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FINAL

Highland Pit Lake Ecological Risk Assessment

Converse County, Wyoming

April 2007

ARCADIS BBL

Rebecca D. Lindeman, P.E.
Senior Engineer

Highland Pit Lake Ecological Risk Assessment

Converse County, Wyoming

Prepared for:
ExxonMobil Corporation

Prepared by:
ARCADIS U.S., Inc.
14142 Denver West Parkway
Suite 350
Golden
Colorado 80401
Tel 303.231.9115
Fax 303.231.9571

Our Ref.:
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1. INTRODUCTION

Blasland Bouck and Lee (BBL) has conducted this Ecological Risk Assessment (ERA) on behalf of ExxonMobil Corporation for the Highland Pit Lake and surrounding habitat. This report was initially prepared on behalf of ExxonMobil Corporation (ExxonMobil) by MFG, Inc. (MFG), formerly Shepherd Miller, Inc. (SMI). Blasland, Bouck, and Lee, Inc. (BBL), an ARCADIS Company has incorporated third party comments from the final draft, prepared by MFG, into this version for final submittal.

The Pit Lake is located in Converse County, Wyoming, north of Douglas. Water quality monitoring of the lake water indicated that concentrations of selenium and uranium were elevated above relevant water quality standards and this ERA was initiated to evaluate potential adverse effects to potential aquatic and terrestrial receptors in and around the lake.

1.1 Project Background

In the late 1960s, Humble Oil and Refinery discovered a uranium deposit in the southern Powder River Basin, Wyoming, and initiated mining activities, which subsequently became known as the Highland Uranium Operations. Multiple mining techniques were employed to extract uranium ore, including surface mining from a series of four open pits, beginning in 1970 and continuing through 1984 (Water Waste and Land [WWL], 1989). The final two pits (pits 3 and 4) were not completely backfilled and, beginning in March 1984, groundwater from the surrounding aquifer was allowed to discharge into the two pits, forming the Highland Pit Lake (Figure 1-1). At this stage of formation of the lake, aquatic biota were very likely not present.

While the regional hydrology and geology of the Pit Lake is relatively well understood, very little was known about the biological resources of the area (i.e., no catalog of aquatic fauna and flora that live in the lake or of avian and mammalian species that use the lake environs existed). There was also a lack of information on the concentrations of chemicals in Pit Lake biota and on current local ecology, including biomass and biotic diversity, and the associated amount and quality of habitat available to sustain biota. The current need for an environmental assessment of Highland Pit Lake was largely source-driven since lake water contains elevated levels of selenium and uranium relative to Wyoming Department of Environmental Quality (WDEQ) water quality standards for protection of aquatic life. WDEQ water quality standards for selenium and uranium are 0.005 ppm and <1.4 ppm, respectively. Current selenium and uranium concentrations in Pit Lake water exceed those standards by a factor of

about 20 and 2 times, respectively. Computer modeling of the geochemical evolution of the Pit Lake water indicates that selenium and uranium concentrations will likely remain above WDEQ standards at steady state.

The formation of the lake has resulted in open water habitat that is not naturally abundant in the region. As a result, waterfowl, wading birds, and other wildlife may be attracted to the area. Relevant historical data were limited to anecdotal information based on casual observations suggesting that waterfowl, raptors, and passerine birds might nest in the area. Consequently, a major data gap relative to the Pit Lake was the level and kinds of use of the lake environs by aquatic and terrestrial wildlife. To address this data gap, a field study was initiated in September 2004 and completed in September 2005 to characterize some of the fauna, flora, and habitat associated with the Pit Lake. In addition to biological data, chemical data were collected for selenium and uranium[1] for various environmental media and biota tissue from in and around the lake. The results of the field study serve as the primary basis for this ecological risk assessment (ERA). The biological data (e.g., type and amount of habitat, species composition, and biomass production associated with aquatic fauna and flora) are used in conjunction with quantitative comparisons of measured selenium and natural uranium in water, soil, sediment and selected biota to available toxicity data as a two-pronged approach for evaluating the potential effects of selenium and uranium on Pit Lake biota within the context of the ecological relationships that currently exist at the lake.

The sampling design for the field study focused on answering the following questions for the ERA:

1. What are the ecological compartment sizes at the lake, including amount and types of habitat, biomass of major aquatic fauna and flora, and inventories of avifauna and terrestrial wildlife using the Pit Lake environs through time?
2. What are the selenium and uranium concentrations with time in water, sediments, and some of the major aquatic biota that use the Pit Lake?

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[1] Rationale for the selection of these two compounds as constituents of potential ecological concern is provided in Section 3.4.

3. Do measured levels of selenium and uranium in biota pose unacceptable risks to aquatic and terrestrial biota when compared to toxicity benchmarks or reference values, and relative to existing ecological relationships at the Pit Lake?

Field data collected to answer these questions consisted of 1) surface water temperature, dissolved oxygen, pH, conductivity, and turbidity, 2) habitat and biomass of aquatic plants and invertebrates, 3) selenium and uranium concentrations in water, sediment, aquatic plants and invertebrates, amphibians, and shoreline soil, vegetation, insects and rodents, and 4) observations of seasonal use of the lake by nesting and migratory birds and mammals. Measurements were collected for a reference site (Box Creek) in addition to the Pit Lake and replicated when possible to characterize variation in biomass and chemical concentrations within and between species and with time. These data are presented and discussed in more detail Section 2.

1.2 Approach to Risk Assessment

U.S. EPA (EPA 1998) describes three primary phases in conducting a risk assessment: 1) Problem Formulation, 2) Risk Analysis, and 3) Risk Characterization. The problem formulation phase describes the goals, scope, focus, and data needed for conducting the risk analysis. This includes the development of a conceptual site model (CSM) to identify complete exposure pathways between site-related chemicals and ecological resources at the site, selection of constituents of potential ecological concern (COPECs), and selection of assessment and measurement endpoints (i.e., the ecological resources at the site that require protection and the metrics that will be used to assess potential adverse effects). The analysis phase consists of an exposure assessment, an effects assessment and the integration of these two components by comparing estimates of exposure based on the measured chemical concentrations in various media to background concentrations or published toxicity benchmarks or reference concentrations that are considered safe levels for ecological receptors.

The analysis of the ERA is conducted using a tiered approach. In the first tier, highly conservative estimates of exposure and effects were used to estimate potential risk. As a first step in the Tier 1 risk analysis, maximum concentrations of selenium and uranium were screened against concentrations obtained from a small pond in Box Creek about 2 km west of the Pit Lake. Box Creek is an ephemeral spring fed stream with intermittent surface water expressions and eventually drains into the Cheyenne River and then the North Platte. No true background or control site for the Pit Lake exists that closely duplicates the lake environment in all respects except for the selenium and uranium concentrations. However, samples from the pond were considered to represent general area selenium and uranium levels in an aquatic

environment that could be expected to represent regional background. While we expressly state that the Box Creek pond was not intended to serve as a background for the Pit Lake, we do consider the comparison of data from the pond with that from the Pit Lake as useful for scaling Pit Lake concentration data to regional levels[2]. In addition to this comparison, the Tier 1 analysis includes a comparison of maximum concentrations of selenium and uranium to toxicity thresholds based on lower limits of the range of no adverse effect levels (NOAELs).

Any COPEC/receptor pair for which the maximum detected concentration exceeded the NOAEL-based threshold was carried forward for a more site-specific and focused analysis in Tier 2. The Tier 2 analysis includes a more realistic exposure estimate (i.e., based on 95% upper confidence limits) and effects thresholds (e.g., based on mid range NOAEL and lowest observed adverse effect levels when available).

As a final step in the assessment, overall risks were characterized by integrating ecological factors with the results of the quantitative Tier 2 risk analysis in order to evaluate any potential risk in the context of available habitat, species present over time, and species biomass.

1.3 Report Organization

This ERA relies on the data collected during the 2004 and 2005 field efforts as described in the Scope of Work (MFG 2004a), as well as information presented in historical documents that address long-term groundwater and Pit Lake hydrology (MFG, 2006a) and, long-term geochemical evolution of Highland Pit Lake (MFG, 2006b). These two documents provide a detailed description of the geology and current and future predicted states of the hydrology and water chemistry of the Pit Lake in MFG (2006a and 2006b). This ERA is organized as follows:

The remaining sections of the report are organized as follows:

- Section 2: Presents the findings of the field sampling to measure the physical, biological, and chemical characteristics of the Pit Lake.

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[2] Comparisons of the Box Creek and Pit Lake data were not used to screen out any exposure pathways prior to conducting additional risk analysis.

- Section 3: Defines the nature and extent of the assessment problem.
- Section 4: Includes a Tier 1 and Tier 2 assessment of both exposure and effects.
- Section 5: Includes a Tier 1 and Tier 2 risk estimate, interprets risk based on the data obtained, discusses and analyzes the sources of uncertainties, and summarizes the results of the evaluation. .

2. DATA COLLECTED FOR THE ERA

The data used to support this ERA was collected based on the approach developed by MFG and presented in the Scope of Work (MFG 2004a). The field study to collect data for the ERA was initiated in September 2004 and completed in September 2005 to characterize some of the fauna, flora, and habitat associated with the Pit Lake. In addition to biological data, chemical data were collected for selenium and uranium[3] for various environmental media and biota tissue from in and around the lake. This section presents a summary of the data collected for and used in the ERA.

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Key Elements

Data Collected include:

- Biomass
- Cattails
- Copepods
- Benthic Invertebrates
- Habitat /Species Observation
- Limnetic
- Littoral
- Near-shore Terrestrial
- Avian Surveys
- 25 surveys over 2 years
- Chemical Data
- Surface Water, Sediment, Soil
- Aquatic and Terrestrial Plant Tissue
- Aquatic and Benthic Invertebrate Tissue
- Small Mammal Tissue

2.1 Biological Data

Biological data collected for the site include biomass measurements, habitat observations and species surveys. Periodic measurements on the biomass of the rooted macrophyte, copepods and benthic invertebrate communities were made throughout the study period using techniques described below. Habitat and species observations were made during all field activity and formal avian surveys were conducted in and around the lake on 25 occasions. The results of the data collection for each of these data types are summarized below.

2.1.1 Aquatic Vegetation

The only emergent rooted macrophyte in the Pit Lake (Figures 2-1 and 2-2) was the cattail (*Typha latifolia*). A limited amount of the algae, Stonewort, (*Chara Sp*) occurs in the littoral zone and is primarily associated with a narrow band extending from shoreline out to a couple of meters from shore. The 0.9 ha comprising the littoral zone with rooted macrophytes also supports a sparse benthic invertebrate community. In addition to the cattails, the major source of organic matter in the littoral zone appears to be shoreline grass being inundated by the rising water level of the

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[3] Rationale for the selection of these two compounds as constituents of potential ecological concern is provided in Section 3.4.

lake. This narrow band of submerged grass was where most of the benthic invertebrate biomass was concentrated.

Cattail biomass was estimated in July 2005 using a 0.5 m^2 quadrat and long handled clippers to provide biomass estimates on a m^2 basis. Plants were clipped at the root crown. The one acre (4100 m^2) of cattail beds in the littoral zone had a total biomass that averaged just over 4000 kg dry weight based on three replicates (Figure 2-3). This value represents total dry weight production of cattails for the entire lake.

Biomass was obtained on cattails but not algae (stonewort) as the latter was sparsely distributed in a narrow band close to shore and sampling techniques were inadequate for adequate biomass estimates on this species. In addition, no measurements were made of biomass of terrestrial grass that was covered by the rising water levels.

2.1.2 Aquatic and Benthic Biota

Copepods of the genus Cyclops, were the only species identified in the limnetic zone[4] of the lake. This planktonic species apparently feeds on microscopic plants and animals in the water column although phytoplankton were never observed in the 150 micron tow net used to collect copepods samples. While not confirmed, it is likely that microscopic organisms such as cyanobacteria, rotifers, and protzoans served as food sources for the copepods in the Pit Lake. Copepod biomass was estimated using a 150 µm haul net retrieved vertically in the water column. Each haul represented a discrete sample. Three locations, distributed across the lake were sampled for copepod biomass on several occasions during the study period. Because the dimensions of the haul net and depth to which it was lowered was known, the mass of copepods in the haul net could be converted to total biomass in the lake by multiplying copepod mass/liter of water sampled by the total liters in the Pit Lake.

Because copepods are phototrophic (shun direct sunlight), they show diurnal patterns in their distribution in the water column. Several samples were taken on separate occasions and light conditions (i.e., cloudy versus direct sunlight) to determine the maximum depth to which copepods are found in the water column. Although several patterns were observed depending on ambient light conditions (Figure 2-4), the

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[4] The limnetic zone is the open water area of the lake. The habitat distinctions within the lake are discussed in more detail in Section 3.3.

conclusion drawn from all of these studies was that copepods were not found below a depth zone of 40 to 60 ft and that at 95% of the copepod biomass was confined to the upper 40 ft of the lake. Based upon these special studies, the volume of lake water that was used in calculating total copepod mass was that contained in the upper 40 ft of the water column. Total copepod biomass was estimated four times during 2005. Summary statistics for copepod biomass estimates by sampling period are shown in Table 2-1.

Mean total copepod biomass for the entire lake varied by about a factor of two from a minimum of about 300 kg to a little over 700 kg. Highest biomass was measure during June as would be expected with the warmer water temperatures. Variation as expressed by the coefficient of variation (i.e., (standard deviation/mean) for total copepod biomass on a particular sampling date ranged from about 25% - 50%.

Benthic invertebrate biomass was obtained using an Ekman Dredge to sample a given area on the sediment surface. The open face of the dredge used in this study had a surface area of 232 cm^2. The dredge was lowered to the sediment surface and the closure jaws activated to collect sediment and any contained benthic organisms. Each sample was transferred to a 60 mesh screen and hand sorted to retrieve benthic invertebrates. Samples were weighed, oven dried and then reweighed. Voucher specimens were also taken to identify the species collected.

Results show that total benthic invertebrate biomass in the 0.9 ha of littoral zone containing cattails averaged 25-36 kilograms on 3 different sampling dates and for sample sizes of 14 to 23 depending on sampling date (Table 2-2). Differences in estimates of biomass between sampling dates were not significant ($p \leq 0.05$). The coefficient of variation was about 100% of the mean and the mean plus the 95% UCL ranged from 37-59 kg. Samples were taken at many other locations around the lake in the zone from shore to a 5 ft water depth. The only place benthic invertebrates were found was in the small area of littoral zone containing cattails. A list of the taxa observed in the Pit Lake is provided in Table 2-3.

2.1.3 Terrestrial Vegetation and Biota

Biomass estimates for terrestrial vegetation and rodents were not obtained due to the sharp gradient in vegetation biomass with distance away from the shoreline and because of the changing conditions of the shoreline due to the rising water level. Ocular estimates of vegetation biomass from locations sampled near shore (i.e., within 10 ft of the water) supported from 50 to 100 g/m^2 of grass (Section 2.1). The

abundance of rodents, primarily *Microtus montanus*, was also low as evidenced by a few tunnel systems confined to the narrow band of green shoreline vegetation that had responded to the saturated conditions within 10' of the shoreline. The changing conditions created by the rising water levels and saturated soil conditions near shore likely contributed to the low abundance of meadow voles. Trapping over several days caught primarily meadow voles. Terrestrial invertebrates were not found in the near-shore terrestrial area adjacent to the lake.

2.1.4 Wildlife Surveys

Bird surveys were conducted at the Pit Lake from September 18, 2004 to August 26, 2005 on 25 different occasions (Table 2-4). A total of 1054 individual birds of 26 different species were observed over the 10 month period in the Pit Lake environs. Of that total, 393, or 37% were waterfowl species of 7 different species. Of the 544 birds that were not raptors or waterfowl, 55% were cliff swallows. The total number of bird species observed during each visit ranged from 1 to 14. As would be expected, most birds were present in the lake environs only during the summer months although some species were observed year round in the lake environs, especially Canada geese, owls, and golden eagles.

Waterfowl reproduction at the lake was also noted during the field surveys (results shown in Appendix F). Only four bird species were observed to nest at the Pit Lake during this study and they were a pair of Canada geese, one of blue winged teal, one of red-winged blackbirds, and numerous cliff swallows. The goose and red-winged blackbird nests were destroyed by predators before egg hatching and the nests were not re-established. Both of these nests were exposed due to a lack of good nesting cover. The blue winged teal nest produced two young that were alive two weeks after hatching. It is believed that the teal nest was in a small wetland located an upland area several hundred yards above and to the west of the Pit Lake as numerous intensive bird surveys failed to find the teal nest around the lake shore. Upon hatching, the teal likely brought here young from the small wetland to the Pit Lake for protection against mammalian predators. The cliff swallow nests were constructed on the vertical walls above the south end of the lake and were not accessible so records were not maintained on this species. With the exception of the cliff swallows, a total of three birds were observed to nest in the Pit Lake area during the 2005 season and only one was successful in producing young. Predation was responsible for the loss of the other two nests. Detailed field notes from each individual survey recorded not only the presence of birds but also all other wildlife that were seen during visits to the study site (Appendix F). The dominant large mammalian species observed during the study was

the Rocky Mountain mule deer (204 observed) along with a limited number of pronghorn (7) in the Pit Lake environs.

2.2 Chemical Data

Chemical data were collected for all site media (i.e., surface water, sediment, and soil from the transitional area adjacent to the lake.) as well as for tissue from aquatic and terrestrial biota found in and around the lake. The following sections provide an assessment of the data quality for use in the ERA and a summary of the results for each of these media types.

2.2.1 Data Quality

Sediment, soil, surface water and tissue samples collected from Highland Pit Lake from September 2004 through February 2005 and June 2005 through July 2005 were sent to Energy Laboratories in Casper, Wyoming for analysis. The analytical results received from Energy Laboratories for all samples were evaluated for data quality. Sample collection and transfer was verified; all samples were analyzed within holding times and according to requested methodologies. Quality control parameters for accuracy and precision were acceptable for all analyses. The results are considered to be usable with no qualifications. The analytical protocols and reported detection limits for selenium and uranium in sampled media are presented in Table 2-5. The complete data validation report is provided in Appendix G.

2.2.2 Surface Water

Concentrations of dissolved selenium and uranium in water samples from the Pit Lake and Box Creek were measured in September, 2004 and June, 2005. The means were based on a locations and 2 depths (1/3 and 2/3 total water column depth) during each sample event. Concentrations of selenium and uranium in Pit Lake water showed very little variation within or between sampling dates suggesting that the lake was well mixed both horizontally and vertically. Mean concentrations of selenium and uranium averaged 0.11 ppm and 3.0 ppm with coefficients of variation (i.e. SD/Mean X 100) was no more than 5% of the mean for both within and between date comparisons. In water samples from Box Creek, concentrations of selenium were non-detectable (<0.0005 ppm) while total uranium averaged about 0.008 ppm (detection limit = 0.0003 mg/l). Table 2-6 lists the minimum, maximum, mean, standard deviation, and the 95th UCL for selenium and uranium concentrations in surface water samples.

2.2.3 Sediment

Sediment was sampled in the limnetic and littoral[5] zone at the Pit Lake and in Box Creek using an Ekman dredge. Samples were taken at the same 3 general locations as water and copepod biomass samples. Over the course of the study, a total of 16 sediment samples were collected on two different sampling dates in both the limnetic and littoral zones of the lake. The depth to which each sediment sample was taken was variable due to differences in bottom characteristics. In general, sediment depths collected by the Ekman Dredge averaged about 2 to 3 inches.

Table 2-6 lists the minimum, maximum, mean, standard deviation, and the 95th UCL for selenium and uranium concentrations in sediment samples. Selenium and uranium in sediments collected from the limnetic and littoral zone were not significantly different ($p<0.05$). Selenium averaged 21 mg/kg while uranium averaged 144 mg/kg. Selenium concentrations averaged 50 to 150 times higher and uranium 20 to 40 times higher in Pit Lake sediments than corresponding samples from Box Creek. Concentrations of selenium and uranium in Pit Lake sediments were moderately variable with coefficients of variation (SD/mean x 100) ranging from about 50% to 100% of the mean.

2.2.4 Soil

Soil samples at the Pit Lake were collected on two occasions within 10 ft of the shoreline adjacent to the littoral zone area supporting cattails (Figure 2-1 and 2-2). Soil samples were restricted to this area as it was the primary area of use by mule deer which periodically use the lake for drinking water and forage. Access to the water by deer was very limited due to the very steep banks around most of the shoreline. Soil samples from Box Creek were also taken around the shore of the pond. Samples at both locations were taken with a step coring tool to a depth of 6 inches

Summary statistics for selenium and uranium concentrations in soil samples are presented in Table 2-6. Mean concentrations of selenium between Pit Lake and Box Creek samples were within a factor of about 2 and, in the case of Pit Lake soil, were 10 to 30 times lower than concentrations in Pit Lake sediment. Uranium concentrations in

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[5] The littoral zone is a shallow-water, near-shore habitat within the lake in which most of the aquatic biological activity likely occurs. The habitats within the lake are discussed in more detail in Section 3.3.

Pit Lake soil averaged about 5 to 8 times higher than those in soil from Box Creek while Pit Lake soil uranium averaged 10 to 20 times lower than that in Pit Lake sediments.

2.2.5 Biotic Tissue

Biota data collected for the site include aquatic and terrestrial vegetation, aquatic and benthic invertebrates, amphibians and small mammals. The collection and results for each of these tissue types is described below.

2.2.5.1 Aquatic and Terrestrial Vegetation

Grab samples of aquatic and shoreline vegetation from the Pit Lake (Figure 2-2) and Box Creek pond were collected by clipping plants at the root crown. As mentioned, biomass sampling of terrestrial vegetation was not done because of the sharp gradient in biomass with distance from the shoreline. However, occular estimates, based past experience in estimating plant biomass, suggested that 50 to 100 g/m^2 of vegetation was present in sampled areas. Grass samples from the Pit Lake consisted of a mixture of the perennial species used to revegetate the reclaimed areas around the lake (Section 2.1) while the aquatic vegetation was primarily cattail. Some algae (stonewort), was also collected but was very sparsely distributed and occurred only in a narrow band with 10 ft of shore. No trees or shrubs occurred at the Pit Lake or Box Creek.

Pit Lake vegetation samples were taken on three dates in 2004 and 2005. Box Creek samples were taken on one occasion in July 2005. Box Creek aquatic vegetation was more diverse than that in the Pit Lake. Species sampled included cattail and stonewort, which also occur at the Pit Lake, but also bulrush (*Scirpus sp.*), sedge (*Carex sp.*) and pondweed (*Potamageton sp.*). Table 2-6 presents the minimum, maximum, mean, standard deviation, 95th UCL, and total number of for the concentrations of the selenium and uranium in vegetation samples.

Concentrations of selenium and uranium in vegetation were a function of species sampled and sampling location. Highest concentrations in aquatic vegetation were measured in stonewort. This algal species had concentrations of both selenium and uranium that were 2 to 30 times higher than that measured in cattails. With the exception of *astragalus*, near-shore terrestrial vegetation had concentrations of selenium and uranium that were in the lower range of the cattail concentration data. The high levels of selenium in *astragalus* were due to the fact that this species is a

known hyperacculmulator of selenium. Background levels of selenium in vegetation from Box Creek were generally non-detectable. Uranium concentrations in background vegetation averaged at least an order of magnitude lower than that measured in vegetation from the Pit Lake.

2.2.5.2 Aquatic Biota

Aquatic macroinvertebrates inhabiting the littoral zone in the Pit Lake were sampled on several occasions during the study using an Ekman dredge in the littoral zone area containing cattails (Figure 2-2). Because the dredge sampled a defined area on the sediment surface, it provided biomass estimates for organisms contained in the sediment samples. Individual samples were hand sorted to remove individual species for selenium and uranium analysis.

Taxonomic groups collected were primarily comprised of *Notonectids* and *Hemiptera* with minor contributions from species (<10%) such as *Ephemeroptera, Tricoptera, Odonata, Amphipoda, Coleoptera,* and *Diptera* (Table 2-3). Most of the benthic invertebrate species sampled at Box Creek were also occurred at the Pit Lake. As mentioned previously, the aquatic plants and invertebrates occurring in the littoral zone (Figure 2-2) represent recently introduced species groups because 6 to 8 years ago, the current littoral zone, as defined by shoreline out to a 5 ft water depth, was dry land.

Concentration data for benthics in the Pit Lake are shown in Figure 2-5 and Table 2-6 to illustrate the relationship of selenium and uranium concentrations between species. There were no non-detects of either selenium or uranium in Pit Lake or Box Creek samples. Pit Lake concentrations were at least a factor of 50 higher than corresponding data from Box Creek. Highest mean concentrations of selenium were measured in predators including leopard frogs, dragon/damsel fly larvae, and terrestrial spiders. Highest mean concentrations of uranium were measured in copepods, snails, caddis fly larvae, and algae. Summary data for individual species of aquatic organisms are presented in Appendix A.

2.2.5.3 Rodents

Meadow voles (*Microtus montanus*) were collected on two occasions in 2005 in the same area where soil and vegetation were collected (Figure 2-2). Meadow Voles are primarily herbivores that consume herbaceous vegetation, seeds, and plant roots. A very few deer mice (*Peromyscus sp*) were caught but sample sizes precluded including them in this assessment.

The entire meadow vole carcass was analyzed for selenium and uranium. Results (Table 2-6) show that selenium levels in rodents were in the range of those measured in terrestrial vegetation. In contrast uranium levels in rodents were about 10 to 15% of those measured in terrestrial vegetation.

3. PROBLEM FORMULATION

Problem formulation defines the goals and objectives of the risk assessment. This is a formal process to develop and evaluate preliminary hypotheses concerning the likelihood and causes of ecological effects that may have occurred, or may occur, from human activities (USEPA, 1998). The problem formulation for this ERA includes a description of the Pit Lake and the surrounding area, a description of the ecological setting, selection of COPECs, the CSM, the selection of assessment and measurement endpoints, and the selection of representative receptors. The following sections provide details of each step in the problem formulation.

Key Elements

- Habitats evaluated include aquatic and adjacent terrestrial.
- Site-specific surveys conducted and used to characterize site ecology.
- COPECs selected include selenium and uranium.
- CSM identified complete exposure pathways between site-related constituents in surface water and sediment and plant, invertebrate, and wildlife receptors.
- Assessment endpoints: 4 terrestrial and 5 aquatic.
- Receptors of concern selected to maximize exposure based on species observed in the site area.

3.1 Pit Lake Description

In the late 1960s, Humble Oil and Refinery discovered a uranium deposit in the southern Powder River Basin, Wyoming, and initiated mining activities, which subsequently became known as the Highland Uranium Operations. The uranium occurred as a roll front deposit trending roughly northwest in the area of the Highland property (Langden and Kidwell, 1973). Multiple mining techniques were employed to extract uranium ore, including surface mining from a series of four open pits, beginning in 1970 and continuing through 1984 (Water Waste and Land [WWL], 1989). Overburden and waste rock removed during stripping operations were initially stockpiled and were then used to backfill previously opened pits. The final two pits (pits 3 and 4) were not completely backfilled and, beginning in March 1984, groundwater from the surrounding aquifer was allowed to discharge into the two pits, forming the Highland Pit Lake. As mentioned, a functioning aquatic community did not exist in the lake during this period.

Open-pit mining at the Highland project followed the general strike of the roll-front. The current shape of the Pit Lake represents the final extent of open pit mining. Therefore, portions of the pit-wall in the ore body exposed the mineralized roll-front. Even though portions of the pit-walls were covered with backfill (EPRCO, 1983), groundwater flowing from up gradient in the ore body leached uranium, radium, and selenium from mineralized zones and transported the metals into the Highland Pit Lake. Other sources of water flowing to the Highland Pit Lake include: (1) surface runoff, (2) direct

precipitation, and (3) discharge from a perched aquifer. Outflow of water from the Highland Pit Lake is limited to evaporation based upon the current hydrological model. A more complete discussion of lake and groundwater hydrology can be found in a previous report (MFG, 2003).

The Pit Lake is oriented roughly southwest-northeast, covers about 110 acres (46 ha), is over 130 ft (41 m) deep, and has a water level that was rising about 1 ft/yr during the study period of the field data collection described in Section 2. The current elevation of the lake surface is about 5,030 feet. Due to the relatively recent age of the lake (~ 20 yrs) and the cold NE Wyoming climate, the lake would be expected to exhibit a limited biological component as is typical of cold water, low productivity oligotrophic lakes.

The total area of the lake is about 4,950,000 m^2 while the total area of the region from shoreline to 5 ft depth is 269,180 m^2 or 5.44% of the total lake area (Figure 2-2). The littoral zone, as defined above, comprised only about 0.4% and 5% of the total lake volume and surface area, respectively. About 2% of the total lake area, or 0.9 ha (~2 ac) supported emergent vegetation and associated fauna.

3.2 Ecological Description

The Highland Pit Lake environs experiences a dry continental climate, typical of the Northern Rockies, with prevailing winds and weather patterns moving from west to east. The mountain ranges to the west of the Highland site cause Pacific storms to drop much of their moisture before they reach the Pit Lake area, resulting in low precipitation of about 12 inches (~ 300 mm) annually. The most abundant rainfall occurs in the spring and early summer. In the winter months, total snowfall averages 44 inches, and snow cover remains on the ground through much of November to March or April. July temperatures in the region are mild, ranging from 44° to 82° F, while January temperatures fall to a range of 4 to 28° F (NOAA, 2005).

3.2.1 Upland/Terrestrial Ecology

In undisturbed areas, the temperate climate and low precipitation support primarily grasses and forbs with shrubs and trees occurring on steep north facing slopes and along water courses. However, most of the vegetation surrounding the Pit Lake reflects species used for past reclamation activities. Currently, the vegetation around the lake is dominated by western wheatgrass, crested wheatgrass, thickspike wheatgrass, Great Basin wild rye, and smooth brome. A limited amount of vetch (*Astragalus sp.*)

occurs near the shore line at the Pit Lake. This species is known as a hyperaccumulator of selenium (Sors, et al., 2005).

A number of faunal species are associated with the lake environs (Appendix F). Terrestrial species include Rocky Mountain mule deer, which are abundant in the area during the summer and use the lake for drinking water. In addition, muskrats, meadow voles, deer mice, and a variety of insects, inhabit the shore area. Some of the mammalian predators include the coyote, red fox, skunk, badger, and raccoon. Avian predators are very abundant during the summer nesting season. Many species of terrestrial birds occur in the general area, including several species of raptors, owls, and a variety of passerine birds. Waterfowl species have been observed at the lake from Spring through the Fall (Section 4.3). During the study period, most waterfowl used the lake for resting and or loafing. Canada geese observed on the lake appeared to be acclimated to human presence suggesting that they likely were "city geese" that had flown from Douglas Wyoming to rest on the Pit Lake during the day. Four bird species were observed to nest at the Pit Lake during the field surveys and they were a pair of Canada geese, one of blue winged teal, one of red-winged blackbirds, and numerous cliff swallows.

While no listed species were recorded in Wyoming Natural Diversity Database (1/23/06) as occurring in the township containing the Pit Lake, two of these were observed in the general area of the Pit Lake. The short-eared owl (Asio flammeus) and golden eagle (Aquila chrysaetos) were both observed on several occasions in the general area of the Pit Lake. The short-eared owl, a ground nester, was assumed to have nested in the area based on repeated observations of the bird/s in the same general area.

3.3 Aquatic Ecology

There are two distinct zones, or habitats, in the Pit Lake (Figure 2-1). The first is an open water or limnetic zone, and the second, a near shore, shallow water or littoral zone. This near shore littoral zone (i.e., foreground in Figure 2-1) with its associated flora and fauna has formed recently as water levels 6 to 8 years ago would not have covered this shallow water area. In many deep, cold, freshwater lakes, most aquatic biological activity is associated with the littoral zone, where water temperatures rise during summer months allowing for the establishment of rooted and submerged vegetation, including periphyton, that contributes organic matter to bottom sediments. This organic matter serves as the basis of the food web that supports benthic invertebrates and other aquatic biota including amphibians.

The shore around the perimeter of the lake is primarily comprised of very steep slopes ranging from near vertical to a very limited area with more gentle slopes of about 10% (Figure 2-1). These slopes consist of exposed soil and rock with sparse grass on the very steep areas (photo in Figure 2-2) and, on the more gentle slopes, a heavier grass cover consisting of western wheatgrass, crested wheatgrass, thickspike wheatgrass, great basin wild rye, and smooth brome, species that were associated with past reclamation work on the tailing and waste rock areas around the Pit Lake.

The steepness of the shore slopes limits areas that can be easily accessed by larger terrestrial species that might use the lake for drinking water or forage. Consequently, nearly all of the mule deer seen utilizing the lake for drinking water (Appendix F) did so in the small area that supported rooted aquatic vegetation and had relatively gentle slopes (foreground in Figure 2-1). The area around the lake within at least a kilometer from shore completely lacks trees and shrubs (Figure 2-1) that might provide lake side nesting and hunting habitat for avian species. For this study, the littoral zone in the Pit Lake was defined as the zone from shore to a maximum water depth of 5 ft (current extent of littoral zone shown by the blue contour line in Figure 2-2). This definition is based upon the fact that maximum water depths increase dramatically beyond the 5 ft depth in the littoral zone owing to the vertical walls associated with the pit shaped configuration of the lake. As mention previously, as little as 6 to 8 years ago, none of the area defined herein as littoral zone would have existed because of the rising lake water levels.

The euphotic zone (i.e., lake surface to depth of sunlight penetration) is very limited at the Pit Lake with sunlight penetrating to a maximum of about 2 m as measured by Secchi disk visibility (Figure 3-1). Reasons for the turbidity of the lake water are not known at this time but may be related to calcite concentrations in the water. Saturated oxygen levels in the lake as a function of time and depth ranged from 100% down to about 70% (Figure 3-2). Saturated oxygen levels were highest in the winter months and lowest during the summer months. There was also a consistent decrease in saturated oxygen levels with depth in the lake independent of season. In any case, oxygen levels were sufficiently high to support aquatic life. The pH levels in Pit Lake water (Figure 3-3) was around 8.0 near the lake surface but decreased to as low as 7.65 at depths of 100 feet or more. Water hardness was calculated from the calcium, magnesium, and sulfate levels in Pit Lake water (MFG, 2004b). Results show that total hardness as $CaCO_3$ was estimated to be about 200 mg/l.

The open water, or limnetic zone (i.e., water depths > 150 cm), comprises about 96% and 99+%, respectively, of the lake surface area and volume. The limnetic zone had a

maximum depth of about 40 m (130 ft) during the study. The lake stratifies during the summer with a thermocline developing at the 55 to 65 depth (Figure 3-4). The thermocline persists from May through September and begins to dissipate in October. Water temperatures from November through April are cold from top to bottom and reach a minimum of about 2 degrees Centigrade throughout the water column in February.

The total area of the rooted vegetation in the lake, which is shown as the green shaded areas in Figure 2-2, was estimated as 4100 m^2. This means that rooted macrophytes contributed 0.08% to total lake area or about 1.5 % to the 0 to 5 ft region defined as the littoral zone. The low contribution of the littoral zone to plant production is not expected to change as the lake reaches its final level because of the steep nature of the shore area precludes any expansion of the littoral zone.

