Mount Hope Project Pit Lake Screening-Level Ecological Risk Assessment

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Report Prepared for

GENERAL MOLY
Eureka Moly, LLC

Report Prepared by

SRK Consulting
Engineers and Scientists

March 2009
(Revised July 2010)

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Executive Summary

Eureka Moly, LLC (Eureka Moly) is proposing to construct, operate, and close the Mount Hope molybdenum mine located in Eureka County, Nevada. A post-mining pit lake is expected to form. A geochemical model was undertaken to obtain predictions of the future pit lake water quality following closure and reclamation of the site. A Screening-Level Ecological Risk Assessment (SLERA) was prepared by SRK using the predicted water quality results. The principal objectives of the investigation were to:

- Identify those inorganic chemical constituents and chemical characteristics (e.g., pH, TDS, etc.) based on the model's predictions that may have the potential to contribute to adverse effects on terrestrial and avian wildlife as per NAC 445A.429;
- Identify ecological receptors, and/or appropriate surrogate species occupying similar niches, with the highest potential for exposure to chemical constituents in the pit water;
- Identify complete exposure pathways between the post-mining pit lake and the identified receptors; and
- Quantitatively and/or qualitatively assess the ecological risks to select terrestrial and avian wildlife receptors exposed to inorganic chemical constituents in water whose concentration in the post-mining pit lake is predicted to exceed the calculated screening-level toxicity criteria.

The SLERA is an early-stage, decision-making tool, the results of which will be used by Eureka Moly, in coordination and cooperation with the Bureau of Land Management (BLM), the Nevada Division of Environmental Protection (NDEP), and the Nevada Department of Wildlife (NDOW), to evaluate the potential risks posed by the predicted future pit lake water, and to support the decision-making process with respect to the possible need for mitigation activities.

The general approach to this SLERA is similar to that developed by the Environmental Sciences Division and Life Sciences Division of Oak Ridge National Laboratory for the U.S. Department of Energy (Sample *et al.*, 1996). In addition, the SLERA incorporated more recent toxicity reference values (TRVs) for certain inorganic chemical constituents derived by the EPA (2003). Together, these were used to develop species-specific toxicity criteria to which the predicted constituents in the pit water were compared.

The toxicity criteria were developed based on species-specific No-Observed-Adverse-Effects-Levels (NOAELs) and TRVs, published and calculated water ingestion rates, and average individual body weights. Criteria were developed for eight species, including the little brown bat, white-footed mouse, cottontail rabbit, white-tailed deer, red-tailed hawk, mallard duck, common barn owl, and rough-winged swallow. These species are considered reasonable surrogate species for the populations inhabiting the region in and around the Mount Hope Project site. A surrogate species, while not necessarily occurring at the investigation site, typically occupies similar niches, has similar body masses, and similar exposure parameters to the known occupants of the area. For

example, because literature data are limited on mule deer (a common animal in the area), the white-tailed deer was selected as a substitute species for evaluation. The same holds for the other test species.

Protective criteria for the surrogate species are likely to be protective of local species occupying similar ecological niches at the Mount Hope Project site. Additionally, it was assumed that the wildlife receptors would consume water from the pit; and, that this water would constitute 100 percent of each species individual daily water requirements (i.e., no outside sources of water would be utilized over the life of the animal). This is considered an extremely conservative assumption.

The results of the assessment indicate that the most likely predicted water quality of the modeled future pit lake water at the Mount Hope Project could represent a low-moderate toxicological threat to livestock (cattle, sheep, swine, horses, poultry, etc.) based on Nevada's beneficial use standard for livestock watering. However, since this water is not intended to be a livestock watering source, and the standards were based on limited toxicological information, the probable risk to livestock would be *Low*.

For wildlife (terrestrial and avian), the results of the assessment indicate a low risk based on calculated species-specific toxicity criteria using more recent EPA developed TRVs. None of the chemicals of potential ecological concern (COPECs) identified in the Mount Hope Project predicted pit lake water poses a credible risk to wildlife that may inhabit the site and use the pit as a drinking water source; the potential to affect adversely the health of terrestrial or avian life is considered negligible. Based on the predicted pit lake chemistry, calculated toxicity criteria, and predicted utilization of the Mount Hope Project open pit by wildlife, the overall ecological risk is, therefore, considered to be *Low*.

Table of Contents

List of Figures

List of Tables

List of Appendices

List of Acronyms and Abbreviations

amsl	above mean sea level
ATSDR	Agency for Toxic Substances and Disease Registry
BLM	U.S. Bureau of Land Management
BMRR	Bureau of Mining Regulation and Reclamation
bw	Body weight
C_w	Criteria concentration in water
COPEC	Chemical of Potential Ecological Concern
CSM	Conceptual Site Model
DOE	Department of Energy
ECO-SSL	Ecological Soil Screening Level
E_h	Oxidation/Reduction Potential
EPA	U.S. Environmental Protection Agency
e.g.	Latin phrase *exempli gratia* meaning "for example"
et seq.	Latin phrase *et sequentes* meaning "and the following…"
et al.	Latin phrase *et alii* meaning "and others."
HQ	Hazard Quotient
i.e.	Latin phrase *id est* meaning "That is (to say)…"
IDL	Instrument Detection Level
kg	Kilograms
LD	Lethal Dose
L/d	Liters per day
LOAEL	Lowest Observed Adverse Effects Level
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
NAC	Nevada Administrative Code
NAS	National Academy of Sciences
NDEP	Nevada Division of Environmental Protection
NDOW	Nevada Department of Wildlife
NOAEL	No Observed Adverse Effects Level
NOAEC	No Observed Adverse Effects Concentration
ORNL	Oak Ridge National laboratory
RTECS	Registry of Toxic Effects of Chemical Substances
SLERA	Screening-Level Ecological Risk Assessment
TRV	Toxicity Reference Value
s.u.	Standard Units (of pH)
TDS	Total Dissolved Solids
USAF	U.S. Air Force
W	Daily water consumption rate

1 INTRODUCTION

The following Screening-Level Ecological Risk Assessment (SLERA) has been prepared to evaluate any potential toxicological threats posed by the predicted post-mining pit lake water quality at the Mount Hope Project in Eureka County, Nevada. The site is located in central Nevada, about 23 miles north of the town of Eureka.

The quantitative evaluation of ecological risk associated with the pit water is based on predicted surface water chemistry for the future pit lake, as described and presented in the *Mount Hope Project Pit Lake Geochemistry Report* (Schlumberger Water Services, 2010). Utilizing the boundary conditions for the future pit lake, the SLERA was designed to evaluate the predicted metal and major ion concentrations in the pit water using conservative assumptions and exposure parameters for ecological wildlife receptors that could potentially be exposed to the water following closure of the facility. Screening-level assessments provide a simplified evaluation in order to eliminate, with reasonable confidence, chemical constituents not expected to result in probable or elevated risk to living organisms. Additionally, screening-level assessments can quickly identify chemicals most likely to contribute to site-related risks, so that further evaluation efforts, if warranted, can be focused on those chemicals and receptors that are potentially affected.

The approach used to evaluate the potential risks associated with exposure of wildlife to the water in the future Mount Hope Project open pit principally follows guidance provided in the U.S. Department of the Interior, Bureau of Land Management (BLM) *Ecological Risk Assessment Guidelines for Open Pit Mine Lakes in Nevada (2008)*. Since 1996, the BLM has been utilizing ecological risk assessments in Nevada to evaluate the potential impacts of post-mining pit lakes. In recent years, however, the development of new ecological screening information, criteria and tools by the U.S. Fish and Wildlife Service (USFWS), U.S. Environmental Protection Agency (EPA), U.S. Department of Energy (DOE), national laboratories, state universities, and state agencies, has prompted the BLM to issue more specific guidelines for risk evaluations in Nevada. In addition to the BLM (2008) guidance, the Mount Hope Project SLERA considers the guidance or approach (or utilizes toxicity information) from these additional sources:

- U.S. Environmental Protection Agency (EPA) *Guidelines for Ecological Risk Assessment* (1998);
- *Guidance for Developing Ecological Soil Screening Levels* (EPA, 2003); and
- Oak Ridge National Laboratory's *Toxicological Benchmarks for Wildlife* (Sample *et al*., 1996).

The methods and approach used the Mount Hope Project SLERA are appropriate for the identified ecological receptors.

1.1 Purpose and Scope

The purpose of this SLERA is to quantitatively evaluate the potential exposure and toxicological risk to the environment, specifically terrestrial and avian wildlife associated with the future open pit mine lake at the Mount Hope Project site. The results of this evaluation are intended to be used by Eureka Moly, in coordination with the Nevada Division of Environmental Protection (NDEP), Bureau of Mining Regulation and Reclamation (BMRR), the Nevada Department of Wildlife (NDOW), and the BLM to evaluate the potential toxicological risks posed by the future pit lake water, and to support the decision-making process with respect to the possible need for additional mitigation measures, if necessary.

1.2 General Approach

In general, a screening-level ecological risk assessment is a Tier 1 approach that utilizes previously published and readily available information to quickly determine if further evaluation of potential ecological risks may be warranted. For the Mount Hope Project SLERA, predicted water quality concentrations for the future Mount Hope Project open pit mine lake (prepared and developed by Schlumberger Water Services, 2010) were compared to (screened against) previously published and calculated species-specific toxicity criteria for a number of terrestrial and avian wildlife receptors, as well as promulgated livestock standards. The chemical constituents that were found to exceed the established screening criteria were then retained for additional analysis and a determination of the magnitude of potential risk.

Screening criteria used for comparison in ecological risk assessments are generally derived from published Toxicity Reference Values (TRV).The principal source of chemical-specific toxicity data for the majority of the constituents of interest predicted to exist in the future Mount Hope Project pit lake, was derived from EPA (2003), and represent receptor-class specific estimates of No-Observed-Adverse-Effect-Levels (NOAELs) for the respective contaminant for chronic exposure. While EPA (2003) used the TRVs to develop soil screening levels based on soil ingestion rates of organisms, the toxicity data can also be applied to other potentially contaminated media. The EPA NOAELs were determined from experimental study and observation as daily ingested doses (expressed as mg/kg-d) and, when combined with organism body weights and water intake rates, were used to yield a specific comparison criterion in mg/L (see below).

For some chemical constituents for which EPA (2003) did not derive a specific TRV, the SLERA deferred to the TRVs developed by Sample *et al.* (1996). As with the TRVs developed by EPA (2003), the Sample *et al.* (1996) TRVs also represent NOAELs for avian and mammalian wildlife species. However, in some cases, experimental data yielded only Lowest-Observed-Adverse-Effect-Levels (LOAELs) rather than the preferred NOAEL. In these cases, an uncertainty factor of 10 was applied to the LOAEL to estimate a NOAEL, an approach consistent with EPA (1997b) guidance.

