PUBLIC REVIEW DRAFT

BASELINE ECOLOGICAL RISK ASSESSMENT FOR THE STANDARD MINE SITE GUNNISON COUNTY, COLORADO

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LIST OF ACRONYMS AND ABBREVIATIONS

AUF	Area Use Factor
AWQC	Ambient Water Quality Criteria
BERA	Baseline Ecological Risk Assessment
CDOW	Colorado Department of Fish and Wildlife
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
DF	Dietary Fraction
EPC	Exposure Point Concentration
GLWQI	Great Lakes Water Quality Initiatives
HQ	Hazard Quotient
LOAEL	Lowest Observed Adverse Effect Level
NOAEL	No Observed Adverse Effect Level
PEC	Probable Effect Concentration
RBA	Relative Bioavailability
RBP	Rapid Bioassessment Protocol
SLERA	Screening-Level Ecological Risk Assessment
TEC	Threshold Effect Concentration
TRV	Toxicity Reference Value
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency

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EXECUTIVE SUMMARY

PURPOSE OF THIS DOCUMENT

This document is a Baseline Ecological Risk Assessment (BERA) for the Standard Mine site, which is located in Gunnison County, Colorado. The purpose of the BERA is to describe the likelihood, nature, and extent of adverse effects to ecological receptors resulting from exposure to contaminants released to the environment as a result of past or present mining activities at the site. This information, along with other relevant information, is used by risk managers to decide whether remedial actions are needed to protect the environment from site-related releases.

SITE DESCRIPTION

The Standard Mine Site is located in heavily forested mountainous terrain about 5 miles west of the community of Crested Butte. The site is drained by Elk Creek, which flows primarily south from the site until it joins Coal Creek, which flows eastward toward Crested Butte. Both Elk Creek and Coal Creek are habitat for a variety of aquatic species, including coldwater fish (primarily brook trout) and a variety of benthic macroinvertebrates. Vegetation in the vicinity of the site ranges from lush willow and scrub undergrowth in the stream bottoms through aspen, fir, and spruce forests on the mountain slopes to treeless alpine tundra vegetation on the ridge tops. The area is suitable habitat for a wide variety of birds and mammals.

BASIS FOR CONCERN

Mining activities often result in soil contamination with several types of solid wastes (tailings, ore, waste rock) that contain elevated levels of a number of metals. In addition, mine adits often serve as a pathway for release of contaminated water into area streams. At this site, there is clear evidence for the presence of tailings and other solid wastes at and around the site, and the main adit at the site has been observed to discharge contaminated water into Elk Creek.

SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

Characterization of ecological risks at the site began with the preparation of a screening level ecological risk assessment (SLERA). The purpose of the SLERA was to formulate an initial conceptual model that characterized ecological exposure scenarios of potential concern, to determine which, if any, exposure scenarios may be excluded from further assessment, and to identify data gaps that limit confidence in the initial risk characterization. The SLERA identified the following exposure pathways as the primary means by which ecological receptors might be impacted by contaminants released from the site into the environment:

- Direct contact of fish and benthic invertebrates with surface water
- Direct contact of benthic invertebrates with sediment
- Direct contact of terrestrial plants and soil invertebrates with on-site soil
- Ingestion of on-site soil, surface water, and food items by birds and mammals

Each of these exposure pathways was evaluated in the SLERA using the data that were available at that time, and using simplified and conservative approaches. The SLERA found that none of the exposure scenarios listed above could be excluded from further evaluation, so all were carried forward to the BERA for further analysis.

APPROACH USED IN THE BERA

Based on the results of the SLERA, the BERA performed a more detailed assessment of each of the exposures scenarios above, using new data that were collected by EPA to support the assessment. Whenever possible, the assessment considered the findings from three alternate approaches for risk characterization:

- Hazard Quotients (HQs)
- Site-specific toxicity tests
- Observations of population and community demographics

Because each of these approaches has advantages and limitations, final conclusions were based on a weight of evidence consideration of all of the available data.

RISK EVALUATION FOR AQUATIC RECEPTORS

Aquatic receptors living in Elk and Coal Creeks may be exposed to site-related contaminants through two main pathways:

- Direct contact with chemicals in surface water. This pathway is applicable to fish and to benthic organisms that reside in the uppermost portion of the sediment substrate or the water column.

- Direct contact with chemicals in sediment. This pathway is most applicable to benthic invertebrate species that live within the sediment substrate.

The finding for each of these media are summarized below.

Evaluations of Risks to Aquatic Receptors from Surface Water

Three lines of evidence were evaluated to assess the potential effects of contaminated surface water on aquatic receptors.

- The HQ approach identified numerous chemicals (cadmium, copper, lead, manganese and zinc) that yielded HQ values in a range of potential concern. Highest values were observed in Elk Creek. For Coal Creek immediately downstream of the confluence with Elk Creek, HQ values were lower than in Elk Creek, but several chemicals continued to be above a level of concern for acute and/or chronic exposures.

- Site specific surface water toxicity tests performed using rainbow trout fry showed high mortality (60-100%) for waters collected from Elk Creek. The highest mortality (100%) was observed at the upstream stations closest to the mine, and there was tendency for a slight decrease in mortality with increasing distance from Standard Mine. Fish exposed to water from Coal Creek immediately downstream of the confluence with Elk Creek showed low mortality, and this level of mortality was not different than observed in Coal Creek just upstream of Elk Creek. This suggests that waters from Elk Creek are sufficiently diluted by Coal Creek that site-related contaminants have only a minimal impact the survival of fish in Coal Creek.

- Fish surveys performed along Elk Creek indicate that some fish are present at the mouth of the creek (possibly immigrants from Coal Creek), but that there are no fish present at stations above the mouth. This observations supports the conclusion that water in Elk Creek is toxic to fish. Fish density and biomass appear to be generally similar in Coal Creek above and below the confluence with Elk Creek. This suggests that fish in Coal Creek are not strongly impacted by releases from Elk Creek.

Based on these three lines of evidence, the weight of evidence conclusions regarding risks to aquatic receptors from contaminants in surface water are as follows:

- Mining-related releases from Standard Mine into surface water are substantially toxic to fish in Elk Creek.

- Water discharged from Elk Creek into Coal Creek elevates concentrations of metals in Coal Creek but this appears to have only minimal to moderate toxicity on fish.

Evaluations of Risks to Benthic Invertebrates from Sediment

Four lines of evidence were evaluated to assess the potential effects of contaminated sediments on benthic macroinvertebrates.

- An HQ approach based on measurements of metals in bulk sediment in Elk Creek identified a number of chemicals with HQ values in a range of concern, including cadmium, copper, lead, silver and zinc. For Coal Creek immediately downstream of the

confluence with Elk Creek, HQ values were lower than in Elk Creek, but a number of chemicals had HQ values that remained in a range of concern.

- An HQ approach based on measurements of metals in sediment pore water in Elk Creek identified a number of chemicals with HQ values in a range of concern, especially cadmium and zinc. In Coal Creek just downstream of the confluence with Elk Creek, porewater-based HQ values remained elevated for most chemicals, but the magnitude of the exceedences was generally low.

- Site-specific sediment toxicity tests using a small freshwater crustacean (*Hyalella azteca)* revealed very high (98-100%) mortality for all Elk Creek locations tested. Toxicity test results for Coal Creek immediately downstream of the confluence with Elk Creek showed low mortality that was similar to that seen in Coal Creek upstream of Elk Creek, suggesting that sediments from Elk Creek are not having a clear effect on benthic invertebrates in Coal Creek.

- Benthic macroinvertebrates surveys performed by EPA in 2005 and 2006 reveal decreased density and diversity of organisms in Elk Creek compared to a reference station, especially in the upper reaches of Elk Creek just below the mine. When the benthic community data are adjusted for habitat factors, observations in Elk Creek below the mine indicate that the benthic communities are of lower quality than expected based on habitat factors alone, indicating a probable effect of water and/or sediment contamination from Standard Mine. For Coal Creek, the results suggest a slight impairment to the benthic community, but less than in Elk Creek.

Based on these multiple lines of evidence, it is concluded that sediments in Elk Creek are likely to have significant adverse effects on benthic organisms residing in the sediment, but that hazards are lower and of lesser concern in Coal Creek.

RISK EVALUATION FOR PLANTS AND SOIL INVERTEBRATES

The plant and soil invertebrate community are important components of any ecosystem because they provide a significant portion of the energy, organic matter, and nutrient inputs for terrestrial systems as well as providing habitat and forage for a variety of wildlife species. Terrestrial plants and soil invertebrates are good indicators of soil condition because they reside directly in the soil and are not mobile.

EPA collected an extensive set of soil samples from the Standard Mine site, and these samples were used to assess risks to plants and soil invertebrates using the HQ approach. Site-specific toxicity tests and community surveys are not available.

Based on the HQ approach, there are a number of metals in on-site soils that are of potential concern for plants and/or soil invertebrates, including aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, selenium, silver, thallium, vanadium, and zinc. Some of these chemicals may not be higher than background, but the data are too limited to support any firm conclusions.

These predictions of risk to plants and soil invertebrates must be interpreted with caution, for two reasons. First, data on the concentrations of metals in soil that cause toxicity to plants and soil invertebrates are usually based on laboratory studies in which soluble forms of test metals are added to test soils. Thus, these values do not account for occurrence of metals in mineral forms that are largely insoluble and do not contribute as much toxicity as soluble forms. Second, because only one line of evidence is available, other lines of evidence (site-specific toxicity tests and/or community surveys) would be needed to further clarify the actual risks from site-related contaminants to plants and soil invertebrates.

RISK EVALUATION FOR BIRDS AND MAMMALS

Birds and mammals that reside on or near the Standard Mine site may be exposed by three pathways: 1) ingestion of contaminated food items, 2) incidental ingestion of soil or sediment while feeding, and 3) ingestion of on-site surface waters. Only one line of evidence (the HQ approach) is available for assessment of risks to birds and mammals from these pathways. This approach was used to assess risks to a number of different receptors, each selected to represent a feeding guild that might occur at the site. This included:

Feeding Guild	Representative Avian Species	Representative Mammalian Species
Aerial and/or Terrestrial Insectivores	Cliff Swallow Northern Flicker	Big Brown Bat Masked Shrew
Aquatic Insectivores	American Dipper	
Herbivores	Greater-Sage Grouse	Mule Deer
Omnivores	American Robin	Deer Mouse
Piscivores	Belted Kingfisher	
Carnivores	Red-tailed Hawk	Red Fox Lynx

As noted above, EPA collected an extensive data set for on-site soils and surface water, and also collected and analyzed a number of samples of plants, benthic invertebrates and fish for use in estimating dietary exposure of various receptors. Data on contaminant levels in tissues were not

collected for soil invertebrates or small mammals, so tissue concentrations for these food categories were estimated using mathematical models.