Several species of benthic invertebrates occupy a small, shallow water area in the Pit Lake. Amphibian species that are thought to occur in the Pit Lake area include the tiger salamander (*Ambystoma tigrinum*), leopard frog (*Rana pipiens*), and a toad (*Bufo sp.*). Only the leopard frog and toad were observed during the 2004 and 2005 field investigations (Appendix F). A total of about 45,000 rainbow trout, cutthroat trout, and hybrids of the two species were planted in the Pit Lake on two occasions in the 1990's in an attempt to establish a fishery in the lake. However, fish have never been caught from the lake leading to the conclusion that the stocked fish did not survive, likely due to the lack of a prey base for the fish in the lake at that time. Repeated attempts to catch fish using gill nets, cast nets and tackle during a prior survey and during this study were unsuccessful.

3.4 Chemicals of Potential Ecological Concern

Long term monitoring of Pit Lake water for a variety of chemicals identified only selenium and uranium as exceeding State of Wyoming surface or groundwater standards for protection of aquatic life in 2004 (Table 3-1). Surface and groundwater monitoring data for Ra-226, TDS, Ca, Mg, Na, Cl, SO_4, and HCO_3 were all less than applicable Wyoming or Federal water quality standards in 2004. The WDEQ water quality standards for selenium and uranium for use by livestock are 0.05 mg/l and 5 mg/l respectively.

Monitoring data show that concentrations of selenium and uranium in Pit Lake water have decreased with time following an initial pulse probably due to a release of soluble constituents from the exposed ore bodies covered by the rising water. However, over

the long term, the modeling studies (MFG, 2004b) predict that groundwater will become a more important source of selenium and uranium in the lake with time as the exposed ore body in the pit becomes depleted in soluble selenium and uranium. The modeling studies also predict that selenium and uranium concentrations over the long term may increase slightly as evaporation from the lake concentrates chemicals in the water (MFG, 2004b). Thus, this ERA focuses on selenium and uranium as the COPECs.

Potential for radiological exposure associated with uranium was considered in this assessment, however, ecological receptors are considered more sensitive to the chemical toxicity than to potential radiological exposure (Sheppard et al, 2005). Therefore, this assessment focuses on the chemical toxicity of uranium and is expected to be protective of any exposure of ecological receptors to radiation.

While this assessment focuses on selenium and uranium, sediment data for a number of other metals were collected for the site as a part of the field data collection in 2004. For conservatism, these data were compared to available sediment quality benchmarks (Probable Effects Levels [MacDonald et al, 2000] and to a dataset available from the United States Geological Service (USGS) that was collected to characterize general concentrations of metals in stream sediments in the Wyoming ecoregion of the Yellowstone River Basin (USGS 1998). When the 95th percentile values of data collected from geologically similar areas were compared to the site data, only selenium and uranium exceeded the USGS values (Table 3-2). This further supports the water-based assessment that selenium and uranium are the primary COPECs.

3.5 Pit Lake Conceptual Site Model

The CSM considers the site setting in an ecological context and identifies important site receptors, ecological exposure pathways, and potential pathways of chemical transport (USEPA, 1992). The CSM is then used to aid in the selection of assessment and measurement endpoints. The CSM schematically presents the relationship between chemical sources and classes of receptors at the site (Figure 3-5), and identifies potentially complete and significant pathways through which ecological receptors may be exposed to the identified COPECs.

The CSM for the site was developed based on historical site activities and the biological surveys conducted at the site. Conceptualization of the structural and functional relationships, including chemical exposure pathways, was used to identify

data needed to evaluate the potential risks from chemicals to Pit Lake receptors. From the model, identified data needs included: 1) specific Pit Lake chemicals that are of interest, 2) applicable standards for chemicals of interest, 3) biota that might be exposed to the chemicals, 4) concentration of chemicals in biota, 5) physical and biological attributes of the lake habitat including size of the various physical and biological compartments, and 6) a methodology for integrating the physical, chemical, and biological information to estimate risks to biota associated with the Pit Lake. Blue shaded boxes in the model were sampled to estimate selenium and uranium concentrations. The gray-shaded boxes depict pathways which were examined in the risk analysis.

3.5.1 Site Sources and Chemical Migration Pathways

The exposed ore body is the primary source of selenium and uranium to the Pit Lake through leaching of chemicals directly into lake surface water. Based on surface and groundwater monitoring data and computer modeling studies (MFG, 2004b), leaching of chemicals into groundwater and subsequent flow into the lake is a more minor secondary source. Constituents in surface water can then either deposit into sediments or be assimilated into aquatic or benthic biota. Fugitive dust that may have deposited in soils around the lake from historical mining activity may also be a minor additional source to receptors that might use the transitional vegetated area between the lake and the surrounding upland environment for forage and cover. These compounds can be assimilated into plants and consumed by herbivorous and omnivorous wildlife. In turn, these herbivorous or omnivorous species may be consumed by upper trophic level carnivores.

3.5.2 Identification of Potentially Complete Exposure Pathways

To identify potentially complete exposure pathways, ecological guilds (i.e. groups of species that use the same set of resources in a similar manner) were identified based on the potential for organisms in these guilds to either reside in or obtain a significant portion of their diet from the site. Ecological guilds that have been identified as including organisms potentially occurring in the Pit Lake or the surrounding transitional environment are aquatic and terrestrial plants; aquatic and benthic invertebrates; amphibians, and herbivorous, omnivorous, and carnivorous birds and mammals. The complete exposure pathways identified at the site for aquatic and transitional terrestrial habitats are summarized in the CSM on Figure 3-5. For some receptors, some of the exposure pathways that are considered complete are considered insignificant or cannot be quantitatively evaluated due to lack of toxicity data. These pathways are

marked on Figure 3-5. Complete pathways that are quantitatively evaluated in the ERA include:

Aquatic Receptors

- Aquatic plants and lake surface water – direct contact/uptake;
- Benthic (i.e., sediment) invertebrates and lake sediments – direct contact/uptake;
- Aquatic invertebrates and amphibians and lake surface water – direct contact/uptake;
- Aquatic-feeding herbivorous birds and lake sediment, water and impacted plant tissue – ingestion; and
- Aquatic-feeding omnivorous birds and lake sediments and impacted aquatic plant or prey tissue – ingestion.

Terrestrial receptors

- Terrestrial plants – direct contact/uptake;
- Terrestrial herbivorous birds and soils from the transitional habitat around the lake and impacted terrestrial plant tissue – ingestion;
- Terrestrial herbivorous mammals and soils from the transitional habitat around the lake, lake water and impacted terrestrial plant tissue – ingestion, and;
- Terrestrial carnivorous birds and soils from the transitional habitat around the lake and impacted terrestrial prey tissue – ingestion.

3.6 Identification of Assessment and Measurement Endpoints

Based on the ecological guilds and complete exposure pathways identified in the previous sections, assessment endpoints (AE) were developed to identify the ecological values at the Site that should be protected. The measurement endpoints (ME) were developed as a means of measuring potential ecological effects and determining if any potential risk is associated with the COPEC concentrations in each media.

In general, assessment endpoint selection must consider the ecosystem, communities, and species relevant to a specific site. As defined by the EPA (1997), assessment endpoints are formal expressions of the actual environmental values that are to be protected at a site. Assessment endpoints are defined based on technical considerations including the significance of exposure pathways, the presence of receptors, and a COPEC's biotic transfer pathway. The selection of assessment endpoints depends on:

- the chemicals present and their concentration;

- mechanisms of toxicity of the chemicals to different groups of organisms;
- ecologically relevant receptor groups that are potentially sensitive or highly exposed to the chemicals; and
- potentially complete exposure pathways.

Measurement endpoints are defined as "measurable ecological characteristic[s] that [are] related to the valued characteristic chosen as the assessment endpoint" and are a measure of biological effects (e.g., mortality, reproduction, growth) (EPA, 1997). In addition to the MEs used for quantitative analysis, ancillary measurements on the composition and biological productivity of the Pit Lake ecosystem will be considered in the final assessment of each AE. The types and amount of habitat and plant and animal biomass production formed is key to the interpretation of the chemical data. This will be discussed in detail in the risk characterization.

The AEs selected for the ERA for both aquatic and terrestrial areas are summarized below. The risk questions, AEs and associated MEs are summarized in Table 3-3.

Aquatic Assessment Endpoints

AE: A1. Survival growth and reproduction of aquatic plant populations
AE: A2. Survival growth and reproduction of aquatic invertebrate populations
AE: A3. Survival growth and reproduction of benthic invertebrate populations
AE: A4. Survival, growth and reproduction amphibian populations
AE: A5. Survival, growth and reproduction of omnivorous bird populations

Terrestrial Assessment Endpoints

AE: T1. Survival, growth and reproduction of terrestrial plant populations
AE: T2. Survival, growth and reproduction of herbivorous bird populations
AE: T3. Survival, growth and reproduction of herbivorous mammal populations
AE: T4. Survival, growth and reproduction of carnivorous bird populations

3.6.1 Identification of Representative Receptors

Because it impractical to assess the toxic effects of COPECs to all potentially exposed ecological receptors, a subset of potential receptors was chosen as "surrogate species" for each AE. These representative receptors are:

- species that represent a functional group of organisms at the site for the evaluation of AEs; and

- species that are chosen based primarily on their function in the ecosystem and secondarily on taxonomic relatedness and known or presumed similarities in physiology and life history.

Because they represent a larger group, representative receptors were selected so that they maximize exposure, thus producing conservative estimates of risk. For those AEs that are generic in nature (e.g., AEs: A1, A2, A3 and T1), selection of representative receptors was not necessary. These AEs are evaluated using toxicity thresholds that are not specific to a particular species. For example, the phytotoxicity benchmarks used to evaluate terrestrial plants (AE T1) are developed based on observed toxicity to a variety of plant species and are thus considered protective of a variety of species. Therefore, it is not necessary to select a specific representative species for these AEs. The selection of representative receptors included all AEs that focus on upper trophic-level groups.

The first step in the ROC selection process was to review the list of species that have been observed on-site and are common visitors. Avian and mammalian species that have been observed at the site are summarized in Table 2-4. In general, representative receptors were selected for each AE from this subset of species based on one or more of the following criteria:

- Receptor observed breeding on-site – Species breeding on-site are likely to experience greater exposure and have life history stages (young) that may be more sensitive to site-associated contaminants.

- Receptor has feeding strategy likely to maximize exposure to site-associated contaminants and has diet preferences that are representative of the guild in question.

- Receptor has a small relative body size – Smaller species have larger chemical absorbing surfaces per unit volume than larger species (Suter, 1993).

- Receptor has a small relative home range – Animals with smaller home ranges are likely to spend more time foraging on the site than animals with larger home ranges.

- Receptor-specific life history data (exposure parameters) are readily available.

For this ERA, the following species were selected to represent the wildlife assessment endpoints:

E: A5. Survival, growth and reproduction of aquatic feeding omnivorous bird populations – lesser scaup

AE: T2. Survival, growth and reproduction of terrestrial herbivorous bird populations – red-winged blackbird

AE: T3. Survival, growth and reproduction of terrestrial herbivorous mammal populations – meadow vole and mule deer

AE: T4. Survival, growth and reproduction of carnivorous bird populations – red tailed hawk

4. RISK ANALYSIS

Comparison of measured concentrations of selenium and uranium in Pit Lake and Box Creek samples presented in Section 2.0 (Table 2-6) showed that levels of these two chemicals in surface water, soil, sediment, plants and animals in Pit Lake samples were higher than those from Box Creek. While Box Creek samples do not represent a true background site for the Pit Lake, they do represent regional concentrations in aquatic and terrestrial samples from an area unaffected by the Pit Lake and associated mill. Thus, the Box Creek data are useful for scaling Pit Lake data against concentrations representative of background.

Given that Pit Lake samples exhibited elevated concentrations of selenium and uranium relative to those in samples from a distant area not influenced by the mine and mill site, a risk analysis was done to evaluate potential ecological impacts associated with elevated selenium and uranium concentrations in the Pit Lake area.

Key Elements

Exposure Assessment

- **Tier 1 and Tier 2 Exposure Estimates:**
  - Direct Contact Exposure Point Concentrations
  - Food web exposure models (i.e., daily dose model)

Effects Assessment

- **Tier 1 and Tier 2 Toxicity Thresholds (i.e., TRVs)**
- **Low TRVs:**
  - Lower range of NOAEL values
  - 10th percentile of LOAEL data
- **High TRVs based on:**
  - Upper range of NOAEL values
  - LOAEL
  - 25th or 50th percentile of LOAEL data
- **High TRVs based on:**
  - Upper range of NOAEL values
  - LOAEL
  - 25th or 50th percentile of LOAEL data

4.1 Risk Analysis Procedure

The risk analysis includes two primary steps: 1) development of exposure estimates for the identified AEs or representative receptors; and 2) development of estimates of effects to compare to these exposure estimates. The following sections describe the methods used to develop exposure estimates for receptors based on the measured concentrations in media and biota (i.e., the exposure assessment), the rationale for the selection of toxicity thresholds (i.e., the effects assessment) and the results of the quantitative comparison of these two components (i.e., the risk estimates).

For this ERA, direct measures of stressor (i.e., selenium and uranium) concentrations in various environmental media and biota were collected used in the risk estimate. No direct measures of effects were collected. Thus, this risk analysis compares the site-specific measures of exposure to non-site-specific effect levels (i.e., toxicity thresholds) identified in available guidance documents and literature to quantify potential risk. In addition, measures of ecosystem and receptor characteristics were collected and are used in the risk characterization along with the quantitative risk analysis to interpret potential risk.

4.2 Exposure Assessment

As described in Section 2, concentrations of selenium and uranium were measured in environmental media (surface water, sediment and soil) and biota (aquatic and terrestrial plants, aquatic and benthic invertebrates, amphibians and small mammals). These measured concentrations were used to develop Tier 1 and Tier 2 exposure estimates for those receptors that are directly exposed to environmental media (e.g., plants and invertebrates) as well as for food chain exposures (e.g. water fowl or carnivorous birds) as described below.

4.2.1 Tier 1 Exposure Estimates

Tier 1 exposure estimates for all receptors are described below. Exposure point concentrations (EPCs) are developed for both direct contact and food web-based exposure.

4.2.1.1 Direct Contact

For the Tier 1 assessment, EPCs for aquatic plants (AE: A1), aquatic invertebrates (AE: A2), and amphibians (AE: A3) are based on maximum detected concentrations of selenium and uranium in water. EPCs for benthic invertebrates (AE: A4) are based on maximum detected concentrations of selenium and uranium in sediment.

4.2.1.2 Food Web Exposure

Tier 1 EPCs for waterfowl that might forage in the Pit Lake (AE: A5) are based on modeled food web exposure. The maximum detected concentration of selenium and uranium in each appropriate media is used to estimate a daily dose to the lesser scaup. The maximum detected concentrations and summary statistics for each COPEC in each media are presented in Table 2-6.

The dose calculation model for all upper trophic level receptors provides a conservative estimate of food-chain exposure using conservative parameters to estimate the uptake of contaminants via the ingestion of food items and the incidental ingestion of soil, sediment, or water.

The dose model follows the general equation:

$$\text{Dose} = \frac{SUF * IR_{food}\ [(C_{prey\,1} * Pd_{prey1}) + (C_{prey2} * Pd_{prey2}) + (C_{prey3} * Pd_{prey3}) + (Pd_{media} * C_{media})]}{BW}$$

Equation 1

where:

Dose = estimated daily dose of COPEC from ingestion ($mg/kg_{body\ weight}/day$)

IR_{food} = amount of food ingested per day (kg (dry weight) /day)

BW = body weight (kg)

SUF = site use factor (unitless)

Pd_{prey} = proportion of diet from prey items (unitless)

C_{prey} = concentration of COPEC in prey items (i.e., plants, invertebrates or small mammals or birds) (mg/kg)

Pd_{media} = proportion of diet from soil, sediment, or water (unitless)

C_{media} = concentration of COPEC in media (i.e., water [mg/L] or soil and sediment [mg/kg-dry weight])

In general, exposure parameters for the selected receptors of concern (Section 3.6.1) were taken from the USEPA's *Wildlife Exposure Factors Handbook* (1993). Every effort was made to select ecologically relevant and conservative ingestion rates, body weights, and dietary compositions. To maintain conservatism, a site use factor (SUF) of 1 was assumed for each receptor for the Tier 1 exposure estimate. In other words, it was assumed that each receptor obtains 100% of its prey from the site. The selected exposure parameters for each receptor are summarized in Table 4-1.

4.2.2 Tier 2 Exposure Estimates

The Tier 2 exposure assessment is based on a more realistic but conservative exposure estimate for each media and tissue type, the 95% upper confidence limit on the mean (95% UCL). The 95% UCL in each media is the EPC for the direct contact AEs (A1, A2, A3, A4, and T1). The EPCs for the wildlife AEs (i.e., food chain exposures for AEs A5, T2, T3, T4 and T5) are modeled daily doses as described in Section 4.2.1.2, but based on the 95% UCL media or prey tissue concentrations.

To calculate the 95% UCL, USEPA's ProUCL program (USEPA, 2002) was used. This program evaluates contaminant distributions (normal, gamma, lognormal, or non-parametric) and recommends a specific 95% UCL based on the distribution. The Pro UCL output for each media and tissue type is provided in Appendix A.

4.2.2.1 Food web Exposure

For the Tier 2 analysis, the dietary food web model follows the same form outlined in Section 4.2.1.1. For Tier 2, two primary variations from Tier 1 were employed. First, a site-specific site use factor (SUF) was calculated and used for each receptor. The SUF is the home range of the receptor divided by the site area. Thus, if the home range of the receptor is greater than the site area, it would be expected that the receptor would not obtain 100% of its food from the site. Because there are other water and food sources in the area of the Pit Lake, it is expected that receptors such as the mule deer and the red tailed hawk would only use the lake and its environment in a limited way. The application of a SUF of less than 1 to the dietary exposure model accounts for this. Site-specific SUFs are presented for each receptor in Table 4-1.

The second variation from Tier 1 is specifically for terrestrial herbivores. The exposure estimate in Tier 1 was based on the maximum detected concentration in plants which was from the species astragalus. This species is known to be a hyper accumulator of selenium and is thought to be toxic and therefore not a primary food source for herbivorous wildlife. Thus, for Tier 2, the astragalus plant tissue (2 samples) was excluded from the terrestrial plant tissue concentration estimates for selenium. The resulting plant tissue estimates are likely more reflective of the diet of an herbivorous receptor in the area.

4.3 Effects Assessment

Direct measures of effects of selenium and uranium on receptors, such as reduced productivity or reproduction, were not made for this Pit Lake assessment. Part of the reason for not making measurements of direct effects is that variables such as reproduction or biomass production can be influenced not only by selenium and uranium but by non-chemical factors such as season and food availability. As discussed previously, an appropriate background site that duplicated the Pit Lake in all aspects but selenium and uranium concentrations, do not exist. Because evaluation of direct measures of effects requires a reference site for comparison, it was not feasible to measure effects for this assessment. As such, this effects assessment consists of the identification of appropriate toxicity effects thresholds or benchmarks from available scientific literature and other published sources for comparison to the exposure estimates described in Section 4.2 above. For the purposes of this document, these thresholds will be referred to as toxicity reference values (TRVs). TRVs generally represent levels of effects for specific exposure ranges based upon dose-response studies conducted primarily in the laboratory.

In general, TRVs were selected to be conservative estimators of potential toxic effects. In other words, benchmarks were selected to minimize the possibility of reaching a finding of no risk when risk actually exists. TRVs were identified based on both no adverse effect levels (NOAEL) and lowest observed adverse effects levels (LOAEL). The NOAEL values, referred to hereafter as low TRVs, represent a toxicological threshold below which there is high confidence in a finding of no risk. Low TRVs may also be based on a 10th percentile of low effects data for non-lethal endpoints. LOAEL values, referred to hereafter as high TRVs, represent a level above which risk may be probable or further evaluation is needed. The high value may also be based on a specified percentile (e.g., 25th or 50th) of low effects data for non-lethal endpoints. Concentrations that fall between the low and high TRVs represent a level above which there is a possibility of some level of risk but are uncertain as the actual toxicity threshold falls in between the low and high value and the exact threshold is unknown.

Toxicological reference values for ecological components are concentrations of chemicals that are reasonably considered to be the highest acceptable concentration at or below which there adverse effects on individual species (low TRVs) or populations of species (high TRVs). The assumptions inherent in TRVs are that exposures to target organisms are continuous (i.e., chronic), that bioavailability of the chemicals of interest is 100%, and that they represent concentration limits that are

protective of an individual organism or a population of that organism under chronic exposure.

The following sections describe the development of TRVs for Tier 1 and 2.

4.3.1 Tier 1 TRV Development

In Tier 1, highly conservative low TRVs were identified from readily available published sources. These sources included WDEQ standards for water quality (WDEQ, 2005), databases such as that available from Oak Ridge National Laboratories (ORNL), Cal Ecotox, USEPA (draft) Ecological Soil Screening Level (EcoSSL) document (USEPA 2000) and Risk Assessment Information Services (RAIS). When readily available sources were not available, studies from the available scientific literature were considered and the Tier 1 TRV was selected from the low end of the range of identified NOAEL values. A thorough review of published toxicological data for selenium and uranium was performed, and the literature considered on selenium and uranium toxicology is summarized in Appendices B through E. The types of general TRVs used for Tier 1 are typically based on the low end of the range of concentrations considered safe for a particular exposure pathway in order to provide protection to the most sensitive species. These low TRV standards are often used generically across a wide range of site and source conditions. As such, they are highly protective but do not take into account local conditions and species that may be much less sensitive to the receptors under study. Table 4-2 summarizes the Tier 1 TRVs for each receptor. The following sections describe the selected TRVs for each receptor

4.3.1.1 Aquatic Life (AE: A1, A2 and A4)

For selenium, the chronic water quality criteria for the state of Wyoming (WDEQ 2005) was used as the TRV for all aquatic life for which the primary exposure would be concentrations of selenium in the water (i.e., aquatic plants, aquatic invertebrates, and amphibians). This value is considered protective of all aquatic life as it is based on studies from a range of species under varying conditions that measured a number of different endpoints. In addition to this value, the USEPA has recently developed a tissue-based criteria for selenium in aquatic life (USEPA 2004). The value is based on fish because fish are considered to be the most sensitive aquatic organism to chronic selenium exposure. While no fish are present in the Pit Lake, the tissue based criteria for fish is expected to be protective of all aquatic life and was used as a secondary Tier 1 TRV for aquatic life.

No WDEQ aquatic life criteria for surface water was available for uranium. However, the WDEQ does provide a range of values for groundwater that are considered protective of aquatic life. For the Tier 1 TRV for aquatic life, the low end of this range was selected.

4.3.1.2 Benthic Invertebrate TRVs (AE: A3)

The propensity of selenium to cycle through the food web, and its ability to cause reproductive impairment in fish and wildlife has long been considered its primary environmental risk (Van Derveer and Canton, 1997). As a result, no threshold effects values based on sediment exposure effects to benthic invertebrates are available. Van Derveer and Canton (1997) developed sediment toxicity thresholds, based on bird and fish tissue and egg residue values and direct observations of deformities, using the ERL and ERM approach of Long and Morgan (1991). A value of 2.5 mg/Kg was derived based on the 10th percentile of predicted effects data, and a value of 4 mg/Kg was derived based on the 10th percentile of observed effects data. The predicted effects-based value was selected as the Tier 1 TRV.

The uranium benchmark values are derived from the Priority Substances List Assessment Report on Releases of Radionuclides from Nuclear Facilities (Environment Canada, 2000). Specific TRVs for uranium were developed in northern Saskatchewan in the location of Canada's operating uranium mines (Environment Canada 2000). Environmental monitoring data for sediment contaminant concentrations and co-occurring benthic invertebrate monitoring data in northern Saskatchewan lakes near operational and pre-operational uranium mines were used to calculate NOAEL and LOAEL values. The NOAEL value is selected as the Tier 1 TRV for benthic invertebrates.

4.3.1.3 Terrestrial plant TRVs (AE: T1)

For both selenium and uranium, a value was available that was developed by the Oak Ridge National Laboratory (ORNL) for screening contaminants of potential concern based on potential toxicity to terrestrial plants (Efroymson et al, 1997). While the authors of the benchmark document state that there is low confidence in both of these numbers due to high levels of uncertainty in the underlying toxicity data, these values represent conservative estimates for screening purposes.

4.3.1.4 Mammalian Dietary TRVs (AE: T3)

NOAEL-based TRVs for mammals were available for both selenium and uranium from ORNL (Sample et al, 1996). These values were used for the Tier 1 food web analysis. Because the mule deer is significantly larger than the test species that the TRVs are based on (e.g., the black rat), the TRV for the mule deer was allometrically converted using the approach recommended by Sample (1999) to adjust for potential toxicity differences between small and large mammals.

4.3.1.5 Avian Dietary TRVs (AE: A5, T2 and T4)

NOAEL-based TRVs for birds were available for both selenium and uranium from ORNL (Sample et al, 1996). For selenium, TRVs were available specifically for water fowl and for carnivorous birds. Therefore, the most conservative TRV based on the mallard was selected for the lesser scaup (AE: A5) and the TRV based on the screech owl was used for the red tailed hawk. The more conservative of the two avian values was used for the red-winged black bird (AE: T2) assessment.

4.3.2 Tier 2 High TRVs

While the Tier 1 TRVs are also used in the Tier 2 analysis, high values were developed to bound the conservative risk estimates based on the Tier 1 values. The Tier 2 effects assessment identifies low and high benchmarks for aquatic and terrestrial plants (AE: A1 and T1), aquatic invertebrates (AE: A2), benthic invertebrates (AE: A3), birds (AEs: A5, T2, and T4), and mammals (AE: T3). No Tier 2 TRVs were available for amphibians (AE: A4). The underlying toxicity data that were considered in developing these values are summarized in Appendices B-E. Table 4-3 summarizes the selected Tier 2 TRVs for each receptor. Tier 2 high TRVs are described below.

4.3.2.1 Aquatic Life TRVs (AE: A1, A2 and A4)

For selenium the Tier 2 high TRV is based on the acute WDEQ water quality criterion for protection of aquatic life. This value is considered protective of all aquatic life including aquatic plants, invertebrates and amphibians. For uranium, the upper end of the range of the groundwater values described above for Tier 1 was selected.

4.3.2.2 Benthic Invertebrate TRVs (AE: A3)

As described above, no sediment-based values protective of benthic invertebrates were available. The NOAEL value developed by Van Derveer and Canton (1997) based on observed effects was selected as the Tier 2 high TRV. For uranium, the LOAEL value developed by Environment Canada (2000) was selected as the high TRV.

4.3.2.3 Terrestrial Plant TRVs (AE: T1)

For both selenium and uranium, the Tier 2 high TRVs are based on the 2nd lowest values from the underlying literature used to develop the Tier 1 values described above.

4.3.2.4 Mammalian Dietary TRVs (AE: T3)

LOAEL-based TRVs for mammals were available for both selenium and uranium from ORNL (Sample et al, 1996). These values were used for the Tier 2 food web analysis. Because the mule deer is significantly larger than the test species that the TRVs are based on (e.g., the black rat), the TRV for the mule deer was allometrically converted using the approach recommended by Sample (1999) to adjust for potential toxicity differences between small and large mammals.

4.3.2.5 Avian Dietary TRVs (AE: A5, T2 and T4)

LOAEL-based TRVs birds were available for both selenium and uranium from ORNL (Sample et al, 1996). As for Tier 1, the selenium, TRVs available specifically for water fowl were used for the lesser scaup and blackbird analysis and the TRV for the screech owl was used for the red tailed hawk. A complete review of the literature for avian and mammalian TRVs is presented in Appendix D.

5. RISK CHARACTERIZATION

In Tier 1, risk is estimated by comparing highly conservative exposure estimates and toxicity criteria to calculate HQs. If the Tier 1 HQ is greater than one for any of the representative receptor/COPEC pairs identified in the problem formulation (Section 3), that receptor/COPEC is carried forward for further analysis in Tier 2. In Tier 2, more realistic, but still conservative exposure estimates are calculated and compared to less conservative toxicity thresholds (when available).

While a quantitative risk estimate based on HQs may indicate a potential for adverse effects, it is important to interpret the significance of the risk analysis within the context of the physical and biological characteristics of the Pit Lake. Thus, the next step in the assessment evaluates the significance of selenium and uranium concentrations in environmental media and biota with respect to the type and amounts of habitat, biological productivity, and recorded use of the Pit Lake by wildlife. These physical and biological attributes of the Pit Lake determine the potential magnitude and significance of food chain transport of selenium and uranium to aquatic and terrestrial consumers. Uncertainties associated with the underlying assumptions of the ERA and how these uncertainties might result in over or under estimation of potential risk are discussed and then final conclusions are presented based on all of the analyses, interpretation of results and uncertainties.

Key Elements

Tier 1 Risk Estimate

- Potential risk for all receptors except carnivorous birds and large herbivorous mammals from U.

Tier 2 Risk Estimate

- Potential risk to aquatic plants and invertebrates, benthic invertebrates, amphibians, and terrestrial plants from both Se and U.
- Potential risk to small herbivorous mammals and birds from Se only.
- De Minimus risk to water fowl, large herbivorous mammals, and carnivorous birds.

Risk Interpretation

- Potential risk mitigated by the fact that the Pit Lake provides limited habitat and prey base for identified receptors.

5.1 Tier 1 Risk Estimate

As described previously, the Tier 1 assessment used a highly-conservative approach which included the comparison of the maximum detected concentrations as the EPCs and highly conservative NOAEL-based TRVs. Hazard quotients were calculated by dividing the exposure estimate by the TRV. If the HQ was less than 1.0 (indicating the exposure concentration or dose is less than the TRV), the occurrence of adverse effects is considered de minimus. If the HQ is greater than 1.0 (indicating the exposure is greater than the TRV), there is some potential for adverse effects to occur (USEPA, 1997). Thus, when the HQ was greater than 1 for the Tier 1 screen, the COPEC-receptor pair was carried forward to Tier 2.

The results of the Tier 1 screen are summarized in Tables 5-1 and 5-2. HQs were greater than 1 for all receptors for both compounds with the exception of the mule deer (AE: T3), the red-winged blackbird (AE:T3), and the red-tailed hawk (AE: T4) for uranium. These three receptors are not evaluated further for uranium in the Tier 2 analysis. All other receptors are evaluated in Tier 2.

5.2 Tier 2 Risk Estimate

The Tier 2 risk analysis was conducted to further evaluate the Tier 1 exposure scenarios that yielded HQs greater than 1. Less conservative assumptions were used for the Tier 2 assessment including use of the 95% UCL concentrations to estimate exposures (instead of maximums) and less conservative high or LOAEL-based TRVs when available. The Tier 2 risk estimate results for each assessment endpoint are listed below and summarized in Tables 5-3 and 5-4.

- Aquatic Plants: AE: A1 – Low TRV HQs were greater than 1 for selenium and uranium and high TRV HQs were greater than 1 but less than 10 for both COPECs.

- Aquatic Invertebrates: AE: A2 – Low TRV HQs were greater than 1 for selenium and uranium and high TRV HQs were greater than 1 but less than 10 for both COPECs.

- Benthic Invertebrates: AE: A3 – Low TRV HQs were greater than 1 for selenium and uranium and high TRV HQs were greater than 1 but less than 10 for both COPECs.

- Amphibians: AE: A4 – Low TRV HQs were greater than 1 for selenium and uranium and high TRV HQs were greater than 1 but less than 10 for both COPECs.

- Omnivorous Water Fowl (the lesser scaup): AE: A5 – Both low and high TRV HQs were less than or equal to 1 for selenium and uranium.

- Terrestrial Plants: AE: T1 – Low soil-based TRV HQs were greater than 1 for selenium and uranium and high TRV HQs were greater than 1 but less than 10 for both COPECs. The low tissue-based TRV HQ for selenium was greater than 1 and the high TRV-HQ was greater than 1 but less than 10. The low tissue-based TRV HQ for uranium was greater than 1 while the high TRV HQ was less than 1.

For astragalus (a selenium hyperaccumulator), the tissue-based low TRV HQ was less than 1.

- Herbivorous Birds (the red-winged blackbird): AE: T2 – Both low and high TRV HQs for selenium were greater than 1, but magnitude was low (HQ = 2.6). Uranium was not a Tier 2 COPEC for the red-winged blackbird.

- Herbivorous Small Mammals (meadow vole): AE: T3 – Both low and high TRV HQs for selenium were greater than 1. For uranium, the low TRV HQ was greater than 1 and the high TRV HQ was equal to one.

- Herbivorous Large Mammals (mule deer): AE: T3 – Both low and high TRV HQs were less than 1 for selenium. Uranium was not a Tier 2 COPEC for the mule deer.

- Carnivorous Birds (red-tailed hawk): AE: T4 – Both low and high TRV HQs were less than 1 for selenium. Uranium was not a Tier 2 COPEC for the red-tailed hawk.

5.3 Risk Interpretation

An important part of this risk assessment was an evaluation of the physical and biological characteristics of the Pit Lake that influence the significance of selenium and uranium exposures to the different plants and animals. Factors that can influence the exposure frequency and duration include seasonal and daily patterns of habitat usage by the receptors, availability of food items, quantity of available food, feeding behaviors, and population structure of the exposed receptors. Field observations were made using both formal survey techniques (i.e., for the bird surveys) and general observations during other field activity to characterize the physical and biological composition and biomass in the Pit Lake ecosystem. Information from the literature on migration and nesting behavior, home range, and other behavior were used as appropriate but the primary information used in this interpretation was derived from detailed field notes taken during each of the 25 visits to the lake. Evidence of usage included visual observations of individual receptors, the presence of scat or tracks, and evidence of feeding and nesting behavior. Because field sampling was conducted during more than one season, these observations provide some insight into seasonal patterns of usage of the Pit Lake by the different receptors. Results of these surveys are summarized in Appendix F.

This section evaluates the ecological significance of selenium and uranium risk estimates presented in Section 5.2 in the context of what is known about the Pit Lake ecosystem.

5.3.1 Aquatic Life Assessment Endpoints (AE: A1 – AE5)

Assessment endpoints (AEs) for aquatic biota were selected to ensure that selenium and uranium concentrations do not adversely impact populations of aquatic plants (A1), aquatic invertebrates (A2), benthic invertebrates (A3), amphibians (A4) or water fowl (A5). Exposure pathways included direct contact with sediment and water for AEs A1-A4 and dietary exposure to sediment, water and prey tissue (AE: A5). Risk estimates based exclusively on a modeled daily dose and conservative TRVs indicated that risk is not likely for water fowl (A5) due primarily to the small amount of time these species would likely forage in or around the lake. The assumptions regarding site use by water fowl are discussed in more detail in the uncertainty analysis below. Risk estimates for all other aquatic assessment endpoints (i.e., A1-A4) indicate that risk is possible for aquatic plants, aquatic and benthic invertebrates and amphibians. For aquatic species such as benthic invertebrates, amphibians, and copepods, the habitat, including food sources, must be sufficient to maintain these populations indefinitely. Based on the 2004 and 2005 observations, there is little prey base in or around the lake to sustain a population of invertebrates or amphibians. Plant species in the littoral zone appear to be limited by the available suitable habitat.