The selected TRVs were then used to derive species-specific no-effect, screening-level concentrations in water for each individual chemical of interest. The no-effect concentration of the contaminant in the drinking water of a specific animal (C_w, in mg/L) resulting in a dose equivalent to a selected TRV or $NOAEL_w$ can then be calculated using the daily water consumption rate (W, in L/day) and the average body weight (bw_w) for the particular animal species of interest using the following equation:

$$C_w = \frac{NOAEL_w \times bw_w}{W}$$

Water consumption rates are available from various sources, including the *Wildlife Exposure Factors Handbook* (EPA, 1993), other published literature, or can be estimated from allometric regression models based on body weight (in kg) (Calder and Braun, 1983).

Once the species-specific no-effect, screening-level concentration has been determined, it can then be compared to the predicted concentration in the future Mount Hope Project pit lake. Exceedences of the species-specific screening criteria were then selected for further analysis during with the degree of exceedence (or a risk ranking) could be applied.

Similar to the Hazard Quotient (HQ) approach used in human-health risk assessments, if the predicted concentration of a chemical in the pit lake water is lower than the lowest calculated toxicity criteria, then the chemical is unlikely to represent a toxicological threat under normal site conditions (i.e., *Low* to *No* risk).

$$HQ = \frac{Exposure\ Concentration}{Toxicity\ Criterion} \leq 1.0$$

If the chemical concentration (or the reported analytical detection limit) of a chemical constituent exceeds (is greater than) a specific toxicity criterion (hence, the HQ >1), then further analysis (including evaluation of the TRV basis) may be warranted to determine what, if any, hazard is posed by that chemical to the particular ecological receptor(s) and the local environment as a whole. In simplistic terms, the more a chemical concentration exceeds a criterion value, the higher the HQ, and the more likely it is that the specific contaminant may pose a credible risk to the receptor(s). However, while the dose-response for a given analyte, on which a TRV and subsequent criterion are based, is not necessarily linear, an analyte with an HQ of 1.1 is less likely to present a significant risk to an ecological receptor than an analyte with an HQ of 10, or even 100.

To characterize the relative significance of each risk calculation (HQ), the SLERA referred to the guidance document, *Risk Management Criteria for Metals at BLM Mining Sites* (BLM, 2004), which suggests that exceedences of a criterion be interpreted as follows:

- Less than the criterion (HQ < 1) = "Low" risk
- 1-10 times the criterion (HQ = 1 to 10) = "Moderate" risk
- 10-100 times the criterion (HQ = 10 to 100) = "High" risk

- >100 times the criterion (HQ > 100) = "Extremely High" risk.

According to the BLM (2004), given the uncertainties associated with ecological screening criteria and the values inherent in ecosystem management, moderate risk may be addressed by management and or institutional controls, whereas high risk may require remediation. In the end, the Mount Hope Project SLERA, and the toxicity criteria developed herein, provide a quick way to prioritize possible contaminants in the pit lake, and will allow the stakeholders to make informed decisions regarding future management of the site.

2 PROBLEM FORMULATION

The problem formulation process describes the physical and ecological setting of the site; provides an evaluation of contaminant sources and discusses selection of the chemicals of interest; develops the ecological conceptual site model (CSM); identifies the assessment endpoints and measures, including identification of representative species; and provides summaries of the available data.

2.1 General Environmental Setting

The Mount Hope Project is located in central Nevada about 23 miles north of the town of Eureka. The deposit is located in the central Great Basin section of the Basin and Range Physiographic Province and underlies Mount Hope, with a maximum altitude of about 8,380 feet above mean sea level (amsl) surrounded by Diamond Valley to the east, Kobeh Valley to the southwest, and Pine Valley to the north and northeast.

Surface water, in the form of streams or lakes, is limited in the area. Virtually all of the surface water flows are ephemeral and contain water only during storms or intense snowmelt. As such, the existence of an open water body would represent a significant attractant for wildlife in the region.

The mammal species within Mount Hope Project Area include those typically found in lower and mid-elevation Great Basin habitats. Mule deer utilize the wooded hills and sagebrush habitats within and adjacent to the site. Other mammalian species include black-tailed jackrabbits, yellowbelly marmots, coyote, bobcat, mountain cottontail and a variety of small mammals (i.e., mice, voles, chipmunks, etc.). Several bat species also have the potential to occur within the area. The historic underground mine workings are potential habitat for bats.

Few game birds are known to occur within the Mount Hope Project area. However, sage grouse, chukar, and mourning dove occur in and adjacent to the site. Raptors are also fairly common near the Project. The rocky outcrops and ledges at the upper elevations of Mount Hope were surveyed by helicopter for raptor nests, although none were observed.

The Mount Hope Project is located within the Pacific Flyway for migrating waterfowl. A variety of songbirds also inhabit the area, with most migrating to and from the area in spring and fall and occurring only as summer residents. This would limit any long-term exposure to the future open pit mine lake water.

2.1.1 Pit Lake Formation

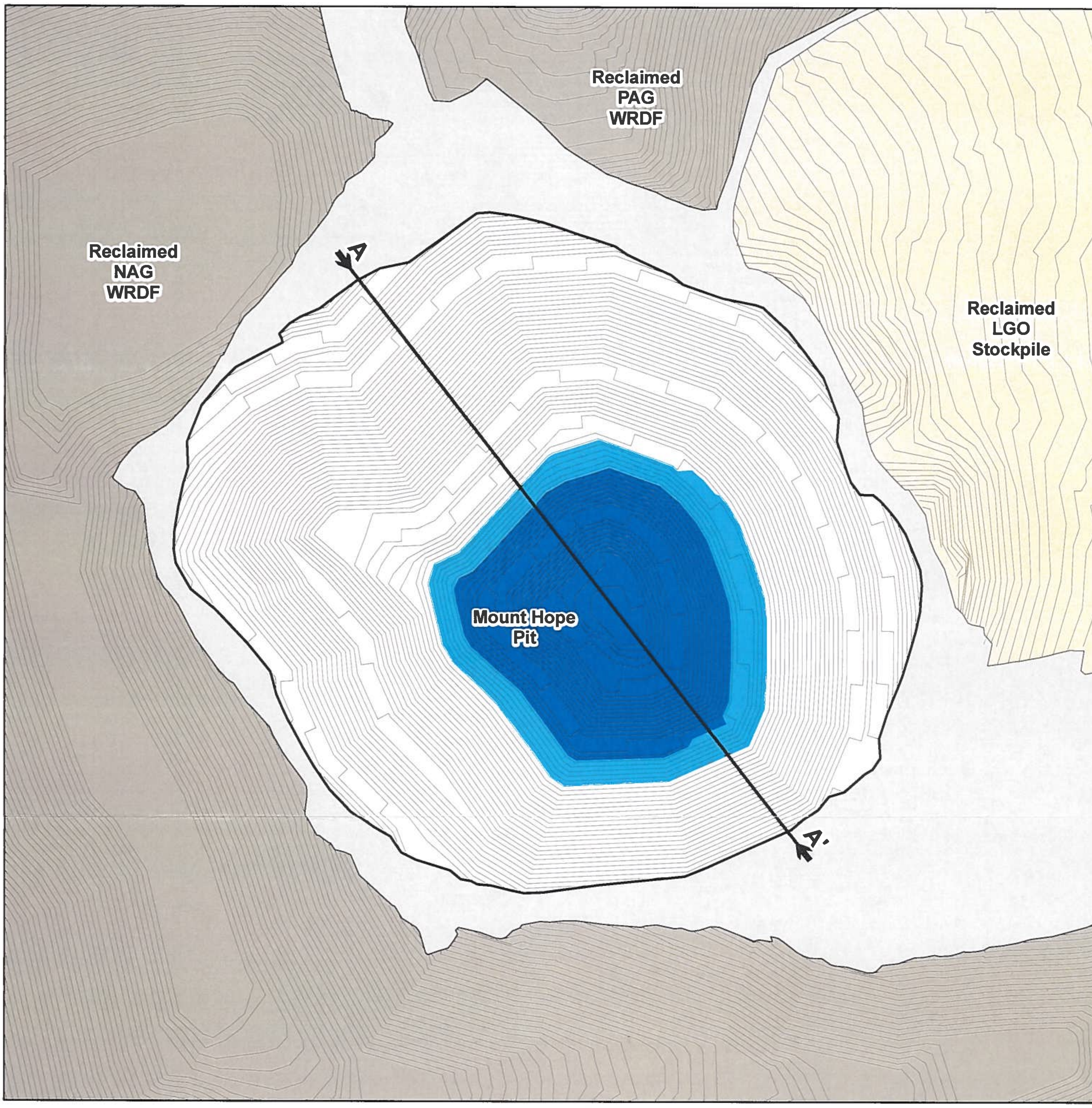
A detailed assessment of the hydrologic formation and geochemical conditions of the predicted Mount Hope Project pit lake is provided in the reports, *Hydrogeology and Numerical Flow Modeling - Mount Hope Area* (Interflow *et al.*, 2009) and *Mount Hope Project Pit Lake Geochemistry Report* (Schlumberger Water Services, 2010). In general, the pit lake would begin forming immediately upon cessation of mining and dewatering activities, currently estimated at year 32 of the project life.