In this case, two different types of HQ values were calculated. The first type is based on the No-Observed-Adverse-Effect-Level (NOAEL), which is an estimate of the highest daily dose of a chemical that may be ingested without any unacceptable adverse effect occurring. The second type is based on the Lowest-Observed-Adverse-Effect-Level (LOAEL), which is an estimate of the lowest ingested daily dose that is likely to result in an observable adverse effect. If an HQ is below 1 based on the NOAEL TRV, it is believed that risks are minimal. If the HQ is above 1 based on the LOAEL TRV, it is considered likely that some adverse effects will occur. If the HQ is above 1 based on the NOAEL and below 1 based on the LOAEL, it is considered that adverse effects are possible, but they are likely to be minor in extent and/or severity.

Many receptors (cliff swallow, dipper, sage grouse, kingfisher, red-tailed hawk, mule deer, fox, lynx, and bat) have no significant HQ exceedences based on either the NOAEL- or LOAEL-based TRV. This indicates that risk to these receptors from site-related contaminants is likely to be minimal. There are four receptors (robin, flicker, shrew, and mouse) that have NOAEL-based HQ values above 1 for multiple chemicals. These elevated HQ values are attributable to intake of contaminants in soil and/or diet (terrestrial invertebrates), with no significant contribution from surface water. However, in nearly all cases, LOAEL-based HQ values did not exceed 1. These results indicate that the magnitude and/or severity of any adverse effects on these four receptors is likely to be low to moderate.

These conclusions regarding risks to birds and mammals must be interpreted with caution, since calculations of exposure require a number of assumptions and approximations, and toxicity data are limited for many of the receptor types included in the assessment. In particular, HQ values may be overestimated for receptors with a high intake of soil and/or a high dietary intake of terrestrial invertebrates (e.g., robin, flicker, shrew and mouse), since conservative assumptions were employed in estimating intake and absorption from these pathways. In addition, because only one line of evidence is available, other lines of evidence (site-specific toxicity tests and/or community surveys) would be needed to further clarify the actual risks from site-related contaminants to birds and mammals.

1.0 INTRODUCTION

1.1 Purpose of This Document

This document is a Baseline Ecological Risk Assessment (BERA) for the Standard Mine site, which is located in Gunnison County, CO. The purpose of the BERA is to describe the likelihood, nature, and extent of adverse effects to ecological receptors resulting from exposure to contaminants released to the environment as a result of past or present site activities. This information, along with other relevant information, is used by risk managers to decide whether remedial actions are needed to protect the environment from site-related releases.

1.2 Overview of the Ecological Risk Assessment Process

This BERA was performed in accordance with current United States Environmental Protection Agency (USEPA) guidance for ecological risk assessments (USEPA, 1992; 1997; 1998). The general sequence of steps used to carry out an ecological risk assessment at a Superfund site is illustrated in Figure 1-1 (USEPA, 1997).

As seen, the ecological risk assessment process consists of eight steps. The first two steps are screening-level evaluations that are intentionally simplified and conservative, and usually tend to overestimate the amount of potential risk. This allows for the elimination of those factors that are not associated with risk, allowing subsequent efforts to focus on factors that are of potential concern. These two screening level steps have been completed previously, and are presented in the Screening Level Ecological Risk Assessment for the Standard Mine site (USEPA 2006).

The remaining steps of the 8-step process are intended to support the development of the baseline assessment. This includes the process of problem formulation (Step 3), collection of data needed to support the baseline assessment (Steps 4-6), evaluation and interpretation of the data (Step 7), and use of the data to make risk management decisions (Step 8). It is important to realize that the steps shown in Figure 1-1 are not intended to represent a linear sequence of mandatory tasks. Rather, some tasks may proceed in parallel, some tasks may be performed in a phased or iterative fashion, and some tasks may be judged to be unnecessary at certain sites.

1.3 Document Organization

In addition to this introduction, this report is organized into the following main sections.

> **Section 2** - This section describes the location, history, and environmental setting of the Standard Mine site.

Section 3 - This section presents the ecological problem formulation, including a summary of the preliminary findings and conclusions from the screening assessment, the site conceptual model, the selection of assessment and measurement endpoints, and a description of the basic methods used in the baseline assessment.

Section 4 - This section presents the ecological risk characterization for aquatic receptors of concern.

Section 5 - This section presents the ecological risk characterization for terrestrial plants and soil organisms.

Section 6 - This section presents the ecological risk characterization for birds and mammals.

Section 7 - This section provides citations for all data, methods, studies, and reports utilized in the BERA.

2.0 SITE CHARACTERIZATION

2.1 Site Location

The Standard Mine is located within the Coal Creek Watershed in Gunnison County, Colorado, about 5 miles west of the community of Crested Butte. A map of the site is provided in Figure 2-1. The watershed includes a total area of 24.4 square miles and lies in the Ruby-Anthracite Range of west central Colorado.

2.2 Site History

The Coal Creek Watershed has a long history of mining. Successive periods of mining activity have occurred in the area including precious metals extraction, coal mining, and the mining of heavy metals. Mining first began in the Irwin silver district in 1874 when the land was still a part of the Ute Indian Reservation. Silver mining activity ceased by 1890 in this area except for the Forest Queen Mine (URSOS, 1999). Gold, silver, zinc, and copper ores were sporadically to continuously mined between 1901 and 1974. The three largest producing mines were the Standard Mine, the Forest Queen Mine, and the Keystone Mine, all located on the south flank of the Scarp Ridge. The Keystone Mine was ranked third in silver production in Colorado for several years between 1955 and 1964 (URSOS, 2000). At present, active mining in the Coal Creek watershed has ceased.

2.3 Physical Setting

Most of the area near the mine is heavily forested, and is managed by the U.S. Forest Service (Stantec Consulting Ltd., 2005). The terrain is mountainous with incised stream valleys with steep slopes. Elevations range from a low of 8,900 feet above sea level at the town of Crested Butte, to a high of 13,000 feet above sea level along the Ruby Range at the western edge of the mining district. The Standard Mine Site and nearby lands are currently used by humans mainly for recreation. Multiple-use trails for horseback riding, hiking, and mountain biking exist for summer recreation and forest roads are used for cross-country skiing, snowshoeing, and snowmobiling in the winter. Motorized vehicle traffic during the summer months is high, especially along County Road 12. Off-road traffic on forest service roads also occurs during summer months in the watershed.

2.4 Ecological Setting

Aquatic Environment

The Standard Mine site is drained by Elk Creek, which is the primary surface water drainage from the southeastern half of the mining district (Figure 2-1). Elk Creek flows primarily south

and crosses County Road 12 approximately 4 miles west of Crested Butte, just before its confluence with Coal Creek. Coal Creek flows eastward out of Lake Irwin and receives waters from Forest Queen Mine drainage, Splain's Gulch, Elk Creek, Iron Bog, Keystone Mine drainage, and Wildcat Creek before reaching the town of Crested Butte, where it flows into the Slate River.

Benthic surveys that have been conducted in the area indicate that, similar to other high mountain areas in the Rocky Mountain west, unimpacted streams near the site are expected to be populated by a wide variety of insect species, including multiple species of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, and Diptera, as well as numerous other types of benthic invertebrates (ostracods, copepods, oligochaetes, etc) (Peckarsky, unpublished data). In addition, a number of fish species, including brown trout, brook trout, and Colorado River cutthroats, are expected to occur in streams in this area (CDOW 2006).

Terrestrial Environment

Vegetation ranges from lush willow and scrub undergrowth in the stream bottoms through aspen, fir, and spruce forests on the mountain slopes to treeless alpine tundra vegetation on the ridge tops more than 12,800 feet above sea level (URSOS 2000). The area around the site is suitable habitat for a wide variety of birds and mammals.

According to surveys performed by the State of Colorado, there are 74 bird species and 46 mammalian species that are abundant or common in Gunnison County (NDIS 2006). These species are listed in Table 2-1.

Threatened and Endangered Species in Gunnison County, Colorado

Table 2-2 identifies species that are considered threatened, endangered, or are of special concern to the Federal government and/or the State of Colorado, and which are known to occur in Gunnison County (NDIS 2006). There are no Federal or State listed species of fish in Gunnison County.

Note that not all of the species in Table 2-2 are equally likely to utilize the types of habitat that occur in the vicinity of the Standard Mine Site. Based on professional judgment, species that are thought to be most likely to occur in the area of the site include the lynx, the bald eagle, and potentially the boreal toad.

3.0 PROBLEM FORMULATION

Problem formulation is a planning step that identifies the major concerns and issues to be considered in an ecological risk assessment, along with a description of the basic approaches that will be used to characterize the potential risks that may exist.

3.1 Screening Level Ecological Risk Assessment

As noted previously, the problem formulation step is an iterative process that begins with an initial screening level ecological risk assessment (SLERA). The SLERA is performed using whatever data are available at the time, and employing intentionally simplified and conservative approaches. The purpose of the SLERA is to help refine the initial problem formulation by determining which, if any, exposure pathways may be excluded from further assessment, and to identify data gaps that limit confidence in the risk characterization. This screening-level assessment was completed for the Standard Mine Site in September 2006 (USEPA 2006). This section summarizes the main findings of the SLERA, which in turn helped refine the problem formulation step for the BERA.

Screening Level Conceptual Site Model

One of the earliest steps in problem formulation is development of a Conceptual Site Model (CSM). The purpose of the CSM is to summarize current understanding of the primary sources of environmental contamination at a site, and identify the exposure pathways by which environmental receptors at or near the site might be exposed to site-related contaminants.

