compared to Slovakian residents overall. In Mexico, Moreno, et al. (2010) documented elevated blood and urinary levels of several metals identified as 108(b) Priority COCs in children living near a mining area, including some exposures above reference levels. In Korea and China, researchers investigating contamination of food crops have documented elevated levels of some metals that are 108(b) Priority COCs in rice, and estimated health effects for those food consumers (Jung and Thornton, 1997, and Park et al., 2011). In Norway, researchers have documented adverse health effects in a population of birds living near a mining and mineral processing site (Berglund et al., 2010). Unfortunately, these international studies include insufficient information to fully compare the mining and mineral processing practices in these countries, to the practices in the United States. It is also unclear to what extent behavioral differences between U.S., Korean, Chinese, Mexican, and Slovakian populations could affect the relevance of these studies' results to the United States.

Human health effects of low-probability, high-consequence releases of CERCLA hazardous substances from mining and mineral processing sites have been documented. The 2010 bauxite processing "red mud" tailings impoundment failure in Kolontár, Hungary, resulted in initial fatalities due to the flood, but also may have caused exposures to 108(b) Priority COCs. Researchers who studied a 1985 Chinese lead-zinc tailings impoundment failure concluded that metals levels in food crops contaminated due to the spill exceeded allowable concentrations for arsenic and cadmium (both considered 108(b) Priority COCs) by factors of 24 and 13, respectively (Liu et al., 2005). However, although generally identifying additional potential catastrophic events with CERCLA hazardous substances, not enough data are available to translate to current U.S. mining or mineral processing sites.

4.5.3 Ecological Impacts of Acidic Mine Drainage

The potential impacts of acidic mine drainage on aquatic organisms deserves special consideration, since this form of environmental contamination is prevalent at a number of mining and mineral processing sites. Acidic mine drainage[9] poses two types of potential threats to aquatic organisms.

First, the pH, or hydrogen ion potential, of the drainage water can be low enough that contact with the water can cause direct damage to aquatic organisms' tissues, resulting either in morbidity or mortality. Drainage that remains acidic for a long enough period can kill entire populations of aquatic organisms, causing a collapse of the aquatic ecosystem and also adversely affecting the surrounding terrestrial ecosystem.

The second type of potential threat may occur when the pH levels are not low enough to cause aquatic organism morbidity or mortality directly, but can cause higher concentrations of dissolved metals in the water than would occur at a more neutral pH range. These higher concentrations of dissolved metals are toxic to the aquatic organisms, causing morbidity or mortality. However, because of the way hazardous substances are defined in CERCLA, and the intersection of that definition with RCRA hazardous waste regulations for mining and mineral processing sites,[10] only the second of the two types of potential threat to aquatic organism is

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[9] Conversely, alkaline mine drainage can occur, with high pH drainage water. Both types of effects described in the text for acidic mine drainage could occur due to alkaline mine drainage as well.

[10] CERCLA defines hazardous substances at 40 CFR 302.8. If acidic mine drainage were classified as a corrosive hazardous waste under the RCRA regulations, then the pH of the drainage water could be investigated separately as a causative agent in aquatic organism morbidity/mortality. Due to a regulatory exemption in the RCRA hazardous waste regulations (at 40 CFR 261.4(b)(7)), the acidic drainage water is not classified as a RCRA hazardous waste. Thus, Superfund risk assessments are constrained to consider only those hazardous substances, pollutants, or contaminants that are present within the acidic mine drainage and surface water bodies at levels higher than would be expected were the drainage to be a more neutral pH.

typically evaluated in Superfund ecological risk assessments – the potential threat from elevated levels of metals in the surface water or sediment, due to the lowered pH of the water.

Acidic mine drainage was identified as causing, or contributing to, CERCLA hazardous substance releases at six of the Case Study Historical sites. At these six sites, only one had quantified impacts on aquatic organisms that were above the level of concern. At the remaining five sites, impacts on aquatic organisms either were not quantified, or were not definitively attributable to the acidic mine drainage.