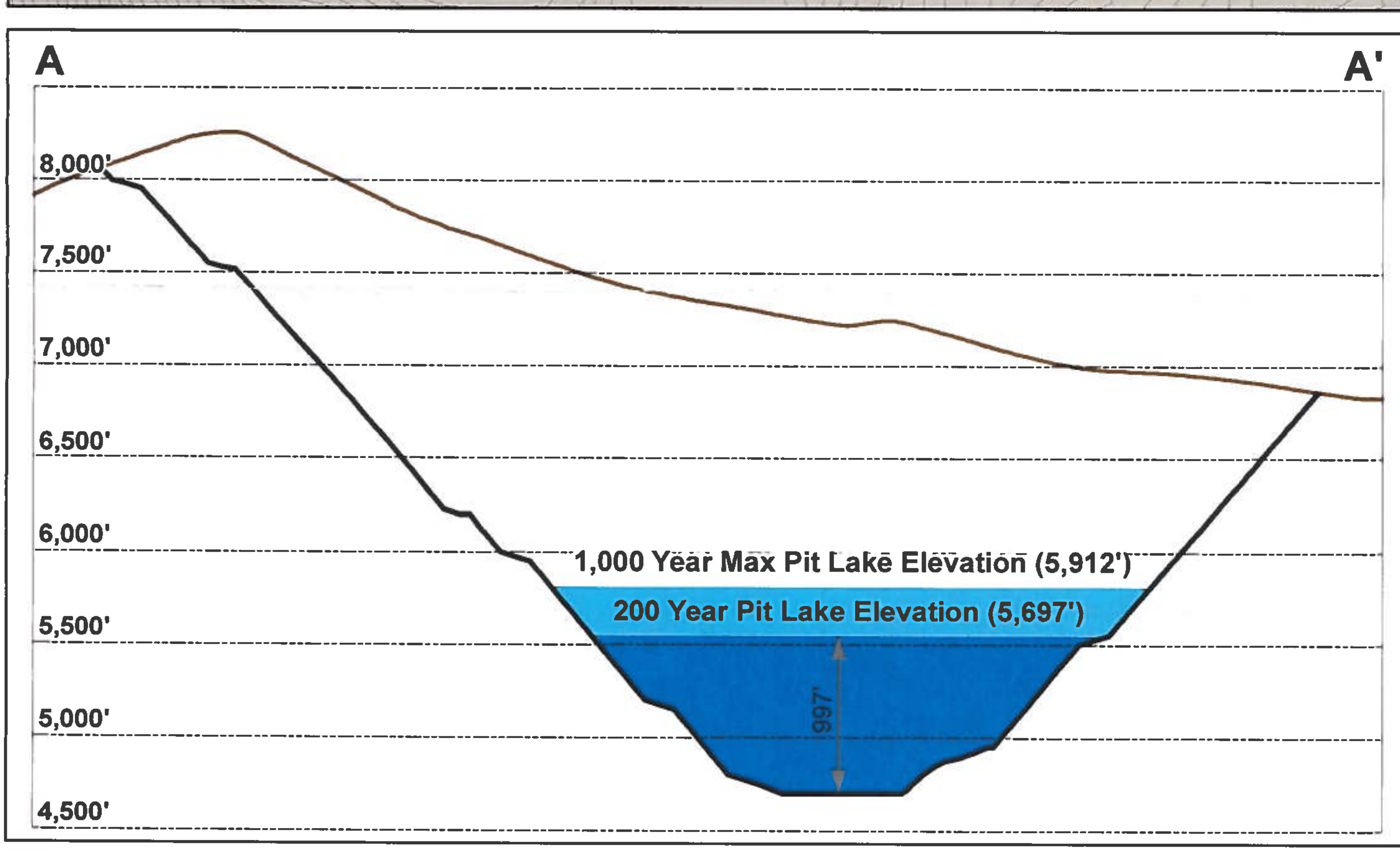
Water levels in the lake are anticipated to rise slowly, approaching hydrological equilibrium approximately 1,000 years after mining and dewatering ceases. At this time, the lake is predicted to be on the order of 1,212 feet deep. The hydrological model also predicts that water levels would not reach the elevation required to result in movement of water from the lake into the surrounding aquifer; thus, for the expected climatic conditions, the future pit lake is predicted to behave as a hydrologic sink, with evaporation consuming all precipitation and groundwater inflow to the lake. This condition will result in the gradual evapo-concentration of salts and minerals.

Given the current state-of-the-art of surface water modeling at hard rock mines, the uncertainties associated with the hydrological and geochemical modeling efforts become too extreme beyond a certain point to be considered valid. For this reason, the BLM and the project proponent, Eureka Moly, agreed to set a limit on the predicted extent of the Mount Hope pit lake model for purposes of impact assessment. A snapshot of the lake at 200 years post closure was set as the limit on the modeling effort. As such, the SLERA has also been limited to this particular time in the development of the future pit lake. The lake will be approximately 82 percent filled (by depth) at that point in time. A graphical representation of the 200-year pit lake and the 1,000-year pit lake depicting the difference in depth and lateral extent is presented in **Figure 1**. The figure illustrates the relative distances from the original ground surface, the steepness of the pit walls, and overall depth of the lake with respect to surrounding landforms and habitat types. Pit Lake Water Quality

The geochemical model used to predict the Mount Hope Project pit lake chemistry at 200 years after cessation of dewatering, did so by mixing waters from the various inflow sources, evapo-concentrating the mixture, and then allowing the resulting water to equilibrate with specified mineral and gas species (Schlumberger Water Services, 2010). As agreed to by the BLM, the modeled pit lake water chemistry was evaluated for ecological risks under the Base Case scenario. The Base Case scenario represents the chemistry anticipated to be the most likely condition of the pit lake water quality at 200 years post closure. However, it should be noted that this scenario does not represent equilibrium conditions, as hydrodynamic equilibrium is expected to take approximately 1,000 years following closure, and geochemical equilibrium is anticipated to require several centuries beyond that.

For the Base Case geochemical model scenario, the pH of the pit lake water is predicted to be neutral to slightly alkaline, with a pH of approximately 7.7 standard units (s.u.) throughout the 200-year filling period of interest (Schlumberger Water Services, 2010). At this circum-neutral pH, the potential for increased mobilization of additional metals and metalloids into the water column is considered low (Stumm and Morgan, 1981).





EXPLANATION

- Pit Surface
- Original Surface
- Low Grade Ore Stockpile (25' Contours)
- Waste Rock Disposal Facility (20' Contours)
- Pit (50' Contours)
- 1,000 Year Max Pit Lake Elevation (5,912' AMSL)
- 200 Year Pit Lake Elevation (5,697' AMSL)

N

Feet
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DESIGN: MW	DRAWN: BVB	REVIEWED: VS
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GENERAL MOLY

DRAWING TITLE:
MOUNT HOPE PROJECT PREDICTED PIT LAKE FORMATION

DRAWING NO. FIGURE 1
SRK JOB NO. 157503.000
REVISION NO. A

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Most trace metals/metalloid concentrations are predicted to be low or below analytical detection; however, concentrations of fluoride, cadmium, and manganese are predicted to be present at concentrations above NDEP reference standards during early pit lake filling and throughout the modeling period. In general, constituent concentrations in the pit lake are predicted to increase over time due to evapo-concentration (Schlumberger Water Services, 2010). Therefore, the higher concentrations anticipated to occur at the 200-year evaluation point would represent a conservative exposure point assumption.

Because the water in the pit lake will be exposed to mineral bearing rock, and no anthropogenic organic substances are anticipated to be in the water or added to the water, the constituents (chemicals) selected for assessment in this SLERA are limited to inorganic elements and compounds. These constituents, as modeled by Schlumberger Water Services (2010), are presented in **Table 1**.

Table 1: Selected Constituents for SLERA Assessment

pH (s.u.)	Alkalinity, as $CaCO_3$	
Major Ions		
Calcium ✓	Magnesium ✓	Potassium ✓
Chloride ✓	Nitrate, as N ✓	Sodium ✓
Fluoride ✓	Phosphorus ✓	Sulfate, as SO_4^{2-} ✓
Metals/Metalloids		
Aluminum ✓	Cobalt	Nickel
Antimony ✓	Copper	Selenium
Arsenic ✓	Iron	Silver
Barium	Lead	Strontium
Beryllium	Lithium	Thallium
Boron	Manganese	Tin
Cadmium	Mercury	Vanadium
Chromium	Molybdenum	Zinc

A complete discussion and detailed analysis of the modeling approach used to derive the predicted water quality is available in the *Mount Hope Project Pit Lake Geochemistry Report* (Schlumberger Water Services, 2010).

2.2 Habitat Conditions and Potential for Future Habitat Development

While reclamation of the general mine site should produce satisfactory wildlife habitat on the upland and lowland areas of the mine site, the interior of the future open pit is deemed low-quality habitat for long-term residence of terrestrial animals due to its sheer steepness, the anticipated lack of adequate protective cover and food resources, and the distance (1,500 feet) from the pit rim to the surface of the pit lake.

Biological development within the future pit lake, including the potential for littoral zone development, is questionable, and will depend on the pit lake's physical characteristics, its water chemistry and nutrient availability, and the environment in which it is situated. Based on these characteristics, and the possibility of accidental and/or opportunistic colonization of the lake by bacterial, vegetal and invertebrate taxa, the expected habitat of the pit may include, riparian and littoral zones potentially capable of supporting wildlife populations, and an upland habitat along the pit walls.

Aquatic and Littoral Habitats

Like other Nevada pit lakes, the Mount Hope Project pit lake, once mature, is expected to be oligotrophic due to low nutrient (nitrate and phosphate) concentrations and low light penetration because of the geometry of the pit lake. Oligotrophic lakes are characteristically nutrient-poor and often deep, with low primary productivity (Wetzel and Likens, 1991; Wetzel, 2001).

Oligotrophic lakes typically have a minimal littoral zone. In pit lakes, the establishment of a littoral zone typically occurs in isolated patches around the shoreline, on remnant mine benches that occur at the same elevation as the ultimate pit lake surface. Potential littoral zones within the Mount Hope pit lake would be limited to the width of a typical highwall bench, currently estimated at 45 to 65 feet wide. The steep, sheer pit walls and sloughing of rock at the wall/water interface will likely limit the robust establishment of a shallow lake bottom sufficiently flat to allow accumulation of a soft-bottom substrate (silt and sediment) and the establishment of rooting aquatic species. Littoral zone productivity in analog pit lakes is relatively low (typically 10% or less) when compared with naturally occurring reservoirs (Horecka *et al.*, 1994; Kalin *et al.*, 2001).

For these reasons, this risk assessment assumed that a mature and productive littoral zone, capable of fully supporting the receptor populations, would not develop within the Mount Hope pit in the 200-year evaluation period designated by the BLM for this analysis.

Riparian Habitats

The riparian habitat represents the aquatic/upland interface of a lake shoreline. Once the lake level stabilizes, limited stands of riparian species may develop along the lake boundary, providing some forage and temporary shelter for wildlife. The Mount Hope Project pit lake will not reach hydrodynamic equilibrium for 1,000 years post closure, and the water would continue to rise and fall on a seasonal and annual basis. These fluctuations are characteristic of riparian habitats and are considered to have direct influence on the development of biological communities in this zone. However, the location of riparian zones (over 1,000 feet down steep pit walls will limit the abundance and diversity of any biological systems.

Upland Habitats

The upland habitat includes the pit walls, upper mine benches, and the areas immediately adjacent to the pit rim and beyond. The pit walls could potentially provide habitat for nesting species such as bats, cliff swallows, and some raptors. While certainly possible, the movement of terrestrial organisms down to the water surface will be limited.

2.3 Selection of Ecological Receptors

Evaluation of potential risks to all of the local, indigenous animal species inhabiting the region in and around the Mount Hope Project is beyond the scope of this assessment. Instead, several more common species, for which adequate toxicological data are available, were selected as representative surrogate species for the native populations. Where possible, the species were selected to represent different trophic levels, body masses, and ecosystem niches to provide a broad-spectrum assessment of the site. The species selected for analysis are presented in **Table 2**.

