Baseline Ecological Risk Assessment for the Gilt Edge Mine Lead, South Dakota

Final

November 2003

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PROLOGUE

This document represents an assessment of risks for ecological receptors at the Gilt Edge Mine Site for conditions that were present from July 1995 to June 2002. Current conditions at the Gilt Edge Mine site were changed from that present in 2002 as a result of two primary events. First, the Ruby Waste Repository was filled and capped and second, the waste water treatment system that discharged treated mine waste water from the site to Strawberry Creek was completely replaced. The original waste water treatment system was a sodium (or aluminum) hydroxide addition system the primarily raised the pH of mine waters prior to discharge. The new wastewater treatment system came online in September of 2003 and is a lime (bicarbonate) addition system. The description of baseline risks for aquatic and terrestrial receptors provided in this document may not reflect current site conditions.

EXECUTIVE SUMMARY

Introduction

This document is a baseline ecological risk assessment (ERA) for the Gilt Edge Mine located southeast of Lead and Deadwood, South Dakota (Figure ES-1). The purpose of the ERA is to describe the likelihood, nature, and extent of adverse effects to ecological receptors resulting from exposure to contaminants released at the mine and to surrounding areas as a result of site activities. This information, along with other relevant information, is used by risk managers to make decisions whether remedial actions are needed to protect the environment.

This ERA is completed according to current United States Environmental Protection Agency (USEPA) guidance for ecological risk assessments (USEPA 1992, 1997a, 1998). For the Gilt Edge Mine site, the ERA process was initiated by performing a screening-level ecological risk assessment (SERA) in January of 2001 (USEPA 2001a). The SERA concluded that risks from site-related chemicals could not be excluded for any of these ecological receptors, and identified data needed for the completion of a more detailed evaluation. The ERA report is organized into the nine sections including: Introduction, site characterization, nature and extent of contamination, problem formulation, risks to aquatic organisms, risks to terrestrial plants and soil invertebrates, risks to wildlife receptors, uncertainties, and references.

Site Characterization

The Gilt Edge Mine is listed as CERCLIS Site # SDD987673985 and is also known as the Strawberry Creek Tailing Piles and Brohm Gold Mine. The site is situated in the northern Black Hills of western South Dakota (SDDENR, 1999) near the town of Lead and Deadwood to the west and Galena to the east (Figure ES-2). The Gilt Edge Mine is part of the Bear Butte Mining District, which has been the site of numerous gold mining operations since the mid-1870's (Brohm Mining Corp., 1988). Historic underground mining operations extracted sulfide-bearing gold ores from irregular deposits in veins and fracture zones in the volcanic rocks. Some limited surface mining was also conducted at the site (USDOI, 2000). Production of gold and silver, along with small amounts of copper, lead, and zinc are reported. The Gilt Edge Mine Site including Anchor Hill encompasses approximately 412 acres including the Sunday Pit, the Dakota Maid Pit, the Anchor Hill Pit, the Langley Pit, the Ruby Gulch Waste Rock Dump, the Heap Leach Pad, relic tailings and other features.

Surface water from the Gilt Edge Mine Site drains through three sub-basins into Bear Butte Creek (OEA, 1998; USEPA, 1993c; SDDENR, 1999). Except during spring runoff, Bear Butte Creek disappears into sinkholes in the Madison limestone approximately 2.5 miles below the confluence with Ruby Gulch. The three main drainages pertinent to the Gilt Edge Mine site included Ruby Gulch, Strawberry Creek, and Hoodoo Gulch. For the purposes of this assessment two streams are used as references: Butcher Gulch, upstream Bear Butte Creek, Boomer Gulch, and Two-Bit Creek.

Nature and Extent of Contamination

Several investigations of the Gilt Edge Mine Site were completed prior to and subsequent to the SERA. The SERA identified the presence of a number of contaminants of potential concern in site soil, sediment, groundwater, and surface water. In the SERA, the USEPA reviewed the adequacy of the available data to support reliable ecological risk evaluations, and identified several data gaps. The USEPA recommended additional sampling and analysis of environmental media needed to support risk assessment at site-related locations based on the results of a scoping meeting and a site visit conducted August 8 to 9, 2000. A field investigation was conducted in September 2000. A second field investigation was completed in October 2001 to document possible changes in water and sediment chemistry and toxicity, and the benthic macroinvertebrate community resulting from changes in the waste water treatment plant. A report issued in April of 2000 summarizes the data collection and results for both the September 2000 and October 2001 field investigations (USEPA, 2002).

For the purposes of this assessment, the available data for the Gilt Edge Mine site are divided into two conceptual categories: Mine Source Area and Riparian Area. Mine source area refers to data collected within the boundaries of the mine site and workings while Riparian Area refers to data collected in surface water drainages (surface water, sediment, soil and biological tissue) outside of the boundary of the mine site and workings. All samples from Strawberry Creek, Hoodoo Gulch and Ruby Gulch are considered to be "Riparian Area". The USEPA has compiled a master database of all results with the assistance of CDM Federal. The ERA uses a subset of data from this master database (as of the date of this document) with some additions and modifications.

Riparian Areas. For the purposes of this assessment, areas of potential ecological exposure are divided into a number of reaches, including several locations that are not believed to be impacted by site-related releases and that serve as reference areas. These reaches and reference areas are listed below and are shown in Figure ES-3.

Exposure Reaches for Surface Water		
Reach	**Description**	**Designation**
Strawberry Creek	Strawberry Creek and surrounding areas	Site
Ruby Gulch	Ruby Gulch and surrounding areas	Site
Hoodoo Gulch	Hoodoo Gulch and surrounding areas.	Site
Downstream Bear Butte Creek	Bear Butte Creek downstream of confluence with Strawberry Creek	Site
Upstream Bear Butte Creek	Bear Butte Creek upstream of confluence with Strawberry Creek	Reference for Bear Butte Creek

Exposure Reaches for Surface Water		
Reach	**Description**	**Designation**
Boomer Gulch	Boomer Gulch and surrounding areas.	Reference for Strawberry Creek
Butcher Gulch	Butcher Gulch and surrounding areas.	Reference for Strawberry Creek
Two Bit Creek	Two Bit Creek (Anchor Gulch) and surrounding areas.	Reference for Strawberry Creek

Mine Source Area. Surface material within the mine source area is composed of fill material, waste rock and some soil (surface and subsurface). The material most recently present within the Mine Source area has been characterized as the result of four separate investigations:

Problem Formulation

Problem formulation is a systematic planning step that identifies the major concerns and issues to be considered in the ERA, and a description of the basic approach that will be used to characterize the potential risks that may exist (USEPA 1997a). The problem formulation for this baseline ecological risk assessment began with a SERA that was completed for the site in March 2001 (USEPA 2001a).

Site Conceptual Model. Figure ES-4 presents the site conceptual model (SCM) for the baseline ecological risk assessment. As indicated in the SCM, although there are a number of complete exposure pathways by which ecological receptors may come into contact with site-related contamination. It is not feasible to evaluate exposures and risks for each avian and mammalian species potentially present at the site. For this reason, specific wildlife species are identified as surrogates (representative species) for the purpose of estimating exposure and risk. The surrogate species are wildlife species present at the site that are representative of other species with similar dietary preferences and feeding guilds. The species identified as surrogate species at this site include the masked shrew (*Sorex cinereus*), the American robin (*Turdus migratorius*), the belted kingfisher (*Ceryle alcyon*), the mink (*Mustela vison*), the deer mouse (*Peromyscus maniculatus*), and the bobwhite quail (*Galliformes phasiadinae*).

Management Goals. Management goals are descriptions of the basic objectives which the risk manager at a site wishes to achieve. The overall management goal identified for ecological health at the Gilt Edge Mine site as first described in the SERA is as follows (USEPA 2001a):

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

"Adequate protection" is generally defined as protection of growth, reproduction, and survival of local populations. That is, the focus is on ensuring sustainability of the local population, rather than on protection of every individual in the population.

In order to provide greater specificity regarding this general goal and to identify specific measurable ecological values to be protected, the following list of sub-goals was derived:

- Ensure adequate protection of terrestrial plant communities, including native plant communities, by protecting them from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.

- Ensure adequate protection of aquatic life in Strawberry Creek and Bear Butte Creek from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.

- Ensure adequate protection of terrestrial mammal and bird populations by protecting them from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.

- Ensure adequate protection of threatened and endangered species (including candidate species) and species of special concern and their habitat by protecting them from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.

Assessment and Measurement Endpoints. Assessment endpoints are explicit statements of the characteristics of the ecological system that are to be protected. Assessment endpoints are either measured directly or are evaluated through indirect measures. Measurement endpoints represent quantifiable ecological characteristics that can be measured, interpreted, and related to the valued ecological components chosen as the assessment endpoints (USEPA 1992, 1997a). Table ES-1 describes the assessment and measurement endpoints used to interpret potential ecological risks for the Gilt Edge Mine site. These measurement endpoints can be divided into three basic categories of approach:

- Hazard Quotients (HQs)
- Site-specific toxicity tests (SSTTs)
- Observations of population and community demographics (Pop/Comm. Dem.)

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

Risks to Aquatic Receptors

Based on the site conceptual model (Figure ES-), the following exposure pathways are quantitatively evaluated using the HQ approach:

- Direct contact with contaminants dissolved and/or suspended in surface water. This pathway is most applicable to fish, but is also applicable to benthic organisms that reside in the uppermost portion of the sediment substrate.
- Direct contact with contaminants in sediment. This pathway is most applicable to benthic macroinvertebrate species that live buried within the sediment substrate.
- Exposure of fish by all pathways combined, based on tissue levels of contaminants in fish tissue.

Each of these evaluations are described below.

Risks to the Aquatic Community from Direct Contact with Surface Water. Three lines of evidence (the HQ approach) are used to evaluate risks to aquatic receptors from direct contact exposure to surface water. These lines of evidence include the hazard quotient (HQ) calculations, the toxicity testing of surface water and the biological community data (benthic invertebrate and fish). The findings from the lines of evidence evaluated for exposures of aquatic receptors to COPCs in surface water are summarized in the following table.

Line of Evidence	Findings
HQ calculations based on surface water concentrations	For Strawberry Creek, acute toxicity (risk) is associated with aluminum, cadmium, copper and zinc and to a lesser extent to chromium, manganese, and selenium. Chronic toxicity (risk) is associated with cadmium and to a lesser extent calcium and manganese, aluminum, cobalt, copper, selenium and sodium. For Hoodoo Gulch , acute toxicity (risk) is associated with aluminum, cadmium, copper and zinc and to a lesser extent manganese. Chronic toxicity (risk) is associated with aluminum and manganese and to a lesser extent beryllium, cadmium, cobalt, copper, and nickel. For Ruby Gulch, acute toxicity (risk) is associated with aluminum, cadmium, copper and zinc although to a lesser extent compared to Strawberry Creek and Hoodoo Gulch.. Chronic toxicity (risk) is associated with cadmium. For Bear Butte Creek only moderate acute risks are identified associated with copper downstream of Strawberry Creek.
Direct Toxicity Testing	For Strawberry Creek, surface water toxicity testing identified that site surface waters are significantly toxic and reduced both the survival and growth of fathead minnows in all samples tested. For Bear Butte Creek, surface water samples were not toxic to fathead minnows.
Population Observation Benthic Community Structure	For Strawberry Creek, the benthic macroinvertebrate community is severely or moderately impaired compared to reference stations (Figure 5-28). For Bear Butte Creek, the benthic macroinvertebrate community is slightly impaired relative to reference stations.
Population Observation Fish Community Structure	For Strawberry Creek, the fish community is impaired relative to upstream Bear Butte Creek in that some types of fish are absent or severely limited in number. There does appear to be some recovery at the station located just above the confluence with Bear Butte creek. For Bear Butte Creek, the fish community does not appear to be impaired downstream of Strawberry Creek compared to upstream.

Based on these lines of evidence, it is concluded that site-related COPCs in surface water pose an unacceptable risk to aquatic receptors in Strawberry Creek. Based on the weight of evidence, risks associated with COPCs in surface water are not predicted for Bear Butte Creek This conclusion is based on the observations that 1) the HQ values calculated for Bear Butte Creek do not predict risk; 2) toxicity tests do not demonstrate toxicity; and 3) the benthic macroinvertebrate community is only slightly impaired and this impairment may be associated with sediment contamination.

In order to increase the usefulness of the weight of evidence evaluation and to attempt to identify the possible cause of toxicity observed in the surface water toxicity testing, the surface water toxicity testing results are further analyzed. Several COPCs as significantly correlated with the toxicity observed (either reduced survival or reduced growth). Several constituents that are correlated with toxicity are components of total dissolved solids (TDS). TDS consists of minerals, organic matter, and nutrients dissolved in water. Equivalent terminology in Standard Methods is filtrable residue (USEPA, 1987). The major components of TDS in natural waters include: bicarbonate (HCO_3^-), calcium (Ca^{+2}), sulfate (SO_4^{-2}), hydrogen (H^+), silica (SiO_4), chlorine (Cl^-), magnesium (Mg^{+2}), sodium (Na^+), potassium (K^+), nitrogen (N_2, NH_3, NO^{-2}, NO^{-3}), and phosphorus in the form of phosphate (PO_4^{-3}). These components are listed in general order from most concentrated to least concentrated in typical surface waters. Bicarbonate can make up 50% of TDS in some streams. Minor constituents that are normally just a trace in streams include: iron (Fe^{+3}), copper (Cu^{+2}), zinc (Zn^+), boron (B^{+3}), manganese (Mn^{+2}), and molybdenum (Mo^+). A constant level of TDS is essential for the maintenance of aquatic life because the density of total solids determines flow of water in and out of an organism's cells (osmosis). A sudden or extreme change in TDS can be detrimental to aquatic life. For instance, an increase in salts could kill freshwater species whose bodies are not constructed to live in saltwater.

For most purposes EPA considers the terms TDS and salinity to be equivalent (USEPA, 1987) although salinity is different than TDS. Salinity refers only to salts and is defined as the concentration of all ionic constituents that include halides, bicarbonates, and sodium chloride. USDOI (1998) provides a summary of data concerning the toxicity of salinity to freshwater organisms. In general, the acute toxicity threshold for fathead minnow is reported for 6 to 10 parts per thousand (ppt); for daphnia from 6 to 10 ppt; for *Hyalella azteca* from 16 to 19.5 ppt and *Chironomus utahensis* at 13.3 ppt (USDOI, 1998). The State of South Dakota also has a water quality standard for TDS set at 1.75 ppt. All of the TDS components measured in the samples for toxicity testing, with the exception of potassium, are correlated with the observed toxicity.

An evaluation was completed to identify which of the COPC concentrations could explain the observed toxicity. The results of the definitive surface water tests are compared to known toxicity levels (LC_{50}) values for each of the COPCs identified as being significantly correlated with the observed toxicity (cadmium, calcium, cobalt, magnesium, manganese, nickel, selenium, sodium, sulfate, and TDS). The toxicity of the sample(s) is not explained by concentrations of calcium, cadmium, magnesium, nickel, selenium, sodium and TDS. Cobalt, manganese, and sulfate are identified as possible contributors to toxicity. The toxicity of the Strawberry Creek surface water samples represents the effects of the mixture of COPCs including possible antagonistic, synergistic and/or additive effects between individual components. The toxicity of the mixture is represented directly by the measured results of tests with the surface water samples but may not be well represented by the individual single-compound results. In other words, our comparison of single contaminant LC_{50} values may not be a good measure of the overall toxicity. In making these comparisons it is assumed that the single contaminant (COPC) is the sole cause of toxicity and it's toxicity is not affected by other constituents (COPCs). Interpretation of the cause of toxicity is also confounded by the following factors:

- The analyses of the COPCs in the test water samples represents the state of the sample at the time of collection and may not represent the actual exposure conditions in the test beakers after manipulation in the laboratory.

- Toxicity could be associated with an constituent or multiple constituents that were not analyzed for in the test samples.

In order to develop a tool for assessing major ion toxicity, Mount et al. (1997) performed a series of acute toxicity tests with three freshwater species on solutions enriched with varying combinations of major ions. Results of these tests were incorporated into multivariate logistic regression models that predict survival of the three test species based on major ion concentrations. Using this model, the predictive toxicity for Strawberry Creek associated with TDS components is much less than that observed. This comparison infers that toxicity observed for the water samples cannot be explained by TDS alone and clearly indicates the presence of another toxicant(s). As previously stated, toxicity may be caused by constituents(s) that were not analyzed for in the surface water samples. Historic use of polymers (surfactants) has been documented for the waste water treatment system prior to discharge to Strawberry Creek. These organic chemicals are a possible cause of the observed toxicity in surface water samples. It is not possible to confirm the exact cause of toxicity. To confirm a specific cause(s) or to ensure that future discharges of treated effluent are not toxic, site-specific toxicity testing is recommended in addition to monitoring for COPC concentrations and water quality parameters.

Risks to the Aquatic Community from Direct Contact with Sediments. Three lines of evidence are available to evaluate risks from sediments to benthic organisms. The findings from the lines of evidence are summarized below.

Line of Evidence	Findings
HQ Calculations	For Strawberry Creek, risks are categorized as severe for benthic organisms exposed to cadmium, copper, lead and zinc in sediment. Risks associated with silver are high and for aluminum and manganese are moderate. For Hoodoo Gulch, risks are categorized as severe for benthic organisms exposed to cadmium, copper, lead, silver, and zinc. Risks associated with manganese are moderate. For Ruby Gulch, risks are categorized as high for benthic organisms exposed to copper. Risks associated with copper are moderate. For Bear Butte Creek (downstream) risks are categorized as severe for benthic organisms exposed to cadmium, copper, and zinc. Risks associated with lead and silver are high.

Line of Evidence	Findings
Direct Toxicity Testing	For Strawberry Creek, very high toxicity was observed in sediment toxicity testing. Survival of *H. azteca* was very low ranging from 6 to 30% compared to 70 to 100% in controls (September 2000). Very high toxicity was also observed in samples collected almost a year later (October 2001). For Bear Butte creek, toxicity was not observed in the sediment toxicity testing.
Population Observations Benthic Community Structure	For Strawberry Creek, the benthic macroinvertebrate community is severely or moderately impaired compared to reference stations. For Bear Butte Creek, the benthic macroinvertebrate community is slightly impaired relative to reference stations.

In summary, based on a weight of evidence approach, it is concluded that COPCs in sediments are adversely impacting benthic organisms in Strawberry Creek. For downstream Bear Butte Creek, the HQs predict toxicity but none was observed in sediment testing and the benthic macroinvertebrate community is only slightly impaired relative to reference. Risks to aquatic receptors in Bear Butte Creek from exposure to COPCs in sediment is not considered to be significant.

In order to increase the usefulness of the weight of evidence evaluation, the sediment toxicity testing results are compared to concentrations of COPCs in the sediment samples. This analysis identifies copper ($p < 0.0001$; $R2 = 0.93$) in the sediment samples as a possible cause of the toxicity observed.

<u>Risks from All Pathways Combined</u>. One line of evidence (tissue-based HQ values for fish) is available to evaluate risks to aquatic receptors (fish) from all aquatic exposure pathways combined (surface water, sediment and dietary exposure). The findings from this line of evidence are summarized below.

Line of Evidence	Findings
HQ calculations based on fish tissue burdens	For cadmium, risks are identified as severe in Strawberry Creek and downstream Bear Butte Creek. For lead and chromium risks are identified as minimal.

Based on this line of evidence, it is concluded that risks to fish from COPCs in all media (surface water, sediment, and diet) are significant in Strawberry Creek and downstream Bear Butte Creek associated with cadmium.

<u>Overall Conclusion Regarding Risks to Aquatic Receptors</u>. The weight of evidence combined across all observations indicates that risks to aquatic receptors from site-related COPCs are high in Strawberry Creek, Hoodoo Gulch and Ruby Gulch and unacceptable risks do not extend downstream into Bear Butte Creek.