In addition, Highland Pit Lake provides little habitat or primary and secondary biological productivity to maintain a significant permanent aquatic plant and animal community or to host migrant species that frequent the lake primarily during summer months. For benthic organisms and wildlife that depends on aquatic plants and benthic invertebrates for a prey base, this is primarily due to the general configuration of the lake which has very steep banks with a very small shallow water zone conducive to establishment of an aquatic biological community. As mentioned in Sections 2.0 and 3.0, littoral zone habitat that supports vegetation and benthic invertebrate communities comprises less that 2 acres (0.9 ha) of the 130 acre lake surface area. The rooted macrophyte, cattail, occupies about 1 acre in this 2 acres of the littoral zone or about 0.08% of the total lake area. The benthic invertebrate community is almost exclusively confined to a small area (about 2 acres) of the littoral zone supporting cattails. Standing crop biomass estimates made periodically throughout the 10 month study period averaged only about 40 kg of benthic invertebrates for the entire littoral zone. This amount of benthic invertebrate biomass as a food source would sustain a very low number of any organism that required a benthic invertebrate food base. For aquatic

plants, invertebrates, and fish, the lack of productivity is likely due to the isolated nature of the lake and the lack of connectivity to other water systems that could provide larval and juvenile stocks to the lake. Whether the concentrations of selenium and uranium in the lake affect the general productivity of aquatic life is unknown and is discussed further in the uncertainty analysis.

5.3.2 Terrestrial Assessment Endpoints (AE: T1-T4)

The assessment endpoint for terrestrial biota were to ensure that selenium and uranium in the transitional terrestrial habitat adjacent to the lake that could be used for foraging by ecological receptors did not limit viable populations of plants (AE: T1), herbivorous birds (AE: T2), herbivorous mammals (AE: T3) and carnivorous birds (AE: T4). Risk estimates indicated that risk is unlikely to large herbivorous mammals and carnivorous birds. Risk is possible, but low in magnitude for plants, herbivorous small mammals and herbivorous birds that might have higher site use. In assessing ecological risk, chemical concentration data, relevant TRVs, and the resulting HQs must be evaluated in light of available habitat and food sources that serve in hosting and sustaining resident and migratory wildlife. For visiting wildlife including migratory birds, and large mammals including mule deer, sufficient habitat and food sources must exist to support the activities of migrant species. This means that the level of risk to these migrant species will also depend on the abundance of food and nesting habitat.

5.4 Uncertainty Analysis

Uncertainty in the risk estimation and characterization can result from a number of sources. The primary sources of uncertainty in this evaluation are associated with assumptions regarding exposure and effects that were used to calculate the risk estimates. In addition, a great deal of uncertainty is associated with the future ecological condition of the lake. Each of these uncertainties is discussed in detail below.

5.4.1 Exposure Assumptions

The primary exposure related uncertainties are associated with estimating exposure to higher trophic level organisms. In this ERA, a food web model was employed to estimate dietary exposure which is typically thought to be the primary exposure route. Each of these is discussed below.

5.4.1.1 Variability in measured selenium and uranium concentrations in media and tissue

Selenium and uranium concentration data used in the exposure estimates were based on field data from the Pit Lake. Those data were intended to represent the important aquatic and terrestrial components and pathways for selenium and uranium. Although extensive sampling of certain physical and biological components was conducted, uncertainty remains with regard to the accuracy with which the data represent true concentration distributions. This is particularly true for sediments and biological components where spatial distribution and selenium and uranium concentrations can vary appreciably. In the case of the Pit Lake, the coefficient of variation (i.e., (SD/mean) x 100) for selenium and uranium in biota was typically 100-200% of the mean. To counter this uncertainty, highly conservative assumptions (i.e., maximum and 95th UCL exposure point concentrations) were used to estimate exposure point concentrations, consistent with USEPA guidance. In reality, average concentrations of selenium and uranium in Pit Lake samples better reflects exposures to current aquatic and terrestrial biota. Thus, the EPCs used in the ERA likely over estimate potential exposure.

5.4.1.2 Site use assumptions

Assumptions about site use by birds and mammals were based on available home range information in the literature. Specifically a site use factor (SUF) was applied for each receptor based on the size of the biologically active zone of the lake divided by the home range of the receptor. Because the home range information for each receptor was not site-specific, the SUF could over or under estimate the actual site use by species in the area of the Pit Lake. However, the site use assumptions used in the ERA did not include any adjustment for the fact that the lake does not contain a significant prey base for wildlife (see Section 3 for a summary of biomass measurements in the lake).

For example, if waterfowl would use the lake as a food source, a 2 pound (900g) duck would consume about 5% of its body weight a day or 45 grams of food per day. Over the course of a year, that would amount to 16.4kg consumed /year-duck. If the benthic invertebrate population could sustain a 30% predation rate, about 12 kg (40 kg x 0.3) would be available as for duck consumption per year. Obviously the low benthic invertebrate standing crop of 40 kg would be inadequate to support a resident waterfowl population relying on benthic invertebrates as a food source. A similar calculation could be made for other species would require zooplankton or benthic invertebrates as a food source with a similar conclusion. The copepod biomass in the limnetic zone of the lake averaged 422 kg for measurements made on five different

occasions during the study period. Copepods serve primarily as a food source for fish. However, fish do not occur in the Pit Lake. However, if a similar calculation is done to that for benthic invertebrates, the results show that the standing crop of copepods, assuming a 30% predation rate, would support 15 fish weighing 1 lb (or 15 waterfowl of the same weight). The low benthic invertebrate and copepod productivity likely explains why none of the 45,000 fish stocked in the lake survived. The existing food base was not sufficient to maintain the introduced fish.

The lack of littoral zone habitat, including the small area of rooted macrophytes and the low food availability helps explain why observations (made on 25 visits to the lake) to observe waterfowl and other bird species, almost never showed the lake to be used by birds as a food source. On one occasion, an eared grebe was observed to be feeding in the littoral zone near the cattail beds but this occurred only once and was never observed on subsequent visits.

Thus, based on these observations, while receptors could theoretically spend time foraging in the lake, it is unlikely that they are obtaining a significant portion of their diet from this area. Because of the limited prey base, the site use assumptions used in the ERA likely over estimate potential exposure to wildlife.

5.4.1.3 No soil invertebrate exposure estimated

Because soil invertebrates were not found at the site, no exposure was estimated to wildlife from consumption of invertebrates. While a significant effort was made to collect invertebrates and none were found, it is possible that invertebrates are present or may be present in the future. Thus, this could result in an under estimate of potential risk to insectivorous or omnivorous wildlife. However, the analysis of herbivorous wildlife is likely protective of insectivores at the site.

5.4.1.4 Exclusion of astragalus sp *from exposure estimate for herbivores*

To estimate exposure to herbivorous wildlife, measured plant tissue was used in the model. However, astragalus is known to be a hyperaccumulator of selenium and is not thought to be a primary food source for herbivorous wildlife. Therefore, the EPCs for plant tissue that were used in the food web model for herbivorous wildlife excluded the astragalus samples. This could result in an underestimation or potential risk if these receptors consumed a great deal of this plant species.

5.4.2 Effects Assumptions

The uncertainties associated with the TRVs developed for the ERA are the most significant uncertainties. In general, risk assessments draw from information gained from laboratory and other carefully controlled experimental exposures. This information is then used to extrapolate conditions likely to exist in the natural environment. The laboratory information often does not provide complete linkages for these extrapolations. Consequently, assessment factors are often used to compensate for the many uncertainties inherent in the extrapolation from laboratory effects data to effects in natural ecosystems (Warren-Hicks and Moore 1998). Uncertainties arise, for example, when extrapolations are made from (Calabrese and Baldwin 1993):

1. Acute to chronic endpoints;

2. One life stage to and entire life cycle;

3. Individual effects to effects at the population level or higher;

4. One species to many species;

5. Laboratory to field conditions;

6. One to all exposure routes;

7. Direct to indirect effects;

8. One ecosystem to all ecosystems; and/or

9. One location or time to others.

The net effect of these uncertainties may result in either an overestimate or underestimate of effects potentials, depending on site-specific conditions, the types of receptors included in the evaluation, and the chemicals under study. The uncertainties associated with specific TRVs used in the ERA are discussed below.

5.4.2.1 Aquatic life TRVs

Because the toxicity of both uranium and selenium are greatly affected by water quality parameters such as hardness, pH and TOC, the applicability of the generic water

quality criteria used as TRVs to the Pit Lake is not known. Because the TRVs selected are developed to be protective of a wide range of receptors and conditions, it is likely that they overstate the potential toxicity of the concentrations present in the water of the Pit Lake.

5.4.2.2 Benthic Invertebrate TRVs

The TRVs for benthic invertebrates for selenium are not based on benthic invertebrates but rather are based on values that are expected to be protective of fish and birds that might consume benthic invertebrates. Data regarding direct toxicity to benthic invertebrates were lacking. Because the primary concern with selenium is its uptake and movement through the food web, it is likely that the TRVs used are protective of benthic invertebrates.

5.4.2.3 Wildlife TRVs

The primary sources of uncertainty associated with the selected wildlife TRVs are the relevance of 1) the form of selenium and uranium used in the underlying study to the form present in the Pit Lake media and prey; 2) the dose method (e.g., dietary, drinking water, intubation); and 3) the test species compared to species present at the Pit Lake. In many cases, the forms of chemicals used in laboratory studies are selected to maximize absorption and therefore exposure and are thus highly soluble and may not mimic the less soluble forms that are likely present in nature in terms of bioavailability. This could overestimate potential toxicity. Likewise, when the dosing regime is a method that is not relevant in nature (e.g., intubation was the dose method in the study used for the mammalian uranium TRV), exposure and therefore toxicity may be overestimated. Lastly, the test species used in the laboratory study may be more or less sensitive to concentrations of selenium or uranium than the species present at the lake. While in most cases typical laboratory strains of test species (e.g., white mice, rats, etc) are more sensitive than actual wildlife species, there is no specific information available on this for the receptors and test species used in this ERA. Therefore differences in test species could result in either ran over or under estimate of toxicity.

5.4.2.4 Risk estimates based on additional toxicity data in the literature

In the Tier 2 assessment, both low and high TRVs from the Tier 1 sources were considered. The values from these sources were generally developed to be protective of a wide range of species in a wide range of conditions and are thus highly conservative. A number of individual toxicity studies are available for both selenium

and uranium from the peer reviewed literature that demonstrate that levels of toxicity can vary greatly according to such parameters as the test conditions, species tested and chemical form used. For example, the Tier 2 HQs for aquatic invertebrates for selenium are 22 and 5.4 based on the WDEQ chronic and acute water quality criteria respectively. When available studies specifically for aquatic invertebrates were considered, two studies demonstrated NOAEL values for daphnia magna of 0.15 mg/l[6]. Because the lake selenium EPC of 0.11 mg/l is below this value, it is possible that lake selenium concentrations are not adversely affecting aquatic invertebrates. Because it is not known which TRVs best represent toxicity at the Pit Lake, the assessment used the more broadly applicable and conservative values as the primary line of evidence in this ERA. However, it is possible based on alternative TRVs that current concentrations of selenium and uranium in the Pit Lake and biota are within acceptable levels.

5.4.3 Biological Conditions at the Pit Lake

Currently the biological resources within the Pit Lake are very limited as indicated by the lack of established benthic invertebrate, water column invertebrate and/or fish communities. Although the primary cause (or causes) of the limited biological resources within the lake may be non-contaminant related, the underlying causes of the limited productivity within the lake have not been specifically identified. While the selenium and/or uranium concentrations in the lake may represent limiting factors, there are a number of other factors that could also limit productivity, possibly to a greater degree. These factors could include water quality parameters such as pH, dissolved oxygen, and the amount and specific makeup of dissolved nutrients/ions. In addition, because the lake is an isolated, closed system that is not connected to upstream waterbodies, nutrients and other essential larval or juvenile stocks of aquatic water column and/or benthic species could limit recruitment, limit or slow natural succession in the lake, and ultimately impact both short and long-term productivity. Prior to making any risk management decisions regarding the Pit Lake based on conclusions drawn from predictive and relatively generic ecological risk endpoints (e.g., comparisons of environmental concentrations of compounds to generic water quality criteria), these significant uncertainties should be addressed.

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[6] The additional toxicity data that were reviewed and considered in the ERA are summarized in Appendices B-E.

5.5 Conclusions

During planning of the Highland Pit Lake assessment, the potential for unacceptable risks from selenium and uranium to aquatic and nearby terrestrial biota were of primary interest. A tiered approach was used to assess risks from selenium and uranium to Pit Lake biota via several exposure pathways. Initially, measured concentrations of selenium and uranium in Pit Lake samples were compared with corresponding samples from the Box Creek control site. Results showed that concentrations of these elements in Pit Lake samples exceeded those in background samples. Subsequently, the Tier 1 assessment proceeded with a toxicological evaluation of Pit Lake samples. The toxicological evaluation was based on comparisons of maximum measured concentrations of selenium and uranium in Pit Lake samples with highly conservative, lower limit TRVs. These "lower limit" TRVs generally represent no adverse effect levels (NOAELs) at or below which potential risk is considered de minimus. The results of this evaluation, presented as calculated HQs, showed that most maximum concentrations in Pit Lake samples exceeded the conservative TRVs yielding HQs that exceeded 1 for one or more receptors.

Tier 2 of the evaluation used the more realistic 95% UCL exposure concentration and less conservative TRVs. These less conservative TRVs generally represent lowest observed adverse effects levels (LOAELs) or an upper bound of NOAEL values. Concentrations above these values indicate that risk is possible. Results of this analysis showed that potentially unacceptable risks, as represented by calculated HQs, were indicated for selenium and uranium for aquatic plants, aquatic and benthic invertebrates, amphibians, and terrestrial plants. Based on the results of the risk assessment risk from uranium to birds and mammals are expected to be de minimus and there is a low potential for risk to small mammals and herbivorous birds from selenium. It is important to note that calculated HQs for all assessment endpoints are relatively low in magnitude. Because the calculated HQs are based on highly conservative exposure assumptions which overstate current exposure and provide conservative estimates for potential future exposure (i.e., assuming that natural succession will result in a more significant prey base in the future), and because toxicity criteria were selected to minimize the potential for underestimating risk, these low magnitude HQs do not necessarily indicate unacceptable risk. The risk conclusions presented in this report should be considered in the context current conditions and potential future conditions, and should be considered separately for upper trophic level receptor (i.e., birds and mammals), terrestrial plants and invertebrates, and aquatic biota (i.e., benthic and water column invertebrates).

Terrestrial Plants

Low soil-based TRV HQs were greater than 1 for selenium and uranium and high TRV HQs were greater than 1 but less than 10 for both COPECs. The low tissue-based TRV HQ for selenium was greater than 1 and the high TRV-HQ was greater than 1 but less than 10. The low tissue-based TRV HQ for uranium was greater than 1 while the high TRV HQ was less than 1. For astragalus (a selenium hyperaccumulator), the tissue-based low TRV HQ was less than 1. While this assessment was focused on the pit lake and associated aquatic biota, the terrestrial vegetation adjacent to the shoreline was assessed as a potential food source for herbivorous wildlife that might use the nearshore lake environment for foraging and cover (meadow vole) or drinking (mule deer). The small area assessed does not represent a plant population in and of itself and any potential impacts to this area would not represent a significant impact on regional plant populations.

Aquatic Biota

Aquatic biota evaluated include primary producers (i.e., aquatic plants), aquatic invertebrates (i.e., benthic and water column invertebrates), and amphibians. When considering the results of the risk assessment, it is important to interpret the results of risk comparisons in the context of the physical habitat present, and the ecological relationships between the various aquatic receptors evaluated. It is also important to consider that the risk assessment of these receptors presented in this report is somewhat theoretical, given that aquatic biota are currently not present in the Pit Lake in significant numbers.

True aquatic plants and benthic invertebrates require on the presence of benthic (littoral) substrate/habitat. As previously discussed, the littoral zone habitat that supports vegetation and benthic invertebrate communities in the Pit Lake comprises less that 2 acres (0.9 ha) of the 130 acre lake surface area. True aquatic plants (i.e., cattail) occupies about 1 acre in this 2 acres of the littoral zone or about 0.08% of the total lake area. The benthic invertebrate community is almost exclusively confined to a small area (about 2 acres) of the littoral zone supporting cattails. Given the lack of appropriate habitat in the Pit Lake for benthic invertebrates and plants, exceedances of low TRVs and low magnitude exceedances of high TRVs for benthic invertebrates and aquatic plants should not be interpreted as indicating that contaminant-related exposure represents the most significant limiting factor for benthic invertebrates and aquatic plants. It is far more likely that the lack of productivity is a result of physical habitat limitations. Regardless of concentrations of uranium and selenium, the presence and abundance of aquatic plants and benthic invertebrates will likely remain

limited unless the physical characteristics and the associated habitat of the Pit Lake are significantly changed.

Some water column aquatic invertebrates rely to some degree on the presence of an established benthic community as a food source, while others feed primarily in the water column and rely on the presence of planktonic (pyto- and zooplankton) organisms, and larger macro-biota in the water column as food sources. Considering the non-contaminant factors that likely limit the presence and abundance of the benthic community in the pit lake, the water column invertebrate communities in the lake are likely limited by non-contaminant factors (to the degree they rely on the benthic invertebrate community as a food source). It is unclear, however, if the lack of an established and abundant water column community can be explained solely by the lack of benthic invertebrate community, and the associated non-contaminant limiting factors.

Although fish were not identified as a specific assessment endpoint in this risk assessment due to their absence in the Pit Lake, the water quality criteria used to evaluate aquatic biota in general, are also protective of fish. The conclusions associated with the aquatic community therefore has some relevance to fish. Fish can and may be limited by the same non-contaminant factors as fish. Additionally, fish may also be limited by lake-associated contaminants (similar to aquatic biota).

Risk estimates for aquatic biota (i.e., Tier 2 HQs) exceed 1 for selenium using WDEQ chronic (HQ=22) and acute (HQ=5.4) water quality criteria indicating the potential for unacceptable risk to aquatic life (i.e., plants, amphibians, and invertebrates) and that contaminant-related factors may contribute to the limited water column invertebrate communities in the Pit Lake. However, there is a great deal of uncertainty, regarding the implications of these exceedances, as no-effect thresholds from two independent studies (reported in peer-reviewed literature) indicate that lake selenium concentrations may be lower than concentrations associated with adverse effects to daphnia magna (an established and sensitive water column invertebrate toxicity test species).

While there is uncertainty regarding any conclusion of risk to aquatic biota, it is also important, to consider that the ecological relevance of this risk-based conclusion can not be determined given the current understanding of the ecological succession occurring in the Pit Lake. The Pit Lake is relatively young, in an early stage of succession, and the rate of ecological development and establishment of biological communities in the Pit Lake may be influenced by many factors including a number of significant non-contaminant related factors such as the physical characteristics of the lake which limit habitat, the isolated nature of the lake, and the lack of connectivity to

other water systems that could provide larval and juvenile stocks to the lake. The relative importance of and interaction between these factors and any potential contaminated-related impacts would need to be better understood prior to concluding, based on screening-level risk comparisons, that selenium or uranium pose unacceptable risk to aquatic biota, and/or that contaminant-related impacts are responsible for the lack of productivity in the Pit Lake.

Birds and Mammals

As previously discussed, conservative risk estimates (i.e., HQs) indicate that the potential for unacceptable risk is low for large herbivorous mammals and carnivorous birds. Risk estimates indicate that risk is possible, but low in magnitude for herbivorous small mammals and herbivorous birds that might have higher site use. The current availability and quality of habitat and food sources for upper trophic-level receptors were considered, and it was concluded that the lack of suitable habitat and abundant food sources greatly limit the potential of the Pit Lake as a source of selenium and uranium to wildlife species. From a current conditions perspective, the limited prey base associated with the Pit Lake results in limited exposure to birds and mammals. This fact, coupled with the low magnitude of the calculated HQs for birds and mammals, supports a conclusion of no unacceptable risk for birds and mammals under current conditions. Given the lack of variable and high quality habitat, and the isolated nature of the lake, productivity in the lake will likely be limited for the foreseeable future, thus making it unlikely that the lake would provided significant prey base for wildlife in the future.

Summary

Based on the current lack of habitat for benthic invertebrates and aquatic plants, and the lack of a significant prey based for upper trophic-level receptors (birds and mammals), it can be concluded that current conditions in the Pit Lake are not resulting in unacceptable risk to these receptor groups (i.e., current conditions are protective).

There is significant uncertainty regarding the relative importance and contribution of potentially limiting factors (i.e., both contaminant and non contaminant-related) to the apparent lack of productivity in the Pit Lake, particularly for plankton, water column invertebrates, and fish. Given that these receptor groups are not currently present in the Pit Lake in significant numbers, any potential impacts are localized to the Pit Lake, and are not impacting regional communities or populations of these receptor groups. From this perspective current conditions in the Pit Lake can be considered "protective". The primary question and uncertainty relates to the questions of whether

concentrations of selenium or uranium in the Pit Lake may be slowing or preventing succession based on the establishment of a water column prey base (e.g., plankton and water column invertebrates), which could in turn support the establishment of a fish community, which could thereby provide a food source for higher trophic level receptors.

Because of the lack of significant aquatic communities under current conditions in the Pit Lake, the results of this risk assessment should be interpreted as theoretical for potential future conditions. Given the high likelihood that the limited presence of aquatic communities (i.e., limited productivity of the lake) is strongly influenced by non-contaminant causes, exposure to these communities is considered to be minimal under current conditions and therefore there is no unacceptable risk in the Pit Lake.

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TABLES

TABLE 2-1
SUMMARY STATISTICS FOR TOTAL COPEPOD BIOMASS ESTIMATES (kg)

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

	n	Mean	SD	Mean-95UCL	Mean+95UCL
Feb-05	6	298.4	166	147	450
Mar-05	5	400	82	318	482
Apr-05	1	295	0	295	295
Jun-05	3	727.7	403	206	1249

Notes:
n--number of samples
SD--standard deviation
95UCL--95% upper confidence limit

TABLE 2-2

SUMMARY STATISTICS FOR BENTHIC INVERTEBRATE BIOMASS ESTIMATES (kg) BY SAMPLING DATE

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

	Mean	SD	Mean-95UCL	Mean+95UCL	n
Feb-05	25	32.1	13	45	21
Mar-05	20	28	9	37	21
Jun-05	36	36	22	59	23

Notes:
n--number of samples
SD--standard deviation
95UCL--95% upper confidence limit

TABLE 2-3
BENTHIC INVERTEBRATE TAXA PRESENT IN HIGHLAND PIT CREEK AND BOX CREEK

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Location	Order	Family	Genus	Species	Common name	Life stage
pit lake	Coleoptera	Dystiscidae	Dytiscus	sp	Predaceous diving beetle	Adult
pit lake	Hemiptera	Notonectidae	Notonecta	undulata	Groused backswimmer	Adult
pit lake	Hemiptera	Corixidae	Sigara	alternata	Water boatman	Adult
pit lake	Diptera	Stratiomydae	Stratiomys	sp	Aquatic soldier fly	Larva
pit lake	Trichoptera	Rhyacophilidae	Rhycophila	sp	Free living caddisfly	Larva
pit lake	Diptera	Syphidae	Eristalis	sp	Rattailed maggot	Larva
pit lake	Ephemeroptera	Heptadeniidae	Stenacron	interpunctatum	Flat-headed mayfly	Larva
pit lake	Odonata	Libellulidae	Libellula	sp	Common skinner	Larva
Box Creek	Odonata	Gomphidae	Gomphus	vastus	Desolate clubtail	Adult
Box Creek	Coleoptera	Dytiscidae	Coptotomus	interrogatus	Predaceous diving beetle	Adult
Box Creek	Hemiptera	Corixidae	Sigara	alternata	Water boatman	Adult
Box Creek	Hemiptera	Notonectidae	Notonecta	undulata	Groused backswimmer	Adult
Box Creek	Ephemeroptera	Heptadeniidae	Stenacron	interpunctatum	Flat-headed mayfly	Larva
Box Creek	Araneae	Tetragnathidae	Tetragnatha	sp	Long jawed spider	Adult
Box Creek	Orthoptera	Acrididae	Melanoplus	sp	Grasshopper	Adult

Notes:
sp = species

TABLE 2-4

CATALOG OF AVIAN SPECIES OBSSERVED AT HIGHLAND PIT LAKE OVER A 10 MONTH PERIOD IN 2004 AND 2005

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

	2004	2005																								
Species	9/13	9/14	9/15	10/25	10/26	10/27	2/21	2/22	2/23	2/24	3/23	3/24	4/6	4/11	4/12	4/29	5/24	6/2	6/9	6/17	6/22	7/1	7/7	7/14	8/26
Blue-winged teal		X	X	X	X	X											X		X		X				
Canada geese	X						X	X		X	X	X	X	X	X	X									
Cliff swallow																	X	X	X	X	X	X	X	X	X
Falcon			X																						
Franklin's gull		X	X		X																				
Golden Eagle		X	X	X	X				X		X														
Great horned owl											X		X		X		X	X	X						
Herring gull						X																			
Eared grebe	X	X	X		X	X																			X
Horned lark	X	X	X	X	X	X							X				X	X	X	X	X	X	X	X	
Kestrel													X												
Killdeer															X		X		X	X	X				
Lesser scaup														X			X								
Mallard					X						X		X	X			X		X						
Marshhawk	X	X	X	X	X	X					X		X				X	X	X	X	X	X	X	X	
Pintail							X				X				X			X							
Prairie Falcon																									
Redtail hawk													X				X	X	X	X	X	X	X		
Red-winged blackbird																	X	X	X	X	X	X	X	X	
Rough legged hawk													X		X										
Scaup											X														
Short-eared owl											X	X	X		X		X		X		X				
Shoveler			X																						
Spotted sandpiper																	X								
Vesper sparrow																	X		X	X					
Western meadowlark													X				X	X	X	X	X			X	
Yellow-headed blackbird	X	X																							
Total Observed	**16**	**16**	**46**	**55**	**97**	**105**	**1**	**45**	**1**	**18**	**30**	**6**	**29**	**9**	**24**	**1**	**109**	**52**	**45**	**63**	**118**	**84**	**61**	**31**	**5**

TABLE 2-5
SAMPLE ANALYTICAL METHODS FOR REPORTING LIMITS

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Sample Media	Analyte	Method	Required Reporting Limit	Units*
Surface water	Selenium (Se)	A 3114 B -hydride	0.0005	mg/l
	Uranium (Unat)	EPA 200.7/EPA 200.8	0.0003	mg/l
Sediment	Selenium (Se)	EPA 3050B, M7742-hydride	0.1	mg/kg
	Uranium (Unat)	EPA 3050B, M6020	0.01	mg/kg
Benthic Invertebrates, Plankton, Vegetation	Selenium (Se)	EPA 600 (4-81- 55)/M7742-hydride	0.1	mg/kg
	Uranium (Unat)	EPA 600 (4-81-055)/M6020	0.01	mg/kg

Notes:
mg/l -- milligram per Liter
mg/kg -- milligram per kilogram
*--mg/kg reporting on solid dry/weight basis

TABLE 2-6
SELENIUM AND URANIUM SUMMARY STATISTICS BY MATRIX

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Summary of Statistics for Highland Pit Lake						
	Number of Samples	Min	Mean	Median	Max	EPC (95 UCL or Max)
Selenium						
Water	12	0.097	0.10	0.11	0.11	0.11
Sediment	16	1.7	21	15	84	34
Soil	9	0.50	4.2	0.97	21	11
Aquatic Plant	14	5.2	16	11	50	24
Aquatic Invert	21	5.9	23	23	73	30
Benthic Invert	20	5.5	85	48	287	131
Aquaic and Benthic Invert*	41	5.5	53	27	287	78
Terrestrial Plant	5	6.8	1146	13	4400	4400
Terrestrial Plant - 2**	3	6.8	9.8	9.7	13	NA
Rodent	13	5.8	19	19	48	25
Uranium						
Water	12	2.9	3.1	3.1	3.25	3.17
Sediment	16	17	144	153	273	185
Soil	9	2.0	11	3.4	28	28
Aquatic Plant	14	15	85	47	325	136
Aquatic Invert	21	3.6	282	94	1170	1063
Benthic Invert	20	1.3	59	26	301	103
Aquatic and Benthic Invert*	41	1.3	173	30	1170	613
Terrestrial Plant	5	1.9	6.4	3.3	19	19
Rodent	13	0.090	0.97	0.65	4.3	1.6

Summary of Statistics for Box Creek						
	Number of Samples	Min	Mean	Median	Max	EPC (95 UCL or Max)
Selenium						
Water	3	0.00025	--	--	0.00025	--
Sediment	4	0.10	--	--	0.28	--
Soil	4	0.18	--	--	0.32	--
Aquatic Plant	16	0.050	--	--	0.52	--
Terrestrial Plant	4	0.050	--	--	0.13	--
Uranium						
Water	3	0.0076	--	--	0.0080	--
Sediment	4	2.3	--	--	5.3	--
Soil	4	1.4	--	--	1.4	--
Aquatic Plant	16	0.030	--	--	1.8	--
Terrestrial Plant	4	0.060	--	--	0.080	--

Notes:
EPC = Exposure Point Concentration
95% UCL = the 95% upper confidence limit on the arithmetic mean
95 UCL > Max, Maximum detect used instead
* calculated using a both aquatic and benthic inveretebrates for dietary food web model for waterfowl
** calculated excluding astragalus samples for selenium
-- = sample size too small for calculation of statistics or for Box Creek - underlying data not available

TABLE 3-1
WDEQ WATER QUALITY STANDARDS FOR SELENIUM AND URANIUM COMPARED WITH MEASURED AND PREDICTED CONCENTRATIONS

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

SELENIUM (mg/l)		URANIUM (mg/l)	
Measured at Pit Lake =	0.11	Measured at Pit Lake =	3.12
Predicted Long Term =	0.15	Predicted Long Term =	3.5
WDEQ Stock Water =	0.05	WDEQ Stock Water =	5
WDEQ Aquatic Life =	0.005	WDEQ Aquatic Life =	<1.4

Notes:
WDEQ = Wyoming Department of Environmental Quality

TABLE 3-2
SEDIMENT COPEC SCREEN

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Constituent	Units	Sample Size	%detect	Min Detect	Max Detect	Mean Detect	Sediment Screening Values			Carried Forward as a COPEC
							TEC	PEC	Regional Background[1]	
Aluminum	mg/kg	10	100%	14700	29100	24780	NA	NA	50000	No
Antimony	mg/kg	10	0%	<1	<1	<1	*2*	*25*	NA	No
Arsenic	mg/kg	10	100%	2.6	4.4	3.4	9.79	33	*9*	No
Iron	mg/kg	10	100%	11800	22200	19460	NC	NC	36600	No
Manganese	mg/kg	10	100%	105	223	152.1	NC	NC	655	No
Mercury	mg/kg	10	100%	0.02	0.11	0.05	0.18	1.06	NA	No
Molybdenum	mg/kg	10	100%	0.2	1	0.61	NC	NC	NA	No
Selenium	mg/kg	10	100%	2.5	59.3	21	NC	NC	NA	Yes
Uranium	mg/kg	10	100%	21.3	273	175	NC	NC	6.27	Yes
Vanadium	mg/kg	10	100%	24	73	44.9	NC	NC	114	No
Radium 226	pCi/g	10	100%	2.4	22	6.32	NC	NC	NA	No
Radium 226 precision	pCi/g	10	100%	0.2	0.8	0.3	NC	NC	NA	No
Inorganic carbon, Lime	%	10	100%	0.15	0.76	0.295	NC	NC	NA	No
Total organic carbon	%	10	100%	0.2	1.8	0.78	NC	NC	NA	No
Total organic matter	%	10	100%	0.3	3	1.3	NC	NC	NA	No

Notes:
1. COPEC = constituent of potential ecological concern
2. NA = value not available
3. NC = no criteria (i.e., screening value) available
4. TEC = threshold effect concentration; PEC = probably effect concentraiton
5. TEC and PEC values in italic are actually ERL and ERM values from Long and Morgan 1997
6. [1]Regional background taken from USGS report on Element concentraitons in the bed sediment of Yellowstone River Basin - Table 5 Wyoming ecoregion (bed sediment samples from streams in areas of sedimentary rocks of Tertiary age) - 95th percentile values

TABLE 3-3
PROBLEM FORMULATION SUMMARY

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION – CONVERSE COUNTY, WYOMING

	RISK QUESTION	ASSESSMENT ENDPOINT (AE)	MEASUREMENT ENDPOINT (ME)
Aquatic Habitat			
Primary Producers	Are chemical constituents in the aquatic environment adversely affecting aquatic plant species?	AE-A1: Survival and reproduction of aquatic plant populations conducive to maintenance of the aquatic plant community.	1) Compare sediment concentrations to phytotoxicity benchmarks • Compare to low and high benchmarks
Primary Consumers	Are chemical constituents in lake water adversely affecting the aquatic invertebrate community?	AE-A2: Survival and reproduction of aquatic invertebrate populations conducive to maintenance of the aquatic community.	1) Compare water concentrations to aquatic toxicity benchmarks (e.g., AWQC). • Compare to acute and chronic benchmarks
	Are chemical constituents in lake sediments adversely affecting the benthic invertebrate community?	AE-A3: Survival and reproduction of sediment invertebrate populations conducive to maintenance of the sediment invertebrate community	1) Compare lake sediment concentrations to benthic invertebrate toxicity benchmarks • Compare to low and high benchmarks
Secondary Consumers	Are chemical constituents in aquatic environment adversely affecting amphibian populations?	AE-A4: Survival, growth and reproduction of amphibian populations.	1) Compare water concentrations to aquatic toxicity benchmarks protective of aquatic life (e.g., AWQC). • Compare to acute and chronic benchmarks
	Are chemical constituents in sediment, water or biota adversely affecting omnivorous waterfowl populations?	AE-A5: Survival, growth and reproduction of omnivorous aquatic bird populations.	1) Estimate average daily dose using measured COPEC tissue concentrations in sediment, invertebrate and plant tissue from aquatic area and compare the modeled dose to avian TRVs. • Compare to low and high TRVs

TABLE 3-3
PROBLEM FORMULATION SUMMARY

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION – CONVERSE COUNTY, WYOMING