Table 2: Terrestrial and Avian Ecological Receptors

Indicator Species/Niche	Surrogate Mammalian Test Species	
• Chiropterans	• Little brown bat	*Myotis lucifugus*
• Small Rodents	• White-footed mouse	*Peromyscus leucopus*
• Small Herbivores	• Cottontail rabbit	*Sylvilagus floridanus*
• Large Herbivores	• White-tailed deer	*Odocoileus virginianus*
Indicator Species/Niche	**Surrogate Avian Test Species**	
• Large Raptors	• Red-tailed hawk	*Buteo jamaicensis*
• Waterfowl	• Mallard duck	*Anas platyrhynchos*
• Small Raptors	• Common barn owl	*Tito Alba*
• Passerines	• Rough-winged swallow	*Stelgidopteryx serripennis*

2.3.1 Little Brown Bat

The little brown bat was selected as a surrogate to represent small, insect-eating mammals, especially the bat group in general, which could feed on emergent insects (if available) and drink water directly from the pit. The range of the little brown bat extends over a large portion of the United States, including the West and Southwest. The little brown bat, along with several other bat species, could roost in openings or crevices in pit highwalls. Individual specimens weigh from seven to nine grams (Anthony and Kunz, 1977), are exclusively insectivorous, and consume approximately 25 percent of their body weight, or 2.7 grams of food per day (Hill and Smith, 1994).

2.3.2 White-footed Mouse

In much of its range, the white-footed mouse is one of the most common small mammals. While the white-footed mouse range does not extend into Nevada, it is very similar to, and occupies similar niches as the deer mouse (*Peromyscus maniculatus*), a prevalent species throughout the western United States. The white-footed mouse is, therefore an appropriate surrogate species for the deer mouse and other small rodents likely to inhabit the mine site and potentially drink water directly from the pit. However, the majority of their water requirements will be met through food sources (Ecological Society of America, 1922), and the animals are not likely to venture out into the open to get water from the lake (+1,000 vertical feet below the pit rim) and risk being preyed upon. Food sources are varied, but their chief reliance is on seeds and nuts.

2.3.3 Cottontail Rabbit

Cottontail rabbits are prevalent throughout most of the continental United States, from the eastern cottontail (*Sylvilagus floridanus*) to the western mountain cottontail (*Sylvilagus nuttallii*) and desert cottontail (*Sylvilagus audubonii*). Rabbits are almost entirely herbivorous and eat nearly anything that grows above ground. In the growing season, grasses, sedges, sprouts, and leaves are used heavily. Fruits, branch tips, buds, and bark also are eaten, along with waste grain around areas that are farmed. The cottontail rabbits represent medium-sized, herbivorous species which could consume the water from the Mount Hope Project open pit lake.

2.3.4 White-tailed Deer

The white-tailed deer is an appropriate surrogate species for the western mule deer (*Odocoileus hemionus*) which inhabits much of the range of the western United States, including the immediate vicinity of the Mount Hope Mine. Ecological impacts determined for deer are likely to be similar to that of other large herbivores in the area, including the pronghorn antelope (*Antilocapra americana*). Though no pronghorn have been observed at the site, delineated pronghorn habitat exists to the north of the Mount Hope Project area. A deer that ventures to the pit bottom could browse on vegetation and drink directly from the pit lake.

2.3.5 Red-tailed Hawk

Because of its abundance and wide distribution, the red-tailed hawk is one of the most common raptor species in the western United States, and can be considered an appropriate surrogate species for most all of the raptors likely to hunt in the vicinity of, and obtain at least a portion of their daily water requirements from the Mount Hope Project pit lake. The red-tail is Nevada's largest hawk. As with most raptors, the female is nearly ⅓ larger than the male and may have a wing span of 56 inches. Although not truly migratory, they do adjust seasonally to areas of the most abundant prey. This means that the pit is not likely to be their sole source of water.

2.3.6 Mallard Duck

Of the several races of mallard duck, the common mallard (*Anas platyrhynchos*) breeds throughout Europe, most of Asia, and northern North America; it winters as far south as North Africa, India, and southern Mexico. The drake has a metallic green head (purplish in some lights), reddish breast, and light-gray body; the hen is mottled yellowish brown. Both sexes have a yellow bill and a purplish-blue wing mark bordered front and rear with white. Mallards are called dabbler ducks because they feed by "dabbling" at the surface of water bodies. They also feed by upending. They eat mainly seeds of grasses, sedges, pond weeds and other aquatic vegetation commonly found in the littoral zones of water bodies. Sometimes they will consume snails, insects and small fish. The mallard therefore represents the most exposed receptor, capable of landing in the open pit lake and exploiting it for water, and possibly food. The other animals identified thus far cannot risk extended periods out in the open to obtain water, thus reducing their overall exposure.

2.3.7 Common Barn Owl

The barn owl is common to all four of the southwestern deserts, including much of Nevada. It hunts in areas rich in rodents, along desert washes and canyons, where trees for perching are available. Barn owls choose nesting sites almost anywhere, in old buildings, hollow trees and on or in the ground. Nesting barn owls have been observed in old underground mine workings at the Mount Hope site. The barn owl represented medium sized birds inhabiting the area that could consume water directly from the pit lake.

2.3.8 Rough-winged Swallow

The rough-winged swallow was selected to represent small passerine birds, especially the swallows and other aerial feeders that forage for emergent insects and could drink directly from the water in the pit. In addition, the swallow is known to utilize mud and sediments in nest building. This material could come from the littoral zone of the pit lake. As such, the swallow could also be exposed to potential contaminants in these sediments and soils.

The rough-winged swallow generally inhabits open country, including open woodlands. In the Midwest and West, it is often found around gravel pits, stream banks, and other exposed banks of sand, dirt, or gravel. Suitable nest sites for the rough-winged swallow are preferably near, but up to ½ mile from water. Like many passerine birds, the swallows feed on the wing, catching primarily flies and other flying insects.

2.4 Assessment Endpoints

Assessment endpoints are explicit statements of the actual environmental value that is to be protected (EPA, 1998). The primary assessment endpoint identified for this SLERA is the protection of growth, development, reproduction, and survival of future pit lake individual organisms of mammalian and avian wildlife species, including waterfowl and opportunistic raptors, against adverse impacts due to metal constituent concentrations in surface waters of the pit lake.

To this end, the selection of a particular study and a particular toxicity endpoint and the identification of NOAELs (and, as necessary, LOAELs) for use as TRVs, was based on an evaluation of the available data, with emphasis placed on those studies in which reproductive and developmental endpoints were considered (i.e., endpoints that may be directly related to potential population-level effects). In addition, consideration was given to studies using multiple exposure levels, and investigations where the reported results were evaluated statistically to identify significant differences from control values.

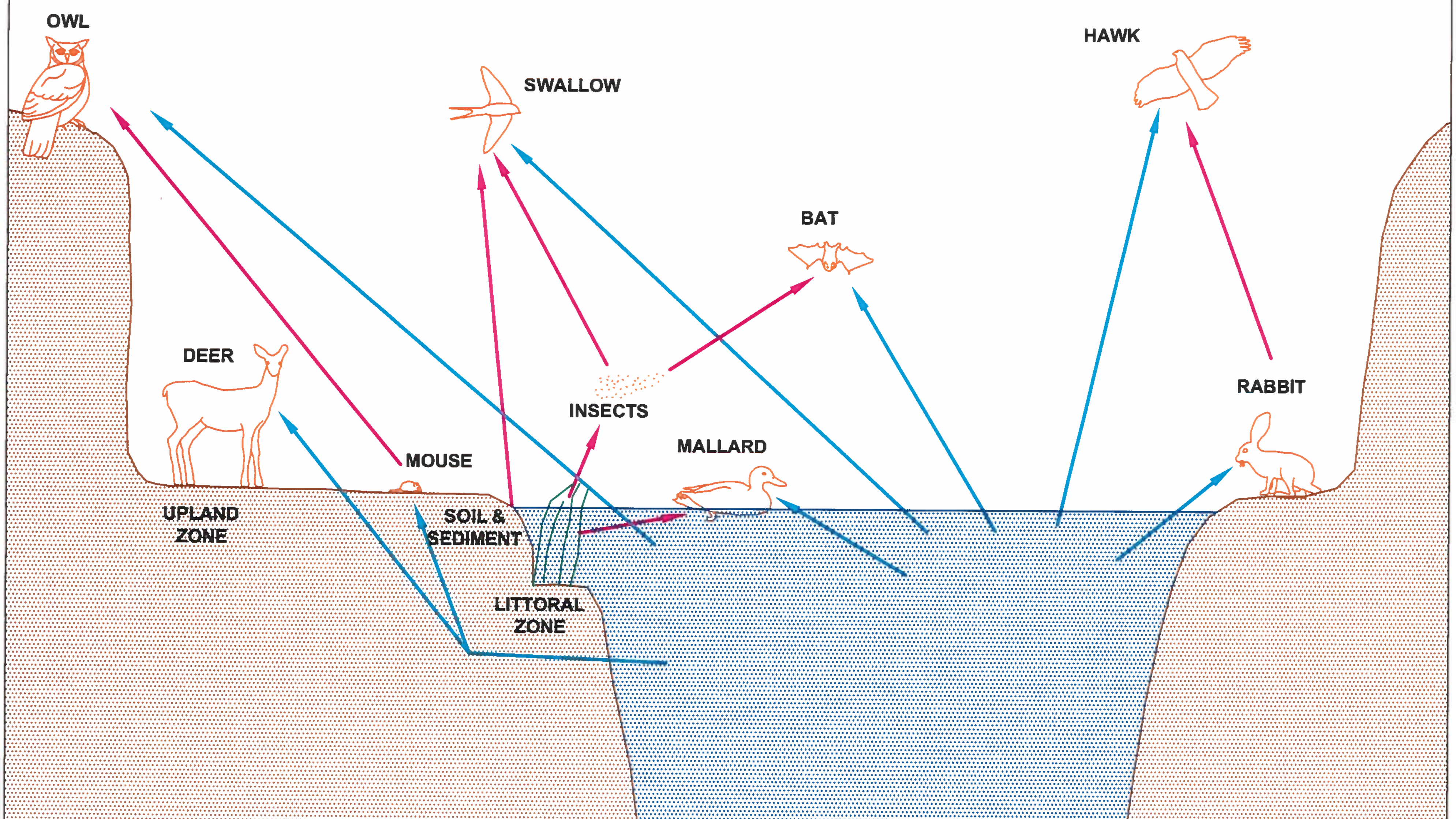
2.5 Conceptual Site Model

A simplified Conceptual Site Model (CSM) was developed using the site ecological conditions, exposure assumptions, potential ecological receptors, and assessment endpoints. A number of complete exposure pathways are likely to exist between the selected ecological receptors and the Mount Hope Project open pit lake water. However, some of these pathways are considered minor, and are likely to be overshadowed by the direct consumption of water pathway. The complete, and potentially complete but minor, pathways are illustrated in **Figure 2**, and include:

- Direct consumption of the pit water by all of the identified ecological receptors.
- Consumption of littoral vegetation by the mallard.
- The emergence of aquatic insects in the littoral zones and subsequent consumption of those (potentially exposed invertebrates) by passerines and chiropterans.
- Incidental ingestion of soils and sediments (potentially affected by the pit lake water) from the riparian and littoral zones by the swallow during nest-building activities, or mallard during feeding.
- Indirect exposure of higher-level predators via consumption of smaller prey species that have been exposed to the pit lake water.

