Draft Report

Screening-level Ecological Risk Assessment for the ASARCO LLC Hayden Plant Site Hayden, Gila County, Arizona

Prepared for

U.S. Environmental Protection Agency Region IX

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Acronyms and Abbreviations

μg/L	micrograms per liter
AGFD	Arizona Game and Fish Department
ASARCO	ASARCO LLC
ASWQS	Arizona State Water Quality Standards
BAF	bioaccumulation factor
BERA	baseline ecological risk assessment
BLM	U.S. Bureau of Land Management
cfs	cubic feet per second
COPEC	contaminant of potential ecological concern
CSM	conceptual site model
EcoSSL	Ecological Soil Screening Level
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
ER-L	effects range low
ER-M	effects range median
ESA	Endangered Species Act
FPXRF	field portable x-ray fluorescence
HQ	Hazard Quotient
IRIS	EPA Integrated Risk Information System database
LCV	lowest chronic value
LOAEL	lowest observed adverse effects levels
LOEC	lowest observed effect concentrations
mg/L	milligrams per liter
msl	mean sea level
NAWQC	National Ambient Water Quality Criteria
NOAEL	no observed adverse effects levels

NOEC	no observed effects concentrations
ORNL	Oak Ridge National Laboratory
PEC	Probable Effects Concentrations
Qal	Quaternary alluvium
Qo	older Quaternary deposits
RI	Remedial Investigation
Site	Hayden Plant Site
SLERA	Screening-level Ecological Risk Assessment
SVOC	semivolatile organic compound
TDS	total dissolved solids
TEC	Threshold Effects Concentration
TNC	The Nature Conservancy
TRV	toxicity reference value
Ts	Tertiary sediments
UCL	upper confidence limit of the mean
USACHPPM	United States Army Center for Health Promotion and Preventive Medicine
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
UTL	upper tolerance limit
VOC	volatile organic compound
WSC	Wildlife of Special Concern
WSCA	Wildlife of Special Concern in Arizona

Executive Summary

Historic and current activities at the ASARCO LLC Hayden Plant Site (Site) resulted in release of contaminants (primarily metals and other inorganics) from smelter emissions, crushing and concentrator operations, the tailings impoundments, process water discharges to unlined ponds, and other process operations to the air, surface soil, sediments, and groundwater in the Hayden area. Discharge/runoff from the tailings impoundments and drainages into the Gila River and aerial deposition of contaminants were the primary release mechanisms of concern to ecological receptors. This screening-level ecological risk assessment (SLERA) was conducted in support of the Remedial Investigation (RI) for the Site. Risks to ecological receptors in the vicinity of the Site were evaluated. A brief summary of the ERA approach (Section ES.1), risk conclusions (Section ES.2), and recommendations based on those conclusions (Section ES.3) are provided below.

ES.1 ERA Approach

The primary guidance utilized in completing the SLERA was the *Ecological Risk Assessment Guidance for Superfund* (EPA 1997) and the *Final Guidelines for Ecological Risk Assessment* (EPA 1998). In accordance with these guidance documents, this assessment serves as a SLERA. An initial screening and a refined screening assessment were conducted.

The primary sources are current or historic activities of the smelter and concentrator. Primary release mechanisms include air emissions from the 1,000-foot stack and other process locations, as well as solid wastes (the tailings impoundments) and wastewater associated with the processing of the copper ore. Release mechanisms include aerial deposition of stack or fugitive emissions, discharge/runoff from the tailings impoundments (as occurred during flooding in 1993) to the Gila River or to adjacent soils, wind erosion, leaching to groundwater, and surface discharge from groundwater. Secondary sources of potential contaminants are surface soils (including areas affected by aerial deposition, riparian soils), surface water and sediment of the rivers, groundwater, and air.

Complete exposure pathways from contaminated surface soil, surface water, sediment, biota, and groundwater to ecological receptors exist at the Site. Surface soils in the ERA refer to riparian, upland, and wash soils that support ecological habitat. Soils collected from the residential/non-residential areas in the town of Hayden were not evaluated because they lack habitats for ecological receptors. Soils and water collected from the tailings impoundments also were not evaluated due to a lack of suitable ecological habitat.

The areas of greatest potential concern to ecological receptors include:

- Gila River and San Pedro River floodplains and environs, extending along the Gila River from about 2 miles upstream of Winkelman to 5 miles downstream of Last Chance Basin, and along the San Pedro River about 2 miles upstream of the confluence with the Gila River;

- Surface water drainages within Hayden that are near ASARCO process facilities, including Power House, Kennecott, and San Pedro washes; and
- Upland areas.

Based on historic and current Site use and historic media data, aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, and zinc were considered as contaminants of potential ecological concern (COPECs). The measured concentrations in surface water, sediment, soils, and groundwater collected during the RI sampling were the primary data used in the SLERA.

Assessment endpoints for the Site include aquatic plants, water-column invertebrates, benthic invertebrates, fish, amphibians, and aquatic birds and mammals (swallows, belted kingfishers, little brown bats, and mink) in the aquatic habitats and terrestrial plants, soil invertebrates, soil microbial processes, and terrestrial birds and mammals (mourning doves, curve-billed thrashers, red-tailed hawks, southwestern willow flycatchers, desert cottontails, desert shrews, and coyotes) in the terrestrial habitats. The southwestern willow flycatcher is a federally listed endangered species.

In the initial screening evaluation for the Site, maximum contaminant concentrations (or dietary exposure estimates based on maximum concentrations) were compared to conservative literature-derived toxicity values. These toxicity values were published screening-level benchmarks or were based on no observed effects concentrations (NOECs) or no observed adverse effects levels (NOAELs) and may be referred to as toxicity reference values (TRVs).

Analytes that passed the initial screening were not evaluated further. Those analytes that failed the initial screening were retained for evaluation in a refined screening step. The refined screen did not include the collection of additional data, but rather, highly conservative assumptions used in the initial screening evaluation were refined, or risk was evaluated qualitatively.

ES.2 Conclusions

The results of this refined SLERA are intended to determine risks to ecological receptors in support of the RI for the ASARCO LLC., Hayden Plant Site. The findings indicate that multiple analytes pose a possible risk to at least one receptor in each medium and sampling area at the Site.

Possible risks within the aquatic portions of the Site are primarily related to exposures of aquatic plants, water-column invertebrates, fish, and amphibians to surface water (Table ES-1). Benthic invertebrates do not appear to be at risk from sediment exposures in either river, though this is uncertain for cyanide due to an insufficient detection limit. Additionally, aquatic birds and mammals (swallows, belted kingfisher, little brown bats, and mink) may be at risk from cadmium, copper, iron, or mercury in the Gila River and cadmium, or iron in the San Pedro River.

Conclusions for the riparian areas in the onsite portions of the Gila and San Pedro rivers, as with sediment, indicate a low risk to terrestrial receptors (Table ES-2). Risks to terrestrial plants, terrestrial invertebrates, soil microbial processes, individual southwestern willow flycatchers, and desert shrew populations from exposure to copper in Gila River soils are possible. Additionally, possible risks to terrestrial plants from exposure to arsenic, manganese, and molybdenum in Gila River soils, and risks to southwestern willow flycatchers from exposure to mercury in soils of either river and zinc in San Pedro River soils were identified. Although risks to several receptors from exposure to selenium could not be excluded, these risks are uncertain due to insufficient detection limits. Risks due to exposure to boron, iron, or manganese are also uncertain (background data specific to the soils and geologic formations of the Site were not available), but are considered unlikely because onsite concentrations of these analytes are within typical background ranges.

Within the upland and wash areas, possible risks to terrestrial receptors from multiple analytes were observed. Cadmium, copper, lead, molybdenum, selenium, and zinc in upland soils posed a risk to at least four terrestrial receptors, with copper posing a risk to nine of the ten receptors evaluated (Table ES-2). Antimony, arsenic, cobalt, mercury, silver, and thallium were a risk to at least one receptor, but no more than three receptors. Risks from copper are also widespread in the wash areas, with a possible risk conclusion for six of the ten receptors. Molybdenum and zinc were a possible risk to four of the ten receptors. Arsenic, cadmium, chromium, cobalt, lead, mercury, molybdenum, silver, thallium, and vanadium zinc were a risk to at least one receptor, but no more than three. As indicated for the riparian soils, risks identified for boron, iron, or manganese in the upland or wash areas is uncertain, but not likely.

ES.3 Recommendations

Based on conclusions summarized above, the following recommendations would serve to reduce uncertainties associated with the risk estimates:

1. Multiple chemicals exceeded surface water screening values for aquatic organisms and soil screening values for plants and soil invertebrates. Because some chemicals may interact (in additive, antagonistic, or synergistic ways), the actual site-specific risks are somewhat uncertain. Ambient media bioassays, in which receptors are exposed to site media, would serve to reduce this uncertainty. Sediment bioassays are not recommended at the Site because no risks to benthic invertebrates were identified. However, surface water bioassays using fish and *Ceriodaphnia* (a water-column invertebrate) would serve to reduce uncertainties associated with the risks from surface water. Similarly, soil bioassays using appropriate terrestrial plant and invertebrate species would reduce the uncertainties related to risks from soils. However, soil bioassays are recommended only for the upland, and possibly wash, areas of the Site because little or no risks were observed for the riparian soils.

   It should be noted that surface water bioassays are not expected to reduce all uncertainties. In particular, flow in the Gila River is dominated by upstream sources such that determining the source of contamination (i.e., on site vs. upstream) will be difficult. Therefore, sampling for the bioassays would require limitations in time, space, and flow regime. During the groundwater investigation conducted under the RI, hydrologic connections between groundwater and surface water were observed. Specifically, groundwater under the ASARCO operations was discharged to the Gila

River during the wet periods. Slurry water leaching from the tailings impoundments was found to mound above the aquifer and also discharged to surface water in wet periods. During dry periods, water is released from the upstream Coolidge Dam and surface water in the Gila River provides some recharge to the aquifer. These patterns of groundwater discharge and recharge suggest that wet periods would be most suitable for collection of bioassay samples because groundwater from the Site is discharged to Gila River during this time. It would also be important to collected several surface water bioassay samples upstream of the Site on both the Gila and San Pedro rivers.

2. Exposure estimates for birds and mammals included the use of literature-based bioaccumulation models. Because the applicability of these models to the Site is unknown, development of site-specific bioaccumulation models would serve to reduce uncertainties in the risk estimates for birds and mammals. This can be accomplished through collection of co-located abiotic media and biota samples. Development of soil-to-plant and soil-to-invertebrate bioaccumulation models for the upland and wash areas is recommended.

3. The detection limits for some analyte/medium combinations exceeded screening benchmarks for one or more receptors (e.g., selenium and thallium in riparian soils). This indicates that the detection limit was too high and risks are uncertain. Therefore, additional sampling and laboratory analysis using methods to obtain lower detection limits, particularly for selenium and thallium in the riparian areas, may be appropriate. However, it is recommended only if additional sampling is planned in these areas (e.g., collection of soil samples to obtain site-specific bioaccumulation data or to obtain more background data).

4. Background data for sediment were very limited; therefore, adequate background comparisons could not be conducted (though a comparison to upstream and downstream sediment was possible). Collection of additional sediment data from background areas would reduce this uncertainty. However, these additional data may not add value to the risk assessment. Surface water levels and flows in both the Gila and San Pedro rivers are highly variable. At some times during the year, the streambeds are dry, whereas at other times, flash floods or releases from Coolidge Dam on the Gila River result in high flows. Therefore, sediments in these riverbeds are often very mobile and may not store contaminants at high levels. Additionally, current data suggest that cleaner sediments from the San Pedro River may dilute onsite sediment in the Gila River downstream of the confluence of the two rivers.

   In the upland areas, additional background data could be used to determine how much of the observed toxicity is related to the local geology of the area versus the result of contaminant discharges from the Site. Additionally, background measurements of boron, iron, and manganese in soils from the Qal, Qo, and Ts geologic formations would allow for the calculation of background UTLs and may reduce the uncertainty associated with predicted risks to terrestrial receptors from exposure to these analytes

5. The results of the SLERA indicate widespread risks among the upland, and to a lesser extent, wash areas. It is possible that additional study of these areas is needed to determine the spatial extent of these risks. As a first step, the XRF data collected for the RI could be evaluated for key contaminants (e.g., copper). This may lead to a recommendation of additional, limited sampling in the upland areas of the Site.

SECTION 1

Introduction

ASARCO LLC (ASARCO) operates the Hayden Plant Site (Site) located in Hayden, Arizona. The Site operations consist of ASARCO's crusher, concentrator, smelter, and tailings deposition. The operational history of the Site and investigations conducted to date indicate that contaminants (primarily metals and other inorganics) from smelter emissions, crushing and concentrator operations, the tailings impoundments, process water discharges to unlined ponds, and other process operations have migrated to the air, surface soil, sediments, and groundwater in the Hayden area. Of particular concern to ecological receptors is discharge/runoff from the tailings impoundments and drainages into the Gila River, and aerial deposition of contaminants. This Screening-level Ecological Risk Assessment (SLERA) identifies the chemicals, habitats, receptors of concern, and risks posed to ecological receptors in the vicinity of the Site, and is provided in support of the Remedial Investigation (RI) for the Site.

This SLERA was prepared for the U.S. Environmental Protection Agency (EPA) Region IX as Work Assignment No. 298, under Contract No. 298-RICO-09JS.

The following sections outline the technical approach and guidance, as well as the report organization for the SLERA.

1.1 Technical Approach

The technical approach for the SLERA was detailed in the Ecological Risk Assessment Plan for the Site dated June 2006 (CH2M HILL 2006a), and was approved by EPA at the Ecological Risk Assessment Kick-off Meeting on October 26, 2006 (Meeting Summary attached as Appendix A). This section presents the salient features of the approach and the relevant ERA guidance.

ERAs are prepared in phases (sometimes referred to as tiers or levels) as recommended by the EPA (1997, 1998). This approach entails increasingly sophisticated levels of data collection and analysis, wherein the conservative assumptions of the initial evaluations are replaced by more site-specific data and more ecologically realistic assumptions. Using a phased approach results in doing all the work that is necessary, but only that which is needed for completion of the assessment. A tiered process also serves to reduce conservatism and uncertainties in the risk assessment, and focuses effort on issues most likely to drive remedial actions. The three general phases in ERA include: Scoping Assessment, SLERA, and Baseline ERA (BERA).

Upon evaluation of the results from each phase, a review is conducted to determine whether risk management objectives can be achieved or whether more site-specific analysis is warranted. The results of each assessment phase are used to demonstrate whether the concentration of the contaminants in site media pose a threat to ecological receptors. Several actions can be taken upon completion of each assessment phase.

- ***No Further Action.*** No potential for ecological risk is concluded by determining contaminant concentrations at the site do not exceed screening-level benchmarks or finding that there are no complete pathways of exposure between contaminants and receptors. No further assessment or remediation is warranted.
- ***Perform a Higher-level Assessment.*** Contaminant concentrations at the site exceed screening benchmarks and a refined screening or the next assessment phase is conducted with more rigorous, less conservative analysis and/or more site-specific data.
- ***Collect Additional Data***. Insufficient data are available to complete an initial risk assessment or there are data gaps to address. Additional data may be collected to provide more site-specific information and to perform more sophisticated analyses in a higher assessment phase.
- ***Reduce Concentration Levels.*** The potential for risk to ecological receptors exists. Recommendations may include reducing contaminant concentrations through remedial actions (e.g., excavation and hauling, in situ treatment, ex situ treatment) to meet the ecological screening benchmarks.
- ***Reduce Potential Exposure.*** The potential for risk to ecological receptors exists. Management techniques may be recommended to restrict exposure to contaminants of potential ecological concern (COPECs) in surface water, sediment, soil, or groundwater remaining at the site (e.g., engineering barriers).
- Any combination of the above actions.

The components of each ERA phase, and how these were applied to the Site, are described as follows.

1.1.1 Phase 1—Scoping Assessments

Scoping Assessments are performed to determine whether plants or animals may be exposed to Site contaminants and whether further SLERA work is required. Risk can occur only when there is a chemical source, a receptor, and a route of exposure between the source and receptor. A SLERA is recommended only if the Scoping Assessment has determined there is a source of contaminants, receptors are or will be present, and current or future land-use or offsite contaminant migration dictates that receptors may be exposed.

It is already known that potential sources of contaminants (i.e., tailings impoundments and air emissions) exist at the Site. Additionally, the Site is located adjacent to terrestrial and aquatic habitat where complete exposure pathways of ecological receptors to contaminated surface water, sediment, or soil are likely. Therefore, a formal Scoping Assessment was not conducted; rather, evaluation of the Site proceeded directly to the SLERA (Phase 2).

1.1.2 Phase 2—Screening-level Assessments

Screening-level assessments use conservative estimates of exposure and conservative effects data to determine whether toxicologically significant exposure could occur and make preliminary risk conclusions. It is important to note that a SLERA is a one-tailed evaluation. It does not actually determine the presence of risks. Rather, it differentiates between exposures that can be definitively concluded to present no risks (i.e., they 'pass' the screen) and data that, due to the application of multiple conservative assumptions, are insufficient to support a no risk conclusion (i.e., they 'fail' the screen). Conclusions from a SLERA are that a set of analytes, receptors, and locations are not at risk, or alternatively that information is insufficient to exclude potential for risk at areas that fail the screen. A SLERA allows the ERA team to exclude areas, media, or chemicals identified as presenting no risk from further evaluation. It also allows for the identification of data gaps, which helps to focus data collection efforts for subsequent analyses. In particular, data that would contribute most to a reduction in uncertainties (e.g., site-specific bioaccumulation information) should be identified.

In the initial screening evaluation for the Site, maximum contaminant concentrations (or dietary exposure estimates based on maximum concentrations) were compared to conservative literature-derived toxicity values. These toxicity values were published screening-level benchmarks or were based on no observed effects concentrations (NOECs) or no observed adverse effects levels (NOAELs) and may be referred to as toxicity reference values (TRVs).

If all analytes passed the screen, the ERA process was considered complete and no further ecological risk evaluation was recommended. However, if any analytes failed the screen, the SLERA was expanded to include a refined screening evaluation. The refined screen did not include the collection of additional data, but rather, highly conservative assumptions used in the initial screening evaluation were refined or risk was evaluated qualitatively. Depending on available data, elements of the refined screening evaluation for the Site included:

- **Background Screen—**A comparison of onsite concentrations of inorganics to background concentrations was conducted (according to EPA guidance) to exclude those inorganic COPECs that were not elevated relative to background.
- **Comparison to Effects Levels/Magnitude of the Hazard Quotient (HQ)—**Exposure estimates were compared to both no and lowest effects levels. If exposure did not exceed either effect level, risks were absent. If exposure exceeded the no effect level, but not the lowest effect level, risks were possible, but were considered acceptable for populations or communities. If exposure exceeded both effect levels, risks were likely.
- **Frequency of Exceedance—**A low frequency of exceedance may indicate low likelihood of risks.
- **Frequency of Detection—**A low frequency of detection may suggest that contamination is limited to a small area or single location.
- **Incremental Risk—**If the maximum concentration of an inorganic onsite was less than 10 percent greater than the background value and the incremental HQ was less than 1, most of the risk may not be a direct result of site activities.
- **Bioavailability of COPECs—**Chemicals are generally not absorbed by biota with 100 percent efficiency; therefore, if data are available (literature-based in this assessment) on the bioavailability of the COPEC, the exposure estimate and therefore the HQ were reduced by incorporating bioavailability into the exposure calculation (it may also be noted in the discussion that toxicity tests reported in published literature usually use soluble salt forms of the chemical, which may have greater bioavailability than naturally occurring forms).

- **Area Use**—If the home range of a receptor is greater than the area of the site, the risk may be overestimated (the HQ was recalculated using a more accurate estimate of exposure that incorporated an area use factor).

With the exception of the background screen where chemicals can be excluded from further evaluation if site concentrations are consistent with background values, no individual refinement would likely be sufficient to eliminate the conclusion of risk. However, when these refinements are considered together, they may provide a weight-of-evidence conclusion that risk is low and further evaluation in a baseline assessment may not be warranted. Although this risk assessment report makes recommendations based on these refinements, the final decision will be made by the EPA risk managers.

If analytes fail the refined screen, the ERA process may be continued to the next, or baseline, phase. Although briefly described below, there are currently no plans to develop a BERA for the Site. Should a BERA be required for the Site, this will be a separate effort from the refined SLERA presented here.

1.1.3 Phase 3—Baseline (Definitive) Assessments

The BERA uses more ecologically realistic assumptions to estimate the presence, nature, and magnitude of risks associated with analytes retained at the conclusion of the SLERA. Conservative measures of exposure and effects used in the SLERA are replaced with ecologically more realistic and site-specific data. This may include collecting data to determine site-specific contaminant bioaccumulation and bioavailability, performing site-specific toxicity tests to determine toxicity of site media, using multiple tiers of TRVs, and performing biological surveys to complement the toxicity data. Strengths and weaknesses associated with these additional lines of evidence are integrated in a weight-of-evidence evaluation to decrease uncertainty and increase the realism of the risk determinations. The need for a BERA at the Site will be determined following the conclusion of the SLERA and would be scoped as a separate effort.

1.2 Guidance

The procedures followed for conducting the SLERA at the Site were consistent with those described in the following guidance provided by the EPA:

- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final* (EPA 1997)
- *Framework for Ecological Risk Assessment* (EPA, 1992a)
- ECO Updates, Volume 1, Numbers 1 through 5 (EPA 1991a, 1991b, 1992b, 1992c, 1992d)
- ECO Updates, Volume 2, Numbers 1 through 4 (EPA 1994a, 1994b, 1994c, 1994d)
- ECO Updates, Volume 3, Numbers 1 and 2 (EPA 1996a, 1996b)
- *Final Guidelines for Ecological Risk Assessment* (EPA 1998)
- *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA 1999a)

- *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (EPA 1999b)
- *The Role of Screening-Level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments* (EPA 2001a)

In accordance with these guidance documents, this assessment serves as a SLERA. The primary guidance utilized in completing the SLERA was the *Ecological Risk Assessment Guidance for Superfund* (EPA 1997) and the *Final Guidelines for Ecological Risk Assessment* (EPA 1998).

1.3 Report Organization

This report is organized following the ERA framework established by EPA (EPA 1992a) and includes the following sections:

Section 1: Introduction—Describes the purpose of this analysis and provides a description of the ERA approach, the guidance used, and the organization of the ERA report.

Section 2: Problem Formulation—Describes the physical and ecological setting of the Site; provides an evaluation of contaminant sources and discusses selection of the COPECs; develops the ecological conceptual site model (CSM); identifies the assessment endpoints and measures, including identification of representative species; and provides summaries of the available data.

Section 3: Analysis—Presents the exposure assessment and the ecological effects assessment. The exposure assessment identifies exposure pathways to be quantitatively evaluated and exposure point concentrations (EPCs) for soil, sediment, and surface water. The ecological effects assessment presents available literature-based toxicity information on COPECs to determine potential adverse effects for ecological receptors.

Section 4: Screening-level Risk Characterization—Integrates the problem formulation and the exposure/effects analyses to estimate the likelihood of risks to ecological receptors from exposure to COPECs. This section includes the results of the initial screening evaluation.

Section 5: Refined Screening-level Risk Characterization—Evaluates the COPECs that failed the initial screen using a refined screening step that uses more biologically relevant assumptions. This section includes the results of this refined screening evaluation.

Section 6: Uncertainties—Presents a discussion of the uncertainties and limitations associated with the risk assessment data and methodology.

Section 7: Risk Conclusions and Recommendations—Summarizes the overall conclusions concerning ecological risks at the Site and provides recommendations for further investigation at the Site, if needed.

Section 8: References—Lists references cited in the document.

SECTION 2

Problem Formulation

The Problem Formulation integrates available information (sources, contaminants, effects, and environmental setting) and serves to provide focus to the ERA. This section includes a description of the Site setting, identification of COPECs, identification of the important aspects of the Site to be protected (referred to as "assessment endpoints"), the means by which the assessment endpoints were evaluated (measures of exposure and effects), and previous Site investigations. The end product of the problem formulation is a CSM that describes the contaminant sources and transport mechanisms, evaluates potential exposure pathways, and identifies the representative species that were used to assess ecological risk to those and other similar species.

2.1 Physical and Ecological Setting

This section includes a description of the physical and ecological setting for the Site. Detailed descriptions of the Site background including the operational history, areas of potential concern, demographics and land use, and Site topography and drainage are provided in the RI Work Plan (CH2M HILL 2005).

2.1.1 Physical Setting

The Site is located in the town of Hayden, Gila County, Arizona (Figure 2-1). ASARCO manages the concentrator and smelter facilities as distinct operations with separate gated entrances, but integrated in terms of process throughput. ASARCO's overall process operations area includes the No. 9 conveyor, portions of which are overhead, that extends from the crusher facilities on the north side of State Highway 177 to the concentrator facilities on the east edge of the Hayden residential areas, active smelting operations about 0.5 mile northeast of the concentrator, a former Kennecott smelter area north of the concentrator, a tailings slurry pipeline extending from the concentrator to Tailings Impoundment AB/BC and Tailings Impoundment D located adjacent to the Gila River, and various process/stormwater management facilities (ADEQ 2003). The active smelter treats air emissions that are released to the atmosphere through a 1,000-foot stack. Slag from active smelter operations is deposited in a surface impoundment located immediately southeast of the smelter.

Tailings Impoundment AB/BC is located south of State Highway 177 and north of the Gila River (Figure 2-1). It extends for a length of about 2.5 miles, with a maximum width of 1 mile and height of 200 feet. Tailings Impoundment D is located south of the Gila River. It extends for a length of about 2 miles, with maximum width of 1,500 feet and height of 150 feet. Process/stormwater management facilities consist of multiple small surface water impoundments located within the concentrator, smelter, and tailings impoundment areas. Key drainages from the Site include Power House Wash (bisecting the active smelter area and concentrator/Hayden residential areas), Kennecott Wash (draining the central portion of the Hayden residential area), and San Pedro Wash (located immediately west of Hayden).

In addition, water management features include retention and reclaim ponds located south-southeast of Tailings Impoundment AB/BC, a large retention pond (Last Chance Basin) at the northwest edge of Tailings Impoundment AB/BC, and containment berms in selected areas.

The areas of greatest potential concern to ecological receptors include:

- Gila River and San Pedro River floodplains and environs, extending along the Gila River from about 2 miles upstream of Winkelman to 5 miles downstream of Last Chance Basin, and along the San Pedro River about 2 miles upstream of the confluence with the Gila River;
- Surface water drainages within Hayden that are near ASARCO process facilities, including Power House, Kennecott, and San Pedro washes; and
- Upland areas.

2.1.2 Ecological Setting

The Site is located in southern Arizona in the town of Hayden and adjacent to the town of Winkelman. Hayden is at an elevation of about 2,100 feet and Winkelman is at about 1,970 feet in elevation above mean sea level (msl). Based on general climatological information obtained from the Hayden Community Profile provided by the Arizona Department of Commerce, Hayden has an annual average precipitation of 13.9 inches, and temperatures range from a low of about 30ºF in winter to a high of about 103ºF in summer. The yearly average low is 46ºF and the yearly average high is 84ºF. Precipitation primarily occurs in two periods, winter (December to March) and summer/fall (July to October), with the most precipitation in July and August.

Descriptions of the terrestrial and aquatic systems in the Site study area were derived from the literature, as well as from the ecological evaluation Site visit conducted April 27 and 28, 2006 (CH2M HILL 2006b; Appendix B).

2.1.2.1 Terrestrial Systems

As delineated in EPA (2003), the Site is located in the Sonoran Basin and Range Ecoregion (Appendix B), and is in the northeastern corner of the Sonoran desert-scrub biome. This biome represents a large arid region that encompasses most of the Baja California Peninsula, the western half of the State of Sonora, Mexico, and large areas in southeastern California and southwestern Arizona (Brown 1994). The Sonoran Desert has a bimodal rainfall pattern (rains in winter and summer), which allows it to have a greater structural diversity (i.e., large cacti and succulent plants in most regions and trees, tall shrubs, and succulents along drainages) than any of the other North American deserts.