Figure 3-1 presents the CSM that was developed for the screening-level evaluation at the Standard Mine site. As seen, there are a number of exposure pathways by which aquatic and terrestrial ecological receptors may come into contact with site-related contaminants, the most important of which are:

- Direct contact of fish and benthic invertebrates with surface water
- Direct contact of benthic invertebrates with sediment
- Direct contact of terrestrial plants and soil invertebrates with on-site soil
- Ingestion of on-site soil, surface water, and food items by birds and mammals

Each of these exposure pathways were evaluated in the SLERA, and the findings are summarized below.

Summary of Screening-Level Risk Findings

Table 3-1 provides a summary of the screening level risk findings presented in the SLERA. As

seen, screening level risks were above a level of potential concern for aquatic receptors exposed to a number of different mining-related contaminants in surface water and sediment, and screening level risks were above a level of potential concern for plants, invertebrates, birds and mammals exposed to a number of different mining-related contaminants in on-site soils. On this basis, a need for further assessment was identified for all of these exposure scenarios.

3.2 Conceptual Site Model for the Baseline Assessment

As discussed above, the CSM for the baseline assessment is the same as originally developed for the screening assessment (Figure 3-1). The main elements of the CSM for the baseline assessment are discussed below.

Aquatic Receptors

The aquatic receptors of chief concern at the site are fish that reside in Elk Creek and Coal Creek, as well as benthic macroinvertebrates that reside in the sediment.

For fish, the chief exposure pathway of concern is direct contact with surface water. This pathway is evaluated quantitatively. Another pathway of potential concern to fish is ingestion of contaminants that have been taken up into aquatic prey items (primarily benthic macroinvertebrates). This pathway is usually believed to be minor compared to risks from direct contact, so this pathway is not evaluated quantitatively in this assessment.

For benthic invertebrates, the exposure pathways of chief concern are direct contact with surface water and sediment, and each of these pathways is evaluated quantitatively. Ingestion of aquatic food web items (periphyton, detritus, other invertebrates) by benthic invertebrates is a pathway of potential concern, but quantitative evaluation of oral exposures for benthic invertebrates is limited by lack of oral toxicity values for this class of aquatic receptors. Therefore, ingestion exposures of invertebrates is not evaluated quantitatively.

Plants and Soil Organisms

The primary exposure pathway for both terrestrial plants and soil invertebrates is direct contact with contaminated soils. This pathway is evaluated quantitatively for both types of receptor. For terrestrial plants, exposure may also occur due to deposition of dust on foliar (leaf) surfaces, but this pathway is believed to be small compared to root exposures in surface soils, and so this pathway is not evaluated in this assessment.

Birds and Mammals

Birds and mammals may be exposed to site-related contaminants by three main pathways: ingestion of contaminants in or on prey items, incidental ingestion of soil while feeding, and

ingestion of contaminants in surface water used for drinking. All of these pathways are evaluated quantitatively in this assessment.

Direct contact (i.e., dermal exposure) of birds and mammals to soils may occur in some cases, but these exposures are usually considered to be minor in comparison to exposures from ingestion (USEPA, 2003), and are not evaluated quantitatively. Likewise, inhalation exposure to airborne dusts is possible for all birds and mammals, but this pathway is generally considered to be minor compared to ingestion pathways (USEPA, 2003), and is not evaluated quantitatively.

3.3 Management Goals

Management goals are descriptions of the basic objectives which the risk manager at a site wishes to achieve. The overall management goal identified for ecological health at the Standard Mine Site is as follows:

> *Ensure adequate protection of ecological systems within areas impacted by the site by protecting them from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.*

For most species, “adequate protection” is defined as protection of growth, reproduction, and survival of local populations. That is, the focus is on ensuring sustainability of the local population, rather than on protection of every individual in the population. However, for threatened or endangered species, "adequate protection" is generally taken to mean protection of each of the individuals that comprise the population, rather than the population as a whole.

3.4 Assessment and Measurement Endpoints

Assessment Endpoints

Assessment endpoints are explicit statements of the characteristics of the ecological system that are to be protected. In accord with the general management goal identified above, the assessment endpoints selected for this site are:

- Adequate protection of aquatic life in site surface waters and sediments from the deleterious effects of acute and chronic exposures to site-related contaminants.

- Adequate protection of terrestrial plant communities from the deleterious effects of exposures to site-related contaminants.

- Adequate protection of mammal and bird populations, including threatened and endangered species, from the deleterious effects of acute and chronic exposures to site-related contaminants.

Measurement Endpoints

Measurement endpoints represent quantifiable ecological characteristics that can be measured, interpreted, and related to the valued ecological components chosen as the assessment endpoints (USEPA, 1992; 1997). The measurement endpoints for each assessment endpoint are summarized in Table 3-2. As seen, the measurement endpoints can be divided into three basic categories, as follows:

- Hazard Quotients
- Site-specific toxicity tests
- Observations of population and community demographics

These three basic types of measurement endpoints are described in more detail below.

Hazard Quotients

A Hazard Quotient (HQ) is the ratio of the estimated exposure of a receptor at the site to a "benchmark" exposure that is believed to be without significant risk of unacceptable adverse effect:

HQ = Exposure / Benchmark

Exposure may be expressed in a variety of ways, including:

- Concentration in an environmental medium (water, sediment, soil, diet)
- Concentration in the tissues of an exposed receptor
- Amount of chemical ingested by a receptor

In all cases, the benchmark toxicity value must be of the same type as the exposure estimate.

When a receptor is exposed by more than one pathway, HQs for each exposure pathway are added across pathways resulting in a “Total HQ” for each chemical. In accordance with USEPA guidance, HQs for different chemicals are not added unless reliable data are available to indicate that the two (or more) chemicals act on the same target tissue by the same mode of action. At this site, total HQ values for each chemical were not added across different chemicals.

If the value of an HQ is less than or equal to 1, risk of unacceptable adverse effects in exposed organisms is judged to be acceptable. If the HQ exceeds 1, the risk of adverse effects in exposed organisms may be of concern, with the probability and/or severity of adverse effect tending to increase as the value of the HQ increases.

When interpreting HQ results for non-threatened or endangered receptors, it is important to remember that the assessment endpoint is usually based on the sustainability of exposed populations, and risks to some individuals in a population may be acceptable if the population is expected to remain healthy and stable. In these cases, population risk is best characterized by quantifying the fraction of all individuals that have HQ values greater than 1, and by the magnitude of the exceedences. The fraction of the population that must have HQ values below a value of 1 in order for the population to remain stable depends on the species being evaluated and on the toxicological endpoint underlying the toxicity benchmark. Consequently, reliable characterization of the impact of a chemical stressor on an exposed population risks requires knowledge of population size, birth rates, and death rates, as well as immigration and emigration rates. Because this type of detailed knowledge of population dynamics is generally not available on a site-specific basis, extrapolation from a distribution of individual risks to a characterization of population-level risks is generally uncertain. However, if all or nearly all of the HQs for individuals in a population of receptors are below 1, it is very unlikely that unacceptable population-level effects will occur in the exposed population. Conversely, if many or all of the individual receptors have HQs that are above 1, then unacceptable effects on the exposed population are likely, especially if the HQ values are large. If only a small portion of the exposed population has HQ values that exceed 1, some individuals may be impacted, but population-level effects are not likely to occur. As the fraction of the population with HQ values above 1 increases, and as the magnitude of the exceedences increases, risk that a population-level effect will occur also increases. This concept is illustrated schematically in Figure 3-2.

In interpreting HQ values and distributions of HQ values, it is always important to bear in mind that the values are predictions, and are subject to the uncertainties that are inherent in both the estimates of exposure and the estimates of toxicity benchmarks. Therefore, HQ values should be interpreted as estimates rather than highly precise values, and should be viewed as part of the weight-of-evidence along with the results of site-specific toxicity testing and direct observations on the structure and function of the receptor community (see below).

Site-Specific Toxicity Tests

Site-specific toxicity tests measure the response of receptors that are exposed to site media. This may be done either in the field or in the laboratory using media collected on the site. The chief advantage of this approach is that site-specific conditions which can influence toxicity are usually accounted for. A potential disadvantage is that, if toxic effects are observed to occur when test organisms are exposed to a site medium, it is usually not possible to specify which chemical or combination of chemicals is responsible for the effect. Rather, the results of the toxicity testing reflect the combined effect of the mixture of chemicals present in the site medium. In addition, it is often difficult to test the full range of environmental conditions which may occur at the site across time and space, either in the field or in the laboratory, so these studies are not always adequate to identify the boundary between exposures that are acceptable and those that are not.

Population and Community Demographic Observations

A third approach for evaluating impacts of environmental contamination on ecological receptors is to make direct observations on the receptors in the field, seeking to determine whether any receptor population has unusual numbers of individuals (either lower or higher than expected), or whether the diversity (number of different species) of a particular category of receptors (e.g., plants, benthic organisms, small mammals, birds) is different than expected. The chief advantage of this approach is that direct observation of community status does not require making the numerous assumptions and estimates needed in the HQ approach. However, there are also a number of important limitations to this approach. The most important of these is that both the abundance and diversity of an ecological population depend on many site-specific factors (habitat suitability, availability of food, predator pressure, natural population cycles, meteorological conditions, etc.), and it is often difficult to know what the expected (non-impacted) abundance and diversity of an ecological population should be in a particular area. This problem is generally approached by seeking an appropriate "reference area" (either the site itself before the impact occurred, or some similar site that has not been impacted), and comparing the observed abundance and diversity in the reference area to that for the site. However, it is sometimes quite difficult to locate reference areas that are truly a good match for all of the important habitat variables at the site, so comparisons based on this approach do not always establish firm cause-and-effect conclusions regarding the impact of environmental contamination on a receptor population.

Weight of Evidence Evaluation

As noted above, each of the measurement endpoints has advantages but also has limitations. For this reason, conclusions based on only one method of evaluation may be misleading. Therefore, the best approach for deriving reliable conclusions is to combine the findings across all of the methods for which data are available, taking the relative strengths and weaknesses of each method into account. If the methods all yield similar conclusions, confidence in the conclusion is greatly increased. If different methods yield different conclusions, then a careful review must be performed to identify the basis of the discrepancy, and to decide which approach provides the most reliable information.