However, this SLERA assumes that the most relevant, direct and complete exposure pathway for any terrestrial or avian receptor would be through direct uptake of water from the open pit lake. This assumption, as represented in the CSM (**Figure 2**), was selected as the sole complete pathway for evaluation in this SLERA based on the following principal assumptions and assertions as to its significance in comparison to the other pathways:

- While some physical contact may occur incidental to drinking, most wildlife are sufficiently protected against moisture contacting their dermis to rule out dermal contact as a viable exposure pathway. In addition, inorganic constituents (the principal constituents of this evaluation) are generally restricted from passing through dermal layers;
- The inhalation exposure pathway of the water is considered incomplete, as the constituents of interest are all inorganic and non-volatile; and
- Any riparian zones along the lake shoreline would likely be ephemeral in nature, and not support robust populations of organisms;
- The pathway from ingestion of other organisms that have consumed water or sediments from the pit lake is considered to provide a minor component of overall exposure, relative to the amount that would likely be contained in water that is assumed to comprise 100% of an organism's lifetime water intake.



Complete Exposure Pathway

Potentially Complete Exposure Pathway, but Minor

SRK Consulting
Engineers and Scientists

DESIGN: MW	DRAWN: BVB	REVIEWED: -
CHECKED: -	APPROVED: MW	DATE: 7/7/2010
FILE NAME: 157503_Fig_2_Site_Model_BVB_20100707.dwg		

PREPARED FOR:
GENERAL MOLY

DRAWING TITLE:
CONCEPTUAL SITE MODEL FOR MOUNT HOPE PROJECT PIT LAKE WATER EXPOSURE

DRAWING NO.: FIGURE 2
REVISION: A
SRK JOB NO.: 157503-000

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3 EXPOSURE ESTIMATES AND RISK CALCULATIONS

In order for there to be a potential for ecological risks to occur at a site, there must be a potential for stressors, in this case chemicals, to be present where ecological receptors could come into contact with them. Based on the information provided in the Problem Formulation, it is reasonable to assume that ecological receptors could be expected to be exposed, either directly or indirectly, to contaminants in the Mount Hope Project pit lake water. The following sections present the exposure assessment and the ecological effects assessment. The exposure assessment identifies exposure pathways to be quantitatively evaluated and exposure point concentrations for the media of interest; in this case, predicted water quality in the future Mount Hope Project open pit lake. The ecological effects assessment presents available literature-based toxicity information on the chemical constituents of interest to determine potential adverse effects for ecological receptors.

3.1 Exposure Assumptions

There are a number of key exposure assumptions made in this evaluation that have substantive effects on the development of the CSM and the assessment of risk. These assumptions include, but are not limited to:

- The Mount Hope Project open pit lake water is assumed to be the only perennial water source for area wildlife. As such, it would be the only drinking water source available (over an organisms' lifetime) to the ecological receptors used in the assessment;
- The wildlife in the area would have unrestricted access to open pit lake water, and that this water was their only source of drinking water (i.e., 100% of their drinking water consumption would be from this source). This unlikely scenario provides a conservative assessment of the potential toxicity of the water via the ingestion pathway for wildlife; and
- The barren nature of the rock in the pit and limited organic nutrients would preclude the establishment of a robust and productive aquatic habitat suitable for long-term survival of ichthyofauna. A self-sustaining aquatic and littoral habitat capable of providing abundant and sustainable food and nourishment to the receptor populations over a lifetime is not expected to develop, and would be overshadowed by the direct consumption of water.
- While the occurrence and emergence of aquatic insects in the littoral zones and subsequent consumption of those (potentially exposed invertebrates) by passerines and chiropterans could be expected, the limited development of the littoral zone is not likely to provide sufficient food to support an individual bird or bat for a lifetime. Here too, the direct consumption of water overshadows this pathway.
- Incidental ingestion of soils and sediments (potentially contaminated by the pit lake water) from the riparian and littoral zones by the swallow during nest-building activities is considered a very short-term and transient activity, and is overshadowed by the direct consumption pathway.

- The occurrence of sufficient prey species within the pit to fully support a higher-level predator is unlikely. As a result, the indirect exposure of higher-level predators via consumption of smaller prey species that have been exposed to the pit lake water is also considered minor relative to the direct water consumption pathway.

Based on the aforementioned assumptions and assertions, the direct consumption pathway is the most significant completed pathway, and that the other potentially complete pathways are minor in relation to this pathway. As such, the direct consumption pathway was the only pathway evaluated in this SLERA for the 200-year pit lake scenario.

In order to calculate the screening-level criteria using the TRVs, both the body weight (kg) and water consumption rates (L/day) are required as part of the exposure assessment. The body weights and water consumption rates for the selected avian and mammalian wildlife receptors uses in the assessment are provided in **Appendix A**.

3.2 Effects Assessment

The SLERA compared the predicted water quality concentrations for the Mount Hope Project pit lake (Schlumberger Water Services, 2010) to promulgated livestock and wildlife beneficial use criteria, as well as published and calculated terrestrial and avian wildlife toxicity criteria. Constituent concentrations which were determined by the laboratory to be less than the instrument detection limits (IDL), were considered to be at that detection concentration for this evaluation. This added yet another degree of conservatism to the overall assessment.

3.2.1 Criteria for Selection of COPECs

The selection of chemicals of potential ecological concern (COPECs), defined as those chemical constituents that could pose a toxicological risk to the ecological receptor species, was performed by comparing the simulated 200-year, water quality concentrations against chemical and species-specific toxicity criteria developed using the following primary sources:

1. Nevada Beneficial Use Standards for Livestock Watering and Wildlife Propagation (NAC 445A.144 *et seq.*);
2. Species-specific toxicity criteria calculated using TRV data reported in *Ecological Soil Screening Level (ECO-SSL) Guidance* (EPA, 2003) and associated interim ECO-SSL documents (2003 through 2008); and
3. Species-specific toxicity criteria developed and published by the Environmental Sciences Division and Life Sciences Division of Oak Ridge National Laboratory (ORNL) for the U.S. Department of Energy (Sample *et al.*, 1996).

Since the Nevada Beneficial Use Standards are promulgated, legal standards, they were used as the primary screening tool. The Nevada standards were adopted from the National Academy of Science's *Water Quality Criteria* (Blue Book) (1972), and represented "safe concentrations of toxic substances in water for livestock" at the time, and included large margins of safety. As with the other TRVs used in this assessment, growth, reproduction and survivability of the organism were the principal endpoints for selection of the specific TRV used in determining each criterion. As such, each TRV has a specific toxicological endpoint. Each hazard quotient will therefore be interpreted against that endpoint.

Where a Nevada standard was not available, the assessment deferred to the toxicity criteria developed using the EPA (2003) and Sample *et al.* (1996) TRVs. It is recognized that other interpretations of the same data sources may be possible and that future research may provide more comprehensive data from which revised toxicity criteria might be derived. The following sections describe the use of the EPA (2003) and Sample *et al.* (1996) TRVs in calculating the specific toxicity criteria used in this assessment.

3.2.2 EPA ECO-SSL TRV Data

In 2003, the EPA initiated a program to derive a set of risk-based ecological soil screening levels (ECO-SSLs) for many of the soil contaminants that are frequently of ecological concern for plants and animals at hazardous waste sites, and to provide guidance for their use. The ECO-SSLs are concentrations of contaminants in soil that are protective of ecological receptors that commonly come into contact with soil or ingest biota that live in or on soil.

EPA derived the ECO-SSLs in order to conserve resources by limiting the need for EPA and other risk assessors to perform repetitious toxicity data literature searches and data evaluations for the same contaminants at every site. The list of 24 ECO-SSL contaminants contained 17 metals, including aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, selenium, silver, vanadium, and zinc. However, the omission of other contaminants, such as cyanide and mercury, does not imply that these contaminants can be excluded, and the process and procedures established by the EPA for developing the ECO-SSLs were intended to be sufficiently transparent to allow others to derive values for additional contaminants, as needed.

The approach developed for deriving the ECO-SSLs included four steps: (1) conduct literature searches, (2) screen identified literature with exclusion and acceptability criteria, (3) extract, evaluate, and score test results for applicability in deriving an ECO-SSL, and (4) derive the TRV. The wildlife ECO-SSLs were the result of back-calculations from a hazard quotient (HQ) of 1.0. The hazard quotient is equal to the estimated exposure dose divided by the TRV. An HQ of 1.0 is the condition where the exposure and the dose associated with no adverse chronic effects are equal, indicating adverse effects at or below this soil concentration are unlikely. The TRV represents a receptor-class specific estimate of a NOAEL (dose) for the respective contaminant for chronic (long-term) exposure.

For the purposes of establishing the ECO-SSLs, the wildlife TRVs were defined by the EPA (2003) as:

> *Doses above which ecologically relevant effects (growth, reproduction or survival) might occur to wildlife species following chronic dietary exposure and below which it is reasonably expected that such effects will not occur.*

The TRVs selected were based on the examination of all toxicological data extracted and evaluated. These data were then plotted and examined in a weight-of-evidence fashion, instead of the single "critical" study approach used by Sample *et al.* (1996). For the critical study approach, adjustment factors were generally applied to the critical study result to account for "uncertainty" and ensure the protectiveness of the value, and would include factors for interspecies sensitivity.

Instead, for the weight-of-evidence approach, the TRV is selected based on the preponderance of the data. With this approach, all toxicological data extracted from the studies identified in the literature review and determined to be appropriate in establishing a TRV, would be graphically plotted and the relative magnitude of the results examined to identify a criterion that would be protective. The EPA considered the use of NOAEL and LOAEL values as the basis of the wildlife TRV derivation process a reasonable and effective approach when these values are presented across multiple studies, species, and endpoints as depicted in the toxicological plots. In this instance, adjustment factors would not be necessary. For more information on EPA's derivation of the individual TRV values for the 17 metal species used in this assessment, the reader is referred to the respective interim final documents (EPA, 2003-2008).