	RISK QUESTION	ASSESSMENT ENDPOINT (AE)	MEASUREMENT ENDPOINT (ME)
Transitional Terrestrial Habitat			
Primary Producers	Are chemical constituents in the soil adversely affecting terrestrial plant species?	AE-T1: Survival and reproduction of terrestrial plant populations within the transitional area adjacent to the lake, conducive to maintenance of the plant community.	3) Compare near-shore soil concentrations to phytotoxicity benchmarks • Compare to low and high benchmarks
Primary Consumers	Are chemical constituents in the soil or biota adversely affecting herbivorous bird populations?	AE-T2: Survival, growth and reproduction of herbivorous bird populations.	1) Estimate average daily dose using measured COPEC concentrations in plant tissue from near-shore terrestrial habitat and compare the modeled dose to avian TRVs. • Compare to low and high TRVs
	Are chemical constituents in soil or biota adversely affecting herbivorous mammal populations?	AE-T3: Survival, growth and reproduction of herbivorous mammal populations.	1) Estimate average daily dose to an herbivorous small mammal using measured COPEC concentrations in plant tissue from near-shore terrestrial habitat and compare the modeled dose to mammalian TRVs. • Compare to low and high TRVs 2) Estimate average daily dose to an herbivorous large mammal using measured COPEC concentrations in plant tissue from terrestrial habitat and measured water concentrations from the lake and compare the modeled dose to allometrically scaled mammalian TRVs. • Compare to low and high TRVs
Tertiary Consumers	Are chemical constituents in soil or biota adversely affecting carnivorous bird populations?	AE-T4: Survival, growth and reproduction of carnivorous bird populations.	1) Estimate average daily dose to carnivorous birds using measured COPEC concentrations in small mammal tissue and compare the modeled dose to avian TRVs. • Compare to low and high TRVs

Notes:
1. COPEC = constituent of potential ecological concern
2. TRV = toxicity reference value

TABLE 4-1
WILDLIFE EXPOSURE PARAMETERS

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Receptor Species	Diet Composition																
	Invert.	*Ref.*	Veg.	*Ref.*	Small Mammal	*Ref.*	Water Ingestion Rate	*Ref.*	Food Ingestion Rate	*Ref.*	Incidental Soil/Sediment Ingestion Fraction	*Ref.*	Body Weight	*Ref.*	Home Range	*Ref.*	Site Use Factor[b]
Lesser Scaup	0.91	1	0.089	1	0	1	–		0.063	1	0.11	3	0.82	1	89	1	0.000
Meadow Vole	0	1	1	1[a]	0	1	–		0.012	1	0.024	3	0.037	1	0.014	1	0.0
Mule Deer	0	2	1	2	0	2	5.0	1	1.6	5	0.020	3	80	6	100	2	0.0000
Red-winged Blackbird	0	2	1	2[a]	0	2	–		0.0099	5	0.093	3	0.053	7	0.2		0.0
Red-tailed Hawk	0	3	0	3	1	3	–		0.13	1	0.093	3	1.2	4	160	1	0.0000
(units)	(fraction)		(fraction)		(fraction)		(l/day bw)		(kg/day dw)		(fraction)		(kg)		(hectares)		unitless

Notes:
bw = body weight
dw = dry weight
U.S. EPA, 1993. Wildlife Exposure Factors Handbook
CADFG, 2002. California Wildlife Habitat Relationships System
Beyer, et al. 1994. J. Wildlife Management. 58(2):375-382. Soil/sediment ingestion frations based on surrogates with similar eating habits
Dunning, 1993. Avian Body Masses. CRC Press.
Nagy KA, 2001. Nutrition Abstracts and Reviews, Series B. 71, 21R-31R.
UDWR, 1999. Utah Division of Wildlife Resources Wildlife Notebook Series No. 13
Terres, 1991
diet considered to be 100% vegetation since no terrestrial invertebrates were found on site
Area of the littoral zone of the lake that could be used for foraging by bird and mammal receptors = 0.9 hectares
(used for Tier 2 analysis only; SUF assumed to be 1 [100% site use] in Tier 1 analysis)

TABLE 4-2
TIER 1 TOXICITY REFERENCE VALUES

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Receptor	Media	Units	Selenium		Uranium	
			benchmark	*ref*	benchmark	*ref*
Aquatic Plant	water	mg/l	0.005	1a	0.03	1b
Aquatic Invertebrate	water	mg/l	0.005	1a	0.03	1b
Benthic Invertebrate	sediment	mg/kg dw	2.5	2	17	4
Aquatic Life	tissue	mg/kg dw	7.9	3	NA	
Amphibians	water	mg/l	0.005	1a	0.03	1b
Terrestrial Plant	soil	mg/kg dw	1.0	5	5.0	5
Scaup	daily dose	mg/kg bw/day	0.50	6	16	6
Red-tailed Hawk	daily dose	mg/kg bw/day	0.44	6	16	6
Red-winged Blackbird	daily dose	mg/kg bw/day	0.50	6	16	6
Meadow Vole	daily dose	mg/kg bw/day	0.20	6	3.1	6
Mule Deer	daily dose	mg/kg bw/day	0.14	6*	1.9	6*

Notes:
1a - WDEQ - chronic water quality criteria (2004) for protection of aquatic life
1b - WDEQ - quality standard for Wyoming groundwater (2005) - protection of fish/aquatic life (low end of the range - hardness dependent)
2 - NOAEL for protection of fish and birds - Van Derveer and Canton (1997)
3 - USEPA fish tissue-based chronic criteria protective of all aquatic life (2004)
4 - NOAEL - *Environmental Canada, 2000*
5 - Benchmarks for screening COPECs - Efroymson et al., (1997)
6 - Dietary daily dose NOAEL - Sample et al., (1996)
* - TRV allometrically scaled to adjust for significant body weight difference between test species and receptor (Sample 1999)

TABLE 4-3
TIER 2 TOXICITY REFERENCE VALUES

ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Receptor	Media	Units	Selenium			Uranium		
			low	high	ref	low	high	ref
Aquatic Plant	water	mg/l	0.005	0.02	1a,2a	0.03	1.4	1b,2b
Aquatic Invertebrate	water	mg/l	0.005	0.02	1a,2a	0.03	1.4	1b,2b
Benthic Invertebrate	sediment	mg/kg	2.5	4.0	3	17	30	8
Amphibians	water	mg/l	0.005	0.02	1a,2a	0.03	1.4	1b,2b
Terrestrial Plant	soil	mg/kg	1.0	1.5	4	5	10	4
Terrestrial Plant	tissue	mg/kg dw	0.03	2.2	5	0.05	36	9
Astragalus (terr. Plant)	tissue	mg/kg dw	14920	NA	6	NA	NA	
Scaup	daily dose	mg/kg-bw/day	0.50	1.0	7	16	160	7[a]
Redtail Hawk	daily dose	mg/kg-bw/day	0.44	1.5	7	16	160	7[a]
Red-winged Blackbird	daily dose	mg/kg-bw/day	0.50	1.0	7	16	160	7[a]
Meadow Vole	daily dose	mg/kg-bw/day	0.20	0.33	7	3.1	6.1	7[a]
Mule Deer[b]	daily dose	mg/kg-bw/day	0.14	0.24	7	1.9	3.8	7[a]

Notes:
1a - WDEQ - chronic water quality criteria (2004) for protection of aquatic life
1b - WDEQ - quality standard for Wyoming groundwater (2005) - protection of fish/aquatic life (low end of the range - hardness dependent)
2 - WDEQ acute water quality criteria (2004) for protection of aquatic life
2b - WDEQ - quality standard for Wyoming groundwater (2005) - protection of fish/aquatic life (high end of the range - hardness dependent)
3 - NOAEL for protection of fish and birds - Van Derveer and Canton (1997)
4 - Low is benchmark for screening COPECs: high is 2nd lowest LOEC from underlying data - Efroymson et al., (1997)
5 - Low is lowest reported NOAEL and high is highest reported NOAEL - Fergusson (1990)
6 - Species-specific NOAEL - Knott and McCay (1959)
7 - Dietary NOAEL daily dose (low) and LOAEL (high) - Sample et al., (1996)
8 - Low = NOAEL and high = LOAEL - Environmental Canada, 2000
9 - Low is lowest reported NOAEL for relevant (non-agricultural) species and high is highest reported NOAEL - Dreesen et al. (1982)
[a] - LOAEL extrapolated from NOAEL using a factor of 10
[b] - TRV corrected for body weight using allometric equation from Sample 1999

TABLE 5-1
TIER 1 RISK ESTIMATE FOR DIRECT CONTACT RECEPTORS

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Receptor	Media	Units	Selenium			Uranium		
			EPC	TRV	HQ	EPC	TRV	HQ
Aquatic Plant	water	mg/l	0.11	0.005	23	3.25	1.4	2
Aquatic Plant	tissue[1]	mg/kg dw	50	7.9	6	325	NA	NA
Aquatic Invertebrate	water	mg/l	0.11	0.005	23	3.3	1.4	2.3
Aquatic Invertebrate	tissue[1]	mg/kg dw	73	7.9	9	1170	NA	NA
Aquatic Life (amphibians)	water	mg/l	0.11	0.005	23	3.3	1.4	2.3
Aquatic Life (amphibians)	tissue[1]	mg/kg dw	136	7.9	17	15.1	NA	NA
Benthic Invertebrate	sediment	mg/kg	84	2.5	34	273	17	16
Benthic Invertebrate	tissue[1]	mg/kg dw	287	7.9	36	301	NA	NA
Upland Plant	soil	mg/kg	21	1.0	21	28	5	5.52

Notes:

[1] Tissue-based benchmark for selenium is for fish and is expected to be protective of all aquatic life.
Shaded Cells indicate HQ greater than 1.
NA - Tissue-based benchmark not available for uranium
EPC = exposure point concentration
TRV = toxicity reference value
HQ = hazard quotient

TABLE 5-2
TIER 1 RISK ESTIMATES FOR WILDLIFE RECEPTORS

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

		Water EPC	Soil/ Sediment EPC	Invert Conc.*	Plant Conc.	Prey Conc.	Site Use Factor	Calculated Dose	TRV	Hazard Quotient
Receptor Species	COPEC	(mg/l)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(mg/kg dw)	(unitless)	(mg/kg day)	(mg/kg/day)	(unitless)
Aquatic										
Scaup	Selenium	1.1E-01	8.4E+01	2.9E+02	5.0E+01	NA	1.0E+00	2.1E+01	5.0E-01	4.2E+01
	Uranium	3.3E+00	2.7E+02	1.2E+03	3.3E+02	NA	1.0E+00	8.7E+01	1.6E+01	5.4E+00
Terrestrial										
Meadow Vole	Selenium	1.1E-01	2.1E+01	NA	4.4E+03	4.8E+01	1.0E+00	1.4E+03	2.0E-01	7.2E+03
	Uranium	3.3E+00	2.8E+01	NA	1.9E+01	4.3E+00	1.0E+00	6.2E+00	3.1E+00	2.0E+00
Mule Deer	Selenium	1.1E-01	2.1E+01	NA	4.4E+03	4.8E+01	1.0E+00	8.7E+01	1.4E-01	6.0E+02
	Uranium	3.3E+00	2.8E+01	NA	1.9E+01	4.3E+00	1.0E+00	5.8E-01	1.9E+00	3.0E-01
Red-tailed Hawk	Selenium	1.1E-01	2.1E+01	NA	4.4E+03	4.8E+01	1.0E+00	5.2E+00	4.4E-01	1.2E+01
	Uranium	3.3E+00	2.8E+01	NA	1.9E+01	4.3E+00	1.0E+00	7.2E-01	1.6E+01	4.5E-02
Red-winged Blackbird	Selenium	1.1E-01	2.1E+01	NA	4.4E+03	4.8E+01	1.0E+00	8.3E+02	5.0E-01	1.7E+03
	Uranium	3.3E+00	2.8E+01	NA	1.9E+01	4.3E+00	1.0E+00	4.0E+00	1.6E+01	2.5E-01

Notes:
* invertebrate concentration for the scaup diet is based on a combination of aquatic and benthic invertebrates
shaded cells indicate HQ > 1
EPC = Exposure Point Concentration
COPEC = Constituent of potential ecological concern
NA = Not applicable
NOAEL = no observed adverse effect level
LOAEL = lowest observed adverse effect level
TRV = Toxicity Reference Value

TABLE 5-3
TIER 2 RISK ESTIMATE FOR DIRECT CONTACT RECEPTORS

ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Receptor	Media	Units	Selenium					Uranium				
			EPC	Low TRV	High TRV	Low TRV HQ	High TRV HQ	EPC	Low TRV	High TRV	Low TRV HQ	High TRV HQ
Aquatic Plant	water	mg/l	0.11	0.005	0.02	22	5.4	3.2	0.03	1.40	106	2.3
Aquatic Invertebrate	water	mg/l	0.11	0.005	0.02	22	5.4	3.2	0.03	1.4	106	2.3
Benthic Invertebrate	sediment	mg/kg	34	2.5	4.0	13	8.4	185	17	30	11	6.3
Amphibians	water	mg/l	0.11	0.005	0.02	22	5.4	3.2	0.03	1.4	106	2.3
Terrestrial Plant	soil	mg/kg	11	1.0	1.5	11	7.03	28	5.0	10	5.5	2.8
Terrestrial Plant	tissue	mg/kg dw	13	0.03	2.2	406	5.9	19	0.05	36	370	0.51
Astragalus (terr. Plant)	tissue	mg/kg dw	4400	14920	NA	0.3	NA	NA	NA	NA	NA	NA

Shaded Cells indicate High TRV HQ >1, or when no high TRV was available, low TRV HQ > 10.

NA - Tissue-based benchmark not available for uranium

EPC = exposure point concentration

TRV = toxicity reference value

HQ = hazard quotient

TABLE 5-4
TIER 2 RISK ESTIMATES FOR WILDLIFE RECEPTORS

ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING

Receptor Species	COPEC	Water EPC	Soil/Sediment EPC	Invert Conc.*	Plant Conc.	Prey Conc.	Site Use Factor	Calculated Dose	NOAEL TRV	NOAEL Hazard Quotient	LOAEL TRV	LOAEL Hazard Quotient
		(mg/l)	(mg/kg dw)	(mg/kg inv dw)	(mg/kg veg dw)	(mg/kg prey dw)	(unitless)	(mg/kg*day dw)	(mg/kg*day dw)	(unitless)	(mg/kg*day dw)	(unitless)
Aquatic												
Lesser Scaup	Selenium	1.1E-01	3.4E+01	7.8E+01	2.4E+01	NA	1.0E-02	6.0E-02	5.0E-01	1.2E-01	1.0E+00	6.0E-02
	Uranium	3.2E+00	1.9E+02	6.1E+02	1.4E+02	NA	1.0E-02	4.6E-01	1.6E+01	2.9E-02	1.6E+02	2.9E-03
Terrestrial												
Meadow Vole	Selenium	1.1E-01	1.1E+01	NA	1.3E+01	2.5E+01	1.0E+00	4.3E+00	2.0E-01	2.2E+01	3.3E-01	1.3E+01
	Uranium	3.2E+00	2.8E+01	NA	1.9E+01	1.6E+00	1.0E+00	6.2E+00	3.1E+00	2.0E+00	6.1E+00	1.0E+00
Mule Deer	Selenium	1.1E-01	1.1E+01	NA	1.3E+01	2.5E+01	9.0E-03	2.4E-03	1.4E-01	1.7E-02	2.4E-01	1.0E-02
	Uranium	3.2E+00	2.8E+01	NA	1.9E+01	1.6E+00	9.0E-03	5.2E-03	1.9E+00	2.7E-03	3.8E+00	1.4E-03
Red-winged Blackbird	Selenium	1.1E-01	1.1E+01	NA	1.3E+01	2.5E+01	1.0E+00	2.6E+00	5.0E-01	5.2E+00	1.0E+00	2.6E+00
	Uranium	3.2E+00	2.8E+01	NA	1.9E+01	1.6E+00	1.0E+00	4.0E+00	1.6E+01	2.5E-01	1.6E+02	2.5E-02
Red-tailed Hawk	Selenium	1.1E-01	1.1E+01	NA	1.3E+01	2.5E+01	5.6E-03	1.5E-02	4.4E-01	3.5E-02	1.5E+00	1.0E-02
	Uranium	3.2E+00	2.8E+01	NA	1.9E+01	1.6E+00	5.6E-03	2.5E-03	1.6E+01	1.5E-04	1.6E+02	1.5E-05

* invertebrate concentration for the scaup diet is based on a combination of aquatic and benthic invertebrates
shaded cells indicate HQ > 1
EPC = Exposure Point Concentration
COPEC = Constituent of potential ecological concern
NA = Not applicable
NOAEL = no observed adverse effect level
LOAEL = lowest observed adverse effect level
TRV = Toxicity Reference Value

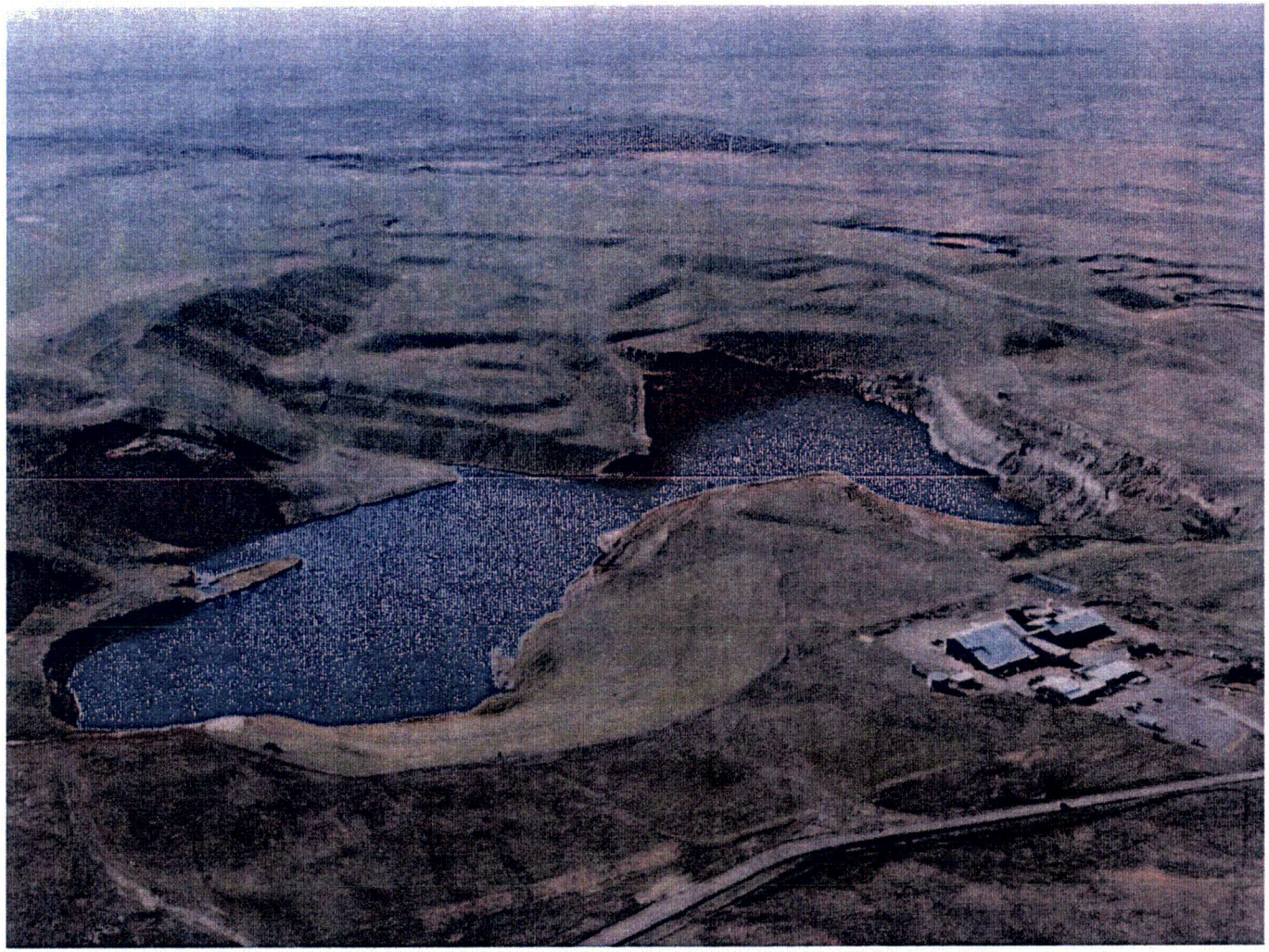
ARCADIS BBL

FIGURES

FIGURES

FIGURE 1-1
HIGHLAND PIT LAKE SHOWING STEEP SHORELINE AND GENERAL ECOLOGY OF THE AREA SURROUNDING THE LAKE

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING



FIG[illegible] 2-1
PIT LAKE SHOWING SHORELINE SHOWING STEEP SLOPES AND CLIFFS THAT COMPRISE MOST OF THE SHORELINE

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING

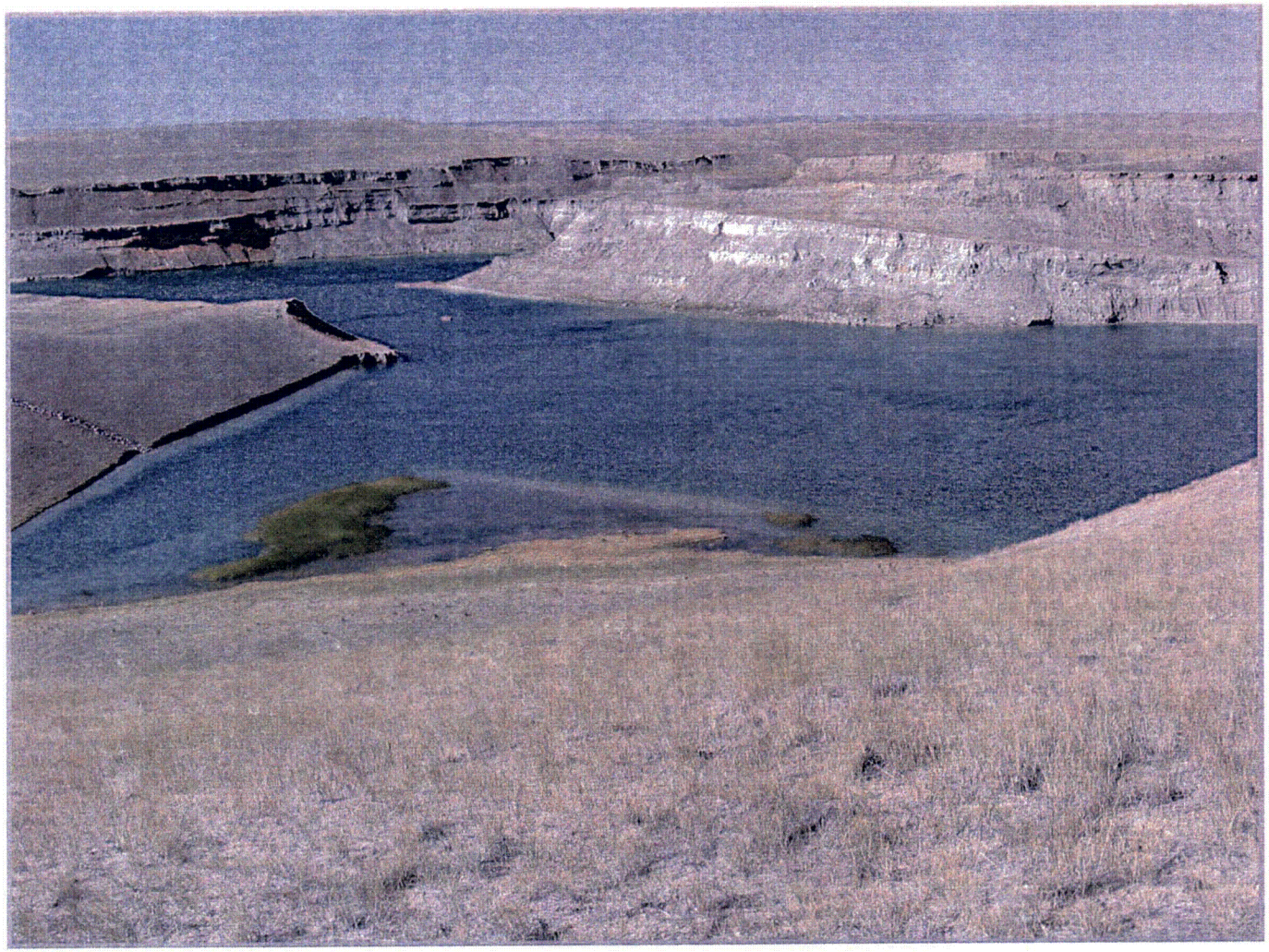
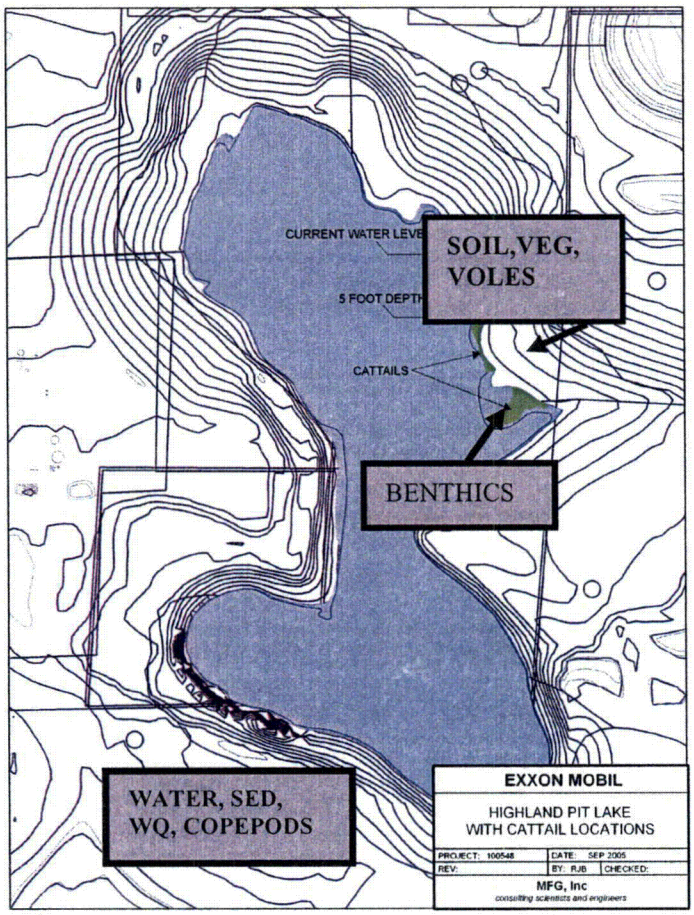


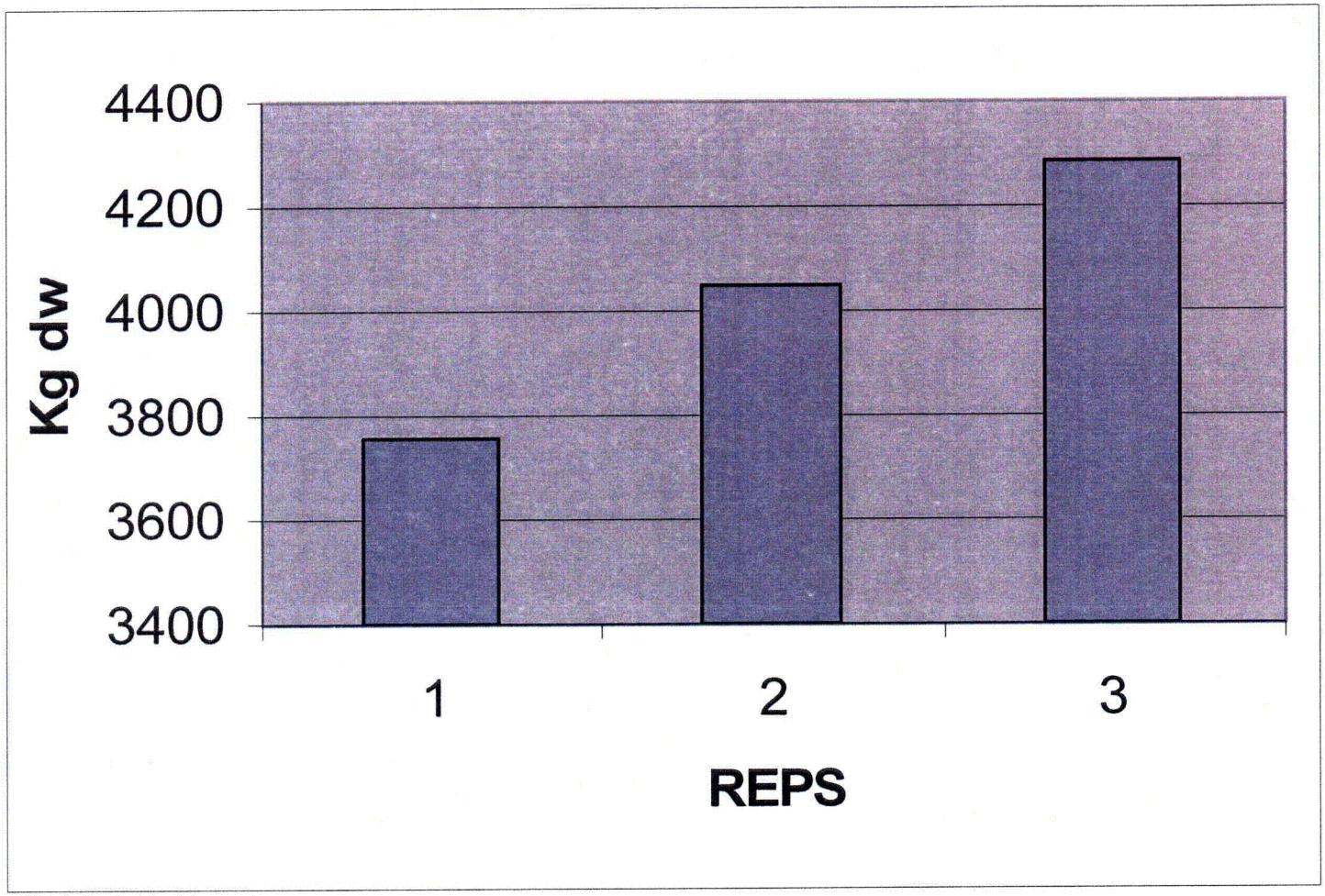
FIGURE 2-2
PLAN VIEW OF HIGHLAND PIT LAKE SHOWING THE CURRENT EXTENT OF LITTORAL ZONE (SHORE TO 5 FT WATER DEPTH SHOWN AS BLUE CONTOUR LINE) AND THE EXTENT OF THE CATTAIL BEDS (GREEN SHADED AREA)

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING



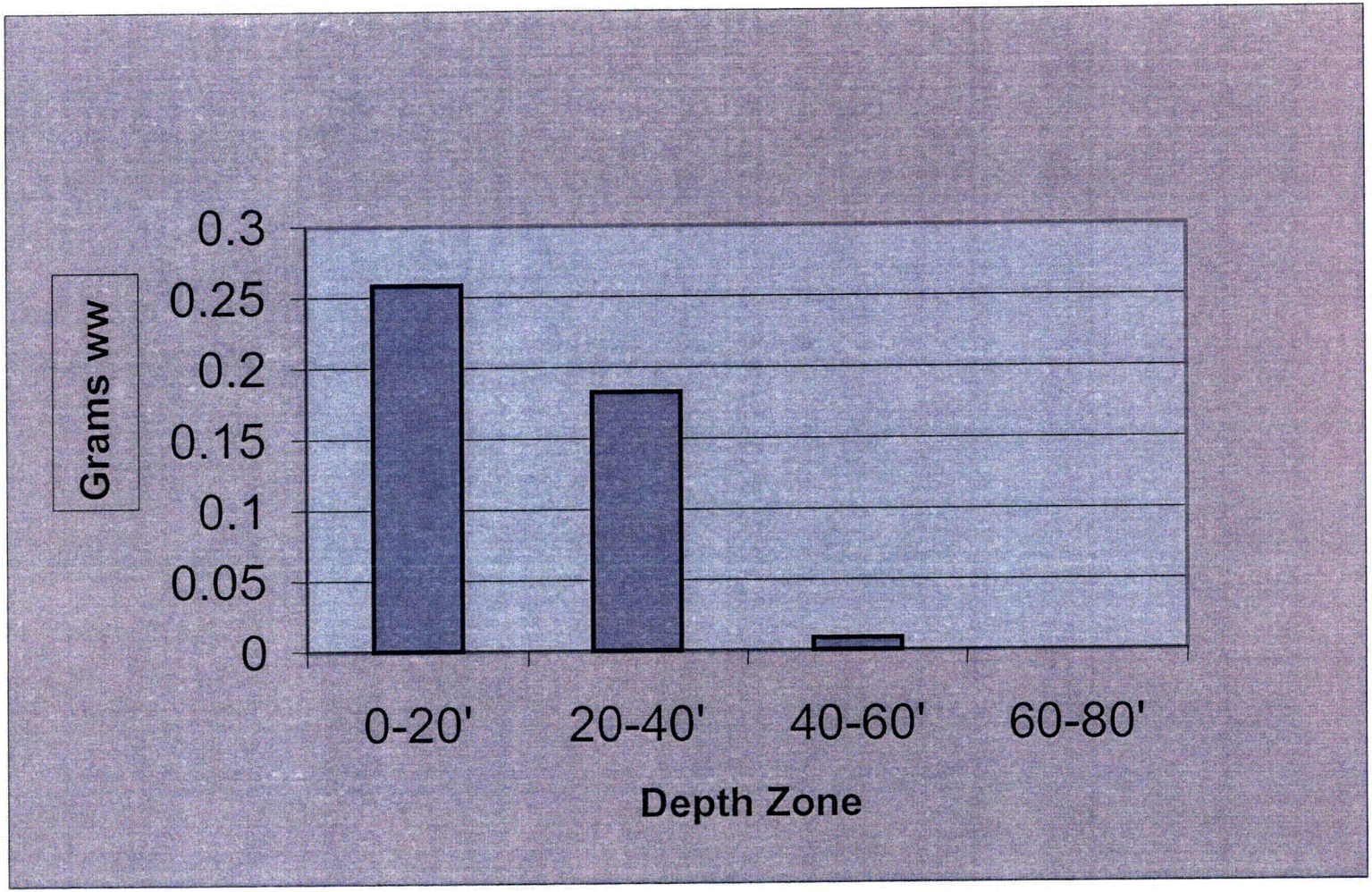
FIG[illegible]2-3
TOTAL ESTIMATED CATTAIL BIOMASS IN THE LITTORAL ZONE AT HIGHLAND PIT LAKE IN 2005