4.0 RISK EVALUATION FOR AQUATIC RECEPTORS

As discussed in Section 3, site-related contaminants may be of concern to aquatic receptors (fish and benthic macroinvertebrates) in Elk Creek and in Coal Creek downstream of the confluence with Elk Creek. Aquatic receptors living in Elk and Coal Creeks may be exposed to site-related contaminants through several potential pathways. As shown in the site conceptual model (Figure 3-1), the following exposure pathways were selected for quantitative evaluation.

- Direct contact with chemicals in surface water. This pathway is applicable to fish and to benthic organisms that reside in the uppermost portion of the sediment substrate or the water column.

- Direct contact with chemicals in sediment. This pathway is most applicable to benthic invertebrate species that live within the sediment substrate.

4.1 Evaluations of Risks to Aquatic Receptors from Surface Water

4.1.1 HQ Approach

Chemicals of Potential Concern

Based on the results of the initial screening step performed in the SLERA, the chemicals of potential concern for exposure of aquatic receptors (fish, benthic invertebrates) to surface water are aluminum, cadmium, calcium, copper, lead, manganese, nickel, silver, and zinc.

Data

Data on the concentration of metals in surface water at and near the site are available from a number of studies. Table 4-1 lists the studies and the data that were used in this assessment. Studies that were performed prior to 1995 (Colburn 1982, 1986, Moran and Wentz 1974, Rumberg et al. 1978, Wentz 1974) were not selected for use because it is considered likely that the data from this time may not be representative of current site conditions.

Figure 4-1 shows the sampling stations where surface water data have been collected. Raw data for surface water samples are provided in Appendix A, along with summary statistics stratified by chemical and location.

Concentration values of metals in surface water may be expressed either as total recoverable or as “dissolved” (that which passes through a fine-pore filter). There is general consensus that toxicity to aquatic receptors is dominated by the level of dissolved chemicals (Prothro 1993), since chemicals that are adsorbed onto particulate matter may be less toxic than the dissolved

forms. Therefore, exposures of aquatic receptors to inorganic contaminants in surface water were evaluated using dissolved concentrations. When dissolved concentrations were not available, the total recoverable concentrations were used instead. Based on a set of samples where both total recoverable and dissolved measurements are available, there is relatively little difference between the two measurements, so it is considered likely that use of this approach is not likely to result in a substantial overestimate of risk.

Toxicity Assessment

Toxicity benchmark values for the protection of aquatic life from direct contact with chemicals in surface water are available from several sources, including the State of Colorado Table Value Standards, National Ambient Water Quality Criteria (AWQC), Great Lakes Water Quality Initiatives (GRWQI), and USEPA Region IV. Each of the sources evaluated in deriving surface water toxicity benchmarks is described in Appendix B. This appendix also describes the hierarchy used to identify the most relevant and reliable toxicity benchmark value when more than one value was available. For chemicals where the acute and chronic benchmarks were hardness-dependent, toxicity benchmarks were calculated for each sample based on the hardness of that sample. The acute and chronic toxicity benchmark values selected for use in this assessment are shown in Table 4-2. Part A of the table presents values for chemicals that are independent of hardness, and Part B of the table presents the equations used for chemicals whose toxicity is hardness dependent.

Exposure Assessment

For aquatic receptors (fish and benthic invertebrates), each sample of water or sediment may be viewed as representing an environmental exposure location in which one or more organisms may be exposed. Thus, HQ values were calculated for all available samples. In accord with USEPA guidance, non-detects were evaluated at one-half the detection limit.

Risk Characterization Based on HQs for Surface Water

Detailed calculations of HQ for exposure of aquatic receptors to surface water are provided in Appendix D. The results are presented graphically as scatter plots of the calculated HQ values, grouped by location (reach), which allows a ready assessment of the frequency and magnitude of HQ values above 1 in each site area, as well as a comparison of the distribution of HQ values in site areas to appropriate background or reference areas.

Table 4-3 presents summary statistics for HQ values in Elk Creek and Coal Creek, along with statistics for several reference and background locations. Figures 4-2 and 4-3 present example distributions of HQ values for cadmium and zinc. These data are interpreted semi-quantitatively as discussed in Section 3 (see Figure 3-2). Based on this approach, inspection of Table 4-3 and the graphs in Appendix D reveal the following main conclusions:

- For Elk Creek at Standard Mine and Elk Creek downstream of Standard Mine, there are several chemicals that have a high frequency of acute and/or chronic HQ values above 1. The highest chronic risks, with HQ values often ranging into the 10-100 range, are associated with cadmium, copper, lead, manganese, silver, and zinc. Comparison of the HQ values seen in Elk Creek to background locations (Splain's Gulch, Wildcat Creek, and Copley Lake outfall), indicate that, except for silver, all of the values in Elk Creek are clearly higher than background and are attributable to releases from the site.

- For Coal Creek immediately downstream of the confluence with Elk Creek, HQ values are lower than in Elk Creek, but cadmium, copper, lead, silver, and zinc continue to above a level of concern for acute and/or chronic exposures. Except for silver, the frequency and magnitude of HQ exceedences in Coal Creek immediately downstream of Elk Creek are higher than those in Coal Creek just upstream of Elk Creek, reflecting the impact of Elk Creek on Coal Creek.

- For reaches of Coal Creek further downstream from Elk Creek (beginning just above the iron bog and continuing to the Slate River), a number of HQ exceedences continue to be observed for cadmium, copper, lead, silver, and zinc. In evaluating these results, it is important to remember that there are additional potential sources of metals release to Coal Creek along this reach, including the Iron bog area and Keystone mine.

4.1.2 Site-Specific Surface Water Toxicity Testing

One way to help reduce the uncertainty associated with risk predictions based on the HQ approach is to perform direct toxicity testing using site-specific media. Tests of this type have been performed by the U. S. Environmental Protection Agency laboratory in Golden, CO. The tests used rainbow trout (*Oncorynchus mykiss*) fry as the test organisms, and used surface water samples collected from five locations along Elk Creek as well as two locations along Coal Creek (Coal-15 and Coal-20) and two reference locations (Copley-01 and Splains-00). The toxicity test results are summarized in Figure 4-4.

As seen, statistically significant increases in mortality compared to reference and control were seen for all Elk Creek locations. The highest mortality (100%) was observed at the upstream stations closest to the mine, and there was tendency for a slight decrease in mortality with increasing distance from Standard Mine. These findings support the conclusion that surface water in Elk Creek is likely to be highly toxic to fish.

Toxicity test results for fish exposed to water from Coal Creek immediately downstream of the confluence with Elk Creek (Coal-15) show low mortality, and this level of mortality is not different that observed in Coal Creek just upstream of Elk Creek (Coal-20). This suggests that

waters from Elk Creek are sufficiently diluted by Coal Creek that site-related contaminants have only a minimal impact the survival of fish in Coal Creek.

4.1.3 Site-Specific Surveys of Fish Populations

In 2006, the Colorado Department of Fish and Wildlife (CDOW) conducted a fish survey at three locations on Elk Creek (Elk-00, Elk-01, and Elk-08), various locations along Coal Creek both above (Coal-25) and below (Coal-15, Coal-10 and Coal-02) Elk Creek, and at 2 background locations on Splain's Gulch (Sp-00, Sp-01). Additional data are available from sampling performed by CDOW along Coal Creek in the late 1970's and 1980's. The raw data are provided as Appendix E, and Figure 4-5 presents the data graphically.

The most common species of fish observed at all stations was brook trout, constituting 93% of all fish that were captured. Therefore, results in Figure 4-4 are not stratified by species. Inspection of these data yields the following main conclusions:

- At any one station where data are available for more than one year, values vary substantially. This is expected because fish populations may be influenced by a wide range of factors that can vary substantially from year to year. Thus, comparisons between different years must be done with caution.

- For Elk Creek, some fish are present at the mouth of the creek (Elk-00), but none are present at stations further upstream (Elk-01 and Elk-08). The reach at Elk-00 is very close to Coal Creek, and it is considered likely that fish at this location are immigrants from Coal Creek. Although there is only one year of data, it appears that the density and biomass of fish at Elk-00 are lower (perhaps about 1/2) than at the most nearly matching reference location (Sp-00). These data support the view that water in Elk Creek does not support fish except at the mouth, and even there, density is lower than expected.

- Fish density and biomass in Coal Creek appear to be generally similar immediately above and below the confluence with Elk Creek. This suggests that fish in Coal Creek are not strongly impacted by releases from Elk Creek.

4.1.4 Weight of Evidence Evaluation for Surface Water

Elk Creek

For Elk Creek, the HQ approach and site-specific surface water toxicity testing strongly agree that water in Elk Creek is likely to be substantially toxic to fish. Only one fish survey is available for Elk Creek, but the data from this study also indicate that fish are absent from Elk Creek except at the mouth, where immigrants from Coal Creek may occur in low numbers. Note that the presence of fish at this station is not inconsistent with the HQ and toxicity test results,

because both the HQ approach and toxicity testing are based on the most susceptible life stage (fry), while the fish observed in the fish survey were fingerlings or adults (> 10 cm in length), and fish of this size are generally much less susceptible to chemical toxicity than are fry.

> *Taken together, the weight of evidence supports the conclusion that mining-related releases from Standard Mine are substantially toxic to fish in Elk Creek.*

Coal Creek

For fish in Coal Creek below the confluence with Elk Creek, HQ values are above 1 for several chemicals, and are clearly higher than in Coal Creek upstream of Elk Creek. However, fish toxicity studies and one fish survey suggest that water in Coal Creek below the confluence with Elk Creek indicate that waters in Coal Creek below Elk Creek are not substantially toxic and are not clearly different that Coal Creek upstream of Elk Creek.

> *Taken together, the weight of evidence indicates that water discharged from Elk Creek into Coal Creek elevates concentrations of metals in Coal Creek but is likely to have only minimal to moderate toxicity on fish.*

4.2 Evaluations of Risks to Aquatic Receptors from Sediment

4.2.1 HQ Approach Based on Bulk Sediment

Chemicals of Potential Concern

Based on the results of the initial screening step described in the SLERA, the chemicals of potential concern for exposure of benthic invertebrates to bulk sediment are aluminum, arsenic, cadmium, copper, lead, manganese, silver, and zinc.

Data

Data on the concentration of metals in bulk sediment samples at and near the site are available from a number of studies. Table 4-4 lists the studies and the data that were used in this assessment. Raw data for sediment samples are provided in Appendix A, along with summary statistics stratified by chemical and location.