3.2.3 Derivation of Toxicity Criteria Using EPA (2003) TRVs

For the limited metal constituents evaluated by the EPA (2003), SRK used the EPA-selected TRV to calculate new toxicity criteria for use in the Mount Hope pit lake SLERA. The chemical constituents selected by the EPA for their analysis and the respective TRVs that were determined are provided in **Table 3**. Because of the approach used by the EPA in deriving the TRVs, no adjustment for differences in body weight were necessary. Following the HQ approach for developing a protective benchmark (i.e., $NOAEL_w$ = TRV), the same equation used by Sample *et al.* (1996) could be applied:

$$C_w = \frac{NOAEL_w \times bw_w}{W} = \frac{TRV \times bw_w}{W}$$

Table 3: NOAEL TRVs Developed by EPA (2003)

Chemical Constituent	Mammalian TRV (mg/kg-bw per day)	Avian TRV (mg/kg-bw per day)
Aluminum	--	--
Antimony	0.059	--
Arsenic	1.04	2.24
Barium	51.8	--
Beryllium	0.532	--
Cadmium	0.770	1.47
Chromium^{III}	2.4	2.66
Chromium^{VI}	9.24	--
Cobalt	7.33	7.61
Copper	5.60	4.05
Iron	--	--
Lead	4.70	1.63
Manganese	51.5	179
Nickel	1.70	6.71
Selenium	0.143	0.290
Silver	6.02	2.02
Vanadium	4.16	0.344
Zinc	75.4	66.1

Source: EPA (2003), including subsequent element-specific screening level documents, which were issued periodically from 2003 to 2008.

3.2.4 Derivation of Toxicity Criteria Using Sample *et al.* (1996) TRVs

A number of chemical constituents of interest in this SLERA were not evaluated by EPA (2003), and therefore did not have TRVs available from that primary source. For those constituents, the Mount Hope Project SLERA referred to Sample *et al.* (1996) for the relevant TRVs.

The general method used by Sample *et al.* (1996) is one based on the EPA methodology for deriving human toxicity criteria from animal data (EPA, 1992). Experimentally derived NOAELs and/or LOAELs for laboratory test species were used to estimate NOAELs for wildlife by adjusting the dose according to differences in body size. The concentrations of the contaminant in the wildlife species' food or drinking water that would be equivalent to the NOAEL were then estimated from the species' rate of food consumption and/or water intake.

NOAELs and LOAELs for mammals and domestic and wild birds were obtained from the primary literature, EPA review documents, and secondary sources, such as the *Registry of Toxic Effects of Chemical Substances* (RTECS) (EPA, 2002) and the *Integrated Risk Information System* (IRIS) (EPA, 1994). The selection of a particular study and a particular toxicity endpoint, and the identification of NOAELs and LOAELs were based on an evaluation of the data. Emphasis was placed on those studies in which reproductive and developmental endpoints were considered, multiple exposure levels were investigated, and the reported results were evaluated statistically to identify significant differences from control values.

When no NOAEL was available from the experimental data and literature sources, Sample *et al.* (1996) applied an uncertainty factor of 10 to the representative LOAEL in order to estimate, with reasonable confidence, a NOAEL for use in their toxicity criteria development. As such, the Sample *et al.* (1996) TRVs also represent NOAELs and can be used to calculate no-effect toxicity criteria. The NOAEL TRVs developed by Sample *et al.* (1996) are provided in **Table 4** only for those chemical constituents for which TRVs were not developed by EPA (2003).

Table 4: NOAEL TRVs Developed by Sample et al. (1996)

Chemical Constituent	Mammalian TRV (mg/kg-bw per day)	Avian TRV (mg/kg-bw per day)
Aluminum	1.93	109.7
Boron	28	28.2
Fluoride	31.37	7.8
Lithium	9.4	--
Mercury	1	0.0064
Molybdenum	0.26	3.5
Nitrate	507	--
Strontium	263	--
Thallium	0.0074	--
Tin	23.4	6.8

Source: Sample *et al.* (1996).

In keeping with the methodology and approach by Sample *et al.* (1996), NOAELs represent daily dose levels normalized to the body weight of the test animals (e.g., milligrams of chemical per kilogram body weight per day). The presentation of toxicity data on a mg/kg per day basis allows comparisons across tests and across species with appropriate consideration for differences in body size. For Sample *et al.* (1996), if the NOAEL was available for a mammalian test species ($NOAEL_t$), then the equivalent NOAEL for a mammalian wildlife species ($NOAEL_w$) was calculated by using an adjustment factor for differences in body weight (expressed in kg) from the test species (bw_t) to the wildlife species (bw_w):

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w}\right)^{1/4}$$

For avian species, Sample *et al.* (1996) proceeded on the assumption that physiological scaling factors developed for mammals were not appropriate for interspecies extrapolation among birds. As such, if a NOAEL was available for an avian test species ($NOAEL_t$), the equivalent NOAEL for an avian wildlife species ($NOAEL_w$) was calculated by using another adjustment factor for differences in body size, resulting in:

$$NOAEL_w = NOAEL_t (\frac{bw_t}{bw_w})^0 = NOAEL_t (1) = NOAEL_t$$

Thus, the NOAEL of the avian wildlife species is essentially equivalent to the avian test species.

The concentration of the contaminant in the drinking water of an animal (C_w, in mg/L) resulting in a dose equivalent to a $NOAEL_w$ can then be calculated as it was with EPA (2003) from the daily water consumption rate (W, in L/day) and the average body weight (bw_w, in kg) for the species:

$$C_w = \frac{NOAEL_w \times bw_w}{W}$$

3.2.5 Wildlife Receptor-Specific Exposure Factors

Water consumption rates (W, in L/day) for the selected terrestrial and avian wildlife receptors are available from various sources, including the *Wildlife Exposure Factors Handbook* (EPA, 1993), other published literature, or can be estimated from allometric regression models based on body weight (in kg) (Calder and Braun, 1983):

$$W = 0.099\,(bw)^{0.90}$$

A similar model has also been developed for birds (Calder and Braun, 1983):

$$W = 0.059\,(bw)^{0.67}$$

The body weights and food and water consumption rates for selected avian and mammalian wildlife endpoint species used in this assessment are provided in **Appendix A**. Also included in Appendix A are the test species TRVs and calculated toxicity criteria used. The NOAEL-based water concentration toxicity criteria for each species identified in **Table 2** are summarized below in **Table 5**. The concentrations, presented in mg/L, represent the threshold toxicity criteria concentration below which no effect on the receptor species is expected to occur.

Table 5: Comparison of Predicted Pit Lake Water Quality [illegible] Ecological Screening-Level Toxicity Criteria for Wildlife

Chemical Constituent *(mg/L unless noted otherwise)*	**Mount Hope Project Pit Lake Water Quality** *Base Case (200 yrs)*	**NV-Beneficial Use Standard** Livestock Watering ***NAC445A.144***	**NV-Beneficial Use Standard** Wildlife Propagation ***NAC445A.144***	**Mammalian Receptor Species**				**Avian Receptor Species**			
				Little Brown Bat	**White-footed Mouse**	**Eastern Cottontail**	**White-tailed Deer**	**Rough-winged Swallow**	**Barn Owl**	**Red-tailed Hawk**	**Mallard**
Aluminum	<0.02	–	–	17.1	7.0	7.9	4.5	471	1,461	1,930	1,944
Antimony	0.0076	–	–	0.4	0.2	0.6	0.9	–	–	–	–
Arsenic	<0.0005	0.2	–	6.5	3.5	10.8	15.9	9.6	30	39	39.7
Barium	0.010	–	–	323.8	172.7	535.9	791.0	89	277	366	369
Beryllium	<0.0002	–	–	3.3	1.8	5.5	8.1	–	–	–	–
Boron	0.065	5	–	457	186	213	120	121	375	496	500
Cadmium	**0.067**	**0.05**	–	4.8	2.6	8.0	11.8	6	20	26	26
Calcium	62	–	–	–	–	–	–	–	–	–	–
Chloride	10.8	1,500	1,500	–	–	–	–	–	–	–	–
Chromium III	<0.001	–	–	15	8	25	37	11	35	47	47
Chromium VI	<0.001	1 (Cr Total)	–	58	31	96	141	–	–	–	–
Cobalt	0.016	–	–	46	24	76	112	33	101	134	135
Copper	0.018	0.5	–	35	19	58	86	17	54	71	72
Cyanide (WAD)		–	–	1,122	457	522	294	–	–	–	–
Fluoride	**3.7**	**2**	–	666	272	310	175	34	104	137	138
Iron	<0.01	–	–	–	–	–	–	–	–	–	–
Lead	0.00053	0.1	–	29	16	49	72	7	22	29	29
Lithium	0.0090	–	–	154	63	71	40	–	–	–	–
Magnesium	10	–	–	–	–	–	–	–	–	–	–
Manganese	1.4	–	–	322	172	533	786	769	2,383	3,149	3,172
Mercury	<0.0002	0.01	–	21.2	8.7	9.9	5.6	0.03	0.1	0.1	0.1
Molybdenum	0.13	–	–	2.3	0.9	1.1	0.6	15	47	62	62
Nickel	0.043	–	–	11	6	18	26	29	89	118	119
Phosphorous	<0.05	–	–	–	–	–	–	–	–	–	–
Potassium	6.8	–	–	–	–	–	–	–	–	–	–
Selenium	<0.001	0.05	–	0.9	0.5	1.5	2.2	1.2	3.9	5.1	5.1
Silver	<0.005	–	–	38	20	62	92	9	27	36	36
Sodium	42	–	–	–	–	–	–	–	–	–	–
Strontium	0.28	–	–	4,296	1,751	1,999	1,127	–	–	–	–
Sulfate	214	–	–	–	–	–	–	–	–	–	–
Thallium	0.00083	–	–	0.121	0.049	0.056	0.03	–	–	–	–
Tin	<0.001	–	–	207	84	96	54	29	91	120	120
Vanadium	<0.005	–	–	26	14	43	64	1	5	6	6
Zinc	3.5	25	–	471	251	780	1,151	284	880	1,163	1,171
pH (s.u.)	7.7	6.5-9.0	7.0-9.2	–	–	–	–	–	–	–	–
T.D.S.	–	3,000	–	–	–	–	–	–	–	–	–
Alkalinity- Total	59	–	30-130	–	–	–	–	–	–	–	–
Nitrate (as N)	<0.05	100	100 (10 as NO_2)	10,369.2	4,225.8	4,825.7	2,719.4	–	–	–	–

Note: **Bold** constituent indicates toxicity criteria derived from TRV data developed by EPA (2003).

[shaded] = Predicted concentration in Mount Hope Project pit lake water exceeds identified screening-level criteria.

4 RISK ASSESSMENT

4.1 SLERA Comparison Results

Based on a comparison of the predicted pit lake water quality concentrations with the screening-level toxicity criteria calculated using TRVs developed by EPA (2003) and Sample *et al.* (1996), none of the modeled chemical constituents in the Base Case Scenario (at 200 years post closure) are expected to pose a toxicological threat to future terrestrial and avian wildlife that could be exposed to the water through direct consumption. However, two constituents, cadmium and fluoride, did exceed their respective promulgated livestock watering standard:

- The cadmium concentration for the Base Case Scenario (at 200 years post closure) is predicted to be 0.067 mg/L. This concentration exceeds the current Nevada livestock watering beneficial use standard of 0.05 mg/L for cadmium. The predicted concentration of cadmium for this scenario is well below the species-specific toxicity criteria for both the terrestrial and avian wildlife receptors.
- Similarly, the fluoride concentration for the Base Case Scenario (3.7 mg/L) is predicted to exceed the current Nevada livestock watering standard of 2 mg/L. The concentration of fluoride is also well below the species-specific toxicity criteria for terrestrial and avian wildlife used in this assessment.