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING



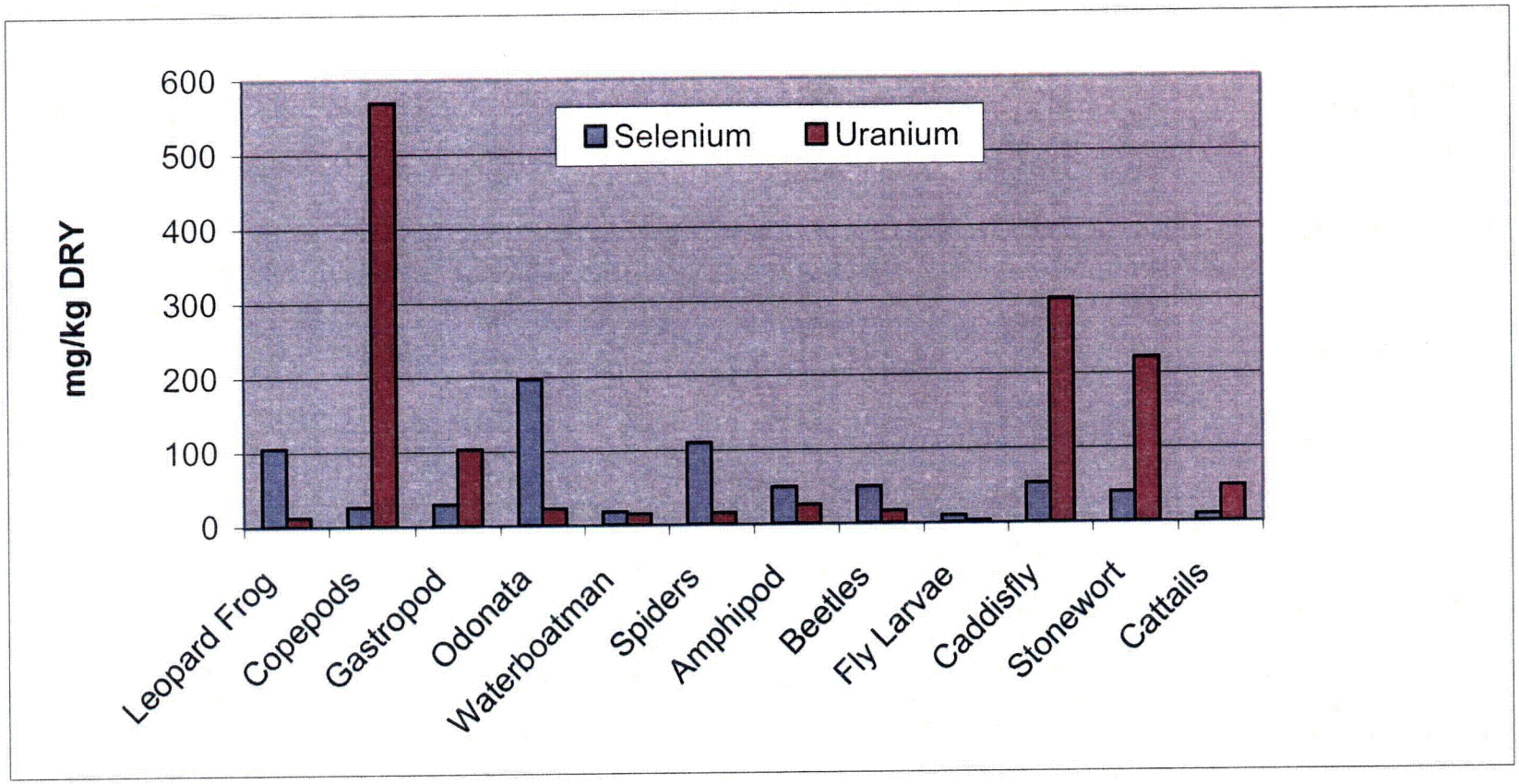
FIG[illegible]2-4
RELATIONSHIP OF COPEPOD BIOMASS (g/20ft DEPTH ZONE)
TO SAMPLING DEPTH IN HIGHLAND PIT LAKE DURING 2004 AND 2005

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING



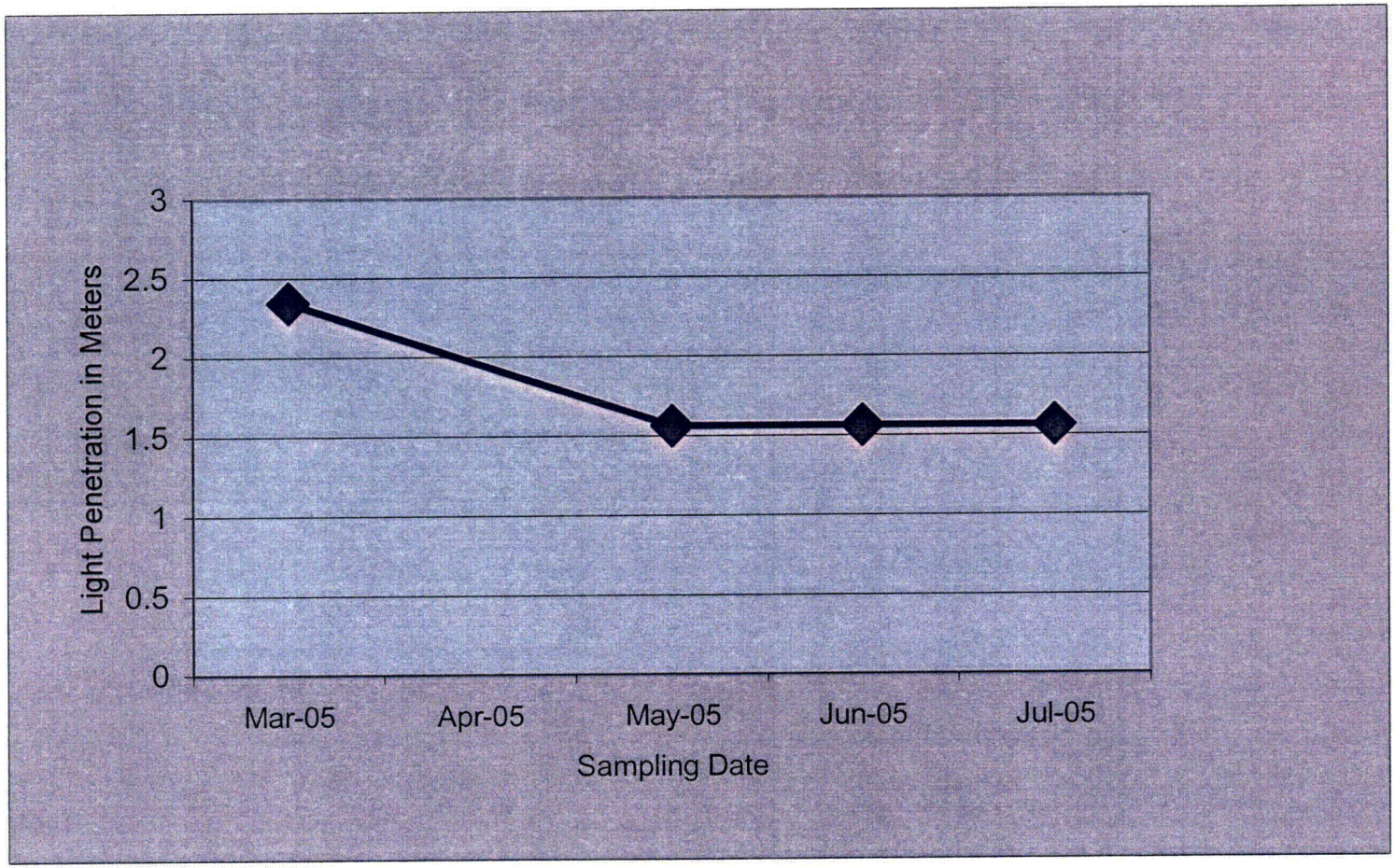
FIG[illegible]2-5
SELENIUM AND URANIUM IN BIOTA FROM THE HIGHLAND PIT LAKE DURING 2004 AND 2005

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING



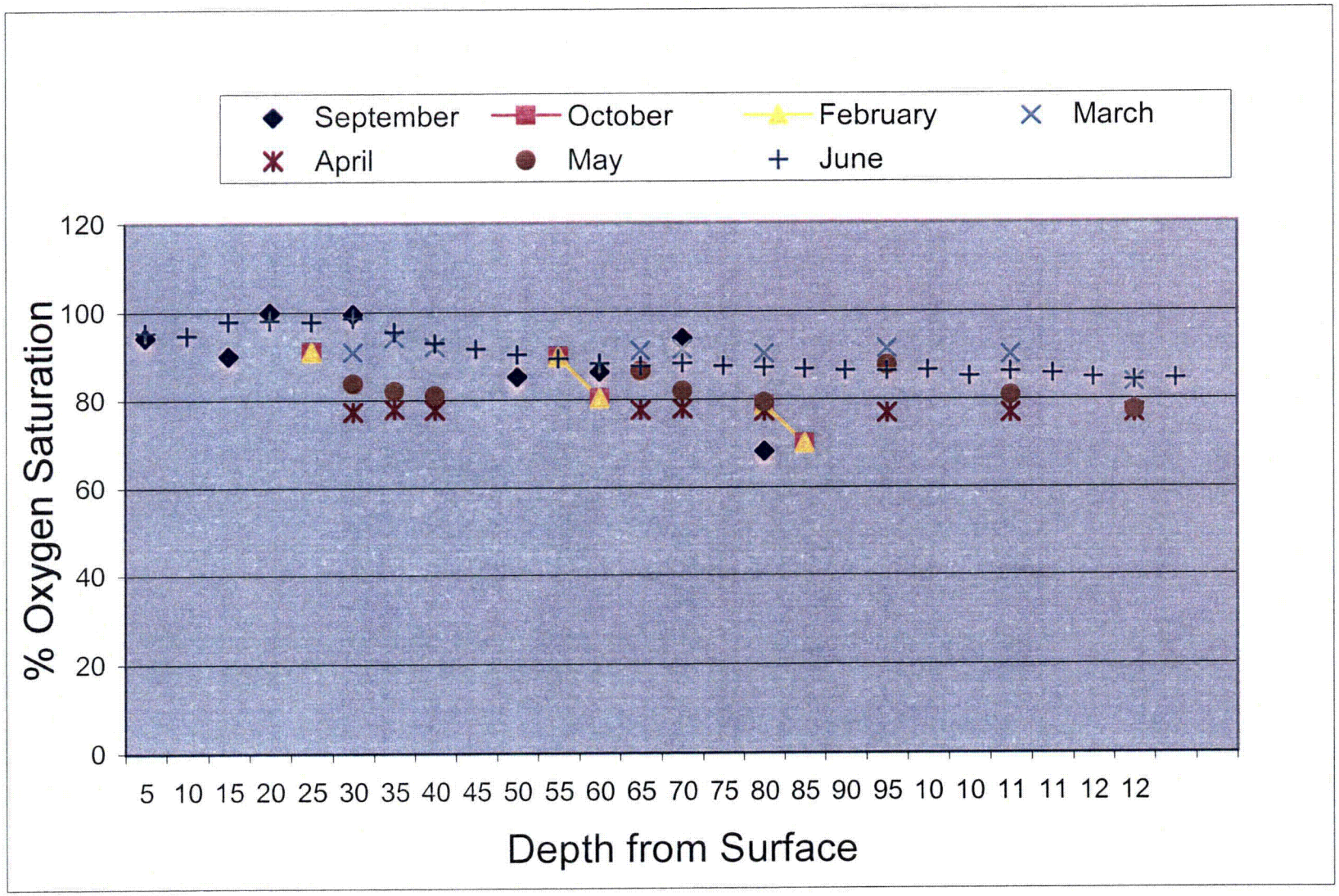
FIG[illegible] 3-1
DEPTH OF SUNLIGHT PENETRATION AS MEASURED BY SECCHI VISIBILITY IN HIGHLAND PIT LAKE DURING 2005

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING



FIG[illegible]3-2
HIGHLAND PIT LAKE DISSOLVED OXYGEN LEVELS DURING 2004 AND 2005

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING



FIG[illegible] 3-3
pH IN HIGHLAND PIT LAKE SHOWING WATER AS A FUNCTION OF DEPTH DURING 2004 AND 2005

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING

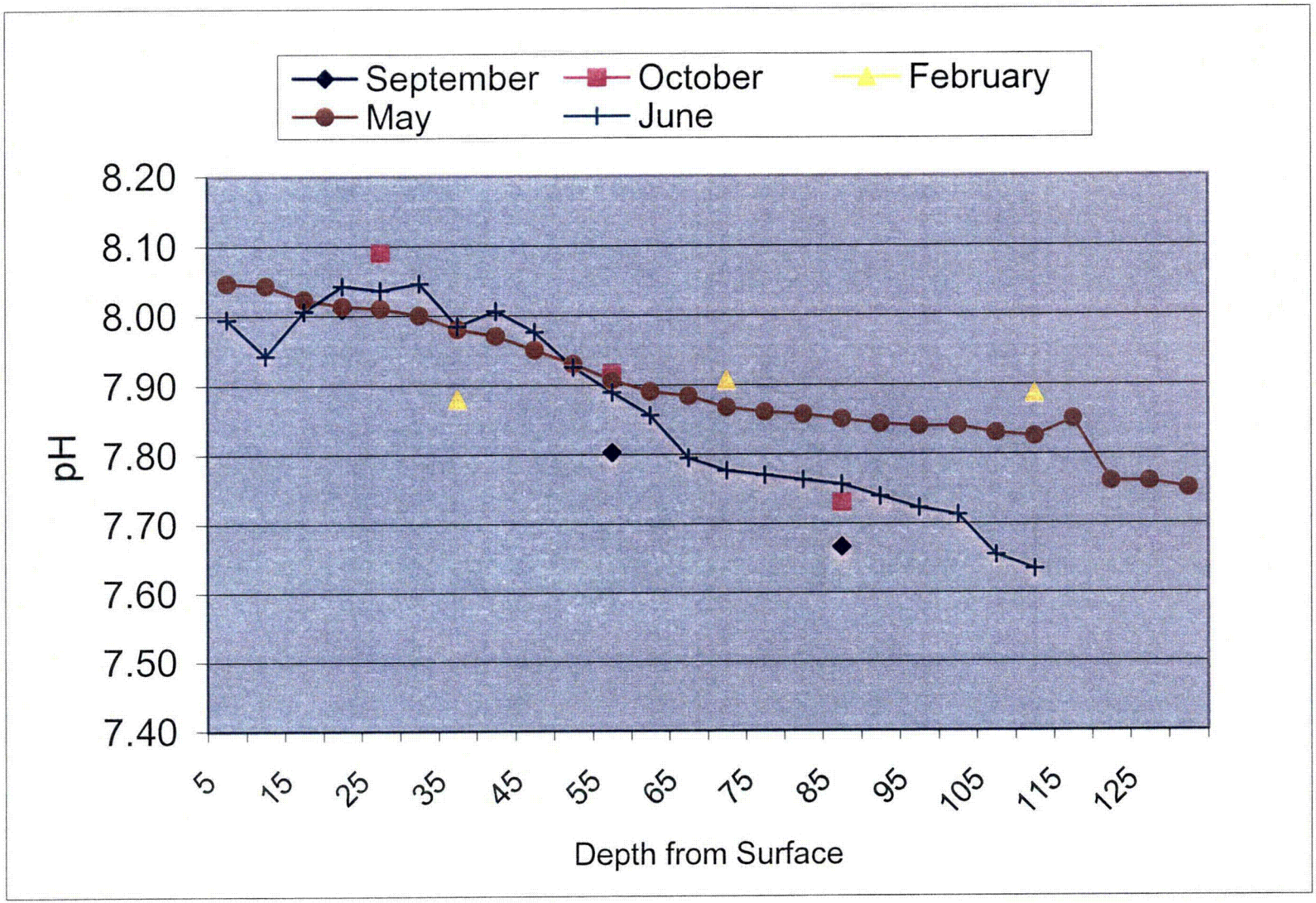


FIG 3-4
HIGHLAND PIT LAKE WATER TEMPERATURES DURING 2004 AND 2005

FINAL HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL – HIGHLAND MINE SITE, CONVERSE COUNTY, WYOMING

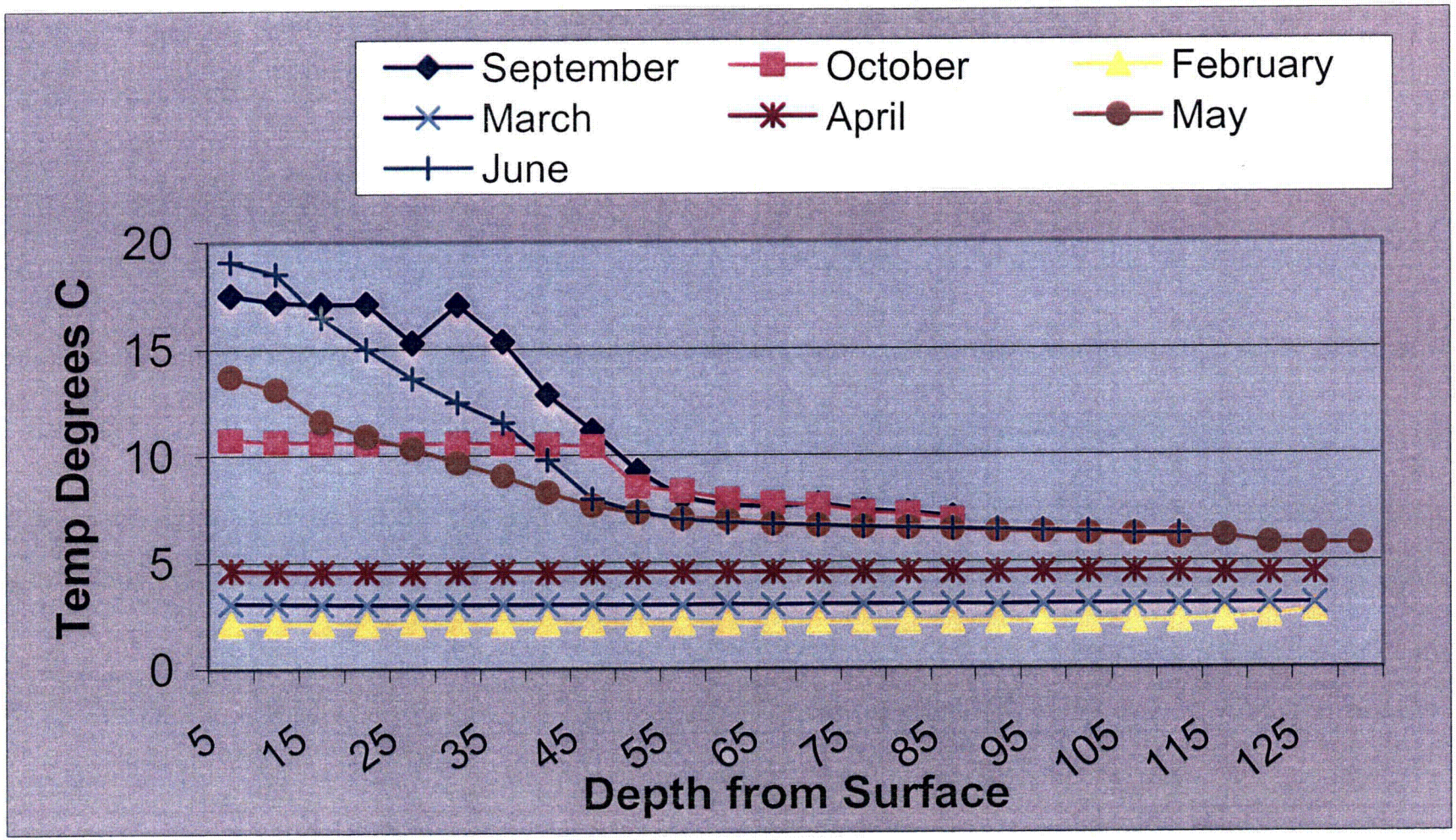
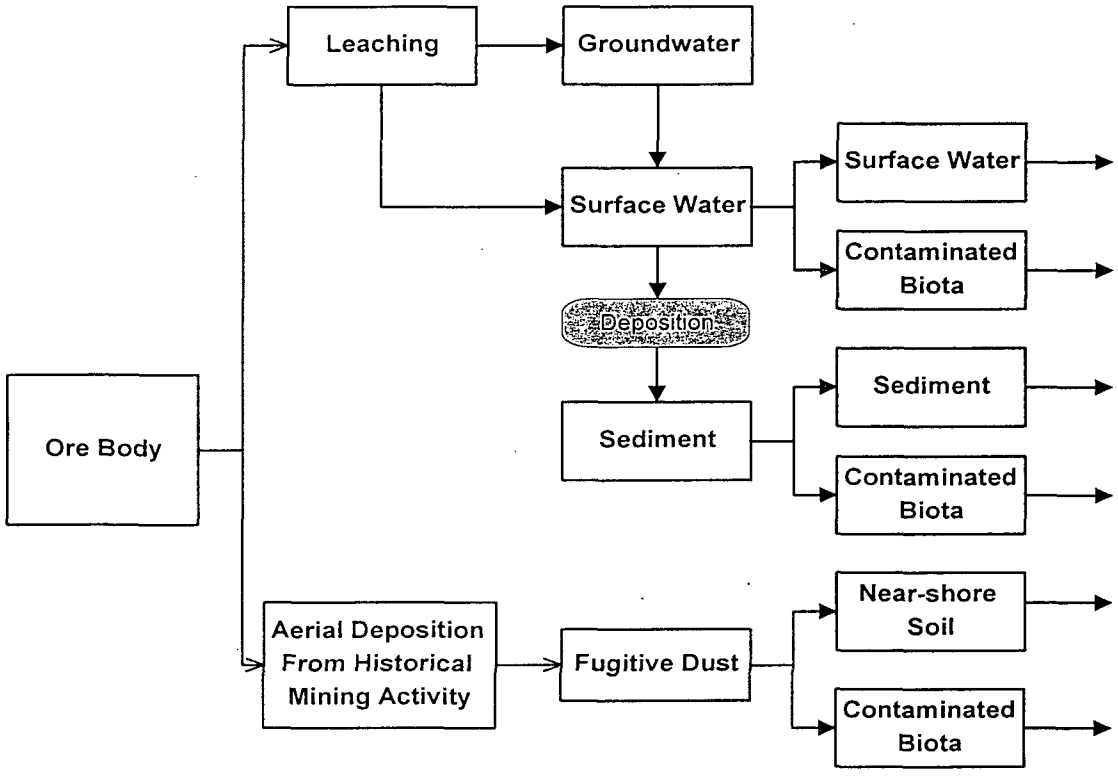


FIGURE 3-5
CONCEPTUAL SITE MODEL FOR HIGHLAND PIT LAKE ERA

HIGHLAND PIT LAKE ECOLOGICAL RISK ASSESSMENT
EXXONMOBIL CORPORATION - CONVERSE COUNTY, WYOMING



EXPOSURE ROUTE(S)	Aquatic					Riparian			
	Plants	Aquatic inverts	Benthic inverts	Amphibians	Birds	Plants	Soil inverts**	Birds	Mammals
Uptake*	●	●		●					
Ingestion					●			●	●
Dermal Contact					◘			◘	◘
Ingestion				◊	●				
Uptake*	●		●						
Ingestion					●				
Dermal Contact					◘				
Ingestion				◊	●				
Uptake*						●	●		
Ingestion								●	●
Dermal Contact								◘	◘
Ingestion								●	●

*Uptake is defined as all exposure routes (i.e., absorption, ingestion and inhalation)

** No soil invertebrates observed in the site area

Legend:

● =Potentially complete exposure pathway quantitatively evaluated in the ERA

◊ =Potentially complete exposure pathway. Cannot be quantitatively evaluated due to insufficient toxicity data

◘ = Potentiall complete pathway but is considered insignificant and is not quantitatively evaluated

Appendix A

Selenium and Uranium Data
Summary and Pro UCL Output

Table A-1. Data Summary for Surface Water, Sediment, and Aquatic Biota

Highland Pit Lake
Converse County, WY

Date Sampled	Sample ID	Description	Rep	Selenium	Uranium	% Moisture
Surface Water				mg/l	mg/l	
9/15/2004	HPL-SW-091504-1 1/3	SW		0.101	3.06	--
9/15/2004	HPL-SW-091504-1 2/3	SW		0.103	3.13	--
9/15/2004	HPL-SW-091504-2 1/3	NE		0.1	3.25	--
9/15/2004	HPL-SW-091504-2 2/3	NE		0.097	3.05	--
9/15/2004	HPL-SW-091504-3 1/3	MIDDLE		0.098	3.03	--
9/15/2004	HPL-SW-091504-3 2/3	MIDDLE		0.098	3.25	--
6/22/2005	Water SW	SW		0.113	2.89	--
6/22/2005	Water NE	NE		0.112	2.99	--
6/22/2005	Water NW	NW		0.113	3.1	--
6/22/2005	Water Littoral1		1	0.107	3.16	--
6/22/2005	Water Littoral 2		2	0.107	3.23	--
6/22/2005	Water Littoral 3		3	0.109	3.2	--
Sediment				mg/kg-dw	mg/kg-dw	
9/14/2004	LMZ/SED/091404/01/001	LIMNETIC SED		18.2	83.6	45%
9/14/2004	LMZ/SED/091404/01/002	LIMNETIC SED		59.3	178	60%
9/14/2004	LMZ/SED/091404/01/003	LIMNETIC		3.7	21.3	35%
9/14/2004	LTZ/SED/091404/01/001	LITTORAL		16.2	223	33%
9/14/2004	LTZ/SED/091404/01/002	LITTORAL SED		25.6	273	43%
9/14/2004	LTZ/SED/091404/01/003	LITTORAL SED		23.7	262	14%
9/14/2004	LTZ/SED/091404/01/004	LITTORAL SED		32.3	260	53%
9/14/2004	LTZ/SED/091404/01/005	LITTORAL SED	1	14.7	191	33%
9/14/2004	LTZ/SED/091404/02/005	LITTORAL SED	2	13.8	233	33%
9/14/2004	LTZ/SED/091404/01/006	LITTORAL SED		2.5	28.7	24%
7/8/2005	Sed Littoral 1	LITTORAL	1	4.8	85.4	48%
7/8/2005	Sed Littoral 2	LITTORAL	2	84	107	34%
7/8/2005	Sed Littoral 3	LITTORAL	3	1.7	17.3	44%
7/8/2005	Sed Limnetic	LIMNETIC SW		8.4	28.6	53%
7/8/2005	Sed Limnetic	LIMNETIC NW		9.2	127	66%
7/8/2005	Sed Limnetic	LIMNETIC NE		19	193	41%
Aquatic Vegetation				mg/kg-dw	mg/kg-dw	
9/13/2004	LTZ/VEG/091304/01/001	TYPHUS		9.9	77	78%
9/13/2004	LTZ/VEG/091304/01/002	TYPHUS		9.7	24	80%
9/13/2004	LTZ/VEG/091304/01/003	TYPHUS		16.2	129	81%
9/13/2004	LTZ/VEG/091304/01/004	TYPHUS	1	12.6	31.8	76%
9/13/2004	LTZ/VEG/091304/02/004	TYPHUS	2	11.7	39.3	76%
9/13/2004	LTZ/VEG/091304/01/005	TYPHUS		13.4	15.1	75%
9/13/2004	LTZ/VEG/091304/01/006	TYPHUS		5.2	71.8	82%
10/26/2004	LTZ/VEG/102604/01/001	TYPHUS	1	6	23.9	81%
10/26/2004	LTZ/VEG/102604/02/001	TYPHUS	2	6.6	22.4	81%
10/26/2004	LTZ/VEG/102604/01/006	TYPHUS		8.5	53.8	80%
10/26/2004	LTZ/VEG/102604/01/003	TYPHUS		5.4	40.6	79%
6/22/2005	Stonewort No. 1 Grab	Stonewort		50	325	94%
6/22/2005	Stonewort No. 2-BR	Stonewort		36	171	94%
6/22/2005	Stonewort No. 3-BR	Stonewort		36	168	95%

Rep = replicate
-- = parameter not applicable to surface water
NA = data not available

Table A-1. Data Summary for Surface Water, Sediment, and Aquatic Biota

Highland Pit Lake
Converse County, WY

Date Sampled	Sample ID	Description	Rep	Selenium	Uranium	% Moisture
Amphibians				mg/kg-dw	mg/kg-dw	
9/13/2004	LTZ/LF/091304/01/001	L Frog	1	135	15.1	63%
9/13/2004	LTZ/LF/091304/02/001	L Frog	2	136	14.6	63%
9/13/2004	LTZ/LF/091304/01/002	L Frog		111	9.1	67%
9/13/2004	LTZ/LF/091304/01/004	L Frog		95.1	14.7	65%
6/21/2005	Leopard Frog - BR	L Frog		50	8.49	NA
Aquatic and Benthic Invertebrates				mg/kg-dw	mg/kg-dw	
9/13/2004	LTZ/GP/091304/01/001	SNAILS	1	44.5	128	67%
9/13/2004	LTZ/GP/091304/01/002	SNAILS	2	43.2	206	72%
10/26/2004	LTZ/GP/102604/01/001	SNAILS		36	91.2	77%
10/26/2004	LTZ/GP/102604/01/002	SNAILS		27	83.2	77%
2/24/2005		SNAILS		9.4	95.2	NA
6/20/2005	Snails - BR	SNAILS		15	56.2	NA
9/13/2004	LTZ/OD/091304/01/001	ODONATA		130	64.4	85%
6/20/2005	Damsel Flies - BR	ODONATA		130	18.6	NA
6/21/2005	Dragonflies - BR	ODONATA		250	1.3	NA
6/22/2005	Dragon Fly - BR	ODONATA		287	3.4	NA
6/22/2005	Dragon Fly Larva - BR	ODONATA		257	29.6	NA
6/22/2005	Stone Fly - Boat Ramp	ODONATA		130	19.1	NA
2/24/2005		Fly Larvae-1		12	3.48	NA
2/24/2005		Fly Larvae-2		5.5	2.5	NA
2/24/2005		Fly Larvae-3		12	2.79	NA
6/21/2005	Spiders			110	15.6	NA
6/20/2005	Amphipod - BR			54	22	NA
6/22/2005	Amphipods - BR			46	29	NA
6/20/2005	Beetles - BR			50	16	NA
2/24/2005	Caddisfly			53	301	NA
9/13/2004	LTZ/CO/091304/01/001	COPEPODS		39.3	516	96%
10/26/2004	LMZ/CO/102604/01/001	COPEPODS		25	613	97%
2/24/2005	Copepod-1	COPEPODS		12	404	NA
2/24/2005	Copepod-2	COPEPODS		8.7	411	NA
2/24/2005	Copepod-3	COPEPODS		8.3	411	NA
2/24/2005	Copepod-4	COPEPODS		14	225	NA
2/24/2005	Copepod-5	COPEPODS		12	277	NA
6/22/2005	Cope Rep 1	COPEPODS		36	1160	96%
6/22/2005	Cope Rep 2	COPEPODS		73	505	93%
6/22/2005	Cope Rep 3	COPEPODS		31	1170	92%
9/13/2004	LTZ/WB/091304/01/001	WATER BOAT	1	20.9	7.17	68%
9/13/2004	LTZ/WB/091304/01/002	WATER BOAT	2	13.4	3.7	67%
10/26/2004	LTZ/WB/102604/01/001	WATER BOAT		36	93.6	81%
10/26/2004	LTZ/WB/102604/01/002	WATER BOAT		27	83.2	81%
2/24/2005		Water Boatman-1		6.5	4.27	NA
2/24/2005		Water Boatman-2		5.9	3.59	NA
2/24/2005		Water Boatman-3		6.2	5.12	NA
6/20/2005		Water Boatmen - BR		38	6.64	NA
6/22/2005		Water Boatmen - BR		23.1	4.27	NA
6/22/2005		Back Swimmes - BR		22.9	7.56	NA
6/20/2005		Back Swimmers - BR		23	7.35	NA

Rep = replicate
-- = parameter not applicable to surface water
NA = data not available

Table A-2. Data Summary for Soil and Terrestrial Biota

Highland Pit Lake

Converse County, WY

Date Sampled	Sample ID	Description	Se (mg/kg-dw)	U (mg/kg-dw)	% Moisture
Soil					
2/24/2005	M-Soil #1		0.92	3.35	NA
2/24/2005	M-Soil #2		0.97	27.6	NA
2/24/2005	M-Soil #3		0.6	2.69	NA
2/24/2005	M-Soil #4		0.5	2.1	NA
2/24/2005	M-Soil #5		0.65	3.16	NA
2/24/2005	M-Soil #6		1.3	1.96	NA
6/22/2005	Soil		1.3	7.98	NA
6/22/2005	Soil No. 1		2	20.8	NA
6/22/2005	Soil No. 2		3.6	4.02	NA
Terrestrial Vegetation					
6/22/2005	Astragalus	Astragalus	4400	6.08	77%
6/22/2005	Astragalus No. 2	Astragalus	1300	3.33	73%
6/22/2005	Terrestrial Veg #3	Grass	13	2.16	59%
6/22/2005	Terrestrial Veg #2	Grass	9.7	1.94	61%
6/22/2005	Terrestrial Grass No. 1	Grass	6.8	18.5	63%
Rodents					
2/5/2005	Rodents	meadow vole	10	0.65	NA
2/5/2005	Rodents	meadow vole	9	0.71	NA
2/5/2005	Rodents	meadow vole	14	0.46	NA
2/5/2005	Rodents	meadow vole	8.9	0.26	NA
2/5/2005	Rodents	meadow vole	5.8	0.67	NA
2/5/2005	Rodents	meadow vole	20	4.34	NA
2/5/2005	Rodents	meadow vole	36	1.26	NA
2/5/2005	Rodents	meadow vole	19	0.55	NA
2/5/2005	Rodents	meadow vole	25	0.64	NA
6/5/2005	Rodents	meadow vole	21	1.58	NA
6/5/2005	Rodents	meadow vole	48	1.13	NA
6/5/2005	Rodents	meadow vole	13	0.09	NA
6/5/2005	Rodents	meadow vole	20	0.26	NA

NA = data not avaialable

Table A-3. Sediment Data for All Constituents

Highland Pit Lake

Converse County, Wyoming

Constituent	Units	LMZ/01/001	LMZ/01/002	LMZ/01/003	LTZ/01/001	LTZ/01/002	LTZ/01/003	LTZ/01/004	LTZ/01/005	LTZ/01/006	LTZ/02/005
Aluminum	mg/kg	27800	29100	22900	27800	23400	27600	23400	27300	14700	23800
Antimony	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Arsenic	mg/kg	4.3	4.4	2.9	3.5	3.3	3.9	3.2	3.1	2.6	2.8
Iron	mg/kg	20800	20800	19200	21000	18100	21400	18900	22200	11800	20400
Manganese	mg/kg	223	171	146	193	136	151	168	121	107	105
Mercury	mg/kg	0.09	0.07	0.11	0.02	0.03	0.03	0.03	0.04	0.05	0.03
Molybdenum	mg/kg	0.4	0.5	0.3	0.7	1	0.8	1	0.5	0.2	0.7
Selenium	mg/kg	18.2	59.3	3.7	16.2	25.6	23.7	32.3	14.7	2.5	13.8
Uranium	mg/kg	83.6	178	21.3	223	273	262	260	191	28.7	233
Vanadium	mg/kg	56	73	37	47	39	46	40	48	24	39
Radium 226	pCi/g	12	22	4.2	4	4.6	3.2	5	2.4	3.4	2.4
Radium 226 precision	pCi/g	0.4	0.8	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.2
Inorganic carbon, Lim	%	0.47	0.76	0.2	0.28	0.22	0.25	0.24	0.18	0.15	0.2
Total organic carbon	%	0.5	0.5	0.4	0.9	1	1.8	1	0.8	0.2	0.7
Total organic matter	%	0.8	0.9	0.7	1.5	1.7	3	1.6	1.3	0.3	1.2