Exposure Assessment

Although concentrations of chemicals in sediment are usually not as time-variable as concentrations in surface water, concentrations do fluctuate as contaminated material is added or removed by surface water flow. In addition, there may be significant small scale variability in sediment concentrations at any specific sampling station. Therefore, exposure to sediments is

usually best characterized as a distribution of individual values at a specific location. In accord with USEPA guidance, non-detects were evaluated at one-half the detection limit.

Toxicity Assessment

Toxicity benchmark values for the protection of benthic invertebrates from direct contact with sediment are available from several sources. Each of the sources evaluated in deriving sediment toxicity benchmarks is described briefly in Appendix B-2. This appendix also describes the hierarchy used to identify the most relevant and reliable toxicity benchmark value when more than one value was available. For each chemical, a threshold effect concentration (TEC) and a probable effect concentration (PEC) were identified. Sediment toxicity should be observed only rarely below the TEC and should be frequently observed above the PEC. The toxicity benchmark values selected for evaluation of risks from direct contact with sediment are shown in Table 4-5.

Risk Characterization Based on Bulk Sediment HQs

Detailed risk calculations of risks from bulk sediment are provided in Appendix F. The results are presented graphically as scatter plots of the calculated HQ values, grouped by location (reach), which allows a ready assessment of the frequency and magnitude of HQ values above 1 in each site area, as well as a comparison of the distribution of HQ values in site areas to appropriate reference or background areas. Figures 4-6 and 4-7 present example distributions of HQ values for cadmium and zinc. Table 4-6 provides HQ summary statistics for Elk Creek at and downstream of Standard Mine, Coal Creek immediately downstream of the confluence with Elk Creek, Coal Creek downstream of Iron Bog, and data for reference and background areas. Inspection of Table 4-6 and the graphs in Appendix F reveal the following main conclusions:

- For Elk Creek at and downstream of Standard Mine, there are multiple chemicals in sediment that have a high frequency of HQ values above 1, often ranging into the 10-100 range based on the TEC benchmark. The highest risks appear to be due to cadmium, copper, lead, and zinc, with an additional contribution from silver. Comparison of sediment HQ values seen in Elk Creek to background locations (Splain's Gulch, Wildcat Creek, and Copley Lake outfall) indicate that the frequency and magnitude of HQ exceedences are clearly higher than background for cadmium, copper, lead, silver, and zinc, and that the elevated risks from these chemicals are attributable to releases from the site. HQ values for arsenic and manganese in Elk Creek appear to be generally similar to those from background and reference areas, suggesting that these chemicals in sediment may be largely natural in origin.

- For Coal Creek immediately downstream of the confluence with Elk Creek, HQ values for cadmium, copper, lead and zinc are lower than in Elk Creek, but the frequency and magnitude of HQ exceedences remains in a range of concern. HQ values in Coal Creek

immediately downstream of Elk Creek are clearly higher for these chemicals than for Coal Creek just upstream of Elk Creek, reflecting the impact of Elk Creek on sediments in Coal Creek.

- For Coal Creek further downstream of the confluence with Elk Creek, a number of HQ exceedences continue to be observed for cadmium, copper, lead and zinc. In evaluating these results, it is important to remember that there are additional potential sources along this reach that might release contaminated sediments to Coal Creek, including the iron bog area and Keystone mine.

4.2.2 HQ Approach Based on Sediment Porewater

As noted previously, adverse effects from direct contact with sediment are likely to be mediated primarily by chemicals that have dissolved into sediment porewater from the bulk sediment. Thus, another approach for evaluating toxicity from chemicals in sediment is to measure the concentrations in the sediment porewater and compare those concentrations to water-based toxicity values. The following sections describe the inputs used to calculate HQs and summarize the predicted risks to benthic invertebrates from sediment porewater.

Chemicals of Potential Concern

Chemicals evaluated in sediment porewater were the same as evaluated in sediment (aluminum, arsenic, cadmium, calcium, copper, lead, manganese, silver, and zinc).

Data

Porewater data were collected by EPA in July of 2006 from multiple locations along Coal Creek and Elk Creek with background samples collected from Copley and Splain's Gulch. Raw data for sediment porewater samples are provided in Appendix A, along with summary statistics stratified by chemical and location.

Exposure Assessment

Since there may be both spatial and temporal variability in sediment porewater concentrations at any specific sampling station, exposure to benthic macroinvertebrates is usually best characterized as a distribution of concentration values at a specific location. As noted above, because toxicity to aquatic receptors from water exposure is dominated by the level of dissolved chemicals, exposures to inorganics in sediment porewater were evaluated using dissolved concentrations.

Toxicity Assessment

Toxicity benchmarks specifically for the protection of benthic invertebrates from contaminants in surface are not generally available, so benchmarks for the protection of aquatic communities (including fish, benthic invertebrates, aquatic plants, etc.) from direct contact with chemicals in surface water were used. These are the same values presented earlier for the evaluation of risks to aquatic receptors from surface water (see Table 4-2).

Risk Characterization Based on Sediment Porewater HQs

Detailed risk calculations of risks to benthic organisms from exposure to sediment pore water are provided in Appendix G. The results are presented graphically as scatter plots of the calculated HQ values, grouped by location (reach), which allows a ready assessment of the frequency and magnitude of HQ values above 1 in each site area, as well as a comparison of the distribution of HQ values in site areas to appropriate reference or background areas. Figures 4-8 and 4-9 present example distributions of HQ values for cadmium and zinc. Table 4-7 provides summary statistics for Elk Creek at and downstream of Standard Mine, Coal Creek immediately downstream of the confluence with Elk Creek, Coal Creek downstream of Iron Bog, and data for reference and background areas.

Inspection of Table 4-7 and the graphs in Appendix G reveal the following main conclusions:

- For Elk Creek downstream of Standard Mine, HQ values above 1 based on acute and/or chronic benchmarks are observed for cadmium, copper, lead, silver, and zinc. The highest HQ values are for cadmium and zinc. Comparison of the porewater-based HQ values in Elk Creek to those from background locations indicates the values seen in Elk Creek are clearly higher for cadmium, copper, lead, and zinc, supporting the conclusion that sediments from Standard Mine are an important source of pore water contamination for these chemicals. For silver, HQ values in background and reference areas appear to be similar to Elk Creek, suggesting that silver in sediment pore water may be largely natural in origin.

- For Coal Creek just downstream of the confluence with Elk Creek, acute and/or chronic HQs remain elevated for most chemicals, but the magnitude of the exceedences is generally low (HQ in the range of 2-4). Although data are limited, porewater HQ values for most chemicals except silver appear higher in Coal Creek downstream of Elk Creek than in Coal Creek upstream of Elk Creek, reflecting the impact of sediments derived from the mine site.

- For Coal Creek further downstream from Elk Creek (from the iron bog and beyond), HQ exceedences continue to occur for cadmium, silver, and zinc. In evaluating these results, it is important to remember that there are additional potential sources along this reach that

might release contaminated sediments to Coal Creek, including the iron bog area and Keystone mine.

4.2.3 Site-Specific Sediment Toxicity Tests

A 10-day flow through sediment toxicity test was conducted at the Region 8 Laboratory to determine the acute toxicity of sediments collected from drainages associated with the Standard Mine. All tests were conducted on the amphipod *Hyalella azteca* (*H. azteca*), with evaluation endpoints of growth and mortality. The toxicity test results are summarized in Figure 4-10.

As seen, statistically significant increases in mortality were seen for all Elk Creek locations tested, with mortality rates ranging from 98%-100%. These findings support the conclusion that sediment in Elk Creek is likely to be causing significant adverse effects on survival of benthic invertebrates in these locations.

Toxicity test results for Coal Creek immediately downstream of the confluence with Elk Creek (Coal-15) show mortality (8%) that is similar to that seen in Coal Creek upstream of Elk Creek (Coal-20), suggesting that sediments from Elk Creek are not having a clear effect on benthic invertebrates in Coal Creek. Comparison of the toxicity observed in Coal Creek to background locations (Copley Lake outfall, Splain's Gulch) do not reveal any statistically significant differences. Results based on weight gain by surviving organisms do not reveal any clear effects in Coal Creek compared to reference or control organisms.

4.2.4 Site-Specific Benthic Community Surveys

Benthic macroinvertebrates were collected from the multiple sampling locations in Elk Creek, Coal Creek, and Splain's Gulch in September 2005, July 2006, and September 2006. The raw data are presented in Appendix H, and Figures 4-11 and 4-12 summarize the results for six selected metrics of community status:

- Panel A shows the total number of different taxa that were observed (an indicator of community diversity)

- Panel B shows the total number of organisms observed (an indicator of community abundance and density). Note that the total number or organisms should be interpreted only semi-quantitatively, since the sample collection protocol does not require that identical areas be sampled at each station.

- Panel C shows the fraction of all individuals observed that are from the order Ephemeroptera (mayflies). Mayflies are often adversely impacted by mining-related contamination.

- Panel D shows the EPT index, which is the percent of all organisms that are from the Orders Ephemeroptera (mayflies), Plecoptera (stoneflies), or Trichoptera (caddis flies). As above, insects in these orders are often adversely impacted by mining contamination.

- Panel E shows the fraction of the total taxa observed that are considered to be tolerant to mining pollution. A high fraction of tolerant taxa is an indication that sensitive species have been impacted.

- Panel F shows the fraction of the total individuals that are contributed by the dominant (most abundant) taxon. A high fraction for the dominant taxon is an indication of reduced diversity.

Inspection of these data indicates that, at any one station where data are available for more than one year, values of each metric may vary substantially between observations. This is expected because benthic invertebrate populations may be influenced by a wide range of factors that can vary substantially from year to year. Thus, comparisons of metrices between stations, especially between different years, must be done with caution.

For Elk Creek (Figure 4-11), evaluation of spatial patterns in community metrices reveals the following:

- Taxa richness (Panel A) is lowest at Elk-10 (immediately downstream of the mine), tending to increase somewhat as distance downstream from the mine increases. At the mouth of Elk Creek (Elk-00), taxa richness is similar to (but slightly less than) that in the reference location (Splain's Gulch).

- Abundance of benthic organisms (Panel B) is very low immediately downstream of the mine, with a tendency to increase somewhat as distance from the mine increases. However, the total number of benthic organisms at the mouth of Elk Creek (Elk-00) is lower than in Splain's Gulch.