4.5.4 Impacts from Low-Probability, High-Consequence Events

Although beyond the scope of the exposures and receptors considered in this report, the potential for CERCLA hazardous substance releases due to low-probability, high-consequence events exists at sites with engineered structures designed to hold accumulations of liquid wastes (i.e., impoundments, also sometimes called ponds, pits or lagoons) or accumulations of solid mining or mineral processing materials. Examples of low-probability, high-consequence events include extreme flooding situations, seismic events of sufficient magnitude to cause CERCLA hazardous substance releases from engineered structures, fires and explosions, or a wide variety of unanticipated human-caused events that increase in probability as human activities encroach onto nearby land. Some sites in the 108(b) Historical CERCLA Sites universe have become cleanup sites in the aftermath of such low-probability, high-consequence events; for example, Flat Creek/Iron Mountain Mine in Montana (USEPA, 2011d), or the Unimin Mine Fire site in North Carolina (USEPA, 2008).

4.6 Uncertainty in This Report

This report presents a general discussion of the potential for human and ecological exposures to CERCLA hazardous substance releases from 2009 Current sites, representing mining and mineral processing activities occurring in the United States. The report uses data from Superfund risk assessments (and other CERCLA site documents) of U.S. mining and mineral processing sites, as well as data from two federal agencies that monitor the activities at 2009 Current sites, EPA data regarding CERCLA hazardous substances present at 2009 Current sites, and data from several other publicly available sources. At a limited number of 2009 Current sites, environmental samples and surveys and health studies have been performed that provide direct evidence of the presence and release of CERCLA hazardous substances to environmental media, concentrations of those CERCLA hazardous substances in environmental biota and, sometimes, in humans, that can be attributed to exposures from the mining and mineral processing activities. This report also uses information from studies published in the scientific literature that were performed at mining and mineral processing sites outside of the U.S.

4.6.1 Time Interval Assumptions

One source of uncertainty in this report results from using data for calendar year 2009 to represent mining and mineral processing sites that were active in years both prior and subsequent to 2009. As economic conditions and legislative policies change, and as technological improvements occur within the industry, changes in mining and mineral processing practices can be expected to occur. Thus, the data presented in this report should be considered the best public data available at the time the analysis took place, to reflect potential human and ecological exposures to CERCLA hazardous substance releases from the mines and mineral processors that may be required to comply with the CERCLA 108(b) financial assurance requirements.

4.6.2 Data Gaps for 2009 Current Sites

Although substantial amounts of data are available on many of the factors influencing human and ecological exposures, direct evidence of exposures of either human or ecological receptors to CERCLA hazardous substances, with corresponding evidence of adverse effects, is available for only a few 2009 Current sites. This data gap constitutes the largest source of uncertainty in the overall comparison to the Case Study Historical sites. EPA has attempted to bridge this data gap by compiling information on potential receptor proximities, and thus, potential exposures.

4.6.3 Mine and Processor Site Locations

A source of uncertainty in the newly compiled information on potential receptor proximities is the uncertainty regarding the accuracy of the 2009 Current site locations. The MSHA database did not include latitude/longitude coordinates for the actual mining or mineral processing sites; therefore, sites from that database could not be geographically mapped using data from MSHA. EPA used several approaches to identify the location of each mine and mineral processor, including geocoding of the location based on address, followed by detailed, manual investigation of each address using high-quality aerial imagery. In general, the mine site locations are likely to be less certain than the mineral processor locations. Inaccuracies in the site locations could have a significant impact on various geospatial analyses performed using the locations. Inaccuracies in these locations would have a direct bearing on the accuracy of any conclusions that EPA might draw regarding proximity, and resulting exposure, of human and ecological receptors. **Appendix E** contains a detailed accounting of the uncertainties involved when using the results from the GIS analysis. It also explains uncertainties associated with using the data on 100-year flood areas, critical habitat of federally listed threatened/endangered species, stretches of surface water bodies that are classified as impaired waters, and drinking water supply areas.

4.6.4 Identifying COCs

The detailed review of available documentation for the Case Study Historical sites attempted to identify all CERCLA hazardous substances that were designated as COCs in Superfund risk assessments. However, the search sometimes did not locate documentation for all the operable units at a site. It is therefore possible, though not highly likely, that some CERCLA hazardous substances designated as COCs were not identified for this report. Furthermore, the use of a subset of sites to represent the entire population of sites creates the uncertainty that some factors, including identifying individual COCs, may be missing from the sample population. However, because similar COCs were identified across the Case Study Historical sites, the exclusion of a COC from this analysis is not highly likely.