Brown (1994) presents six subdivisions of this biome, including Lower Colorado River Valley, Arizona Upland, Plains of Sonora, Vizcaino, Central Gulf Coast, and Magdalena Plain. The smelter is located in habitat characterized as Arizona Upland. This subdivision is also referred to as Arizona Desert, Paloverde-Cacti Desert, and Cercidium-Opuntia Desert. About 90 percent of this region is on slopes, broken ground, and multi-dissected sloping plains. It is the best watered and least desert-like desert-scrub habitat in North America.

Upland communities are dominated by paloverde (*Cercidium* spp.) and cacti (*Opuntia* spp.) desert associations (Hatten and Paradzick 2003). Three series in the subdivision include Paloverde-Cacti-Mixed Scrub series (the most extensive series), Jojaba-Mixed Scrub series, and Creosotebush-Crucifixion-thorn series (Brown 1994). The Paloverde-Cacti-Mixed Scrub series is dominated by paloverde (*Cercidium* spp.), a leguminous tree, and the columnar saguaro cactus (*Carnegiea gigantean*). As indicated in the name, the Jojoba-Mixed Scrub series is dominated by Jojoba (*Simmondsia chinensis*), which is a very valuable forage plant for game and domestic stock. The Creosotebush-Crucifixion-thorn series is common near the San Carlos Reservoir, upstream of Hayden, Arizona. The crucifixion-thorn (*Canotia holocantha*) is a low, spiny, leafless tree generally found on hillsides. It often grows with creosotebush (*Larrea* spp.). This series often shares many characteristics with the Mojave Desert. As expected, large areas dominated by shrubs such as creosotebush were observed during the ecological evaluation. Additionally, paloverde and saguaro were associated with specific soil types, and were found to be common in some areas (Appendix B).

Because of the proximity of the Site to the Gila and San Pedro rivers, the Site supports a variety of reptilian, avian, and mammalian species. Although no specific reptiles were observed during the Site visit, the species diversity of reptiles at ASARCO is likely high, typical of the southwestern desert environment (Appendix B). Within the Arizona Upland subdivision, there are many Sonoran and other desert reptiles, including some with more restricted ranges. For example, the regal horned lizard (*Phrynosoma solare*), western whiptail (*Cnemidophorus tigris gracilis*), Gila monster (*Heloderma suspectum*), Arizona glossy snake (*Arizona elegans noctivaga*), Arizona coral snake (*Micruroides euryxanthus*), and tiger rattlesnake (*Crotalus tigris*) are typical species in the upland subdivision (Brown 1994).

The bird community is diverse, with particular bird communities associated with specific plant communities and seasons. Common birds observed onsite during the ecological investigation included a variety of sparrows and finches, phainopepla (*Phainopepla nitens*), red-winged blackbird (*Agelaius phoeniceus*), cliff swallows (*Petrochelidon pyrrhonota*), Swainson's hawk (*Buteo swainsonii*), and turkey vulture (*Cathartes aura*). Because the Site is near the Gila-San Pedro River confluence, the area is a breeding site for the federally endangered southwestern willow flycatcher (*Empidonax traillii extimus*) (Appendix B). Other species such as the cactus woodpeckers (*Melanerpes uropygialis*, *Colaptes chrysoides*, and *Picoides scalaris*), curve-billed thrashers (*Toxostoma curvirostre*), and cactus wren (*Campylorhynchus brunneicapillus*) also utilize these Paloverde-Cacti-Mixed Scrub communities (Brown 1994).

The mammal community present at the Site includes small herbivorous species such as desert cottontail (*Sylvilagus audubonii*), Arizona pocket mouse (*Perognathus amplus*), and Harris antelope squirrel (*Ammospermophilus harrissii*); a number of larger omnivores and predators including gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), and coyote (*Canis latrans*); and large herbivores such as feral horse and desert mule deer (*Odocoileus hemionous crooki*) (Appendix B).

The Arizona Game and Fish Department (AGFD) responded to a request made by CH2M HILL on April 19, 2006, for information regarding special-status species associated with the Site. The response letter dated April 24, 2006, is included as Appendix C. The AGFD provided records from their Heritage Data Management System on special-status species occurring within 3 miles of the project vicinity. Special-status terrestrial species within the project area include three plants, one invertebrate, one reptile, seven birds, and one mammal (Table 2-1). In addition, there is a bat colony within a 3-mile radius of the Site and the project area occurs in the vicinity of designated critical habitats for the southwestern willow flycatcher.

2.1.2.2 Riparian and Aquatic Systems

The Site is located near the confluence of the San Pedro and Gila rivers. This area is within the Middle Gila River watershed, which spans from below Coolidge Dam at San Carlos Reservoir to Gillespie Dam southwest of Phoenix (ADWR 2005). From Coolidge Dam, the Gila River flows from the northeast along the east side of Winkelman, after which it shifts to the west until it reaches the confluence with the San Pedro River (about 0.5-mile upstream of the Site) (ADEQ 2003). The Gila River then flows northwest from the Site between the bermed Tailings Impoundment D and Tailings Impoundment AB/BC toward the town of Kearny.

The Gila River and its tributaries are major lotic waters (i.e., actively moving) in the area and provide vital riparian habitat for wildlife in southeastern Arizona (Andrews and King 1997). Paxton et al. (1997) described both rivers as perennial (i.e., contain water year-round), although both have been known to be dry during low rain periods (ADEQ 2003). The Gila River is considered a fishery with flow characteristics from 100 cubic feet per second (cfs) to 1,000 cfs (ADEQ 2003). It should be noted that flow in the Gila River between Coolidge Dam and Ashurst-Hayden Diversion Dam is attributed to releases from the San Carlos Reservoir and to natural flow in the river (ADWR 2005).

The San Pedro River water is of the calcium-biocarbonate type with an annual average concentration of total dissolved solids (TDS) of 676 milligrams per liter (mg/L) near Winkelman. Exceedances of water quality standards for turbidity, selected metals, bacteria, TDS, and nutrients have been reported along the Gila River (ADWR 2005).

The riparian area near the confluence of the San Pedro and Gila rivers consists of mixed exotic and native vegetation. Riparian areas along the confluence of these rivers have been described as varying from "monotypic tamarisk (*Tamarix ramosissima*) to stands of native Gooddings willow (*Salix gooddingii*) and Fremont cottonwood (*Populus fremontii*)," with average canopy heights between 4 to 15 meters as described by Smith et al. (2004). Hatten and Paradzick (2003) indicate that this area is classified as Sonoran Riparian Deciduous Forest, with Freemont cottonwood, Gooddings willow, mesquite (*Prosopis* spp.), seepwillow (*Baccharis salicifolia*), and the non-native tamarisk (also known as saltcedar). These authors also indicated that the riparian habitat occurs as spatially heterogeneous patches along the San Pedro and Gila rivers.

Although these areas are dominated by cottonwood and willow, there are substantial amounts of dense saltcedar. Saltcedar may occur as a dense understory amidst the cottonwood, willow, ash, or boxelder overstory or it may border the edge of the native vegetation as stated by Finch and Stoleson (2000). These riparian areas are surrounded by the Arizona Upland subdivision vegetation as described previously, although agricultural fields border the riparian habitat along some portions of the San Pedro River (Andrews and King 1997).

The dominant vegetation observed in aquatic and wash areas of the Site include willows (*Salix* sp.), tamarisk, cottonwood, and cat's claw (*Acacia greggi*) (Appendix B). Amphibians may be abundant in the area; however, none were observed during the Site visit and amphibians are seasonal in their occurrence outside of the permanent rivers and streams (Appendix B). Avian species supported by the riparian habitat along the Gila River include the federally endangered southwestern willow flycatcher, as well as other riparian species such as the yellow-billed cuckoo (*Coccyzus americanus*), common snipe (*Gallinago gallinago*), belted kingfisher (*Ceryle alcyon*), and various warblers. Southwestern willow flycatchers and bald eagles (*Haliaeetus leucocephalus*) have been documented in the Site vicinity (ADEQ 2003). Some of the riparian-associated avian species observed at the Site during the ecological investigation included cliff swallows, marsh wrens (*Cistothorus palustris*), and red-winged blackbirds (Appendix B). The AGFD (2006) identified one aquatic plant and three fish species that have special-status ratings (Table 2-1).

2.2 Identification of Chemicals of Potential Ecological Concern

COPECs are those chemicals present at the Site in concentrations that may exceed toxicity thresholds for ecological receptors. These chemicals are identified by the evaluation of known Site practices and analytical results. It is important to recognize that COPECs often vary from chemicals of potential concern for human health exposures. The Site is a copper ore processing facility that has operated since its founding about 95 years ago. The concentrator operations at the Site have resulted in large accumulations (covering about 1,700 total acres) of tailings, which have been deposited adjacent to the Gila River near the confluence with the San Pedro River. In 1993, flood waters washed about 292,000 tons of the tailings into the Gila River, potentially impacting surface waters and sediment in the downstream areas (ADEQ 2003). Air emissions from the crushing, concentrating, and smelting process have been deposited in the Site vicinity, including surface soils and water in the terrestrial, riparian, and aquatic areas around the Site. Based on the windroses developed for the Montgomery Ranch (west of the concentrator) and Hayden Jail (in Hayden near the concentrator) air monitoring stations presented in the RI Work Plan (CH2M HILL 2005), the primary deposition is likely to be in an east-west direction. In contrast, data from the Globe Highway air monitoring station (east of the smelter) indicate deposition in a primarily southwest-northeast direction, generally following the Gila River orientation up the canyon located northeast of Winkelman.

Existing data (described in Section 2.6) indicate that arsenic and copper, and to a lesser extent cadmium, lead, mercury, and zinc, are at levels of potential concern. Therefore, all of these analytes were considered COPECs in surface water, sediment, soil, and groundwater.

Although other classes of chemicals (e.g., volatile organic compounds [VOCs], semivolatile organic compounds [SVOCs], and radionuclides) are often associated with mining and ore processing activities and may be of concern in the direct vicinity of the Site, there is currently no evidence, based on available data, that these are chemicals of concern for ecological receptors. In addition to arsenic, cadmium, copper, lead, mercury, and zinc, other inorganics including aluminum, antimony, barium, beryllium, boron, chromium, cobalt, cyanide, iron, magnesium, manganese, molybdenum, nickel, selenium, silver, thallium, and vanadium are considered of potential ecological concern. Although several of these metals and other inorganics were recorded below levels of concern in previous investigations (ADEQ 2003), many of the ecological habitats in the project area (e.g., upland areas that may be located within the air emissions deposition area) have not been well characterized. Therefore, all these inorganics were considered COPECs.

Summary statistics for the COPECs, including the number of samples with detected concentrations, the total number of samples, arithmetic mean and standard deviation, and the minimum, median, and maximum values are provided in Table 2-2. The abiotic data include surface water, sediment, and soil collected from the Middle Gila and San Pedro watersheds; soil data collected from the San Pedro, Kennecott, and Power House washes; soil data from upland areas on either side of the Gila River; and groundwater data collected from the Gila River floodplain. Some of the contaminant data were derived from literature sources and may not fall within the project area. These data are identified as “offsite” in the summary table. The entire ERA dataset is included in Appendix D.

2.3 Conceptual Site Model

The CSM is a written and visual presentation of predicted relationships among stressors, exposure pathways, and assessment endpoints. It includes a description of the complete exposure pathways and outlines the potential routes of exposure for each assessment endpoint. A CSM diagram for ecological exposures was developed for the Site and is presented in Figure 2-2.

The primary sources are current or historic activities of the smelter and concentrator. Primary release mechanisms include air emissions from the 1,000-foot stack and other process locations, as well as solid wastes (the tailings impoundments) and wastewater associated with the processing of the copper ore. Release mechanisms include aerial deposition of stack or fugitive emissions, discharge/runoff from the tailings impoundments (as occurred during flooding in 1993) to the Gila River or to adjacent soils, wind erosion, leaching to groundwater, and surface discharge from groundwater. Secondary sources of potential contaminants are surface soils (including areas affected by aerial deposition, riparian soils), surface water and sediment of the rivers, groundwater, and air.

Complete exposure pathways from contaminated surface soil, surface water, sediment, biota, and groundwater to ecological receptors exist at the Site. Surface soils in the ERA refer to riparian, upland, and wash soils that support ecological habitat. Soils collected from the residential/non-residential areas in the town of Hayden were not evaluated because they lack habitats for ecological receptors. Soils and water collected from the tailings impoundments also were not evaluated due to a lack of suitable ecological habitat (Appendix A).

Contaminants in soil may be directly bioaccumulated by terrestrial plants, soil invertebrates, or micro-organisms resident in Site soils. Additionally, terrestrial plants may be exposed by uptake from contaminated groundwater or surface water sources or by aerial deposition onto foliage. Aquatic plants are primarily exposed via contaminated sediment. Although benthic invertebrates, fish, and amphibians may be exposed to contaminants via surface water or sediment, benthic invertebrates are primarily exposed through sediment, and fish and amphibians are primarily exposed through surface water. Terrestrial and aquatic wildlife (e.g., herbivores, omnivores, invertivores, and carnivores), including reptiles, may be exposed directly to contaminants in surface water through ingestion and to contaminants in soil or sediment by incidental soil or sediment ingestion, by dermal contact, or by the inhalation of wind-borne particles. Terrestrial and aquatic invertebrates, fish, and wildlife (i.e., amphibians, reptiles, birds, and mammals) may also receive contaminant exposure through food-web transfer of chemicals from lower trophic levels (e.g., plants to herbivores, plants and prey animals to omnivores, etc.).

2.4 Assessment Endpoints

Assessment endpoints are an expression of the important ecological values that should be protected at a site (Suter 1990, 1993; EPA 1998; Suter et al. 2000). Assessment endpoints are developed based on known information concerning the contaminants present, the study area, the ecological CSM, and risk hypotheses. There are three components to each assessment endpoint: an *entity* (e.g., migratory birds), an *attribute* of that entity (e.g., individual survival), and a *measure* (e.g., a measurable value, such as an effect level). Measures are described following the general description of assessment endpoints (EPA 1998, Suter et al. 2000).

The assessment endpoint entities for the Site were selected based on the following principal criteria:

- Ecological relevance
- Societal relevance
- Susceptibility (or high exposure) to known or potential stressors at the Site

The attribute selected for each entity was based on the organizational level of the entity and the primary criteria that were used to select it. Entities and attributes were selected for community, population, and individual levels of assessment.

The maximum acceptable adverse effect levels generally selected for population- and community-level assessment endpoints are lowest observed effect concentrations (LOECs) or lowest observed adverse effects levels (LOAELs). For individual-level assessment endpoints (e.g., threatened and endangered species), there is no acceptable adverse effect level; consequently, NOECs or NOAELs were used for these endpoints.

Assessment endpoints for the Site include aquatic plants, water-column invertebrates, fish, amphibians, benthic invertebrates, and aquatic birds and mammals in the aquatic habitats and terrestrial plants, soil invertebrates, soil microbial processes, reptiles, and terrestrial birds and mammals in the terrestrial habitats. In addition, the federally endangered southwestern willow flycatcher occurs within the vicinity of the Site and was included as an assessment endpoint.

Where appropriate, representative ecological receptors (i.e., specific species) were selected from these communities to fulfill as many of the following criteria as possible:

- Species that are known to occur or are likely to occur at the Site
- Species that relate to the assessment endpoints selected
- Species that are likely to be maximally exposed to the site-related COPECs
- Sedentary species or species with a small home range

- Species with high reproductive rates
- Species that are known to play an integral role in the ecological community structure at the Site
- Species that are known or likely to be especially sensitive to the Site-related COPECs, and thus are an indication of ecological change
- Species that are representative of the foraging guild (i.e., a group of species with similar ecological resource requirements and foraging strategies and, therefore, similar roles in the ecosystem) or that serve as food items for higher trophic levels.

Bird and mammal receptors include species representative of trophic levels and foraging guilds (e.g., herbivores, omnivores, invertivores, and carnivores), as well as special-status species in the area. The representative receptors were selected during the October ERA kick-off meeting and include swallows, belted kingfishers, mourning doves, curve-billed thrashers, red-tailed hawks, southwestern willow flycatchers, little brown bats, mink, desert cottontails, desert shrews, and coyotes (Appendix A). The assessment endpoints are outlined in Table 2-3.

2.5 Measures of Exposure and Effects

Measures (formerly referred to as measurement endpoints) are measurable attributes used to evaluate the risk hypotheses and are predictive of effects on the assessment endpoints (EPA 1998). The three categories of measures include the following.

- Measures of exposure—used to evaluate levels at which exposures may be occurring.
- Measures of effect—used to evaluate the response of the assessment endpoints when exposed to the stressors.
- Measures of ecosystem and receptor characteristics—used to evaluate the ecosystem characteristics that influence the assessment endpoints, the distribution of stressors, and the characteristics of the assessment endpoints that may affect exposure or response to the stressor.

For this assessment, measures of exposure and effects were the primary measures used. Measures of ecosystem and receptor characteristics were available for some receptor groups, but were limited in their scope and use.

2.5.1 Measures of Exposure

Measures of exposure can be an EPC of a chemical in an environmental medium or food item, or a related dose estimate. In the initial screening assessment, maximum detected or non-detected (if all samples were non-detects or if the maximum non-detect exceeded the maximum detect) concentrations were used as the EPC for all receptors. A point-by-point evaluation of all analytes retained from the initial screen was conducted for immobile or nearly immobile receptors (e.g., plants and invertebrates) in the refined screening assessment. Although fish could be considered mobile receptors, they were evaluated on a point-by-point basis in the refined screening step. For mobile receptors (i.e., birds and mammals), the EPC was represented by the maximum media concentrations in the initial screen and the 95 percent upper confidence limit of the mean (95 UCL) for each retained analyte. Additionally, bird and mammal receptors were assumed to forage exclusively onsite in the initial screening evaluation.

2.5.2 Measures of Effects

Measures of effects include media-specific ecological benchmarks and TRVs. Because Site-related chemicals can induce ecotoxicological effects in exposed receptors if present at sufficiently high concentrations, ecotoxicity-based benchmarks and TRVs are also measurement endpoints. As previously indicated, TRVs in the initial screen were represented by literature-based screening benchmarks, NOECs, or NOAELs. In the refined screen, NOECs and NOAELs, as well as LOECs and LOAELs were used. The exception was for receptors assessed at the individual level (i.e., special-status species) for which exceedance of the NOAEL is unacceptable.

Literature-based toxicity data were used. For example, Ecological Soil Screening Levels (EcoSSL) developed by EPA (EPA 2007a) were used as available, as were other published screening data for plants, soil invertebrates, and soil microbial processes (e.g., Efroymson et al. 1997a, 1997b). For the aquatic environment, published screening levels for surface water (e.g., ADEQ 2007, EPA 2006, Suter and Tsao 1996) and sediment (e.g., MacDonald et al. 2000) were also used. Avian and mammalian toxicity values were extracted from EFA West (1998), Sample et al. (1996), and published literature, as appropriate.

The measures of exposure and effects are provided along with the assessment endpoints in Table 2-3.

2.5.3 Measures of Ecosystem and Receptor Characteristics

Measures of ecosystem and receptor characteristics include site-specific studies of the diversity and abundance of receptors and/or quantitative or qualitative evaluations of the habitat quality and functioning at the Site. These measures are not generally included in screening-level assessments. However, site-specific population studies were available for fish and the southwestern willow flycatchers (Section 2.6.3.1), and a qualitative ecological evaluation was conducted as part of the RI (Section 2.6.3.2). These studies are limited in scope and, in the case of the fish and flycatcher studies, were not conducted as part of the ERA data collection effort. Therefore, their use in the SLERA is also limited. The results of these studies were applied to the refined risk characterization as possible.

2.6 Available Data and Uses

2.6.1 Historic Media Data

Prior sampling of abiotic media at the Site included surface water and sediment, non-river sediment, surficial soils, groundwater, and air monitoring. These data are described in detail in the RI Work Plan (CH2M HILL 2005). Briefly, surface water and sediment samples have been collected from the Gila River. Additionally, sediment samples were collected from the

San Pedro River, Power House Wash, and Kennecott Wash.[1] Non-river sediment samples were collected from containment pond CP-1, Tailings Impoundment AB/BC, Tailings Impoundment D, and the stormwater pond. Surficial soils were sampled primarily within residential and public areas in the towns of Hayden, Winkelman, and Kearny. Groundwater samples have been collected from monitoring and production groundwater wells in the Hayden and Winkelman areas. These wells fall into five groups including:

- Upgradient Gila River Alluvial wells that may serve as background for the Gila River Alluvium;
- Gila River Alluvial wells located downgradient of the tailings impoundments that measure the potential for groundwater to affect the surface water quality of the Gila River;
- Gila River/San Pedro River water supply wells;
- Bedrock wells that supply water quality information on the groundwater found in the bedrock, which is primarily located in higher elevation areas above the Gila River floodplain; and
- Anomalous Response wells that indicate levels of contamination that are anomalous to their surface or depth location.

Finally, air monitoring has been conducted in the Hayden area since the early 1970s. The air data, however, were not used in exposure estimates because inhalation is not predicted to be a major exposure pathway for ecological receptors. It should be noted that air data were used in the SLERA to support identification of Site-associated contaminants. The historic data for surface water, sediment, surficial soils, and groundwater data were used to scope the RI data collection, but were not used in this SLERA.

2.6.2 Data Collected Under the RI Work Plan

Based on an analysis of the historic data, additional sampling of surface water, sediment, surficial soils, groundwater, and air was conducted as outlined in the RI Work Plan (CH2M HILL 2005). Additionally, a groundwater flow investigation to determine whether there is groundwater discharge from beneath the ASARCO operations to the Gila River was performed, as was an ecological investigation of the terrestrial and wildlife habitat in the study area. Details of the additional sampling and other investigations are provided in the RI Work Plan and are summarized in this document.

Surface Water and Sediment—Although historic sampling had included collection of some surface water and sediment samples, those data were not deemed sufficient to characterize those areas of ecological habitat potentially affected by Site releases. The areas of interest for surface water and sediment sampling were generally defined as the:

1. Gila River extending from about 2 miles upstream of Winkelman to about 5 miles downstream of Last Chance Basin.

[1] For the purposes of this SLERA, “sediment” samples collected from the three washes were considered soil and were used to determine risk to terrestrial receptors utilizing the wash areas.

2. San Pedro River extending about 3 miles upstream from its confluence with the Gila River.
3. San Pedro, Kennecott, and Power House washes (considered soil for the purposes of the SLERA).
4. Tailings Impoundments AB/BC and D (not used in the SLERA due to an absence of ecological habitat).
5. Stable and unstable riparian communities within the Gila River floodplain (considered soil for the purposes of the SLERA).

Three types of investigative techniques were used including electrical conductivity survey, field portable x-ray fluorescence (FPXRF), and sample collection and laboratory analysis. Only those samples analyzed in the laboratory were included in the risk assessment.

Surface water and in-stream sediment sampling locations are shown in Figure 2-3.

Surficial Soils—Because historic sampling did not adequately address habitat in the vicinity of the Site, the RI sampling approach included a combination of FPXRF sampling to provide real time screening-level data and locate areas needing more focused sampling, and biased sampling with laboratory analysis in areas determined to be of concern based on potential ecological habitat and FPXRF results. Surficial soils included riparian and upland soils, with riparian soils being divided into two groups, stable and unstable (ruderal or disturbed). Samples collected from the San Pedro, Kennecott, and Power House washes were also considered surficial soils for the purposes of the SLERA.

Ten upland and 29 riparian sampling locations were selected to represent ecological exposures in those habitats. These locations are depicted in Figure 2-3. (Note: only samples analyzed in the laboratory were used in the ERA.) Additionally, soil was collected from 37 locations within the three main washes in the project area (Figure 2-4).

Groundwater—The groundwater investigation conducted under the RI indicated a hydrologic connection between groundwater and surface water, with groundwater under the ASARCO operations discharging to the Gila River during the wet periods. Additionally, slurry water leaching from the tailings impoundments was found to mound above the aquifer and discharge to surface water. During dry periods when the water table is lower and additional water is released from the upstream Coolidge Dam, surface water in the Gila River provides some recharge to the aquifer. Groundwater data collected from six wells (H-1, H-2A, H-5, GW-03, HWF-21, and H-10) completed in the Gila River floodplain were applicable to the SLERA. These locations are shown in Figure 2-3.

Air—Collection of additional air monitoring data was included in the RI sampling; however, as previously indicated, air data were not used in the ecological exposure estimates. Instead, these data were used as additional support for identification of Site-associated contaminants.

Ecological Investigations—Characterization of the aquatic and terrestrial habitat within the project area included general habitat mapping and wildlife observations. Methods and results for the ecological evaluation are described in Section 2.6.3.2. Generally, the project area included all aquatic and terrestrial habitat within the area trending northwest-southeast and superimposed over the Gila and San Pedro River valleys as shown in Figure 2-3. The project area includes upland areas 5 miles on each side of a line extending from 2 miles east-southeast of Winkelman to northwest of Hayden about halfway to the town of Kearny. This area also incorporates the towns of Hayden, Winkelman, and associated ASARCO process facilities, although little ecological habitat is present in these process areas. A reference area just upstream of the Site boundaries (GRREF01, Figure 2-3), which has similar terrestrial and aquatic habitats as the project area, was also evaluated. For wildlife observations, direct observation, calls, or sign of wildlife in the project area were recorded during the terrestrial and aquatic habitat characterization field surveys.

The results for the surface water, sediment, soil, groundwater, and air samples collected during the RI sampling will be presented in the final RI Report. A preliminary summary of the surface water, in-stream sediment, and riparian sediment sampling was developed for EPA use only (CH2M HILL 2006c). The measured concentrations in surface water, sediment, soils, and groundwater from the RI sampling that were used in the SLERA are included in the ERA dataset (Appendix D).

2.6.3 Site-specific Ecological Studies

The site-specific ecological studies include those obtained from the literature and the ecological investigation conducted as part of the RI sampling in 2006. These studies are described as follows.

2.6.3.1 Literature-based Ecological Studies

Five contaminant-related ecological studies have been conducted in or near the project area. One study evaluated contaminants in sediment, lizards, and fish collected from the Middle Gila River (King and Baker 1995). Contaminants in sediment, lizards, fish, and birds were studied in the Upper Gila River (Baker and King 1994) and the San Pedro River (King et al. 1992). A fourth study evaluated contaminants in sediment and fish of Mineral Creek and the Middle Gila River (Andrews and King 1997). A final study reported contaminants in southwestern willow flycatcher eggs, nestlings, and prey items collected near several drainages in southeastern Arizona, including at the confluence of the San Pedro and Gila rivers (King et al. 2002). The contaminant data reported in these studies are included in the dataset for the Site (Appendix D) and were used as possible in the risk evaluations.

The Gila-San Pedro River confluence area has been reasonably well characterized due to the presence of the southwestern willow flycatcher, a federally endangered species, in the area. The following list of flycatcher-related studies is available for use in the risk evaluations for this species:

- *Southwestern Willow Flycatcher Survey and Nest Monitoring Reports* for 2000 through 2003 (Paradzick et al. 2001, Smith et al. 2002, 2003, 2004);
- *Southwestern Willow Flycatcher Breeding Site and Territory Summaries* for 2000 through 2002 (Sogge et al. 2001, 2002, 2003);
- *Physiological Condition of Southwestern Willow Flycatchers in Native and Saltcedar Habitats* (Owen and Sogge 2002);
- *A Quantitative Analysis of the Diet of Southwestern Willow Flycatchers in the Gila Valley, New Mexico* (DeLay et al. 2002);

- *Mapping and Monitoring Southwestern Willow Flycatcher Breeding Habitat in Arizona: A Remote Sensing Approach* (Dockens and Paradzick 2004);
- *Banding and Population Genetics of Southwestern Willow Flycatchers in Arizona – 1997 Summary Report* (Paxton et al. 1997);
- *Food Habits of the Endangered Southwestern Willow Flycatcher* (Drost et al. 2001);
- *Survivorship and Movements of Southwestern Willow Flycatchers in Arizona – 2000* (Luff et al. 2000);
- *Survivorship and Movements of Southwestern Willow Flycatchers at Roosevelt Lake, Arizona – 2001 and 2003 reports* (Kenwood and Paxton 2001);
- *Status, Ecology, and Conservation of the Southwestern Willow Flycatcher* (Finch and Stoleson 2000);
- *Nestling Sex Ratio in the Southwestern Willow Flycatcher* (Paxton et al. 2002); and
- *A Multi-scaled Model of Southwestern Willow Flycatcher Breeding Habitat* (Hatten and Paradzick 2003).