Risks to Terrestrial Plants and Soil Organisms

This section provides an assessment of risks to terrestrial plant and soil organisms living in soils which are potentially impacted by contaminants from the Gilt Edge Mine site. Based on the site conceptual model (Figure ES-), the following exposure pathways are selected for quantitative evaluation:

- Direct contact of plant roots with chemicals in surface soils.
- Direct contact with soils by soil invertebrates.

Only one line of evidence (the HQ approach) is available to evaluate risks to plants and soil invertebrates from COPCs in soils. The findings from this line of evidence are summarized in the following text table.

Line of Evidence	Findings
HQ calculations based on concentrations measured in soil	For Strawberry Creek, risks are categorized as severe for plants and soil invertebrates exposed to copper and silver in soils. Risks associated with selenium and thallium are high and zinc are moderate. For Bear Butte Creek, risks are categorized as high for plants and soil invertebrates exposed to copper and zinc. Risks associated with silver and thallium are moderate. For Mine Source Area Soils certain soil, fill and waste rock samples have HQ values greater than 1 for arsenic, copper, lead, zinc, thallium, silver and selenium.

Based on this line of evidence, it is concluded that risks from site-related contaminants in surface soil are of concern in the riparian area of Strawberry Creek and Bear Butte Creek and in the Mine Source Area area. Risks for riparian soils are associated with copper, silver, thallium, and zinc. Risks for Mine source area soils are associated with arsenic, copper, lead, selenium, silver, thallium, and zinc.

Use of HQ values to interpret risks does not consider environmental factors which may influence the toxicity of COPCs in soils to plants and soil invertebrates. The total metal content of soils is not a good predictor of potential toxicity. Soil-solution free metal activity

For lead and copper in soils it is possible to more accurately predict the toxicity of soils based on the measured pH and organic carbon content of the soils using a data set and regression equations developed by Sauve et al (2000). Sauve et al. (2000) developed regression equations to predict toxicity to plant and soil organisms from copper and lead. Using the measured bulk metal concentrations and soil pH, the free metal concentrations in the soil solution is estimated. The free metal activity is then used to predict the expected inhibition of the plant and soil organism communities and microbial processes. A 25% inhibition corresponds to the level at which most organisms will begin to exhibit adverse effects and represents the threshold for the beginning of ecosystem toxicity (Suave et al., 2000). A 50% inhibition represents a drastic impact on the ecosystem with major impacts on microbial processes, moderate impacts to organisms of average sensitivity, and alterations of plant productivity and species competition (Suave et al., 2000).

The predictive model (equation) was applied to the data for fill material, soil stockpiles, and waste rock for copper and lead. The results are sorted conceptually into three categories:

- Low (low inhibition <10%)
- Medium (from 10 to 30% inhibition)
- High (>30% inhibition)

The results indicate that most fill material samples are not toxic but most waste rock and soil stockpile samples are toxic.

Risks to Wildlife Receptors

Exposure of wildlife receptors may occur through ingestion of contaminated surface water while drinking, ingestion of contaminated soil or sediment while feeding, and ingestion of contaminated food web items. It is not feasible to evaluate exposures and risks for each avian and mammalian species potentially present within the site. For this reason, specific wildlife species are identified as surrogates (representative species) for the purpose of estimation of exposure and risk in the ERA. The surrogate species at the Gilt Edge site and the exposure pathways evaluated for each species include:

Surrogate Species for Riparian Exposure Reaches		
Surrogate Species	**Feeding Guild**	**Exposure Pathways Evaluated**
Mink	Mammalian piscivore	Ingestion of surface water, sediment, and fish
Belted Kingfisher	Avian piscivore	
Masked Shrew	Mammalian insectivore	Ingestion of surface water, soil, and soil invertebrates
American Robin	Avian omnivore	Ingestion of surface water, soil, plants and soil invertebrates
Deer mouse	Mammalian omnivore	
Bobwhite quail	Avian herbivore	Ingestion of surface water, soil and plants

Surrogate Species for Mine Source Area		
Surrogate Species	**Feeding Guild**	**Exposure Pathways Evaluated**
Deer mouse	Mammalian omnivore	Ingestion of soil (soil, fill material or waste rock) and plants
Bobwhite quail	Avian herbivore	

The basic equation used for calculation of an HQ value for exposure of a terrestrial wildlife receptor to a contaminant by ingestion of an environmental medium is:

$$HQ_{r,c,m} = \frac{C_{c,m} \cdot IR_{m,r} \cdot DF_{m,r} \cdot RBA_{c,m}}{BW_r \cdot TRV_{c,r}}$$

where:

$HQ_{r,c,m}$	=	HQ for exposure of receptor "r" to COPC "c" in medium "m"
$C_{c,m}$	=	Concentration of COPC "c" in medium "m" (mg/kg)
$IR_{m,r}$	=	Intake rate of medium "m" by receptor "r" (kg/day)
BW_r	=	Body weight of receptor "r" (kg)
$DF_{m,r}$	=	Dietary fraction of medium "m" by receptor "r" derived from site (%)
$RBA_{c,m}$	=	Relative bioavailability of COPC "c" in medium "m" (%)

$TRV_{c,r}$	=	Toxicity reference value for COPC "c" for receptor "r" (mg/kg BW/d)

Because all receptors are exposed to more than one environmental medium, the total Hazard Index (total HI) for a receptor from a specific COPC is calculated as the sum of HQs for that COPC across all exposure pathways:

$$HI_{c,r} = \sum HQ_{c,m,r}$$

If the total HI is below 1E+00, it is believed that no unacceptable effects will occur in the exposed receptor from the COPC. If the total HI is above 1E+00, then unacceptable effects may occur, with the likelihood and/or severity of effects tending to increase as the value of the HI becomes larger.

Exposure of wildlife receptors for Riparian Areas for each COPC in each medium (surface water, soil, sediment, and fish) within each exposure reach is based on the 95% upper confidence limit (UCL) of the mean concentration or the maximum concentration, whichever is lower. The 95% UCL is calculated based on the assumption that concentration values within each reach are distributed lognormally. Non-detects are evaluated by assuming a concentration value equal to one-half the detection limit. For exposures related to ingestion of plants and soil invertebrates, site-specific measurements of COPC concentrations in these food items are not available for the Gilt Edge Mine site. COPC concentrations in plants and soil invertebrates are estimated based on available equations that relate the soil concentration of the COPC to the concentration in food type.

Exposures for wildlife to the Mine source area (the mine workings) is evaluated in the same manner as risks for terrestrial receptors (plants and soil invertebrates) by sampling location. COPC concentrations in plants are estimated in the same manner as for the Riparian areas.

Toxicity Assessment. Toxicity Reference Values (TRVs) for terrestrial wildlife (mammals and birds) were derived by EPA for the calculation of Ecological Soil Screening Levels (Eco-SSLs). Using specific procedures for the Eco-SSLs, one mammalian and one avian TRV are derived and expressed as mg contaminant per kg body weight. The TRV derivation procedures extract and plot two different toxicity values. The first value is the exposure dose that is not associated with any adverse effects to the test organism. This is referred to as the No Observed Adverse Effect

Level (NOAEL). The second value is the reported exposure dose that causes an observable adverse effect, and is referred to as the Lowest Observed Adverse Effect Level (LOAEL). NOAEL and LOAEL values are grouped by six types of endpoints (biochemical, behavior, pathology, reproduction, growth and mortality). The TRV value, in most cases, is equal to the geometric mean of the NOAEL for growth and reproductive effects or the highest bounded NOAEL lower than the lowest bounded LOAEL for growth, reproduction or survival. For contaminants where Eco-SSL TRVs are not available, TRVs are derived from other literature sources.

The TRVs for wildlife are expressed in units of ingested dose. However, the toxicity from an ingested dose depends on how much of the ingested dose is actually absorbed, which in turn depends on the properties of both the contaminant and the exposure medium. Ideally, toxicity studies would be available that establish empiric TRVs for all site media of concern (water, food, soil, sediment). However, most laboratory tests use either food or water as the exposure medium, and essentially no studies use soil or sediment. Therefore, in cases where a TRV is based on a study in which the oral absorption fraction is different that what would be expected for a site medium, it is necessary to adjust the TRV to account for the difference in absorption.

The ratio of absorption from the study medium compared to absorption from site medium is referred to as the relative bioavailability (RBA). For inorganic COPCs, available data on cadmium and manganese suggest that absorption from the diet is about half that from water (IRIS 2002). Based on this, when toxicity data for inorganic COPCs are available from studies in food or water, but not both, the RBA for a contaminant in food compared to that for water or other soluble forms (e.g., capsule) is assumed to be 0.5 (50%). That is:

$$TRV_{water} = TRV_{diet} \cdot 0.50$$
$$TRV_{diet} = TRV_{water\ or\ capsule} / 0.50$$

In the absence of any site specific data, it is assumed that contaminants in soil and sediment are absorbed to the same degree as contaminants in food. It is considered likely that this approach may tend to overestimate exposure and risk from ingestion of soil, but this is not known for certain.

<u>Risk Calculations</u>.

The total HIs for each wildlife receptor for each COPC within each exposure reach are interpreted as follows:

- Exposure reaches with HI values that are all less than or equal to one are classified as having no risk.

- For exposure reaches where some HI values are greater than one but the HI values are similar to those calculated for the reference reaches, the risks are identified as being associated with reference conditions. Risks are not identified for these reaches.

- For exposure reaches where some HQ values are greater than one, potential risks are identified and specific exposure pathway associated with the risks are discussed.

Inspection HI values for each surrogate species and each riparian exposure reach reveals the following main conclusions:

- Risks are above a level of concern in Strawberry Creek for ingestion of aluminum in surface water; incidental ingestion of arsenic, and lead in soil; ingestion of arsenic, cadmium, lead, selenium, and thallium in soil invertebrates; and ingestion of antimony, arsenic, lead, and thallium in plants.

- Risks are above a level of concern in Ruby Gulch for ingestion of aluminum in surface water; and ingestion of cadmium and chromium in soil invertebrates and antimony in plants.

- Risks are below a level of concern in HooDoo Gulch for all wildlife receptors.

- Risks are above a level of concern in downstream Bear Butte Creek for ingestion of antimony, and lead in plants; and ingestion of arsenic, cadmium, lead, and vanadium in soil invertebrates.

Inspection of HQs for the mine source area reveals the following:

- Some location specific HQs for surface soil or fill material samples are within a level of concern (> 1) for arsenic, manganese, selenium, vanadium, lead, and zinc. These HQs are higher than those associated with the range of possible background soil concentrations. Risks are associated with the ingestion of manganese, selenium, vanadium, lead, and zinc in plants and the incidental ingestion of arsenic in the soil and/or fill material.

- Some location specific HQs for for antimony, chromium, molybdenum, and lead in waste rock samples are within a level of concern (HQ >1) but are not within a level of concern for the other waste types (surface soil, soil, fill material). These HQs are higher than those associated with the range of possible background soil concentrations. Risks are associated with the ingestion of antimony, chromium and molybdenum in plants and the incidental ingestion of antimony and lead in waste rock.

- HQs for all remaining COPCs for all samples and sample types are below a level of concern. Either HQ values are all ≤ 1 or the HQ values are less than HQ values a background conditions.

Only one line of evidence is available to evaluate risks for wildlife. A summary of the risk evaluation is provided in the following text table.

Weight of Evidence for Riparian Exposure Reaches	
Line of Evidence	**Findings**
HI calculations based on COPC concentrations measured in soil, water and diet	For Strawberry Creek (Riparian area) risks are above a level of concern for ingestion of aluminum in surface water; incidental ingestion of arsenic and lead in soil; and ingestion of arsenic, cadmium, lead, selenium, and thallium in soil invertebrates and ingestion of antimony, arsenic, lead and thallium in plants. For Ruby Gulch (Riparian area) risks are above a level of concern for ingestion of aluminum in surface water; ingestion of cadmium and chromium in soil invertebrates; and ingestion of antimony in plants. For Hoodoo Gulch (Riparian area) risks are above a level of concern for incidental ingestion of aluminum in sediment. For downstream Bear Butte Creek risks are above a level of concern for ingestion of antimony and lead in plants; and ingestion of arsenic, cadmium, lead, and vanadium in soil invertebrates.

Weight of Evidence for Riparian Exposure Reaches	
Line of Evidence	**Findings**
HQ calculations based on COPC concentrations measured in surface soil, subsurface soil, fill material, waste rock, and plants.	For the Mine Source Area, risks are above a level of concern for ingestion of manganese, selenium, vanadium, lead, and zinc in plants and the incidental ingestion of arsenic in environmental media (soil, surface soil, waste rock or fill material). For the Mine Source Area, risks are above a level of concern for exposures to waste rock (but not other waste material types) for ingestion of antimony, chromium and molybdenum in plants (growing on the waste rock) and the incidental ingestion of antimony and lead in waste rock.

Based on this line of evidence, it is concluded that risks from site-related COPCs in surface water and soil are of concern to wildlife receptors in the Riparian Area along Strawberry Creek, Ruby Gulch and downstream Bear Butte Creek.

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List of Acronyms and Abbreviations

AOI	Area of Interest
BW	Body Weight
C	Concentration
COPC	Chemicals Of Potential Concern
DF	Dietary Fraction
DNAPL	Dense Non-Aqueous Phase Liquid
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESG	Equilibrium Partitioning Sediment Guideline
FCV	Final Chronic Value
GC-MS	Gas Chromatography - Mass Spectrometry
HI	Hazard Index
HQ	Hazard Quotient
IR	Intake Rate
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
MATC	Maximum Acceptable Tissue Concentration
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
RBA	Relative Bioavailability
RBP	Rapid Bioassessment Protocols
SAP	Sampling and Analysis Plan
SCM	Site Conceptual Model
SEC	Sediment Effect Concentration
SERA	Screening-Level Ecological Risk Assessment
SIM	Selective Ion Monitoring
SVOC	Semi-volatile Organic Compound
TCDD	*2,3,7,8*-Tetrachlorodibenzodioxin
TEF	Toxicity Equivalency Factor
TEQ	TCDD Equivalent Concentration
TOC	Total Organic Carbon
TRV	Toxicity Reference Value
UCL	Upper Confidence Limit

USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

1.0 INTRODUCTION

1.1 Purpose

This document is a baseline ecological risk assessment (ERA) for the Gilt Edge Mine located southeast of Lead and Deadwood, South Dakota (Figure 1-1). The purpose of the ERA is to describe the likelihood, nature, and extent of adverse effects to ecological receptors resulting from exposure to contaminants released at the mine and to surrounding areas as a result of site activities. This information, along with other relevant information, is used by risk managers to make decisions whether remedial actions are needed to protect the environment. If remediation is warranted, a separate investigation is performed to evaluate the relative merits of a range of alternative remedial actions which might be undertaken to achieve the risk management goals and reduce risks.

1.2 Approach

This ERA is completed according to current United States Environmental Protection Agency (USEPA) guidance for ecological risk assessments (USEPA 1992, 1997a, 1998). The general sequence of steps used to complete an ERA for a Superfund site is illustrated in Figure 1-2 (USEPA 1997a). It is important to realize that the eight steps shown in Figure 1-2 are not intended to represent a linear sequence of mandatory tasks. Rather, some tasks may proceed in parallel, some tasks may be performed in a phased or iterative fashion, and some tasks may be judged to be unnecessary at certain sites.

For the Gilt Edge Mine site, the ERA process was initiated by performing a screening-level ecological risk assessment (SERA) in January of 2001 (USEPA 2001a). Because a SERA normally uses a number of simplifying assumptions and approaches and is intentionally conservative, the SERA was not intended to support any final quantitative conclusions about the magnitude of the potential ecological risks. Rather, the SERA provided preliminary information on the potential for adverse effects to aquatic receptors (including benthic invertebrates and fish) exposed via direct contact to chemicals of potential concern (COPCs) in surface water and sediments, and to terrestrial wildlife receptors exposed via ingestion of surface water, sediments, and fish. The SERA concluded that risks from site-related chemicals could not be excluded for any of these ecological receptors, and identified data needed for the completion of a more detailed evaluation.

Following completion of the SERA, additional data collection efforts were conducted by the USEPA to support a more detailed and thorough evaluation of ecological impacts at the site. These efforts included collection of additional abiotic and biotic samples, site-specific sediment and surface water toxicity testing, and an analysis of the aquatic habitat and benthic and fish communities in potentially impacted surface waters. This report uses these new data along with the historical data to provide an updated and refined ecological risk evaluation for the site.

1.3 Organization

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

Section 2 - This section presents the location, description, and environmental setting of the Gilt Edge Mine site.

Section 3 - This section discusses the available data for the Gilt Edge Mine Site including a description of the nature and extent of contamination present in surface water, sediment, surface soils, and biological tissues

Section 4 - This section presents the ecological problem formulation, including a summary of the SERA findings and conclusions, the site conceptual model, the assessment and measurement endpoints, and a description of the basic methods used in the assessment.

Section 5 - This section presents the ecological risk characterization for aquatic receptors of concern, including fish and benthic macroinvertebrates.

Section 6 - This section presents the ecological risk characterization for terrestrial receptors of concern, including plants and soil organisms.

Section 7 - This section presents the ecological risk characterization for wildlife receptors of concern.

Section 8 - This section presents an analyses of uncertainties in the ecological risk assessment

Section 9 - This section provides references for the ecological risk assessment.

2.0 SITE CHARACTERIZATION

2.1 Site Location

The Gilt Edge Mine is listed as CERCLIS Site # SDD987673985 and is also known as the Strawberry Creek Tailing Piles and Brohm Gold Mine. The site is situated in the northern Black Hills of western South Dakota (SDDENR, 1999) near the town of Lead and Deadwood to the west and Galena to the east (Figure 1-1).

2.2 Site Description

The Gilt Edge Mine is part of the Bear Butte Mining District, which has been the site of numerous gold mining operations since the mid-1870's (Brohm Mining Corp., 1988). The Gilt Edge Mine is situated at an elevation between 5,200 and 5,600 feet. The mine is located at the top of the Strawberry Creek watershed. Historic mining operations in the Strawberry Creek/Ruby Gulch drainages accounted for 210,776 tons of ore extracted to produce 41,200 ounces of gold (U.S. Department of Interior, Bureau of Mines (BOM), 1940). The mined ores contained aquiferous limonite, which fill small fractures or impregnations of the decomposed portion of a quartz-monsonite porphry. The limonite merges into pyrite and other sulfides, including copper sulfide (BOM, 1940; URS, 1999a).

The property of the Gilt Edge Mines, Inc. is a consolidation of claims, including the Sunday, Rattlesnake Jack, Golden Reward, Oro Fino groups, and others. Mining activities began at the site in 1876, when the Gilt Edge and Dakota Maid claims were located. Historic underground mining operations extracted sulfide-bearing gold ores from irregular deposits in veins and fracture zones in the volcanic rocks. Some limited surface mining was also conducted at the site (USDOI, 2000). Production of gold and silver, along with small amounts of copper, lead, and zinc are reported. Underground mines include the Gilt Edge, Pyrite, Rattlesnake Jack, Hoodoo, Union Hill, and Anchor. The Gilt Edge Mine Site including Anchor Hill encompasses approximately 412 acres and includes the following features (Figure 2-1):

> **Sunday Pit**. 29.5 acre inactive pit that is partially backfilled and partially reclaimed. In 1998, the pit contained approximately 57 million gallons of acid water (USEPA, 2000). . The Sunday Pit has been excavated to depths extending below the water table in the bedrock aquifer. Bottom grade of the Sunday Pit is at an approximately 5,275 feet. Pre-mining water levels were at approximately 5,340 feet (Brohm Mining Corp., 1988). Groundwater flow into the Sunday Pit is at 5,250 feet (Hydro Engineering, 1997).