4.6.5 Identifying Receptor Locations

The locations and number of potential human receptors near 2009 Current sites were estimated using 2000 Census data (including census geographic boundaries). Also, source water protection areas (SPAs) were used to estimate presence of drinking water intakes downstream of 2009 Current sites.

Uncertainty about the accuracy of the Census data stems from the age of these data sources and because Census findings are largely based on sampled data (specifically, the Census long form data, which is a sample of 1 in 6 households). Sample surveys have uncertainty associated with the size of the sample and some built-in inaccuracies that are created to decrease the chance of identifying individuals from Census data.

SPAs are polygons that were created as approximate areas of drinking water sources. For security reasons, actual drinking water source locations are not available, and SPAs were developed as proxies for actual locations. Using SPAs to estimate the presence or absence of drinking water intakes has considerable uncertainty because an SPA polygon may intersect with a 2009 Current site downstream area, but the actual drinking water intake location (within the SPA) may fall outside of the 2009 Current site downstream area.

Sources of ecological receptor locations have considerable uncertainty because few ecological area boundaries have been accurately mapped. Sources such as boundaries of national parks or boundaries of land that the U.S. Fish and Wildlife Service owns, manages, or may acquire are probably more accurate than some boundaries that represent critical habitats for threatened and endangered species. Uncertainty in the quality and accuracy of the boundaries of the national sources used to represent ecological receptor locations will affect the accuracy of the results of any spatial analysis.

4.6.6 Estimating Exposures

Some uncertainties are inherent in the spatial methods used to estimate exposure of human and ecological receptors.

To estimate human populations within given distances of 2009 Current sites, an area apportionment method was used to estimate the number of persons in Census polygons that fall within a “buffer” polygon (a polygon drawn around the point of interest) based on the proportion of the Census polygon that fits inside vs. outside the buffer polygon (see **Figure 4-1**). This method implicitly assumes that population is evenly distributed within each Census polygon. This (necessary) assumption leads to some uncertainty in the estimates of population and population characteristics. In addition, because the 2009 Current sites are represented as points in the GIS, a buffer zone created around the point is likely not to properly estimate the true area within a particular distance of the edge of the mine or processor.

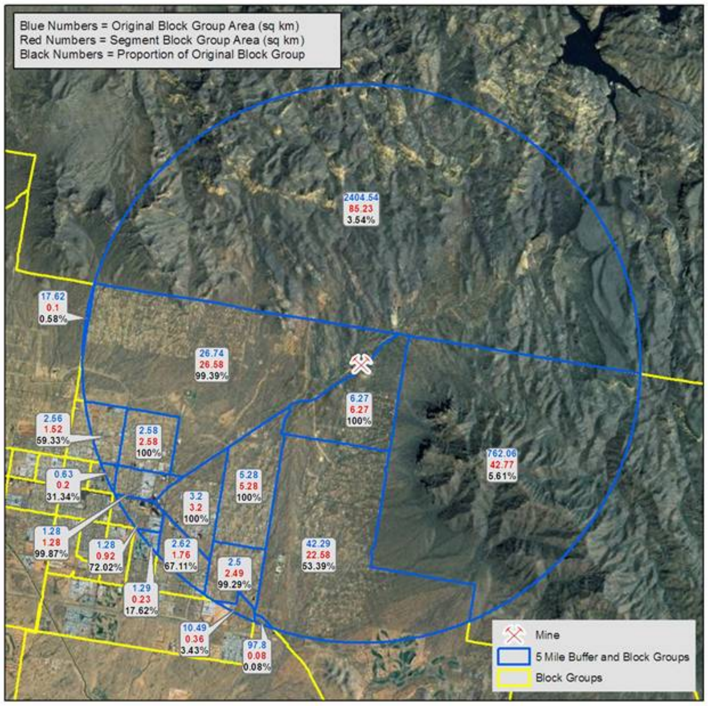

Figure 4-1. Example of a five-mile buffer zone intersected with Census block group boundaries, illustrating how block group areas are split by the buffer zone.

The process for estimating aquatic ecological receptors used National Hydrography Dataset polygon “catchments” to estimate downstream travel from each 2009 Current site. Catchment polygons represent the very small river basins surrounding each river reach. However, these catchments are approximations of actual basins, and therefore, the area encompassed by the downstream travel could over- or underestimate the true area that “catches” the surface runoff from the land surface. When ecologically sensitive boundaries (such as critical habitats) are overlaid on the downstream catchment areas, some intersections may exist in the computerized simulation that do not exist in reality, thus leading to over- or underestimation of the presence of ecological receptors within the catchment areas.