Additional ecological studies in the project area include a fish monitoring study being conducted by the AGFD and Bureau of Reclamation (Voeltz 2005), a herp (reptiles and amphibians) study being conducted by the Bureau of Reclamation (Messing 2005), and the annual Christmas bird counts conducted in the area by the National Audubon Society (McCarthey 2005). Following are brief descriptions of these three studies.

The AGFD and Bureau of Reclamation have conducted a fish monitoring study that includes portions of the Gila River adjacent to and downstream of the Site and in areas within the San Pedro River (Voeltz 2005). Two of the Gila River sites are located on ASARCO property, two are upstream of the property, two are downstream of the property, and one is upstream in the San Pedro River. This study is part of the annual sampling conducted in agreement with the Bureau of Reclamation to monitor 22 sites in the Gila River Basin. This study does not measure contaminant levels, but provides population/community data (e.g., species abundance and richness). It should be noted that the ASARCO property sites were dry during the November 2004 sampling, as were the sites in 2003. Information on species present in past years (1999 to 2006) was available.

The Bureau of Reclamation conducted a pilot study to compare the species diversity of herps (primarily lizards, but occasionally also toads) between mature saltcedar habitat and mature cottonwood-willow habitat in southern Arizona (Messing 2005). The saltcedar site is located adjacent to the Gila River on ASARCO property and the cottonwood-willow habitat is located near The Nature Conservancy (TNC) preserve adjacent to the San Pedro River. Three arrays (or sampling locations) are located within each area. An array consists of a central 5-gallon bucket dug into the ground and three outer buckets about 25 feet away connected by a drift fence. The arrays were checked every other day during May through September 2004. A second collection effort was conducted during May through September 2005, and some vegetation data were also collected. Arthropods (e.g., spiders) were also observed in the pitfall traps during the pilot study.

The National Audubon Society has been conducting nationwide Christmas bird counts in December and early January for more than 100 years. For the past 5 years, Christmas bird counts have been performed in the 15-mile radius area centered at Dudleyville, Arizona (McCarthey 2005). This area includes the towns of Hayden and Winkelman and the ASARCO LLC Hayden properties. Volunteers survey for 1 day and the data are compiled for the entire area. This information is useful for documenting avian species in the general project area during the winter, but did not provide information specific to the project area.

2.6.3.2 Site Ecological Investigation

Field surveys of the aquatic and terrestrial habitats within the project area were included in the RI sampling effort. A detailed description of the study methods and results was provided in the technical memorandum titled *Summary of Ecological Evaluation Site Visit of April 27-28, 2006* (CH2M HILL 2006b; Appendix B).

These characterizations in the project and reference areas included general habitat mapping (Figure 2-5) and wildlife observations, and were generally conducted according to guidance for ecological assessments provided by EPA (1997). Limited field surveys were conducted to verify/ground-truth assigned aquatic and terrestrial habitat types as determined by the initial habitat mapping effort; to identify habitats in the vicinity of surface water, sediment, and soil sampling areas; and to record characteristic vegetation and general wildlife utilization patterns within the project area, as well as within a reference area (i.e., an area with similar vegetation, geology, slope, etc., but that is likely not affected by the Site). The locations of the sites surveyed on April 27 and 28, 2006, are shown in Figure 2-3, and the detailed results for each survey location are provided in Appendix B. The time spent at each site was limited and wildlife observations were not systematic but opportunistic.

The ASARCO Hayden Site is located in the Sonoran Basin and Range Ecoregion as delineated by EPA (2003). Soil conditions in this area strongly affect the distribution and composition of plant communities in this ecoregion and presumably at the Site. The Site consists of large areas dominated by shrubs such as cresote bush. Depending on the specific soil type present in an area, common plant species include paloverde and saguaro. Within the aquatic and wash areas, dominant vegetation includes willow, tamarisk, cottonwood, and cat’s claw.

Amphibians may be abundant in the project area; however, none were observed during the ecological evaluation and amphibians are seasonal in their occurrence outside of the permanent rivers and streams. Although no reptiles were observed during the Site visit, the species diversity of reptiles at ASARCO is likely high, typical of the southwestern desert environment. The bird community was diverse, with particular bird communities associated with specific plant communities and seasons. Common herbivorous and insectivorous birds included a variety of sparrows and finches, phainopepla, red-winged blackbird, and cliff swallows. Birds of prey included Swainson’s hawk and turkey vulture. Because the Site is near the Gila-San Pedro River confluence, the area is a breeding site for the federally endangered southwestern willow flycatcher. Flycatchers were not observed during the Site visit. The mammal community present at the Site included small herbivorous species (desert cottontail, pocket mouse, and antelope squirrel), a number of larger omnivores and predators (fox, bobcat, and coyote), and large herbivores (feral horse and mule deer).

Signs of vegetative stress were recorded for two of the riparian locations, GR04 and GR10. Dead cottonwoods were observed at GR04 (see photo GR04-3 in Appendix B). These trees were upland of the current riparian area and quite a distance from the river so they were not included in the evaluation of the river. Other vegetation around the cottonwoods did not appear stressed, suggesting that the cottonwoods may have died as a result of changes in their access to water. At GR10, multiple instances of shrubs with brown, chlorotic, or otherwise stressed foliage were observed (see photo GR10-Stress1, GR10-Stress2, and GR10-Stress3 in Appendix B). Potential causes of this stress were not readily apparent.

2.6.4 Non Site-specific Literature-derived Toxicity Data

Site-specific toxicity data and avian and mammalian life-history parameters required for calculation of exposure estimates (e.g., body weight, food ingestion rates, and dietary components) were not available for each receptor. Therefore, life-history parameters for avian and mammalian receptors were derived from the literature. Toxicity data for each receptor group were obtained from many sources including published benchmarks from data compiled by the National Oceanic and Atmospheric Administration (Buchman 1999), EPA (2006), and the Oak Ridge National Laboratory (ORNL) (Suter and Tsao 1996). Additional toxicity data were derived from published studies as needed, and are detailed in Section 3.2.

SECTION 3

Analysis

The analysis phase consists of the technical evaluation of chemical and ecological data to determine potential for ecological exposure and adverse effects. The analysis phase includes the characterization of exposure and the characterization of effects.

3.1 Exposure Characterization

The exposure characterization provides a description and quantification of the nature and magnitude of the interaction between COPECs in surface water, sediment, soil, or groundwater and ecological receptors. The exposure models and assumptions for each receptor at the Site are described as follows.

3.1.1 Aquatic Plants, Water-column Invertebrates, Amphibians, and Fish

3.1.1.1 Media-based Exposures

Aquatic plants, water-column invertebrates, amphibians, and fish at the Site experience exposure primarily through the medium where they live. Although aquatic plants and invertebrates, amphibians, and fish are exposed to COPECs in both surface water and sediment, the primary exposure medium is surface water. For these receptors, exposure occurs as a consequence of living in a contaminated medium (i.e., receptors are directly exposed to COPECs). Although other exposure pathways (e.g., direct exposure to water or dietary exposure for invertebrates or fish) may contribute to total exposure for these receptors, exposure through surface water predominates. Consequently, estimates of exposure for aquatic plants and invertebrates, amphibians, and fish may be represented as the concentration of COPECs in surface water (micrograms per liter [µg/L]).

EPCs for the initial screening estimates are the maximum detected or non-detected measured surface water concentration (Table 2-2). Either the total or dissolved concentration was used in the screening, depending on the applicability of the screening benchmarks (i.e., some were developed for use with total metals concentrations and others for use with dissolved metals concentrations). For COPECs that failed the screening assessment, EPCs were represented by the entire distribution of values, resulting in a point-by-point evaluation for each of these receptors. Surface water data collected from the Gila and San Pedro rivers were evaluated separately.

3.1.1.2 Tissue-Based Exposures

Concentrations of COPECs in tissues of receptor animals may exert adverse effects through various mechanisms, including toxicity to the target organ (e.g., liver or kidneys where metabolism and excretion occur) or release from tissue reserves during episodic events (e.g., mobilization of contaminants from fat during winter or spawning). Thus, body burden or tissue data provide a measure of exposure. Tissue data for fish have been collected within the Upper and Middle Gila River, Mineral Creek, and the San Pedro River (Section 2.6.3.1;

King et al. 1992, Baker and King 1994, King and Baker 1995, Andrews and King 1997). However, none of the sampling locations in these studies were within the project area. Therefore, tissue concentrations were not used as a measure of exposure for onsite fish communities.

3.1.2 Benthic Invertebrates

As with aquatic plants, water-column invertebrates, amphibians, and fish, benthic invertebrates at the Site experience exposure primarily through the medium where they live. Benthic invertebrates are exposed to COPECs in both surface water and sediment; however, the primary exposure medium is sediment. Although other exposure pathways (e.g., direct exposure to water or dietary exposure for invertebrates) may contribute to total exposure for these receptors, exposure through sediment predominates. Consequently, estimates of exposure for benthic invertebrates may be represented as the concentration of COPECs in sediment (mg/kg).

Initial screening estimates were the maximum measured detected or non-detected sediment concentration (Table 2-2). For COPECs that failed the screening assessment, EPCs were represented by the entire distribution of values, resulting in a point-by-point evaluation for these receptors. Sediment data collected from the Gila and San Pedro rivers were evaluated separately.

3.1.3 Terrestrial Plants, Soil Invertebrates, and Soil Microbial Processes

Terrestrial plants, soil invertebrates, and soil microbial processes experience exposure primarily through the soil in which they live. This exposure occurs as a consequence of living in a contaminated medium (i.e., receptors are directly exposed to COPECs). Although other exposure pathways (e.g., dietary exposure for invertebrates or foliar uptake) may contribute to total exposure for these receptors, exposure through the soil predominates. Consequently, estimates of exposure for terrestrial plants, soil invertebrates, and soil microbial processes may be represented by the concentration of COPECs in the soil (mg/kg). For plants in desert environments, root systems can be very deep, tapping into groundwater sources (especially in riparian zones). Therefore, exposure to plants at the Site may also be represented by the concentration of COPECs in groundwater (µg/L).

As previously indicated, the EPCs for the initial screening were the maximum measured concentration (detected or non-detected) of the COPEC (Table 2-2). For the refined screen, the EPCs were represented by the entire distribution of values for the retained COPECs, resulting in a point-by-point evaluation.

Soils at the Site were grouped into five categories: combined stable and unstable riparian, stable riparian, unstable riparian, upland, and wash soils. Based on the results of statistical comparisons, concentrations of 19 analytes and two soil attributes (total organic carbon and pH) in stable and unstable riparian soils did not differ. Therefore, the results for the stable and unstable riparian soils for these analytes were combined for the risk evaluation (Table 2-2). Seven analytes and one parameter (percent solids) differed between the two riparian soil types and were evaluated separately in the risk characterization. Upland soils are those collected in the upland areas located outside the riparian zone, and wash soils were collected from the San Pedro, Kennecott, and Power House washes.

Because the highest concentrations of COPECs are expected to occur at or near the soil surface due to aerial deposition of potential contaminants at the Site, the EPCs used for terrestrial plants, soil invertebrates, and soil microbial processes included soil data from the top 6 inches. Precipitation at the Site is limited, resulting in limited infiltration. Therefore, assuming exposure for soil biota to be represented by concentrations in the top 6 inches of soil is both representative and protective.

3.1.4 Birds and Mammals

3.1.4.1 Oral Exposure

Birds and mammals experience exposure through multiple pathways, including ingestion of abiotic media (surface water and sediment/soil) and biotic media (food), as well as inhalation and dermal contact. To address this multiple pathway exposure, modeling is required. The end product, or exposure estimate, for birds and mammals is a dosage (amount of chemical in milligrams per kilogram receptor body weight per day [mg/kg/day]) rather than a media concentration, as is the case for the other receptors. This is a function of both the multiple pathway approach and the typical methods used in toxicity testing for birds and mammals.

The general form of the model used to estimate exposure of birds and mammals to COPECs in surface water, sediment/soil, and food items is as follows (Suter et al. 2000):

$$E_t = E_o + E_d + E_i$$

Where,

E_t = the total chemical exposure experienced by wildlife

E_o, E_d, and E_i = oral, dermal, and inhalation exposure, respectively

Oral exposure occurs through the consumption of contaminated food, water, or sediment/soil. Dermal exposure occurs when contaminants are absorbed directly through the skin and inhalation exposure occurs when volatile compounds or fine particulates are inhaled into the lungs. Although methods are available for assessing dermal exposure to humans (EPA 1992e), data necessary to estimate dermal exposure generally are not available for wildlife (EPA 1993). Similarly, methods and data necessary to estimate wildlife inhalation exposures are poorly developed (EPA 1993) or limited (i.e., some data are available through the EPA Integrated Risk Information System [IRIS] database). Additionally, a wildlife receptor's exposure to contaminants by inhalation and dermal contact usually contributes little to its overall exposure. Dermal exposure also is likely to be low, even in burrow-dwelling animals, because of the presence of protective dermal layers (e.g., feathers, fur, or scales). Therefore, for the purposes of this assessment, both dermal and inhalation exposure were assumed to be negligible.

Because dermal and inhalation exposures are excluded, total chemical exposure experienced by wildlife (E_t) is equal to oral exposure (E_o). By replacing E_o with a generalized exposure model modified from Suter et al. (2000), the previous equation was rewritten as follows:

$$E_t = \left[\left[\sum_{i=1}^{n} B_{ij} \times P_i \times FIR \right] + \left[Soil_j \times P_s \times FIR \right] + \left[Water_j \times WIR \right] \right] x\, AUF$$

where:

E_t	=	total exposure (mg/kg/d)
$Soil_j$	=	chemical concentration in sediment/soil (mg/kg dry weight)
P_s	=	sediment/soil ingestion rate as proportion of diet (unitless)
FIR	=	food ingestion rate (kg food/kg body weight/d)
B_{ij}	=	chemical concentration in biota type (i) (mg/kg wet weight)
P_i	=	proportion of biota type (i) in diet (unitless)
$Water_j$	=	chemical concentration in water (mg/L)
WIR	=	water ingestion rate (L water/kg body weight/d)
AUF	=	area use factor (area of site/home range of receptor) (unitless)

Model Parameterization

To apply the exposure model, appropriate model parameters must be defined. These model parameters are outlined below.

Exposure Point Concentrations. Data from the top 6 inches were used to calculate the EPC for incidental sediment or soil ingestion by bird and mammal receptors and for exposure to prey items at the Site. This is because the highest concentrations of COPECs are expected to occur in surface soils (i.e., one primary release mechanism is aerial deposition and precipitation in the area is limited), it is both representative and protective to assume that exposure for burrowing animals is represented by concentrations in the top 6 inches of soil. Both dissolved and total metals were measured in surface water collected from the Site. Because exposure of wildlife occurs through ingestion of surface water, the total metal concentration for each COPEC were EPCs for surface water.

For the initial screen, the maximum media concentration (detected or non-detected) of each COPEC was used for the EPC (Table 2-2). Because wildlife are mobile, traveling and experiencing exposure over the range of habitats they occupy, their exposure is best described by mean chemical concentrations in areas they inhabit (Suter et al. 2000). Therefore, 95 UCLs for retained analytes in surface water, sediment and soil were used in the refined screening evaluation (these values are presented in Section 5). The 95 UCL was calculated using ProUCL

Version 4.0 (EPA 2007b). In cases where a particular COPEC was not detected in some samples, a value of one-half the reporting limit was used to calculate the 95 UCL.

Life History Parameters. The specific life history parameters required to estimate exposure of each receptor to COPECs include body weight, ingestion rates of food and water, dietary components and percentage of the overall diet represented by each major food type, and approximate amount of soil and/or sediment that may be incidentally ingested based on feeding habits. These parameters, as well as foraging or home range information, were obtained from the literature and are presented in Table 3-1.

Many wildlife species are highly mobile, covering large areas in search of food, water, and shelter. The exposure that individuals experience depends on the amount of time they spend at a contaminated site. Site use depends on the size of the site relative to the receptor's home range. As a conservative assumption, wildlife receptors initially were assumed to forage onsite 100 percent of the time. In the refined screening, home range size would generally be considered in the exposure estimate by application of an AUF. However, the Site is large, with about 20 km of river and over 200 ha of riparian habitat within the study area, such that even wide-ranging bird and mammal receptors may forage exclusively onsite. Therefore, an AUF of one (i.e., 100 percent onsite) was also used in the refined screening.

Bioaccumulation Models. Measurements of concentrations of COPECs in wildlife foods (e.g., aquatic invertebrates, fish, plants, soil invertebrates, small mammals) are a critical component for the estimation of oral exposure of birds and mammals. However, these site-specific measured data are generally not available or used in a screening-level assessment. Instead, bioaccumulation models derived from the literature are applied to develop risk estimates. The literature-based bioaccumulation models that describe uptake from sediment-to-aquatic/ benthic invertebrates, surface water-to-fish, soil-to-plants, soil-to-soil invertebrates, and soil to small mammals are presented in Tables 3-2, 3-3, 3-4, 3-5, and 3-6, respectively.

In cases where sediment-to-invertebrate models were lacking, the corresponding soil-to-soil invertebrate model was used as a surrogate. For soil-associated accumulation, the models presented in the EPA EcoSSLs methodology (EPA 2007a) were used preferentially. However, as a more conservative approach for the initial screening evaluation, the 90th percentile bioaccumulation factor (BAF) from the source selected by EPA was used instead of the median BAF that applied to development of the EcoSSLs. The application median BAF was used in the refined screening. Some bioaccumulation models for small mammals were diet-to-small mammal tissue rather than soil-to-small mammal. In these cases, a small mammal diet consisting of 50 percent plants and 50 percent soil invertebrates was assumed in calculating exposure estimates.

Bioavailability. For the initial screen, 100 percent bioavailability of analytes was assumed. However, COPECs present in media consumed by wildlife receptors are not absorbed with perfect (100 percent) efficiency; to assume so overestimates both exposure and risk. The absorption efficiency or bioavailability of a chemical varies as a function of many factors, including the chemical form of the COPEC, medium in which the COPEC is present, interactions with other COPECs, interactions with ingested food, the environment within the receptor's gastrointestinal tract, etc. To account for the bioavailability of COPECs at the

Site being less than 100 percent, total exposure estimates were adjusted by bioavailability fractions specific for each COPEC.

U.S. EPA Region X guidance for human health risk assessment recommends that arsenic resulting from mining activities be assumed to be 60 percent available through oral ingestion (EPA Region X 2000), although other values may be used for human exposures if site-specific mineralogy or speciation data are available.[2] This value was developed from mammal data for human health. Because data for birds were not available, the bioavailable fraction for mammals was also assumed to be representative of birds.

In a review of bioavailability of various forms of cadmium in mammals, Hrudey et al. (1995) found oral bioavailability to vary from less than 1 to 9 percent. Data for birds were not located, therefore, for the purposes of this assessment, bioavailability of cadmium to both birds and mammals was assumed to be 9 percent.

In mammals, oral absorption of copper decreases as intake increases (Hrudey et al. 1995). The highest rates of copper absorption (71 percent) were observed when copper deficiency in the diet was present. Absorption of copper was 20 to 40 percent when present at daily-required levels. Data for birds were not located; for the purposes of this assessment, bioavailability of copper to birds and mammals was assumed to be 40 percent.

Bioavailability studies conducted in Idaho in the Coeur d'Alene Basin (another area affected by mining activities) were available for lead for both birds and mammals. Maddaloni et al. (1998) evaluated lead bioavailability in the Coeur d'Alene Basin by dosing human volunteers with lead-contaminated soil. Fasted individuals absorbed 26.2 percent of ingested lead, but only 2.52 percent was absorbed by individuals who had eaten prior to ingesting lead. For the purposes of this assessment, lead bioavailability for mammals was assumed to be 26.2 percent. Hoffman et al. (2000) fed mallard ducklings diets containing lead-contaminated sediments from the Coeur d'Alene Basin and an equivalent concentration of lead acetate for 6 weeks. Concentrations of lead in blood, liver, and kidney were measured in both sets of birds. Lead concentrations in all three tissues were 2.01 to 2.25 times higher in birds exposed to lead acetate as compared to those exposed to contaminated sediments. This indicates that the bioavailability of lead in sediment is about 50 percent relative to lead acetate. For the purposes of this assessment, lead bioavailability for birds was assumed to be 50 percent.

Bioavailability of inorganic mercury is low, but that for organic mercury (i.e., methylmercury) is high. Owens (1990) reported oral bioavailability of inorganic mercury in mammals to be about 15 percent while that for organic mercury was 95 percent. Bioavailability data for birds were not located. In the environment, inorganic forms of mercury dominate in abiotic media, while organic forms dominate in biota (Wren et al. 1995, Eisler 2000). Therefore, for the purposes of this assessment, mercury in soil, sediment, and water was assumed to be inorganic with bioavailability of 15 percent and all mercury in biota was assumed to be organic with bioavailability of 95 percent. Mercury bioavailability for birds was assumed to be equal to that for mammals.

[2] A value of 80 percent is currently being used in the human health risk assessment for the Site. This value is tentative and may change as site-specific data become available. Therefore, future phases of the ERA may use a value other than 60 percent for the bioavailability to arsenic. The value of 60 percent is consistent with other ERAs conducted in Region IX (e.g., Lava Cap Mine, CH2M HILL 2001).

Finally, Owen (1990) reported the oral bioavailability of barium, selenium, and zinc in mammals to be 10, 60, and 50 percent, respectively. Data for birds were unavailable; therefore, for the purposes of this assessment, bioavailability of barium, selenium, and zinc to birds and mammals was assumed to be 10, 60, and 50 percent, respectively.

3.1.4.2 Tissue-based Exposure

Target-organ-based exposures consist of concentrations of COPECs in tissues of receptor species that are the focus of contaminant toxicity. These concentrations may be measured directly from field-collected birds and/or mammals or they may be modeled using site-specific or literature-derived information. They can then be compared to available literature information for concentrations of chemicals in specific tissues that are associated with adverse effects. This provides another measure of the potential nature and magnitude of effects that birds and mammals may experience at the Site.

Measured Tissue Data

Some egg tissue data for the southwestern willow flycatcher have been collected in the vicinity of the Site (King et al. 2002). Of the eggs collected, only two samples were from within the project study area. The inorganics concentrations in these two samples were considered to be measures of exposure to southwestern willow flycatchers.

Modeled Tissue Data

Literature-based models to estimate tissue concentrations of some metals in the liver and kidneys of small mammals were available (CH2M HILL and URS Corp. 2001). The models are summarized here with supporting information presented in Appendix E.

Previous research has shown that concentrations of chemicals in small mammal tissues may be estimated based on soil concentrations (Sample et al. 1998, Shore 1995). Thus, soil-to-liver and soil-to-kidney bioaccumulation models were developed for small mammals based on literature-derived data. Using an approach comparable to that employed in Sample et al. (1998), co-located soil and small mammal organ concentration data were extracted from published studies. Appendix E, Tables E-1 and E-2 provide a summary of data used for model development. Log-linear regression models were developed for all small mammals combined, and for specific trophic guilds (e.g., insectivores, herbivores, and omnivores). Tables E-3 and E-4 in Appendix E summarize soil-to-kidney and soil-to-liver regression models, respectively.

Significant regression models with r-square values of 0.2 or greater were applied to maximum soil concentrations from the Site to generate estimated concentrations of cadmium, lead, and zinc in tissues of insectivorous and herbivorous small mammals (Table 3-7). For riparian soils, the maximum concentration across all categories (i.e., Gila River, San Pedro River, stable, unstable) was used. Estimates for insectivorous small mammals are assumed to be representative of desert shrews. Estimates for herbivorous small mammals are assumed to be representative of desert cottontails.

3.2 Effects Assessment

The ecological effects assessment consists of an evaluation of available toxicity or other effects information that can be used to relate the exposures to COPECs and adverse effects in ecological receptors. Data that can be used include literature-derived or site-specific single-chemical toxicity data, site-specific ambient-media toxicity tests, and site-specific field surveys (Suter et al. 2000). For the Site, single-chemical toxicity data from literature sources were the primary effects data. Limited information from ecological studies within the area was also available (Sections 2.6.3.1 and 2.6.3.2).

3.2.1 Aquatic Plants, Water-column Invertebrates, Amphibians and Fish

3.2.1.1 Media-based Effects Data

Aquatic toxicity values for aquatic plants, water-column invertebrates, amphibians, and fish were derived from the Arizona State Water Quality Standards (ASWQS; ADEQ 2007), National Ambient Water Quality Criteria (NAWQC) document (EPA 2006), and the ORNL aquatic organism benchmarks (Suter and Tsao 1996) that complement the promulgated ASWQS and NAWQC. The ORNL benchmarks include acute and chronic Tier II values and lowest chronic values (LCV) for aquatic organisms (e.g., fish, daphnids, non-daphnid invertebrates, aquatic plants, and all species). For the purposes of this SLERA, chronic TRVs were selected because the Gila and San Pedro rivers may contain water year-round. However, it should be noted that these rivers seasonally dry up during some low-precipitation years.

For screening purposes, the lower of either the ASWQS or NAWQC were selected. For analytes lacking ASWQS or NAWQC, the lowest chronic ORNL benchmark was selected as possible. These screening values for aquatic organisms are presented in Table 3-8.

3.2.1.2 Site-specific Field Surveys

As described in Section 2.6.3.1, field studies on fish abundance and diversity have been conducted within the vicinity of the Site. These data were applied, as possible, to the refined screening-level risk characterization.

3.2.2 Benthic Invertebrates

3.2.2.1 Media-based Effects Data

Currently, there are no EPA criteria for sediment. In general, it is difficult to predict sediment concentrations at which toxicity occurs because the type and form of the sediment and the water chemistry of the overlying water affect bioavailability. However, sediment guidelines have been derived based on the relationship between the contaminant concentration in bulk sediment, the contaminant concentration in pore water, and measured biological effects (e.g., Ingersoll et al. 1996, Long and Morgan 1989, Long et al. 1995, Persaud et al. 1993). These sediment guidelines provide an initial benchmark for predicting the potential for adverse effects due to elevated COPEC concentrations in sediment.

The freshwater sediment benchmarks were represented by the Threshold Effects Concentrations (TEC) and Probable Effects Concentrations (PEC) from MacDonald et al. (2000) as available. When TEC and PEC values were lacking, available effects range low (ER-L) and effects range median (ER-M) values were used. In the absence of either of these types of benchmarks, other sediment quality guidelines were selected. The screening benchmarks for benthic invertebrates are shown in Table 3-9.

3.2.3 Terrestrial Plants, Soil Invertebrates, and Soil Microbial Processes

3.2.3.1 Media-based Effects Data

Single-chemical screening-level toxicity values for terrestrial plants and soil invertebrates have been developed for a limited number of analytes as part of the EPA EcoSSLs (EPA 2005). For analytes lacking EcoSSLs, additional data for terrestrial plants, soil invertebrates, and soil microbial processes were obtained from the ORNL benchmark reports (Efroymson et al. 1997a, b). In cases when neither EPA nor ORNL screening values were available, other literature sources were utilized as possible.

Soil screening values for terrestrial plants, soil invertebrates, and soil microbes are outlined in Table 3-10. Terrestrial plants were also screened against benchmarks for exposure to groundwater at the Site. These benchmarks are represented by the soil solution screening levels developed in Efroymson et al. (1997a) and are presented in Table 3-11.

3.2.3.2 Site-specific Field Surveys

As summarized in Section 2.6.3.2, terrestrial plants were evaluated in the ecological investigation conducted in April 2006 at the Site. These data were limited in nature and are primarily represented by qualitative descriptions of the vegetation present at the Site. The information collected at each survey location is presented in Appendix B. These qualitative assessments were applied to the refined screening-level risk characterization as possible.