Dakota Maid Pit. A 17.1 acre inactive pit that is partially backfilled and partially reclaimed. In 1998, the pit contained approximately 4 million gallons of acid water (USEPA, 2000). The Dakota Maid Pit was excavated below the water table in the bedrock aquifer. Historic underground workings are known to interconnect with the pit and water levels in the pit area are influenced by these workings. Discharges from the King Mine flow into Pond D. The King Adit controls the water level in the Dakota Maid Pit at an elevation of 5,320 feet (Water Management Consultants, Inc., 1999). Brohm began pumping water from the Dakota Maid Pit to the Sunday Pit on June 23, 1994 (Brohm Mining Corp., 1994). Their intention was to pump the pit as dry as possible to eliminate the seep and minimize groundwater flow into the pit by attempting to seal the old workings. Brohm was unable to reduce the water level low enough to seal the seep or the sources of groundwater flow into the pit from the old workings (SDDENR, Minerals and Mining Program, 1998, personal communication).

Anchor Hill Pit. The Anchor Hill Pit located near the headwaters of Strawberry Creek is a 23.6 acre pit mined as recently as 1997 (USEPA, 2000). The Anchor Hill Pit was excavated to an elevation of 5,340 feet. Mining was performed in a partially oxidized fracture zone which trends approximately N 30 degrees-40 degrees East, dipping 80 to 90 degrees quartz trachyte porphyry (Tqtp) (Water Management Consultants, Inc., 1999; USDOI, 2000). Although a relatively impervious rock mass surrounds the pit, the permeability is unknown because the hydrology of the Deadwood Formation is not completely understood. The basal quartzite may transmit groundwater into and out of the pit area (USDOI, 2000).

Langley Pit. 8.1 acre pit mined by Brohm Mining Corp. in the first half of 1997. The northern portion of the pit is partially backfilled and reclaimed (USEPA, 2000).

Ruby Gulch Waste Rock Dump. 59.1-acre area where Brohm Mining Corp. placed a majority of the waste rock from Sunday, Dakota Maid, Langley, and Anchor Hill Pits, and off-loaded spent ore (approximately 13.4 million tons of waste rock and spent ore) (SDDENR, 1999). Ruby Repository is the main source of acid mine drainage (USEPA, 2000).

Heap Leach Pad. 37 acres loaded with spent ore (USEPA, 2000). From more recent activities, the Gilt Edge Mine includes two heap leach pads, in addition to several ore extraction pits. The Gilt Edge heap leach pad covers approximately 37 acres (28 acres from the original pad and 8 acres from the 1996 addition), with approximately 3.2 million tons of spent ore. A six-acre expansion to this pad was started with grubbing and liner placement in 1997, however, no ore was processed on the 1997 expansion pad (SDDENR, 1999). The on/off leach pad is bermed to prevent surface runoff (Brohm Mining Corp., 1988). The original, 28 acre pad is underlain by a multiple liner system. The heap leaching operation involved loading crushed ore onto a single on-off leach pad designed not to have discharge to surface or groundwater. The crushed ore was leached with a weak sodium cyanide (barren) solutions, dissolving the gold out of the ore and creating a pregnant (gold-bearing) solution. This solution flowed to the pregnant sump and then to a clarifier, where organic contaminants were removed. From the clarifier, the solution was pumped to de-aeration towers for oxygen removal. After the oxygen was removed, the solution flowed to the process plant, where zinc replaced gold in the solution and the gold precipitated out. The gold then went through a filter press and on to be processed. Once the gold was recovered from the solution, the barren solution was recharged with cyanide and pumped back to the leach pad for reuse (USEPA, 2000).

Relic Tailings. In December 1939, mill tailings were deposited in Strawberry Creek by Gilt Edge Mines, Inc. at the request of residents of Galena and Sturgis in an effort to have the tailings plug up limestone caverns in Bear Butte Creek to preserve stream flow through the town of Galena (USDOI, 2000). The Gilt Edge Mine initially included two piles of finely ground, abandoned mine tailings immediately adjacent to the upper reaches of Strawberry Creek and there is some evidence that tailings were directly released into Strawberry Creek (SDWNR, 1990; URS, 1999a). Some of the abandoned mine tailings adjacent to Strawberry Creek were incorporated into the heap leach pad (Durkin, 1994). The majority of the remaining relic tailings were removed from Strawberry Creek and back-filled mine source area in 1993 and 1994 (SDDENR, Minerals and Mining Program, 1994, personal communication).

Other Features. Other features include plant Buildings, Surge Pond, Neutralization Pond, and Diatomaceous Earth Pond (DE Pond) totaling 14.5 acres (USEPA, 2000); access, haulage and utility corridors totaling 150 acres (Brohm Mining Corp., 1995); and land application area totaling 42 acres (Brohm Mining Corp., 1995); crusher and ore Storage Area totaling 10.3 acres (USEPA, 2000) and fill material used for constructing haul and access roads (USEPA, 2000).

2.3 Site History

The general history of the Gilt Edge Mine Site is discussed in some detail in the SERA (USEPA, 2001a). Subsequent to this report other documents have been issued by EPA that provide detailed information on the history of the mine and the current site conditions. As detailed information is provided elsewhere, this ERA document does not duplicate this information. This document is focused on the resultant ecological risks associated with the mine operations. Instead table is provided that summarizes the history of the Gilt Edge Mine Site and is presented in Table 2-1. The historical mine operation processes and current acid mine drainage treatment (AMD) processes are depicted in Figures 2-2 and 2-3, respectively.

2.4 Environmental Setting

The Gilt Edge Mine Site is located in the North-Central Black Hills of South Dakota. The topography is characterized by mountainous terrain with narrow valleys. Anchor Hill forms the highest point on the north side of the site area at an elevation of 5,680 feet. An unnamed peak on the east side of the site area is at an elevation of 5,650 feet. The lowest point is at an elevation of 4,880 feet, which is located at the confluence of Bear Butte Creek and Ruby Gulch. The mountain slopes range from 6 to 60 percent and the soil permeability is classified as moderate, averaging about four inches per hour (JMM, 1985).

The Gilt Edge Mine Site is located at the headwaters of drainages that flow to the north, east and south (JMM, 1988). The primary drainage downstream of the Gilt Edge Mine Site is Bear Butte Creek. Bear Butte Creek is a third-order tributary of the Belle Fourche River. Bear Butte Creek flows within 0.5 mile of the eastern edge of the former mining permit boundary. Strawberry Creek, Ruby Gulch and Butcher Gulch all flow into Bear Butte Creek

Surface water from the Gilt Edge Mine Site drains through three sub-basins into Bear Butte Creek (OEA, 1998; USEPA, 1993c; SDDENR, 1999). Except during spring runoff, Bear Butte Creek disappears into sinkholes in the Madison limestone approximately 2.5 miles below the confluence with Ruby Gulch. The three main drainages pertinent to the Gilt Edge Mine site are:

- Ruby Gulch (0.07 miles^2) - Ruby Gulch is a moderately steep mountain stream with a gradient estimated to be approximately 0.074 ft/ft (JMM, 1988). Spent ore and waste rock have been deposited at the head of Ruby Gulch, which drains into Bear Butte Creek. These repositories are the primary source of AMD which is collected in a containment pond and then pumped over to the Sunday Pit and Dakota Maid Pit. Surface water in the

Ruby Gulch drainage is ephemeral in the upper reaches and intermittent in the lower levels (JMM, 1988; SDDENR, 1999).

- Strawberry Creek drainage (0.39 miles^2) - Strawberry Creek has its headwaters within the site boundaries and flows approximately 2.1 miles to Bear Butte Creek. Above its confluence with Bear Butte Creek, Strawberry Creek has an average discharge of 0.76 ft^3/s. Several areas within the Gilt Edge Mine Site have impacted this drainage (URS, 1999b). The stream channel downstream from the WWTF outfall is approximately 0.6 m (2 ft) in width and ranges to 25 cm (10 in.) in depth. Although the gradient is steep and the water velocity generally fast, there are numerous pools and areas of slow flow behind boulders and other obstructions. The stream substrate in the riffle areas consists primarily of cobble to boulder sized particles and the substrate in the pools and quiet areas was hard packed sand. A white-grey precipitate covered the substrate throughout the reach extending from the outfall to the Hoodoo Gulch (USEPA, 2002). Along the streambanks and on the dry faces of rocks, the precipitate has hardened into a white crusty deposit, whereas in the pools, the precipitate had accumulated into a gelatinous floc-like material (USEPA, 2002). The alkalinity and total organic carbon (TOC) content of the flocculent material is high (11,400 mg/kg and 31,200 mg/kg, respectively).

- Hoodoo Gulch (0.05 miles^2) - Hoodoo Gulch is located on the southeastern corner of the site (Figure 2-1) and drains into Strawberry Creek. Runoff from the site into the portion of Hoodoo Gulch was treated in a passive system that channeled flow into a basin containing sodium hydroxide pellets (USEPA, 2002). Two settling ponds are located in series downstream of the sodium hydroxide treatment basin. Both of these ponds are approximately 7.5 m (25 ft) in diameter and are positioned on a terrace created by an earthen berm on the downstream edge. The precipitate resulting from the elevated pH settles in these ponds, and the clarified effluent flows down the gulch and enters Strawberry Creek. Although the treatment efficiency of these ponds was a function of discharge, contact time was typically high enough to raise the pH sufficiently to cause significant dissolution of inorganic constituents, and to produce a hydroxide precipitate. The hydroxide precipitate was observed in September of 2000 but not in October of 2001 (USEPA, 2002). As part of the maintenance of the treatment system, the ponds were periodically drained, and the sludge was removed (USEPA, 2002). It is also reported that mine tailings were historically disposed of in Hoodoo Gulch (Brohm Mining Corp., 1998b).

For the purposes of this assessment, reference locations represent upgradient (upstream) concentrations of metals; those concentrations that do not represent contamination from the site. However, these locations are not assumed to be pristine. For this assessment, four drainages are used as reference:

- Butcher Gulch - It is reported that no Gilt Edge Mining activities have affected this drainage, although historical activities (pre-Brohm) may have impacted this area. This drainage is used as a reference for Strawberry Creek. This drainage was also used by URS in the Site Inspection (SI) as a reference (URS, 1999b).

- Upstream Bear Butte Creek - The area upstream of the confluence with Strawberry Creek is used in this assessment as a reference for the portion of Bear Butte Creek downstream of the confluence. This drainage was also used by URS in the Site Inspection (SI) as a reference (URS, 1999b).

- Boomer Gulch - Boomer Gulch is a small perennial tributary with a one-square mile watershed. This tributary enters Strawberry Creek about 0.25 mile upstream of Bear Butte Creek. This tributary is used as a reference for Strawberry Creek.

- Two Bit Creek - Two Bit Creek flows in a northern direction until it reaches the confluence of Boulder Creek, which then flows in an eastern direction until it reaches the confluence of Bear Butte Creek, downgradient of Galena near Boulder Park. A portion of Two Bit Creek is used as a reference for Strawberry Creek.

3.0 NATURE AND EXTENT OF CONTAMINATION

Several investigations of the Gilt Edge Mine Site were completed prior to and subsequent to the SERA. The SERA identified the presence of a number of contaminants of potential concern in site soil, sediment, groundwater, and surface water. In the SERA, the USEPA reviewed the adequacy of the available data to support reliable ecological risk evaluations, and identified several data gaps. The USEPA recommended additional sampling and analysis of environmental media needed to support risk assessment at site-related locations based on the results of a scoping meeting and a site visit conducted August 8 to 9, 2000. A field investigation was conducted in September 2000. A second field investigation was completed in October 2001 to document possible changes in water and sediment chemistry and toxicity, and the benthic macroinvertebrate community resulting from changes in the waste water treatment plant. A report issued in April of 2000 summarizes the data collection and results for both the September 2000 and October 2001 field investigations (USEPA, 2002).

For the purposes of this assessment, the available data for the Gilt Edge Mine site are divided into two conceptual categories: Mine Source Area and Riparian Area. Mine source area refers to data collected within the boundaries of the mine site and workings while Riparian Area refers to data collected in surface water drainages (surface water, sediment, soil and biological tissue) outside of the boundary of the mine site and workings. All samples from Strawberry Creek, Hoodoo Gulch and Ruby Gulch are considered to be "Riparian Area".

The USEPA has compiled a master database of all results with the assistance of CDM Federal. The ERA uses a subset of data from this master database (as of the date of this document) with some additions and modifications. Additions to the database included the creation of new labels (columns) to assist with groupings of data necessary for the risk assessment and the addition of data from USEPA (2002a) added for October 2001 sampling event. Data was modified to reflect consistent units of measure (conversions were made where necessary). Data were excluded from use in the ERA in the following cases:

- Data rejected and flagged with an "R" qualifier
- Data from "Brohm.dbf" as results appear to be duplicate entries and cannot be verified from an original source
- Data where Mine Source Area or Riparian Area exposure reach determinations cannot be made

3.1 Riparian Areas

3.1.1 Surface Water Data

For the purposes of this assessment, areas of potential ecological exposure are divided into a number of reaches, including several locations that are not believed to be impacted by site-related releases and that serve as reference areas. These reaches and reference areas are listed below and are shown in Figure 3-1.

Exposure Reaches for Surface Water		
Reach	**Description**	**Designation**
Strawberry Creek	Strawberry Creek and surrounding areas	Site
Ruby Gulch	Ruby Gulch and surrounding areas	Site
Hoodoo Gulch	Hoodoo Gulch and surrounding areas.	Site
Downstream Bear Butte Creek	Bear Butte Creek downstream of confluence with Strawberry Creek	Site
Upstream Bear Butte Creek	Bear Butte Creek upstream of confluence with Strawberry Creek	Reference for Bear Butte Creek
Boomer Gulch	Boomer Gulch and surrounding areas.	Reference for Strawberry Creek
Butcher Gulch	Butcher Gulch and surrounding areas.	Reference for Strawberry Creek
Two Bit Creek	Two Bit Creek (Anchor Gulch) and surrounding areas.	Reference for Strawberry Creek

Surface water sampling stations grouped by reaches are summarized in Table 3-1. Figure 3-2 provides a map of the sampling locations. Appendix A provides summary statistics (detection frequency, average, minimum, maximum) for each analyte in each medium in each reach.

3.1.2 Sediment Data

For the purposes of this assessment, the sediment data are divided into the same reaches as described in Section 3.1.2 for the surface water data. The sediment sampling stations grouped by reach are summarized in Table 3-2. Figure 3-2 provides a map of the sampling locations.

Appendix A provides summary statistics (detection frequency, average, minimum, maximum) for each analyte in sediment in each reach.

3.1.3 Soil Data

For the purposes of this assessment, the soils data are divided into the same reaches as described in Section 3.1.2 for the surface water data and Section 3.1.3 for the sediment data. The soil sampling stations grouped by reach are summarized in Table 3-3. Appendix A provides summary statistics (detection frequency, average, minimum, maximum) for each analyte in soil in each reach. The soils data for the Riparian Area area are limited to those collected in January of 2001 by EPA (2001b) (Figure 3-3).

3.1.4 Biological Tissue Data

Fish tissue data are available for Strawberry Creek, upstream Bear Butte Creek (reference), downstream Bear Butte Creek, and Boomer Gulch (reference) from one investigation completed in September of 2000 (USEPA, 2002b). These sample were collected by the South Dakota Game, Fish and Parks Commission (SDGFPC) using multiple pass removal by electrofishing. The SDGFPC conducted community sampling at ten locations (Figure 3-4). EPA retained a subsample of fish from the September 2000 collection effort for tissue analysis (USEPA, 2002b). Whole fish were composited by species to obtain the necessary sample volume. Three replicates (composites or individuals, as appropriate) were collected per location. Fish were only analyzed if three replicates were collected. A summary of the fish tissue samples collected is provided as Table 3-4. Fish tissue was analyzed for TAL metals, cyanide, percent lipids, and percent moisture. Appendix A-4 provides summary statistics (detection frequency, average, minimum, maximum) for each analyte in whole body fish tissue in each reach.

3.2 Mine source area Data

3.2.1 Surface Water

Surface water is present within the mine source area area as standing water in the mine working pits, ponds, and culverts. In this assessment, it is necessary to understand risks associated with a possible release of mine source area waters untreated (without going through the wastewater treatment plant) to Riparian Area surface waters. The surface water sampling stations used to evaluate risks for the Mine Source are summarized in Table 3-5. Appendix A-5 provides summary statistics (detection frequency, average, minimum, maximum) for each analyte in mine source area surface water.

3.2.2 Soil and Other Materials

Surface material within the mine source area area is composed of fill material, waste rock and some soil (surface and subsurface). The material most recently present within the Mine Source area has been characterized as the result of four separate investigations:

URS (1999) Site Inspection Data. The Site Inspection (SI) completed for the Gilt Edge Mine Site in 1999 included collection of seven soil samples within the mine source area area (URS, 1999). The results for each sampling location are used in this assessment to evaluate risks.

Robertson Geoconsultants Waste Rock Study. A survey of waste rock was completed by Robertson GeoConsultants in 2000 (Robertson GeoConsultants, 2000). This survey was completed to identify current (ARD) sources and to identify any material that could be used for construction and cover purposes. Samples were collected at 14 different areas as summarized in Table 3-6 and were analyzed for metal content. The results for each sampling location (depicted on Figure 3-5) are used in this assessment to evaluate risks.

Site-Wide Soil and Vegetation Investigation. An investigation was completed in October of 2001 to determine surface and subsurface physical and chemical characteristics of topsoil resources at the site USEPA (2001b) . This study is referred to as the *"Site-Wide Soil and Vegetation Investigation"*. A total of 52 soil samples were collected for eight soil stockpiles and 3 cover soil areas located within the mine site boundary (Table 3-6 and Figure 3-6). The samples were analyzed for TAL list metals and total cyanide. The data for soil samples within each soil stockpile area and cover soil area (depicted on Figure 3-6) are used in this assessment to evaluate risks.

Site-Wide Fill Material Investigation. An investigation was completed in the fall of 2001 to characterize 14 zones of fill material for the purpose of determining remedial alternatives (USEPA, 2002b). This study is referred to as the *"Site-Wide Fill Material Investigation"*. The fill material zones represent overburden rock and soil that was used as fill to build mine process foundations, embankments, and site roads. Two test pit samples (vertical composites of subsamples collected at 4-foot depth intervals) were collected from each fill material location as shown on Figure 3-7. These samples were analyzed for TAL metals. The data for soil samples within each fill material zone (depicted on Figure 3-7) are used in this assessment to evaluate risks.

Human Health Risk Assessment Support Study. As part of the *Site-Wide Fill Material Investigation*, surface soil samples (0 to 2") in depth were collected from each of the14 fill material zones (Figure 3-7). In each fill material zone, five grab samples in the vicinity of the test pit (sample locations are shown as green circles in Figure 3-7) were collected, composited, sieved, and analyzed for TAL metals. The data for soil samples within each fill material zone are used in this assessment to evaluate risks (USEPA, 2002c).

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4.0 PROBLEM FORMULATION

Problem formulation is a systematic planning step that identifies the major concerns and issues to be considered in the ERA, and a description of the basic approach that will be used to characterize the potential risks that may exist (USEPA 1997a). Problem formulation usually begins by development of a conceptual site model that identifies sources of chemical release to the environment, evaluates the fate and transport of chemicals in the environment, and identifies exposure pathways of potential concern for ecological receptors. Based on the conceptual site model, assessment endpoints, measurement endpoints, and testable hypotheses are identified that form the basis of the ERA.

As discussed in USEPA guidance (USEPA 1997a), problem formulation is an iterative process, undergoing refinement as new information and findings become available. The problem formulation for this baseline ecological risk assessment began with a SERA that was completed for the site in March 2001 (USEPA 2001a). The purpose of the SERA was to determine if there was a need for additional data collection and/or additional risk assessment at the site, and to help focus any additional effort on the main issues of concern. Because a SERA is intentionally simplistic and conservative, it is not intended to support any final quantitative conclusions about the magnitude of the potential ecological risks identified. The following section summarizes the main findings of the SERA, which in turn helped define the problem formulation for the baseline risk assessment.

4.1 Screening-Level ERA Summary

Ecological Receptors of Potential Concern

Ecological receptors evaluated in the SERA included terrestrial wildlife receptors (mammals and birds) and aquatic species (fish and benthic macroinvertebrates) in the Bear Butte Creek, Strawberry Creek, Ruby Gulch, Hoodoo Gulch, Butcher Gulch, and Boomer Gulch.