< = constituent not detected at specified level

mg/kg = milligrams per kilogram

pCi/g = pico curries per gram

Data File

Variable: Sediment Se

Raw Statistics	
Number of Valid Samples	16
Number of Unique Samples	16
Minimum	1.7
Maximum	84
Mean	21.06875
Median	15.45
Standard Deviation	22.04969
Variance	486.189
Coefficient of Variation	1.046559
Skewness	1.982368

Gamma Statistics	
k hat	1.170343
k star (bias corrected)	0.992571
Theta hat	18.0022
Theta star	21.22645
nu hat	37.45099
nu star	31.76226
Approx.Chi Square Value (.05)	19.88152
Adjusted Level of Significance	0.03348
Adjusted Chi Square Value	18.81551

Log-transformed Statistics	
Minimum of log data	0.530628
Maximum of log data	4.430817
Mean of log data	2.563203
Standard Deviation of log data	1.079992
Variance of log data	1.166383

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.77193
Shapiro-Wilk 5% Critical Value	0.887
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	30.7323

Gamma Distribution Test	
A-D Test Statistic	0.242539
A-D 5% Critical Value	0.760367
K-S Test Statistic	0.11229
K-S 5% Critical Value	0.22039
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	33.65895
Adjusted Gamma UCL	35.56594

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.972918
Shapiro-Wilk 5% Critical Value	0.887
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	51.33364
95% Chebyshev (MVUE) UCL	50.85816
97.5% Chebyshev (MVUE) UCL	63.32083
99% Chebyshev (MVUE) UCL	87.80134

95% Non-parametric UCLs	
CLT UCL	30.13588
Adj-CLT UCL (Adjusted for skewness)	33.05497
Mod-t UCL (Adjusted for skewness)	31.18762
Jackknife UCL	30.7323
Standard Bootstrap UCL	29.66292
Bootstrap-t UCL	39.28444
Hall's Bootstrap UCL	80.13985
Percentile Bootstrap UCL	30.275
BCA Bootstrap UCL	33.0125
95% Chebyshev (Mean, Sd) UCL	45.09685
97.5% Chebyshev (Mean, Sd) UCL	55.49382
99% Chebyshev (Mean, Sd) UCL	75.91667

Data File

Variable: Sediment U

Raw Statistics	
Number of Valid Samples	16
Number of Unique Samples	16
Minimum	17.3
Maximum	273
Mean	144.4938
Median	152.5
Standard Deviation	93.23971
Variance	8693.643
Coefficient of Variation	0.645285
Skewness	-0.076295

Gamma Statistics	
k hat	1.66572
k star (bias corrected)	1.395064
Theta hat	86.74552
Theta star	103.575
nu hat	53.30304
nu star	44.64206
Approx.Chi Square Value (.05)	30.31426
Adjusted Level of Significance	0.03348
Adjusted Chi Square Value	28.97323

Log-transformed Statistics	
Minimum of log data	2.850707
Maximum of log data	5.609472
Mean of log data	4.643974
Standard Deviation of log data	0.968882
Variance of log data	0.938732

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.904225
Shapiro-Wilk 5% Critical Value	0.887

Data are normal at 5% significance level

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	185.3572

Gamma Distribution Test	
A-D Test Statistic	0.790771
A-D 5% Critical Value	0.753228
K-S Test Statistic	0.203819
K-S 5% Critical Value	0.218559

Data follow approximate gamma distibution at 5% significance level

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	212.7876
Adjusted Gamma UCL	222.6365

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.84426
Shapiro-Wilk 5% Critical Value	0.887

Data not lognormal at 5% significance level

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	323.8516
95% Chebyshev (MVUE) UCL	344.2599
97.5% Chebyshev (MVUE) UCL	424.1212
99% Chebyshev (MVUE) UCL	580.9934

95% Non-parametric UCLs	
CLT UCL	182.8352
Adj-CLT UCL (Adjusted for skewness)	182.3601
Mod-t UCL (Adjusted for skewness)	185.2831
Jackknife UCL	185.3572
Standard Bootstrap UCL	182.8204
Bootstrap-t UCL	184.3865
Hall's Bootstrap UCL	180.9648
Percentile Bootstrap UCL	180.625
BCA Bootstrap UCL	183.1313
95% Chebyshev (Mean, Sd) UCL	246.0994
97.5% Chebyshev (Mean, Sd) UCL	290.0642
99% Chebyshev (Mean, Sd) UCL	376.4246

Data File

Variable: Soil Se

Raw Statistics	
Number of Valid Samples	9
Number of Unique Samples	9
Minimum	0.5
Maximum	20.8
Mean	4.193333
Median	0.97
Standard Deviation	6.6964
Variance	44.84178
Coefficient of Variation	1.596916
Skewness	2.354985

Gamma Statistics	
k hat	0.691083
k star (bias corrected)	0.534796
Theta hat	6.067769
Theta star	7.840993
nu hat	12.4395
nu star	9.626332
Approx.Chi Square Value (.05)	3.708776
Adjusted Level of Significance	0.02308
Adjusted Chi Square Value	2.97564

Log-transformed Statistics	
Minimum of log data	-0.693147
Maximum of log data	3.034953
Mean of log data	0.557438
Standard Deviation of log data	1.307064
Variance of log data	1.708416

RECOMMENDATION

Data are lognormal (0.05)

Use 95% Chebyshev (MVUE) UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.631277
Shapiro-Wilk 5% Critical Value	0.829
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	8.344093

Gamma Distribution Test	
A-D Test Statistic	0.883612
A-D 5% Critical Value	0.755992
K-S Test Statistic	0.317629
K-S 5% Critical Value	0.290411
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	10.88403
Adjusted Gamma UCL	13.56563

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.859479
Shapiro-Wilk 5% Critical Value	0.829
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	26.57143
95% Chebyshev (MVUE) UCL	10.55021
97.5% Chebyshev (MVUE) UCL	13.57891
99% Chebyshev (MVUE) UCL	19.52821

95% Non-parametric UCLs	
CLT UCL	7.864866
Adj-CLT UCL (Adjusted for skewness)	9.737132
Mod-t UCL (Adjusted for skewness)	8.636128
Jackknife UCL	8.344093
Standard Bootstrap UCL	7.623084
Bootstrap-t UCL	22.62485
Hall's Bootstrap UCL	24.58439
Percentile Bootstrap UCL	7.958889
BCA Bootstrap UCL	9.912222
95% Chebyshev (Mean, Sd) UCL	13.92298
97.5% Chebyshev (Mean, Sd) UCL	18.133
99% Chebyshev (Mean, Sd) UCL	26.40278

Data File

Variable: Soil U

Raw Statistics	
Number of Valid Samples	9
Number of Unique Samples	9
Minimum	1.96
Maximum	27.6
Mean	11.36222
Median	3.35
Standard Deviation	10.576
Variance	111.8519
Coefficient of Variation	0.930804
Skewness	0.440989

Gamma Statistics	
k hat	1.086452
k star (bias corrected)	0.798375
Theta hat	10.4581
Theta star	14.23168
nu hat	19.55614
nu star	14.37076
Approx.Chi Square Value (.05)	6.824803
Adjusted Level of Significance	0.02308
Adjusted Chi Square Value	5.764426

Log-transformed Statistics	
Minimum of log data	0.672944
Maximum of log data	3.317816
Mean of log data	1.904031
Standard Deviation of log data	1.14453
Variance of log data	1.309949

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.778647
Shapiro-Wilk 5% Critical Value	0.829
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	17.91775

Gamma Distribution Test	
A-D Test Statistic	1.019028
A-D 5% Critical Value	0.741895
K-S Test Statistic	0.318248
K-S 5% Critical Value	0.286395
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	23.92505
Adjusted Gamma UCL	28.32611

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.792899
Shapiro-Wilk 5% Critical Value	0.829
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	56.42488
95% Chebyshev (MVUE) UCL	31.79316
97.5% Chebyshev (MVUE) UCL	40.50504
99% Chebyshev (MVUE) UCL	57.61784

95% Non-parametric UCLs	
CLT UCL	17.16088
Adj-CLT UCL (Adjusted for skewness)	17.7146
Mod-t UCL (Adjusted for skewness)	18.00412
Jackknife UCL	17.91775
Standard Bootstrap UCL	16.74763
Bootstrap-t UCL	18.14667
Hall's Bootstrap UCL	15.84094
Percentile Bootstrap UCL	16.97556
BCA Bootstrap UCL	17.32333
95% Chebyshev (Mean, Sd) UCL	26.7288
97.5% Chebyshev (Mean, Sd) UCL	33.37793
99% Chebyshev (Mean, Sd) UCL	46.43886

RECOMMENDATION

Data are Non-parametric (0.05)

Use 99% Chebyshev (Mean, Sd) UCL

Recommended UCL exceeds the maximum observation
Consider using 95% or 97.5% Chebyshev (Mean, Sd) UCL

Data File

Variable: Rodent Se

Raw Statistics	
Number of Valid Samples	13
Number of Unique Samples	12
Minimum	5.8
Maximum	48
Mean	19.20769
Median	19
Standard Deviation	11.86623
Variance	140.8074
Coefficient of Variation	0.617785
Skewness	1.360095

Gamma Statistics	
k hat	3.227051
k star (bias corrected)	2.533629
Theta hat	5.952088
Theta star	7.581099
nu hat	83.90333
nu star	65.87436
Approx.Chi Square Value (.05)	48.19449
Adjusted Level of Significance	0.03009
Adjusted Chi Square Value	46.04525

Log-transformed Statistics	
Minimum of log data	1.757858
Maximum of log data	3.871201
Mean of log data	2.792442
Standard Deviation of log data	0.594998
Variance of log data	0.354022

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.875198
Shapiro-Wilk 5% Critical Value	0.866
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	25.07338

Gamma Distribution Test	
A-D Test Statistic	0.269844
A-D 5% Critical Value	0.73873
K-S Test Statistic	0.13313
K-S 5% Critical Value	0.238103
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	26.25392
Adjusted Gamma UCL	27.47937

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.976564
Shapiro-Wilk 5% Critical Value	0.866
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	28.59532
95% Chebyshev (MVUE) UCL	33.46826
97.5% Chebyshev (MVUE) UCL	39.64987
99% Chebyshev (MVUE) UCL	51.79244

95% Non-parametric UCLs	
CLT UCL	24.62107
Adj-CLT UCL (Adjusted for skewness)	25.94761
Mod-t UCL (Adjusted for skewness)	25.28029
Jackknife UCL	25.07338
Standard Bootstrap UCL	24.32703
Bootstrap-t UCL	28.24429
Hall's Bootstrap UCL	36.41976
Percentile Bootstrap UCL	24.81538
BCA Bootstrap UCL	25.76923
95% Chebyshev (Mean, Sd) UCL	33.55327
97.5% Chebyshev (Mean, Sd) UCL	39.76061
99% Chebyshev (Mean, Sd) UCL	51.95373

Data File

Variable: Rodent U

Raw Statistics	
Number of Valid Samples	13
Number of Unique Samples	12
Minimum	0.09
Maximum	4.34
Mean	0.969231
Median	0.65
Standard Deviation	1.09646
Variance	1.202224
Coefficient of Variation	1.131268
Skewness	2.752709

Gamma Statistics	
k hat	1.343368
k star (bias corrected)	1.084642
Theta hat	0.721493
Theta star	0.893595
nu hat	34.92757
nu star	28.2007
Approx.Chi Square Value (.05)	17.08245
Adjusted Level of Significance	0.03009
Adjusted Chi Square Value	15.85912

Log-transformed Statistics	
Minimum of log data	-2.407946
Maximum of log data	1.467874
Mean of log data	-0.447528
Standard Deviation of log data	0.952139
Variance of log data	0.906569

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.662369
Shapiro-Wilk 5% Critical Value	0.866
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	1.51123

Gamma Distribution Test	
A-D Test Statistic	0.470956
A-D 5% Critical Value	0.752545
K-S Test Statistic	0.210611
K-S 5% Critical Value	0.241588
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	1.600062
Adjusted Gamma UCL	1.723487

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.965942
Shapiro-Wilk 5% Critical Value	0.866
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	2.156907
95% Chebyshev (MVUE) UCL	2.145966
97.5% Chebyshev (MVUE) UCL	2.659131
99% Chebyshev (MVUE) UCL	3.667146

95% Non-parametric UCLs	
CLT UCL	1.469436
Adj-CLT UCL (Adjusted for skewness)	1.717515
Mod-t UCL (Adjusted for skewness)	1.549926
Jackknife UCL	1.51123
Standard Bootstrap UCL	1.451693
Bootstrap-t UCL	2.252033
Hall's Bootstrap UCL	3.503067
Percentile Bootstrap UCL	1.492308
BCA Bootstrap UCL	1.736923
95% Chebyshev (Mean, Sd) UCL	2.294786
97.5% Chebyshev (Mean, Sd) UCL	2.868355
99% Chebyshev (Mean, Sd) UCL	3.99502

Data File

Variable: U Plant Se

Raw Statistics	
Number of Valid Samples	5
Number of Unique Samples	5
Minimum	6.8
Maximum	4400
Mean	1145.9
Median	13
Standard Deviation	1902.95
Variance	3621219
Coefficient of Variation	1.66066
Skewness	1.817771

Gamma Statistics	
k hat	0.271519
k star (bias corrected)	0.241941
Theta hat	4220.329
Theta star	4736.279
nu hat	2.715191
nu star	2.41941
Approx.Chi Square Value (.05)	0.223375
Adjusted Level of Significance	0.0086
Adjusted Chi Square Value	0.08892

Log-transformed Statistics	
Minimum of log data	1.916923
Maximum of log data	8.38936
Mean of log data	4.462695
Standard Deviation of log data	3.067158
Variance of log data	9.407458

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Adjusted Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.720739
Shapiro-Wilk 5% Critical Value	0.762
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	2960.154

Gamma Distribution Test	
A-D Test Statistic	0.608864
A-D 5% Critical Value	0.749462
K-S Test Statistic	0.369588
K-S 5% Critical Value	0.382351
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	12411.44
Adjusted Gamma UCL	31178.73

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.799058
Shapiro-Wilk 5% Critical Value	0.762
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	3.10E+13
95% Chebyshev (MVUE) UCL	5946.244
97.5% Chebyshev (MVUE) UCL	7997.821
99% Chebyshev (MVUE) UCL	12027.75

95% Non-parametric UCLs	
CLT UCL	2545.712
Adj-CLT UCL (Adjusted for skewness)	3284.937
Mod-t UCL (Adjusted for skewness)	3075.459
Jackknife UCL	2960.154
Standard Bootstrap UCL	2433.096
Bootstrap-t UCL	787629.2
Hall's Bootstrap UCL	315571.5
Percentile Bootstrap UCL	2643.3
BCA Bootstrap UCL	2901.94
95% Chebyshev (Mean, Sd) UCL	4855.433
97.5% Chebyshev (Mean, Sd) UCL	6460.55
99% Chebyshev (Mean, Sd) UCL	9613.493

Recommended UCL exceeds the maximum observation

Data File

Variable: U plant U

Raw Statistics	
Number of Valid Samples	5
Number of Unique Samples	5
Minimum	1.94
Maximum	18.5
Mean	6.402
Median	3.33
Standard Deviation	6.96072
Variance	48.45162
Coefficient of Variation	1.087273
Skewness	1.947679

Gamma Statistics	
k hat	1.443027
k star (bias corrected)	0.710544
Theta hat	4.436508
Theta star	9.009997
nu hat	14.43027
nu star	7.105441
Approx.Chi Square Value (.05)	2.227995
Adjusted Level of Significance	0.0086
Adjusted Chi Square Value	1.226534

Log-transformed Statistics	
Minimum of log data	0.662688
Maximum of log data	2.917771
Mean of log data	1.471709
Standard Deviation of log data	0.924819
Variance of log data	0.85529

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.737037
Shapiro-Wilk 5% Critical Value	0.762
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	13.03828

Gamma Distribution Test	
A-D Test Statistic	0.475446
A-D 5% Critical Value	0.686954
K-S Test Statistic	0.261306
K-S 5% Critical Value	0.361982
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	20.41703
Adjusted Gamma UCL	37.08748

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.893578
Shapiro-Wilk 5% Critical Value	0.762
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	55.62053
95% Chebyshev (MVUE) UCL	16.5153
97.5% Chebyshev (MVUE) UCL	21.05352
99% Chebyshev (MVUE) UCL	29.96798

95% Non-parametric UCLs	
CLT UCL	11.52231
Adj-CLT UCL (Adjusted for skewness)	14.41953
Mod-t UCL (Adjusted for skewness)	13.49019
Jackknife UCL	13.03828
Standard Bootstrap UCL	11.03847
Bootstrap-t UCL	45.09187
Hall's Bootstrap UCL	32.19941
Percentile Bootstrap UCL	11.964
BCA Bootstrap UCL	12.748
95% Chebyshev (Mean, Sd) UCL	19.97094
97.5% Chebyshev (Mean, Sd) UCL	25.84223
99% Chebyshev (Mean, Sd) UCL	37.37525

Recommended UCL exceeds the maximum observation

Data File

Variable: Water Se

Raw Statistics	
Number of Valid Samples	12
Number of Unique Samples	9
Minimum	0.097
Maximum	0.113
Mean	0.104833
Median	0.105
Standard Deviation	0.006088
Variance	3.71E-05
Coefficient of Variation	0.058071
Skewness	0.123729

Gamma Statistics	
k hat	324.2148
k star (bias corrected)	243.2167
Theta hat	0.000323
Theta star	0.000431
nu hat	7781.155
nu star	5837.2
Approx.Chi Square Value (.05)	5660.583
Adjusted Level of Significance	0.02896
Adjusted Chi Square Value	5634

Log-transformed Statistics	
Minimum of log data	-2.333044
Maximum of log data	-2.180367
Mean of log data	-2.256926
Standard Deviation of log data	0.057997
Variance of log data	0.003364

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.898165
Shapiro-Wilk 5% Critical Value	0.859
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	0.107989

Gamma Distribution Test	
A-D Test Statistic	0.491499
A-D 5% Critical Value	0.7312
K-S Test Statistic	0.158186
K-S 5% Critical Value	0.24495
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	0.108104
Adjusted Gamma UCL	0.108614

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.899461
Shapiro-Wilk 5% Critical Value	0.859
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	N/A
95% Chebyshev (MVUE) UCL	0.112486
97.5% Chebyshev (MVUE) UCL	0.115798
99% Chebyshev (MVUE) UCL	0.122303

95% Non-parametric UCLs	
CLT UCL	0.107724
Adj-CLT UCL (Adjusted for skewness)	0.107791
Mod-t UCL (Adjusted for skewness)	0.108
Jackknife UCL	0.107989
Standard Bootstrap UCL	0.107572
Bootstrap-t UCL	0.10816
Hall's Bootstrap UCL	0.107399
Percentile Bootstrap UCL	0.107583
BCA Bootstrap UCL	0.1075
95% Chebyshev (Mean, Sd) UCL	0.112494
97.5% Chebyshev (Mean, Sd) UCL	0.115808
99% Chebyshev (Mean, Sd) UCL	0.122319

Data File

Variable: Water U

Raw Statistics	
Number of Valid Samples	12
Number of Unique Samples	11
Minimum	2.89
Maximum	3.25
Mean	3.111667
Median	3.115
Standard Deviation	0.112802
Variance	0.012724
Coefficient of Variation	0.036251
Skewness	-0.444771

Gamma Statistics	
k hat	821.7737
k star (bias corrected)	616.3858
Theta hat	0.003787
Theta star	0.005048
nu hat	19722.57
nu star	14793.26
Approx.Chi Square Value (.05)	14511.41
Adjusted Level of Significance	0.02896
Adjusted Chi Square Value	14468.75

Log-transformed Statistics	
Minimum of log data	1.061257
Maximum of log data	1.178655
Mean of log data	1.13455
Standard Deviation of log data	0.036535
Variance of log data	0.001335

RECOMMENDATION

Data are normal (0.05)

Use Student's-t UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.948754
Shapiro-Wilk 5% Critical Value	0.859
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	3.170146

Gamma Distribution Test	
A-D Test Statistic	0.251236
A-D 5% Critical Value	0.7312
K-S Test Statistic	0.1266
K-S 5% Critical Value	0.24495
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	3.172103
Adjusted Gamma UCL	3.181457

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.946269
Shapiro-Wilk 5% Critical Value	0.859
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	N/A
95% Chebyshev (MVUE) UCL	3.254748
97.5% Chebyshev (MVUE) UCL	3.316655
99% Chebyshev (MVUE) UCL	3.438259

95% Non-parametric UCLs	
CLT UCL	3.165228
Adj-CLT UCL (Adjusted for skewness)	3.160761
Mod-t UCL (Adjusted for skewness)	3.169449
Jackknife UCL	3.170146
Standard Bootstrap UCL	3.162716
Bootstrap-t UCL	3.165115
Hall's Bootstrap UCL	3.160933
Percentile Bootstrap UCL	3.1625
BCA Bootstrap UCL	3.16
95% Chebyshev (Mean, Sd) UCL	3.253606
97.5% Chebyshev (Mean, Sd) UCL	3.315023
99% Chebyshev (Mean, Sd) UCL	3.435665

Data File

Variable: Aq Plant Se

Raw Statistics	
Number of Valid Samples	14
Number of Unique Samples	13
Minimum	5.2
Maximum	50
Mean	16.22857
Median	10.8
Standard Deviation	13.98524
Variance	195.5868
Coefficient of Variation	0.861766
Skewness	1.582832

Gamma Statistics	
k hat	1.971594
k star (bias corrected)	1.596729
Theta hat	8.231192
Theta star	10.16364
nu hat	55.20464
nu star	44.70841
Approx.Chi Square Value (.05)	30.36901
Adjusted Level of Significance	0.03122
Adjusted Chi Square Value	28.80678

Log-transformed Statistics	
Minimum of log data	1.648659
Maximum of log data	3.912023
Mean of log data	2.51223
Standard Deviation of log data	0.729666
Variance of log data	0.532412

RECOMMENDATION

Assuming gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.749321
Shapiro-Wilk 5% Critical Value	0.874
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	22.84781

Gamma Distribution Test	
A-D Test Statistic	0.860246
A-D 5% Critical Value	0.746198
K-S Test Statistic	0.221329
K-S 5% Critical Value	0.231702
Data follow approximate gamma distibution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	23.89125
Adjusted Gamma UCL	25.18691

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.903008
Shapiro-Wilk 5% Critical Value	0.874
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	26.06877
95% Chebyshev (MVUE) UCL	29.81946
97.5% Chebyshev (MVUE) UCL	35.91647
99% Chebyshev (MVUE) UCL	47.89285

95% Non-parametric UCLs	
CLT UCL	22.37656
Adj-CLT UCL (Adjusted for skewness)	24.06606
Mod-t UCL (Adjusted for skewness)	23.11134
Jackknife UCL	22.84781
Standard Bootstrap UCL	22.15877
Bootstrap-t UCL	26.11509
Hall's Bootstrap UCL	22.21343
Percentile Bootstrap UCL	22.63571
BCA Bootstrap UCL	23.60714
95% Chebyshev (Mean, Sd) UCL	32.52088
97.5% Chebyshev (Mean, Sd) UCL	39.57057
99% Chebyshev (Mean, Sd) UCL	53.41833

Data File

Variable: Aq Plant U

Raw Statistics	
Number of Valid Samples	14
Number of Unique Samples	14
Minimum	15.1
Maximum	325
Mean	85.19286
Median	47.2
Standard Deviation	86.90456
Variance	7552.402
Coefficient of Variation	1.020092
Skewness	1.866631

Gamma Statistics	
k hat	1.3694
k star (bias corrected)	1.123576
Theta hat	62.21181
Theta star	75.82294
nu hat	38.3432
nu star	31.46014
Approx.Chi Square Value (.05)	19.64234
Adjusted Level of Significance	0.03122
Adjusted Chi Square Value	18.41066

Log-transformed Statistics	
Minimum of log data	2.714695
Maximum of log data	5.783825
Mean of log data	4.037313
Standard Deviation of log data	0.917933
Variance of log data	0.842601

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.768512
Shapiro-Wilk 5% Critical Value	0.874
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	126.3249

Gamma Distribution Test	
A-D Test Statistic	0.525321
A-D 5% Critical Value	0.753082
K-S Test Statistic	0.181176
K-S 5% Critical Value	0.233357
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	136.4491
Adjusted Gamma UCL	145.5775

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.951866
Shapiro-Wilk 5% Critical Value	0.874
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	170.3119
95% Chebyshev (MVUE) UCL	178.5401
97.5% Chebyshev (MVUE) UCL	219.8784
99% Chebyshev (MVUE) UCL	301.0793

95% Non-parametric UCLs	
CLT UCL	123.3966
Adj-CLT UCL (Adjusted for skewness)	135.7775
Mod-t UCL (Adjusted for skewness)	128.2561
Jackknife UCL	126.3249
Standard Bootstrap UCL	121.6716
Bootstrap-t UCL	155.627
Hall's Bootstrap UCL	146.2958
Percentile Bootstrap UCL	125.9143
BCA Bootstrap UCL	134.6071
95% Chebyshev (Mean, Sd) UCL	186.4336
97.5% Chebyshev (Mean, Sd) UCL	230.2406
99% Chebyshev (Mean, Sd) UCL	316.2908

Data File

Variable: Aq + Benth Invert Se

Raw Statistics	
Number of Valid Samples	41
Number of Unique Samples	33
Minimum	5.5
Maximum	287
Mean	53.27317
Median	27
Standard Deviation	68.99488
Variance	4760.294
Coefficient of Variation	1.295115
Skewness	2.322593

Gamma Statistics	
k hat	0.984936
k star (bias corrected)	0.929128
Theta hat	54.08796
Theta star	57.33677
nu hat	80.76475
nu star	76.18846
Approx.Chi Square Value (.05)	57.07946
Adjusted Level of Significance	0.044146
Adjusted Chi Square Value	56.47537

Log-transformed Statistics	
Minimum of log data	1.704748
Maximum of log data	5.659482
Mean of log data	3.38834
Standard Deviation of log data	1.06201
Variance of log data	1.127865

RECOMMENDATION

Data are lognormal (0.05)

Use H-UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.656135
Shapiro-Wilk 5% Critical Value	0.941
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	71.41698

Gamma Distribution Test	
A-D Test Statistic	1.459484
A-D 5% Critical Value	0.779013
K-S Test Statistic	0.166844
K-S 5% Critical Value	0.142178
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	71.10791
Adjusted Gamma UCL	71.86852

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.951353
Shapiro-Wilk 5% Critical Value	0.941
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	78.33075
95% Chebyshev (MVUE) UCL	94.62476
97.5% Chebyshev (MVUE) UCL	113.5075
99% Chebyshev (MVUE) UCL	150.599

95% Non-parametric UCLs	
CLT UCL	70.99678
Adj-CLT UCL (Adjusted for skewness)	75.17303
Mod-t UCL (Adjusted for skewness)	72.06839
Jackknife UCL	71.41698
Standard Bootstrap UCL	70.7144
Bootstrap-t UCL	78.23318
Hall's Bootstrap UCL	73.91156
Percentile Bootstrap UCL	72.0561
BCA Bootstrap UCL	75.95854
95% Chebyshev (Mean, Sd) UCL	100.2411
97.5% Chebyshev (Mean, Sd) UCL	120.5642
99% Chebyshev (Mean, Sd) UCL	160.485

Data File

Variable: Aq + Benth Invert U

Raw Statistics	
Number of Valid Samples	41
Number of Unique Samples	38
Minimum	1.3
Maximum	1170
Mean	173.3595
Median	29.6
Standard Deviation	283.2072
Variance	80206.3
Coefficient of Variation	1.633641
Skewness	2.379495

Gamma Statistics	
k hat	0.431361
k star (bias corrected)	0.416058
Theta hat	401.8897
Theta star	416.6714
nu hat	35.37159
nu star	34.11676
Approx.Chi Square Value (.05)	21.75555
Adjusted Level of Significance	0.044146
Adjusted Chi Square Value	21.39419

Log-transformed Statistics	
Minimum of log data	0.262364
Maximum of log data	7.064759
Mean of log data	3.648228
Standard Deviation of log data	1.982077
Variance of log data	3.928628

RECOMMENDATION

Data are Non-parametric (0.05)

Use 99% Chebyshev (Mean, Sd) UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.648937
Shapiro-Wilk 5% Critical Value	0.941
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	247.8354

Gamma Distribution Test	
A-D Test Statistic	1.254631
A-D 5% Critical Value	0.828743
K-S Test Statistic	0.153788
K-S 5% Critical Value	0.147244
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	271.8601
Adjusted Gamma UCL	276.452

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.930861
Shapiro-Wilk 5% Critical Value	0.941
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	858.6619
95% Chebyshev (MVUE) UCL	701.8605
97.5% Chebyshev (MVUE) UCL	901.151
99% Chebyshev (MVUE) UCL	1292.619

95% Non-parametric UCLs	
CLT UCL	246.1106
Adj-CLT UCL (Adjusted for skewness)	263.6731
Mod-t UCL (Adjusted for skewness)	250.5748
Jackknife UCL	247.8354
Standard Bootstrap UCL	245.8764
Bootstrap-t UCL	282.244
Hall's Bootstrap UCL	296.4817
Percentile Bootstrap UCL	251.2566
BCA Bootstrap UCL	262.3885
95% Chebyshev (Mean, Sd) UCL	366.1516
97.5% Chebyshev (Mean, Sd) UCL	449.5728
99% Chebyshev (Mean, Sd) UCL	613.4378

Data File

Variable: Aq Invert Se

Raw Statistics	
Number of Valid Samples	21
Number of Unique Samples	19
Minimum	5.9
Maximum	73
Mean	22.9619
Median	22.9
Standard Deviation	15.9683
Variance	254.9865
Coefficient of Variation	0.695426
Skewness	1.542473

Gamma Statistics	
k hat	2.39017
k star (bias corrected)	2.080463
Theta hat	9.60681
Theta star	11.03692
nu hat	100.3871
nu star	87.37944
Approx.Chi Square Value (.05)	66.82601
Adjusted Level of Significance	0.0383
Adjusted Chi Square Value	65.44538

Log-transformed Statistics	
Minimum of log data	1.774952
Maximum of log data	4.290459
Mean of log data	2.910297
Standard Deviation of log data	0.702703
Variance of log data	0.493792

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.85916
Shapiro-Wilk 5% Critical Value	0.908
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	28.9718

Gamma Distribution Test	
A-D Test Statistic	0.357367
A-D 5% Critical Value	0.752097
K-S Test Statistic	0.113626
K-S 5% Critical Value	0.191434
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	30.02421
Adjusted Gamma UCL	30.6576

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.953918
Shapiro-Wilk 5% Critical Value	0.908
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	33.17959
95% Chebyshev (MVUE) UCL	39.73834
97.5% Chebyshev (MVUE) UCL	46.9062
99% Chebyshev (MVUE) UCL	60.98607

95% Non-parametric UCLs	
CLT UCL	28.69351
Adj-CLT UCL (Adjusted for skewness)	29.94676
Mod-t UCL (Adjusted for skewness)	29.16728
Jackknife UCL	28.9718
Standard Bootstrap UCL	28.48517
Bootstrap-t UCL	30.4493
Hall's Bootstrap UCL	32.78777
Percentile Bootstrap UCL	28.95238
BCA Bootstrap UCL	29.82381
95% Chebyshev (Mean, Sd) UCL	38.15078
97.5% Chebyshev (Mean, Sd) UCL	44.72302
99% Chebyshev (Mean, Sd) UCL	57.63292

Data File

Variable: Aq Invert U

Raw Statistics	
Number of Valid Samples	21
Number of Unique Samples	19
Minimum	3.59
Maximum	1170
Mean	281.8319
Median	93.6
Standard Deviation	359.7171
Variance	129396.4
Coefficient of Variation	1.276353
Skewness	1.471851

Gamma Statistics	
k hat	0.422567
k star (bias corrected)	0.393946
Theta hat	666.9526
Theta star	715.4074
nu hat	17.7478
nu star	16.54573
Approx.Chi Square Value (.05)	8.347269
Adjusted Level of Significance	0.0383
Adjusted Chi Square Value	7.901585

Log-transformed Statistics	
Minimum of log data	1.278152
Maximum of log data	7.064759
Mean of log data	4.097734
Standard Deviation of log data	2.251388
Variance of log data	5.068747

RECOMMENDATION

Data are Non-parametric (0.05)

Use 99% Chebyshev (Mean, Sd) UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.771013
Shapiro-Wilk 5% Critical Value	0.908
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	417.2166

Gamma Distribution Test	
A-D Test Statistic	1.226729
A-D 5% Critical Value	0.820959
K-S Test Statistic	0.259199
K-S 5% Critical Value	0.202311
Data do not follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	558.6396
Adjusted Gamma UCL	590.1494

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.829357
Shapiro-Wilk 5% Critical Value	0.908
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	7594.32
95% Chebyshev (MVUE) UCL	2003.563
97.5% Chebyshev (MVUE) UCL	2634.969
99% Chebyshev (MVUE) UCL	3875.244

95% Non-parametric UCLs	
CLT UCL	410.9475
Adj-CLT UCL (Adjusted for skewness)	437.8868
Mod-t UCL (Adjusted for skewness)	421.4186
Jackknife UCL	417.2166
Standard Bootstrap UCL	405.9793
Bootstrap-t UCL	462.2907
Hall's Bootstrap UCL	497.1837
Percentile Bootstrap UCL	415.4448
BCA Bootstrap UCL	434.6886
95% Chebyshev (Mean, Sd) UCL	623.9911
97.5% Chebyshev (Mean, Sd) UCL	772.0436
99% Chebyshev (Mean, Sd) UCL	1062.864

Data File

Variable: B Invert Se

Raw Statistics	
Number of Valid Samples	20
Number of Unique Samples	17
Minimum	5.5
Maximum	287
Mean	85.1
Median	48.2
Standard Deviation	87.58721
Variance	7671.519
Coefficient of Variation	1.029227
Skewness	1.340085

Gamma Statistics	
k hat	1.038237
k star (bias corrected)	0.915835
Theta hat	81.96589
Theta star	92.92071
nu hat	41.52947
nu star	36.63339
Approx.Chi Square Value (.05)	23.77682
Adjusted Level of Significance	0.038
Adjusted Chi Square Value	22.95855

Log-transformed Statistics	
Minimum of log data	1.704748
Maximum of log data	5.659482
Mean of log data	3.890285
Standard Deviation of log data	1.156236
Variance of log data	1.336881

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.794112
Shapiro-Wilk 5% Critical Value	0.905
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	118.9652

Gamma Distribution Test	
A-D Test Statistic	0.482979
A-D 5% Critical Value	0.767163
K-S Test Statistic	0.185907
K-S 5% Critical Value	0.199204
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	131.1151
Adjusted Gamma UCL	135.7882

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.953496
Shapiro-Wilk 5% Critical Value	0.905
Data are lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	201.6776
95% Chebyshev (MVUE) UCL	207.7577
97.5% Chebyshev (MVUE) UCL	258.4152
99% Chebyshev (MVUE) UCL	357.9219

95% Non-parametric UCLs	
CLT UCL	117.3146
Adj-CLT UCL (Adjusted for skewness)	123.5854
Mod-t UCL (Adjusted for skewness)	119.9433
Jackknife UCL	118.9652
Standard Bootstrap UCL	116.5511
Bootstrap-t UCL	127.9937
Hall's Bootstrap UCL	119.3667
Percentile Bootstrap UCL	117.99
BCA Bootstrap UCL	123.46
95% Chebyshev (Mean, Sd) UCL	170.4695
97.5% Chebyshev (Mean, Sd) UCL	207.4089
99% Chebyshev (Mean, Sd) UCL	279.9692

Data File

Variable: B Invert U

Raw Statistics

Number of Valid Samples	20
Number of Unique Samples	20
Minimum	1.3
Maximum	301
Mean	59.4635
Median	25.65
Standard Deviation	77.38726
Variance	5988.788
Coefficient of Variation	1.301425
Skewness	2.060684

Gamma Statistics

k hat	0.669011
k star (bias corrected)	0.601993
Theta hat	88.88269
Theta star	98.77777
nu hat	26.76044
nu star	24.07971
Approx.Chi Square Value (.05)	13.90757
Adjusted Level of Significance	0.038
Adjusted Chi Square Value	13.29756

Log-transformed Statistics

Minimum of log data	0.262364
Maximum of log data	5.70711
Mean of log data	3.176246
Standard Deviation of log data	1.573993
Variance of log data	2.477455

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

Normal Distribution Test

Shapiro-Wilk Test Statisitic	0.740915
Shapiro-Wilk 5% Critical Value	0.905

Data not normal at 5% significance level

95% UCL (Assuming Normal Distribution)

Student's-t UCL	89.38496

Gamma Distribution Test

A-D Test Statistic	0.334879
A-D 5% Critical Value	0.786967
K-S Test Statistic	0.133401
K-S 5% Critical Value	0.20251

Data follow gamma distribution
at 5% significance level

95% UCLs (Assuming Gamma Distribution)

Approximate Gamma UCL	102.9557
Adjusted Gamma UCL	107.6787

Lognormal Distribution Test

Shapiro-Wilk Test Statisitic	0.948941
Shapiro-Wilk 5% Critical Value	0.905

Data are lognormal at 5% significance level

95% UCLs (Assuming Lognormal Distribution)

95% H-UCL	290.7972
95% Chebyshev (MVUE) UCL	208.7392
97.5% Chebyshev (MVUE) UCL	267.3381
99% Chebyshev (MVUE) UCL	382.4443

95% Non-parametric UCLs

CLT UCL	87.92657
Adj-CLT UCL (Adjusted for skewness)	96.44641
Mod-t UCL (Adjusted for skewness)	90.71388
Jackknife UCL	89.38496
Standard Bootstrap UCL	87.30319
Bootstrap-t UCL	107.2041
Hall's Bootstrap UCL	201.7739
Percentile Bootstrap UCL	89.944
BCA Bootstrap UCL	96.78
95% Chebyshev (Mean, Sd) UCL	134.8913
97.5% Chebyshev (Mean, Sd) UCL	167.5289
99% Chebyshev (Mean, Sd) UCL	231.6393

Appendix B

A Literature Review on the Toxicity of Selenium

Toxicity to Birds

Black-crowned night herons were fed diets containing Se as selenomethionine at concentrations of 0 and 10 mg/kg for 13 days prior to egg laying (Smith et al. 1988). Hatching success, organ weights, hemoglobin concentration, hematocrit and eggshell thickness did not differ between controls and experimental birds. Developmental malformations commonly associated with Se exposure were not observed in heron embryos or hatchlings. An ingestion rate of 0.161 kg/day (Kushlan 1978) and body weight of 0.883 kg (Dunning 1993) were used to convert the exposure concentrations to units of mg/kgBW/day. A NOAEL of 1.8 mg/kgBW/day and an estimated LOAEL of 18.0 mg/kgBW/day were calculated based on the results of this experiment.