- The fraction of organisms that are Ephemeroptera (Panel C) or EPT (Panel D) tend to be lowest immediately downstream of the mine, with a tendency to increase as a function of distance downstream from the mine. This difference is not seen for two stations in Splain’s Gulch (Splain-00 and Splain-01), suggesting the trend is more likely to be related to chemical toxicity than to altitude.

- The percent tolerant taxa (Panel E) and the percent dominant taxon (Panel F) do not display any clear or consistent spatial pattern.

For Coal Creek (Figure 12), spatial patterns are not as clear as in Elk Creek. In general, comparison of Coal-15 (downstream of Elk Creek) to Coal-20 (upstream of Elk Creek) does not

reveal any clear and consistent difference, suggesting that discharge from Elk Creek is having no substantial effect on benthic organisms in Coal Creek. Panel B suggests there may be a trend toward declining benthic macroinvertebrate abundance at stations further below Coal-15, at least in September 2005 and September 2006, although this pattern was not observed in July 2006. If so, the trend is most likely attributable to sources of contaminant release along Coal Creek (e.g., the iron bog, keystone mine) and/or trends in habitat (see below).

When comparing benthic community metrices between stations, it is important to recognize that differences may result from differences in habitat as well as differences in chemical contamination level. The EPA has developed a standardized approach for performing this habitat adjustment, referred to as the Rapid Bioassessment Protocol (RBP), as summarized in Figure 4-13 (USEPA 1989b, 1999). In this approach, a number of alternative metrices of benthic community status are combined to yield the Biological Condition Score, and a number of alternative measures of habitat are combined to yield the Habitat Quality Score. Both the Biological Condition Score and the Habitat Quality Score are then expressed as a percentage of corresponding scores from a suitable reference station, matched in time whenever possible. A comparison of the Biological Condition Score (Percent of Reference) to the Habitat Quality Score (Percent of Reference) provides information on the likely contribution of non-habitat factors (e.g., chemical pollution) on the benthic community.

Habitat parameters needed to perform the RBP assessment were measured in July and September 2006, using the RBP methods. The raw data on habitat parameters are detailed in Appendix I, along with the calculation of the Habitat Quality Score for each station.

Figure 4-14 plots the Biological Condition Score (Percent of Reference) for stations in Elk Creek as a function of the Habitat Quality Score (Percent of Reference). For Elk-00, data from Sp-00 were used as reference. For stations further upstream on Elk Creek, Sp-01 was used as reference when available (2006). When data from SP-01 were not available (2005), data from SP-00 were used as reference for all Elk Creek stations. Data points that fall near the solid line have benthic communities that are similar to what would be expected based on a consideration of habitat alone. Data points that fall below the line have benthic communities that are of lower quality than would be expected based on habitat alone, suggesting an adverse effect of chemical contamination. As seen, except for data from Elk-29 (which is located above the main sources of mining contamination at the site), all of the observations from Elk Creek tend to lie below the solid line, and most have relatively low Biological Condition scores. This pattern is consistent with an adverse effect of mining-related contamination on the benthic community in Elk Creek.

Figure 4-15 plots the data for a number of stations in Coal Creek below the confluence with Elk Creek. Coal-20 (upstream of Elk Creek) was used as the reference. As seen, all of the data lie close to or slightly below the solid line, and all are characterized by relatively high Biological Condition scores. These findings suggest that benthic communities in Coal Creek may be slightly impaired compared to expected, but that the differences are relatively minor.

4.2.5 Weight of Evidence Evaluation for Sediment

Four different lines of evidence are available to support an evaluation of risks to benthic organisms in Elk Creek and Coal Creek: HQ values based on bulk sediment, HQ values based on porewater measurements, sediment toxicity tests, and benthic community surveys. Both HQ-based approaches indicate that risks from sediments in Elk Creek are relatively high, with somewhat lower values in Coal Creek below Elk Creek. Sediment toxicity testing supports the view that sediment toxicity is high in Elk Creek, but low in Coal Creek. Benthic population studies provide several indications of adverse effects on benthic organisms in Elk Creek, especially in the upper reaches just below the mine, with relatively little evidence for an effect in Coal Creek immediately below Elk Creek.

> *Taken together, the weight of evidence supports the conclusion that sediments in Elk Creek are likely to have significant adverse effects on benthic organisms residing in the sediment, but that hazards are lower and less likely to be of significant concern in Coal Creek.*

4.3 Uncertainty

There are a number of sources of uncertainty that remain in the evaluation of risks to aquatic receptors from mining-related releases from the Standard Mine site. These sources of uncertainty are discussed below.

4.3.1 Uncertainty in Measured Concentration Values

Surface water and sediment data are available from multiple locations in Elk Creek, Coal Creek downstream of Elk Creek, and from several additional locations which serve as reference areas or background locations. Thus, spatial representativeness is generally good. However, concentrations of contaminants in surface water tend to be highly variable over time, and concentrations in sediment may also vary over time. Thus, data from many sampling events are needed to fully characterize the range of concentrations that may occur. At this site, surface water data are available under both high flow (spring) and low flow (summer/fall) time from several different years between 1999 and 2006. For sediment, data are available form three years (1999, 2005 and 2006). While these data do provide valuable information on the within- and between-year variation in concentration, the data may not provide a clear understanding of the full range of variability within and between years.

4.3.2 Uncertainty in Toxicity Values

Surface Water Benchmarks

Benchmark values used to predict risk to aquatic receptors from contaminants in surface water are based on Colorado Table Standards, National Ambient Water Quality Criteria, or Great Lakes Tier II values. These benchmarks are based on multiple toxicity studies and are intended to be protective of most aquatic species for which reliable toxicity data are available. However, the set of organisms for which there are data may not include the organisms most likely to be present in the site and reference waters. In addition, these benchmarks are based on studies performed in laboratory waters, and may not account for site-specific factors that influence toxicity of metals. Because of this, risk predictions based on these benchmarks may either overestimate or underestimate risks to site species.

Sediment Benchmarks

Sediment toxicity benchmarks for benthic invertebrates used in the screening level evaluation are based on studies in which multiple contaminants were present and assumes all of the observed toxicity was due to the contaminant of interest, even though other contaminants in the sediment may be associated with observed toxicity. Therefore, there is uncertainty that exceedence of the benchmark for a particular chemical will actually cause toxicity in benthic organisms. In addition, there may be a wide variety of differences between sediments from the Standard Mine site and those used to establish the toxicity benchmarks, which could influence the relative toxicity of chemicals in the sediments. Because of these limitations in bulk sediment benchmarks, HQ values based on the benchmarks should be considered uncertain, and more likely to overestimate than underestimate risks.

4.3.3 Uncertainty in Toxicity Tests

Toxicity tests, both for surface water and for sediment, are uncertain for two main reasons: 1) tests are performed on only a limited set of samples from the site, so the samples are unlikely to capture the full range of variability over time and space, and 2) all tests based on observed responses of biological organisms are inherently variable due to random differences between organisms. At this site, the effects of exposure of fish to site waters and exposure of benthic organisms to site sediments are sufficiently clear (severe increases in mortality are seen in both cases) that neither of these sources of uncertainty is an important limitation in the conclusion that both water and sediment from Elk Creek are substantially toxic to aquatic receptors.

4.3.4 Uncertainty in Community Demographic Surveys

As noted above, measures of fish and benthic community status are inherently variable over space and time. At this site, the available population data for fish and benthic communities are

based on only a relatively small number of observations, so these data must be used with caution in making comparisons between locations and drawing inferences regarding the effects of chemical toxicity. Nevertheless, the available data for both fish and benthic macroinvertebrates are generally consistent with the conclusions based on the HQ approach and the toxicity testing approach, and add to the strength of the weight of evidence conclusions.

5.0 RISK EVALUATION FOR PLANTS AND SOIL ORGANISMS

The plant and soil invertebrate community are important components of any ecosystem because they provide a significant portion of the energy, organic matter, and nutrient inputs for terrestrial systems as well as providing habitat and forage for a variety of wildlife species. Terrestrial plants and soil invertebrates are good indicators of soil condition because they reside directly in the soil and are not mobile.

This section provides evaluation of risks for terrestrial plant and soil organisms living in soils which are potentially impacted by contaminants from the Standard Mine site. Only one line of evidence (the HQ approach) is available for assessment of these two classes of receptors. The available data and the assessment findings based on this line of evidence are presented below.

5.1 Data

At the time the SLERA was performed, data for metals in soil at the site were quite limited. In order to address this gap, a large soil-sampling effort was performed by EPA that resulted in the collection of 190 surface soil samples in a grid pattern across the entire site. These sampling locations are shown in Figure 5-1, and the raw data from each sample are presented in Appendix A.

Although soil samples have been collected from a number of locations outside the area of the Standard Mine site, most of these are from areas that are likely to have been impacted by other mining activities. After a review of the available data, only one sample (taken along Coal Creek upstream of Elk Creek) is considered to be reasonably representative of background (USEPA 2006). This data point is used below as a frame of reference for evaluating site data, but it is evident that a single data point is not sufficient to support strong conclusions about the degree to which the site is, or is not, higher than background.

5.2 Chemicals of Potential Concern

Chemicals of potential concern to plants and soil invertebrates that were identified in the SLERA were based on a limited set of soil measurements, so the COPC selection procedure was repeated for the BERA using the expanded data set for on-site soils that were available. In brief, an HQ was calculated for both plants and soil invertebrates for each chemical based on the maximum detected concentration in on-site soil. If the HQ exceed 1.0, the chemical was retained as a COPC. The results are summarized below:

Plants		Soil Invertebrates	
Aluminum Antimony Arsenic Barium Cadmium Chromium Cobalt Copper	Lead Manganese Mercury Selenium Silver Thallium Vanadium Zinc	Arsenic Barium Chromium Copper	Lead Manganese Mercury Zinc

5.3 Exposure Assessment

Because plants are sessile and most soil invertebrates are not highly mobile, exposures were calculated on a sample-by-sample basis, rather than on average concentrations over some larger area. In accord with USEPA guidance, non-detects were evaluated at one-half the detection limit.