Exposure Pathways Evaluated

Exposure pathways that were quantitatively evaluated in the SERA included:

- Direct contact of aquatic receptors with surface water
- Direct contact of benthic macroinvertebrates with sediment
- Ingestion of surface water by terrestrial wildlife (mammals and birds)

- Incidental ingestion of sediment by terrestrial wildlife (mammals and birds)
- Ingestion of fish by terrestrial wildlife (mammals and birds)

Exposure Pathways that could not be Evaluated in the SERA

Exposure pathways that could not be quantitatively evaluated in the SERA included:

- Incidental ingestion of soil by terrestrial wildlife (mammals and birds)
- Ingestion of plants and soil invertebrates by terrestrial wildlife (mammals and birds)
- Direct contact of terrestrial receptors (plants and soil invertebrates) with soil

Summary of Screening-Level Risk Findings

Based on the preliminary risk characterization in the SERA, none of the exposure pathways considered in the SERA could be excluded, and further evaluation was recommended for all exposure pathways. However, in many cases, the available information on the nature and extent of contamination was limited, and the SERA identified a number of data areas where additional information was needed to help improve the reliability and accuracy of the risk assessment. These data gaps were considered in the development of the sampling completed by EPA in September of 2000 and October of 2001 (USEPA, 2001a).

4.2 Baseline ERA Site Conceptual Model

Figure 4-1 presents the site conceptual model (SCM) for the baseline ecological risk assessment. Because no pathways could be excluded as a result of the SERA, this site model is very similar to the site model that was developed for the SERA. One difference in the models (between SERA and baseline) is the distinction between interrupted and non-interrupted flow from the sources to secondary source media. This is further discussed in the following section

4.2.1 Sources

The first portion of the SCM identifies the sources for potential transport and release and migration pathways of contaminants from original source to secondary source media (soil, dust, surface soil, sediment, surface water and groundwater). Several source media related to mine operations are or could contribute to contamination to the surrounding environment. A brief general description of the sources is provided in the following paragraphs:.

Relic or Historic Tailings. Historically tailings were deposited into the Strawberry Creek and Hoodoo Gulch drainages (Brohm Mining Corp., 1998b). Mine tailings were deposited in Strawberry Creek by Gilt Edge Mines, Inc., at the request of residents of Galena and Sturgis, in an effort to have the tailings plug up limestone caverns in Bear Butte Creek to preserve stream flow through the town of Galena. A majority of the tailings in Strawberry Creek were removed in 1993 as previously described in Section 2. The remaining tailings in Strawberry Creek and tailings in Hoodoo Gulch could be a source of contamination for soils within the floodplain as well as surface water and sediments within these drainages.

Waste Rock and Crushed Ore. Approximately 13.4 million tons of waste rock and spent ore were deposited in the headwaters of Ruby Gulch (Brohm Mining Corp., 1998b). This material contained sulfide mineralization (Brohm Mining Corp., 1994, 1998b) and contributed AMD to the downgradient drainages. The Ruby Waste Rock repository has recently been remediated and reclaimed. A leachate detection system is currently in place.

Heap Leach Pad. The Heap Leach Pad is a source of AMD to groundwater and drainages and was a historical source of cyanide.

Acidic Waste Fill Material. Several of the haul roads and plant areas are built on fill composed of acidic waste. This material is a source of contamination for groundwater and surface soil in areas where it was not covered. Several efforts have been completed to map these areas and to characterize the nature of the fill material.

Underground Mine Workings. Discharges from underground mine workings may contribute to contamination in groundwater or any of the surface drainages. For example, drainage from the King Mine flows into Pond D and the King Adit controls the water level in the Dakota Maid Pit (Water Management Consultants, Inc., 1999).

Containment Pond An AMD collection pond was constructed downstream from of the Ruby Gulch waste rock repository within the Ruby Gulch drainage. The AMD in the containment pond was pumped to the Dakota Maid and Sunday Pits (Brohm Mining Corp, 1998a).

Ore Pits (Langley, Dakota Maid, Sunday, Anchor Hill). Water is pumped from the Dakota Maid Pit to the Sunday Pit (Brohm Mining Corp., 1994, personal communication). Water from the Sunday Pit is pumped through the co-precipitation water treatment plant and discharged under a Surface Water NPDES Permit. There were numerous violations of the permitted discharge limits. Prior to January 1996, the resulting sludge from the wastewater treatment was pumped back into the Sunday Pit. The sludge was then pumped at a rate of 50 to 60 gallons per minute to unlined shallow trenches on top of the waste rock dump where the sludge migrated from the unlined trenches to the toe of the Ruby Gulch waste dump. The Ruby Gulch waste dump has subsequently been closed and capped. An AMD detection and collection system has also been installed. The Anchor Hill Pit is located near the headwaters of Strawberry Creek The AMD contained in the pits is a source of contamination for groundwater and the drainages of Ruby Gulch, Strawberry Creek, and Hoodoo Gulch which ultimately drain to Bear Butte Creek. The sludge(s) disposed of at the waste rock dump was a potential source of groundwater and soil contamination and may have contributed contamination to the Ruby Gulch drainage.

Turbo Misters. As part of process for removing the water from the pits, turbo misters were operated near the Sunday Pit which sprayed water from the pit on surrounding land. The use of these misters may have transported metal contaminants onto surface soils.

4.2.2 Release Mechanisms and Secondary Source Media

The potential release of contaminants from the identified sources can be classified into four types: wind erosion, interrupted flow, uninterrupted flow, and leaching. These release mechanisms may result in the contamination of suspended soil or dust, surface soil, sediment, surface water or groundwater which are also referred to as secondary source media.

Wind Erosion

Source material may be eroded by wind resulting in suspended dust or soil that may be inhaled or may also result in the further contamination of soils as the suspended materials are deposited.

Interrupted Flow

Interrupted flow refers to the interception and treatment of acid mine drainage. There are two types of interrupted flow at the Gilt Edge Mine site including the release of treated effluent from a wastewater treatment plant into Strawberry Creek and the instream treatment of surface water with sodium hydroxide in Hoodoo Gulch.

Prior to 2002, acid mine drainage (AMD) from the Dakota Maid and Sunday Pits was treated in a sodium hydroxide precipitation wastewater treatment plant (WWTP) located near the top of Ruby Gulch and the effluent discharged directly to the headwaters of Strawberry Creek (Station 001 on Figure 3-2). Over the past 2 years, several studies were completed to evaluate the effectiveness of the treatment plant. As a result of the investigations, the WWTP is currently (as of the date of this report) being physically changed to a lime amendment process. The direct discharge of WWTP effluent to the headwaters of Strawberry Creek resulted in metals contamination of the surface water and sediments. In September of 2000, a white-grey precipitate was observed on the bottom substrate of Strawberry Creek throughout the reach extending from the outfall downstream to the confluence with Hoodoo Gulch (USEPA, 2002a). Along the streambanks and on the dry faces of rocks, the precipitate has hardened into a white crusty deposit, whereas in the pools, the precipitate had accumulated into a gelatinous floc-like material (USEPA, 2002a).

Runoff from the mine site into Hoodoo Gulch is treated in a passive system that channeled flow into a basin containing sodium hydroxide pellets (USEPA, 2002a). Two settling ponds are located in a series downstream of the sodium hydroxide treatment basin. The precipitate resulting from the elevated pH settles in these ponds, and the clarified effluent flows downstream to Strawberry Creek (USEPA, 2002a).

Uninterrupted Flow

Uninterrupted flow refers to the release of contaminants from the sources that is not intercepted by any treatment system. Uninterrupted flow includes the release of contaminants from sources by seepage, run-off, or direct discharge (turbo misters) to surface water, sediment and surface soil.

Leaching

The leaching of contaminants from sources may result in the contamination of groundwater which then can be discharged to surface water.

4.2.3 Exposure Pathways and Receptors

Receptors identified for this assessment include aquatic receptors (fish and benthic macroinvertebrates), terrestrial receptors (plants and soil invertebrates), and wildlife receptors (avian and mammalian). These receptors may be potentially exposed to contaminants via one or more exposure media (Figure 4-1), including surface water, sediment, aquatic food items, surface soil, and terrestrial food items.

As indicated in the SCM, although there are a number of complete exposure pathways by which ecological receptors may come into contact with site-related contaminants, not all exposure pathways are likely to be of equal concern. For the purposes of this risk assessment, each complete exposure pathway has been classified as follows:

- The pathway is considered to be of potential concern, and sufficient data exist to support a quantitative risk evaluation. These cases are indicated by boxes containing a solid circle (●). These pathways are the primary focus of this risk assessment.

- The pathway is considered to be of potential concern, but available data are too limited to support a reliable quantitative risk evaluation. These cases are shown by boxes with an open circle (○).

- The risk posed by the pathway is likely to be minor, either on an absolute basis and/or in comparison to other exposure pathways that affect the same receptor. These cases are indicated by boxes with an "X". Because these pathways are judged to be of minor concern, they are not evaluated quantitatively in the ERA.

- The pathway is considered to be incomplete. These cases are shown by empty, open boxes.

The following identifies which pathways are of chief concern at the Gilt Edge Mine site and are selected for quantitative evaluation.

Aquatic Receptors

- The main pathway of exposure for all aquatic receptors is direct contact with surface water. This pathway is evaluated quantitatively for fish and benthic macroinvertebrates.

- Direct contact with sediment is a potentially significant pathway for benthic macroinvertebrates. Data are available to allow an assessment of risks from direct contact with sediment and porewater, and these pathways are evaluated quantitatively. Fish have much less direct contact with sediment, and exposure of fish to this medium is considered minor or negligible.

- Ingestion of aquatic food web items is a pathway of potential concern for fish and benthic invertebrates. Likewise, incidental ingestion of sediment by these receptors might occur in some cases. Quantitative evaluation of oral exposure for aquatic receptors is limited by lack of oral toxicity values for aquatic receptors, so ingestion exposures are evaluated qualitatively rather than quantitatively for fish and benthic macroinvertebrates.

Terrestrial Plants and Soil Invertebrates

- The primary exposure pathway for both terrestrial plants and soil invertebrates is direct contact with contaminated soils. This pathway is evaluated quantitatively for both receptors. For soil invertebrates, this evaluation includes both direct contact and soil ingestion.

Wildlife Receptors

- Wildlife receptors (birds, mammals) may be exposed by ingestion of surface water, and this pathway is evaluated quantitatively.

- Wildlife receptors (birds, mammals) may be exposed by ingestion of food web items (either from the terrestrial environment and/or from the aquatic environment). Data are available on the tissue levels of contaminants in fish and risks to wildlife from ingestion of fish are evaluated quantitatively. Data are not available on the tissue levels of site-related chemicals in other types of food web items (e.g., benthic invertebrates, plants, and soil invertebrates). Exposures related to ingestion of these food items is estimated based on either simple assumptions or bioaccumulation models.

- Wildlife receptors may ingest soil or sediment during feeding, especially for soil- or sediment-dwelling prey items. This pathway can be important in some cases and is valuated quantitatively.

- Direct contact (i.e., dermal exposure) of wildlife receptors to soils, sediments, and surface water may occur in some cases, but these exposures are judged to be minor in comparison to risks from ingestion exposure, and one not evaluated quantitatively.

- Inhalation exposure to airborne dusts is possible for all terrestrial receptors. However, this pathway is generally very minor, and is not evaluated quantitatively.

Selection of Wildlife Indicator Species

It is not feasible to evaluate exposures and risks for each avian and mammalian species potentially present at the site. For this reason, specific wildlife species are identified as surrogates (representative species) for the purpose of estimating exposure and risk. The surrogate species are wildlife species present at the site that are representative of other species with similar dietary preferences and feeding guilds. Selection criteria for wildlife surrogate species include trophic level, feeding habits, and the availability of life history information. The species identified as surrogate species at this site include:

Masked shrew (*Sorex cinereus*). The masked shrew represents mammalian insectivorous species that feed primarily on soil invertebrates.

American robin (*Turdus migratorius*). The American robin represents avian insectivorous passerine species that feed primarily on soil invertebrates.

Belted kingfisher (*Ceryle alcyon*). The belted kingfisher represents piscivorus avian species that feed primarily on fish.

Mink (*Mustela vison*). The mink represents semi-aquatic mammalian species that feed primarily on fish.

Deer Mouse (*Peromyscus maniculatus*). The deer mouse represents omnivorous mammalian species that feed on plants and seeds and soil invertebrates.

Bobwhite Quail (*Galliformes phasiadinae*). The bobwhite quail represents avian species that feed primarily on plants and seeds.

Exposure profiles are presented for each of these representative species in Appendix B.

4.3 Management Goals

Management goals are descriptions of the basic objectives which the risk manager at a site wishes to achieve. The overall management goal identified for ecological health at the Gilt Edge Mine site as first described in the SERA is as follows (USEPA 2001a):

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

"Adequate protection" is generally defined as protection of growth, reproduction, and survival of local populations. That is, the focus is on ensuring sustainability of the local population, rather than on protection of every individual in the population.

In order to provide greater specificity regarding this general goal and to identify specific measurable ecological values to be protected, the following list of sub-goals was derived:

- Ensure adequate protection of terrestrial plant communities, including native plant communities, by protecting them from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.

- Ensure adequate protection of aquatic life in Strawberry Creek and Bear Butte Creek from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.

- Ensure adequate protection of terrestrial mammal and bird populations by protecting them from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.

- Ensure adequate protection of threatened and endangered species (including candidate species) and species of special concern and their habitat by protecting them from the deleterious effects of acute and chronic exposures to site-related contaminants of potential concern.

4.4 Assessment and Measurement Endpoints

Assessment endpoints are explicit statements of the characteristics of the ecological system that are to be protected. Assessment endpoints are either measured directly or are evaluated through indirect measures. Measurement endpoints represent quantifiable ecological characteristics that can be measured, interpreted, and related to the valued ecological components chosen as the assessment endpoints (USEPA 1992, 1997a).

Table 4-1 presents the assessment and measurement endpoints used to interpret potential ecological risks for the Gilt Edge Mine site. These measurement endpoints can be divided into three basic categories of approach, as follows:

- Hazard Quotients (HQs)
- Site-specific toxicity tests (SSTTs)
- Observations of population and community demographics (Pop/Comm. Dem.)

Each of these three basic approaches is described below.

<u>Method 1: Hazard Quotients</u>

Basic Equation

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

HQ = Exposure / Benchmark

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

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

In all cases, the exposure and benchmark must be expressed in like units. For example, exposure to silver in surface water (mg/L) must be compared to a silver benchmark in mg/L and an exposure to cadmium in muscle tissue (mg/kg) must be compared to a benchmark for muscle tissue (mg/kg).

Interpretation of HQ Values

If the value of an HQ is less than or equal to 1E+00, risk of unacceptable adverse effects in the exposed individual is judged to be acceptable. If the HQ exceeds 1E+00, the risk of adverse effect in the exposed individual is of potential concern. When interpreting HQ results for ecological receptors, it is important to remember that the assessment endpoint is usually based on the sustainability of exposed populations, and risks to some individuals in a population may be acceptable if the population is expected to remain healthy and stable. It may be more appropriate to characterize risks by quantifying the fraction of individuals that have HQ values greater than 1E+00, and by the magnitude of the exceedences. Clearly, if all HQs for individuals are below 1E+00, it is believed that no unacceptable effects will occur in the exposed population. Conversely, if many or all of the individual receptors have HQs that are above 1E+00, then unacceptable effects on the exposed population are likely, especially if the HQ values are large. If only a small portion of the exposed population has HQ values that exceed 1E+00, some individuals may be impacted, but population-level effects may not occur.

It is, however, difficult to identify the specific fraction (or fractions for specific endpoints, receptors and exposure pathways) of individuals that would need to be affected before the population is adversely affected. The fraction of the population that must have HQ values below a value of 1E+00 in order for the population to remain stable depends on the species being evaluated and on the toxicological endpoint underlying the toxicity benchmark (USEPA 2001d). Reliable characterization of the impact of a chemical stressor on an exposed population requires knowledge of the population size, birth rates, and death rates, as well as immigration and emigration rates. Because this type of detailed knowledge of site-specific population dynamics is generally not available, extrapolation from a distribution of individual risks to a characterization of population-level risks is generally uncertain and not possible.

To assist in interpreting HQ values, the HQ results are classified by the fraction of values that exceed 1E+00. This concept is illustrated schematically in Figure 4-2. The classification of risks is used to interpret the risk characterization results to allow for comparison of results across exposure reaches, to reference reaches and background conditions (reference reaches are used for the aquatic portion of the assessment as described in Sections 2 and 3 while background concentrations are used to interpret soils data). These relative risk results are intended to aide in the identification and selection of remedial action objectives. Based on this approach, risks to receptors residing in an exposure reach are classified into one of five categories, as shown below.

Classification of Risks based on HQ Values				
Distribution of HQ values	**Risk Category (Acute)**	**Preliminary Conclusion**	**Risk Category (Chronic)**	**Preliminary Conclusion**
All HQ values are less than or equal to 1	None	Risks are not present	None	Risks are not present
Less than 20% of the HQs values are greater than 1E+00	Moderate	Risks to the receptor group within this exposure reach are considered to be moderate.	Minimal	Risks to the receptor group within this exposure reach are possible but considered minimal
21% to 50% of the HQs values are greater than 1E+00	High	Risks to the receptor group within this exposure reach are considered to be high.	Moderate	Risks to the receptor group within this exposure reach are considered to be moderate.
51% to 99% of the HQ values are greater than 1E+00	Severe	Risks to the receptor group within this exposure reach are considered to be severe.	High	Risks to the receptor group within this exposure reach are considered to be high.
100% of the HQ values are greater than 1E+00.	Severe	Risks to the receptor group within this exposure reach are considered to be severe.	Severe	Risks to the receptor group within this exposure reach are considered to be severe.

In most cases, HQ values are not based on site-specific toxicity data, and do not account for site-specific factors that may either increase or decrease the toxicity of the metals compared to what is observed in the laboratory. Consequently, most HQ values should be interpreted as estimates rather than highly precise predictions and should be viewed as part of the weight-of-evidence along with the results of site-specific toxicity testing and direct observations on the structure and function of the aquatic community (see below).

<u>Method 2: Site-Specific Toxicity Tests</u>

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

Method 3: Population and Community Demographic Observations

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

4.5 Weight of Evidence Evaluation

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

5.0 RISKS TO AQUATIC RECEPTORS

5.1 Hazard Quotient Approach

As discussed in Section 4.3, site-related contaminants are of potential concern in Strawberry Creek, Bear Butte Creek, Hoodoo Gulch, and Ruby Gulch. Aquatic receptors living in these waters may be exposed to contaminants through several exposure pathways. Based on the site conceptual model (Figure 4-1), the following exposure pathways are quantitatively evaluated using the HQ approach:

- Direct contact with contaminants dissolved and/or suspended in surface water. This pathway is most applicable to fish, but is also applicable to benthic organisms that reside in the uppermost portion of the sediment substrate.

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

- Exposure of fish by all pathways combined, based on tissue levels of contaminants in fish tissue.

Each of these HQ-based evaluations is described below.

5.1.1 Risks to the Aquatic Community from Direct Contact with Surface Water

Surface Water COPC Selection

Surface water COPCs for aquatic receptors are selected using the procedure described in Appendix C based on all available surface water data from upstream Bear Butte Creek, downstream Bear Butte Creek, Strawberry Creek, Ruby Gulch, Butcher Gulch, Boomer Gulch and Two Bit Creek/ Anchor Gulch. Maximum surface water concentrations for each contaminant are compared to their respective chronic benchmark values (see Table D-1a,b). The concentration value of a contaminant in surface water may be expressed either as total recoverable or as "dissolved" (that which passes through a fine-pore filter). There is general consensus that toxicity to aquatic receptors is dominated by the level of dissolved metals (Prothro, 1993), since metals that are adsorbed onto particulate mater may be less toxic that the dissolved forms. Therefore the selection of COPCs in surface water is based on dissolved measurements.