4.7 Summary of Findings Regarding the Potential for Human Health and Ecological Impacts from 2009 Current Sites

The following summarizes the findings from the analyses described above to support the potential for risks resulting from human and ecological receptor exposure to CERCLA hazardous substance releases from 2009 Current sites, and by extension, all current and future sites.

Human Health

- Superfund risk assessments of the Case Study Historical sites demonstrate consistencies in CERCLA hazardous substance releases, complete exposure pathways and receptor types, and risk estimates that exceed levels of concern. As discussed in Section 4.4.3, 2009 Current sites demonstrate the potential for similar complete exposure pathways to the same receptor types.
- Superfund risk assessments of the Case Study Historical sites reveal a consistent pattern in the COCs most often found to pose risks of concern (i.e., antimony, arsenic, cadmium,

manganese, and zinc). Many of these Priority COCs are also released from 2009 Current sites.

Ecological Impacts

- Superfund risk assessments of the Case Study Historical sites report a pattern of risks to federally designated threatened or endangered species.
- In Superfund risk assessments of Case Study Historical sites, the Priority COCs for ecological risks include arsenic, cadmium, copper, lead, zinc, and others. This list is similar to, but not identical to, the Priority COCs for human health risks, reflecting differences in toxicity and exposures between humans and other organisms.
- Based on the experiences with the Case Study Historical sites, it is reasonable to expect that acidic mine drainage problems may pose morbidity and mortality threats to aquatic organisms in surface water bodies downgradient from 2009 Current sites with sulfide-bearing host rock or overburden, and at which CERCLA hazardous substances are released.
- Based on the experiences with Case Study Historical sites, it is also reasonable to expect that 2009 Current sites with soil, sediment, and surface water contamination patterns that are similar to those observed at Case Study Historical sites may present similar potential risks to ecological receptors at those sites.

4.8 Overall Findings

EPA’s findings on known and potential human health and ecological impacts from U.S. mining and mineral processing sites include:

1. **Based on similarities in CERCLA hazardous substances and exposure potential between Case Study Historical sites and 2009 Current sites, CERCLA hazardous substance releases from mining and mineral processing sites subject to 108(b) regulation could potentially lead to human health and ecological risks above levels of concern.** Due to site-specific conditions and considerations at each of the Case Study Historical sites, Superfund risk assessments quantified human health and ecological risk estimates exceeding levels of concern varied by five orders of magnitude. The ecological risk estimates in Superfund risk assessments are more influenced by site-specific conditions, and are therefore more variable than the human health risk estimates.

   Superfund human health and ecological risk estimates are highly site-specific, involving site-specific conditions and uncertainties: quantifiable exposure and risk estimates from one site are not designed to be directly applicable to another site. Nevertheless, the similarities in CERCLA hazardous substances, receptors and potential exposure pathways suggests that risks exceeding levels of concern from exposure to CERCLA hazardous substance releases from sites subject to 108(b) regulation would be possible.

2. **Based on the experience of the fund, Superfund could continue to be called upon to address contamination from mining and mineral processing practices not currently employed by the mines and mineral processors subject to 108(b) regulation.** Superfund is responsible for addressing site contamination regardless of the industrial practices currently in use at a site. Based on the results of this report, example past practices include the following:

- Some copper high-temperature smelting processors have, in the past, caused considerable air and soil contamination in surrounding communities or caused ecological harm (U.S. FWS, 2008; U.S. EPA, 2002a; Phelps Dodge, 2005). An investigation by the state of New Mexico (New Mexico, 2009), found that similar contamination is occurring at a high-temperature smelter still operating in the United States. Recent federal requirements (Clean Air Act Maximum Available Control Technology regulations) for copper smelting facilities may address ongoing contamination of this type.
- Some copper processing sites using processes other than high-temperature smelting have, in the past, caused environmental contamination from their waste disposal practices (e.g., Kennecott South Zone; Cyprus Tohono; Tyrone Mine).
- Some lead smelters have, in the past, caused considerable air and soil contamination in surrounding communities.
- Some aluminum smelters have, in the past, caused groundwater contamination from on-site waste disposal. However, RCRA regulations now control these disposal practices.

5.0 References

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