3.2.4 Birds and Mammals

3.2.4.1 Oral Toxicity Data

Single-chemical toxicity data for birds and mammals consist of NOAEL and LOAEL TRVs. The NOAELs were used in the initial screening evaluation, and LOAELs were used in the refined screening for population-level receptors. Southwestern willow flycatchers (a special-status species) were evaluated using NOAELs in both the initial and refined screening assessments. Appropriate toxicity studies were selected based on several criteria:

- Studies were of chronic exposures or exposures during a critical stage of life (e.g., reproduction).
- Exposure was oral through food to ensure data were representative of oral exposures expected for wildlife in the field.
- Emphasis was placed on studies of reproductive impacts to ensure relevancy to population-level effects.
- Studies presented adequate information to evaluate and determine the magnitude of exposure and effects (or no-effects concentrations).

Specifically, toxicity studies were selected to serve as the TRV if exposure was chronic or during reproduction (a critical lifestage), the dosing regime was sufficient to identify both an NOAEL and an LOAEL, and the study considered ecologically relevant effects (e.g., growth, reproduction, or survival). If multiple studies for a given COPEC meet these criteria, the study generating the lowest reliable toxicity value was selected to be the TRV. The bird and mammal TRVs are presented in Table 3-12.

3.2.4.2 Tissue-based Effects Data

Tissue-based effects levels for birds (eggs) and mammals (kidney and liver) were extracted from published literature, and are summarized in Tables 3-13 and 3-14, respectively.

3.2.4.3 Site-specific Field Surveys

As described in Section 2.6.3.1, field studies for the southwestern willow flycatcher have been conducted within the vicinity of the Site. Although these data are limited in their use, they were applied to the refined screening-level risk characterization to the extent possible.

SECTION 4

Screening-level Risk Characterization

In the risk characterization, exposure and effects data are integrated to draw conclusions concerning the presence, nature, and magnitude of effects that may exist at the Site. This section outlines the process by which exposure and effects data were integrated to estimate risk in the screening-level risk characterization and presents the results of the initial screening assessments. The methods and results for the refined screening assessment are presented in Section 5, and the uncertainties associated with the screening-level and refined screening-level ERAs are outlined in Section 6.

Risks at the Site were evaluated based on the ratio of exposure concentrations or doses to TRVs, resulting in HQs, and are described by the following equation:

$$HQ = C/TRV_{SL} \text{ or } ED/TRV_{NOAEL}$$

where:

HQ	=	Ecological hazard quotient (unitless)
C	=	media concentration (µg/L for water and mg/kg for sediment/soil)
ED	=	Estimated chemical intake (dose) by wildlife receptor (mg/kg-day)
TRV_{SL}	=	Screening-level (SL) Toxicity Reference Value (µg/L or mg/kg)
TRV_{NOAEL}	=	NOAEL-based Toxicity Reference Value (mg/kg-day)

SL-based or NOAEL HQ values less than 1.0 indicate that adverse effects associated with exposure to a given analyte are unlikely (EPA 1997). These analytes were not considered to present unacceptable risk and were excluded from further evaluation. When the estimated exposure for any COPEC exceeds the TRV_{SL} or TRV_{NOAEL}, an HQ greater than 1.0 is obtained. An HQ equal to or greater than 1.0 indicates data are insufficient to exclude the potential for risk, but does not indicate that risks are actually present. COPECs with HQs equal to or greater than 1.0 were retained for a more detailed evaluation in the refinement stage of the SLERA. COPECS for which appropriate toxicity data were unavailable or for which detection limits were insufficient were not further evaluated, but were retained as uncertainties.

The outcome of the initial screening is a list of COPECs for each media-receptor combination that were: (a) determined to present no unacceptable risk, (b) retained for further evaluation in the refined screen, or (c) retained as an uncertainty.

4.1 Freshwater Aquatic Organisms

Maximum concentrations of COPECs in water were compared to the warm water aquatic and wildlife criteria available from the ADEQ (2007), or the criteria continuous concentration from EPA (2006), or the Tier II Secondary Chronic Value (SCV) from Suter and Tsao (1996). Benchmarks were selected by hierarchy, in which the ADEQ criteria were used first for comparison. If the ADEQ criterion value was not equal to or less than the corresponding EPA criterion, then the EPA criterion value was selected. In the absence of ADEQ and EPA criteria, the Suter and Tsao benchmarks were selected for comparison. Six analytes (bicarbonate alkalinity, carbonate alkalinity, hydroxide alkalinity, total alkalinity, total organic carbon, and total suspended solids) were not screened as they were considered to represent general water quality characteristics and not toxic contaminants. Calculated HQ values for all other comparisons are presented in Table 4-1.

4.1.1 Middle Gila River

Concentrations of all metals and other inorganics, except ammonia as N, dissolved antimony, dissolved arsenic, dissolved chromium, magnesium, molybdenum, dissolved nickel, potassium, sodium, dissolved thallium, and dissolved zinc exceeded their respective lowest chronic screening benchmarks. HQ values for exceedances ranged from 1.0 for selenium to 713 for aluminum.

Results of the water screening evaluation are as follows:

- Ammonia as N, dissolved antimony, dissolved arsenic, dissolved chromium, magnesium, molybdenum, dissolved nickel, potassium, sodium, dissolved thallium, and dissolved zinc had HQs less than one. Therefore, these COPECs do not pose an unacceptable risk to aquatic plants, water-column invertebrates, amphibians and fish in the Middle Gila River portion of the Site and were dropped from further consideration.
- Although the maximum non-detected value for silver exceeded the screening benchmark, the maximum detected value did not. Therefore, silver was retained for further evaluation, though risk due to exposure for this COPEC was considered unlikely.
- Aluminum, barium, beryllium, boron, dissolved cadmium, calcium, cobalt, dissolved copper, cyanide, iron, dissolved lead, manganese, dissolved mercury, selenium, silver, vanadium, and TDS had HQs greater than one. Therefore, these COPECs were retained for further evaluation in the refined screening evaluation.

4.1.2 San Pedro River

Aluminum, barium, beryllium, boron, calcium, cyanide, iron, manganese, dissolved mercury, vanadium, and TDS concentrations exceeded their respective lowest chronic screening benchmarks. The calculated HQ values for exceedances ranged from 1.1 for vanadium to 141 for boron.

Results of the water screening evaluation are as follows:

- Ammonia as N, dissolved antimony, dissolved arsenic, dissolved cadmium, dissolved chromium, cobalt, dissolved copper, dissolved lead, magnesium, molybdenum, dissolved nickel, potassium, selenium, silver, sodium, dissolved thallium, and dissolved zinc had HQs less than one. Therefore, these COPECs do not pose an unacceptable risk to aquatic plants and invertebrates, amphibians, and fish at the San Pedro River portion of the Site and were dropped from further consideration.

- Cyanide and dissolved mercury were not detected in any of the water samples based on the maximum detection limit, but had HQs greater than one. These COPECs were retained for further evaluation, but risk from exposure to these COPECs was considered unlikely.
- Aluminum, barium, beryllium, boron, calcium, iron, manganese, vanadium, and TDS had HQs greater than one. Therefore, these COPECs were retained for further evaluation in the refined screening evaluation.

4.2 Benthic Invertebrates

The maximum concentration of each COPEC in sediment was compared to the corresponding TEC (MacDonald et al. 2000), ER-L (Ingersoll et al. 1996 or Long et al. 1995), SQG (Texas Commission on Environmental Quality 1996 or EPA 1977), SBA (Persaud et al. 1993), or benchmark value from NIWQP (1998). TECs were selected first as the benchmark for the corresponding analyte. If a TEC was not available for the corresponding analyte, an ER-L was selected. If neither of these benchmarks was available, the most appropriate benchmark, previously listed, was used for comparison. COPECs that exceeded the benchmark failed the screening and were retained for evaluation in the refined screen. Calculated HQs are presented in Table 4-2.

It should be noted that calcium, magnesium, and potassium are considered macronutrients and are not likely to pose a risk to benthic invertebrates. Sodium is also considered a macronutrient, although high levels of this element could preclude survival of certain freshwater species. Consequently, with no screening values, these analytes were dropped from further consideration. In addition, sediment screening values were not available for beryllium, boron, cobalt, molybdenum, strontium, thallium, and vanadium. These COPECs were retained as uncertainties for both the Middle Gila and San Pedro River areas.

4.2.1 Middle Gila River

Maximum concentrations of aluminum, antimony, copper, cyanide, manganese, nickel, selenium, silver, and p,p'-DDE exceeded their respective TEC or similar benchmark. The remaining analytes had HQ values less than one.

The results of the screening evaluation indicated:

- Antimony, arsenic, barium, chromium, iron, lead, mercury, selenium, and zinc had HQs less than one; therefore, these COPECs in sediment do not pose an unacceptable risk to benthic invertebrates and were dropped from further consideration.
- While cyanide and p,p'-DDE were not detected in any of the samples, the HQ values were greater than one based on the maximum detection limits. Additionally, the maximum detection limits for cadmium and silver exceeded screening benchmarks; therefore, these COPECs were retained for further evaluation though risks were considered unlikely.
- Aluminum, copper, manganese, and nickel had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.2.2 San Pedro River

Aluminum, copper, cyanide, manganese, and p,p′-DDE exceeded their respective TEC or similar benchmark. The remaining analytes had HQ values less than one.

The results of the screening evaluation indicated:

- Antimony, arsenic, barium, cadmium, chromium, iron, lead, mercury, nickel, selenium, silver, and zinc had HQs less than one; therefore, these COPECs in sediment do not pose an unacceptable risk to benthic invertebrates and were dropped from further consideration.
- Cyanide and p,p′-DDE were not detected in any of the samples, but, the HQ values were greater than one; therefore, these COPECs were retained for further evaluation.
- Aluminum, copper, and manganese had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.3 Terrestrial Plants

Maximum concentrations of COPECs in soil were compared to either plant EcoSSLs (EPA 2007a) or, if a plant EcoSSL was not available, plant soil screening benchmarks (Efroymson et al. 1997a) (Table 4-3). In addition, maximum concentrations of COPECs in groundwater near the Gila River were compared to plant soil solution screening benchmarks (Efroymson et al. 1997a) (Table 4-4). COPECs that exceeded benchmark values were retained for further analysis in the refined assessment.

No soil screening values were available for calcium, magnesium, potassium, and sodium. These analytes are considered macronutrients and are not expected to adversely affect terrestrial plants, although high levels of sodium may preclude growth of some plant species and enable growth of some salt-tolerant (or estuarine) plant species. Accordingly, these COPECs were dropped from further consideration. Furthermore, soil screening values for cyanide were not available and this analyte was retained as an uncertainty.

4.3.1 Riparian Soils

4.3.1.1 Middle Gila River—Combined Stable and Unstable Riparian Soil

As stated in Section 3.1.3, concentrations of 19 analytes and two soil attributes in stable and unstable riparian soils did not differ. The results for the stable and unstable riparian soils for these analytes were combined for the risk evaluation. Eight COPECs exceeded screening levels, one were retained as uncertainties, and the remaining COPECs had HQ values less than one.

Results of the screening evaluation for terrestrial plants include:

- Antimony, arsenic, beryllium, cadmium, lead, mercury, and silver had HQs less than one. Therefore, these analytes do not pose a risk to the terrestrial plant community along the Gila River portion of the Site and were dropped from further consideration.
- Cyanide was retained as an uncertainty due to the lack of phytotoxicity data.

- Although selenium and thallium were never detected in any sample, detection limits exceeded the plant screening values so they were retained for further evaluation.
- Boron, chromium, copper, molybdenum, vanadium, and zinc exceeded the corresponding plant screening benchmarks and were retained for further evaluation in the refined screening evaluation.

4.3.1.2 Middle Gila River—Stable Riparian Soil

Two of six COPECs with concentrations that differed between stable and unstable riparian soils had concentrations that exceeded screening levels and four analytes had HQ values less than one.

Results of the screening evaluation for terrestrial plants include:

- Aluminum, barium, cobalt, and nickel had HQs less than one. Therefore, these analytes do not pose a risk to the terrestrial plant community in this area and were dropped from further consideration.
- Iron and manganese had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.3.1.3 Middle Gila River—Unstable Riparian Soil

Three of six COPECs evaluated exceeded screening levels and three analytes had HQ values less than one.

Results of the screening evaluation for terrestrial plants include:

- Aluminum, barium, and nickel had HQs less than one. Therefore, these analytes do not pose a risk to the terrestrial plant community in this area and were dropped from further consideration.
- Cobalt, iron, and manganese had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.3.1.4 San Pedro River—Combined Stable and Unstable Riparian Soil

The COPECs at the San Pedro River portion of the Site – Combined Stable and Unstable Riparian Soil have different EPCs than the Middle Gila River portion, resulting in different HQ values; however, the results of the screening evaluations are the same as those for the Middle Gila River – Combined Stable and Unstable Riparian Soil (Section 4.3.1.1).

4.3.1.5 San Pedro River—Stable Riparian Soil

Iron exceeded the screening level, and the remaining five analytes had HQ values less than one.

Results of the screening evaluation for terrestrial plants include:

- Aluminum, barium, cobalt, manganese, and nickel had HQs less than one. Therefore, these analytes do not pose a risk to the terrestrial plant community along the San Pedro River portion of the Site and were dropped from further consideration.

- Iron had a HQ greater than one and was retained for further evaluation in the refined screening evaluation.

4.3.1.6 San Pedro River—Unstable Riparian Soil

Iron and manganese exceeded the screening levels, and the remaining four analytes had HQ values less than one.

Results of the screening evaluation for terrestrial plants include:

- Aluminum, barium, cobalt, and nickel had HQs less than one. Therefore, these analytes do not pose a risk to the terrestrial plant community in this area and were dropped from further consideration.
- Iron and manganese had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.3.2 Upland Soils

Seventeen analytes exceeded screening levels, cyanide was retained as and uncertainty, and four COPECs had HQ values less than one.

Results of the screening evaluation for terrestrial plants include:

- Aluminum, barium, beryllium, and silver had HQs less than one. Therefore, these analytes do not pose a risk to the terrestrial plant community in the upland portions of the Site and were dropped from further consideration.
- Cyanide was retained as an uncertainty due to the lack of phytotoxicity data.
- Although thallium was never detected in any sample, the detection limit exceeded the plant screening values, so it was retained for further evaluation.
- Antimony, arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium, and zinc had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.3.3 Wash Soils

Sixteen COPECs exceeded screening levels, cyanide was retained as and uncertainty, and five analytes had HQ values less than one.

Results of the screening evaluation for terrestrial plants include:

- Aluminum, barium, beryllium, cadmium, and silver had HQs less than one. Therefore, these analytes do not pose a risk to the terrestrial plant community in the wash areas of the Site and were dropped from further consideration.
- Cyanide was retained as an uncertainty due to the lack of phytotoxicity data.
- Similar to the Upland soil HQ result evaluations, thallium was retained as for further evaluation due to insufficient detection limits.

- Antimony, arsenic, boron, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium, and zinc had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.3.4 Groundwater Near Gila River

Two analytes, arsenic and manganese, exceeded their respective benchmarks (Table 4-4). The remaining analytes had HQ values less than one or did not have available screening values.

Results of the screening evaluation for terrestrial plants include:

- Aluminum, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc had HQs less than one. Therefore, these analytes do not pose a risk to the terrestrial plant community along the Gila River portions of the Site and were dropped from further consideration.
- Antimony, barium, and cyanide did not have plant screening values and were retained as uncertainties.
- Arsenic and manganese had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.4 Soil Invertebrates

Maximum concentrations of COPECs in soil were compared to either invertebrate EcoSSLs (EPA 2007a) or, if an invertebrate EcoSSL was not available, invertebrate soil screening benchmarks (Efoymson et al. 1997a) (Table 4-3). COPECs that exceeded these screening or benchmark values were retained for further analysis in the refined assessment.

As with plants, no soil screening values were available for calcium, magnesium, potassium, and sodium. These analytes are considered macronutrients, and are not expected to adversely affect soil invertebrates, although high levels of sodium may preclude survival of some soil invertebrate species. Accordingly, these COPECs were dropped from further consideration. Soil invertebrate screening values were not available for boron, cobalt, cyanide, iron, molybdenum, silver, thallium, and vanadium, so these analytes were retained as uncertainties.

4.4.1 Riparian Soils

4.4.1.1 Middle Gila River—Combined Stable and Unstable Riparian Soil

Four COPECs exceeded benchmark values. The remaining six analytes with screening values had HQs less than one.

Results of the screening evaluation for invertebrates include:

- Antimony, arsenic, beryllium, cadmium, lead, and selenium had HQs less than one. Therefore, these analytes do not pose a risk to the soil invertebrate community in this area and were dropped from further consideration.

- Although the maximum non-detected concentration for mercury exceeded the screening benchmark, the maximum detected value did not. Therefore, mercury was retained for further evaluation, though risk due to exposure from this COPEC was considered unlikely.
- Chromium, copper, and zinc had HQs greater than one, and were retained for further evaluation in the refined screening evaluation.

4.4.1.2 Middle Gila River—Stable Riparian Soil

Manganese exceeded the benchmark value. The remaining three analytes with screening values had HQs less than one.

Results of the screening evaluation for invertebrates include:

- Aluminum, barium, and nickel had HQs less than one. Therefore, these analytes do not pose a risk to the soil invertebrate community in this area and were dropped from further consideration.
- Manganese had a HQ greater than one, and was retained for further evaluation in the refined screening evaluation.

4.4.1.3 Middle Gila River—Unstable Riparian Soil

While the concentrations of COPECs in stable riparian soil and unstable riparian soil are different, resulting in different HQ values (Table 4-3), the results of the screening evaluations for the unstable riparian soil are identical to the stable riparian soil (Section 4.4.1.2).

4.4.1.4 San Pedro River—Combined Stable and Unstable Riparian Soil

Three analytes exceeded benchmark values. The remaining seven analytes with screening values had HQs less than one.

Results of the screening evaluation for invertebrates include:

- Antimony, arsenic, beryllium, cadmium, lead, selenium, and zinc had HQs less than one. Therefore, these analytes do not pose a risk to the soil invertebrate community in this area and were dropped from further consideration.
- Although the maximum non-detected concentration for mercury exceeded the screening benchmarks, the maximum detected value did not. Mercury was retained as an uncertainty, though risk due to exposure from this COPEC was considered unlikely.
- Chromium and copper had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.4.1.5 San Pedro River—Stable Riparian Soil

No COPECs exceeded the corresponding benchmark values. All four analytes with screening values had HQs less than one.

Results of the screening evaluation for invertebrates include:

- Aluminum, barium, manganese, and nickel had HQs less than one. Therefore, these analytes do not pose a risk to the soil invertebrate community in this area and were dropped from further consideration.
- No analytes were retained for further evaluation in the refined screening evaluation.

4.4.1.6 San Pedro River—Unstable Riparian Soil

Manganese exceeded the benchmark value. The remaining three analytes with screening values had HQs less than one.

Results of the screening evaluation for invertebrates include:

- Aluminum, barium, and nickel had HQs less than one. Therefore, these analytes do not pose a risk to the soil invertebrate community in this area and were dropped from further consideration.
- Manganese had a HQ greater than one, and was retained for further evaluation in the refined screening evaluation.

4.4.2 Upland Soils

Seven COPECs exceeded the benchmark values, and eight analytes had HQs less than one.

Results of the screening evaluation for invertebrates include:

- Aluminum, antimony, barium, beryllium, cadmium, lead, nickel, and selenium had HQs less than one. Therefore, these analytes do not pose a risk to the soil invertebrate community in the upland portions of the Site and were dropped from further consideration.
- Arsenic, chromium, copper, manganese, mercury, and zinc had a HQ greater than one, and were retained for further evaluation in the refined screening evaluation.

4.4.3 Wash Soils

The HQ screening evaluations for the Wash Soils are identical to the Upland Soils with the exception of nickel being retained for the refined screening for the Upland Soils and being dropped from further consideration for the Wash Soils.

Results of the screening evaluation for invertebrates include:

- Aluminum, antimony, barium, beryllium, cadmium, lead, nickel, and selenium had HQs less than one. Therefore, these analytes do not pose a risk to the soil invertebrate community in the wash areas of the Site and were dropped from further consideration.
- Arsenic, chromium, copper, manganese, mercury, and zinc had a HQ greater than one, and were retained for further evaluation in the refined screening evaluation.

4.5 Soil Microbes

Maximum concentrations of COPECs in soil were compared to soil microbes screening benchmarks (Efoymson et al. 1997a) (Table 4-3). COPECs that exceeded these benchmark values failed the screening and were retained for further analysis in the refined assessment.

As with plants and invertebrates, no soil screening values were available for macronutrients calcium, magnesium, potassium, and sodium. These analytes are not expected to adversely affect soil microbes and were dropped from further consideration. In addition, screening values were not available for antimony, beryllium, cyanide, and thallium, so they were retained as uncertainties.

4.5.1 Riparian Soils

4.5.1.1 Middle Gila River—Combined Stable and Unstable Riparian Soil

Five COPECs exceeded benchmark values. The remaining seven analytes with screening values had HQs less than one.

Results of the screening evaluation for soil microbes include:

- Arsenic, cadmium, lead, mercury, molybdenum, selenium, and silver had HQs less than one. Therefore, these analytes do not pose a risk to the soil microbial community in this area and were dropped from further consideration.
- Boron, chromium, copper, vanadium, and zinc had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.5.1.2 Middle Gila River—Stable Riparian Soil

Iron and manganese exceeded benchmark values, and the remaining four analytes with screening values had HQs less than one.

Results of the screening evaluation for invertebrates include:

- Aluminum, barium, cobalt, and nickel had HQs less than one. Therefore, these analytes do not pose a risk to the soil microbial community in this area and were dropped from further consideration.
- Iron and manganese had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.5.1.3 Middle Gila River—Unstable Riparian Soil

The concentrations of COPECs in stable and unstable riparian soils are different, resulting in different HQ values. However, the results of the screening evaluations for the unstable riparian soil are the same as for stable riparian soil (Section 4.5.1.2).

4.5.1.4 San Pedro River—Combined Stable and Unstable Riparian Soil

Three COPECs exceeded benchmark values. The remaining nine analytes with screening values had HQs less than one.

Results of the screening evaluation for soil microbes include:

- Arsenic, boron, cadmium, lead, mercury, molybdenum, selenium, silver, and zinc had HQs less than one. Therefore, these analytes do not pose a risk to the soil microbial community in this area and were dropped from further consideration.
- Chromium, copper, and vanadium had HQs greater than one and were retained for further evaluation in the refined screening evaluation.

4.5.1.5 San Pedro River—Stable Riparian Soil

The EPCs and HQs for this portion of the Site are different from those for the Middle Gila River portion, but the resulting evaluations produced are identical to those presented in Section 4.5.1.2.

4.5.1.6 San Pedro River—Unstable Riparian Soil

Similar to the Middle Gila River portion of the Site, the HQ values for the stable riparian soil and the unstable riparian soil along the San Pedro River produced identical screening results. Therefore, the unstable riparian soil results are the same as those presented for the Middle Gila River – Stable Riparian Soil (Section 4.5.1.2).

4.5.2 Upland Soils

Nine COPECs exceeded benchmark values, and the remaining nine analytes had HQs less than one.

Results of the screening evaluation for soil microbes include:

- Aluminum, barium, boron, cobalt, lead, mercury, nickel, selenium, and silver had HQs less than one. Therefore, these analytes do not pose a risk to the soil microbial community in the upland portions of the Site and were dropped from further consideration.
- Arsenic, cadmium, chromium, copper, iron, manganese, molybdenum, vanadium, and zinc had HQs greater than one, and were retained for further evaluation in the refined screening evaluation.

4.5.3 Wash Soils

Six COPECs exceeded benchmark values, and the remaining 12 analytes had HQs less than one.

Results of the screening evaluation for soil microbes include:

- Aluminum, arsenic, barium, boron, cadmium, cobalt, lead, mercury, molybdenum, nickel, selenium, and silver had HQs less than one. Therefore, these analytes do not pose a risk to the soil microbial community in the wash areas of the Site and were dropped from further consideration.
- Chromium, copper, iron, manganese, vanadium, and zinc had HQs greater than one, and were retained for further evaluation in the refined screening evaluation.

4.6 Birds and Mammals

4.6.1 Aquatic Birds and Mammals

In the initial screening evaluation, exposure estimates based on maximum surface water and sediment concentrations were compared to NOAELs. Exceedance of the NOAEL indicated a failure to pass the screening evaluation and these COPEC-receptor combinations were retained for evaluation in the refined screening. It should be noted that avian and mammalian screening values were not available for calcium, magnesium, potassium, and sodium. Because these are considered naturally occurring essential macronutrients, adverse effects to bird and mammal populations from these analytes are not expected, and they were therefore dropped from further consideration. In addition, there were no avian screening values for antimony, beryllium, and cyanide, which were retained as uncertainties. The initial screening results for aquatic birds and mammals are presented in Tables 4-5 through 4-8 and described below by aquatic ecological receptor.

Surface water and sediment data were available for the Gila and San Pedro rivers. Several analytes failed the screening evaluation for one or more bird or mammal receptors at both the Middle Gila River and San Pedro River portions of the Site; however, aluminum was retained for all receptors in both areas. The COPECs retained for analysis in the refined risk characterization are presented below. Note that analytes retained for both areas are in bold, while analytes retained for only the Middle Gila River are not in bold text.

- Swallow—**aluminum, cadmium, copper, iron, lead, manganese,** mercury**, silver, thallium,** vanadium, **zinc,** and **p,p′-DDE.**
- Belted Kingfisher—**aluminum, cadmium,** iron, lead, **mercury, selenium,** and zinc.
- Little Brown Bat—**aluminum, antimony, arsenic, beryllium, copper, cyanide, iron, lead, manganese, mercury, molybdenum,** selenium, silver, and **vanadium.**
- Mink—**aluminum,** cadmium, **iron, mercury,** and selenium.

4.6.2 Terrestrial Birds and Mammals

Terrestrial wildlife were evaluated using oral exposure estimates for all species and also for tissue-based exposure estimates for southwestern willow flycatchers, desert cottontails, and desert shrews. The results of the initial screening evaluations for these two types of exposures are presented below.

4.6.2.1 Oral Exposures

As with the aquatic birds and mammals, oral exposure estimates were based on maximum media concentrations (soil and surface water) and were compared to NOAELs. Exceedance of the NOAEL indicated a failure to pass the initial screening evaluation, and these COPEC-receptor combinations were retained for evaluation in the refined screening. Avian and mammalian screening values were not available for the essential macronutrients calcium, magnesium, potassium, and sodium. These analytes are not expected to cause adverse effects to bird and mammal populations, and were dropped from further consideration. Additionally, avian TRVs for antimony, beryllium, and cyanide and mammalian TRVs for cyanide were not available. Therefore, these analytes were retained as uncertainties.

Soil data were available from the riparian areas along both the Gila and San Pedro rivers, the upland areas of the Site, and the three washes near the town of Hayden (Kennecott, San Pedro, and Power House washes). Surface water data were available for the Gila and San Pedro rivers. For the purposes of this assessment, the Gila River surface water data were used with the upland and wash soil data in estimating exposure for terrestrial wildlife receptors. The initial screening results for terrestrial birds and mammals are presented in Tables 4-9 through 4-15, and are summarized below by location and receptor. Several analytes failed the screening evaluation for one or more bird or mammal receptor. The COPECs retained for analysis in the refined risk characterization are outlined below by location and receptor.