The results of the COPC selection procedure for exposure of aquatic receptors to surface water are detailed in Appendix C-1. The COPCs selected for quantitative evaluation are presented below.

Quantitative COPCs for Exposure of Aquatic Receptors to Riparian Area Surface Water Target Analyte List (TAL) Metals		
Aluminum	Cobalt	Nickel
Arsenic	Copper	Selenium
Barium	Cyanide	Silver
Beryllium	Iron	Sodium
Cadmium	Lead	Thallium
Calcium	Magnesium	Vanadium
Chromium	Manganese	Zinc

Water quality parameters other than Target Analyte Liste (TAL) metal content may adversely affect aquatic life. For the protection of surface water streams for fish and wildlife propagation, recreation and stock watering under South Dakota Article 74:51:01:52 standards are identified for alkalinity, total dissolved solids (TDS), conductivity, nitrates, pH, total petroleum hydrocarbons and oil/grease. Additional standards (above the minimum for fish and wildlife propagation, recreation and stock watering) also apply to streams designated as beneficial use Class 3 Streams (classification of Strawberry Creek and Bear Butte Creek). These additional standards include those for unionized ammonia, dissolved oxygen, undissociated hydrogen sulfide, total suspended solids and water temperature. All surface water quality parameters for which data are available for the Gilt Edge mine site are identified as COPCs. COPC selection for water quality parameters is applied to the riparian areas only as the water quality standards apply to flowing streams, rivers or lakes. The surface water quality parameters selected as COPCs are listed in the following table:

Quantitative COPCs for Exposure of Aquatic Receptors to Riparian Area Surface Water Water Quality Parameters	
Alkalinity	Nitrates
Ammonia	pH
Conductivity	Salinity (same as TDS)
Dissolved Oxygen	Total Suspended Solids (TSS)
Filterable Residue (same as TDS)	Total Dissolved Solids (TDS)

Exposure Assessment

Because concentrations of contaminants in surface water can vary significantly over time and location, exposure of aquatic receptors is best characterized as a distribution of individual values at each sampling location, rather than as an average of values over time and/or over location. That is, an HQ value is calculated for each sample for each contaminant. In accord with USEPA guidance, non-detects are evaluated at one-half the detection limit. As noted above, all exposure values for aquatic receptors are based on dissolved metals.

Toxicity Assessment

Toxicity benchmark values for the protection of aquatic life from direct contact with contaminants in surface water are available from several sources. Each of the sources evaluated in deriving surface water benchmarks is described briefly in Appendix D-1, along with a hierarchy for identifying the most relevant and reliable benchmark value when more than one value is available. The selected toxicity benchmark values for all contaminants analyzed in surface water are shown in Table D-1a (non-hardness dependent benchmarks) and in Table D-1b (hardness dependent benchmarks) of Appendix D. The identified benchmarks are used for both the selection of COPCs and the calculation of HQ values in the risk characterization. For COPC selection, a hardness of 250 mg/L is used to derive the surface water toxicity benchmarks that are hardness dependant. This value represents the low end of the range of values observed in Gilt Edge riparian area surface waters but is the upper end of the range of hardness values in the toxicity testing used to derive the Ambient Water Quality Criteria (AWQC) benchmarks. For the HQ calculations in the risk characterization, sampling location specific measurements of hardness are used to calculate surface water benchmarks that are hardness dependant.

Hazard Quotients for Direct Contact with Riparian Area Surface Water

Because the toxicity of COPCs in surface water to aquatic receptors is usually dependent on the length of exposure, the HQ was calculated both for short-term (acute) and long-term (chronic) exposure conditions. In cases where the acute and chronic benchmarks are hardness-dependent, toxicity benchmarks are calculated for each sample based on the hardness of that sample.

Figures 5-1a to 5-1u provide graphs showing the distribution of the HQ values for samples collected within each Exposure Reach (Figure 3-1) for each COPC. In each figure, the upper panel shows the distribution of HQ values for acute toxicity, while the lower panel reflects the distribution of risks for chronic toxicity. HQs based on non-detects are shown as open-circles and HQs based on detects are shown as closed circles. Note that the results in these figures are plotted on a log-scale, so large differences between HQ values are somewhat compressed.

As discussed in Section 4.5, the risk in each exposure reach is classified into one of five risk categories based on the fraction of the HQ distribution above a value of 1E+00. The data presented in the figures are further interpreted and the results of the evaluation recorded in Table 5-1 as a summary of risks. Interpretation of the HQ plots in Figures 5-1a through 5-1u is as follows:

- Exposure reaches with HQ values that are all less than or equal to one are classified as "none" for no risks identified.

- For exposure reaches where some HQ values are greater than one but the distribution of values is similar to those calculated for the reference reaches, the risks are identified as being associated with background conditions. Risks are not identified for these reaches.

- For exposure reaches where some HQ values are greater than one, the risks are classified into one of four categories (minimal, moderate, high or severe) as described in Section 4 and depicted on Table 5-1.

The results are summarized in Table 5-1. Inspection of Table 5-1, along with Figures 5-1a through 5-1u, yield the following main conclusions:

<u>Acute Risks</u>

- Based on the acute benchmarks, severe risks are identified for Strawberry Creek, associated with aluminum, cadmium, copper, and zinc. Moderate risks are associated with chromium, manganese and selenium.

- Based on the acute benchmarks, severe risks are identified for Hoodoo Gulch associated with aluminum, cadmium, copper and zinc.

- Based on the acute benchmarks, moderate risks are identified for Ruby Gulch associated with aluminum, cadmium, copper and zinc.

- Based on the acute benchmarks, moderate risks are identified for downstream Bear Butte Creek associated with copper.

Chronic Risks

- Based on the chronic benchmarks, severe risks are identified for Strawberry Creek associated with cadmium. High risks are associated with calcium and manganese and moderate risks with aluminum, cobalt, copper, selenium, and sodium.

- Based on the chronic benchmarks, severe risks are identified for Hoodoo Gulch associated with manganese. High risks are associated with aluminum and moderate risks with beryllium, cadmium, cobalt, copper, and nickel.

- Based on the chronic benchmarks, moderate risks are identified for Ruby Gulch for cadmium.

Water Quality Parameters

For the water quality parameter COPCs, the distribution of measurements within each exposure reach are plotted relative to the South Dakota water quality parameter standards. Concentrations are plotted on Figures 5-2a through 5-2j for alkalinity, ammonia, conductivity, dissolved oxygen, nitrate, pH, filterable residue, salinity, TDS and TSS, respectively. Salinity and filterable residue are approximate estimates of TDS. In cases where TDS, salinity or filtrable measurements are not available, it is estimated based on conductivity measurements. TDS is different than conductivity, which is a measure of the electrical conductance of water. TDS measures the amount of ions in water, while conductivity measures those ions' ability to conduct electricity. Distilled water (very low TDS) has little capacity for electron conductivity. The more ions in the water, the higher the electron flow. Usually there is a strong correlation between conductivity and TDS, but there is still a difference between the two. Conductivity is only an approximate predictor of TDS. For specific conductance less than 5,000 µS/cm at 25°C (USDOI, 1998):

$$TDS = 0.584 * SC + 22.1$$

where:

TDS = total dissolved solids in mg/L; and
SC = specific conductance in µS/cm

For specific conductance from 5,000 to 9,000 µS/cm at 25°C:

$$TDS = 0.682 * SC - 269$$

Figures 5-2a through 5-2j provide the distribution of measurements of each of the water quality parameters in comparison with respective daily maximum and 30 day standards. The 30-day average concentration is defined as the *"the arithmetic mean of a minimum of 3 consecutive grab or composite samples taken on separate weeks in a 30-day period"*. These measurements are not available from the Gilt Edge database and could not be derived from the database, therefore comparisons are made between the distribution of observed concentrations and the daily maximum standard. Inspection of Figures 5-2a through 5-2j reveals the following:

- Alkalinity. There are no measurements of alkalinity in any of the exposure reaches that exceed the 30 day average or daily maximum concentrations (Figure 5-2a).

- Ammonia. Only one surface water sample collected from Strawberry Creek exceeds the daily maximum standard for ammonia. All other measurements are less than the standard (Figure 5-2b).

- Conductivity. In general, conductivity is higher in Strawberry Creek, HooDoo Gulch and Ruby Gulch relative to upstream Bear Butte (reference) and Boomer Gulch (reference) (Figure5-2c). However, only 6 measurements in 267 samples (or 2%) from Strawberry Creek exceed the standard. In Butcher Gulch (a reference location) 3 measurements in 15 samples (20%) exceed the standard. All other measurements are below the daily maximum standard (Figure 5-2c).

- Dissolved Oxygen. Dissolved oxygen (DO) measurements are equal to or above the standard with the exception of a few samples collected from Strawberry Creek (Figure 5-2d).

- Nitrates. All measurements of nitrates in all exposure reaches fall below the daily maximum standard (Figure 5-2e).

- pH. The maximum and minimum measurements of pH in Strawberry Creek fall outside of the acceptable range (Figure 5-2f). In Hoodoo Gulch and Ruby Gulch, about 50% of the samples are lower than the lower bound of the acceptable pH range.

- Filterable residue. According to EPA (USEPA, 1987) this measurement is equivalent to TDS and available measurements in Strawberry Creek are compared to the TDS standard in Figure 5-2g. More than 50% of the measurements in exceed the TDS standard.

- Salinity. For most purposes, EPA considers measurements of salinity and TDS to be equivalent (USEPA, 1987). For salinity measurements available at Gilt Edge, only a few measurements are above the daily maximum standard for TDS (Figure 5-2h).

- TDS. There are 490 measurements of TDS in Strawberry Creek, of these 14 or 3% exceed the daily maximum standard. All other measurements of TDS are below the standard (Figure 5-2i).

- TSS. There are 490 measurements of TSS in Strawberry Creek, of these 154 or 31% exceed the daily maximum standard for TSS. In Hoodoo Gulch, Ruby Gulch and downstream Bear Butte Creek, 32%, 12%, and 49% , respectively, of the measurements exceed the daily maximum standard. In comparison, only 2% of the measurements in the upstream Bear Butte reference exceed the standard (Figure 5-2j).

In summary, TDS and TSS may be having an adverse impact on Strawberry Creek. Increased TSS may also have an adverse impact to downstream Bear Butte Creek.

Evaluation of the HQ values is useful in assessing risks to the aquatic community as a whole, but does not provide information on which species may be most at risk. Figures 5-3 thru 5-6 compare the distributions of surface water concentrations for aluminum, cadmium, copper, and zinc to TRVs derived for a number of different species and age groups of fish and invertebrate receptors. In both figures, TRVs for fish are shown on the left side, while TRVs for invertebrates are shown on the right side. All of the TRVs for fish and benthic invertebrates are derived from the corresponding AWQC Documents prepared by EPA (1985b-e, 1987, 1996), as follows:

Acute TRV = Species or genus mean LC50 / 2
Chronic TRV = Species or genus mean chronic value

Because the toxicity of most of the contaminants of concern depends on water hardness, all of the data (both the toxicity values and the concentration values) are normalized to a hardness of 100 mg/L. This normalization is achieved using the following equation:

$$C(60) = C(H) \times TRV(60) / TRV(H)$$

where:

C(60) = normalized concentration
C(H) = original concentration (hardness = H)
TRV(60) = Acute AWQC (dissolved) at a hardness of 60 mg/L
TRV(H) = Acute AWQC (dissolved) at hardness = H

In the case of aluminum (Figure 5-3), it may be seen that mean concentrations in Strawberry Creek exceed the reported chronic TRV values for brook trout and fathead minnow and acute TRVs for *Ceriodaphnia sp.* Mean concentrations in Ruby Gulch exceed all available acute TRVs. At all other exposure reaches the maximum concentrations are less than all acute and chronic TRVs for fish and invertebrates.

In the case of cadmium (Figure 5-4), the mean concentrations in Strawberry Creek approach or exceed the chronic TRV for Daphnia and the acute TRVs for rainbow trout and brook trout. The mean concentrations of cadmium in Hoodoo Gulch and Ruby Gulch also exceed the acute TRVs for Bull trout and chronic TRVs for snails. At all other exposure reaches the maximum concentrations are less than all acute and chronic TRVs for fish and invertebrates.

In the case of copper (Figure 5-5), the mean concentrations approach or exceed the acute TRVs for rainbow trout and northern squawfish, tubificid worms, amphipods, *Daphnia sp. Ceriodaphnia sp.* and chronic TRVs for brown trout, white sucker, rainbow trout, brook trout, snails, amphipods, daphnia and fathead minnow. Mean concentrations in Ruby Gulch exceed all TRVs for fish and invertebrates. Mean concentrations in Butcher Gulch exceed only the acute TRVs for N. squawfish, *Daphnia sp.*, and *Ceriodaphnia sp.* and chronic TRVs for amphipods, *Daphnia sp.* and fathead minnow. The mean concentrations in all other exposure reaches are less than the acute and chronic TRVs for fish and invertebrates.

In the case of zinc (Figure 5-6), the mean concentrations in Hoodoo Gulch and Ruby Gulch approach or exceed acute TRVs for fathead minnow, and amphipods, *Daphnia sp Ceriodaphnia sp.* and chronic TRVs for fathead minnow, *Daphnia sp*, snails and *Ceriodaphnia sp.* The mean concentration in Strawberry Creek exceed the acute TRVs for *Daphnia sp.* and *Ceriodaphnia sp.* and the chronic TRVs for *Daphnia sp.*, snails and *Ceriodaphnia sp.*

These graphs illustrate that aluminum, cadmium, copper and zinc are expected to have adverse effects on a number of different species of both fish and invertebrates in the aquatic community, and that severe community level effects are likely to exist due to the toxicity of these COPCs.

The aluminum exposures may be related to a release of aluminum to Strawberry Creek associated with the use of aluminum hydroxide in the WWTP (use now terminated).

For the COPCs associated with either acute or chronic risks classified as severe, the HQ results are presented geographically as maps. It should be noted that not all of the points plotted on Figures 5-1a through 5-1u for each COPC for each exposure reach could be plotted on the maps for two reasons. First some sampling locations have more than one result available per coordinate. In these cases, the mean concentration across all samples is plotted. Second, for some of the data points on Figures 5-1a through 5-1u, geographic coordinates are not available thus the HQ values could not be plotted.

The Acute HQ values for aluminum, cadmium, copper and zinc are presented spatially as maps in Figures 5-7 to 5-10. Inspection of these maps reveals that HQ values are the highest in upper Ruby Gulch, upper Hoodoo Gulch and upper Strawberry Creek. Downstream all locations have HQ values less than 1. These maps show that acute effects are restricted to Strawberry Creek upstream of the confluence with Hoodoo Gulch, Hoodoo Gulch and Ruby Gulch.

The chronic HQ values for aluminum, cadmium, copper, manganese and zinc are presented spatially as maps in Figures 5-11 to 5-15. Inspection of these maps reveals that HQ values are highest upstream in Strawberry Creek, Hoodoo Gulch and Ruby Gulch. Most chronic HQ values in Strawberry Creek are greater than 1 and less than 10 downstream to Bear Butte Creek. With the exception of one location for copper, the chronic HQ values (for aluminum, cadmium, copper, manganese and zinc) are less than 1 in Bear Butte Creek upstream of Strawberry Creek. In Bear Butte Creek downstream of the confluence with Strawberry Creek, some HQ values for cadmium and manganese exceed 1 but are less than 10. Examination of the results in Figure 5-1 also shows chronic HQ values in Bear Butte Creek downstream of Strawberry Gulch exceeding one for aluminum, copper, lead, nickel and selenium.

5.1.2 Risks to Aquatic Receptors from Mine Source Area Surface Waters

During discussions with the Biological Technical Assistance Group (BTAG) for the Gilt Edge Mine Site, several concerns were raised concerning the potential risks for aquatic receptors in Strawberry Creek if the surface waters within the mine source area (pits and ponds) was allowed to drain off-site untreated. To address this concern, HQ values were calculated for Mine source area surface waters. The data used for these calculations is listed in Appendix A and includes samples from:

Sampling Locations Used in Calculation of HQ Values for Ons-Site Surface Water		
Pond A	Pit water	Ruby Pond
Anchor Pit	Pond B	Stormwater
Dakota Maid Pit	Pond C	Sunday Sump
King Adit	Pond C culvert	Surge Pond
Langley Adit	Pond D	Wood Weir
Langley Pit	Pond E	Wastewater Treatment Effluent
Pad Effluent	Ruby Dump	

COPCs for the Mine source area surface waters included all TAL metals detected. The exposure point concentration for each COPC is equal to the upper 95[th] percent confidence interval of the arithmetic mean or the maximum detected concentration whichever is lower (Appendix A-5). The following HQ values are calculated for the Mine source area surface waters:

HQ Values for Mine Source Area Surface Waters					
Contaminant	**Acute**	**Chronic**	**Contaminant**	**Acute**	**Chronic**
Aluminum	4000	31,000	Manganese	60	1000
Arsenic	40	90	Mercury	< 1	< 1
Barium	1	30	Molybdenum	< 1	< 1
Beryllium	2	100	Nickel	2	20
Cadmium	800	8000	Potassium	Not calculated	< 1
Chromium (VI)	10	20	Selenium	< 1	4
Cobalt	2	100	Silver	2	20
Copper	16,000	30,000	Sodium	Not calculated	< 1
Iron	Not	8,000	Strontium	< 1	5
Lead	calculated	4	Thallium	< 1	< 1
Lithium	< 1	20	Vanadium	< 1	3
Magnesium	< 1	3	Zinc	200	200

These HQ values clearly establish that Mine source area surface water would be acutely toxic to aquatic receptors if it were released untreated from the Mine source area to receiving surface waters.

5.1.3 Risks to Benthic Macroinvertebrates from Direct Contact with Sediment

Sediment COPC Selection

Sediment COPCs for benthic macroinvertebrates are selected for the riparian area based on all available sediment data from Bear Butte Creek, Strawberry Creek, Ruby Gulch, Butcher Gulch, Boomer Gulch and Two Bit Creek/Anchor Gulch. Sediment concentrations for each contaminant are compared to the sediment screening toxicity benchmark. The results of the COPC selection procedure for sediment are detailed in Appendix C-2 and the contaminants selected for quantitative evaluation are presented below.

Quantitative COPCs for Riparian Area Sediments		
Aluminum Antimony Arsenic Cadmium Chromium Cobalt	Copper Cyanide Iron Lead Manganese Mercury	Nickel Selenium Silver Vanadium Zinc

Exposure Assessment

Benthic macroinvertebrates that spend some or most of their life cycle within the sediment substrate are exposed to contaminants through direct contact with sediment. Although concentrations of contaminants in sediment are usually not as time-variable as concentrations in surface water, concentrations do fluctuate as contaminated material is added or removed by surface water flow. In addition, there may be significant small scale variability in sediment concentrations at any specific sampling station. Therefore, exposure to sediments is usually best characterized as a distribution of individual values at a specific location. At this site, there is only one measurement of sediment concentration available per sampling location, so exposure is based on that single concentration value. Non-detects are evaluated at one-half the detection limit.

Toxicity Assessment

Toxicity values for the protection aquatic life (mainly benthic organisms) from contaminants in sediment are available from several sources. Each of the sources evaluated in deriving sediment benchmarks is described briefly in Appendix D-2, along with a hierarchy for identifying the most relevant and reliable benchmark value when more than one value is available. The selected toxicity benchmark values for all contaminants analyzed in sediment are shown in Table D-2 of Appendix D. These benchmarks are used both for COPC selection (previously discussed) and calculation of HQ values (discussed in the following section).

Hazard Quotients for Direct Contact with Sediment

Figure 5-16a through 5-16p provide the HQ values for each sampling location within an exposure reach for each COPC. As discussed in Section 4.5, the risk in each exposure reach is classified into one of five risk categories based on the fraction of the HQ distribution above a value of 1E+00. Note that the results in these figures are plotted on a log-scale, so large differences between HQ values are somewhat compressed.