It should be noted that TRV data (and thus toxicity criteria) do not exist, or could not be developed for calcium, cobalt, iron, magnesium, phosphorus, potassium, sodium, and sulfate. These ions are largely responsible for salinity in water and are generally not toxic (NAS, 1972). Most of these constituents are considered essential biological nutrients for organisms, and lack any toxicological data from which to develop screening-level benchmarks. They are not considered to pose a toxicological threat to wildlife under most circumstances. Even cobalt, considered by some to be toxic to organisms, is essential as a component of vitamin B_{12} required for the production of red blood cells and prevention of pernicious anemia (Goyer, 1991), and can be tolerated at concentrations well above those predicted to occur in the future pit lake (Underwood, 1971; ATSDR, 2004). In fact, NAS (1972) recommends an upper limit for cobalt in livestock waters of 1.0 mg/L to provide for a satisfactory margin of safety. This is over 50 times higher than the predicted cobalt concentration in the pit water. Radioactive cobalt, however, is extremely toxic to animals and humans, but is not the form found in the Mount Hope Project pit lake.

The sulfate concentration (214 mg/L) [which would contribute to the Total Dissolved Solids (TDS) concentration in the water] is well below the livestock beneficial use standard for TDS of 3,000 mg/L, and does not merit additional consideration.

4.2 Toxicity Assessment

The following provides a summary of the available toxicological information on the two COPECs identified in Section 3.2.2, cadmium and fluoride, with respect to potential ecological effects. Much of the information was obtained from the *Risk Assessment Information System* (DOE, 2009), *Mineral Tolerance of Domestic Animals* (NAS, 1980), and *Ecotoxicological Profiles for Selected Metals and Other Inorganic Chemicals* (Sample *et al.*, 1997). References made within these publications have been included herein for completeness.

4.2.1 Cadmium

Cadmium is a naturally occurring metal that is used in various chemical forms in metallurgical and other industrial processes, and in the production of pigments. Environmental exposure can occur via the diet and drinking water (ATSDR, 1989).

Cadmium is absorbed more efficiently by the lungs (30 to 60%) than by the gastrointestinal tract, the latter being a saturable process (Nordberg *et al.*, 1985). Cadmium is transported in the blood and widely distributed in the body but accumulates primarily in the liver and kidneys (Goyer, 1991). Cadmium burden (especially in the kidneys and liver) tends to increase in a linear fashion up to about 50 or 60 years of age (in humans) after which the body burden remains somewhat constant. Metabolic transformations of cadmium are limited to its binding to protein and non-protein sulfhydryl groups, and various macromolecules, such as metallothionein, which is especially important in the kidneys and liver (ATSDR, 1989). Cadmium is excreted primarily in the urine.

Oral LD_{50} values (Lethal Dose in which 50 percent of the specimens died) in animals range from 63 to 1,125 mg/kg, depending on the cadmium compound (USAF, 1990). Longer term exposure to cadmium primarily affects the kidneys, resulting in tubular proteinosis although other conditions such as "itai-itai" disease may involve the skeletal system. Cadmium involvement in hypertension is not fully understood (Goyer, 1991).

Most information about the biological behavior of cadmium shows it to be toxic and a potent antagonist of several essential minerals, notably zinc, iron, copper, and calcium. Diets low in these minerals and in protein permit greater absorption/toxicity of cadmium (Spivey Fox, 1974). Almost nothing is known of interactions between cadmium and other nonessential toxic elements.

The Nevada livestock watering beneficial use standard for cadmium was adopted from the *Water Quality Criteria* (Blue Book) (NAS, 1972). The recommended upper limit of 0.050 mg/L was based on limited reproductive and developmental endpoint studies, and, by its own admission, was complicated by the interactions of cadmium with several other trace elements. As a result, the recommended criteria included a large margin of safety.

4.2.2 Fluoride

Fluoride is a halogen, estimated as the 13th most abundant element in the earth's crust (0.065%). It is widely distributed in nature (rocks, soils, water, vegetation, and animals) and, because of its high reactivity; fluorine occurs predominantly as inorganic fluoride compounds (IPCS, 1984). The precise dietary concentration at which fluoride ingestion becomes harmful is difficult to define. No single value is appropriate because low-level toxicosis depends upon duration of ingestion, solubility of the fluoride source, general nutritional status, species of animal, age when ingested, and toxicity-modifying components of the animal's overall diet (NAS, 1980).

Most data on the levels of inorganic fluoride in wildlife [such as deer (*Odocoileus virginianus*), martens (*Martes Americana*), beaver (*Castor Canadensis*), fox (*Vulpes vulpes*), hare (*Lepus americanus*), and moose (*Alces alces*)] were obtained during the 1960s and 1970s (Karstad, 1967; Alcan, 1979). Investigations of the effects of fluoride on wildlife have focused primarily on impacts on the structural integrity of teeth and bone.

Most observations have involved large herbivores. For example, several lesions were found in mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), and American bison (*Bison bison*) exposed to elevated levels (no specific anthropogenic sources identified) of fluoride in Utah, Idaho, Montana, and Wyoming (Shupe *et al.,* 1984). Black-tailed deer (*Odocoileus hemionus columbianus*) near an aluminum smelter in Washington State were found to have dental disfigurement, with the premolars of one individual being worn down to the gumline. The remaining studies tend to focus on animals collected near aluminum smelters, a common source of fluoride emissions. Karstad (1967), reported dental disfigurement and jaw fracturing in white-tailed deer drinking water from a contaminated pond on an industrial facility (site unspecified). Mandibular bone fluoride content ranged from 4,300 to 7,125 mg/kg fat-free basis, while levels in control deer ranged from 167 to 560 mg/kg. The report did not specify the concentration of fluoride in the pond water.

In animals, fluoride accumulates primarily in the bone in vertebrates. There is little or no accumulation in soft, edible tissues. Exposure of predatory wildlife is therefore often minimal, as fluoride is largely unavailable to those mammalian and avian predators that do not digest bone. For example, barn owls regurgitate pellets that contain virtually intact skeletons of their prey (Thomson, 1987).

The lowest dietary level observed to cause an effect on wild ungulates was in a controlled captive study, where white-tailed deer were exposed to 10 (control feed), 35, and 60 mg/kg wet weight fluoride (as sodium fluoride) in their diet for 2 years (Suttie *et al.*, 1985). A general mottling of the incisors characteristic of dental fluorosis was noted in the animals at the 35 mg/kg diet dose; those on the higher dose also experienced minor increased wear of the molars, as well as mild hyperostoses of the long bones of the leg. No gross abnormalities of the mandible were observed. Based on a body weight of 56.5 kg (Smith, 1991) and a water intake of 3.7 L/d, the 35 mg/kg dose would equate to a water concentration of approximately 535 mg/L for a period of two years, assuming that there is only one source of water, and that no fluoride is obtained through solid foods.

Studies demonstrating effects on other mammals and wild birds are scarce. Deer mice (*Peromyscus maniculatus*) fed diets of 38 (control), 1,065, 1,355, and 1,936 mg/kg diet dry weight (as sodium fluoride) for eight weeks exhibited, at all concentrations above the control, marked weight loss, mortality, changes in femur size, and dental disfigurement (Newman and Markey, 1976). Bank voles (*Clethrionomys glareolus*) showed a reduction in the number of litters per female, an increase in the number of days from mating to producing the first litter, increased mortality of offspring, and a changed sex ratio (greater number of males) in offspring of animals fed 97 mg/kg diet (wet or dry basis not specified) [Krasowska, 1989]. Animals fed 47 mg/kg diet also showed these effects, but the differences were not significant from the control. Fluoride was suggested as the cause of reduced milk production with subsequent mortality of kits in farm-raised foxes (*Vulpes vulpes*) fed a diet containing 97.6 to 136.8 mg/kg diet dry weight fluoride (Eckerling *et al.*, 1986).

Diets containing 1,000 mg/kg of fluoride as sodium fluoride fed to chicks for 28 days resulted in reduced growth (Doberenz *et al.*, 1965). Hatching success in eastern screech owls (*Otus asio*) was adversely affected at dietary concentrations of 232 mg/kg fluoride as sodium fluoride (wet weight), but not at concentrations of < 56.5 mg/kg (Hoffman *et al.*, 1985; Pattee *et al.*, 1988). High levels of fluoride (700 – 1,000 mg/kg) in diet of chickens resulted in reduced egg size and increased mortality (Guenter, 1979). At 700 mg/kg in the diet, a body weight of 0.0159 kg (Dunning, 1984), and a water ingestion rate of 0.0037 L/d, the concentration in the water to reach this level would need to be on the order of 3,000 mg/L, assuming that there is only one source of water, and that no fluoride is obtained through solid foods.

There is only a single published report of possible fluoride-induced mortality of wildfowl (Andreasen and Stroud, 1987). Descriptive reports suggest that community and population effects may occur, but experimental evidence is lacking. Again, most fluoride toxicosis was observed near aluminum site with excessive fluoride emissions.

Fluoride is not listed as an essential element for birds (Scott *et al.*, 1976). However, the addition of fluoride to poultry diets has been repeatedly investigated as a means of strengthening bone and eggshell.

The Nevada livestock watering beneficial use standard for fluoride was adopted from the *Water Quality Criteria* (Blue Book) (NAS, 1972). The recommended upper limit of 2 mg/L was based almost entirely on the review and discussion of Underwood (1971). NAS (1972) concluded that "maximum levels of the element in waters that are tolerated by livestock are difficult to define from available [1972] experimental data." In the end, the limit was set a 2 mg/L based on tooth mottling, but that " at least a several-fold increase in its concentration seems, however, required to produce other injurious effects."

4.3 Risk Characterization

The risk characterization process integrates the problem formulation and the exposure/effects analyses to estimate the likelihood of risks to ecological receptors from exposure to COPECs. This section includes the results of the initial screening evaluation.

As indicated in Section 3.1, there are a number of conservative exposure assumptions made in this evaluation that have substantive effects on results of the evaluation. These assumptions included:

- The Mount Hope Project open pit lake water is assumed to be the only perennial water source for area wildlife and livestock. As such, it would be the only drinking water source available (over their lifetime) to the ecological receptors used in the assessment;
- The wildlife in the area would have unrestricted access to open pit lake water, and that this water was their only source of drinking water (i.e., 100% of their drinking water consumption would be from this source). This unlikely scenario provides a conservative assessment of the potential toxicity of the water via the ingestion pathway for wildlife; and
- The barren nature of the rock in the pit and the lack of organic nutrients would preclude the establishment of an aquatic, or semi-aquatic, habitat within the pit. A self-sustaining aquatic habitat capable of providing food and nourishment to wildlife populations over a lifetime is not expected to develop.