A feeding study with mallard ducks was conducted to identify diagnostic criteria for Se toxicosis in birds (Albers et al. 1996). One-year old male mallards were fed diets containing 0, 10, 20, 40 or 80 mg/kg Se as seleno-DL-methionine for 16 weeks. All ducks receiving diets containing 80 mg/kg died; 15 % of the birds fed 40 mg/kg Se died. Food consumption and body weight were significantly decreased in birds that received the 40 mg/kg Se diet; muscular atrophy, delayed molt, sloughed or broken claws and loss of feathers from the head and neck were also observed in this group. Testis weights were significantly decreased in the males which received the 20 mg/kg diet. Proposed diagnostic criteria for non-fatal chronic selenosis were low body weight due mostly to loss of breast muscle mass, poor plumage, delayed molt, a liver Se concentration that exceeds 66 mg/kg dry weight, reduced hatching success or an increased number of musculoskeletal abnormalities in embryos, or eggs that have a concentration of Se exceeding 10 mg/kg dry weight. An ingestion rate of 0.139 kg/day and adult body weight of 1.25 kg (Piccirillo and Quesenberry 1980) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 2.2 mg/kgBW/day (20 mg/kg; effects on testis) and a NOAEL of 1.1 mg/kgBW/day (10 mg/kg) were calculated based on the results of this experiment.

American kestrels were fed diets containing Se (as selenomethionine) at concentrations of 0, 6 or 12 mg/kg (dry weight) for 11 weeks (Santolo et al. 1999). No differences in egg production, hatchability, or incidence of embryonic malformations were observed in any treatment group. Fertility was significantly lower in birds fed diets containing 12 mg/kg Se as compared to control birds. To convert the dietary concentration from dry to wet weight, a percent moisture content of 32 % (mean water content for small mammals; Sample and Suter 1994) was assumed, resulting in dietary exposure concentrations of 4.08 and 8.16 mg/kg. An ingestion rate of 0.0307 kg/day (Barrett and Mackey 1975) and body weight of 0.111 kg (Dunning 1993) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL

of 2.26 mg/kgBW/day and a NOAEL of 1.13 mg/kgBW/day were calculated based on the results of this experiment.

Wiemeyer and Hoffman (1996) evaluated dietary toxicity of Se (as selenomethionine) to Eastern screech owls. Owls were fed diets containing 0, 4.4 or 13.2 mg/kg Se (wet weight). Laboratory analysis of the diets confirmed the following exposure concentrations: not detected (ND) to 0.13 mg/kg for the control group, and 3.53 and 12 mg/kg for the two exposure groups. Adult body weight, number of eggs laid per pair, number of eggs hatched per pair, and number of nestlings surviving to five days were significantly lower for birds which received the highest dose. Control and low dosage birds did not differ in adult body weight, food consumption, or reproductive parameters. An ingestion rate of 0.025 kg/day (Pattee et al. 1988) and adult body weight of 0.185 kg (Dunning 1993) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 1.62 mg/kgBW/day and a NOAEL of 0.48 mg/kgBW/day were derived based on the results of this study.

Mallard ducks were fed diets containing Se as selenomethionine at concentrations of 0 and 10 mg/kg for 41 days prior to egg laying (Heinz et al. 1987). Birds exposed to dietary Se produced fewer young and had a higher incidence of abnormal embyros than controls. An ingestion rate of 0.139 kg/day and body weight of 1.25 kg (Piccirillo and Quesenberry 1980) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 1.11 mg/kgBW/day and an estimated NOAEL of 0.11 mg/kgBW/day were calculated based on the results of this experiment.

Heinz et al. (1989) evaluated dietary toxicity of organic Se as selenomethionine to mallard ducks. Ducks were exposed to diets containing 0, 1, 2, 4, 8 or 16 mg/kg Se diet (wet weight) for 100 days. Reduced duckling survival was observed in groups fed diets containing 8 mg/kg Se. Diets containing 8 and 16 mg/kg Se caused malformations in 6.8 and 67.9 %, respectively, of unhatched eggs compared with 0.6 % for controls. An ingestion rate of 0.10 kg/day and body weight of 1.0 kg (cited by authors) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 0.8 mg/kgBW/day and a NOAEL of 0.4 mg/kgBW/day were calculated. Based on the ecological significance of the endpoint (survival) and because the LOAEL is the lowest cited adverse effect level for birds, the TRV values from this study will be used to evaluate the risk posed by Se to avian receptors.

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Toxicity to Mammals

Male house rats (*Rattus rattus*) were fed diets containing Se (as sodium selenite) at concentrations of 0, 2 and 4 mg/kg for 5 weeks (Kaur and Parshad 1994). Ingestion of a diet containing Se at 4 mg/kg caused a significant decrease in sperm concentration, motility, the percentage of live spermatozoa, and testicular and cauda epididymal weight. A dose-dependant effect of Se on sperm morphology was observed; sperm from rats fed 2 mg/kg and 4 mg/kg dietary Se had three and 20 times more abnormalities than sperm from control rats, respectively. An ingestion rate of 0.016 kg/day (U.S. EPA 1988; value cited for 150 g Fischer 344 rats) and body weights of 0.14 and 0.15 kg (cited by authors for rats from the 4 and 2 mg/kg groups, respectively) were used to convert the exposure units to mg/kgBW/day. A LOAEL of 0.46 mg/kgBW/day and a NOAEL of 0.21 mg/kgBW/day were calculated based on the results of this experiment.

Rosenfeld and Beath (1954) evaluated toxicity of Se in drinking water to rats. Rats were exposed to potassium selenate at concentrations of 1.5, 2.5 and 7.5 mg/L for one year. No adverse effects on reproduction were observed among rats exposed to 1.5 m/L Se, but the number of second generation

young was reduced by 50 % in the group exposed to 2.5 mg/L. An ingestion rate of 0.046 L/day and body weight of 0.35 kg (U.S. EPA 1988) were used to convert the exposure concentrations to units of mg/kgBW/day. A LOAEL of 0.33 mg/kgBW/day and a NOAEL of 0.20 mg/kgBW/day were calculated based on the results of this experiment.

Long-Evans rats were given drinking water containing Se (either as sodium selenite or sodium selenate) at concentrations of 0 or 2 Φg/ml for 180 days (Schroeder 1967). Mice (Charles River CD strain) were given selenite in drinking water at a concentration of 0 or 2 Φg/ml for 360 days. Increased mortality was observed in rats given selenite in drinking water (58 and 30 % after two months for males and females, respectively). Livers of rats that died were grossly abnormal, with fatty infiltration and degeneration, and cellular atrophy. No adverse effects were observed in mice. A water ingestion rate of 0.053 L/day and body weight of 0.43 kg (U.S. EPA 1988) were used to convert the exposure concentrations to units of mg/kgBW/day. Based on the mortality observed in rats, a LOAEL of 0.25 mg/kgBW/day and an estimated NOAEL of 0.025 mg/kgBW/day were calculated based on the results of this experiment. Based on the ecological significance of the endpoint (survival) and because the LOAEL is the lowest cited adverse effect level for mammals, the TRV values from this study will be used to evaluate the risk posed by Se to mammalian receptors.

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Appendix C

A Literature Review on the Toxicity of Uranium

Toxicity to Birds

Kupsh et al. (1991) evaluated renal damage in Japanese quail exposed to uranyl nitrate. Uranyl nitrate solution at concentrations of 0.15 or 50 micromoles per kilogram (ΦMol/kg) BW as uranium (U) was administered intravenously. Eighteen hours later, the quail were sacrificed and the kidneys were examined. Severe damage was observed in the quail exposed to a U concentration of 50 ΦMol/kg body weight, particularly in the distal tubules. Glomerular damage was marked in quail kidneys, with atrophy, necrosis, and proteinuria. Due to the exposure route, this study was not used to derive a TRV for U to birds. Only studies that evaluated oral exposure to U were used to derive a TRV for this risk assessment, which is evaluating dietary exposure to contaminants of concern.

Three-week old Leghorn chicks were injected with 0 or 250 mg uranyl nitrate/kg BW (Mollenhauer et al. 1986). Dosages were administered subcutaneously at the base of the neck. Degenerative changes were observed in kidneys of U-treated birds, and were present in the proximal and distal tubules and collecting ducts. Kidneys of chickens, like those of mammals, were confirmed as a site of U storage. Due to the exposure route, this study was not used to derive a TRV for U to birds.

One-day old Leghorn cockerels (Hy-Line, W-36) were administered doses of uranyl nitrate by subcutaneous injection at concentrations of untreated controls, saline controls, 70, 100, 130, 160, 190, 220, 250, 280, 310, 340, 370, 400, 430, or 460 mg UN/kg BW (Harvey et al. 1986). Mortality was monitored for seven days and an LD_{50} value was calculated. The lowest dose that resulted in mortality was 160 mg/kg BW. The 7-day LD_{50} for uranyl nitrate was 235 mg/kg BW. Microscopic examination revealed mild focal proximal convulated tubular degeneration in kidneys within 12 hours of injection. At 48 hours, renal lesions included moderate to severe nephrosis, cellular and protein casts, and some regeneration. By 96 hours, no major lesions in kidneys were observed. Severe hepatic necrosis was present in liver sections. Due to the exposure route, this study was not used to derive a TRV for U to birds.

Japanese quail were given intravenous injections of UCl_3 or $OU(NO_3)$ at a concentration of 1.5 Φmol/100g to evaluate distribution in tissues and eggs (Robinson et al. 1984). Whole body losses 18 hours following injection were 24% for females and 72% for males. Cumulative deposition in yolks of eggs laid over 8 days following injection were 1.9% for U(III) and 1.7% for U(VI). Marked deposition of U was observed in leg bones of female quail [12.5% for U(III) and 14.1% for U(VI)]. Tissue distribution

was the only effect measured in this experiment. Due to the exposure route, this study was not used to derive a TRV for U to birds.

American black ducks were fed diets containing powdered U at concentrations of 0, 25, 100, 400 or 1,600 mg/kg for 6 weeks (Haseltine and Sileo 1983). One male in the 100 mg/kg treatment group died during the experiment, but pathological kidney changes associated with U toxicity in mammals were not observed; the authors did not attribute the death to U exposure. Treatment-related weight loss was not observed at any exposure concentration. No significant gross or microscopic lesions were observed in birds exposed at any concentration. Examination of the kidneys did not reveal any lesions in the distal third of the proximal convoluted tubule, which is characteristic of U exposure in mammals. A body weight of 1.25 kg (Dunning 1993) and an ingestion rate of 0.125 kg/day (Heinz *et al.* 1989) were used to convert the exposure concentrations to units of mg/kgBW/day. A NOAEL of 160 mg/kgBW/day and an estimated LOAEL of 1600 mg/kgBW/day will be used to evaluate the toxicity of U to avian receptors.

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Toxicity to Mammals

Acute toxicity of U to male Sprague-Dawley rats and male Swiss mice was evaluated by (Domingo *et al.* 1987). Single doses of uranyl acetate were administered by subcutaneous injection or orally via gavage. Oral and subcutaneous exposure concentrations for rats were 0, 20, 40, 80, 160, 320, 640 or 1,280 mg/kg and 0, 1.25, 2.5, 5, 10, 20, or 40 mg/kg. Exposure concentrations for mice were 0, 44, 80, 144, 259, 466, or 839 mg/kg and 0, 10, 15, 22.5, 33 or 50 mg/kg. For animals whose exposure was via gavage, LD_{50}

concentrations were 204 and 242 mg/kg for rats and mice, respectively. The LD_{50} values for subcutaneous exposure were much lower, 8.3 mg/kg for rats and 20.4 mg/kg for mice.

Sprague-Dawley rats were given uranyl nitrate hexahydrate in drinking water at concentrations of 0, 0.96, 4.8, 24, 120 or 600 mg/L for 91 days (Gilman *et al.* 1998a). At the end of the study, animals were euthanized and hematological, biochemical and histopathological analyses were conducted. No significant differences in weight gain, food consumption, or water intake were observed at any exposure concentration. Significant histopathological changes were observed in the kidney and liver. Incidence and severity of renal lesions were significantly different from control animals at all U exposure concentrations. A LOAEL of 0.06 and 0.09 mg/kgBW/day for male and female rats, respectively, (units reported by authors) and estimated NOAEL of 0.006 and 0.009 mg/kgBW/day were identified from this study. The biological significance of kidney lesions is not known; therefore, this study was not used to select a TRV for this risk assessment.

New Zealand white rabbits were given uranyl nitrate hexahydrate in drinking water for 91 days (Gilman *et al.* 1998b). Males were exposed at concentrations of 0, 0.96, 4.8, 24, 120 or 600 mg/L, while exposure concentrations for females were 0, 4.8, 24 or 600 mg/L. At the end of the study, animals were euthanized and hematological, biochemical and histopathological analyses were conducted. No significant differences in weight gain, food consumption, or water intake were observed for either sex at any exposure concentration. Significant dose-related histopathological changes were observed in the kidney and thyroid glands, and to a lesser extent in the liver. Incidence and severity of renal lesions were significantly different from control animals at all U exposure concentrations. A LOAEL of 0.05 mg/kgBW/day (units reported by authors) and an estimated NOAEL of 0.005 mg/kgBW/day were identified from this study. The biological significance of kidney lesions is not known; therefore, this study was not used to select a TRV for this risk assessment.

Sprague-Dawley rats were exposed to uranyl acetate dihydrate in drinking water at concentrations of 0, 2, 4, 8 and 16 mg/kgBW/day for 4 weeks (Ortega *et al.* 1989). No significant differences in weight gain, food or water consumption were observed at any exposure concentration. Histopathological lesions in kidneys, liver and spleen were observed in rats exposed at a concentration of 16 mg/kgBW/day. A LOAEL of 16 mg/kgBW/day and a NOAEL of 8 mg/kgBW/day were identified from this experiment. The biological significance of kidney lesions is not known; therefore, this study was not used to select a TRV for this risk assessment.

Reproductive toxicity of uranyl acetate to male Swiss mice was evaluated by (Llobet *et al.* 1991). Mice were exposed to U in drinking water at concentrations of 0, 10, 20, 40 or 80 mg/kgBW/day for 64 days. At the end of the treatment period, each mouse was mated with two untreated females for four days. There was a significant decrease in pregnancy rate for all females mated to U exposed mice. Number of implantations, resorptions and dead fetuses did not differ in females that became pregnant. Adult body weights were significantly lower than controls for the 80 mg/kgBW/day exposure group. Testicular function and spermatogenesis were not significantly different from controls for any exposure group. Based on the decreased pregnancy rate, a LOAEL of 10 mg/kgBW/day and an estimated NOAEL of 1.0 mg/kgBW/day were identified from this experiment.

Swiss mice were administered uranyl acetate dihydrate at concentrations of 0, 5, 10, and 25 mg/kgBW/day (Paternian *et al.* 1989). Male mice were exposed for 60 days prior to mating, and female mice were exposed for 14 days prior to mating. Treatment of the females continued throughout mating, gestation, and nursing of the litters. Oral doses were given intragastrically. No adverse effects on fertility were observed at any exposure concentration. Numbers of late resorptions and dead fetuses were significantly increased for the 25 mg/kg/day exposure group. There was a significant increase in the number of dead young per litter for both the 10 and 25 mg/kg/day exposure groups. Growth of the offspring was significantly lower in all U-treated groups, and a significant dose-response relationship was observed. Based on the reduced growth, a LOAEL of 5 mg/kgBW/day and an estimated NOAEL of 0.5 mg/kgBW/day were identified.

To evaluate developmental toxicity of U, pregnant Swiss mice were given by gavage daily doses of 0, 5, 10, 25 and 50 mg/kgBW/day of uranyl acetate dihydrate on gestational days 6 to 15 (Domingo *et al.* 1989). Maternal toxicity was observed. Maternal weight gain was significantly lower in the 10, 25 and 50 mg/kg exposure groups, and food consumption was significantly lower in all U-exposed mice. Relative liver weights were significantly higher in all exposed females. There were no treatment-related effects on number of implantations, incidence of post-implantation loss, number of live fetuses per litter, or fetal sex ratio. Body weights of live fetuses were significantly reduced in all U-treated groups, and a significant dose-response relationship was observed. Uranium treatment resulted in a significantly increased incidence of external malformations (cleft palate, short or curled tails, hematoma) at all exposure concentrations. An increased incidence of poorly ossified or unossified skeletal elements was observed in mouse fetuses at exposure concentrations of 25 and 50 mg/kgBW/day. Based on the reduced fetal weight and increased incidence of external malformations, a LOAEL of 5 mg/kgBW/day and a estimated NOAEL of 0.5 mg/kgBW/day were identified from this experiment, and will be used to evaluated risk to mammals from exposure to U.

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Appendix D

Literature Review of Toxicity Data to Develop Selenium Toxicity Reference Values

Selenium

Species		Se (ppm)	Effect	Reference
MAMMALS-DIETARY				
General		0.1	Safe limit	Kabata-Pendias and Kabata (1992)
Swine		0.13	NOAEL	Lindberg (1968)
General		2	Safe limit	Hapke (1991a)
Swine		2.5	NOAEL	Moxon and Mahan (1981)
Rat		3.75	Increased reproduction	Halverson (1974)- DW=WW/0.2
General		4.5	Critical conc.	NAS (1980a), Underwood (1977)
General		5	Upper critical conc.	Davis et al. (1978)
General		5	Safe limit	NAS (1980)
Pronghorn antelope		15	NOAEL	Raisbeck et al. (1996)
Cattle		4	LOAEL	Underwood (1977)
General		4	Toxic	Hapke (1991a)
Cattle		5	Toxic	NAS (1976), Underwood (1977), Cumbie and Van Horn (1978)
Dogs		5	Chronic poisoning	Munsell et al. (1936)
Swine		5	Weight loss	Moxon and Mahan (1981)
Rat		5	Toxic	NAS (1976)
General		5	Prevented normal growth	Rosenfeld and Beath (1964)
Dogs		7.2	Toxic	Olson (1986)
Sheep		8	Weight loss	Pierce and Jones (1968)
General		9	Lethal to juveniles	Rosenfeld and Beath (1964)
Swine		10	Reduced reproduction	Wahlstrom and Olson (1959)
Swine		10	Selenosis	Rosenfeld and Beath (1954)
Sheep		10	Toxic	Hapke (1991a)
General		10	Decreased adult food intake	Rosenfeld and Beath (1964)
General		10	Decreased reproduction	Wahlstrom and Olson (1959)
Sheep		16	Some mortality	Pierce and Jones (1968)
Dogs		20	Lethal	Munsell et al. (1936)
Swine		20	Toxic/lethal	Moxon and Mahan (1981)
Human		3300	Hair loss, nail splitting	Dickson (1969)
MAMMALS-IN TISSUE				
Human	Lung	0.21	NOAEL	Berman (1980)
	Heart	0.27	NOAEL	Bowen (1979)
	Liver	0.39	NOAEL	Berman (1980)
	Muscle	0.4	NOAEL	Berman (1980)
	Body	0.53	NOAEL	Fergusson (1990), DW=WW/0.35
	Kidney	0.63	NOAEL	Berman (1980)
	Body	0.83	NOAEL	Kieffer (1979), DW=WW/0.35
	Lung	1	NOAEL	Anspaugh et al. (1971), DW=WW/0.2
	Liver	1.45	NOAEL	Brune et al. (1974), DW=WW/0.2
	Muscle	2	NOAEL	Anspaugh et al. (1971), DW=WW/0.2
	Kidney	3.95	NOAEL	Brune et al. (1974), DW=WW/0.2
	Body	12.9	NOAEL	Stewart et al. (1978), DW=WW/0.35

Selenium, Continued

Species	Se (ppm)	Effect	Reference
MAMMALS-IN TISSUE			
Swine			
Muscle	0.52	NOAEL	Lindberg (1968)
Heart	1.05	NOAEL	Lindberg (1968)
Lung	1.13	NOAEL	Lindberg (1968)
Spleen	1.26	NOAEL	Lindberg (1968)
Pancreas	1.42	NOAEL	Lindberg (1968)
Liver	1.82	NOAEL	Lindberg (1968)
Kidney	11.47	NOAEL	Lindberg (1968)
MAMMALS-DIETARY WATER			
Human	0.05	Safe drinking water	EPA MCL
Hamster	3	NOAEL	Hadjimarkos (1970)
Monkey	11	Lesions	Bowen (1972)
Rats	12	Tumor production	Schroeder and Mitchner (1971a)
Rats	3	Toxic	Hadjimarkos (1970)
Hamster	9	LOAEL	Beath (1962)
AVIFUANA-DIETARY			
Chicken- juvenile	2	NOAEL	Arnold et al. (1973)
Mallard- juvenile	10	NOAEL	O'Toole and Raisbeck (1997)
Chicken- juvenile	3	Min toxic level	Munsell et al. (1936)
Chicken- juvenile	5	Reduced hatching	Moxon and Polley (1938)
Chicken- juvenile	8	Reduced hatching	Arnold et al. (1973)
Chicken- juvenile	10	0% hatching	Moxon and Polley (1938)
Chicken- juvenile	10	20% growth red	Berg and Martinson (1972)
Mallard- juvenile	25	Lesions, weight loss	O'Toole and Raisbeck (1997)
AVIFAUNA-IN TISSUE			
Barn swallow	7.5-11	NOAEL	US Bureau of Reclamation (1988)
Coot-liver	8.5	NOAEL	Stephen et al. (1992)
Meadowlark	22	NOAEL	US Bureau of Reclamation (1988)
INVERTEBRATES DIETARY AQUATIC			
Daphnia magna	295	NOAEL	Foe and Knight (1986)
INVERTEBRATES-WATER AQUATIC			
Daphnia magna	0.15	NOAEL	Foe and Knight (1986)
Crabs	1	LC50-96hr	Forstner and Wittmann (1981)
Daphnia magna	1.99	Toxic	Dunber et al. (1983)

Selenium, Continued

Species	Se (ppm)	Effect	Reference
PLANTS / GRASS-TISSUE			
General	0.032	NOAEL	Fergusson (1990)
General	0.033	NOAEL	Kabata-Pendias and Pendias(1992)
Wheat	0.7	NOAEL	Zook et al. (1968)
Wheat	0.7	NOAEL	Lindberg (1968)
Wheat	0.8	NOAEL	Scott and Thompson (1971)
General	1	NOAEL	Bennet (1983)
Wheat	2.2	NOAEL	Fergusson (1990)
Barley	30	Upper critical concentration	Davis et al. (1978)
PLANTS / FORB TISSUE			
General	0.1	NOAEL	Hapke (1991b)
Alfalfa	0.1	NOAEL	Kabata-Pendias and Pendias(1992)
Clover	0.1	NOAEL	Kabata-Pendias and Pendias(1992)
Brassica oleracea	0.13	NOAEL	Bowen (1974)
Kale	0.13	NOAEL	Fergusson (1990)
Cabbage	0.15	NOAEL	Fergusson (1990)
Clover	0.32	NOAEL	Allaway and Hodgson (1964), Gissel-Nielsen (1975)
General	1	NOAEL	Kabata-Pendias and Pendias(1992)
General	2	NOAEL	Fergusson (1990)
Neptunia amplexicaulis	4000	NOAEL	Knott and McCay (1959), highly tolerant
Astragulas racemosis	14920	NOAEL	Knott and McCay (1959), highly tolerant
General	5	Toxic	Fergusson (1990)
General	15	Growth reduction	Kloke et al. (1984)
General	18	Toxic	Kabata-Pendias and Pendias(1992)
PLANTS / WOODY-TISSUE			
Angiosperms	0.03	NOAEL	Conner and Shacklette (1975)
Gymnosperms	0.03	NOAEL	Conner and Shacklette (1975)
PLANTS / AQUATIC-WATER			
Algae			
Green	0.01	NOAEL	Bowen (1979)
General	0.05	NOAEL	Foe and Knight (1986)
Chorella spp.	0.03	Toxic	Hutchinson (1979)
Selenastrum spp.	0.03	Toxic	Foe and Knight (1986)
Selenastrum spp.	0.1	Sublethal	Knight et al. (1987)
Selenastrum spp.	0.1	Decreased replication	Foe and Knight (1986)
Scenedesmus spp.	0.1	Reduced growth	Moede et al. (1979)
Chorella spp.	0.13	Toxic	Shrift (1954)
Selenastrum spp.	0.3	Reduced growth	Vocke et al. (1980)
Scenedesmus spp.	2.2-1	Reduced growth	Moede et al. (1979)

Selenium, Continued

Species	Se (ppm)	Effect	Reference
PLANTS / AQUATIC-WATER			
Blue-green			
Anabaena spp.	0.025	Toxic	Kumar and Prakash (1971)
Phormidium spp.	0.56	Toxic	Sielicki and Burnham (1973)
Microcoleus spp.	52	Toxic	Vocke et al. (1980)
Microcoleus spp.	10	Reduced growth	Vocke et al. (1980)
Anabaena spp.	20	Toxic	Moede et al. (1979)
Anabaena spp.	22	Reduced growth	Moede et al. (1980)
Anacystis spp.	39	Toxic	Kumar and Prakash (1971)
Lemna minor	2	LOAEL - >10% growth decrease	Zayed et al. (1998)

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Appendix E

Literature Review of Toxicity Data to Develop Uranium Toxicity Reference Values

Uranium

Species	U(ppm)	Effect	Ref
MAMMALS-DIETARY			
Ruminants	0.4	Max. recommended level	Dreesel and Marple (1979)
Mice	2-237	NOAEL	NAS (1980)
Rats	474	NOAEL	NAS (1980)
Rats	500	Tolerated	Venugopal and Luckey (1978), soluble U salts
Rats	200000	Tolerated	Venugopal and Luckey (1978), insoluble U salts
Rabbit	56	LOAEL: renal damage	IRIS (1999); Maynard and Hodge (1949)
Rats	>500	Growth depression	Venugopal and Luckey (1978), soluble U salts
Rats	1000-4000	Mortality	Venugopal and Luckey (1978), soluble U salts
Rats	2370	Growth depression	NAS (1980)
Mice	2370	Growth depression	NAS (1980)
Mice	4740	Mortality	NAS (1980)
Rats	9480	Mortality	NAS (1980)
MAMMALS-IN-TISSUE			
Elk			
Muscle	0.002-0.005	NOAEL	Fresquez et al. (1994)
Brain	0.0032-0.0045	NOAEL	Fresquez et al. (1994)
Liver	0.006-0.009	NOAEL	Fresquez et al. (1994)
Heart	0.011-0.019	NOAEL	Fresquez et al. (1994)
Kidney	0.022-0.134	NOAEL	Fresquez et al. (1994)
Human			
Liver	0.003	NOAEL	Iyengar et al. (1978)
Kidney	0.017	NOAEL	Iyengar et al. (1978)
Body	0.09	NOAEL	Snyder (1975)
Bone	0.12	NOAEL	Bowen (1979)
Muscle	0.36	NOAEL	Bowen (1979)
Rabbit			
Bone	0.05	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
Kidney	0.16-0.42	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
Muscle	0.29	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
Heart	0.455	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
Liver	0.68	NOAEL	Ferretti and Schwartz (1951), DW=WW/0.2
General: kidney	1	Renal damage	Berlin and Rudell (1977)
MAMMALS-DIETARY WATER			
Human	0.035	Safe limit	NAS (1983)
Mice	26-235	Decreased pregnancy rate	Elobet et al. (1991); non-dose dependent
Mice	235	Decreased body weight	Elobet et al. (1991)
AVIFAUNA-DIETARY			
Am. black duck	25-1600	NOAEL	Haseltine and Sileo (1983)
Species	**U(ppm)**	**Effect**	**Ref**
AVIFAUNA-IN TISSUE			
Japanese quail	0.08	NOAEL	Robinson et al. (1984), DW=WW/0.35
Ruffed grouse			
Liver	0.2	NOAEL	Clulow et al. (1992)
Muscle	0.2	NOAEL	Clulow et al. (1992)
Bone	0.4	NOAEL	Clulow et al. (1992)

Uranium, Continued

Species	U(ppm)	Effect	Ref
INVERTEBRATES-SOIL TERRESTRIAL			
Lumbricus terrestris	3-100	NOAEL	Sheppard et al. (1992)
Lumbricus terrestris	>1000	Decreased longevity	Sheppard et al. (1992)
INVERTEBRATES-TISSUE TERRESTRIAL			
Blackflies	2.85	NOAEL	Swanson (1985), DW=WW/0.2
Dragonflies	4.75	NOAEL	Swanson (1985), DW=WW/0.2
Caddisflies	22	NOAEL	Swanson (1985), DW=WW/0.2
INVERTEBRATES-WATER AQUATIC			
Cladoceran- Moinodaphnia macleayi	0.01	NOAEL	Hyne et al. (1993)
Cladoceran- Moinodaphnia macleayi	>0.025	Decreased survival	Hyne et al. (1993)
Daphnia magna	0.52	Decreased reproduction	Poston et al. (1984)
Daphnia magna	1.44	No reproduction	Poston et al. (1984)
Daphnia magna	5.3	LC50-48hr-67ppm CaCO3	Poston et al. (1984)
Daphnia magna	44.6	LC50-48hr-126ppm CaCO3	Poston et al. (1984)
Daphnia magna	74.3	LC50-48hr-188ppm CaCO3	Poston et al. (1984)
PLANTS / GRASS-TISSUE			
Corn	0.008	NOAEL	Laul et al. (1979)
Sporobolius airoides	0.05-0.17	NOAEL	Dreesen and Marple (1979)
Calamagrostis rubescens	0.06	NOAEL	Mahon and Mathewes (1983)
General	36	NOAEL	Dreesen et al. (1982)
PLANTS / GRASS-IN SOIL			
Sporobolius airoides	2-176	NOAEL	Dreesen and Marple (1979)
Aristida purpurea	50-5000	NOAEL	Meyer and McLendon (1997)
Buchloe dactyloides	50-5000	NOAEL	Meyer and McLendon (1997)
Schizachyrium scoparium	50-5000	NOAEL	Meyer and McLendon (1997)
Aristida purpurea	25000	Decreased survival, biomass, fecundity	Meyer and McLendon (1997)
Buchloe dactyloides	25000	Decreased survival, biomass, fecundity	Meyer and McLendon (1997)
Schizachyrium scoparium	>25000	Decreased survival, biomass, fecundity	Meyer and McLendon (1997)
Species	**U(ppm)**	**Effect**	**Ref**
PLANTS / FORB TISSUE			
Brassica oleracea	0.011	NOAEL	Bowen (1979)
Lupinus articus	0.025	NOAEL	Mahon and Mathewes (1983)
Equisetum	0.03	NOAEL	Wahlgren et al. (1976)
Epilobium angustifolium	0.03	NOAEL	Mahon and Mathewes (1983)
General	0.04	NOAEL	Cali (1976)
General	0.12	NOAEL	Bowen (1979)
Astraglus spp	0.12	NOAEL	Zafrir et al. (1992), DW=AW/0.1
Cleome droserifolia	0.185	NOAEL	Zafrir et al. (1992), DW=AW/0.1
Aster subspicatus	0.32	NOAEL	Mahon and Mattewes (1983)
Annuals	12	NOAEL	Dressen et al. (1982)