Gila River Riparian Soils and Surface Water

- **Mourning Dove**—boron, lead, and thallium for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-9)
- **Curve-billed Thrasher**—cadmium, chromium, copper, lead, mercury, selenium, silver, thallium, and zinc for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-10)
- **Red-tailed Hawk**—lead, thallium, and zinc for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-11)
- **Southwestern Willow Flycatcher**—cadmium, chromium, copper, lead, mercury, molybdenum, selenium, silver, thallium, and zinc for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-12)
- **Desert Cottontail**—arsenic, boron, molybdenum, and vanadium for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-13)
- **Desert Shrew**—antimony, arsenic, cadmium, chromium, copper, cyanide, lead, mercury, molybdenum, selenium, silver, and vanadium for combined stable and unstable soils; aluminum, iron, and nickel in both stable and unstable soils (Table 4-14)
- **Coyote**—molybdenum for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-15)

San Pedro River Riparian Soils and Surface Water

- **Mourning Dove**—lead and thallium for combined stable and unstable soils; iron in stable riparian soils and aluminum and iron in unstable riparian soils (Table 4-9)
- **Curve-billed Thrasher**—cadmium, chromium, copper, lead, mercury, selenium, silver, thallium, and zinc for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-10)
- **Red-tailed Hawk**—lead, thallium, and zinc for combined stable and unstable soils; iron in stable riparian soils and aluminum and iron in unstable riparian soils (Table 4-11)

- **Southwestern Willow Flycatcher**—cadmium, chromium, copper, lead, mercury, selenium, silver, thallium, and zinc for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-12)
- **Desert Cottontail**—molybdenum for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-13)
- **Desert Shrew**—antimony, cadmium, chromium, copper, cyanide, lead, mercury, molybdenum, selenium, silver, and vanadium for combined stable and unstable soils; aluminum, iron, and nickel in both stable and unstable soils (Table 4-14)
- **Coyote**— no analytes retained for combined stable and unstable soils; aluminum and iron in both stable and unstable soils (Table 4-15)

Upland Soils and Gila River Surface Water

- **Mourning Dove**—aluminum, arsenic, cadmium, chromium, copper, iron, lead, molybdenum, selenium, thallium, and zinc (Table 4-9)
- **Curve-billed Thrasher**—aluminum, cadmium, chromium, cobalt, copper, iron, lead, mercury, molybdenum, selenium, silver, thallium, and zinc (Table 4-10)
- **Red-tailed Hawk**—aluminum, cadmium, iron, lead, molybdenum, silver, thallium, and zinc (Table 4-11)
- **Southwestern Willow Flycatcher**—aluminum, cadmium, chromium, cobalt, copper, iron, lead, mercury, molybdenum, selenium, silver, thallium, and zinc (Table 4-12)
- **Desert Cottontail**—aluminum, arsenic, copper, iron, lead, molybdenum, selenium, and vanadium (Table 4-13)
- **Desert Shrew**—aluminum, antimony, arsenic, cadmium, chromium, cobalt, copper, cyanide, iron, lead, mercury, molybdenum, nickel, selenium, silver, vanadium, and zinc (Table 4 -14)
- **Coyote**—aluminum, arsenic, copper, iron, lead, and molybdenum (Table 4-15)

Wash Soils and Gila River Surface Water

- **Mourning Dove**—aluminum, cadmium, chromium, copper, iron, lead, molybdenum, selenium, thallium, and zinc (Table 4-9)
- **Curve-billed Thrasher**—aluminum, cadmium, chromium, cobalt, copper, iron, lead, mercury, molybdenum, selenium, silver, thallium, and zinc (Table 4-10)
- **Red-tailed Hawk**—aluminum, chromium, iron, lead, molybdenum, silver, thallium, and zinc (Table 4-11)
- **Southwestern Willow Flycatcher**—aluminum, cadmium, chromium, cobalt, copper, iron, lead, mercury, molybdenum, nickel, selenium, silver, thallium, and zinc (Table 4 -12)
- **Desert Cottontail**—aluminum, antimony, arsenic, copper, iron, lead, molybdenum, selenium, and vanadium (Table 4-13)

- **Desert Shrew**—aluminum, antimony, arsenic, cadmium, chromium, cobalt, copper, cyanide, iron, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc (Table 4-14)
- **Coyote**—aluminum, copper, iron, and molybdenum (Table 4-15)

4.6.2.2 Tissue-based Exposures

Measured concentrations of metals in southwestern willow flycatcher eggs collected onsite and estimated liver and kidney concentrations for small mammals were available as measures of exposure for southwestern willow flycatchers and for desert cottontails and desert shrews, respectively.

Southwestern Willow Flycatchers

The U.S. Fish and Wildlife Service (USFWS) conducted a cooperative study with the AGFD and the U.S. Geological Survey (USGS) from 1998 to 2000. The study documented concentrations and potential effects of organochlorine compounds and metals in addled eggs and potential prey of the endangered southwestern willow flycatcher (USFWS 2002). Of the six sites evaluated, only one (CB Crossing) was within the ASARCO study area boundaries. The two eggs collected at that site were considered to be "onsite" and were evaluated in this SLERA.

The CB Crossing site was located 1.2 miles upstream of the San Pedro River/Gila River confluence, between the San Pedro River to the west and agricultural fields to the east. The habitat consists of a small patch of mixed exotic and native vegetation and receives periodic irrigation runoff. The eggs were analyzed for aluminum, barium, boron, cadmium, copper, iron, magnesium, manganese, mercury, selenium, strontium, and zinc. Benchmarks for evaluating the effects of egg tissue concentrations to developing birds were available for boron, copper, mercury, nickel, selenium, and zinc. COPECs for which benchmarks were not available were retained as uncertainties.

All metals were detected in both eggs, and these were compared to the literature-based NOECs and LOECs, as available. Benchmarks for evaluating the effects of egg tissue concentrations on developing bird reproduction were available for boron, copper, mercury, nickel, selenium, and zinc (Table 3-13). The results of the screening are presented in Table 4-16, and are summarized as follows:

- Measured concentrations of boron, copper, mercury, nickel, and selenium were below the no effects levels. Therefore, transfer of these metals to the eggs of nesting flycatchers was not considered to be a risk to the developing embryo.
- Zinc in one egg exceeded the NOEC (50 mg/kg dw); therefore, zinc was retained for further evaluation in the refined screening.
- COPECs for which benchmarks were not available were retained as uncertainties.

Small Mammals

Tissue concentrations of cadmium, copper, mercury, and lead in small mammal liver and kidney tissue were estimated using the maximum measured soil concentration in each of the riparian (Gila or San Pedro watersheds), upland, and wash areas (Table 3-7). For the purposes of this assessment, the herbivore models were considered surrogates for desert cottontails and the insectivore models were considered surrogates for desert shrews. Exceptions included the mercury regression for uptake from soil-to-kidney, in which the general model was selected because models for herbivores and insectivores were not available. Additionally, the soil-to-kidney model for insectivores did not have the required minimum r^2 value of 0.2; therefore, only the herbivore model was used. There was not a statistically significant soil-to-liver model for mercury. Consequently, mercury in liver tissue was not evaluated.

The estimated tissue-based exposures were compared to toxicity thresholds presented in Table 3-14. The results of the initial screening are presented in Table 4-17 and are summarized below.

Within the riparian areas of the Site, none of the metals evaluated exceeded threshold values for either kidney or liver tissue. Therefore, these metals are not expected to accumulate to toxic levels in herbivorous (cottontail) and insectivorous (shrew) small mammals utilizing the onsite riparian habitats. However, in the upland and wash areas, accumulation to toxic levels is expected to occur as follows:

- Upland Areas
  - Herbivore (cottontail) – risk from lead in kidney tissue
  - Insectivore (shrew) – likely risk from copper in liver and risk from lead in liver and kidney
- Wash Areas
  - Herbivore (cottontail) – risk from lead in kidney tissue
  - Insectivore (shrew) – likely risk from copper in liver and risk from lead in kidney

4.7 Summary of Screening-level Risk Characterization Results

This section provides a summary of the initial screening evaluation for aquatic and terrestrial receptors.

4.7.1 Aquatic Receptors

Aquatic plants, water-column invertebrates, amphibians, fish, and aquatic birds and mammals were evaluated using surface water and/or sediment collected along the Gila and San Pedro rivers. The initial screening results for these receptors by river are summarized in Table 4-18 and are discussed below.

For each aquatic receptor, at least one COPEC was retained for further evaluation in the refined screening, and only two COPECs in the Gila River and three COPECs in the San Pedro River passed the screening evaluation for every receptor (Table 4-18). Namely, ammonia as N and chromium in both rivers and nickel in the San Pedro River did not present a risk to any aquatic receptor. Aluminum in both rivers was found to present risk to all aquatic receptors. Although benchmark values for cobalt and strontium were not available for some receptors (e.g., benthic invertebrates) and risk was considered uncertain, a finding of no risk for those receptors with benchmarks suggest that these analytes may be at levels that do not present risk to any aquatic receptor in the San Pedro River. Therefore, ammonia as N, chromium, and strontium in both rivers, and cobalt and nickel in the San Pedro River were not evaluated in the refined screening for aquatic receptors.

COPECs that were retained for further analysis in the refined assessment included those for which the maximum detected concentration exceeded the screening criteria (“Retain”, Table 4-18), those for which the maximum non-detected concentration exceeded the maximum detected concentration and both exceeded the screening criteria (“Retain ND/Det”, Table 4-18), and those COPECs that were not detected in any sample or for which the maximum non-detected concentration exceeded screening criteria, but the maximum detected concentration did not (“Retain ND”, Table 4-18).

4.7.2 Terrestrial Receptors

Terrestrial plants, soil invertebrates, soil microbes, and terrestrial birds and mammals were evaluated using surface water and riparian soil (combined stable and unstable, stable, or unstable) collected along the Gila and San Pedro rivers, as well as surface water from the Gila River and upland or wash soil. The initial screening results for these receptors by soil type and watershed are summarized in Table 4-19 and are discussed below.

For each terrestrial receptor, at least one COPEC was retained for further evaluation in the refined screening, and only barium passed the screening evaluation for every receptor and soil category (Table 4-19). Additionally, arsenic in the combined stable and unstable San Pedro River soils passed the screening evaluation for every receptor. Although benchmark values for cobalt were not available for some terrestrial receptors and risk was considered uncertain, a finding of no risk for those receptors with benchmarks suggest that cobalt may be a levels that do not present risk to any aquatic receptor in the Gila River stable soil areas and the San Pedro River stable and unstable soil areas. Similarly, some terrestrial receptors lacked benchmark values for beryllium, but no risk was found for receptors in all soil categories with benchmarks. Therefore, barium and beryllium in all soil categories, arsenic in combined stable and unstable San Pedro River soil, and cobalt in stable Gila River soil and stable and unstable San Pedro River soil were not evaluated in the refined screening for terrestrial receptors.

Iron in all soil categories was found to present risk to all terrestrial receptors with screening benchmarks (no screening criterion was available for terrestrial invertebrates). However, it is unlikely that iron is a key contaminant at the Site because it is often considered a macronutrient and background levels in the area are often greater than the onsite concentrations, particularly for the riparian soils. These issues are discussed further in the refined screening.

COPECs that were retained for further analysis in the refined assessment included those for which the maximum detected concentration exceeded the screening criteria (“Retain”, Table 4-18), and those that were not detected in any sample or for which the maximum non-detected concentration exceeded screening criteria, but the maximum detected concentration did not (“Retain ND”, Table 4-18).

SECTION 5

Refined Screening-level Risk Characterization

In contrast to the conservative approach used for the initial screening-level evaluation (Section 4), the refined evaluation focuses on the more reasonable potential for exposure of target species to COPECs. The reasonable potential for exposure and adverse effects was evaluated through assessment of the available chemical (magnitude of HQ and frequency of detection and exceedance) and biological (habitat quality and bioavailability of the COPEC) information. The refinements are described here as they relate to the Site.

The first step of the refined screening assessment is to screen concentrations of metals and other inorganics against background values (Section 5.1). Because inorganics naturally occur in the environment, comparison of measured Site concentrations to background values is appropriate. The EPA identifies statistical methods for conducting a background screening evaluation (EPA 2001b). Additionally, the EPA ProUCL software (EPA 2007b) can be used to calculate upper tolerance limits (UTLs) from the background data. Inorganics with concentrations that were not significantly different from background or with maximum concentrations that did not exceed the background UTL were not included in the calculation of unacceptable risk. For retained COPECs that exceeded background values, further refinements were performed according to receptor type. These refinements are described below for directly exposed receptors (aquatic plants, water-column invertebrates, amphibians, fish, benthic invertebrates, terrestrial plants, soil invertebrates, and soil microbial processes), and for those receptors evaluated through the oral exposure pathway (birds and mammals).

For directly exposed receptors, point-by-point analyses were performed using the entire distribution of data. The frequency and magnitude of exceedances were evaluated using the point-by-point analyses, and the frequency of detection for each retained COPEC was also considered. For benthic invertebrates, low and high TRVs were available. As a community-level receptor, exceedance of the low TRV, but not the high TRV, does not indicate an unacceptable risk. Therefore, COPECs that did not exceed the high TRV were not considered to pose an unacceptable risk to benthic invertebrate communities.

The frequency of detection of COPECs serves as an indicator of the extent of contamination across the study area. A low frequency of detection may indicate that the contamination is limited to small portions of the Site (hot spots) or even only in a single location where the sample was collected. If the frequency of detection for a COPEC is low, the results of the other qualitative evaluations (i.e., magnitude and frequency of HQ exceedances and habitat quality) were used to determine whether the chemical was considered to pose risk. Likewise, a low frequency of exceedance of the TRVs may indicate that risk is not widespread and may not be unacceptable for population- and community-level receptors. Specifically, if the frequency of exceedance was less than or equal to 20 percent, risks were considered to be acceptable for population- and community-level receptors.

The magnitude of exceedance is considered a general indication of the magnitude of risk, but it is not an exact estimation of risk. For example, other factors may cause the risk due to a chemical with an HQ of 70 to be less than that for a chemical with an HQ of 20. Therefore, the HQ was considered to be a binary measure in which non-exceedance indicates no potential for risk and exceedance indicates a potential for risk. However, if a COPEC has a low HQ, and the other refined evaluations (i.e., frequency of detection, habitat quality) indicate that the potential for exposure to the COPEC is low, then the COPEC may not be considered to pose an unacceptable risk.

Habitat quality was qualitatively evaluated during the RI field investigations (CH2M HILL 2006; Appendix B). Generally, if habitat quality is low, there may be a low potential for exposure to ecological receptors. However, the habitat evaluation for the Site lacked sufficient rigor to quantify habitat quality. It appeared that habitat quality across the project area was moderate to high, with areas of human disturbance (e.g., Gila River and wash areas) having lower quality habitat than more undisturbed areas. Therefore, the other qualitative evaluations (i.e., frequency of detection and frequency of exceedance) were used to determine if COPECs were considered to pose an unacceptable risk.

The results of the refinements described above were evaluated in a weight-of-evidence approach to determine the likelihood of risk to directly exposed receptors. The refined assessments for freshwater aquatic organisms (aquatic plants, water-column invertebrates, amphibians, and fish), benthic invertebrates, terrestrial plants, soil invertebrates, and soil microbial processes are presented in Sections 5.2 through 5.6, respectively.

For birds and mammals, the refinements following the background analysis included the use of the 95 UCL for media concentrations and the use of median BAFs (as indicated in the procedures for the development of the EcoSSLs [EPA 2007a]) in the exposure estimate. As possible, the bioavailability of individual COPECs was also considered in the exposure estimate. Additionally, a diet that more closely matches the actual diet of the receptor was used as applicable. For example, in the initial screening, a diet of 100 percent small mammals was assumed for the coyote. In contrast, a diet of 25 percent plants, 1 percent terrestrial invertebrates, and 74 percent small mammals was used in the refined exposure estimate.

These refined exposure estimates were compared to both NOAELs and LOAELs, except for special-status species for which only comparison to the NOAEL is appropriate, to obtain HQ values. Risk related to these HQs falls within three broad categories:

- NOAEL-based HQs < 1 = no risk to populations or individuals,
- NOAEL-based HQs $\geq$ 1 and LOAEL-based HQs < 1 = acceptable risk to population-level receptors, but potentially unacceptable risk to individual-level receptors, or
- LOAEL-based HQs $\geq$ 1 = potentially unacceptable risk to populations and unacceptable risk to individual-level receptors.

As with the directly exposed receptors, the detection frequency, magnitude of exceedance, and habitat quality were also considered in a weight-of-evidence approach to determine the potential for risk. The refined assessment for the bird and mammal receptors is presented in Section 5.7.

5.1 Background Comparison

Background data were available for sediment and soil. Soil data were collected during the Expanded Site Investigation (ADEQ 2003), the Removal Assessment (Ecology & Environment, Inc. 2004), and the recent RI sampling (CH2M HILL 2006c), and sediment data were collected during the recent RI sampling events. Although some historical background data collected in the vicinity of the Site were available from a literature source (Earth Technology 1991), these data were not used in the background calculations, but were used as a contrast for the data used in the analysis. A detailed evaluation of background inorganic concentrations in soil for the Site was conducted as a separate effort (CH2M HILL 2008). Portions of that background analysis were relevant to the SLERA and are summarized below.

For the background analysis of the sediment data, a rank transformation of all of the data, followed by an analysis of variance (ANOVA) of the rank-transformed data was performed. This approach was required because more than two groups of data were evaluated, but is the equivalent of a Kruskal-Wallis test and is consistent with the Wilcoxon test in EPA guidance (2001b). A Student-Neumann-Kuhls multiple comparison test was performed to identify which groups differed from each other. For soil, the ProUCL version 4.0 software (EPA 2007b) was used to calculate UTLs for background soils associated with different geological formations.

An initial attempt to use the background soil data for comparison to onsite sediment metals concentrations indicated that the soil data were not suitable as background for sediment. As another means to evaluate onsite sediment, the available sediment data were grouped into five categories for statistical comparisons: offsite and upstream Gila River, onsite Gila River, offsite and downstream Gila River, offsite upstream San Pedro River, and onsite San Pedro River. The onsite data in the Middle Gila and San Pedro rivers were evaluated relative to upstream and downstream Gila River and upstream San Pedro River.

The background evaluation for the Site (CH2M HILL 2008) was used to determine which soil background samples were relevant to the ERA dataset. Specifically, the geologic map (Figure 2 in CH2M HILL 2008) in the background evaluation shows that the riparian soil data at the Site primarily fall in the quaternary alluvium (Qal) formation, whereas the upland and wash soil data appear to fall primarily in the tertiary sediment (Ts) or older quaternary deposit (Qo) formations, with some samples (especially in the washes) falling within the Qal formation. Therefore, UTLs were calculated for each geologic formation and were compared to the maximum concentrations in the ERA dataset. Riparian soils (both stable and unstable) were compared only to the Qal formation soils, and upland and wash soils were compared to all three formations. The background data used for the UTL development included:

- The background soil locations indicated in Tables 1 and 2 of the background evaluation report (CH2M HILL 2008) for Ts and Qo soils, respectively.
- All available background data within the Qal formation, including the Kearny dataset.

These background data, as well as the output from ProUCL, are presented in Appendix F.

The results of these background comparisons for sediment and soil are presented in Tables 5-1 and 5-2, respectively.

5.1.1 Sediment

Barium, boron, chromium, cobalt, and strontium measured in the onsite Gila and San Pedro rivers and nickel in the onsite San Pedro River passed the initial screening evaluation (Table 4-18) and were not retained for further evaluation. However, these COPECs were included in the background screening as an additional conservative step in the assessment.

Based on an evaluation of the upstream, onsite, and downstream Gila River sediments and the upstream and onsite San Pedro River sediments, no additional COPECs could be eliminated as being similar to upstream concentrations. However, there appeared to be a trend in the dataset. In many cases (e.g., cadmium, chromium, lead, etc.; Table 5-1), the concentrations upstream and downstream were consistent with or greater than the onsite Gila River concentrations. Additionally, the concentrations in the San Pedro River were often significantly lower than those in the Gila River (e.g., chromium, copper, iron, etc.; Table 5-1). Therefore, the relatively low concentrations onsite may reflect combined onsite and upstream contamination with dilution by cleaner sediment from the San Pedro River.

Cyanide and p,p'-DDE in both rivers and selenium and silver in the San Pedro River failed the initial screening of some receptors. Because these COPECs were not detected in any of the sediment samples, risks from exposure to these analytes were considered unlikely, but further evaluation was performed. Additionally, aluminum, antimony, arsenic, beryllium, cadmium, copper, iron, lead, manganese, mercury, molybdenum, thallium, vanadium, and zinc in both rivers, as well as nickel, selenium, and silver in the in the Gila River, were detected in at least one sediment sample and failed the initial screening evaluation. These COPECs are evaluated in Section 5.3.

5.1.2 Soil

The stable and unstable riparian soils and the upland and wash soil samples were evaluated relative to available background. Data were not sufficient to develop UTLs for aluminum, boron, calcium, cyanide, iron, magnesium, manganese, potassium, and sodium. As previously indicated in Section 4, calcium, magnesium, potassium, and sodium are considered macronutrients and are not expected to adversely affect terrestrial receptors. Therefore, these analytes were not evaluated further in the refined assessment. Additionally, aluminum was excluded from further evaluation for terrestrial receptors because the pH of the soils at the Site (range 6.2 to 8.8) were greater than pH values associated with aluminum toxicity to terrestrial biota (pH less than 5.5, EPA 2003b). The absence of background data for boron, cyanide, iron, and manganese precluded background comparisons for these analytes.

Maximum onsite concentrations of all other metals, except beryllium exceeded background UTLs for at least one category of soil (Table 5-2). For the riparian soils, all analytes with UTLs passed the background comparison, except barium and molybdenum in stable Gila River soils, cobalt in unstable Gila River soils, copper in stable and unstable Gila River soils, and mercury, selenium, and silver in stable and unstable Gila River and San Pedro River soils. For upland and wash soils, all analytes with UTLs, except beryllium in upland soils and barium and beryllium in wash soils had maximum concentrations that exceeded UTLs in at least one of the geologic formations. Therefore, these COPECs were evaluated further in the refinements for terrestrial plants (Section 5.4), soil invertebrates (Section 5.5), soil microbial processes (Section 5.6), and soil-associated birds and mammals (Section 5.7; mourning dove, curve-billed thrasher, red-tailed hawk, southwestern willow flycatcher, desert cottontail, desert shrew, and coyote) if they failed the initial screening for a receptor-soil type combination.

5.2 Freshwater Aquatic Organisms

Two lines of evidence were available for evaluation of freshwater aquatic organisms. These included media-based effects data for aquatic plants, water-column invertebrates, amphibians, and fish, and site-specific field studies for fish. The results of these evaluations are described below.

5.2.1 Media-based Effects Data

COPECs that failed the initial water screening evaluation (Table 4-1) were further analyzed in a point-by-point evaluation (Table 5-3). As with the initial screening, the total or dissolved concentration of a metal was used based on the available benchmark (i.e., dissolved concentrations [filtered samples] were compared to dissolved benchmarks and total concentrations [unfiltered samples] to total benchmarks). This point-by-point screening includes an evaluation of both the detected and non-detected (i.e., detection limit) concentrations, and the results are summarized in Table 5-4. The refined screening results are described below by watershed.

5.2.1.1 Onsite Middle Gila River

Of the 16 retained inorganics and one retained water parameter, dissolved mercury, cyanide, and silver had low detection frequencies (range 5 to 14%). This may suggest that these metals are not widely distributed at the Site. However, detection limits for all three analytes exceeded their respective benchmarks, which may indicate that there were interferences in the laboratory analyses for these analytes. In contrast, the remaining 12 retained analytes had moderate to high detection frequencies (range 50 to 100%), so they may be widely distributed at the Site. Five analytes (aluminum, barium, boron, iron, and manganese, all as unfiltered concentrations) had a high frequency of exceedance suggesting that risk from these analytes is also widely distributed. Calcium, cobalt, copper, cyanide, selenium, and vanadium had a low magnitude of exceedance (HQs of about 5 or less) (Table 5-4).

Results of the refined screening are as follows:

- TDS were measured in all onsite Gila River samples. TDS measures all the major cations and anions present in the water. Although not exactly equivalent to salinity, TDS is nearly equivalent to salinity and the two terms are often used interchangeably (USDI 1998). Of the 22 samples collected on the Gila River, only 1 (5%) had TDS concentrations that exceeded the screening level. Moreover, the magnitude of exceedance was very low (maximum HQ = 1.1). Therefore, risks from elevated TDS are considered minimal.

- Dissolved copper, calcium, cobalt, selenium, and vanadium had low frequencies of exceedance (< 14%) and low magnitudes of exceedance (all HQs < 5); therefore, risk from these COPECs to aquatic plants, water-column invertebrates, amphibians, and fish is expected to be minimal.
- Dissolved lead had a low frequency of exceedance (9%) and a moderate magnitude of exceedance (maximum HQ = 8.4); therefore, risk from dissolved lead, though possible, is not likely to be widespread or significant.
- Silver had a low frequency of detection (14%) and, in some cases, the detection limit exceeded the screening benchmark. The three detected samples did not exceed the screening benchmarks. Because the detection limit for silver was insufficient, the potential for risk is uncertain, but likely to be minimal given the low frequency of exceedance (9%) and magnitude of exceedance (HQs < 1.5) of the detection limits.
- Dissolved cadmium had a low detection frequency (14%), low frequency of exceedance (9%), and a low magnitude of exceedance (HQs < 1.4). Additionally, none of the non-detected samples exceeded the benchmark. Therefore, risk from dissolved cadmium is expected to be minimal.
- Cyanide and dissolved mercury had low detection frequencies (range 5 to 14%) but the detected and non-detected samples had exceedances for both. This indicates that there is a potential for risk from these analytes, although the extent of this risk is uncertain due to insufficient detection limits.
- Beryllium had a high detection frequency (59%) and 3 of 13 detected concentrations, as well as the detection limit, exceeded the screening benchmark. Therefore, risks from beryllium are possible, though the spatial extent of these risks is uncertain.
- The remaining metals (aluminum, barium, boron, iron, and manganese) were detected in all samples, had high frequencies of exceedance (50 to 100%), and had high magnitudes of exceedances (HQs ranged up to 713). Therefore, risk from these COPECs to freshwater aquatic biota is possible.

5.2.1.2 Onsite San Pedro River

Ten metals and one water parameter in San Pedro River surface water were retained for further evaluation. Although these analytes also failed the initial screening for Gila River surface water, COPEC concentrations, and thus risks, were generally lower in the San Pedro River. Dissolved mercury and cyanide were not detected in any samples. In contrast, the remaining eight retained analytes had moderate to high detection frequencies (range 50 to 100%) and high frequencies of exceedance (range 25 to 100%). Therefore, these metals and risks from these metals may be widely distributed at the Site. Beryllium, calcium, manganese, and vanadium had low magnitudes of exceedance (HQs of less than 5) (Table 5-4).

Results of the refined screening are as follows:

- TDS were measured in all onsite San Pedro River samples. TDS in all four samples exceeded the screening benchmark. Although the magnitude of exceedance was low (HQ range 1.3 to 1.4), risks from TDS are possible.

- Beryllium, calcium, manganese, and vanadium had high frequencies of exceedance (25 to 100%). Although the magnitude of exceedance (all HQs < 5) was low, risk from these COPECs to aquatic plants, water-column invertebrates, amphibians, and fish cannot be excluded.
- Iron was detected in 3 of the 4 samples and had a moderate frequency of exceedance (50%) and magnitude of exceedance (maximum HQ = 9); therefore, risk from iron is possible.
- Cyanide and dissolved mercury were not detected in any sample. The detection limit for both of these analytes exceeded the screening benchmark. Therefore, risks for these analytes were uncertain due to insufficient detection limits.
- Aluminum, barium, and boron were detected in all samples, had high frequencies of exceedance (50 to 100%), and had high magnitudes of exceedances (HQs ranged up to 141). Therefore, risk from these COPECs to freshwater aquatic biota is possible.

5.2.2 Site-specific Field Studies

Annual fish monitoring within the vicinity of the Site has been conducted from 1995 through 2006. The reports containing the results of these fish collection efforts were available for every year, except 2000. Each report includes a list of species collected and the number of individuals collected for each species at each sampling location. Eleven stations along the Gila River and eight stations along the San Pedro River were sampled during each season, though sometimes sampling was not possible at certain stations due to a dry streambed or other issues (e.g., delay in obtaining right of access). Two of the sampling stations, one on the Gila River and one on the San Pedro River, were located within the project area. Additionally, there was one station directly upstream of the Site along both the Gila and San Pedro rivers and one station downstream of the Site along the Gila River.