The classification of risks for each exposure reach as presented in the figures is further interpreted and the results of the evaluation recorded are recorded in Table 5-2 as a summary of risks. Interpretation of the HQ plots is as follows:

- Exposure reaches with HQ values that are all less than or equal to one are classified as "none" for no risks identified.

- For exposure reaches where some HQ values are greater than one but the distribution of the HQ values is similar to the distribution observed for the reference reaches, the risks are identified as being associated with background conditions. Risks are not identified for these reaches.

- For exposure reaches where HQ values are greater than one, the risks are classified into one of four categories as described in Section 4 and depicted on Table 5-2.

Inspection of Figures 5-16a through 5-16p and the evaluation of these results in Table 5-2, yield the following main conclusions:

- Risks are categorized as severe for Strawberry Creek sediments associated with cadmium, copper, and zinc. Risks are categorized as high for silver and moderate for aluminum and manganese. Risks (HQ values and associated categories) for antimony, arsenic, iron, lead, mercury, nickel, and selenium are equal or higher at reference exposure reaches (Bear Butte Creek - upstream and Boomer Gulch) and are not site-related..

- Risks are categorized as severe for Hoodoo Gulch sediments associated with cadmium, copper, lead, silver and zinc. Risks (HQ values and associated categories) for arsenic, iron, manganese, nickel, and selenium are equal or higher at reference exposure reaches (Bear Butte Creek - upstream and Boomer Gulch) and are not site-related.

- Risks are categorized as high for Ruby Gulch sediments associated with copper and moderate for cadmium. Risks (HQ values and associated categories) for arsenic, lead, iron, silver, and zinc are equal or higher at reference exposure reaches (Bear Butte Creek - upstream and Boomer Gulch) and are not site-related.

- Risks are categorized as severe for Bear Butte Creek (downstream) for cadmium, copper, and zinc. Risks are categorized as high for silver. In comparison to Bear Butte Creek - upstream (reference) risks for arsenic, iron, lead, nickel and selenium are equal upstream and downstream of Strawberry Creek and are not identified as site-related.

The HQ values for cadmium, copper, silver and zinc in riparian sediment (all classified as severe) are presented spatially as maps in Figures 5-17 to 5-20. Inspection of these maps reveals that HQ values are highest upstream in Strawberry Creek and Ruby Gulch and decrease with distance downstream. It should be noted that not all of the points shown on Figures 5-16a through 5-16p for each COPC for each exposure reach could be plotted on the maps for two reasons. In some cases there are more than one result for a specific sampling location. In these cases the results are averaged and the average is used to calculate the HQ for the map. In other cases, geographic coordinates are not available for a result presented in Figures 5-16a through 5-16p and it could not be plotted on the maps. The maps, as well as the results shown in Figures 5-16a through 5-16p, show adverse effects to the benthic invertebrate community in Strawberry Creek, Hoodoo Gulch and Ruby Gulch associated with Gilt Edge Mine Site activities, and to a lesser extent in downstream Bear Butte Creek downstream of the confluence with Strawberry Creek.

5.1.4 Risks to Fish Based on Fish Tissue Burdens

One way to estimate risks to fish is to compare the tissue level of contaminants observed in fish collected at the site to tissue concentrations that occur in fish with and without evidence of adverse effects. This approach has the advantage that it integrates exposures over multiple sources (surface water, sediment, food web), and accounts for any site-specific factors that might increase or decrease exposure compared to laboratory conditions.

Fish Tissue COPC Selection

Fish Tissue COPCs for aquatic receptors are selected using the procedure shown in Appendix C based on all available fish tissue data. Maximum fish tissue concentrations for each contaminant are compared to their respective MATC (see Table D-3). The results of the COPC selection procedure for fish are detailed in Appendix C and the contaminants selected for quantitative evaluation are presented below.

Quantitative COPCs for Fish Tissue for Aquatic Receptors	
Aluminum	Lead
Cadmium	Mercury
Chromium	Selenium
Copper	Zinc

Exposure Assessment

Fish tissue data are available for Strawberry Creek, Boomer Gulch and Bear Butte Creek both upstream and downstream of the confluence with Strawberry Creek. These data were collected by EPA in September 2000 as described in USEPA (2002a). Table 3-4 summarizes the available fish tissue data for the Gilt Edge Mine site. Results are available for three species of fish (brook trout, mountain sucker and longnose dace) for whole body analyses. The location of the samples are shown on Figure 3-4. For each sampling location, there are up to three composite samples for each species. Each of the individual composite sample result for each COPC sorted into respective exposure reaches are used as EPCs.

Toxicity Assessment

Jarvinen and Ankley (1999) compiled a comprehensive database of tissue residue data for aquatic organisms exposed to inorganic and organic chemicals. From this database tissue burden benchmarks are selected for fish whole body or muscle for all detected contaminants. The benchmark is equal to the lowest reported concentration that did not cause an adverse effect on survival and growth in freshwater fish species. The tissue burden benchmark values selected for fish tissue are shown in Table D-3. These MATC values are used to select COPCs (previously described) and to calculated HQ values as discussed in the following section.

Hazard Quotients for Fish

Figures 5-21a through 5-21h provide the HQ values for each location for each COPC. At each reach or location, the risks from a COPC are classified into risk categories (as described in Section 4.5) based on the HQ distribution. Note that the results in these figures are plotted on a log-scale, so large differences between HQ values are somewhat compressed. The classification of risks for each exposure reach as presented in the figures is further interpreted as follows:

- Exposure reaches with HQ values that are all less than or equal to one are classified as "none" for no risks identified.

- For exposure reaches where some HQ values are greater than one but the distribution of HQ values is similar to the distribution of HQ values for reference reaches, the risks are identified as being associated with reference conditions. Risks are not identified for these reaches.

- For exposure reaches where HQ values are greater than one, the risks are classified into one of four categories as described in the following text discussion.

Examination of Figures 5-21a through 5-21h yields the following conclusions:

- For selenium and copper, no risks are identified.

- For aluminum, zinc, and mercury some HQ values in Strawberry Creek are greater than one but the distribution of values is less than those for reference reaches and are not considered to be site related.

- For lead and chromium, risks are identified as minimal.

- Risks from cadmium are categorized as severe in Strawberry Creek and downstream Bear Butte Creek.

Based on these risk calculations, some species of fish in Strawberry Creek and downstream Bear Butte Creek may be at risk of adverse effects due to elevated tissue concentrations of cadmium. Adverse effects from other site-related contaminants are not expected.

5.2 Evaluation of Site-Specific Toxicity Tests

One way to help reduce the uncertainty associated with HQ values based on toxicity benchmark values is to perform direct toxicity testing using site-specific media. Toxicity tests are available for site surface water and sediments.

5.2.1 Surface Water Toxicity Tests

Surface water samples were collected in September of 2000 and October 2001 for toxicity testing with larval *Pimephales promelas* (fathead minnow), according to USEPA (1994). Surface water samples were collected in September 2000 from five locations in Strawberry Creek (SC-4, SC-3, SC-2, SC-5 and SC-1) and seven locations in Bear Butte Creek (BB-16, BB-3, BB-14, BB-6, BB-5, BB-2 and BB-1) and one location in Boomer Gulch (BG-1) (Figure 5-22). In October of 2001, surface water samples were collected from five locations in Strawberry Creek (SC-4, SC-3, SC-2, SC-5 and SC-1) and two locations in Bear Butte Creek (BB-3 and BB-14) and one location in Boomer Gulch (BG-1). The results of the testing is summarized in Table 5-3 Figure 5-24 with full results provided in USEPA (2002a).

Surface water toxicity was evaluated using larval *Pimephales promelas* (fathead minnow), according to USEPA testing methods (USEPA, 1994). In September of 2000, testing was completed using 100% undiluted site water) and two control waters. The primary control water (LRW) was equal to moderately hard reconstituted water (MHRW) prepared with hardness and alkalinity adjusted to match reference surface water (BB-16 or BB-3).

The results of the initial surface water testing are provided as Table 5-3 and Figure 5-23. Significant reduced survival was observed at all Strawberry Creek sampling locations with survival ranging from 0 to 38 % in September of 2000 and 5 to 45% in October of 2001. Growth was also significantly reduced in all Strawberry Creek samples. Reduced growth also represents reduced biomass as there is no adjustment for total weight per the number of minnows surviving the test. The reduced growth measurements therefore also reflect a reduced number of fish surviving. For Bear Butte Creek (Figure 5-23), there are no significant reductions in survival or growth compared to the controls or reference.

In September 2000, a definitive test was completed with the sample from SC-4 using surface water concentrations of 100%, 50%, 25%, 12.5%, and 6.25% prepared by serial dilution with LRW and used in the toxicity test (Table 5-4). From the toxicity observed in the definitive dilution three types of test results are recorded:

No Observable Effect Concentration (NOEC). The survival and growth data are statistically analyzed in comparison to the LRW and MHRW results. The NOEC is the highest concentration of toxicant (in this case surface water sample dilution) to which organisms are exposed in a full life-cycle or partial life-cycle (short-term) test, that causes no observable adverse effect on the test organism (i.e., the highest concentration of toxicant in which the values for the observed responses are not statistically different from the controls) (USEPA, 2002c). A NOEC for survival and a NOEC for growth are identified from the results of the definitive test.

Lowest Observable Effect Concentration (LOEC). The survival and growth data are statistically analyzed in comparison to the LRW and MHRW results. The LOEC is the lowest concentration of toxicant (in this case surface water sample dilution) to which organisms are exposed in a full life-cycle or partial life-cycle (short-term) test, that causes an observable adverse effect on the test organism (i.e., the lowest concentration of toxicant in which the values for the observed responses are statistically different from the controls) (USEPA, 2002c). This value is interpreted from the results of the definitive test.

Inhibition Concentration at xx% (IC_{xx}). The toxicant concentration that would cause a given percent reduction in a non-quantile biological measurement for the test population. For example, the IC_{25} is the concentration of the toxicant that would cause a 25% reduction in growth for the test population and the IC_{50} is the concentration of toxicant that would cause a 50% reduction (USEPA, 2002c).

In the September 2000, definitive tests the survival NOEC and LOEC was 12.5% and 25% SC-4 (September 2000) surface water, respectively. The growth NOEC was 12.5% SC-4 surface water and the IC_{25} concentration was 20.7% using LRW as the control and 19.5% SC-4 surface water using MHRW as the control.

In October 2001, definitive tests were initiated using surface waters from SC-4, SC-3, SC-2, and SC-5 at concentrations of 100%, 50%, 25%, 12.5%, and 6.25% (Table 5-4). The following results were determined:

Results of Definitive Surface Water Toxicity Tests (October 2001)				
	SC-4	**SC-3**	**SC-2**	**SC-5**
Survival NOEC	25%	25%	25%	25%

Results of Definitive Surface Water Toxicity Tests (October 2001)				
	SC-4	SC-3	SC-2	SC-5
Survival LOEC	50%	50%	50%	50%
Growth NOEC	25%	25%	25%	25%
Growth IC_{25}	29.6%	42.4%	59.9%	47.9%

The results of both the initial and definitive toxicity tests with surface water provide conclusive evidence that surface water in Strawberry Creek is significantly toxic (lethal) to aquatic organisms. There are, however, no significant effects observed in Bear Butte Creek.

5.2.2 Sediment Toxicity Tests

Sediment toxicity testing was completed by EPA in September 2000 and October 2001 to provide data concerning the availability and toxicity of contaminants in sediment. Sediment toxicity was evaluated using the solid-phase sediment toxicity test methods with the amphipod *Hyalella azteca* (Ingersoll et al. 1994). The procedure was modified slightly—the test duration was 14 days instead of the standard 10 days. Sediment samples were collected from thirteen locations in September 2000 and eight locations in October 2001. The location of the samples is provided on Figure 5-22.

Survival of *H. azteca* in September 2000 was significantly decreased at 3 of the 4 Strawberry Creek locations with survival ranging from 6% at SC-3 to 30% at SC-5 (Table 5-5; Figure 5-24) compared to 70% for the BB-16 reference sample and 93% for the laboratory control. Survival was also significantly reduced at one Bear Butte location (BB-1) at 48% but this result is comparable to the 51% measured in the Boomer Gulch reference.

When tests were repeated in October 2001, similar results were observed. Four of five sediment samples from Strawberry Creek significantly reduced the survival of *H. azteca* (20 to 24% survival) compared to references and controls (96 to 100%). These results provide conclusive evidence that sediments in Strawberry Creek are significantly toxic and may be lethal to benthic macroinvertebrates.

5.3 Evaluation of Aquatic Community Surveys

Effects of chemical stressors on an ecosystem can sometimes be evaluated by direct observation of the density and diversity of species present in the ecosystem. At the Gilt Edge Mine site, observations on the benthic community structure are available from two separate studies.

5.3.1 Benthic Macroinvertebrate Community

Benthic community analyses was completed according to Rapid Bioassessment Protocols (RBP) by EPA (USEPA, 2002) in September of 2000 and October of 2001. *Biological assessment* is an evaluation of the condition of a waterbody using biological surveys and other direct measurements of the resident biota in surface waters. The Rapid Bioassessment Protocols developed by EPA represent an integrated bioaassessment approach comparing habitat (e.g., physical structure, flow regime), water quality and biological measures with empirically defined reference conditions. The protocols derive a relationship between habitat quality and biological condition. Once this relationship between habitat and biological potential is understood, impacts related to water or sediment quality (contaminants) can be objectively discriminated from habitat effects.

The overall approach of the RBP is presented as Figure 5-25. There are three steps to calculation of a biological condition score for each sampling location:

> Step 1: Collect Statistics. For each sampling location in three replicate samples, several parameters are calculated including number of individuals, total number of scrapers (functional feeding group), total number of filterers, total number of shredders, total number of ephemeroptera, plecoptera, and trichoptera (EPT) (mayflies, stoneflies and caddisflies), and chironomid abundance.

> Step 2: Calculate Metrics. For each sampling location a series of 9 metrics (or measures of community structure and function) are calculated as described in USEPA (1989). These metrics include: taxa richness, Hilsenhoff's Biotic Index (HBI), ratio of scrapers to filterers, ratio of EPT abundance to chironomid abundance, % contribution of the dominant taxon (to total abundance), number of EPT taxa, community loss index, and ratio of filterers to shredders.

Step 3: Calculate Biological Condition Score. A biological condition score is calculated for each of the sampling locations using the 9 metrics calculated for each site and comparing these to the appropriate reference. For Strawberry Creek sampling locations, a location in Boomer Gulch (BG-1) is used as the reference and for sampling locations in Bear Butte Creek , the upstream sampling station BB-16 (Figure 5-22) is used as a reference. For six of the metrics a simple ratio (or percent of reference) is calculated by dividing the result for the site by the result for the reference station and multiplying by 100. Using the resulting % of reference result, a score is assigned using the criteria in Figure 5-25 (ranging from 0 to 6 for each metric). For the HBI index the reference result is divided by the site result to obtain the percentage. The community loss index results are directly scored using the criteria in Figure 5-25 and not divided by reference (the community loss index result includes a comparison to reference). The % contribution of dominant taxa metric is also directly scored using the specific result for each sampling location (site and reference). Once scores are calculated for each of the metrics, the individual scores are added to derive a total and this total is divided by the reference total to obtain a Biological Condition Score (% of reference).

As part of the RBP method, a separate Habitat Quality score is calculated for each of the sampling stations. The resulting scores are also compared to reference to obtain a % of reference value. The results of the habitat quality evaluation along with habitat scores are summarized in Table 5-6.

The steps for calculation of Biological Conditions Scores are completed for the Strawberry Creek and Bear Butte Creek sampling locations in Tables 5-7 and 5-8 for data obtained in September of 2000 and October of 2001, respectively. The results are also plotted in Figures 5-26 and 5-27. The biological condition of the stations is categorized according to the guidelines in Figure 5-25.

In order to interpret the Biological Condition Scores based on the similarity of the habitat present at the Strawberry Creek and Bear Butte Creek sampling locations to reference sampling locations, each of the Biological Condition Scores are plotted with respect to their Habitat Quality Score in Figure 5-28. Three Strawberry Creek stations (SC-03 and SC-05 in September 2000 and SC-2 in October of 2001) are severely impaired relative to reference and two are moderately impaired (SC-05 and SC-01 in October of 2001). The habitat present at these sampling locations is supporting of conclusions of impacts related to water quality as it is sufficiently similar in quality to the reference location to rule out differences in habitat quality as the cause of the observed decrease in biological condition.

The Biological Condition of all Bear Butte sampling stations are either classified as non-impaired or slightly impaired (Figure 5-27 and 5-28). The habitat present at these sampling locations is comparable to the reference location.

In September 2000, impacts to the benthic communities are most severe at locations SC-2, where no organisms were collected, followed by SC-3 and SC-5, where very few organisms representing only a few taxa were found. However, the benthic community does recover to some degree with distance downstream, with an increase in condition score at SC-1 (Figure 5-26).

The benthic macroinvertebrate community in Bear Butte Creek is impacted slightly by the discharge from Strawberry Creek, as illustrated by a slight drop in community structure (mostly due to a loss of sensitive taxa and diversity) between BB-3 and BB-14 (Table 5-7). This comparison of community structure upstream and downstream of the confluence with Strawberry Creek indicates that some COPCs may be reaching Bear Butte Creek. It is important to note that the bank of Bear Butte Creek was disturbed by heavy equipment in the area of BB-3 and BB-14. Therefore, the impacts in Bear Butte Creek are better quantified by the reduction in condition score between BB-3 and BB-14 than by the drop in condition score between Stations BB-16 and BB-14. No impacts on Bear Butte Creek from the Ruby Gulch drainage are observed. A second drop in Bear Butte community structure occurs downstream of a seep, as illustrated by the reduction in condition score and loss of sensitive taxa and diversity at BB-2 (Table 5-7). There was a gradual improvement following the confluence of Double Rainbow (located between BB-2 and BB-1), and the community appeared to continue its recovery downstream to BB-15.

Follow up sampling of the benthic macroinvertebrate community was completed by EPA in October of 2001 and similar results are reported (USEPA, 2002). The benthic community in Strawberry Creek continued to be severely impacted by the discharge from Gilt Edge Mine. No organisms were recovered from locations SC-4 and SC-3 and very few organisms representing only a few taxa were recovered in other Strawberry Creek samples (USEPA, 2002). A slight increase in condition score was seen at SC-5 during 2001 relative to 2000, mostly due to an increase in abundance of trichoptera larvae. The significance of this observation is unknown. Given the small number of organisms sampled during both events (average of 8 in 2001 and 2 in 2000), it is unknown as to whether the increase is due to a recovery or simply an artifact resulting from high variability at the station.

Similar to observations in September of 2000, the benthic macroinvertebrate community in Bear Butte Creek is impacted slightly by the discharge from Strawberry Creek, as illustrated by a slight drop in community structure (mostly loss of sensitive taxa and diversity) between stations BB-3 and BB-14. .

Overall, it is apparent that the benthic macroinvertebrate communities of Strawberry Creek are severely or moderately impacted by mine drainage. For Bear Butte Creek, the impacts are considered to be slight. The benthic community in the surrounding area is robust and could be a source of recruitment organisms for recovery of impacted stations once the contaminant sources are controlled (USEPA, 2002).

5.3.2 Fish Community

As part of their routine natural resource management responsibilities, the South Dakota Game, Fish, and Parks Commission (SDGFPC) conducts an annual fish community survey using multiple pass removal by electrofishing. The SDGFPC conducted community sampling at thirteen locations to satisfy the goals of their program. These locations include two in Bear Butte Creek upstream of the confluence with Strawberry Creek; five downstream of the confluence; two in Strawberry Creek and two in Boomer Gulch. The sampling locations are listed in the following table and the location of these (with the exception of two location) are provided on Figure 3-4.