Uranium, Continued

Species	U(ppm)	Effect	Ref
PLANTS / FORB-IN SOIL			
General	2	Beneficial	Stoklasa and Penkava (1928)
Brassica rapa	50-300	NOAEL	Sheppard et al. (1992)
Geranium spp	500	NOAEL	Free (1917)
General	48	LOAEL	Stoklasa and Penkava (1928)
General	476	Thin roots, twisted leaves	Stoklasa and Penkava (1928)
Brassica rapa	1000	Decreased germination	Sheppard et al. (1992)
General	10000	Lethal	Stoklasa and Penkava (1928)
PLANTS / WOODY-TISSUE			
General	0.28	NOAEL	Bowen (1979)
Angiosperms	0.022	NOAEL	Cannon (1960)
Acacia raddiana	0.095	NOAEL	Zafrir et al. (1992), DW=AW/0.1
Betula papyrifera- twig	0.19	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Alnus rugosa- twig	0.29	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Betula papyrifera- leaves	0.51	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Alnus rugosa- leaves	0.54	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Gymnosperms			
Juniper- fruit	0.05-0.1	NOAEL	Cannon (1952), DW=AW/0.1
Picea mariana- terminal 15cm	0.13-0.22	NOAEL	Sheard (1986)
Picea spp- twig	0.19-0.28	NOAEL	Dunn (1981)
Pinus banksiana- twig	0.2	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Pinus banksiana- needles	0.24	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Picea mariana- twig	0.28	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Juniper- stems	0.38	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Picea mariana- needles	0.38	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Juniper- needles	0.48	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Pinus banksiana– terminal 15cm	0.57	NOAEL	Sheard (1986)
Juniper- roots	0.8-2	NOAEL	Cannon (1952), DW=AW/0.1
Species	**U(ppm)**	**Effect**	**Ref**
PLANTS / WOODY TISSUE (continued)			
Shrubs			
Atriplex canescens	0.01-3	NOAEL	Dressen and Marple (1979)
Saltbrush- stems	0.05	NOAEL	Cannon (1952), DW=AW/0.1
Saltbrush- fruits	0.09	NOAEL	Cannon (1952), DW=AW/0.1
Artemesia judaica	0.1	NOAEL	Zafrir et al. (1992), DW=AW/0.1
Alnus crispa- terminal 15cm	0.13	NOAEL	Sheard (1986)
Ledum spp- terminal 15cm	0.16-0.19	NOAEL	Sheard (1986)
Saltbrush- leaves	0.19	NOAEL	Cannon (1952), DW=AW/0.1
Ledum spp- stem	0.19	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Ledum spp- leaves	0.34	NOAEL	Sheppard and Thibault (1984), DW=AW/0.1
Vaccinium myrtilloides	0.51-0.61	NOAEL	Sheard (1986)
Vaccinium vitis-idaea	0.22-0.29	NOAEL	Sheard (1986)

Uranium, Continued

Species	U(ppm)	Effect	Ref
PLANTS / WOODY-IN SOIL			
Atriplex canescens	1.5-176	NOAEL	Dressen and Marple (1979)
PLANTS / AQUATIC-WATER			
Nuphar lutea	0.2-0.34	NOAEL	Mahon and Mathewes (1983)
PLANTS / AQUATIC-WATER			
Nuphar lutea	0.08-0.7	NOAEL	Mahon and Mathewes (1983)
PLANTS / AQUATIC-SEDIMENT			
Nuphar lutea	14-15	NOAEL	Mahon and Mathewes (1983)

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Appendix F

Wildlife Field Notes for Visits to Highland Pit Lake

Avian Activity and Abundance, Highland pit lake				
Species	**# of Birds**	**Activity**	**Location**	**Weather**
9/13/2004				
Canada geese	4	Fly-by	NW corner of pitlake	Sunny, Windy
Eared grebe	1	Juvenile, floating/feeding	Near cattails	
Eared lark	2	Flying	Near cattails	
Marshhawk	1	Flying	Near cattails	
Yellow-headed blackbird	8	Flying	Near cattails	
Sum		**16**		
9/14/2004				
Blue-winged teal	7	Flying, floating	Throughout pitlake	Sunny, pleasant
Franklin's gull	17	Fly-by	North part of lake	
Golden Eagle	2	Yearling+ adult; Hunting, stooping at gulls	North end of pitlake	
Eared grebe	2	Juvenile + adult, floating/feeding	Near cattails	
Eared grebe	3	Flying	Near cattails	
Marshhawk	2	Flying	Near cattails	
Northrn harrier	1	Flying	Near cattails	
Yellow-headed blackbird	2	Flying	Near cattails	
Sum		**16**		
9/15/2004				
Blue-winged teal	7	Floating	Throughout pitlake	Sunny, pleasant
Falcon	3	Flying	Throughout pitlake	
Franklin's gull	12	Floating	Throughout pitlake	
Golden Eagle	2	Yearling+ adult; Hunting	North end of pitlake	
Eared grebe	2	Juvenile + adult, floating/feeding	Near cattails	
Eared grebe	8	Flying	Near cattails	
Marshhawk	2	Flying	Near cattails	
Shoveler	10	Floating	Throughout pitlake	
Sum		**46**		
10/25/2004				
Blue-winged teal	50	Floating	North end of pitlake	Sunny, Windy
Golden Eagle	1	Soaring	Over lake	
Horned lark	3	Flying	Near cattails	
Marshhawk	1	Flying	Near cattails	
Sum		**55**		
10/26/2004				
Blue-winged teal	60	Floating	W end of lake	Sunny, Windy
Franklin's gull	6	Flying	Over lake	
Golden Eagle	2	Soaring	Near turnoff to pitlake	
Horned grebe	8	Floating/diving	W end of lake	
Horned lark	8	Flying	Near turnoff to pitlake	
Mallard	12	Flying	Over lake	
Marshhawk	1	Soaring	Near turnoff to pitlake	
Sum		**97**		

Avian Activity and Abundance, Highland pit lake, Cont'd

Species	# of Birds	Activity	Location	Weather
10/27/2004				
Blue-winged teal	80	Flying over lake	Over lake	Sunny, Windy
Herring gull	1	Swooping down to lake	Lake center	
Horned grebe	15	Floating/diving, W end of lake	W end of lake	
Horned lark	8	Flying near turnoff to pitlake	Near turnoff to pitlake	
Marshhawk	1	Flying	Near cattails	
Sum		**105**		
2/21/2005				
Canada geese	1	Walking	On point bar - N shore	Cloudy, windy
Pintail	0	Old bird nest	30 feet from shore above littoral zone in tall grass clump	
Sum		**1**		
2/22/2005				
Canada geese	45	Flying overhead	North end of pitlake	Sunny, windy
Sum		**45**		
2/23/2005				
Golden Eagle	1	Flying	Over uplands west of pit lake	Cloudy, windy
Sum		**1**		
2/24/2005				
Canada geese	18	10 landing; 8 resting	Northern arm of pit lake; West shoreline	Sunny, pleasant
Sum		**18**		
3/23/2005				
Canada geese	14	Lesser Can's N end of lake	North end of pitlake	Partly sunny, calm
Golden Eagle	1	Soaring	Boner property - over nests	
Great horned owl	1	Nesting	By gate entrance	
Mallard	7	Floating	SW lake location 3	
Marshhawk	3	2 females - male courting displays, flying	Near boat ramp	
Pintail	1	Floating	SW location 3	
Scaup	2	Floating	N end of lake	
Short-eared owl	1	Flying	S of lake near Boner	
Sum		**30**		
3/24/2005				
Canada geese	4	Two separate pairs; look like ready to nest	Near point at lake center	Very windy, snowy
Short-eared owl	2	Flying	S of pit lake	
Sum		**6**		
4/6/2005				
Canada geese	6	Floating pairs; males fought	2 on W end of lake; 2 center of lake; 2 near point	Sunny
Great horned owl	1	Sitting on nest	Nest at S tree near entrance	
Horned lark	12	Flying/landing	Along road	
Kestrel	1	Flying	Near trees at entrance	
Mallard	4	2 flying; 2 floating	2 near W end of lake; 2 on lake near W wall	
Marshhawk	1	Flying	Near W end of lake	

Avian Activity and Abundance, Highland pit lake, Cont'd

Species	# of Birds	Activity	Location	Weather
Redtail hawk	1	Nesting	In trees 200yds N of owl	
Rough legged hawk	1	Soaring	1/2 mile S of lake	
Short-eared owl	1	Flying	W of lake	
Western meadowlark	1	Calling	Near W wetlands	
Sum		**29**		
4/11/2005				
Canada geese	2	1 male floating; female resting on nest	Male near point bar; female on nest at point bar	Very windy
Lesser scaup	2	Floating	In water at Location #3	
Mallard	5	Floating	In water at Location #4	
Sum		**9**		
4/12/2005				
Canada geese	4	2 pairs: 3 floating; 1 sitting on 4 eggs	Near point on pit lake; nest on point bar	Sunny, calm
Great horned owl	2	Sitting in nests	Near gate entrance; near S wetlands	
Killdeer	1	Flying/landing	At point bar	
Pintail	15	Floating	On lake at location # 3	
Rough-legged hawk	1	Flying	SE of boat ramp	
Short-eared owl	1	Flying	S of lake near ridge S of road	
Sum		**24**	At point bar	
4/29/2005				
Canada geese	1	Female nesting on 4 eggs	At point bar	Snowing
Sum		**1**		
5/24/2005				
Blue-winged teal	2	1 pair floating	NE end of lake	Sunny, pleasant
Cliff swallow	75	Building many nests; 1 adult dead in nest	On SW end of pitlake	
Great horned owl	3	3 owlets in nest	2 nest near entrance; 1 nest at wetlands	
Horned lark	4	Flying/landing	Along dirt access road	
Killdeer	2	Flying/landing	1 at boat ramp; 1 near goose nest on point	
Lesser scaup	3	1 dead	1 dead near boat ramp on shore; 2 floating NW end of lake	
Mallard	3	Floating/ flew away	Lake center	
Marshhawk	1	Hunting	1/4 mile south of pitlake	
Meadow lark	5	Singing/ calling	Boatramp; west wetland	
Redtail hawk	1	Resting on nest	On nest near entrance	
Red-winged blackbird	4	Flying/calling	1 pair by boatramp; 1 pr at west shore of ne section of lake	
Short-eared owl	1	Flying/ landing/ hunting	1/4 mile SE of pitlake	
Spotted sandpiper	3	Walking	NW shore of lake	
Vesper sparrow	2	Sitting/ flying	Surrounding grasslands	
Sum		**109**		

Avian Activity and Abundance, Highland pit lake, Cont'd

Species	# of Birds	Activity	Location	Weather
6/2/2005				
Cliff swallow	8	Flying, 3 in nests at SW wall on pitlake	2 near west wetlands, others at SW wall on pitlake	Windy/ cloudy 50s
Great horned owl	4	3 Fledglings out of nest, 1 adult; flying/hunting	Near nest at gate entrance	
Horned lark	12	Flying/landing	Flushed along road	
Marshhawk	3	Pair hunting, possibly nesting as male was aggressive to us; 1 hunting	Pair at west wetland; 1 above boat ramp	
Meadow lark	6	Calling	Near west wetlands	
Prairie falcon	1	Flying	NE end of lake	
Red-tail hawk	2	1 Flying; 1 on nest	Above boat ramp; On nest at gate entrance	
Red-winged blackbird	6	3 pairs calling/ flying, 2 attacked marshhawks	West wetlands	
Sum		52		
6/9/2005				
Blue-winged teal	1	Floating	SW end of lake	Rainy, partly cloudy 50s
Cliff swallow	8	Hunting, swooping	5 NW over lake, 3 flying near west wetland	
Great horned owl	4	Fledglings, flying/ resting in tree - great photo of 1	Near Owl nest at near gate	
Horned lark	12	Flushed, found and marked nest location with 3 eggs	Along road, near boat ramp, nest was 20 ft from road, 1/4 mi from gate	
Killdeer	3	Flushed and flying	1 at boat ramp; 1 along road, 1 outside gate	
Mallard	2	males, fly-by over lake	NE end of lake	
Marshhawk	1	Male, soaring became aggressive...nest?	West wetlands	
Meadow lark	6	Flying, sitting	Near boat ramp	
Red-tail hawk	1	Sitting, flew off as we approached	At nest near gate	
Red-winged blackbird	3	Sitting	West wetlands	
Short-eared owl	1	Hunting, flying	West wetlands	
Vesper sparrow	3	Flying/ sitting	Near boat ramp	
		45		
6/17/2005				
Cliff swallow	35	Flying /hunting	SW and NW edge of pitlake	Sunny, windy 80s
Horned lark	12	Flying/ sitting	Along dirt access road	
Killdeer	3	Walking along shore, flying	Near boat ramp, owls' nest	
Marshhawk	2	malle flying overhead, female sitting on nest with 4 eggs	West wetlands	
Meadow lark	6	Flying/ sitting	3 at west wetlands, 3 at boat ramp	
Red-tail hawk	2	Male hunting, female on nest	Nest near gate entrance	
Red-winged blackbird	2	Male hunting in mud, female on nest w/ 3 eggs	North of boatramp	
Vesper sparrow	1	Sitting on fence post	West wetlands	
		63		

Avian Activity and Abundance, Highland pit lake, Cont'd

Activity	# of Birds	Activity	Location	Weather
6/22/2005				Sunny, 90s
Blue-winged teal	3	Floating on lake, 1 adult w/ 2 juveniles	NW end of lake	
Cliff swallow	75	Flying, touching water, building nests	West side of lake; a few near boat ramp.	
Horned lark	18	Flying	Along access road	
Killdeer	4	Flying	Near boat ramp; wetlands; rockpile; near owls' nest	
Marshhawk	2	1 pr hunting, resting on nest. Found nest with 3 eggs, 1 cracked	S end of lake	
Marshhawk	2	1 pr hunting, resting on nest. Nest with 4 eggs	West wetlands	
Meadow lark	6	Flying	South of lake; Boat ramp; Wetlands	
Red-tail hawk	2	Pair hunting	West wetlands	
Red-winged blackbird	5	2 pairs, 1 juvenile (brief flights at wetland), flying; nest with 3 eggs	West wetlands; North of boat ramp	
Short-eared owl	1	Sitting on fence post	SE of lake 1/3 mile	
		118		
7/1/2005				Sunny, 90s
Cliff swallow	60	Flying, nest building	West side of lake; a few near boat ramp.	
Horned lark	12	Flying	Along access road	
Marshhawk	3	1 pr hunting, resting on nest. Nest with 2 eggs, and 1 hatchling being fed a fresh kill (bird)	S end of lake	
Marshhawk	3	1 pr hunting, resting on nest. Nest with 2 eggs (1 egg missing), 1 hatchling appears larger than lake juvenile	West wetlands	
Red-tail hawk	2	Pair hunting	West wetlands	
Red-winged blackbird	4	1 pr, male hunting, female on nest, 1 egg missing, 1 baby alive and 1 baby dead	West wetlands; North of boat ramp	
		84		
7/7/2005				Sunny, 90s
Cliff swallow	40	Flying, nest building	West side of lake; a few near boat ramp.	
Horned lark	12	Flying	Along access road	
Marshhawk	0	Nest found intact and empty, no sign of adults	S end of lake	
Marshhawk	3	1 pr hunting, resting on nest. Nest (3 eggs now missing), 1 hatchling appears healthy and growing	West wetlands	
Red-tail hawk	2	Male hunting, female stiing on nest; nest too high to see if there are juveniles	West wetlands	
Red-winged blackbird	4	1 male, 3 female flying Nest intact and empty	West wetlands; North of boat ramp	
		61		

Avian Activity and Abundance, Highland pit lake, Cont'd

Species	# off Birds	Activity	Location	Weather
7/14/2005				Sunny, windy
Cliff swallow	20	Flying	West side of lake; a few near boat ramp.	
Horned lark	4	Flying	Along access road	
Marshhawk	2	Female and juvenile on nest	West wetlands	
Meadow lark	2	Singing/ calling	Near boatramp	
Red-winged blackbird	3	2 male, 1 female, hunting	North of boatramp	
		31		
8/26/2005				
Eared Grebe	5	Floating on lake	N-NW part of pit lake	
Cliff swallow	0	Swallows gone		
		5		

Wildlife Observation Notes for Highland pit lake					
Date	**Species**	**#**	**Description**	**Location**	**Notes**
13-Sep-04	Leopard frogs	20		Cattails	
	Mule deer buck	3		Boat launch	
	Mule deer buck	2		Gate	
	Mule deer doe	2		Gate	
	Mule deer fawn	2		Gate	
	Shrew?	2		Boat launch	
14-Sep-04	Mule deer buck	2	Antlers on both, single spikes and medium velvet.	Boat launch	
	Mule deer buck	3		Rock pile	
	Mule deer buck	3		Gate	
	Mule deer doe	2		Gate	
	Mule deer fawn	2		Gate	
	Mule deer buck	5		T intersection past rock pile	
	Mule deer doe	14		T intersection past rock pile	
	Mule deer fawn	5		T intersection past rock pile	
	Muscrat	0	Scat	Shoreline	
	Canada Goose scat	0	Scat	Shorline	
	Cottontail	1	Dead	Floating in water SW corner	
	Shrew?	2		Boat launch	
15-Sep-04	Mule deer buck	3		Rock pile	
	Mule deer buck	3		Gate	
	Mule deer doe	2		Gate	
	Mule deer fawn	2		Gate	
	Mule deer buck	1		Traversing the ridge between Hydrolab location #1 and the boat ramp.	
	Mule deer doe	1		Traversing the ridge between Hydrolab location #1 and the boat ramp.	
	Mule deer buck	6		T intersection past rock pile	
	Mule deer doe	8		T intersection past rock pile	
	Mule deer fawn	2		T intersection past rock pile	
	Shrew?	2		Boat launch	

Wildlife Observation Notes for Highland pit lake – Cont'd					
25-Oct-04	Mule deer buck	1		Rock pile	
	Cottontail	1		Rock pile	
	Mule deer doe	4		NE ridge	
	Mule deer buck	1		E ridge of pitlake	
	Muscrat	1		Cattails	
	Cottontail	10		Rock pile	
26-Oct-04	Mule deer doe	8		Gate	
	Mule deer fawn	2		Gate	
	Mule deer doe	6		East rim of pitlake	
	Mule deer buck	1		East rim of pitlake	
27-Oct-04	Mule deer doe	1		Turnoff to pitlake	
	Mule deer doe	3		Rock pile	
	Mule deer doe	1		Boat launch	
	Mule deer fawn	1		Boat launch	
	Mule deer doe	6		West of boat ramp	
	Mule deer fawn	2		West of boat ramp	
	Mule deer buck	1		West rim of pitlake	
	Mule deer doe	1		West rim of pitlake	
21-Feb-05	Muscrat	1	Dead	Littoral zone shoreline	Ice on a good portion of the pit lake
	Cottontail	2		Rock pile	Meadow voles are working 20-30 feet above littoral zone shoreline
	Mule deer buck	1	With 1 antler - looks rather rough	North end on tailings area	
	Mule deer doe	2		300 yards from lake	
	Mule deer fawn	2		300 yards from lake	
22-Feb-05	Mule deer buck	7		Gate	
	Mule deer doe	10		Gate	
	Mule deer fawn	5		Gate	
	Meadow vole	3	Trapped	Boat launch	
24-Feb-05	Mule deer buck	1	With 1 antler - very sick, could not get up	North end of Pitlake	
	Meadow vole	2	Trapped	Location #3	
	Meadow vole	2	Trapped	Location #4	
	Deer mouse	1	Trapped	Location #3	
22-Mar-05	Mule deer buck	1	With 1 antler - Dead	North end of Pitlake	
	Mule deer buck	1		Boat launch	
	Mule deer doe	2		Boat launch	

6-Apr-05	Cottontail	12		Rock pile	
	Cottontail	3		Rock pile	
	Mule deer buck	2		Gate	
	Mule deer doe	5		Gate	
	Mule deer fawn	2		Gate	

Wildlife Observation Notes for Highland pit lake – Cont'd					
17-Jun-05	Mule deer buck	4		Rock pile	
	Mule deer doe	1		Rock pile	
	Mule deer doe	2		Wetlands	
22-Jun-05	Mule deer buck	6		Rock pile	
	Mule deer doe	8		Rock pile	
	Mule deer fawn	4		Rock pile	
	Pronghorn	7		Boat launch	
	Cottontail	25		Rock pile	
	Cottontail	5		Boat launch	
1-Jul-05	Mule deer buck	4		Rock pile	
	Mule deer doe	7		Rock pile	
	Cottontail	20		Rock pile	
	Deer mouse	1		In boat	
7-Jul-05	Mule deer buck	4		Rock pile	
	Mule deer doe	5		Rock pile	
	Mule deer fawn	2		Rock pile	
	Cottontail	6		On shore near boat ramp within 1st 100 feet	
14-Jul-05	Mule deer buck	1		Rock pile	
	Mule deer doe	2		Rock pile	
	Cottontail	12		Rock pile	
	Bobcat	1	Ran in front of us, then crossed the fence and into the field adjacent to the highway	Crossing the highway, 5 miles south of Highlands Rd tunroff	

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Appendix G

Analytical Data Validation

MFG, INC.

DATA EVALUATION SUMMARY

Sample Collection, Transfer and Analysis

Sediment and tissue samples collected from Highland pit lake from September 2004 through February 2005 were sent to Energy Laboratories in Casper, Wyoming for analysis. The following table includes a summary of laboratory batch #s, sample dates, number of samples, sample IDs and analyses conducted.

Lab Batch #	Sample Media	Sample Dates	Samples	Sample IDs	Analyses
C04091010	sediment, vegetation, invertebrate, amphibian	/13/04 – 9/14/04	0 -sed 7-veg 6 -inv 4 -amph	LTZ/LF/091304/01/001, LTZ/LF/091304/02/001, LTZ/LF/091304/01/002, LTZ/LF/091304/01/003, LMZ/CO/091304/01/001, LTZ/GP/091304/01/001, LTZ/GP/091304/01/002, LTZ/OD/091304/01/001, LTZ/WB/091304/01/001, LTZ/WB/091304/01/002, LTZ/VEG/091304/01/001, LTZ/VEG/091304/01/002, LTZ/VEG/091304/01/003, LTZ/VEG/091304/01/004, LTZ/VEG/091304/02/004, LTZ/VEG/091304/01/005, LTZ/VEG/091304/01/006, LMZ/SED/091404/01/001, LMZ/SED/091404/01/002, LMZ/SED/091404/01/003, LTZ/SED/091304/01/001, LTZ/SED/091304/01/002, LTZ/SED/091304/01/003, LTZ/SED/091304/01/004, LTZ/SED/091304/01/005, LTZ/SED/091304/02/005, LTZ/SED/091304/01/006	-Sed: total organic carbon (TOC), total organic matter (TOM), inorganic carbon, total Al, Sb, As, Fe, Hg, Mn, Mo, Se, U, V and Ra-226 -Veg, inv, amph: total Se, U
C04110479	vegetation, invertebrate	0/26/04	-veg, -inv	LTZ/VEG/102604/01/001, LTZ/VEG/102604/01/006, LTZ/VEG/102604/01/003, LTZ/VEG/102604/02/001, LTZ/CO/102604/01/001, LTZ/WB/102604/01/001, LTZ/WB/102604/02/001, LTZ/GP/102604/01/001, LTZ/GP/102604/02/001	total Se, U
C05010790	fish tissue	/18/05	-fish	PL-1 Fatheads, PL-2 Fatheads, PL-3 Fatheads, BC-2 Fatheads, LMW-L Fatheads, LMW-M Fatheads, Rep1-C Fatheads, Rep2-C Fatheads, Rep3-C Fatheads	total Se, U
C05020645	snail, fish tissue	/7/05, 2/14/05	-snail -fish	BC-2-Snails, BC-2- Snail shells, LMW-L-Snails, LMW-L- Snail shells, LMW-M-Snails, LMW-M-Snail shells, Control Snails, Control Snail shells, LMW-L-Fatheads, LMW-M-Fatheads	total Se, U
C05030609	soil, invertebrate	/24/05	6 -soil 3 -inv	M-Soil #1, M-Soil #2, M-Soil #3, M-Soil #4, M-Soil #5, M-Soil #6, Copepod-1, Copepod-2, Copepod-3, Copepod-4, Copepod-5, Water Boatman-1, Water Boatman-2, Water Boatman-3, Fly Larvae-1, Fly Larvae-2, Fly Larvae-3, Snails, Caddis Fly	total Se, U
C05030630	mouse tissue	/24/05	-mouse	M-1 Mouse, M-2 Mouse, M-3 Mouse, M-4 Mouse, 2A-Mouse, 2B-Mouse, 2C-Mouse, 4A-Mouse, 4B-Mouse	total Se, U

--All samples were dried and prepared at the MFG laboratory before shipping to Energy Labs. The case narratives were reviewed with no problems noted for analyses conducted. All samples listed on the COCs were analyzed. All samples were analyzed within the recommended holding time for each method.

--Analyses were run by the following methods: TOC and TOM (ASA29-3), inorganic carbon (USDA23c), total Al, Fe (SW6010B), total Sb, As, Mn, Mo, U, V (SW6020), total Se (SW7742), total Hg (SW7471A) and total Ra-226 (E903.0).

--Proposed detection limits (DL) were met for all analyses with the exception of U, which reported higher reporting limits (0.03 – 0.3 mg/kg) due to sample interference; project proposed DLs for uranium was 0.01mg/kg.

--The following quality control samples were submitted: replicate samples LTZ/SED/091304/02/005, LTZ/VEG/091304/02/004, LTZ/LF/091304/02/001, LTZ/VEG/102604/02/001, LTZ/WB/102604/02/001 and LTZ/GP/102604/02/001.

Accuracy

The accuracy of the data was evaluated based on the extraction efficiency (laboratory control sample (LCS) %recoveries), matrix spike (MS) and matrix spike duplicate (MSD) % recoveries, and method blank results.

--The recoveries for the LCS were within the laboratory control limits for all analyses, when reported.

--MS and MSD recoveries were within laboratory limits for all analyses with the exception of a few. The MS recoveries for Al (C04091010) exceeded lab limits (85-125%) at 79.4% and 79.3%, but were within project limits (75%-125%). The MSD for Se in batch C04091010 exceeded limits at 73.5% recovery; the other MS and two MSDs for the same batch were within limits. For batch C04110479, the U MSD exceeded limits at 61.6% recovery; however the MS was within at 92.5%. In batch C05010790, the Se MSD recovery was outside limits (156%), but the MS was within limits (104%), also the U MSD recovery was outside limits (129%), but the MS was within (124%). Other QC results were acceptable for the same analytes, thus it was not necessary to qualify sample results.

--The analytes of interest should not be detected in any laboratory method blanks greater than the method detection limit (MDL) for the water quality analysis. Method blank results were ND (not detected) for all analytes with the following exceptions: Al (0.0004 mg/kg), Fe (0.01 mg/kg), Mn (0.00004 mg/kg) and V (0.0003 mg/kg) from C04091010, U at 0.01 mg/kg (RL = 0.006 mg/kg) and Se at 0.008 mg/kg (RL = 0.0003 mg/kg) for C05030609, and U (0.04 mg/kg) from C05030630. With the exception of U for C05030630, all amounts detected were well below the project required reporting limits. There was no method blank data available for the following analyses: Se, U and Hg from batch C04091010, and Se from batch C05020645.

Precision

--Laboratory precision was evaluated based on the RPDs of either the analytical duplicates or the MS/MSD. One duplicate for Se in batch C04091010 was right at laboratory and project RPD control limits (<20% RPD) at 20%; the other two duplicates for the same batch were within limits. The U duplicate RPD from batch C04091010 exceeded limits at 24% RPD, and the MS/MSD RPD for Se in batch C05010790 exceeded at 37% RPD. Higher RPDs occur more frequently in solid samples due to sample heterogeneity. The duplicate and MS/MSD RPDs were within lab and project limits for all remaining analyses.

--RPD results from field sample replicates were used to measure within sample variance, and can also be used as an additional measure of laboratory precision. All of the field sample replicates were below the project designated limit of 50% RPD.

Completeness

--Analytical results were reported for all samples submitted for analysis. The analytical results are usable as reported, noting the data quality concerns observed above.

Summary

The analytical results received from Energy Laboratories for samples collected September 2004 through February 2005 were evaluated for data quality. Sample collection and transfer was verified, all samples were analyzed within holding times and according to requested methodologies. Quality control parameters for accuracy and precision were acceptable for all analyses. The results are considered to be usable with no qualifications.

Reviewer: Jill Richards
Date: 4/6/05

MFG, INC.

DATA EVALUATION SUMMARY

Sample Collection, Transfer and Analysis

Sediment and tissue samples collected from Highland pit lake from June 2005 through July 2005 were sent to Energy Laboratories in Casper, Wyoming for analysis. The following table includes a summary of laboratory batch #s, sample dates, number of samples, sample IDs and analyses conducted.

Lab Batch #	Sample Media	Sample Dates	Samples	Sample IDs	Analyses
C05060792	invertebrate	/20/05	-inv	Stone Fly –Boat Ramp, Back Swimmers –Boat Ramp, Dragon Fly – Boat Ramp, Dragon Fly Larva –BR, Amphipods –BR, Water Boatmen -BR	Se, U, moisture
C05060840	invertebrate, amphibian	/20/05-6/21/05	–inv, -amph	Amphipods –BR, Beetles –BR, Damsel Flies –BR, Water Boatmen – BR, Sanils –BR, Back Swimmers –BR, Dragonflies –BR, Leopard Frog -BR	Se, U, moisture
C05060910	vegetation, soil	/22/05	–veg, -soil	Astragalus, Astragalus No. 2, Terrestrial Grass No. 1, Terrestrial Veg No. 2, Terrestrial Veg No. 3, Stonewort No. 2 –BR, Stonewort No. 3 -BR	Se, U, moisture
C05060911	sediment, vegetation	/22/05	–sed, -veg	Sed Littoral 1, Sed Littoral 2, Sed Littoral 3, Sed Limnetic SW, Sed Limnetic NW, Sed Limnetic NE, Stonewort No. 1 Grab	Se, U, moisture
C05060915	invertebrate, water, insect	/21/05-6/22/05	–inv, –water, -insect	Cope Rep 1, Cope Rep 2, Cope Rep 3, Water SW, Water NE, Water NW, Water Littoral 1, Water Littoral 2, Water Littoral 3, Spiders	Se, U, moisture
C05061005	mouse	/23/05	-mouse	M-1, M-2, M-3, M-4	Se, U, moisture
C05070208	vegetation	/1/05	-veg	CAT 1 Chem, CAT 2 Chem, CAT 3 Chem, CAT 1 Biomass, CAT 2 Biomass, CAT 3 Biomass,	Se, U, moisture, biomass
C05070722	soil, vegetation, invertebrate, amphibian, sediment, water	/18/05	–soil, 0 –veg, 5 –inv, –amph, –sed, -water	Control Soil Rep 1, Control Soil Rep 2, Control Soil Rep 3, Control Soil Rep 4, Control Bullrush Rep 1, Control Bullrush Rep 2, Control Bullrush Rep 3, Control Bullrush Rep 4, Control Cat Rep 1, Control Cat Rep 2, Control Cat Rep 3, Control Cat Rep 4, Control Scirpus Rep 1, Control Scirpus Rep 2, Control Scirpus Rep 3, Control Scirpus Rep 4, Control Pond Weed Rep 1, Control Pond Weed Rep 2, Control Pond Weed Rep 3, Control Pond Weed Rep 4, Control Veg Rep 1, Control Veg Rep 2, Control Veg Rep 3, Control Veg Rep 4, Control Water Boatman, Control Fish, Control Damsel Flies, Control Snail, Control Dragon Fly, Control Leopard Frog Rep 1, Control Leopard Frog Rep 2, Control Leopard Frog Rep 3, Control Leopard Frog Rep 4, Control Sed Rep 1, Control Sed Rep 2, Control Sed Rep 3, Control Sed Rep 4, Control Wetland Water Rep 1, Control Wetland Water Rep 2, Control Wetland Water Rep 3	Se, U, moisture

--Samples preparation was conducted at Energy Labs. The case narratives were reviewed with no problems noted for analyses conducted. All samples listed on the COCs were analyzed. All samples were analyzed within the recommended holding time for each method.

--Analyses were run by the following methods: total Uranium (EPA M6020) and total Selenium (SW7742), for solid samples; U (EPA M200.8) and Se (SM 3114B) for water samples. Results for solid samples were reported on a dry weight basis (mg/kg).

--Proposed detection limits (DL) were met for all analyses with the exception of Uranium, which reported higher reporting limits (0.03 – 0.3 mg/kg) due to sample interference; project proposed DLs for Uranium was 0.01mg/kg.

-No field duplicate or blanks were submitted.

Accuracy

The accuracy of the data was evaluated based on the extraction efficiency (laboratory control sample (LCS) %recoveries), matrix spike (MS) and matrix spike duplicate (MSD) % recoveries, and method blank results.

--The recoveries for the LCS were within the laboratory control limits for all analyses, when reported. LCS recoveries were not available for Uranium or Selenium from C05061005

--MS and MSD recoveries were within laboratory limits for all analyses with the exception of a few. The MS recoveries for analyses which exceeded lab limits due to disproportionate sample/spike concentrations (sample concentration > 4x spike concentration) included Uranium (C05060840, C05060911, C05060915, C05061005 and C05060910) and Selenium (C05060911 and C0506100). Other QC results were acceptable for the same analytes, thus it was not necessary to qualify sample results. Post-digestion spikes, when analyzed, were within limits.

--The analytes of interest should not be detected in any laboratory method blanks greater than the method detection limit (MDL) for the water quality analysis. Method blank results were ND (not detected) for all analytes with the following exceptions: Uranium: 0.005 mg/kg (C05060840), 0.003 mg/kg (C05060915), 0.005 mg/kg (C05061005), 0.1 mg/kg (C05070722) and 0.005 mg/kg (C05060910); reporting limit = 0.003 mg/kg. Selenium: 0.01 mg/kg (C05060840), 0.008 mg/kg (C05060911), 0.01 mg/kg (C05070208) and 0.04 mg/kg (C05060910); reporting limit = 0.003 mg/kg. With the exception of Uranium for C05070722, all amounts detected were well below the project required reporting limits.

Precision

--Laboratory precision was evaluated based on the RPDs of either the analytical duplicates or the MS/MSD. The duplicate and MS/MSD RPDs were within lab and project limits for all analyses.

Completeness

--Analytical results were reported for all samples submitted for analysis. The analytical results are usable as reported, noting the data quality concerns observed above.

Summary

The analytical results received from Energy Laboratories for samples collected June 2005 through July 2005 were evaluated for data quality. Sample collection and transfer was verified, all samples were analyzed within holding times and according to requested methodologies. Quality control parameters for accuracy and precision were acceptable for all analyses. The results are considered to be usable with no qualifications.

Reviewer: Jill Richards
Date: 9/24/05