The 1995 to 1999 and 2001 to 2006 fish monitoring results for these three Gila River and two San Pedro River stations are summarized in Table 5-5. For each sampling location, the total number of fish collected, the number of species represented, and the number of native species is presented. The diversity (i.e., number of species) of native and non-native species does not appear to vary appreciably across the five stations, though it does appear that diversity may be declining from 1995 to 2006. Marsh and Kesner (2006) noted this decline in native species and suspect that drought is a possible factor. In fact, none of the five stations could be sampled in 2004 because the streambeds were dry, and the onsite station along the San Pedro River was dry for three consecutive years (2002 to 2004).

The number of fish collected appears to vary greatly by both location and year. In a five-year analysis of the 1995 to 1999 data, Marsh and Kesner (2004) stated that the individual sample sizes (number of fish) are highly variable in time and space, and are often small, even for relatively abundant species. Specifically, the number of species collected at each site and the number of those that are native fish species does not appear to have a pattern of variation among the sampling stations. They report that this finding is consistent with other studies of fish communities in the arid southwest and that this is a recognized confounding factor in analyzing sample data from these areas.

The conclusion from the fish monitoring data is that there does not appear to be a cross-site trend in the dataset, and that the onsite fish communities appear to be similar to those upstream and downstream of the Site. Although there appears to be a general decline in the number of native species at all stations, drought may be a factor in this decline.

5.2.3 Weight-of-Evidence for Aquatic Organisms

For the Gila River, TDS, dissolved cadmium, calcium, dissolved copper, cobalt, lead, selenium, silver, and vanadium had low frequencies of exceedance (< 14%); therefore, risks from these COPECs are spatially limited and are expected to be minimal. Risks from TDS in the San Pedro River are considered possible and may be widespread (i.e., all samples exceeded the screening level). Risks from cyanide and dissolved mercury in both rivers are possible, though the extent of these risks is uncertain due to an insufficient detection limit. In the Gila River, both detected and non-detected concentrations exceeded the screening benchmarks, but all samples from the San Pedro River were non-detects. Aluminum, barium, boron, iron, and manganese in Gila River surface water had high frequencies and magnitudes of exceedance and therefore may pose a risk to the aquatic plant, water-column invertebrate, amphibian, and fish communities in the onsite portion of the Gila River. For the San Pedro River, risks to aquatic organisms from exposure to aluminum, barium, beryllium, boron, calcium, iron, manganese, and vanadium are possible.

Fish monitoring results along the Gila and San Pedro rivers on and near the Site indicate that the number of native species in these rivers has declined from 1995 to 2006. However, this decline may be attributable to drought conditions in the region that have occurred since 2002. Risks from site-related COPECs could not be supported or excluded using this line of evidence.

The weight-of-evidence conclusion for the San Pedro River is that cyanide and dissolved mercury in the San Pedro River may present risks. However, both analytes were retained based solely on detection limit exceedances (i.e., all samples were non-detects); therefore, risks are uncertain. Risk from cyanide and dissolved mercury in the Gila River is possible (i.e., both detected and non-detected concentrations exceeded the screening benchmark), although the extent of this risk is uncertain also due to insufficient detection limits. Aluminum, barium, boron, iron, and manganese in Gila River surface water and aluminum, barium, beryllium, boron, calcium, iron, manganese, TDS, and vanadium in San Pedro River surface water may pose a risk to the aquatic plant, water-column invertebrate, amphibian, and fish communities in these portions of the Site.

5.3 Benthic Invertebrates

Aluminum, copper, cyanide, manganese, and p,p′-DDE in both the Gila and San Pedro rivers and cadmium, nickel, and silver in the Gila River failed the initial screening and were retained for further analysis (Section 4.2, Table 4-2). TRVs were not available for beryllium, boron, cobalt, molybdenum, strontium, thallium, and vanadium. These COPECs were retained as uncertainties, but no further evaluation was performed. None of the COPECs were eliminated from further evaluation based on the results of the background screening for sediment (Section 5.1). Therefore, all COPECs retained from the initial screening were evaluated on a point-by-point basis (Table 5-6).

This step in the refined screening evaluation for benthic invertebrates included comparison to both the low and high TRVs. Because benthic invertebrates are evaluated at the community level, COPECs that exceeded the low TRV, but not the high TRV were not considered to pose unacceptable risk. The refined screening includes an evaluation of both the detected and non-detected concentrations. The results are summarized in Table 5-7, and are described by watershed below.

5.3.1 Onsite Gila River

Of the eight COPECs retained for further evaluation, five were detected in most or all samples, one was detected in only 1 of 22 samples (< 5%), and two were not detected in any samples. Although there were exceedances of the low TRVs among either (or both) detected and non-detected samples for each of these COPECs, only three (copper, cyanide, and manganese) had exceedances of their high TRVs, though the magnitude of the exceedances for copper and manganese were low (all HQs < 3). The results of the refined screening evaluation are as follows:

- Aluminum, cadmium, nickel, silver, and p,p′-DDE had high TRV-based HQs less than one. Therefore, these COPECs were not considered to pose a risk to the benthic invertebrate community in the Gila River portion of the Site.
- Cyanide was not detected in any of the 22 samples; however, the detection limit exceeded the screening benchmark (HQ range = 10 to 28). Therefore, risk from cyanide is uncertain due to an insufficient detection limit.
- Although copper and manganese were detected in all samples, there was a low frequency of exceedance of the high TRV (17 and 8%, respectively) and the magnitude of the exceedances was low (maximum HQs = 2.6). Therefore, risk from these COPECs to benthic invertebrates is believed to be minimal.

5.3.2 Onsite San Pedro River

Five COPECs were retained for further evaluation of San Pedro River sediments. Cyanide and p,p′-DDE were not detected in any sample. Aluminum, copper, and manganese were detected in all samples. None of the detected samples exceeded the high TRVs, and only the detection limit for cyanide exceeded its high TRV (HQ range = 11 to 13). Therefore, risks from cyanide are uncertain.

5.3.3 Weight-of-Evidence for Benthic Invertebrates

Risks from cyanide in both the Gila and San Pedro rivers are uncertain due to an insufficient detection limit. Although risk from copper and manganese in sediment from the onsite portion of the Gila River cannot be excluded, risks from these COPECs are low (low frequency and magnitude) and may be acceptable.

5.4 Terrestrial Plants

Two lines of evidence were available for evaluation of terrestrial plants. These included media-based effects data for terrestrial plants and site-specific field studies of the upland

and riparian habitats within the study area. The results of these evaluations are described below.

5.4.1 Media-based Effects Data

The refined assessment for terrestrial plant communities using media-based effects data is presented by matrix type below.

5.4.1.1 Riparian Soils

Boron, chromium, copper, molybdenum, selenium, thallium, vanadium, and zinc in combined stable and unstable soils in both Gila River and San Pedro River areas failed the initial screening for terrestrial plants in Section 4.3 (Table 4-3). Additionally, iron and manganese in stable and cobalt, iron, and manganese in unstable riparian Gila River soils failed the screen as did iron in stable riparian and unstable riparian and manganese in unstable riparian San Pedro River.

After the background screening, boron, copper, molybdenum, and selenium in combined soils of the Gila River and boron and selenium in combined soils of the San Pedro River were retained for further evaluation. Additionally, maximum concentrations of cobalt in unstable soils of the Gila River, iron in unstable and stable soils of both rivers, and manganese in stable and unstable soils of the Gila River and unstable soils of the San Pedro River were greater than background. These COPECs were evaluated in the refined screening using a point-by-point analysis (Table 5-8). The refined screening results are presented for detected and non-detected concentrations in Table 5-9 and described here by watershed.

Onsite Gila River

Selenium in combined stable and unstable riparian soils in the Gila River portion of the Site was detected in only 1 of 29 samples collected. The selenium concentration in this sample was below the plant TRV (HQ = 0.7). Although the detection limit (3.5 mg/kg) exceeded the plant TRV (1.0 mg/kg), the magnitude of this exceedance was low (HQ = 3.5). Therefore, risk to the terrestrial plant community from exposure to selenium is uncertain, but cannot be excluded.

Copper and molybdenum in combined Gila River soils were detected all samples and had high frequencies of exceedance (83 and 48%, respectively). Therefore, risks from these analytes are possible.

Boron in combined and iron and manganese in stable and unstable soils of the Gila River also were detected in all samples and had high frequencies of exceedance (25 to 100%). These metals are common structural components of soil, but sufficient background data were not available to make meaningful comparisons. However, iron and manganese concentrations in the Gila River riparian soils are within the typical background concentrations in the United States (20,000 to 550,000 mg/kg for iron, EPA 2003c; 300 to 1,200 mg/kg for manganese in the western states, EPA 2007c), and boron concentrations are within background data collected in the state of Arizona (range 20 to 70 mg/kg, Shacklette and Boerngen 1984). Given the lack of site-specific background data, risks from these analytes are considered uncertain.

Cobalt was detected in all 12 of the unstable riparian soils collected along the onsite portion of the Gila River. However, only one of these samples (8%) exceeded the plant TRV for cobalt and the magnitude of exceedance was low (HQ = 1.3). This suggests that risks from cobalt in unstable riparian soils are low and spatially limited in these portions of the riparian habitat.

Onsite San Pedro River

Selenium was not detected in any San Pedro River riparian soils. As previously discussed, the detection limits for this COPEC exceeded their respective TRVs; however, the magnitude of exceedance is low (HQs < 4). Though uncertain, risks from this COPEC cannot be excluded. As in the Gila River riparian soils, boron, iron, and manganese had high frequencies of exceedance, but maximum concentration of these COPECs were within the range of typically reported background values. Given the lack of site-specific background data, risks from boron, iron, and manganese are uncertain.

5.4.1.2 Upland Soils

For upland soils all but four metals (aluminum, barium, beryllium, and silver) failed the initial screening, and cyanide was retained as an uncertainty because there was no available TRV (Table 4-3). Maximum concentrations of all metals, except beryllium, in upland soils were greater than background UTLs. These COPECs, as well as those lacking background data (boron, iron, and manganese), were evaluated in the refined screening using a point-by-point analysis (Table 5-8). All other COPECs retained from the initial screening had concentrations similar to or less than background and were dropped from further evaluation. The refined screening results are presented for detected and non-detected concentrations in Table 5-9.

Sixteen of the 17 COPECs evaluated in the refined screening evaluation had high detection frequencies (80 to 100%), indicating that these metals are widespread in the upland soils. In contrast, only two of ten samples (20%) had detected concentrations of thallium. Arsenic, copper, molybdenum, selenium, vanadium, and zinc also had high frequencies of exceedance (50 to 90%) and high magnitudes of exceedance (HQs range up to 670). Therefore, these metals are likely to pose a risk to terrestrial plants in the upland areas of the Site. Although chromium also had a high frequency and magnitude of exceedance, risks from chromium are considered unlikely. This is because only one of the ten upland samples exceeded the background UTLs for chromium, and the benchmark (1 mg/kg) is a very conservative value that is generally well below background levels. Additionally, it is based on hexavalent chromium, a more toxic form than trivalent chromium, which is the form likely to dominate in soils. Chromium also is unlikely to be 100% bioavailable (as was assumed in this evaluation). Soluble salts are often used in laboratory toxicity tests and have a higher bioavailability than forms found naturally in soil.

Cobalt and lead also have widespread exceedances (80 and 40% frequency of exceedance, respectively), but maximum HQs were 6.5 and 3.9 for cobalt and lead, respectively. Magnitude of exceedances for antimony, cadmium, mercury, and nickel are low (HQs < 3) and are spatially limited (10 to 20% frequency of exceedance). Iron also has a low frequency of exceedance (20%) suggesting any risks would be spatially limited. For thallium, none of the detected concentrations exceeded the screening benchmark and the frequency of exceedance for the non-detected concentrations was low (10%). Boron and manganese had high frequencies of exceedances; however, as discussed in the riparian soils section, the onsite concentrations of these COPECs were within the ranges reported for typical background.

5.4.1.3 Wash Soils

The initial screening results for wash soils were similar to the upland soils, with all metals except aluminum, barium, beryllium, cadmium, and silver failing the screen (Table 4-3). Of these, concentrations of all metals, except barium and beryllium, in wash soils were greater than background UTLs. These COPECs, as well as those lacking background data (boron, iron, and manganese), were evaluated in the refined screening using a point-by-point analysis (Table 5-8). The refined screening results are presented for detected and non-detected concentrations in Table 5-9.

As with upland soils, all retained COPECs had high detection frequencies (63 to 100%). Copper, molybdenum, selenium, vanadium, and zinc had high frequencies of exceedance (28 to 100%) and high magnitudes of exceedance (HQs range up to 180). Therefore, risk to terrestrial plants from exposure to these metals is likely. As in the upland soils, chromium had a high frequency and magnitude of exceedance, but risks to plants from this COPEC are unlikely given the low proportion of samples exceeding the background UTLs (only 1 of 32 samples), the conservative nature of the benchmark, and the form of chromium used in toxicity testing, relative to what is expected in the field. Arsenic, cobalt, and thallium had high frequencies of exceedance (50 to 88%), but HQs were generally low. This suggests that risks from arsenic, cobalt, and thallium may be low and widespread. Antimony, lead, mercury, and nickel had very low frequencies of exceedance (3%) and low HQs (< 2.5). Because of the low frequency and magnitude of exceedance, risks from antimony, lead, mercury, and nickel are not likely. Boron, iron, and manganese had high frequencies of exceedances; however, as discussed in the riparian soils section, the onsite concentrations of these COPECs were within the ranges reported for typical background.

5.4.1.4 Groundwater

Only arsenic and manganese failed the initial screening of groundwater for terrestrial plants. The point-by-point analysis and summary for these COPECs are presented in Tables 5-10 and 5-11, respectively.

Both arsenic and manganese have a high detection frequency (100 and 80% of samples, respectively). Additionally, all 10 groundwater samples had arsenic at concentrations above the plant TRV, and the magnitude of these exceedances was low to moderate (HQ range = 3.6 to 7.4). Manganese exceeded the plant TRV in 4 of 10 samples, with a maximum HQ of 1.8. This suggests that risks from manganese in groundwater may be widespread, but low, whereas those from arsenic are widespread and moderate.

5.4.2 Site-specific Field Studies

As indicated in Section 2.6.3.2, the ASARCO Hayden Site is located in the Sonoran Basin and Range Ecoregion. Soil conditions strongly affect the distribution and composition of plant communities in this ecoregion and presumably at the Site. The Site consists of large areas dominated by shrubs such as cresote bush. Depending on the specific soil type present in an area, common plant species include paloverde and saguaro. Within the aquatic and wash areas, dominant vegetation includes willows, tamarisk, cottonwood, and cat's claw.

The habitat quality in the riparian portions of the Site was generally considered to be moderate to high, with areas of native willow and cottonwood along the San Pedro River having the highest value and supporting a diversity of wildlife species. Many riparian areas along the Gila River were dominated by introduced tamarisk, also known as saltcedar. This species grows in very dense patches and does not provide the high quality habitat of the native species. In fact, some wildlife species, such as the southwestern willow flycatcher, do not utilize the saltcedar habitat. Additionally, Messing (2007) found that although herp species diversity was similar between the saltcedar and willow-cottonwood habitats, biomass was significantly lower in the saltcedar area. The upland habitats in the project area were largely undisturbed (except areas with roads or near the town and plant) and are typical of a desert environment. The habitat in the upland areas was considered to be high quality. The wash areas are located close to human activities (e.g., roads) and are likely to be somewhat disturbed, though these areas were not specifically evaluated in the ecological investigation. The habitat in the wash areas was considered to be moderate quality.

Signs of vegetative stress were recorded for two of the riparian locations, GR04 and GR10. Dead cottonwoods were observed at GR04 (see photo GR04-3 in Appendix B). However, these trees were located upland of the current riparian area and quite a distance from the river so they were not included in the evaluation of the river. Other vegetation around the cottonwoods did not appear stressed, suggesting that the cottonwoods may have died as a result of changes in their access to water. At GR10, multiple instances of shrubs with brown, chlorotic, or otherwise stressed foliage were observed (see photo GR10-Stress1, GR10-Stress2, and GR10-Stress3 in Appendix B). Potential causes of this stress were not readily apparent.

Boron concentrations at GR04 and GR10 were greater than the plant TRV for boron; however, with moderate HQ values (5 to 10). However, these HQs were less than the maximum boron HQ value (65 at location GR07, Table 5-8) from a sampling location without stressed vegetation. Additionally, boron concentrations in the riparian areas of the Gila River floodplain were within the range of typical background values for Arizona. Copper at GR04 (unstable soils only) and GR10 at manganese at both locations marginally exceeded the plant TRVs (HQs of 1.3 to 2.4) and were also less than the maximum HQ value in an unstressed area (copper HQ of 10 at GR02 and manganese HQ of 4 at GR-REF-01, Table 5-8). Molybdenum concentrations only exceeded plant TRVs in stable soils from GRO4 and GR10, and the HQs were less than 1.1. For iron, only the pH values in stable soils at GR04 were greater than 8 (i.e., in the range of toxic effects to plants). However, the iron concentration at this location was within typically reported background ranges.

Therefore, it is unlikely that elevated boron, copper, iron, manganese, or molybdenum at GR04 or GR10 were causative agents in the observed stressed vegetation. Cobalt concentrations at the two sites were below toxicity thresholds, and selenium and thallium concentrations were below detection limits.

5.4.3 Weight-of-Evidence Evaluation for Terrestrial Plants

The weight-of-evidence conclusions are presented here by area.

Riparian Soils. Selenium had insufficient detection limits (i.e., detection limits exceeded the plant TRVs), therefore, risks from this COPEC in riparian soils along the Gila and San Pedro rivers are uncertain. Copper and molybdenum in combined Gila River soils had high frequencies of exceedance, indicating a possible risk to terrestrial plants. Cobalt in the unstable riparian soils of the Gila River had a low frequency of exceedance (1 of 12 samples) and a low magnitude of exceedance, suggesting that risks to terrestrial plant communities may be spatially limited and low. Boron in combined Gila River soils, iron in stable and unstable soils of both rivers, and manganese in stable and unstable Gila River soils and unstable San Pedro River soils had high frequencies of exceedances. Although the onsite concentrations of these COPECs were within the ranges reported for typical background, site-specific background data were lacking and risks are considered uncertain.

The five groundwater wells that were appropriate for use in the SLERA are all located within the Gila River floodplain. Therefore, the screening results for groundwater are applicable to the riparian habitats along the Gila River. Both arsenic and manganese in groundwater may present a risk to the terrestrial plant community in the Gila River floodplain, though risks from manganese are not as widespread as those for arsenic.

Generally, the riparian areas at the Site are relatively undisturbed and few impacts to the terrestrial plants were observed during the ecological investigation. Signs of vegetative stress were observed at two of the riparian locations. Although the cause of this stress at one location may be attributable to changes in the access to water, the cause of stress is not readily apparent at the other location. Although boron, copper, manganese, and molybdenum at the location exceeded toxicity thresholds for plants, the concentrations of these analytes were lower in the area of stressed vegetation compared to other areas of the Site with no indications of stress. Cobalt and iron at the location were below effects thresholds, and selenium was not detected in either the stable or unstable samples. Due to the amount of uncertainty, very little weight was given to this line of evidence.

Therefore, the weight-of-evidence evaluation indicates that risks to terrestrial plant communities in the Gila River floodplain from arsenic and manganese in groundwater are possible, though those for arsenic are likely more widespread. Additionally, copper and molybdenum in Gila River riparian soils were found to pose a risk to the terrestrial plant community. Risks from selenium in Gila River and San Pedro River riparian soils are uncertain due to an insufficient detection limit, whereas risks from boron, iron, and manganese are uncertain, but unlikely. Although of limited weight, the riparian plant survey data suggest minimal effects in the riparian areas.

Upland Soils. Cobalt and lead had high detection and exceedance frequencies, but the magnitude of exceedance was low. Antimony, cadmium, mercury, and nickel had low frequencies and magnitudes of exceedance, suggesting that risk from these COPECs is minimal. Arsenic, copper, molybdenum, selenium, vanadium, and zinc had high frequencies and magnitudes of exceedance; therefore, these analytes are likely to present a risk to the upland terrestrial plant community at the Site. Chromium had a high frequency and magnitude of exceedance, but risks to plants from this COPEC are unlikely given the low proportion of samples exceeding background and the low confidence in the benchmark.

Boron and manganese also had high frequencies of exceedance; however, a lack of site-specific background data for these analytes makes conclusions of risk uncertain. Additionally, all concentrations of both of the COPECs are within the range typically reported for background. Upland plant surveys did no detect any observable adverse effects in the areas evaluated.

The weight-of-evidence is that arsenic, cobalt, copper, lead, molybdenum, selenium, vanadium, and zinc may pose a risk to upland plant communities at the Site. Risks from boron and manganese are uncertain, but unlikely.

Wash Soils. Arsenic, cobalt, and thallium had high detection and exceedance frequencies, but the magnitude of exceedance was low. Antimony, lead, mercury, and nickel had very low frequencies of exceedance, as well as low HQs; therefore, no risks from these COPECs are expected. Copper, molybdenum, selenium, vanadium, and zinc had high frequencies and magnitudes of exceedance; therefore, these analytes are likely to present a risk to the terrestrial plant community in the wash areas of the Site. Chromium had a high frequency and magnitude of exceedance, but risks to plants from this COPEC are unlikely given the low proportion of samples exceeding background and the low confidence in the benchmark. Boron, iron, and manganese also had high frequencies of exceedance. All concentrations of these COPECs were within typically reported background ranges, but risk conclusions are uncertain due to insufficient site-specific background data. Wash areas of the Site were not specifically evaluated in the plant surveys, but were assumed to be somewhat disturbed though moderate in habitat quality.

The weight-of-evidence is that risks to the terrestrial plant communities in the wash areas of the Site from exposure to arsenic, cobalt, copper, molybdenum, selenium, thallium, and zinc in soil are possible. Risks from boron, iron, and manganese are uncertain, but unlikely.

5.5 Soil Invertebrates

Only one line of evidence, media-based effects data, was available for soil invertebrates. The refined assessment for soil invertebrate communities is presented by matrix type below.

5.5.1 Riparian Soils

Chromium, copper, and mercury in combined stable and unstable soils in both the Gila River and San Pedro River areas failed the initial screening for soil invertebrates in Section 4.3 (Table 4-3). Additionally, zinc in combined stable and unstable Gila River soils, and manganese in both stable and unstable riparian Gila River soils and unstable San Pedro River soils failed the screen.

After the background screening (Table 5-2), copper and mercury in combined soils of the Gila River, mercury in combined soils of the San Pedro River, and manganese in stable and unstable Gila River soils and unstable San Pedro River soils were retained for further evaluation. These COPECs were evaluated in the refined screening using a point-by-point analysis (Table 5-12). A summary of the refined screening results is presented for detected and non-detected concentrations in Table 5-13 and described here by watershed.

5.5.1.1 Onsite Gila River

Copper had a high frequency and magnitude of exceedance, indicating that risk to the soil invertebrate community from exposure to copper is possible. Mercury was detected in 13 of 29 samples collected along the Gila River. Of these, only four exceeded the screening benchmark (low frequency of exceedance) and the magnitude of exceedance was very low (maximum detected HQ = 1.5). Moreover, the detection limit was equal to the benchmark. Therefore, risks from exposure to mercury are considered minimal. Manganese had high frequencies of exceedance in both stable and unstable soils, but the magnitude of exceedance was low (HQs < 2) and all concentrations were within typically reported background ranges. However, actual risks from manganese are uncertain because site-specific background data are lacking.

5.5.1.2 Onsite San Pedro River

Three of four San Pedro River riparian soils had detected mercury concentrations. None of these detected values exceeded the screening benchmark for soil invertebrates, and the detection limit was equal to the benchmark. Thus, mercury concentrations in San Pedro River riparian soils are not likely to pose risks to soil invertebrates. As with unstable Gila River soils, manganese had a high frequency of exceedance in unstable San Pedro River soils. Although risk from manganese exposure are uncertain (i.e., no site-specific background data available), all concentrations were within the range reported for background within the United States.

5.5.2 Upland Soils

For upland soils, arsenic, chromium, copper, manganese, mercury, and zinc failed the initial screening (Table 4-3). Maximum concentrations of all of these analytes in upland soils were also greater than background (Table 5-2). These COPECs were evaluated in the refined screening using a point-by-point analysis (Table 5-12). The refined screening results are presented for detected and non-detected concentrations in Table 5-13.

Arsenic, copper, mercury, and zinc had high detection frequencies (80 to 100%) and high frequencies of exceedance (30 to 90%), indicating that these analytes are widespread in the upland soils and may present a risk to soil invertebrates (Table 5-13). Although chromium also had a high frequency and magnitude of exceedance, qualitative evaluations of chromium, as described above for plants (e.g., low proportion of samples exceeding background and low confidence in the benchmark), suggest that risk from chromium is minimal. Qualitative evaluations for manganese (i.e., concentrations within range of typical background) indicate that risk cannot be excluded, but is unlikely.

5.5.3 Wash Soils

The initial and refined screening results for wash soils were similar to the upland soils, except that risk from arsenic and mercury in the wash soils is likely to be low. Both arsenic and mercury had a low frequency (3 and 19%, respectively) and magnitude of exceedance (maximum HQs of 1.3 and 3, respectively) (Table 5-13). Copper and zinc both had high frequencies and magnitudes of exceedance. Risks from exposure to chromium are not expected because of the low proportion of samples exceeding background and the low confidence in the benchmark. For manganese, risks are considered low (i.e., Site concentrations within range of typically reported background), but uncertain (i.e., no site-specific background data were available).

5.5.4 Weight-of-Evidence Evaluation for Soil Invertebrates

Copper in combined Gila River riparian soils had a high frequency and magnitude of exceedance, indicating the potential for risk to soil invertebrates in this area of the Site. Because mercury had a low frequency of exceedance and low magnitude of exceedance, risks from this analyte to soil invertebrates in the riparian areas of either the Gila or San Pedro river portions of the Site were considered minimal and may be acceptable. Risks from arsenic, copper, mercury, and zinc in the upland areas of the Site may be widespread. Chromium had a high frequency and magnitude of exceedance in upland soils, but risks to soil invertebrates from this COPEC are unlikely given the low proportion of samples exceeding background and the low confidence in the benchmark. In the wash areas of the Site, copper and zinc are also a risk to soil invertebrates, but risks from arsenic and mercury are likely to be low and spatially limited (low frequency of exceedance). Manganese across all soil categories, except stable San Pedro River riparian soil, had high frequencies of exceedance. However, all concentrations in these areas are within the background range reported for the United States. This would suggest that risks are unlikely; however, the lack of site-specific background data for manganese makes a no risk conclusion uncertain.

Therefore, the weight-of-evidence is that copper in combined stable and unstable riparian soils of the Gila River, arsenic, copper, mercury, and zinc concentrations in upland soils, and copper and zinc concentrations in wash soils present a risk the soil invertebrate communities in these portions of the Site. Risks from manganese are uncertain, but unlikely.

5.6 Soil Microbes

As with soil invertebrates, only one line of evidence (media-based effects data) was available for soil microbes. The refined assessment for the soil microbial community is presented by matrix type below.

5.6.1 Riparian Soils

Chromium, copper, and vanadium in combined stable and unstable soils in both Gila River and San Pedro River areas and boron and zinc in combined stable and unstable Gila River soils failed the initial screening for soil microbes in Section 4.3 (Table 4-3). Iron and manganese in both stable and unstable riparian soils of the Gila and San Pedro rivers also failed the screen.

After the background screening (Table 5-2), boron and copper in combined soils of the Gila River, as well as iron and manganese in stable and unstable soils of both rivers, were retained for further evaluation. These COPECs were evaluated in the refined screening using a point-by-point analysis (Table 5-14). A summary of the refined screening results is presented for detected and non-detected concentrations in Table 5-15 and described here by watershed.