5.4 Toxicity Assessment

Toxicity benchmarks for the protection of terrestrial receptors (plants and soil organisms) from chemicals in surface soils are available from several sources. Each of the sources evaluated in deriving soil toxicity benchmarks is described briefly in Appendix B-3, along with a hierarchy for identifying the most relevant and reliable benchmark value when more than one value is available. The toxicity benchmarks for all COPCs in soil are shown in Table B-3 of Appendix B, and the values are summarized in Table 5-1.

5.5 Risk Characterization

The detailed calculations of HQ values are presented in Appendix J (plants) and in Appendix K (soil organisms). The results are presented graphically as scatter plots of the calculated HQ values for soils at the mine site.

Plants

Table 5-2 presents a summary of the frequency and magnitude of HQ values exceeding 1 for plants growing in on-site soils as well as for the background soil sample. Figure 5-2 provides examples of the distribution of HQ values for zinc and cadmium. These data are interpreted semi-quantitatively as discussed in Section 3 (see Figure 3-2). Based on this approach, inspection of Table 5-2 and the figures in Appendix J indicate the following main conclusions for risks to plants:

- Chemicals with a high frequency and/or magnitude of HQ exceedences in on-site soils include aluminum, arsenic, chromium, copper, lead, manganese, selenium, silver, vanadium, and zinc. Because only one background soil sample is available for comparison, it is very difficult to assess whether the levels observed on-site are higher than background or not. However, based on the very limited data, it seems plausible that levels of at least some of these chemicals might not be different from background. However, additional data from background locations would be needed to assess this issue further.

- Antimony, barium, cadmium, cobalt, mercury, and thallium all have a relatively low frequency and magnitude of HQ exceedences, suggesting that these chemicals are likely to be minor sources of toxicity to plants, at least compared to the other COPCs evaluated.

Soil Invertebrates

Table 5-3 presents a summary of the frequency and magnitude of HQ values exceeding 1 for soil invertebrates living in on-site soils, as well as for the one background soil sample. Figure 5-3 provides examples of the distribution of HQ values for zinc and lead. Inspection of Table 5-3 and the figures in Appendix K indicate the following main conclusions for risks to soil invertebrates:

- Chemicals with a high frequency and/or magnitude of HQ exceedences in on-site soils include arsenic, chromium, copper, lead, manganese, and zinc. Because only one background soil sample is available for comparison, it is very difficult to assess whether the levels observed on-site are higher than background or not. Additional data from background locations would be needed to assess this issue further.

- Barium and mercury have only a low frequency and/or magnitude of HQ exceedences, suggesting that they are likely to be minor sources of toxicity to plants, at least compared to the other COPCs evaluated.

5.6 Uncertainties

Representativeness of the Soil Data

The soil data set collected by EPA at the Standard Mine site provides a well-planned systematic representation of the site, and the number of samples collected is more than sufficient to characterize the distribution of on-site concentration values with good certainty. However, an adequate data set for background soils is not available. The one sample that is available provides an initial impression as to whether site soils are higher than background, but clearly one sample is insufficient to support strong conclusions.

Reliability of Soil Benchmarks

The toxicity benchmarks used in HQ calculations for plants and soil invertebrates are usually based on laboratory studies in which soluble forms of test metals are added to test soils. Thus, these values do not account for occurrence of metals in mineral forms that are largely insoluble and do not contribute as much toxicity as soluble forms. In addition, the values do not account for variations in environmental factors such as pH and total organic carbon content which may influence the toxicity of metals in soils to terrestrial plants and invertebrates. Finally, the laboratory tests may not utilize species that are likely to occur in on site soils. Based on these considerations, confidence in the soil benchmark values and hence in the HQ values is low.

6.0 RISK EVALUATION FOR BIRDS AND MAMMALS

This section presents an evaluation of the risks to avian and mammalian wildlife populations that reside within the vicinity of the Standard Mine site. Only one line of evidence (the HQ approach) is available for assessment of these two classes of receptors. The available data and the assessment findings based on this line of evidence are presented below.

6.1 Selection of Representative Indicator Species

Wildlife receptors that may be exposed at the site include a wide variety of mammals and birds that include a number of different feeding guilds. However, it is neither feasible nor necessary to evaluate exposures and risks for each avian and mammalian species potentially present at the site. Rather, specific wildlife species may serve as surrogates (representative species) for the purpose of estimating exposure and risk to a group of species with similar behavior, dietary preferences, and feeding habits. Selection criteria for wildlife surrogate species included trophic level, feeding habits, and the availability of life history information. The species identified as surrogate species at this site include:

Feeding Guild	Avian Surrogate	Mammalian Surrogate
Aerial and/or Terrestrial Insectivores	Cliff Swallow Northern Flicker	Big Brown Bat Masked Shrew
Aquatic Insectivores	American Dipper	
Herbivores	Greater-Sage Grouse	Mule Deer
Omnivores	American Robin	Deer Mouse
Piscivores	Belted Kingfisher	
Carnivores	Red-tailed Hawk	Red Fox Lynx

6.2 Chemicals of Potential Concern

Chemicals of potential concern to birds and wildlife that were identified in the SLERA were based on a limited set of environmental data, especially for soil, so the COPC selection procedure was repeated for the BERA using the expanded data set for on-site soils and surface waters that were available. In brief, an HQ was calculated for each receptor for each chemical based on the maximum detected concentration in each medium (soil, surface water, and diet). If the total HQ for a chemical, summed across all three media, exceed 1.0 for any receptor, the chemical was retained as a COPC. The results are summarized below

COPCs for Birds and Mammals	
Aluminum	Lead
Antimony	Manganese
Arsenic	Mercury
Barium	Nickel
Beryllium	Selenium
Cadmium	Thallium
Chromium	Vanadium
Cobalt	Zinc
Copper	

6.3 HQ Equation

The basic equation used for calculation of an HQ value for exposure of a wildlife receptor to a chemical by ingestion of an environmental medium (soil, dietary prey item) is:

$$HQ_{i,j,r} = \frac{C_{i,j} \times (IR_{j,r} / BW_r) \times DF_{j,r}}{oTRV_{i,r} / RBA_{i,j,r}} \cdot AUF_r$$

where:

$HQ_{i,j,r}$	=	HQ for exposure of receptor "r" to chemical "i" in medium "j"
$C_{i,j}$	=	Concentration of chemical "i" in medium "j" (e.g., mg/kg)
$IR_{j,r}$	=	Intake rate of medium "j" by receptor "r" (e.g., kg/day)
BW_r	=	Body weight of receptor "r" (kg)
$DF_{j,r}$	=	Dietary fraction of medium "j" by receptor "r"
$RBA_{i,j,r}$	=	Relative bioavailability of chemical "i" in medium "j" by receptor "r"
$oTRV_{i,r}$	=	Oral toxicity reference value for chemical "i" in receptor "r" (mg/kg-d)
AUF_r	=	Area use factor for receptor "r"

Because all receptors are exposed to more than one environmental medium, the total hazard quotient (total HQ) to a receptor from a specific chemical is calculated as the sum of HQs across all media.

6.4 Exposure Factors

Exposure parameters and dietary intake factors for each surrogate wildlife receptor were derived from the Wildlife Exposure Factors Handbook (USEPA, 1993), as well as a variety of other sources. The exposure parameters selected for each wildlife receptor are detailed in Appendix L,

and are summarized in Table 6-1. Wildlife exposure factors were selected to represent average year-round adult exposures. In some cases, no quantitative data could be located, so professional judgment was used in selecting exposure parameters.

For receptors with home range sizes larger than the area of the site (33 Ha), the AUF was calculated as the ratio of the area of the site divided by the home range area of the receptor. For receptors with home range sizes smaller than the area of the site, the AUF was assumed to be 1.0. The relative bioavailability (RBA) for all chemicals in all media (including soil) was assumed to be 100%. This assumption is likely to be conservative for the soil exposure pathway, since metals in soils at mining sites often exist in poorly absorbable forms, which tends to decrease the amount of chemical absorbed into the body from an ingested dose of soil.

6.5 Exposure Point Concentrations for Soil

When exposure occurs over a geographic area, risk from a chemical is related to the arithmetic mean concentration averaged over the entire exposure area. Since the true arithmetic mean concentration cannot be calculated with certainty from a limited number of measurements, the USEPA recommends that the upper 95th percentile confidence limit (UCL) of the arithmetic mean of the chemical concentrations be used as the Exposure Point Concentration (EPC) (USEPA, 1992). If the 95% UCL exceeded the highest detected concentration, then the highest detected concentration is used as the EPC (USEPA 1989a). The approach for computing the 95% UCL of a data set depends on a number of factors, including the number of data points available, the shape of the distribution of the concentrations, and the degree of censoring (USEPA, 2002). In accord with current USEPA guidance (USEPA 2002), UCL values were derived using ProUCL v3.0, a software system developed by the USEPA Technical Support Center. This software calculates UCLs for a data set using several different strategies and recommends which UCL is considered preferable based on the properties of the data set. When calculating the UCL, concentrations reported as non-detects (U-qualified by the laboratory) were evaluated by assuming a concentration value equal to one-half the detection limit (USEPA 1989a). Rejected (R-qualified) data were not used when calculating an EPC.

The data set for soil was described previous in Section 5. In brief, 190 data points are available from a systematic investigation of the site (see Figure 5-1). Table 6-2 provides a summary of the EPCs for soil used for wildlife. It is important to note that the values for background locations for soil, earthworms and small mammals are based on only one soil sample, and should be recognized as being only a rough indicator of the true EPC.

6.6 Estimating Dietary Tissue Concentrations

Table 6-2 provides a summary of the EPCs for the concentration of COPCs in the tissues of various types of biotic food items at the site and at reference locations. The derivation of these values is discussed below.

Plants

Two composite samples of plant tissue were collected from on-site locations (Elk-29 and SM-00), and two from a reference location (Sp-01). The raw data are presented in Appendix A. In accord with ProUCL guidance, because there were fewer than four samples in each category, no attempt was made to compute a UCL, and the EPC was taken to be the maximum detected concentration.

Benthic Invertebrates and Fish

No samples of benthic invertebrates or fish have been collected from Elk Creek within the boundaries of the Standard Mine site. For this reason, samples from Elk Creek below the mine are used to estimate concentrations that might occur in organisms collected from on-site locations. For benthic invertebrates, two samples are available (collected at Elk-00 and Elk-05). For fish, three samples are available, all collected from Elk-00. Use of these samples to estimate concentrations in on-site aquatic prey items may tend to underestimate true concentrations, but use of measured data is considered to be preferable to use of values derived using default mathematical uptake models.