Summary of Fish Sampling Locations from SDNR Database			
	Location Abbreviation	**Corresponds with Map Location (Figure 3-4**	**Site Description**
Strawberry Creek	blw GEM	SC-3	70 meters upstream of confluence with Bear Butte Creek at Brohm Mine
	abv BMG	SC-1	Immediately above confluence with Bear Butte Creek
	abv BBC		Immediately above confluence with Boomer Gulch
Boomer Gulch	abv SBC		32 meters upstream of Strawberry Creek
	immed. abv SBC	BG-3	Immediately upstream of Strawberry Creek
Bear Butte Creek	abv SBC	BB-16	Approx. 1/4 mile upstream from confluence with Strawberry Creek
	immed. abv SBC	BB-3	Above Strawberry Creek Confluence
	blw SBC	BB-14	Below Strawberry Creek Confluence
	blw SBC		Below culverts approx. 120 meters downstream of Strawberry Creek Confluence
	abv RBG	BB-6	Immediately Above Ruby Gulch Confluence
	blw RBG	BB-5	Immediately Below Ruby Gulch Confluence
	abv DRM	BB-2	Above Double Rainbow Mine

Summary of Fish Sampling Locations from SDNR Database			
	Location Abbreviation	Corresponds with Map Location (Figure 3-4	*Site Description*
	blw DRM	BB-1	Below Double Rainbow Mine Bridge

Five species have been collected previously at these locations including brook trout (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*), longnose dace (*Rhinichthys cataractae*), white sucker (*Catostomus commersoni*), and mountain sucker (*C. platyrhynchus*).

The mean number of fish per kilometer of stream for each species for sampling completed annually since 1996 is plotted in Figure 5-29 for Strawberry Creek and Bear Butte Creek. Biomass (pounds of fish per hectare) is plotted in Figure 5-30. In some years at some stations sampling was not completed For these a blank space is shown on the figure. In a few cases, sampling was completed but fish were not found. These instances include:

Sampling Events and Locations Where Fish were not Found Since 1996		
Location	**Sampling Station**	**Years**
Strawberry Creek	blw GEM	1997, 1998
Bear Butte Creek	abv RBG	1998

Examination of the data presented in Figures 5-29 and 5-30 yields the following conclusions:

<u>Strawberry Creek</u>

- In the two most upstream sampling locations in Strawberry Creek, fish are either not found or are found with limited numbers (< 500 per km).

- Some species (white sucker, longnose dace and mountain sucker) are typically absent or found at very low density in Strawberry Creek compared to Bear Butte Creek.

- There is some apparent recovery of brook trout at the most downstream sampling station above Bear Butte Creek. At this sampling station (abv BBC) the number of Brook trout observed increases each year from 1999 to 2001 with density in 2001 (1600 per km) being similar to those observed in Bear Butte Creek during the same year.

Bear Butte Creek

- Similar species are found upstream and downstream of the confluence with Strawberry Creek.

- Similar density (when respective sampling years are compared) of brook trout is found upstream and downstream of Strawberry Creek (Figure 5-29). In some cases (2001), density is higher downstream of Strawberry Creek compared to upstream.

- A lower density of dace is consistently observed in Bear Butte Creek sampling stations downstream of the Strawberry Creek confluence (Figure 5-29) compared to upstream.

- The density of mountain sucker is either comparable to or higher at Bear Butte Creek sampling stations downstream of Strawberry Creek.

From these data there are impacts identified for the fish community in Strawberry Creek related to the Gilt Edge mine. For Bear Butte Creek, the fish population (density and biomass) do not appear to be impacted in comparison to reference from inputs related to the Gilt Edge Mine (discharge of Strawberry Creek and Ruby Gulch). The exception to this statement may be the decreased density of dace observed in downstream Bear Butte Creek.

5.4 Weight of Evidence Evaluation

5.4.1 Risks from Surface Water

Three lines of evidence (the HQ approach) are available to evaluate risks to aquatic receptors from direct contact exposure to surface water. These lines of evidence include the HQ calculations, the toxicity testing of surface water and the biological community data (benthic invertebrate and fish). The findings from the lines of evidence evaluated for exposures of aquatic receptors to COPCs in surface water are summarized in the following table.

Line of Evidence	Findings
HQ calculations based on surface water concentrations	For Strawberry Creek, acute toxicity (risk) is associated with aluminum, cadmium, copper and zinc and to a lesser extent to chromium, manganese, and selenium. Chronic toxicity (risk) is associated with cadmium and to a lesser extent calcium and manganese, aluminum, cobalt, copper, selenium and sodium. For Hoodoo Gulch , acute toxicity (risk) is associated with aluminum, cadmium, copper and zinc and to a lesser extent manganese. Chronic toxicity (risk) is associated with aluminum and manganese and to a lesser extent beryllium, cadmium, cobalt, copper, and nickel. For Ruby Gulch, acute toxicity (risk) is associated with aluminum, cadmium, copper and zinc although to a lesser extent compared to Strawberry Creek and Hoodoo Gulch.. Chronic toxicity (risk) is associated with cadmium. For Bear Butte Creek only moderate acute risks are identified associated with copper downstream of Strawberry Creek.
Direct Toxicity Testing	For Strawberry Creek, surface water toxicity testing identified that site surface waters are significantly toxic and reduced both the survival and growth of fathead minnows in all samples tested. For Bear Butte Creek, surface water samples were not toxic to fathead minnows.
Population Observation Benthic Community Structure	For Strawberry Creek, the benthic macroinvertebrate community is severely or moderately impaired compared to reference stations (Figure 5-28). For Bear Butte Creek, the benthic macroinvertebrate community is slightly impaired relative to reference stations (Figure 5-28).
Population Observation Fish Community Structure	For Strawberry Creek, the fish community is impaired relative to upstream Bear Butte Creek in that some types of fish are absent or severely limited in number. There does appear to be some recovery at the station located just above the confluence with Bear Butte creek. For Bear Butte Creek, the fish community does not appear to be impaired downstream of Strawberry Creek compared to upstream.

Based on these lines of evidence, it is concluded that site-related COPCs in surface water pose an unacceptable risk to aquatic receptors in Strawberry Creek. Based on the weight of evidence, risks associated with COPCs in surface water are not predicted for Bear Butte Creek This conclusion is based on the observations that 1) the HQ values calculated for Bear Butte Creek do not predict risk; 2) toxicity tests do not demonstrate toxicity; and 3) the benthic macroinvertebrate community is only slightly impaired and this impairment may be associated with sediment contamination.

Identification of COPCs Associated with Observed Toxicity

In order to increase the usefulness of the weight of evidence evaluation and to attempt to identify the possible cause of toxicity observed in the surface water toxicity testing, the surface water toxicity testing results are compared to concentrations of COPCs in the water sample in Table 5-9. This analysis identifies several COPCs as significantly correlated with the toxicity observed (either reduced survival or reduced growth). The shaded boxes on Table 5-9 indicate where statistical significance was greater than $p < 0.01$ and the correlation coefficient was greater than 0.6. As shown, there are several COPCs with concentrations that correlate significantly with the responses observed (reduced growth or survival).

Several constituents that are correlated with toxicity are components of TDS. TDS consists of minerals, organic matter, and nutrients dissolved in water. Equivalent terminology in Standard Methods is filtrable residue (USEPA, 1987). The major components of TDS in natural waters include: bicarbonate (HCO_3^-), calcium (Ca^{+2}), sulfate (SO_4^{-2}), hydrogen (H^+), silica (SiO_4), chlorine (Cl^-), magnesium (Mg^{+2}), sodium (Na^+), potassium (K^+), nitrogen (N_2, NH_3, NO^{-2}, NO^{-3}), and phosphorus in the form of phosphate (PO_4^{-3}). These components are listed in general order from most concentrated to least concentrated in typical surface waters. Bicarbonate can make up 50% of TDS in some streams. Minor constituents that are normally just a trace in streams include: iron (Fe^{+3}), copper (Cu^{+2}), zinc (Zn^+), boron (B^{+3}), manganese (Mn^{+2}), and molybdenum (Mo^+). A constant level of TDS is essential for the maintenance of aquatic life because the density of total solids determines flow of water in and out of an organism's cells (osmosis). A sudden or extreme change in TDS can be detrimental to aquatic life. For instance, an increase in salts could kill freshwater species whose bodies are not constructed to live in saltwater.

For most purposes EPA considers the terms TDS and salinity to be equivalent (USEPA, 1987) although salinity is different than TDS. Salinity refers only to salts and is defined as the concentration of all ionic constituents that include halides, bicarbonates, and sodium chloride. USDOI (1998) provides a summary of data concerning the toxicity of salinity to freshwater organisms. In general, the acute toxicity threshold for fathead minnow is reported for 6 to 10 parts per thousand (ppt); for daphnia from 6 to 10 ppt; for *Hyalella azteca* from 16 to 19.5 ppt and *Chironomus utahensis* at 13.3 ppt (USDOI, 1998). The State of South Dakota also has a water quality standard for TDS set at 1.75 ppt. The primary components of TDS measured in the samples for toxicity testing are compiled at the bottom of Table 5-9. All of the TDS components, with the exception of potassium are correlated with the observed toxicity.

Further Evaluation of Toxicity

The results compiled in Table 5-9 indicate that any one or more of the COPCs positively correlated with toxicity may be the cause. A positive, significant correlation does not however prove that the COPC is associated with the observed toxicity. It is also possible that any of these COPCs are simply co-located with the causative agent(s). Toxicity is only observed in the samples from Strawberry Creek where several COPCs (including TDS constituents) are orders of magnitude higher than Bear Butte Creek samples.

An evaluation was completed to identify which of the COPC concentrations could explain the observed toxicity. The results of the definitive surface water tests are compared to known toxicity levels (LC_{50}) values for each of the COPCs identified as being significantly correlated with the observed toxicity (cadmium, calcium, cobalt, magnesium, manganese, nickel, selenium, sodium, sulfate, and TDS) (Table 5-9). For each of these COPCs, the results of the definitive tests at SC-4 (September 2000), SC-4 (October 2001), SC-3, SC-2 and SC-5 are plotted (mortality versus dilution) and an LC_{50} identified. The LC_{50} is the dilution associated with 50% mortality in the test sample. Next, a surface water concentration of each COPC at the LC_{50} is estimated by multiplying the LC_{50} dilution by the measured concentration of the COPC in the 100% undiluted surface water sample. This resulting "observed LC_{50} concentration" is then compared to the reported (expected) LC_{50} identified from the literature. If the expected LC_{50} is higher than the observed LC_{50} concentration then that COPC is not identified as a contributor to toxicity. If the expected LC50 is lower than the observed LC_{50} concentration then the COPC might be a contributor to the observed toxicity. The results of this analyses are presented in Table 5-10. Inspection of this table yields the following observations:

- The concentrations of calcium, cadmium, magnesium, nickel, selenium, sodium, and TDS estimated in the Strawberry Creek surface water causing 50% mortality to the fathead minnow are all lower than respective concentrations known to cause 50% mortality. The toxicity of the sample(s) is not explained by any one of these COPCs.

- Cobalt, manganese, and sulfate are identified as possible contributors to toxicity. Respective estimated concentrations of these COPCs in surface water samples associated with 50% mortality are higher than respective concentrations known to cause 50% mortality.

The toxicity of the Strawberry Creek surface water samples represents the effects of the mixture of COPCs including possible antagonistic, synergistic and/or additive effects between individual components. The toxicity of the mixture is represented directly by the measured results of tests with the surface water samples but may not be well represented by the individual single-compound results. In other words, our comparison of single contaminant LC_{50} values may not be a good measure of the overall toxicity. In making these comparisons it is assumed that the single contaminant (COPC) is the sole cause of toxicity and it's toxicity is not affected by other constituents (COPCs). Interpretation of the cause of toxicity is also confounded by the following factors:

- The analyses of the COPCs in the test water samples represents the state of the sample at the time of collection and may not represent the actual exposure conditions in the test beakers after manipulation in the laboratory.

- Toxicity could be associated with an constituent or multiple constituents that were not analyzed for in the test samples.

Toxicity could be associated with an atypical ion ratio in combination with increased salinity. The reported toxicity of TDS (salinity) to the fathead minnow has an underlying or typical ion ratio (that used for the tests). If the ion ratio in site waters (Strawberry Creek) are not comparable to this underlying ratio, then the TDS toxicity value used (in Table 5-10) may not be a good indicator of site-specific toxicity of the ion ratio present. To examine this possibility, the ion concentrations in the waters used for the toxicity tests to determine an acute toxicity threshold for salinity (TDS) for fathead minnows (Ingersoll et al., 1992) are provided in the following table. In comparison to these control waters, the surface water samples from Strawberry Creek are elevated with respect to sulfate, manganese and magnesium. Elevated levels of sulfate in saline water are reportedly stressful to the fathead minnow (Ingersoll et al., 1992). Sulfate concentrations in Strawberry Creek are almost four times higher than that found in the reconstituted control waters used for the toxicity testing.to establish the salinity acute toxicity threshold for the fathead minnow. Manganese concentrations in Strawberry Creek samples are two to three orders magnitude higher compared to the test water ratio.

Analyte	Strawberry Creek Samples for Toxicity Testing (Range)	Waters Used for Toxicity Testing to Establish Acute Toxicity Range for Salinity for Fathead Minnows and Daphnids (8-10 g/L Salinity) (Ingersoll et al., 1992)		
		5 g/L Salinity	12 g/L Salinity	22 g/L Salinity
pH	6.81 to 7.86	8.3	8.3	8.2
Alkalinity (mg/L)	10 to 58	140	140	146
Hardness (mg/L)	904 to 1,256	1,250	2,550	4,000
Conductivity (umhos/cm)	2,979 to 9,021	9,000	20,800	34,000
Sulfate (mg/L)	**3,656 to 4,561**	446	998	1,750
Chloride (mg/L)	not analyzed	3,900	6,920	12,600
As (mg/L)	0.040	<0.04	<0.4	<0.2
Ca (mg/L)	**216 to 360**	111	150	271
Cd (mg/L)	0.002 to 0.0476	<0.003	<0.03	<0.01
Cu (mg/L)	0.032 to 0.046	<0.028	<0.03	<0.01
Mg (mg/L)	270 to **717**	181	412	748
Mn (mg/L)	**0.216 to 2.1**	<0.01	<0.10	0.05
K (mg/L)	2.97 to 4.6	57	130	280
Na (mg/L)	716 to 1,309	1,470	3,390	6,990
Zn (mg/L)	0.0246 to 0.562	0.14	0.12	0.29

In order to develop a tool for assessing major ion toxicity, Mount et al. (1997) performed a series of acute toxicity tests with three freshwater species on solutions enriched with varying combinations of major ions. Results of these tests were incorporated into multivariate logistic regression models that predict survival of the three test species based on major ion concentrations. The predictive model for the fathead minnow is presented in Figure 5-31 along with the predicted versus observed toxicity for Strawberry Creek surface water samples. The predictive toxicity for Strawberry Creek associated with TDS components is much less than that observed. This comparison infers that toxicity observed for the water samples cannot be explained by TDS alone and clearly indicates the presence of another toxicant(s). As previously stated, toxicity may be caused by constituents(s) that were not analyzed for in the surface water samples. Historic use of polymers (surfactants) has been documented for the waste water treatment system prior to discharge to Strawberry Creek (Figure 5-32). These organic chemicals are a possible cause of the observed toxicity in surface water samples..

It is not possible to confirm the exact cause of toxicity. To confirm a specific cause(s) or to ensure that future discharges of treated effluent are not toxic, site-specific toxicity testing is recommended in addition to monitoring for COPC concentrations and water quality parameters.

5.4.2 Risks from Sediments

Three lines of evidence are available to evaluate risks from sediments to benthic organisms.

The findings from the lines of evidence are summarized below.

Line of Evidence	Findings
HQ Calculations	For Strawberry Creek, risks are categorized as severe for benthic organisms exposed to cadmium, copper, lead and zinc in sediment. Risks associated with silver are high and for aluminum and manganese are moderate. For Hoodoo Gulch, risks are categorized as severe for benthic organisms exposed to cadmium, copper, lead, silver, and zinc. Risks associated with manganese are moderate. For Ruby Gulch, risks are categorized as high for benthic organisms exposed to copper. Risks associated with copper are moderate. For Bear Butte Creek (downstream) risks are categorized as severe for benthic organisms exposed to cadmium, copper, and zinc. Risks associated with lead and silver are high.
Direct Toxicity Testing	For Strawberry Creek, very high toxicity was observed in sediment toxicity testing. Survival of *H. azteca* was very low ranging from 6 to 30% compared to 70 to 100% in controls (September 2000). Very high toxicity was also observed in samples collected almost a year later (October 2001) (Table 5-5). For Bear Butte creek, toxicity was not observed in the sediment toxicity testing.
Population Observations Benthic Community Structure	For Strawberry Creek, the benthic macroinvertebrate community is severely or moderately impaired compared to reference stations (Figure 5-28). For Bear Butte Creek, the benthic macroinvertebrate community is slightly impaired relative to reference stations (Figure 5-28).

In summary, based on a weight of evidence approach, it is concluded that COPCs in sediments are adversely impacting benthic organisms in Strawberry Creek. For downstream Bear Butte

Creek, the HQs predict toxicity but none was observed in sediment testing and the benthic macroinvertebrate community is only slightly impaired relative to reference. Risks to aquatic receptors in Bear Butte Creek from exposure to COPCs in sediment is not considered to be significant.

Identification of COPCs Associated with Observed Toxicity

In order to increase the usefulness of the weight of evidence evaluation, the sediment toxicity testing results are compared to concentrations of COPCs in the sediment samples in Table 5-11. This analysis identifies copper ($p< 0.0001$; $R2 =0.93$) in the sediment samples as a possible cause of the toxicity observed.

5.4.3 Risks from All Pathways Combined

One line of evidence (tissue-based HQ values for fish) is available to evaluate risks to aquatic receptors (fish) from all aquatic exposure pathways combined (surface water, sediment and dietary exposure). The findings from this line of evidence are summarized below.

Line of Evidence	Findings
HQ calculations based on fish tissue burdens	For cadmium, risks are identified as severe in Strawberry Creek and downstream Bear Butte Creek. For lead and chromium risks are identified as minimal.

Based on this line of evidence, it is concluded that risks to fish from COPCs in all media (surface water, sediment, and diet) are significant in Strawberry Creek and downstream Bear Butte Creek associated with cadmium.

5.4.4 Overall Conclusion Regarding Risks to Aquatic Receptors

The weight of evidence combined across all observations indicates that risks to aquatic receptors from site-related COPCs are high in Strawberry Creek, Hoodoo Gulch and Ruby Gulch and unacceptable risks do not extend downstream into Bear Butte Creek.

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6.0 RISKS TO TERRESTRIAL PLANTS AND SOIL ORGANISMS

6.1 Hazard Quotient Approach

This section provides an assessment of risks to terrestrial plant and soil organisms living in soils which are potentially impacted by contaminants from the Gilt Edge Mine site. Based on the site conceptual model (Figure 4-1), the following exposure pathways are selected for quantitative evaluation by the HQ approach:

- Direct contact of plant roots with chemicals in surface soils.
- Direct contact with soils by soil invertebrates.

The HQ-based evaluation is described below.

6.1.1 Soil COPC Selection

Soil COPCs for terrestrial receptors are selected based on all available soil data from sampling locations listed in Appendix A. Maximum soil concentrations for each contaminant are compared to their respective toxicity benchmark values (see Table D-4). COPCs are selected separately for the Mine source area versus riparian areas. "Mine source area" refers to the area of the mine workings while the "riparian area" is composed of soil samples collected along Strawberry Creek, Bear Butte Creek and Ruby Gulch. The results of the COPC selection procedure for exposure of terrestrial receptors to soil are detailed in Appendix C and the contaminants selected for quantitative evaluation are presented below.

Quantitative COPCs for Riparian Area Soils for Plants and Soil Invertebrates		
Aluminum	Lead	Silver
Arsenic	Manganese	Thallium
Chromium	Mercury	Vanadium
Cobalt	Nickel	Zinc
Copper	Selenium	

Quantitative COPCs for Mine Source Area Soils for Plants and Soil Invertebrates		
Aluminum Arsenic Barium Chromium Cobalt Copper	Lead Manganese Mercury Molybdenum Nickel	Selenium Silver Thallium Vanadium Zinc

6.1.2 Exposure Assessment

Terrestrial plants are exposed to contaminants in soil principally through their roots. Thus, exposure is characterized by the distribution of COPC levels in soil. Exposure may also occur due to deposition of dust on foliar (leaf) surfaces, but this pathway is believed to be small compared to root exposure. Soil organisms are exposed to contaminants in soil via direct contact and ingestion. Because these terrestrial receptors are not highly mobile, exposures are evaluated on a sample-by-sample basis, rather than on average concentrations over some selected location.