5.6.1.1 Onsite Gila River

Copper had a high frequency and magnitude of exceedance, indicating that risk to the soil microbial community from exposure to copper is possible. For boron, only the maximum measured concentration in the Gila River portion of the Site exceeded the microbe TRV. Based on this low frequency of exceedance, adverse effects from exposure to boron are not expected. As has been discussed for plants and soil invertebrates, risks predicted from manganese and iron based on the high frequency of exceedance are uncertain (site-specific background data were lacking), but unlikely (all concentrations within normally typical background ranges).

5.6.1.2 Onsite San Pedro River

As with the riparian soils in the Gila River, predicted risks to the soil microbial community in the San Pedro River portions of the Site from exposure to iron and manganese are considered to be uncertain, though unlikely.

5.6.2 Upland Soils

Arsenic, cadmium, chromium, copper, iron, manganese, molybdenum, vanadium, and zinc failed the initial screening of upland soils (Table 4-3). Maximum concentrations of all of these analytes in upland soils were also greater than background UTLs. These COPECs were evaluated in the refined screening using a point-by-point analysis (Table 5-14). A summary of the refined screening results is presented for detected and non-detected concentrations in Table 5-15.

All nine COPECs evaluated in the refined screening evaluation had high detection frequencies (90 to 100%) indicating that these analytes are widespread in the upland soils (Table 5-15). Chromium, copper, iron, manganese, vanadium, and zinc had high frequencies of exceedance (60 to 100%), whereas arsenic, cadmium, and molybdenum had spatially limited risks (i.e., 20% frequency of exceedance). Arsenic and cadmium also had low magnitudes of exceedance (HQs < 5). As with plants and soil invertebrates, chromium is not likely to be a risk to soil microbial process because of the low proportion of samples exceeding background and the low confidence in the benchmark. Similar to other receptors at the Site, risks from iron and manganese are uncertain, but unlikely. Therefore, copper, vanadium, and zinc pose a risk to soil microbes in the upland areas of the Site.

5.6.3 Wash Soils

All of the six COPECs (chromium, copper, iron, manganese, vanadium, and zinc) retained from the initial screening of wash soils were retained for further evaluation after the background screening (Table 5-2). All of these metals were detected in all samples, and all had a high frequency of exceedance (78 to 100%; Table 5-15). However, as discussed for the upland soils, risks from exposure to chromium are unlikely and risks from iron and manganese are uncertain, but considered unlikely. Therefore, copper, vanadium, and zinc in wash soil pose a risk to the soil microbial community at the Site.

5.6.4 Weight-of-Evidence Evaluation for Soil Microbes

Copper in combined Gila River riparian soils had a high frequency and magnitude of exceedance, indicating the potential for risk to soil microbial community in this area of the

Site. Because boron in the Gila River riparian soils had a low frequency of exceedance and low magnitude of exceedance, risks from this analyte were considered minimal and likely acceptable at the community level of assessment. In the upland areas of the Site, risks from arsenic, cadmium, and molybdenum are spatially limited (low frequency of exceedance) and may be acceptable. Copper, vanadium, and zinc in the upland and wash soils had high frequencies of detection and exceedance. Chromium had a high frequency and magnitude of exceedance in upland and wash soils, but risks to soil microbes from this COPEC are considered unlikely given the low proportion of samples exceeding background and the low confidence in the benchmark. Iron and manganese across all soil categories had high frequencies of exceedance. However, all concentrations in these areas are within reported background ranges. This would suggest that risks are unlikely; however, the lack of site-specific background data for manganese makes a no risk conclusion uncertain.

Therefore, the weight-of-evidence conclusion is that copper in combined stable and unstable riparian soils of the Gila River, and copper, vanadium, and zinc in upland and wash soils present a risk the soil microbial communities in these portions of the Site. Risks from iron and manganese are uncertain, but unlikely.

5.7 Birds and Mammals

For birds and mammals, the refinements following the background analysis included the use of the 95 UCL for media concentrations, use of median BAFs (as appropriate), bioavailability of individual COPECs, and use of a diet that more closely matches the actual diet of the receptor. As previously noted, the size of the Site is sufficiently large that each receptor was assumed to forage exclusively onsite.

The 95 UCL values for surface water and sediment are presented in Table 5-16, and those for soils (riparian, upland, and wash) are presented in Table 5-17. Median BAFs used in the refined assessment are outlined in Table 5-18. If a regression model was considered the best representation of the bioaccumulation relationship (as presented in Tables 3-2 to 3-6), these regressions were also used in the refined assessment. Bioavailability information was available for arsenic, barium, cadmium, copper, lead, mercury, selenium, and zinc (Table 5-19) and was applied as possible to the risk estimate. The refined diet for each receptor is indicated in the footnotes of the risk estimate tables, and is based on the dietary information provided in Table 3-1.

Results of the ecological investigation (Section 2.6.3.2) indicated that onsite habitat quality was moderate to high. As a non-native species, saltcedar provides a lower quality of habitat than does the native cottonwood/willow riparian habitat. Undisturbed native upland areas were considered to be high quality habitat, whereas wash areas are somewhat disturbed (i.e., are close to roads and human activity near the town of Hayden) and are considered to provide moderate quality habitat for ecological receptors. Because the habitat quality was moderate to high throughout the Site and because wildlife were observed (individuals and sign) in these habitats, habitat quality was not considered a limiting factor in the determination of risk for bird and mammal receptors.

The refined screening results for aquatic and terrestrial birds and mammals are presented in Tables 5-20 through 5-31 and are described below.

5.7.1 Aquatic Birds and Mammals

None of the retained COPECs was eliminated from further evaluation based on the background analysis for sediment (Table 5-1). Therefore, all of the COPECs retained in the initial screening evaluation of the aquatic wildlife receptors (swallows, belted kingfishers, little brown bats, and mink; Section 4.6.1) were evaluated in the refined screening.

5.7.1.1 Swallows

Aluminum, cadmium, copper, iron, lead, manganese, mercury, selenium, silver, thallium, zinc, and p,p′-DDE in sediments from both the Gila and San Pedro rivers and vanadium in Gila River sediments failed the initial screening evaluation (Table 4-5). Of these, exposure estimates of aluminum, iron, lead, thallium, and p,p′-DDE for Gila River sediments and aluminum, iron, lead, selenium, silver, thallium, and p,p′-DDE for San Pedro River sediments exceeded their respective NOAELs (Table 5-20). However, only iron in both rivers also exceeded the LOAEL. Because swallows are evaluated at the population level, exceedance of the NOAEL does not indicate a likely risk. Therefore, lead, selenium, silver, thallium, and p,p′-DDE concentrations in sediment do not pose a risk to swallow populations in the Gila River and San Pedro River portions of the Site.

There was no avian LOAEL available for aluminum, so risk to populations is uncertain, though risk to individual swallows is possible. Additionally, aluminum is generally not predicted to be an issue for areas with pH values greater than 5.5. Because all onsite sediments and surface water had pH values greater than 5.5, aluminum is not expected to present a risk to swallow populations. Exposure estimates for iron in the onsite portions of both rivers exceeded the NOAEL and LOAEL. Although the magnitude of exceedance was low (HQs < 2.3), risk could not be excluded.

The weight-of-evidence conclusion is that risk to swallow populations from exposure to iron along both the Gila and San Pedro rivers cannot be excluded. Although risk to swallow populations from aluminum is uncertain, risks are not likely realistic because aluminum is not expected to be bioavailable (due to pH of sediment).

5.7.1.2 Belted Kingfisher

Aluminum, cadmium, iron, lead, mercury, selenium, and zinc in onsite Gila River sediment and aluminum, cadmium, mercury, and selenium in San Pedro River sediment failed the initial screening evaluation (Table 4-6). Refined exposure estimates for all of these, except iron and selenium in the Gila River, had NOAEL-based HQs greater than one (Table 5-21). However, only cadmium and mercury in the Gila River and cadmium in the San Pedro River had LOAEL-based HQs greater than one.

The weight-of-evidence conclusion is that risk to kingfisher populations from exposure to cadmium along both the Gila and San Pedro rivers and mercury along the Gila River cannot be excluded.

5.7.1.3 Little Brown Bat

Fourteen COPECs failed the initial screening evaluation for both Gila and San Pedro river sediments (Table 4-7). Of these, refined exposure estimates of arsenic, lead, manganese, mercury, selenium, and silver in the Gila River portions of the Site and arsenic, lead, manganese, and mercury in the San Pedro River portions of the Site did not exceed their respective NOAELs (Table 5-22). Therefore, these COPECs do not pose a risk to little brown bat populations in these portions of the Site. Exposure estimates of antimony, beryllium, cyanide, iron, molybdenum, and vanadium for both rivers, as well as mercury for the Gila River and copper for the San Pedro River, exceeded the NOAEL, but not the LOAEL. Therefore, these COPECs also do not pose a risk to the little brown bat populations.

Exposure estimates of aluminum for both rivers exceeded both the NOAEL and LOAEL. However, aluminum is not readily available for uptake from sediments with pH values greater than 5.5. Because the minimum pH for both rivers (7.6 and 8.1; Table 2-2) is greater than this benchmark, risks from aluminum are not expected. Copper and cyanide in the Gila River and cyanide and selenium in the San Pedro River also exceeded their respective NOAELs and LOAELs, but the magnitude of exceedance for the LOAEL was low in these cases (HQs < 2.6). Therefore, risks to the little brown bat population from exposure to copper, cyanide, and selenium, although possible, are likely low. A LOAEL was not available for iron or beryllium; therefore risks to little brown bat populations from these COPECs are uncertain. However, the refined screening results indicate that risks to individual bats may exist (i.e., the NOAEL was exceeded; Table 5-22). It should also be noted that cyanide was not detected in any sediment sample, indicating that risk conclusions for cyanide are also uncertain.

The weight-of-evidence conclusion is that risk to individual little brown bats from exposure to beryllium and iron along the onsite portions of the Gila and San Pedro rivers may exist, but risk to populations is uncertain. Copper and cyanide in the Gila River and selenium and cyanide in the San Pedro River may pose a risk to little brown bat populations utilizing these portions of the Site, although risks from cyanide are uncertain due to insufficient detection limits. Although concentrations of aluminum indicate there is a possible risk, that is not likely realistic because aluminum in not expected to be bioavailable (pH of sediment is above the level of concern).

5.7.1.4 Mink

Exposure estimates of aluminum, iron, and mercury for the onsite portions of the Gila and San Pedro rivers and cadmium, iron, and selenium for the onsite portions of the Gila River failed the initial screening evaluation (Table 4-8). Cadmium and selenium in the Gila River and mercury in the San Pedro River had NOAEL-based HQs that were less than one (Table 5-23), and were therefore considered to pose no risk to mink populations in these portions of the Site. As with the bat, aluminum is not expected to pose a risk to mink populations because pH values in the two rivers are greater than 5.5. Iron may pose a risk to individual mink along both rivers, but risk to the mink populations is uncertain due to the lack of an available LOAEL. Exposure estimates for mercury for the onsite portions of the Gila River exceeded both the NOAEL and LOAEL.

The weight-of-evidence conclusion is that risk to individual mink from exposure to iron along the onsite portions of the Gila and San Pedro rivers may exist, but risk to populations is uncertain. Mercury in the Gila River may pose a risk to mink populations utilizing this portion of the Site. Although concentrations of aluminum indicate there is a possible risk, that is not likely realistic because aluminum in not expected to be bioavailable (due to pH of sediment).

5.7.2 Terrestrial Birds and Mammals

For the riparian soils, all analytes with background UTLs passed the background comparison, except barium and molybdenum in stable Gila River soils, cobalt in unstable Gila River soils, copper in stable and unstable Gila River soils, and mercury, selenium, and silver in stable and unstable Gila River and San Pedro River soils (Section 5.1, Table 5-2). For upland and wash soils, all analytes with background UTLs, except beryllium in upland soils and barium and beryllium in wash soils had maximum concentrations that exceeded UTLs in at least one of the geologic formations. Boron, iron, and manganese lacked sufficient data to develop background UTLs; therefore, predicted risks for these COPECs are uncertain. However, all of the concentrations measured in all soil categories at the Site are within background ranges reported by EPA (EPA 2003c, 2007c) and the U.S. Geological Survey (Shacklette and Boerngen 1984), suggesting that the potential for risk is unlikely or low. These three analytes were evaluated in the refined screening below, and this rationale that predicted risks are uncertain, but unlikely was applied to exceedances of toxicity thresholds.

All COPECs in riparian, upland, and wash soils that passed the background screening were excluded from further refined evaluation. The COPECs that were retained from the initial screening evaluation and the background screening for each terrestrial wildlife receptor (mourning dove, curve-billed thrasher, red-tailed hawk, southwestern willow flycatcher, desert cottontail, desert shrew, and coyote) were evaluated in the refined screening.

5.7.2.1 Mourning Dove

Exposure estimates for boron in onsite combined stable and unstable Gila River soils and iron in all riparian soils of both rivers failed the initial screening (Table 4-9) and the background evaluation (Table 5-2). Arsenic, cadmium, chromium, copper, iron, lead, molybdenum, selenium, thallium, and zinc in the upland and cadmium, chromium, copper, iron, lead, molybdenum, selenium, thallium, and zinc in washes, failed the initial and background screenings. The results of the refined screening are provide below by area.

Riparian Soils. The refined exposure estimate for boron in combined stable and unstable soils from the onsite riparian areas of the Gila River did not exceed the NOAEL or the LOAEL for boron (Table 5-24). Although iron in riparian soils of both rivers exceeded both the NOAEL and LOAEL, risks are uncertain, but unlikely (as previously discussed). Therefore, COPEC concentrations in riparian soils of the two rivers do not pose a risk to mourning dove populations in these areas.

Upland Soils. The exposure estimates for arsenic and chromium did not exceed either the NOAEL or LOAEL. For thallium and zinc, the exposure estimate exceeded the NOAEL, but not the LOAEL. Therefore, arsenic, chromium, thallium, and zinc are not expected to pose a risk to mourning dove populations. Cadmium, copper, lead, molybdenum, and selenium exposure estimates exceeded their respective NOAELs and LOAELs, though the magnitude of exceedance is low (all HQs < 3.3). Risks predicted from exposure to iron are uncertain, but unlikely.

Wash Soils. Exposure estimates for chromium, copper, and selenium did not exceed their respective NOAELs or LOAELs, and those for cadmium, lead, molybdenum, thallium, and zinc exceeded the NOAEL, but not the LOAEL. Therefore, these COPECs do not pose a risk to mourning dove populations utilizing the wash areas of the Site. As previously described, risks predicted for iron are uncertain, but not likely.

The weight-of-evidence conclusion is that exposure to COPECs in the riparian and wash areas of the Site does not pose a risk to mourning dove populations. In the upland areas, risk from exposure to cadmium, copper, lead, molybdenum, and selenium cannot be excluded.

5.7.2.2 Curve-billed Thrasher

Mercury, selenium, and silver exposure estimates in the stable and unstable riparian areas of the Gila and San Pedro river floodplains, as well as copper in combined Gila River soils and iron in both stable and unstable soils of both rivers failed the initial (Table 4-10) and background screening (Table 5-2). Within the upland and wash areas, cadmium, chromium, cobalt, copper, iron, lead, mercury, molybdenum, selenium, silver, thallium, and zinc failed the initial and background screenings.

Riparian Soils. Exposure estimates of mercury, selenium, and silver in combined soils of both rivers and copper in combined Gila River soils did not exceed their respective NOAELs or LOAELs (Table 5-25). Therefore, no risk to the thrasher populations in these areas is predicted. Risks from iron in soils of both rivers are uncertain, but not likely.

Upland Soils. The refined exposure estimate for cobalt did not exceed either the NOAEL or the LOAEL, and that for chromium, mercury, and thallium exceeded the NOAEL, but not the LOAEL (Table 5-25). Therefore, chromium, cobalt, mercury, and thallium do not pose a risk to thrasher populations in the upland areas. Molybdenum, selenium, silver, and zinc refined exposure estimates exceeded their respective NOAEL and LOAEL values, but the magnitude of exceedance was very low (all HQs < 3.1). In contrast, cadmium, copper, and lead exposure estimates exceeded their LOAELs with moderate to high magnitudes of exceedance (HQ range of 7.9 to 56). Iron also exceeded both the NOAEL and LOAEL, but predicted risks are not likely, although this conclusion is uncertain.

Wash Soils. Cadmium, copper, iron, and lead exposure estimates exceeded their LOAELs (Table 5-25). These exceedances were low (HQ of 3.1 for lead) to moderate (HQs of 5.2 and 9.1 for cadmium and copper), risk to curve-billed thrasher populations is possible. However, risks predicted for iron are uncertain, but unlikely. Exposure to the other eight analytes retained for evaluation does not pose a risk, either due to the non-exceedance of the NOAEL (cobalt and selenium) or non-exceedance of the LOAEL (chromium, mercury, molybdenum, silver, thallium, and zinc).

The weight-of-evidence conclusion is that exposure to COPECs in the riparian areas of the Site are not expected to pose a risk to thrasher populations. Risks to curve-billed thrasher populations from exposure to cadmium, copper, lead, molybdenum, selenium, silver, and zinc in the upland soils and cadmium, copper, and lead in the wash soils are possible.

5.7.2.3 Red-tailed Hawk

Exposure estimates for iron in onsite stable and unstable Gila and San Pedro river soils failed the initial screening (Table 4-11) and the background evaluation (Table 5-2). In the upland and wash areas, iron, lead, molybdenum, silver, thallium, and zinc failed the initial and background screenings, as did cadmium in upland soils and chromium in wash soils. The results of the refined screening are provide below by area.

Riparian Soils. Iron exposure estimates in stable and unstable soils from the onsite riparian areas of the Gila and San Pedro rivers exceeded the NOAEL, but not the LOAEL for iron (Table 5-26). Therefore, iron concentrations in riparian soils of the two rivers do not pose a risk to red-tailed hawk populations in these areas.

Upland Soils. The exposure estimate for silver did not exceed either the NOAEL or LOAEL, whereas the exposure estimates for cadmium, thallium, and zinc exceeded the NOAEL, but not the LOAEL. Therefore, cadmium, silver, thallium, and zinc are not expected to pose a risk to red-tailed hawk populations. Lead and molybdenum refined exposure estimates exceeded their respective NOAELs and LOAELs, though the magnitude of exceedance was low (all HQs < 3.3). Predicted risks from iron are uncertain, but unlikely.

Wash Soils. The exposure estimate for chromium and silver in wash soils did not exceed the NOAEL and the exposure estimates for lead, molybdenum, thallium, and zinc exceeded the NOAEL, but not the LOAEL. Therefore, these COPECs do not pose a risk to the red-tailed hawk population in the wash areas. Only iron exceeded both the NOAEL and LOAEL; however, risks from this COPEC are not likely, although this conclusion is uncertain.

The weight-of-evidence conclusion is that exposure to COPECs in the riparian and wash areas of the Site does not pose a risk to red-tailed hawk populations. In the upland areas, risk from exposure to lead and molybdenum cannot be excluded.

5.7.2.4 Southwestern Willow Flycatcher

Three lines of evidence were available for the southwestern willow flycatcher. These included oral exposures, tissue-based exposures, and site-specific studies within the project area. The refined screening results and weight-of-evidence evaluation for the flycatcher are described below.

Oral Exposures

Mercury, selenium, and silver exposure estimates in the combined stable and unstable riparian areas of the Gila and San Pedro river floodplains failed the initial (Table 4-12) and background screenings (Table 5-2). Additionally, copper and molybdenum in combined Gila River soils and iron in all riparian soil categories failed the initial and background screening. Within the upland and wash areas, cadmium, chromium, cobalt, copper, iron, lead, mercury, molybdenum, selenium, silver, thallium, and zinc failed the initial and background screenings. Nickel in wash soils also failed the initial and background screenings.

The southwestern willow flycatcher is a special-status species evaluated at the individual level. COPECs that exceeded the NOAEL were considered to be a possible risk to individual flycatchers, whereas those that exceeded both the NOAEL and LOAEL were considered to pose probable risk to individual flycatchers and possible risk to flycatcher populations.

Riparian Soils. Exposure estimates for molybdenum, selenium, and silver in combined Gila River soils and silver in combined San Pedro River soils did not exceed either the NOAEL or LOAEL. Therefore, these COPECs are not expected to pose a risk to individual flycatchers. Copper and mercury in riparian stable and unstable soils of the Gila River floodplain, and mercury and selenium in stable and unstable soils of the San Pedro River floodplain exceeded the NOAEL, but not the LOAEL (Table 5-27). Although this indicates a possible risk to individual flycatchers in these areas from exposure to copper or mercury, risk from exposure to selenium in San Pedro River soils is uncertain due to an insufficient detection limit (i.e., selenium was not detected in any San Pedro River riparian sample and the exceedance is due solely to the detection limit). Exposure estimates for mercury in both Gila and San Pedro riparian soils and copper in Gila River soils exceeded the NOAEL with a low magnitude of exceedance (HQs < 2). Iron in both stable and unstable riparian soils of both rivers exceeded the NOAEL and LOAEL. Risks from iron are uncertain, but are considered to be unlikely.

Upland Soils. The refined exposure estimate for cobalt did not exceed either the NOAEL or the LOAEL (Table 5-27). Therefore, cobalt does not pose a risk to individual flycatchers in the upland areas. Chromium, mercury, and thallium refined exposure estimates exceeded the NOAEL, but not the LOAEL. This indicates a possible risk to individual flycatchers. Molybdenum, selenium, silver, and zinc refined exposure estimates exceeded their respective NOAEL and LOAEL values. Although the magnitude of the LOAEL exceedances were low (all HQs ≤ 5), risk is considered probable. Exposure estimates for cadmium, copper, and lead also exceeded their LOAELs with moderate to high magnitudes of exceedance (LOAEL-based HQ range of 12 to 103; much higher when based on NOAEL), also indicating a probable risk to individual flycatchers. As for other areas, as well as other receptors, predicted risks from exposure to iron are uncertain, but not likely.

Wash Soils. As with upland soils, cobalt did not exceed either the NOAEL or the LOAEL, and was considered to pose no risk (Table 5-27). Similarly, nickel did not exceed either the NOAEL or LOAEL. Exposure estimates for chromium, mercury, molybdenum, selenium, silver, and thallium exceeded the NOAEL, but not the LOAEL, with low magnitudes of exceedance (all HQs < 5). This indicates a possible risk to individual flycatchers. Cadmium, copper, lead, and zinc pose a probable risk to individual flycatchers as exposure estimates for these COPECs exceeded both the NOAEL and LOAEL. Risks from iron are uncertain, but unlikely.

Tissue-based Exposures

Concentrations of metals in southwestern willow flycatcher eggs collected within the project area were compared to available benchmarks in Section 4.6.2.2. The results of this comparison indicated that zinc in one of the two available eggs exceeded the NOEC. This indicates a possible risk to individual flycatchers.

Site-specific Field Surveys

The recruitment rate necessary to maintain a stable southwestern willow flycatcher population is not known; however, the annual reproduction in Arizona seems low compared to other insectivorous birds and below other published thresholds for most songbird species (Robinson et al. 1993). Prior studies have indicated that loss and/or degradation of breeding habitat (caused primarily by groundwater withdrawal and diversion), inundation of habitat, cattle grazing, and brood parasitism by brown-headed cowbirds (*Molothrus ater*) are all likely contributors to southwestern willow flycatcher population declines (Sogge et al. 1997, Sedgwick 2000).

Paxton et al. (2002) measured nestling sex ratios of southwestern willow flycatchers at four Arizona sites over a five-year period and found significant variation among sites; notably, a skewness toward males was observed at a San Pedro River site located about 7 miles upstream of the ASARCO project area. Given the small population size and geographic isolation of many of the populations, a bias toward males could depress population growth estimates (Stoleson et al. 2000). However, it is not currently known if this sex ratio skewness is a contaminant effect.

Sogge and Paxton (2000) observed a high rate of malformations (1.4%) in adult and nestling southwestern willow flycatchers captured across the southwestern United States (Arizona, New Mexico, southern California, Colorado, Utah, and Nevada). These bill and eye malformations were similar to those associated with selenium toxicosis at other locations (e.g., Hoffman and Heinz 1988, Hoffman et al. 1990, Ohlendorf et al. 1988). King et al. (2002) found potentially elevated selenium concentrations in addled southwestern willow flycatcher eggs, but those in all but one egg were below concentrations associated with effects. This egg was not collected within the ASARCO project area delineated in Figure 2-1.

Weight-of-Evidence Evaluation

Several COPECs exceeded NOAELs within the Gila River, San Pedro River, upland, and wash areas of the Site, indicating a possible risk to individual southwestern willow flycatchers. Additionally, several COPECs within the upland and wash areas were found to pose a probable risk to individual flycatchers and a possible risk to flycatcher populations (i.e., they also exceeded the LOAELs) if flycatchers use those habitats extensively. Based on the tissue data, zinc was found to pose a possible risk to flycatchers nesting within the San Pedro River portion of the Site. The field studies for the southwestern willow flycatcher indicate that populations in Arizona are unstable and in most cases are in decline. Although contaminants cannot be excluded as a possible contributor to these population declines, conclusive evidence is lacking and other factors (e.g., habitat degradation or loss, nest parasitism, cattle grazing) have been identified as definite contributors.

The weight-of-evidence conclusion is that risks to individual willow southwestern flycatchers from exposure to selenium in the San Pedro River riparian areas of the Site are uncertain due to insufficient detection limits for this COPEC. Risks from mercury in both riparian areas, as well as in the upland and wash areas are possible. Similarly, risk from exposure to copper in Gila River riparian soils, chromium and thallium in upland and wash soils, and molybdenum, selenium, and silver in the wash soils is possible. Risks to individual southwestern willow flycatchers from exposure to cadmium, copper, lead, and zinc in upland and wash soils, and molybdenum, selenium, and silver in upland soils are considered to be probable. The conclusion of risk from exposure to zinc was supported by the available egg tissue data, in which zinc exceeded the no effects threshold for bird eggs. Although populations of southwestern willow flycatchers are declining in Arizona, evidence that contaminants are contributing to this decline is inconclusive. Therefore, this line of evidence does not contradict the risk conclusions, but provides little additional support for risk.

5.7.2.5 Desert Cottontail

Oral exposures and tissue-based exposure lines of evidence were available for the desert cottontail.

Oral Exposures

Boron and molybdenum in Gila River riparian soils, and iron in riparian soils or both rivers failed the initial (Table 4-13), and background (Table 5-2) screening evaluations. Arsenic, copper, iron, lead, molybdenum, selenium, and vanadium in both upland and wash soils and antimony in wash soils failed both the initial and background screenings.

Riparian Soils. Refined exposure estimates for boron and molybdenum in combined Gila River soils did not exceed either the NOAEL or LOAEL. Therefore, no risks to the desert cottontail populations from these COPECs is predicted. Iron exposure estimates in stable and unstable riparian soils of both rivers exceeded the NOAEL, but a LOAEL for mammals was unavailable. This lack of a LOAEL adds further uncertainty to the already unlikely, but uncertain risk from exposure to iron.

Upland Soils. The refined exposure estimate for lead did not exceed either the NOAEL or the LOAEL, and that for arsenic and vanadium exceeded the NOAEL, but not the LOAEL (Table 5-28). Therefore, arsenic, lead, and vanadium do not pose a risk to desert cottontail populations in the upland areas. Risks predicted for iron are uncertain, but not likely. Refined exposure estimates for copper, molybdenum, and selenium exceeded their respective NOAELs and LOAELs, and are considered to pose possible risk to cottontail populations.

Wash Soils. The refined exposure estimate for antimony, arsenic, lead, selenium, and vanadium did not exceed either the NOAEL or the LOAEL, and that for copper exceeded the NOAEL, but not the LOAEL (Table 5-28). Therefore, these COPECs do not pose a risk to desert cottontail populations in the wash areas. Risks from iron are not likely, but this conclusion is uncertain. The molybdenum refined exposure estimate exceeded the NOAEL and LOAEL, indicating that risk is possible.

Tissue-based Exposures

Estimated concentrations of metals in small mammal tissues were compared to available tissue-based benchmarks in Section 4.6.2.2. Based on the results of the initial screening (Table 4-17) and the background evaluation (Table 5-2), only lead (soil-to-kidney pathway) in the upland and wash soils was retained for further evaluation of the desert cottontail (herbivore).