Samples are also available from reference locations. For benthic invertebrates, this includes three samples from COP-01, SP-00 and SP-01, and for fish, this includes three samples all from SP-01.

The raw data are presented in Appendix A. As above, because there were fewer than four samples in each category, no attempt was made to compute a UCL, and the EPC was taken to be the maximum detected concentration.

Soil Invertebrates and Small Mammals

Tissue samples from soil invertebrates and small mammals are not available at this site. Therefore, tissue concentrations for these organisms were estimated using soil-to-tissue bioaccumulation models located in the literature, as described in USEPA (2006). These equations and parameters are presented in Appendix C. In cases where no uptake model could be located for a chemical, it was conservatively assumed that the uptake of that chemical was equal to the highest available uptake factor for other chemicals for that food item.

6.7 Toxicity Assessment

Two types of oral toxicity values are used in this assessment. The first type is based on the No-Observed-Adverse-Effect-Level (NOAEL), which is an estimate of the highest daily dose of a chemical that may be ingested without any unacceptable adverse effect occurring. The second

type is based on the Lowest-Observed-Adverse-Effect-Level (LOAEL), which is an estimate of the lowest ingested daily dose that is likely to result in an observable adverse effect. If an HQ is below 1 based on the NOAEL TRV, it is believed that risks are minimal. If the HQ is above 1 based on the LOAEL TRV, it is considered likely that some adverse effects will occur. If the HQ is above 1 based on the NOAEL and below 1 based on the LOAEL, it is considered that adverse effects are possible, but they are likely to be minor in extent and/or severity.

The basis for the NOAEL-based and LOAEL-based TRVs selected for use in this assessment are presented in Appendix B, and the results are summarized in Table 6-3.

6.8 Risk Characterization

Appendix M provides the detailed HQ calculations for each wildlife receptor for each chemical of potential concern from each exposure medium. Table 6-4 summarizes the results. If both a NOAEL- and LOAEL-based TRV are available for a chemical, Table 6-4 shows the range of between the two. If only one type of TRV is available, only that HQ is shown. Inspection of this table reveals the following main observations:

- For a number of receptors (cliff swallow, greater sage grouse, belted king fisher, red-tailed hawk, mule deer, red fox and Canada lynx), risks appear to be below a level of concern based on both NOAEL- and LOAEL-based TRVs. For the American dipper, risks are below a level of concern for all chemicals except for zinc, where the total HQ is below a level of concern (total HQ = 0.2) based on the LOAEL-TRV, but slightly above a level of concern (total HQ = 2) based on the NOAEL-TRV. These results suggest that risks to these receptors are very unlikely to be of significant ecological concern.

- There are four receptors (American robin, northern flicker, masked shrew, and deer mouse) that have NOAEL-based HQ values above 1 for multiple chemicals. These elevated HQ values are attributable to intake of contaminants in soil and/or diet (primarily terrestrial invertebrates), with no significant contribution from surface water (see Appendix M). In interpreting these elevated HQ vales, it should be noted that there are only three cases where the LOAEL-based HQ exceeds 1 (zinc for the American robin, aluminum for the masked shrew and the deer mouse), and that the exceedences for aluminum are similar for on-site and off-site locations. These results (many NOAEL-based but few LOAEL-based HQ values above 1) indicate that the magnitude and/or severity of any adverse effects on these four receptors is likely to be low to moderate. In addition, it should be remembered that risks from ingestion of contaminants in soil are likely to be overestimated because of the assumption of RBA values of 1.0, and that risks from ingestion of soil invertebrates is likely to be overestimated because the concentration of contaminants in the tissues of these organisms is estimated by mathematical uptake models rather than actual measurement. Thus, HQ values for these four receptors should be recognized as uncertain, and are more likely to be high than low.

6.9 Uncertainties

Representativeness of Soil Samples

As noted above, the soil data available for the Standard Mine site is of high quality with respect to spatial representativeness and sample number, and this data set is not a source of significant uncertainty. However, only one soil sample is available from a background location, so comparisons of soil-based exposures to background are uncertain.

Exposure from the Diet

Exposure via the diet is an important exposure pathway for many receptors, and confidence in the accuracy of the risk conclusions is often limited by lack of data on actual concentrations in dietary food items. At this site, data were collected on metal levels in plants, benthic invertebrates and fish, and these data were used in the calculation of exposures for herbivores, insectivores and piscivores. While this helps decrease uncertainty, the number of samples of each food type was sufficiently small that the EPCs were often based on the maximum value, which is more likely to overestimate than underestimate true exposures. Conversely, for fish and benthic organisms, the data were collected downstream of the Standard Mine site, and might tend to underestimate true concentrations in any organisms that might actually reside on site.

For other food web exposures (soil invertebrates, small mammals), no tissue data were collected, so mathematical models were used to estimate tissue concentrations from the available soil data. Such models are generally simplified and often quite conservative, usually tending to overestimate actual tissue concentrations. Thus, HQ values for dietary exposure based on the calculated tissue concentrations have only low confidence.

Uptake from Ingested Soil

Data on soil intake by wildlife species are generally limited, so the soil intake rates used in these calculations are uncertain. For ingested soil it was assumed that the RBA of chemicals in soil is 100%. However, in many cases, the absorption of metals in soil is not as high as from food or water, so this approach will often tend to overestimate risks from soil ingestion. This approach is most likely to impact the assessment for receptors that have a relatively high intake of soil from the diet (see Table 6-1), including the robin, flicker, shrew and mouse. Thus, as noted above, risks to these receptors are especially more likely to be high than low.

Reliability of Wildlife TRVs

Data on the toxicity of chemicals to wildlife receptors are often limited, so it is often necessary to select TRVs for a species or feeding guild that is not a direct match to the group being evaluated.

Hence, these TRVs may not fully account for potential differences in susceptibility between each species in a feeding guild, and may tend to either overestimate or underestimate true hazards. In addition, it is not always possible to select values for both the NOAEL and LOAEL. In these cases, it becomes difficult to interpret the significance of NOAEL-based HQ greater than 1, since it is unknown if the dose approaches or exceeds the LOAEL. Conversely, it is difficult to interpret a LOAEL-based HQ less than 1, since it is not certain whether the dose may be above the NOAEL.

7.0 REFERENCES

CDPHE. 2007. Colorado Department of Health and Environment, Water Quality Control Commission Regulations. Regulation No. 31. The Basic Standards and Methodologies for Surface Water (5 CCR 1002-31). http://www.cdphe.state.co.us/regulations/wqccregs/

Colburn T. 1982. Measurements of low levels of molybdenum in the environment using aquatic insects. Bull. Environ. Contam. Toxicol. 29:422-428.

Colburn T. 1986. The use of the stonefly *Pteronarcys californica* Newport as a measure of biologically active cadmium in a high altitude river system, Colorado, USA. Water Qual. Bull. 11:141-147.

Colorado Division of Wildlife (CDOW). 2006. Email communication from Nicole Vieira to Dan Wall on 5/17/06.

Moran RE, Wentz DA. 1974. Effects of metal mine drainage on water quality in selected areas of Colorado. 1972-73. US Geological Survey. Colorado Water Resources Circular No 25.

NDIS. 2006. Natural Diversity Information Source (NDIS). Colorado Division of Wildlife. Website. http://www.ndis.nrel.colostate.edu/. Accessed 04/04/06.

Peckarsky BL; Cook KZ. 1981. Effect of Keystone mine effluent on colonization of stream benthos. Environmental Entomology 10, 864-871.

Prothro, M. 1993. Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria. Memorandum to Water Management Division Directors and Environmental Services Directors, USEPA Regions I-X. October 1, 1993.

Rumberg CB, Gery BAH, Butcher K. 1978. Gunnison County stream water quality study. EPA-908/3-78-001.

Stantec Consulting Ltd. 2005. Coal Creek Watershed Protection Plan. April 2005.

Thomas, John A. and John T. Galey, Jr. 1982. Exploration and Geology of the Mt. Emmons Molybdenite Deposit, Gunnison County, Colorado. Economic Geology. 77: 1085-1104.

URS Operating Services (URSOS). 1999. Analytical Results Report for Expanded Site Inspection for the Ruby Mining District, South.

URS Operating Services (URSOS). 2000. Analytical Results Report for Expanded Site Inspection for the Ruby Mining District, South.

United States Environmental Protection Agency (USEPA). 1989a. Risk Assessment Guidance for Superfund (RAGS). Volume I. Human Health Evaluation Manual (Part A).

United States Environmental Protection Agency (USEPA). 1989b. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic macroinvertebrates and Fish*. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, D.C. EPA 440-4-89-001.

United States Environmental Protection Agency (USEPA). 1992. Framework for Ecological Risk Assessment. Risk Assessment Forum. EPA/630/R-92/001.

United States Environmental Protection Agency (USEPA). 1993. Wildlife Exposure Factors Handbook, Volumes 1 and II. U.S. Environmental Protection Agency. EPA/600/R-93/187a and b.

United States Environmental Protection Agency (USEPA). 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. U.S. Environmental Protection Agency, Environmental Response Team (Edison, NJ). June 5, 1997.

United States Environmental Protection Agency (USEPA). 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F. April, 1998.

United States Environmental Protection Agency (USEPA). 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*. 2nd Edition. U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds. Washington, D.C. EPA 841-99-002.

United States Environmental Protection Agency (USEPA). 2002. Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. OSWER 9285.6-10. December 2002.

United States Environmental Protection Agency (USEPA). 2003. Guidance for Deriving Ecological Soil Screening Levels (Eco-SSLs). Draft. Office of Solid Waste and Emergency Response. February 2003.

United States Environmental Protection Agency (USEPA). 2006. Screening-Level Ecological Risk Assessment For The Standard Mine Site, Gunnison County, Colorado. Report prepared by USEPA Region 8 with technical support from Syracuse Research Corporation. September 29, 2006

Wentz DA. 1974. Effect of mine drainage on the quality of streams in Colorado, 1971-72. US Geological Survey. Colorado Water Resources Circular No 21.