These assumptions must be fully considered when viewing and interpreting the results of the SLERA, and as part of the overall decision management framework of the project.

The approach used in this assessment for characterizing risk in relation to exposure and toxicity criteria was adapted from *Risk Management Criteria for Metals at BLM Mining Sites* (BLM, 2004), which defines the levels of risk as follows:

- Less than criteria (HQ < 1) = "Low" Risk
- 1-10 times the criteria (HQ = 1 to 10) = "Moderate" Risk
- 10-100 times the criteria (HQ = 10 to 100) = "High" Risk
- >100 times the criteria (HQ > 100) = "Extremely High" Risk

The COPECs identified in the modeled Mount Hope Project open pit lake water could exhibit the following potential risks levels (**Tables 6** and **7**).

Table 6: Potential Risks to Livestock from Predicted Pit Lake Water

Constituent	**Base Case Scenario** (using promulgated livestock criteria)
Cadmium	$HQ = \frac{0.067}{0.05} = 1.34$
Fluoride	$HQ = \frac{3.7}{2} = 1.85$

The results of the assessment indicate that the most likely predicted water quality of the modeled future pit lake water at the Mount Hope Project would represent a *Low-Moderate* (HQ < 2) toxicological threat to livestock (cattle, sheet, swine, horses, poultry, etc.) that may exposed to it via direct ingestion for all chemical constituents. Since this water is not intended to be a livestock watering source, the probable risk to livestock would be *Low*.

The TRV for cadmium used in the Nevada Beneficial Use Standard was based primarily on the accumulation and retention of cadmium in the liver and kidney, which could affect growth. A drinking water limit of 0.1 mg/L was recommended; this limit was reduced to 0.05 mg/L to allow an adequate margin of safety.

The TRV for fluoride used in the Nevada Beneficial Use Standard was based principally on the finding that as little as 2 mg/L may cause tooth mottling under some circumstances, acknowledging that at least a several-fold increase in its concentration seems required to produce other injurious effects (NAS, 1972).

Based on the HQs, and the assessment endpoints used to establish the TRVs, the overall risk potential remains *Low*.

Table 7: Potential Risks to Wildlife from Predicted Pit Lake Water

Constituent	**Base Case Scenario** (using most sensitive receptors)
Cadmium (White-footed mouse)	$HQ = \frac{0.067}{2.6} = 0.03$
Fluoride (Rough-winged swallow)	$HQ = \frac{3.7}{34} = 0.11$

Even using the most sensitive receptors (i.e., lowest toxicity criteria), the results of the assessment indicate that the most likely predicted water quality of the modeled future pit lake water at the Mount Hope Project would represent a *Low* risk (HQ < 1) to wildlife, terrestrial and avian, that are exposed to it via direct ingestion.

5 ASSUMPTIONS AND UNCERTAINTY ANALYSIS

There are a number of points in the decision-making process of a screening-level risk assessment where there are inherent uncertainties and limitations associated with the risk assessment data and methodology that can lead to the under-estimation or overestimation of actual risk. Certain assumptions are made to facilitate the preparation of the risk assessment. However, when information and actual data are lacking, conservative assumptions are made to create a unidirectional uncertainty in favor of protection of the environment. Uncertainties about the assumptions, methods, and parameters used in the problem formulation, analysis, and risk characterization stages were also addressed throughout this document.

This assessment is subject to uncertainty from a variety of sources, including:

- Accuracy of the water quality predictions;
- Prediction of future mine site conditions;
- Selection of representative ecological receptors, surrogate species, and exposure assumptions; and
- Selection of Toxicity Reference Values.

General uncertainties are briefly discussed below.

5.1 Accuracy and Stability of the Water Quality

All actual chemical data used as inputs in the pit lake modeling effort were obtained from Nevada certified laboratories. This provides for reasonable certainty in regard to analytical accuracy and precision for those samples.

This screening-level assessment was predicated on the agreement between the BLM and the project proponent, Eureka Moly, to examine a single 'snapshot' in time for which water quality predictions could reasonably be made. In this instance, that 'snapshot' occurs at 200 years post closure. The SLERA acknowledges that uncertainty exists in the predicted water quality concentrations, but assumes that the output from the geochemical pit lake model (Schlumberger Water Services, 2010) is as accurate as is currently possible given the current state-of-the-art, and that the predicted water chemistry will not appreciably change for the modeled period. As presented by Maest *et al.* (2005), there are a number of inherent variables and uncertainties in modeling and predicting water quality at hard rock mines, all of which could have appreciable affects on the output of a pit lake geochemistry model, and could result in either an over-estimation or underestimation of actual risk. Additional discussion of the variability and uncertainty associated with predicting the water quality in the future Mount Hope Project pit lake is provided in the final report, *Mount Hope Project Pit Lake Geochemistry Report* (Schlumberger Water Services, 2010).

5.2 Prediction of Site Conditions

It was assumed in this SLERA that conditions in and around the Mount Hope Project open pit would be suitable for the existence of complex biological communities capable of supporting the populations of birds and mammals used in this evaluation. In the post closure, human activity will be limited, and no longer have a deterrent effect on terrestrial and avian life.

The effects of physical, chemical or other environmental conditions on the aquatic and semi-aquatic communities that could develop in the Mount Hope pit were not examined in detail in this SLERA. However, based on the predicted physical condition, it was assumed that conditions would not be suitable for aquatic invertebrate and plant proliferation, and that the productivity and abundance of this prey base would not be suitable to fully support local populations of birds and mammals within the 200-year evaluation period.

The low nutrient conditions actually expected to occur in the pit lake will likely prohibit an abundance of aquatic life, and hence the area use and dietary exposure to COPECs was not examined at this time. The same assumption was made for the development of riparian and littoral habitats within the pit. Observations of analog pit lakes, and the general literature, indicate that riparian and littoral zones in pit lakes tend to be ephemeral and/or minimal (Geomega, 2007).

By not considering the potential exposure of terrestrial and avian wildlife from consumption of aquatic micro- and macro-invertebrates, and riparian/littoral vegetation, the SLERA could be underestimating actual risks.

5.3 Exposure Assumptions

The estimation of exposure requires numerous assumptions to describe potential exposure situations. There are a number of uncertainties regarding likelihood of exposure; frequency of contact with the water, or site usage; percentage of food and/or water obtained from the pit, etc. Assumptions used in the assessment were selected to simplify potential future site conditions so that risk management decisions can be made with reasonable confidence.

The assessment, which assumes that drinking of the water is the principal exposure pathway, may underestimate risks associated with alternative routes of exposure, such as inhalation of water aerosols, dermal contact, and ingestion of associated aquatic micro- and macro-invertebrates, riparian/littoral vegetation, and even shoreline sediments. These alternative pathways were considered to be minor in comparison to direct water consumption, which was assumed to be 100% utilization over the lifetime of the receptor species.

The selection of ecological receptors in this assessment is assumed to be representative of some of the actual receptor populations at the site; however, it is not representative of all of the populations that may be present in the vicinity of the pit in the future. By selecting receptor species that represent large groups of organisms, the potential risks should be adequately covered.

Exposure parameters for each receptor organism, such as body weight and ingestion intake, lend some uncertainty to the assessment. The degree of uncertainty, however, depends on whether the parameter values were based on measured data or allometric scaling techniques when measured data were not available. Additional uncertainty exists when allometric scaling is used.

Chemical-specific assumptions can also affect the risk assessment outcome. For example, it is typically assumed in a screening assessment that all chemicals are 100-percent bioavailable. In reality, the bioavailability of chemical constituents in water is greatly influenced by geochemical and environmental constraints including pH, redox conditions, water hardness, and organic matter content. This assumption can lead to a significant overestimation of actual risk.

5.4 Selection of Toxicological Criteria

Selection of the appropriate TRV to use in the estimation of the risk can contribute to the overall uncertainty of the assessment. The TRV and NOAEL values used in this assessment were obtained from EPA (2003) and Sample *et al.* (1996), respectively. They are based on review of the literature (up to that time) and consideration of the test conditions, and were selected as appropriate for use in a screening analysis of ecological risks. Use of these published values eliminates some of the subjective nature in calculating site-specific benchmark criteria which can occur in risk assessments.

Species-specific toxicological information is often limited. While it might be possible to find some literature data for each species included in the risk assessment, the Sample *et al.* (1996) and EPA (2003) databases do not represent an all-inclusive source for the selection of toxicity data. Therefore, surrogate species information was often used when specific toxicological data were not available. The surrogate species could be more or less sensitive to water chemicals than the receptor species in this assessment. Generally, the most conservative literature value was used for extrapolation to site receptor species.

The toxicity of many metals is dependent on its chemical form which is dictated by the physical-chemical characteristics (e.g., pH, E_h) of the medium in which they reside. As many toxicity studies are conducted with highly soluble and readily bioavailable forms of metals (or organo-metallic forms) in food and/or water, the TRVs developed from these studies are by default conservative under most ambient conditions. The more soluble ionic forms could present a greater toxicological risk than forms that are less soluble, and likely to be excreted from the body. However, the predicted pH of the Mount Hope Project pit lake water (7.7 s.u.) is not likely to result in increased solubility of the metal species of interest.

6 CONCLUSIONS

Neither of the COPECs identified in the Mount Hope Project predicted pit lake water (cadmium and fluoride) poses a credible risk to livestock or wildlife that may inhabit the site and use the pit as a drinking water source; the potential to affect adversely the health of terrestrial or avian life is considered negligible.

In addition to the quantitative assessment, the conclusion of low risk is also predicated on the assumption that the wildlife receptor species selected for this study (and livestock, for that matter) would utilize the water in the Mount Hope open pit for 100 percent of their daily intake. This assumption is considered extremely conservative given the nature and accessibility of open pit lakes in Nevada. For smaller mammalian species, travel to and from the water would require a considerable effort, especially for such a large feature as the Mount Hope open pit. In addition, smaller wildlife would have an increased probability of predation in the open environment around the water. Overall, utilization of this water by mammalian species (with the exception of perhaps bats) is considered minimal.

Utilization by the avian species is also considered limited. While some species may roost and nest in the highwalls of the pit, migratory birds, such as the mallard, would only use the water for short periods during their journeys to and from more suitable feeding and breeding grounds. With limited populations of smaller prey mammals (e.g., rodents and lagomorphs) using the open pit for water, raptor activity in and around the pit lake would correspondingly be reduced as well.

Based on the predicted pit lake chemistry, calculated toxicological criteria, and predicted utilization of the Mount Hope Project open pit by livestock and wildlife, the overall ecological risk is considered to be *Low*.

7 MITIGATION POTENTIAL

Given the low risk results identified by the SLERA, mitigation of the predicted Mount Hope Project pit lake water does not appear to be necessary at this time. If, however, the predicted or actual chemistry of the pit lake changes from that used in this assessment, further analysis, and possibly mitigation may be warranted.

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