For the initial screening, the maximum soil concentration was used to estimate the tissue concentration. In the refined screening, the 95 UCL soil concentration was used to estimate the COPEC concentration in small mammal tissue. In the upland area, the 95 UCL for lead was 297.7 mg/kg, which resulted in an estimated kidney tissue concentration for an herbivorous small mammal of 11.5 mg/kg (Table 5-29). This estimate exceeded the threshold for effects, indicating a possible risk to desert cottontail populations from exposure to lead in the upland areas. The 95 UCL for lead in the wash areas was 95.83 mg/kg, which resulted in an estimated kidney tissue concentration for an herbivorous small mammal of 7.4 mg/kg. This estimate was below the threshold for effects; therefore, no risk to cottontail populations from exposure to lead in the wash areas is expected.

Weight-of-Evidence Evaluation

Refined exposure estimates for boron and molybdenum in combined Gila River soils did not exceed either the NOAEL or LOAEL. Additionally, none of the COPECs evaluated within the riparian areas of the Site exceeded threshold values for either kidney or liver tissue in herbivorous small mammal species. The refined estimate for lead in herbivore kidney tissue of small mammals exposed to upland soils exceeded the tissue-based threshold and was considered to pose possible risk to cottontail populations, whereas this estimate in wash soils did not exceed the toxicity threshold. Although the refined oral exposure estimate for lead in upland soils did not exceed the NOAEL (i.e., no risk), oral and tissue-based exposure estimates are of equal weight, so risk from lead cannot be excluded. In the wash areas, the results for both the oral exposure estimate and the tissue-based estimate support a conclusion of no risk from lead. Oral exposure estimates indicate that risks from copper, molybdenum, and selenium in upland soils and molybdenum in wash soils are possible.

The weight-of-evidence conclusion is that exposure to COPECs in the riparian areas of the Site does not pose a risk to desert cottontail populations. Although oral exposure estimates for lead in the upland areas predicted no risk, tissue-based exposure estimates indicated a possible risk. Therefore, risk from lead in the upland areas cannot be excluded. Risk to desert cottontail populations from exposure to copper, selenium, and molybdenum in the upland areas and molybdenum in the wash areas are possible.

5.7.2.6 Desert Shrew

Oral exposures and tissue-based exposure lines of evidence were available for the desert shrew.

Oral Exposures

Cyanide, iron mercury, selenium, and silver exposure estimates in the stable and unstable riparian areas of the Gila and San Pedro river floodplains, as well as copper and molybdenum in combined Gila River soils failed the initial (Table 4-14) and background screening (Table 5-2). Within the upland and wash areas, antimony, arsenic, cadmium, chromium, cobalt, copper, cyanide, iron, lead, mercury, molybdenum, nickel, selenium, silver, vanadium, and zinc failed the initial and background screenings. Additionally, thallium in wash soils failed the initial and background screenings.

Riparian Soils. Refined exposure estimates for cyanide, selenium, and silver in Gila River riparian soils and cyanide and silver in San Pedro River soils did not exceed their respective NOAELs or LOAELs (Table 5-30). Mercury exposure estimates from both watersheds and molybdenum in combined Gila River soils exceeded the NOAEL, but not the LOAEL. Therefore, cyanide, mercury and silver in riparian soils from both rivers and molybdenum and selenium in Gila River riparian soils do not pose a risk to desert shrew populations. The detection limit for selenium in stable and unstable riparian soils of the San Pedro River floodplain exceeded the NOAEL and LOAEL. Although this indicates a possible risk to shrew populations in this area, this risk is uncertain due to an insufficient detection limit (i.e., the exceedance is due solely to the detection limit). Risks from exposure to iron in riparian soils of both rivers are uncertain, but are not considered to be likely.

Upland Soils. The refined exposure estimate for cobalt did not exceed either the NOAEL or the LOAEL, and those for chromium, mercury, nickel, and silver exceeded the NOAEL, but not the LOAEL (Table 5-30). Therefore, chromium, cobalt, mercury, nickel, and silver do not pose a risk to desert shrew populations in the upland areas. Refined exposure estimates for antimony, arsenic, cadmium, copper, lead, molybdenum, selenium, vanadium, and zinc exceeded their respective NOAELs and LOAELs, and are considered to pose possible risk to shrew populations. Cyanide risk estimates exceeded the NOAEL and LOAEL; however, this COPEC was not detected in any upland sample. Therefore, risks are uncertain due to an insufficient detection limit. Risks from iron are also uncertain, and are not considered likely.

Wash Soils. The refined exposure estimates for chromium, cobalt, silver, thallium, and zinc did not exceed either the NOAEL or the LOAEL, and those for antimony, arsenic, mercury, nickel, and vanadium exceeded the NOAEL, but not the LOAEL (Table 5-30). Therefore, these COPECs do not pose a risk to desert shrew populations in the wash areas. The refined exposure estimates for cadmium, copper, lead, molybdenum, and selenium exceeded the NOAEL and LOAEL, though the magnitudes of exceedance for cadmium, lead, molybdenum, and selenium are low. Cyanide exposure exceeded the LOAEL, but risks are uncertain due to an insufficient detection limit. Risks from iron are also uncertain, but are not likely.

Tissue-based Exposures

Estimated concentrations of metals in small mammal tissues were compared to available tissue-based benchmarks in Section 4.6.2.2. Based on the results of the initial screening (Table 4-17) and the background evaluation (Table 5-2), only lead in the upland (soil-to-kidney and soil-to-liver pathways) and wash (soil-to-kidney pathway) soils and copper (soil-to-liver pathway) in upland and wash soils were retained for further evaluation of the desert shrew (insectivore).

Refined tissue-based exposure estimates were calculated using the 95 UCL lead and copper soil concentrations in the upland and wash areas (Table 5-29). For the upland area, the lead exposure estimate for insectivore kidney tissue exceeded the threshold for effects, though the estimate for lead in liver tissue did not. Additionally, the magnitude of exceedance was low (HQ = 1.5). In the wash areas, estimated lead in kidney tissue did not exceed the toxicity threshold. Estimated concentrations of copper in liver tissue for both the upland and wash areas exceeded toxicity thresholds.

Weight-of-Evidence Evaluation

Of the COPECs retained for the riparian areas, only copper in combined Gila River soils and selenium in San Pedro River combined stable and unstable riparian soils posed a possible risk to shrew populations. However, the risk from selenium is uncertain due to an insufficient detection limit. Additionally, none of the COPECs evaluated within the riparian areas of the Site exceeded threshold values for either kidney or liver tissue in insectivorous small mammal species. The refined estimate for lead in insectivore kidney tissue (upland areas) and copper in liver tissue (upland and wash areas) exceeded the tissue-based thresholds and were considered to pose possible risk to desert shrew populations. Although the magnitude of exceedance for these tissue-based exposures was very low, the finding of risk was consistent with a finding of possible risk using oral exposures of lead and copper in the upland areas and copper in the wash areas. The kidney tissue concentration estimated for lead in wash soils did not exceed the toxicity thresholds; however, the oral exposure estimate did exceed both the NOAEL and LOAEL. Because oral and tissue-based exposures have equal weight, risk from lead in the wash areas cannot be excluded. Oral exposure estimates also indicated that risks from antimony, arsenic, cadmium, molybdenum, selenium, vanadium, and zinc in upland soils and cadmium, molybdenum, and selenium in wash soils are possible. Risks from cyanide in the upland and wash areas are uncertain due to insufficient detection limits.

The weight-of-evidence conclusion is that exposures to all COPECs, except copper in Gila River riparian soils and selenium in San Pedro River soils, do not pose a risk to desert shrew populations. Although selenium concentrations in the riparian soils adjacent to the San Pedro River may cause a possible risk to shrew populations, this conclusion is highly uncertain due to an insufficient detection limit. Tissue-based exposure estimates for lead and copper in the upland soils and copper in the wash soils indicated a possible risk to the shrew populations in these areas of the Site. This conclusion of possible risk was supported by the evaluation of oral exposure estimates. Oral estimates of lead exposure in the wash areas also indicated a potential for risk. Therefore, risks from copper and lead in the upland and wash areas are possible. Additionally, exposure to antimony, arsenic, cadmium, molybdenum, selenium, vanadium, and zinc in the upland areas and cadmium, molybdenum, and selenium in the wash areas may pose a risk to desert shrew populations. Because detection limits were insufficient for cyanide, risks predicted for the upland and wash areas are highly uncertain.

5.7.2.7 Coyote

Molybdenum in combined Gila River riparian soils and iron in stable and unstable riparian soils of both rivers failed the initial screening evaluation for coyotes (Table 4-15), as well as the background evaluation (Table 5-2). Copper, iron, and molybdenum in both upland and wash soils and arsenic and lead in upland soils also failed both the initial and background screenings.

Riparian Soils. The refined exposure estimate for molybdenum in combined Gila River soils did not exceed either the NOAEL or the LOAEL. Therefore, risks to the coyote populations from exposure to molybdenum within the Gila River portions of the Site are not expected. Risks predicted from exposure to iron in riparian soils of both rivers are uncertain, but are not likely.

Upland Soils. The refined exposure estimates for arsenic and lead did not exceed either the NOAEL or the LOAEL (Table 5-31), and, therefore, do not pose a risk to coyote populations in the upland areas. Copper and molybdenum refined exposure estimates exceeded both the NOAEL and LOAEL, and are considered to pose possible risk to coyote populations. Risks from iron are uncertain, but unlikely.

Wash Soils. The refined exposure estimate for copper did not exceed either the NOAEL or the LOAEL, and that for molybdenum exceeded the NOAEL, but not the LOAEL (Table 5-31). Therefore, copper and molybdenum do not pose a risk to coyote populations in the wash areas. Risks from iron are uncertain, but are not considered to be likely.

The weight-of-evidence conclusion is that exposure to COPECs in the riparian and wash areas of the Site does not pose a risk to coyote populations utilizing these areas. Possible risks from exposure to copper and molybdenum in the upland areas cannot be excluded.

SECTION 6

Uncertainties

Uncertainties are inherent in all aspects of an ERA and include those related to problem formulation, exposure assessment, ecological effects assessment, and risk estimation and risk characterization. The uncertainties and limitations associated with the proposed methodology and available data for this SLERA are discussed below (in no particular order).

- Data concerning soil ingestion rates for the bird and mammal receptors were not available. Consequently, the soil ingestion rates were estimated based on assumed similarities to other species for which data were available. The suitability of these assumptions is unknown. Although this uncertainty may result in underestimation of exposure (and risk), it is more likely that exposure and risk are overestimated.
- No life history data specific to the sites were available; therefore, exposure parameters were either modeled on the basis of allometric relationships (e.g., food ingestion rates) or were based on data from the same species in other portions of its range. Because diet composition as well as food, water, and soil ingestion rates can differ among individuals and locations, published parameter values may not accurately reflect individuals present at the Site. Consequently, risk may be either overestimated or underestimated.
- No site-specific data on COPEC concentrations in terrestrial plants, terrestrial invertebrates, and small mammals were available for wildlife exposure estimate calculations. Therefore, concentrations in these prey items were estimated from literature-reported bioaccumulation models (90th percentile BAFs or regressions in the initial screening and median BAFs or regressions in the refined screening). The suitability of these bioaccumulation models is unknown. Consequently, concentrations of COPECs in prey items of wildlife may be either greater or less than data used in this assessment.
- Literature-derived toxicity data based on laboratory studies were used to evaluate risk to all receptor groups. It is assumed that effects observed in laboratory species were indicative of effects that would occur in wild species. The suitability of this assumption is unknown. Consequently, risk may be either overestimated or underestimated.
- Toxicity data were not available for some COPEC/receptor combinations considered in this assessment (e.g., cyanide benchmarks were not available for terrestrial plants and invertebrates, soil microbes, and birds). Therefore, COPECs for which toxicity data were unavailable were not evaluated (but were retained as uncertainties). Exclusion of COPECs from evaluation underestimates aggregate risk.
- Reporting limits for some COPECs exceeded the benchmark values (e.g., detection limits for thallium and selenium exceeded screening benchmarks for terrestrial plants). As a consequence, interpretation of risk for these COPECs was considered uncertain, but risk was not excluded. This may overestimate risk.

- Bioavailability in the toxicity studies used for development of TRVs is generally high because many toxicity tests are performed using soluble salts of inorganic chemicals (as in the case of chromium toxicity to plants). Therefore, risk based solely on literature-derived toxicity values may be overestimated.
- Bioavailability data were available for arsenic, barium, cadmium, copper, lead, mercury, selenium, and zinc and were applied to the dose estimate for bird and mammal receptors in the refined SLERA. These data were derived from literature sources. Because the bioavailability of an analyte depends on site-specific conditions (e.g., pH, interactions with other analytes, etc.), these literature-based values may not accurately represent the actual bioavailability of these analytes at the Site. Consequently, risk may be either overestimated or underestimated.
- In this assessment, risks from COPECs were each considered independently (i.e., no ambient media toxicity data were available, and interactions among COPECs in laboratory studies were not considered). Because chemicals may interact in an additive, antagonistic, or synergistic manner, evaluation of single-chemical risk may either underestimate or overestimate risks associated with chemical mixtures.
- The models used to estimate concentrations of cadmium, copper, lead, mercury, and zinc in kidney and liver tissue, as well as arsenic in liver tissue, of small mammals were based on data derived from published studies. It was assumed that the bioavailability and bioaccumulation relationships described in these models were applicable to arsenic, cadmium, copper, lead, mercury, and zinc in soil from the Site. This uncertainty may result in an overestimation or underestimation of exposure and risk.
- Data required for development of background values for aluminum, boron, calcium, cyanide, iron, magnesium, manganese, potassium, and sodium in soil were not available. Predictions of risk for these COPECs are uncertain because comparisons to local concentrations typical of the region and geologic formation were not possible. However, it should be noted that all onsite concentrations of boron, iron, and manganese were found to be within background values reported for the United States or for Arizona. This suggests that risks from these analytes are unlikely.
- Background data for sediment were limited, precluding adequate background analysis. The inability to make background comparisons may overestimate risk because onsite concentrations of locally or regionally abundant analytes may be consistent with background.

SECTION 7

Conclusions and Recommendations

Historic and current activities at the ASARCO LLC Hayden Plant Site resulted in release of contaminants (primarily metals and other inorganics) from smelter emissions, crushing and concentrator operations, the tailings impoundments, process water discharges to unlined ponds, and other process operations to the air, surface soil, sediments, and groundwater in the Hayden area. Discharge/runoff from the tailings impoundments and drainages into the Gila River and aerial deposition of contaminants were the primary release mechanisms of concern to ecological receptors. This SLERA was conducted in support of the RI for the Site. Risks to ecological receptors in the vicinity of the Site were evaluated, and the risk conclusions are summarized below (Section 7.1) along with recommendations based on those conclusions (Section 7.2).

7.1 Conclusions

The risks conclusions for the SLERA are described below for the aquatic and terrestrial portions of the Site.

7.1.1 Aquatic Portions of the Site

Aquatic plants, water-column invertebrates, fish, amphibians, and aquatic birds and mammals were evaluated using surface water and/or sediment collected along the Gila and San Pedro rivers. Based on the results of the initial screening, ammonia (as N) and chromium in both rivers, and cobalt, nickel, and strontium in the San Pedro River were excluded from further evaluation in the refined screening for aquatic receptors. All other COPECs were retained for evaluation in the refined screening step for at least one aquatic receptor. The refined screening results for these receptors by river are summarized in Table 7-1 and are discussed below:

- **Freshwater Aquatic Organisms (surface water; Table 7-1)**: Two lines of evidence were available for aquatic organisms (aquatic plant, water-column invertebrate, fish, and amphibian communities), including media-based effects data and site-specific fish monitoring data. Refined screening results indicate:
  - Risks from **cyanide and dissolved mercury** in the San Pedro River are uncertain due to insufficient detection limits.
  - Possible risks from **beryllium**, **cyanide**, and **dissolved mercury** in the Gila River, though the extent of these risks is uncertain due to an insufficient detection limit.
  - Possible risks from **aluminum**, **barium**, **boron**, **iron**, and **manganese** in Gila River surface water and **aluminum**, **barium**, **beryllium**, **boron**, **calcium**, **iron**, **manganese**, **TDS**, and **vanadium** in San Pedro River surface water.

  - A decline in native fish species, but this decline was consistent among both onsite and offsite stations and may have been related to drought conditions in the area. Results neither support nor exclude potential for risk.

- **Benthic Invertebrates (sediment; Table 7-1)**: Refined screening results for benthic invertebrate communities using media-based effects data indicate:
  - Risks from **cyanide** in both the Gila and San Pedro rivers are uncertain due to an insufficient detection limit.
  - No other COPECs in sediment are likely to present a risk to the benthic invertebrate community in the onsite portions of the Gila and San Pedro rivers.
- Aquatic Birds and Mammals (sediment, surface water, and modeled diet; Table 7-1):
  - **Swallow:** Possible risks from exposure to **iron** in both rivers.
  - **Belted Kingfisher***:* Possible risks from exposure to **cadmium** in both rivers and **mercury** in the Gila River.
  - **Little Brown Bat:** Possible risks to individual little brown bats from exposure to **beryllium** and **iron** in both rivers, but uncertain risk to bat populations. Possible risk to bat populations from exposure to **copper** in the Gila River and **selenium** in the San Pedro River. Although risks from **cyanide** were predicted in both rivers, these risks are uncertain due to an insufficient detection limit.
  - **Mink***:* Possible risk to individual mink from exposure to **iron** in both rivers, but uncertain risk to mink populations. Possible risks to mink populations from exposure to **mercury** in the Gila River.

7.1.2 Terrestrial Portions of the Site

Terrestrial plants, soil invertebrates, soil microbes, and terrestrial birds and mammals were evaluated using surface water (birds and mammals only) and riparian soil (combined stable and unstable, and stable or unstable, separately) collected along the Gila and San Pedro rivers and surface water from the Gila River (birds and mammals only) and upland or wash soil. In addition, terrestrial plants were evaluated using groundwater from the Gila River floodplain. Based on the results of the initial screening, barium and beryllium in all soil categories, arsenic in combined stable and unstable San Pedro River soil, and cobalt in stable Gila River soil and stable and unstable San Pedro River soil were not evaluated in the refined screening for terrestrial receptors. It should be noted that boron, iron, and manganese exceeded toxicity thresholds for at least one terrestrial receptor in at least one soil category. In the cases of iron and manganese, these exceedances were pervasive across soil categories and receptors. Because these three metals lacked sufficient data to develop background UTLs, predicted risks are uncertain. However, risks to terrestrial biota from these three COPECs are unlikely because all of the concentrations measured in all soil categories at the Site are within background ranges reported by EPA (EPA 2003c, 2007c) and the U.S. Geological Survey (Shacklette and Boerngen 1984). The refined screening results for these receptors by soil type and watershed are summarized in Table 7-2 and are discussed below:

- **Terrestrial Plants (soil and groundwater; Table 7-2)**: Two lines of evidence were available for evaluation of terrestrial plants, including media-based effects data and site-specific field studies of the upland and riparian habitats within the study area. Refined screening results indicate:
  - Possible risks to riparian plant communities from **arsenic** and **manganese** in groundwater from the Gila River floodplain.
  - Possible risks to riparian plant communities from exposure to **copper** and **molybdenum** in soils from the Gila River portion of the Site.
  - Risks from **selenium** in Gila River and San Pedro River riparian soils are uncertain due to insufficient detection limits.
  - Possible risks from exposure to **arsenic**, **cobalt**, **copper**, **lead**, **molybdenum**, **selenium**, **vanadium**, and **zinc** in upland soils and **arsenic**, **cobalt**, **copper**, **molybdenum**, **selenium**, **thallium**, and **zinc** in wash soils.
  - Risks from **boron** in combined Gila River, upland, and wash soils; **iron** stable and unstable riparian soils of both rivers and upland soils; and **manganese** in stable and unstable Gila River, unstable San Pedro River, upland, and wash soils are uncertain, but unlikely.
  - Upland plant surveys did not detect any observable adverse effects in these areas, whereas minimal effects (unexplained signs of stress at one location) were observed in the riparian areas.
- **Soil Invertebrates (soil; Table 7-2)**: Refined screening results for soil invertebrate communities using media-based effects data indicate:
  - Possible risks from **copper** in combined riparian soils of the Gila River portions of the Site.
  - Possible risks from **arsenic**, **copper**, **mercury**, and **zinc** concentrations in upland soils and **copper** and **zinc** in wash soils.
  - Risks from **manganese** in stable and unstable Gila River, unstable San Pedro, upland, and wash soils are uncertain, but unlikely.
- **Soil Microbial Processes (soil; Table 7-2)**: Refined screening results for soil microbe communities using media-based effects data indicate:
  - Possible risks from **copper** in combined riparian soils of the Gila River portions of the Site.
  - Possible risks from **copper**, **vanadium**, and **zinc** in upland and wash soils.
  - Risks from **iron** and **manganese** in all soil categories uncertain, but unlikely.

- **Terrestrial Birds and Mammals (soil, surface water, and modeled diet; Table 7-2):**
  - **Mourning Dove:** No unacceptable risks in the riparian and wash areas of the Site. Possible risks from exposure to **cadmium**, **copper**, **lead**, **molybdenum**, and **selenium** in the upland areas.
  - **Curve-billed Thrasher***:* No unacceptable risks in riparian areas of the Site. Possible risks from exposure to **cadmium**, **copper**, **lead**, **molybdenum**, **selenium**, **silver**, and **zinc** in upland soils and **cadmium, copper**, and **lead** in wash soils.
  - **Red-tailed Hawk:** No unacceptable risks in the riparian and wash areas of the Site. Possible risks from exposure to **lead** and **molybdenum** in upland soils.
  - **Southwestern Willow Flycatcher***:* Three lines of evidence were available for evaluation of southwestern willow flycatchers, including oral effects data, tissue-based effects data, and field studies within the vicinity of the Site. Refined screening results indicate:
    - Risks from exposure to **selenium** in the San Pedro River riparian areas are uncertain due to insufficient detection limits.
    - Possible risks from exposure to **mercury** in both riparian areas, **copper** in Gila River riparian areas, **chromium**, **mercury**, and **thallium** in upland areas, and **chromium**, **mercury**, **molybdenum**, **selenium**, **silver**, and **thallium** in wash areas.
    - Probable risks to individual southwestern willow flycatchers from exposure to **cadmium**, **copper**, **lead**, and **zinc** in upland and wash soils and **molybdenum**, **selenium**, and **silver** in upland soils.
    - Egg tissue concentration data support possible risks from exposure to **zinc.**
    - Southwestern willow flycatcher populations are declining in Arizona, but evidence that contaminants are contributing to this decline is inconclusive. Results do not contradict risk conclusions, but provide little additional support.
  - **Desert Cottontail:** Two lines of evidence were available for evaluation of desert cottontails, including oral effects data and tissue-based effects data. Refined screening results indicate:
    - No unacceptable risks in the riparian areas of the Site.
    - Possible risks from exposure to **copper**, **lead** (based on tissue exposure), **molybdenum**, and **selenium** in the upland areas and **molybdenum** in the wash areas.
  - **Desert Shrew:** Two lines of evidence were available for evaluation of desert shrews, including oral effects data and tissue-based effects data. Refined screening results indicate:
    - Risks from exposure to **selenium** in riparian areas of the San Pedro River and **cyanide** in upland and wash areas are uncertain due to insufficient detection limits.

- Possible risks from exposure to **copper** in Gila River riparian soils, **antimony**, **arsenic**, **cadmium**, **copper** (based on oral and tissue exposures), **lead** (based on oral and tissue exposures), **molybdenum**, **selenium**, **vanadium**, and **zinc** in the upland areas and **cadmium**, **copper** (based on oral and tissue exposures), **lead** (based on oral exposure), **molybdenum**, and **selenium** in the wash areas.

– **Coyote:** No unacceptable risks in the riparian and wash areas of the Site. Possible risks from exposure to **copper** and **molybdenum** in the upland areas.

7.2 Recommendations

Based on conclusions summarized above, the following recommendations would serve to reduce uncertainties associated with the risk estimates:

1. Multiple chemicals exceeded surface water screening values for aquatic organisms and soil screening values for plants and soil invertebrates. Because some chemicals may interact (in additive, antagonistic, or synergistic ways), the actual site-specific risks are somewhat uncertain. Ambient media bioassays, in which receptors are exposed to site media, would serve to reduce this uncertainty. Sediment bioassays are not recommended at the Site because no risks to benthic invertebrates were identified. However, surface water bioassays using fish and *Ceriodaphnia* (a water-column invertebrate) would serve to reduce uncertainties associated with the risks from surface water. Similarly, soil bioassays using appropriate terrestrial plant and invertebrate species would reduce the uncertainties related to risks from soils. However, soil bioassays are recommended only for the upland, and possibly wash, areas of the Site because little or no risks were observed for the riparian soils.

   It should be noted that surface water bioassays are not expected to reduce all uncertainties. In particular, flow in the Gila River is dominated by upstream sources such that determining the source of contamination (i.e., on-site vs. upstream) will be difficult. Therefore, sampling for the bioassays would require limitations in time, space, and flow regime. During the groundwater investigation conducted under the RI, hydrologic connections between groundwater and surface water were observed. Specifically, groundwater under the ASARCO operations was discharged to the Gila River during the wet periods. Slurry water leaching from the tailings impoundments was found to mound above the aquifer and also discharged to surface water in wet periods. During dry periods, water is released from the upstream Coolidge Dam and surface water in the Gila River provides some recharge to the aquifer. These patterns of groundwater discharge and recharge suggest that wet periods would be most suitable for collection of bioassay samples because groundwater from the Site is discharged to Gila River during this time. It would also be important to collected several surface water bioassay samples upstream of the Site on both the Gila and San Pedro Rivers.

2. Exposure estimates for birds and mammals included the use of literature-based bioaccumulation models. Because the applicability of these models to the Site is unknown, development of site-specific bioaccumulation models would serve to reduce uncertainties in the risk estimates for birds and mammals. This can be accomplished through collection of co-located abiotic media and biota samples. Development of soil-

to-plant and soil-to-invertebrate bioaccumulation models for the upland and wash areas is recommended.

3. The detection limits for some analyte/medium combinations exceeded screening benchmarks for one or more receptors (e.g., selenium and thallium in riparian soils). This indicates that the detection limit was too high and risks are uncertain. Therefore, additional sampling and laboratory analysis using methods to obtain lower detection limits, particularly for selenium and thallium in the riparian areas, may be appropriate. However, it is recommended only if additional sampling is planned in these areas (e.g., collection of soil samples to obtain site-specific bioaccumulation data or to obtain more background data).

4. Background data for sediment were very limited; therefore, adequate background comparisons could not be conducted (though a comparison to upstream and downstream sediment was possible). Collection of additional sediment data from background areas would reduce this uncertainty. However, these additional data may not add value to the risk assessment. Surface water levels and flows in both the Gila and San Pedro rivers are highly variable. At some times during the year, the streambeds are dry, whereas at other times, flash floods or releases from Coolidge Dam on the Gila River result in high flows. Therefore, sediments in these riverbeds are often very mobile and may not store contaminants at high levels. Additionally, current data suggest that cleaner sediments from the San Pedro River may dilute onsite sediment in the Gila River downstream of the confluence of the two rivers.

   In the upland areas, additional background data could be used to determine how much of the observed toxicity is related to the local geology of the area versus the result of contaminant discharges from the Site. Additionally, background measurements of boron, iron, and manganese in soils from the Qal, Qo, and Ts geologic formations would allow for the calculation of background UTLs and may reduce the uncertainty associated with predicted risks to terrestrial receptors from exposure to these analytes.

5. The results of the SLERA indicate widespread risks among the upland, and to a lesser extent, wash areas. It is possible that additional study of these areas is needed to determine the spatial extent of these risks. As a first step, the XRF data collected for the RI could be evaluated for key contaminants (e.g., copper). This may lead to a recommendation of additional, limited sampling in the upland areas of the Site.

SECTION 8

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