6.1.3 Toxicity Assessment

Toxicity values for the protection of terrestrial receptors (plants and soil organisms) from contaminants in surface soils are available from several sources. These toxicity values are expressed in units of ppm of COPC in soil. Each of the sources evaluated in deriving soil toxicity benchmarks is described briefly in Appendix D, along with a hierarchy for identifying the most relevant and reliable benchmark value when more than one value is available. The selected toxicity benchmark values for all contaminants analyzed in soil are shown in Table D-4 of Appendix D.

6.1.4 Calculation of Hazard Quotients for Riparian Soils

Figures 6-1a through 6-1n provide graphs showing the distribution of the HQ values for each COPC for soil samples collected at each riparian area exposure reach. HQs based on non-detects are shown as open-circles and HQs based on detects are shown as closed circles. Note that the results in these figures are plotted on a log-scale, so large differences between HQ values are somewhat compressed.

The classification of risks for each exposure reach as presented in the figures is further interpreted and the results of the evaluation recorded in Table 6-1 as a summary of risks. Interpretation of the HQ plots is as follows:

- Exposure reaches with HQ values that are all less than or equal to one are classified as "none" for no risks identified.

- For exposure reaches where some HQ values are greater than one but the distribution of the HQ values is similar to the distribution observed for the reference reaches, the risks are identified as being associated with background conditions. Risks are not identified for these reaches.

- For exposure reaches where HQ values are greater than one, the risks are classified into one of four categories as described in Section 4 and depicted on Table 6-1.

Inspection of Table 6-1 and Figures 6-1a through 6-1n yields the following main conclusions:

- Risks are categorized as severe for Strawberry Creek associated with copper and silver. Selenium and thallium risks are high and risks for zinc are moderate. HQ values are greater than 1 for aluminum, arsenic, chromium, manganese, mercury and vanadium; however, these values are equal to or are higher at reference exposure reaches (upstream Bear Butte Creek and Butcher Gulch) and risks are not site-related.

- Risks are not identified for Ruby Gulch. The distribution of HQ values for aluminum, chromium, manganese and vanadium are similar to those for reference reaches are concluded to be not site related.

- Risks for downstream Bear Butte Creek are categorized as high for copper and zinc. Risks for silver and thallium are moderate. Risks for aluminum, arsenic, chromium manganese and vanadium are not site related as they are equal to or higher than those at

The HQ values for COPCs associated with either severe or high risks including copper, selenium, silver, thallium and zinc are presented spatially as maps in Figures 6-2 to 6-6. Inspection of these maps reveals that HQ values are highest upstream in Strawberry Creek and decrease with distance downstream. It should be noted that not all of the points plotted in Figure 6-1 for each COPC for each exposure reach could be plotted on the maps as geographic coordinates were not available. The maps as well as the results shown in Figure 6-1 show the potential for adverse effects to the plants and soil invertebrates in Strawberry Creek and to a lesser extent in downstream Bear Butte Creek (based on relative HQ values). Risks in Strawberry Creek are associated with copper, selenium, silver, thallium and zinc. Risks in Bear Butte Creek are associated with copper, silver, thallium and zinc.

6.1.5 Calculation of Hazard Quotients for Mine Source Area Soils

Figures 6-7a through 6-7p provide graphs showing the distribution of the HQ values for specific environmental media type from a specific sampling investigation (fill material, waste rock, surface soil, soil) for each COPC. Figures 3-5, 3-6 and 3-7 show the locations of these samples. Note that the results in these figures are plotted on a log-scale, so large differences between HQ values are somewhat compressed. The points are plotted with different symbols corresponding to the waste type. Also plotted are the range (minimum and maximum) background concentrations for South Dakota (Shacklette & Boerngen, 1984). Inspection of the results in Figures 6-7a through 6-7p reveals the following:

- Risks are not associated with nickel, mercury, cobalt, and barium as all but a few soil concentrations fall below respective toxicity benchmarks

- HQ values for manganese and vanadium are in most cases greater than one and are similar across all sample types (soil, waste rock and fill material).

- In general, the only chromium concentrations exceeding background concentrations are in waste rock material and not soil samples.

- For arsenic, copper, lead, selenium, silver, thallium and zinc certain samples have HQ values greater than 1.

The HQ values for Mine source area surface soils for arsenic, copper, lead, selenium, silver and zinc are presented spatially as maps in Figures 6-8 to 6-13. Thallium data is limited and not plotted geographically. The HQ values for Mine Source Area subsurface soils for the same COPCs are presented spatially as maps in Figures 6-14 to 6-19. These maps should assist decision makers in the geographic extent of possible risks as decisions are made concern reclamation, removal, treatment or capping of the Mine source area.

6.2 Evaluation of Site-Specific Toxicity Tests

No site-specific toxicity tests for terrestrial receptors are available for the Gilt Edge Mine site.

6.3 Evaluation of Terrestrial Community Surveys

No plant or soil organism community evaluations are available for the Gilt Edge Mine site.

6.4 Weight of Evidence

Only one line of evidence (the HQ approach) is available to evaluate risks to plants and soil invertebrates from COPCs in soils. The findings from this line of evidence are summarized in the following text table.

Line of Evidence	Findings
HQ calculations based on concentrations measured in soil	For Strawberry Creek, risks are categorized as severe for plants and soil invertebrates exposed to copper and silver in soils. Risks associated with selenium and thallium are high and zinc are moderate. For Bear Butte Creek, risks are categorized as high for plants and soil invertebrates exposed to copper and zinc. Risks associated with silver and thallium are moderate. For Mine Source Area Soils certain soil, fill and waste rock samples have HQ values greater than 1 for arsenic, copper, lead, zinc, thallium, silver and selenium.

Based on this line of evidence, it is concluded that risks from site-related contaminants in surface soil are of concern in the riparian area of Strawberry Creek and Bear Butte Creek and in the Mine Source Area area. Risks for riparian soils are associated with copper, silver, thallium, and zinc. Risks for Mine source area soils are associated with arsenic, copper, lead, selenium, silver, thallium, and zinc.

Site Specific Factors which May Influence Bioavailability of Metals in Soils and Risk

Use of HQ values to interpret risks does not consider environmental factors which may influence the toxicity of COPCs in soils to plants and soil invertebrates. The total metal content of soils is not a good predictor of potential toxicity. Soil-solution free metal activity

For lead and copper in soils it is possible to more accurately predict the toxicity of soils based on the measured pH and organic carbon content of the soils using a data set and regression equations developed by Sauve et al (2000). Sauve et al. (2000) developed regression equations to predict toxicity to plant and soil organisms from copper and lead. Using the measured bulk metal concentrations and soil pH, the free metal concentrations in the soil solution is estimated.

$$pCu^{2+} = 1.4 \cdot pH - 1.7 \cdot \log_{10}(\text{Total Cu}) + 3.42 \quad [R^2 = 0.848]$$
$$pPb^{2+} = 0.62 \cdot pH - 0.84 \cdot \log_{10}(\text{Total Pb}) + 6.78 \quad [R^2 = 0.643]$$

where:

pCu^{2+} and pPb^{2+} = negative $\log_{10}$ of the free metal activity (uM)
Total Cu and Total Pb = total recoverable metal concentration (mg/kg dw)

The free metal activity is then used to predict the expected inhibition of the plant and soil organism communities and microbial processes.

$$\%\text{inhibition from Cu} = -13.2 \cdot pCu^{2+} + 151.2 \quad [R^2 = 0.424]$$
$$\%\text{inhibition from Pb} = -19.5 \cdot pPb^{2+} + 210.1 \quad [R^2 = 0.409]$$

A 25% inhibition corresponds to the level at which most organisms will begin to exhibit adverse effects and represents the threshold for the beginning of ecosystem toxicity (Suave et al., 2000). A 50% inhibition represents a drastic impact on the ecosystem with major impacts on microbial processes, moderate impacts to organisms of average sensitivity, and alterations of plant productivity and species competition (Suave et al., 2000).

The predictive model (equation) was applied to the data for fill material, soil stockpiles, and waste rock in Figure 6-15 for copper and Figure 6-16 for lead. Soil pH data is not available for the Riparian soils data collected at the Gilt Edge Mine site but pH data is available for Mine Source Area soils. The results are sorted conceptually into three categories:

- Low (low inhibition <10%)
- Medium (from 10 to 30% inhibition)
- High (>30% inhibition)

The results indicate that most fill material samples are not toxic but most waste rock and soil stockpile samples are toxic.

7.0 RISKS TO WILDLIFE RECEPTORS

This section presents an assessment of the risks to populations of wildlife receptors that reside near the Gilt Edge Mine site. Wildlife receptors include a wide variety of mammals and birds that span a variety of sizes and feeding guilds. Exposure of wildlife receptors may occur through ingestion of contaminated surface water while drinking, ingestion of contaminated soil or sediment while feeding, and ingestion of contaminated food web items.

As discussed in Section 4, it is not feasible to evaluate exposures and risks for each avian and mammalian species potentially present within the site. For this reason, specific wildlife species are identified as surrogates (representative species) for the purpose of estimation of exposure and risk in the ERA. The surrogate species at this site and the exposure pathways evaluated for each species include:

Surrogate Species for Riparian Exposure Reaches		
Surrogate Species	**Feeding Guild**	**Exposure Pathways Evaluated**
Mink	Mammalian piscivore	Ingestion of surface water, sediment, and fish
Belted Kingfisher	Avian piscivore	
Masked Shrew	Mammalian insectivore	Ingestion of surface water, soil, and soil invertebrates
American Robin	Avian omnivore	Ingestion of surface water, soil, plants and soil invertebrates
Deer mouse	Mammalian omnivore	
Bobwhite quail	Avian herbivore	Ingestion of surface water, soil and plants

Surrogate Species for Mine Source Area		
Surrogate Species	**Feeding Guild**	**Exposure Pathways Evaluated**
Deer mouse	Mammalian omnivore	Ingestion of soil (soil, fill material or waste rock) and plants
Bobwhite quail	Avian herbivore	

7.1 Hazard Index Approach

The basic equation used for calculation of an HQ value for exposure of a terrestrial wildlife receptor to a contaminant by ingestion of an environmental medium is:

$$HQ_{r,c,m} = \frac{C_{c,m} \cdot IR_{m,r} \cdot DF_{m,r} \cdot RBA_{c,m}}{BW_r \cdot TRV_{c,r}}$$

where:

$HQ_{r,c,m}$	=	HQ for exposure of receptor "r" to COPC "c" in medium "m"
$C_{c,m}$	=	Concentration of COPC "c" in medium "m" (mg/kg)
$IR_{m,r}$	=	Intake rate of medium "m" by receptor "r" (kg/day)
BW_r	=	Body weight of receptor "r" (kg)
$DF_{m,r}$	=	Dietary fraction of medium "m" by receptor "r" derived from site (%)
$RBA_{c,m}$	=	Relative bioavailability of COPC "c" in medium "m" (%)
$TRV_{c,r}$	=	Toxicity reference value for COPC "c" for receptor "r" (mg/kg BW/d)

Because all receptors are exposed to more than one environmental medium, the total Hazard Index (total HI) for a receptor from a specific COPC is calculated as the sum of HQs for that COPC across all exposure pathways:

$$HI_{c,r} = \sum HQ_{c,m,r}$$

If the total HI is below 1E+00, it is believed that no unacceptable effects will occur in the exposed receptor from the COPC. If the total HI is above 1E+00, then unacceptable effects may occur, with the likelihood and/or severity of effects tending to increase as the value of the HI becomes larger.

7.1.1 COPC Selection

The COPC selection procedure for exposure of wildlife receptors at this site was performed using medium-specific concentration-based benchmarks in water, soil, or the diet. The values employed were derived by Sample et al. (1996) for several different types of mammalian and avian receptors by back-calculation from dose-based no-effect levels in the receptor, assuming typical intakes rates and body weight for the receptor. For COPC selection, the lowest NOAEL concentration-based TRVs for mammals and avian receptors are used. These concentration-based benchmarks are presented in Appendix D-5. The maximum concentration value of each analyte in each medium (surface water, sediment, soil, and fish tissue) is compared to their respective concentration-based toxicity benchmark values, and any analyte with one or more values above the benchmark is retained as a COPC (Appendix C). Contaminants selected for quantitative evaluation for wildlife receptors in one or more media are presented below for both the Riparian Areas and Mine Source Area.

Quantitative COPCs for Exposure of Wildlife Receptors via Ingestion Riparian Areas			
Aluminum	Cadmium	Manganese	Strontium
Antimony	Chromium	Mercury	Thallium
Arsenic	Copper	Molybdenum	Vanadium
Barium	Lead	Nickel	Zinc
Beryllium	Lithium	Selenium	

Quantitative COPCs for Exposure of Wildlife Receptors via Ingestion Mine Source Area		
Aluminum	Cobalt	Nickel
Arsenic	Copper	Selenium
Barium	Lead	Silver
Cadmium	Manganese	Thallium
Chromium	Mercury	Zinc

7.1.2 Exposure Assessment

Riparian Areas

Wildlife receptors are generally mobile, and hence may be exposed to a range of different concentration values in water, soil, and food web items as they move throughout their home range. As described previously in Section 3, for the purposes of this assessment the riparian areas are divided into a number of reaches (Figure 3-1). Exposure of wildlife receptors for each COPC in each medium (surface water, soil, sediment, and fish) within each exposure reach is based on the 95% upper confidence limit (UCL) of the mean concentration or the maximum concentration, whichever is lower. The 95% UCL is calculated based on the assumption that concentration values within each reach are distributed lognormally. Non-detects are evaluated by assuming a concentration value equal to one-half the detection limit.

For exposures related to ingestion of plants and soil invertebrates, site-specific measurements of COPC concentrations in these food items are not available for the Gilt Edge Mine site. It is, however, possible to estimate COPC concentrations in plants and soil invertebrates based on available equations that relate the soil concentration of the COPC to the concentration in food type. The following tables provide the equations used to estimate COPC concentrations in plants and soil invertebrates (earthworms) based on the respective EPC in soil. Where equations are not available for a particular COPC, the concentration in food item is estimated to be equal to the concentration in soil (ratio of 1:1). The EPCs for wildlife in water, sediment, soil, plants, soil invertebrates, and fish are provided in Table 7-1 for each exposure reach.

Equations Used to Estimate Metal Concentrations in Earthworms (Soil Invertebrates)			
	B0	**B1**	**UF**
Arsenic	-1.421	0.706	na
Cadmium	2.114	0.795	na
Chromium	na	na	3.162
Copper	1.675	0.264	na
Lead	-0.218	0.807	na
Manganese	-0.809	0.682	na
Mercury	0.0781	0.3369	na
Nickel	na	na	4.73
Selenium	-0.075	0.733	na
Zinc	4.449	0.328	na

where:
*ln(conc in earthworm) = B0 + B1 * ln(conc in soil) and concentrations are expressed as mg/kg dw.*
or *(conc in earthworm) = UF * (conc in soil) and concentrations are expressed as mg/kg dw.*
From ORNL (1998) Report ID ES/ER/TM-220
Predicted soil invertebrate dry weight concentration is converted to wet weight : Wet weight = Dry weight * Conversion Factor *(0.35 from DOI, 1998)*

Equations Used to Estimate Metal Concentrations in Plants		
	B0	**B1**
Arsenic	-1.992	0.564
Cadmium	-0.476	0.546
Copper	0.669	0.394
Lead	-1.328	0.561
Mercury	-0.996	0.544
Nickel	-2.224	0.748
Selenium	-0.678	1.104
Zinc	1.575	0.555

where:
*ln(conc in plant) = B0 + B1 * ln(conc in soil) and concentrations are expressed as mg/kg dw.*
From ORNL (1998) Report ID BJC/OR-133 - Table 7
*Predicted concentrations converted from dry weight to wet weight: Wet weight = Dry weight * Conversion Factor of 0.53 from DOI (1998)*

Mine Source Area.

Exposures for wildlife to the Mine source area (the mine workings) is evaluated in the same manner as risks for terrestrial receptors by sampling location. Different types of samples are evaluated including: surface soil, soil, waste rock, and fill material. The material types generally follow sampling investigations including the *Site Wide Vegetation Study (USEPA, 2001c)*, *Site Wide Fill Material Study (USEPA, 2001b), Robertson GeoConsultants Waste Rock Survey (RGC, 1999)and URS Site Inspection* (SI) data (USEPA, 1999). The COPC concentrations in plants are estimated in the same manner as that previously described for the Riparian areas.

Wildlife Intake Factors

Exposure parameters and dietary intake factors for each receptor for each medium are derived as described in Appendix B. In some cases, no quantitative data could be located, so professional judgement is used in selecting exposure parameters. The exposure parameters selected for each wildlife receptor are summarized in Table 7-2. These factors are necessary for estimating contaminant exposures (or doses). All intake values shown in these tables are expressed in terms of wet weight except for soil and sediment, which are expressed as dry weight.

In all cases, the fraction of the total dietary intake that comes from within an exposure area is assumed to be 100%. This assumption is used because each of the exposure reaches is relatively large, and most wildlife receptors are expected to derive nearly all of their food from within the exposure reach. If any receptors are to derive a significant portion of their diet from areas outside of the reaches being evaluated, estimated doses and risks could be lower than predicted.

7.1.3 Toxicity Assessment

Toxicity Reference Values (TRVs) for terrestrial wildlife (mammals and birds) were derived by EPA for the calculation of Ecological Soil Screening Levels (Eco-SSLs). Using specific procedures for the Eco-SSLs, one mammalian and one avian TRV are derived and expressed as mg contaminant per kg body weight. The TRV derivation procedures extract and plot two different toxicity values. The first value is the exposure dose that is not associated with any adverse effects to the test organism. This is referred to as the No Observed Adverse Effect Level (NOAEL). The second value is the reported exposure dose that causes an observable adverse effect, and is referred to as the Lowest Observed Adverse Effect Level (LOAEL). NOAEL and LOAEL values are grouped by six types of endpoints (biochemical, behavior, pathology, reproduction, growth and mortality). The TRV value, in most cases, is equal to the geometric mean of the NOAEL for growth and reproductive effects or the highest bounded NOAEL lower than the lowest bounded LOAEL for growth, reproduction or survival. The Eco-SSL TRVs are provided in Tables D-6a and D-6b and are summarized in D-7.

For contaminants where Eco-SSL TRVs are not available, TRVs are derived from Sample et al. (1996). Sample et al. (1996) provide a summary of available data on the toxicity of contaminants to wildlife receptors. Based on these studies, Sample et al. (1996) identified avian and mammalian dose-based NOAEL and LOAEL TRVs for each contaminant for which data are adequate. A summary of the available studies reviewed by Sample et al. (1996) and the selected NOAEL and LOAEL TRVs are presented in Appendix D-6. In cases where the TRVs from Sample et al. (1996) are used the geometric mean of the NOAEL and LOAEL dose-based TRVs is used as the TRV. This value is taken to be an estimate of the threshold dose level where adverse effects first begin to occur in exposed organisms. In cases where only one of the two needed values was available (a NOAEL but no LOAEL, or a LOAEL but no NOAEL), the missing value was estimated by assuming a ratio (LOAEL to NOAEL) of 5. This ratio is based on the observation that the true ratio of the NOAEL to the LOAEL is less than a factor of 5 in 96% of all cases where both values were available (USEPA 1997). Thus, use of a factor of 5 is conservative, and will tend to overestimate extrapolated LOAEL values and will tend to underestimate extrapolated NOAEL values.

Table D-7 of Appendix D presents the dose-based TRVs used in this assessment to evaluate risks to wildlife receptors from ingestion of contaminants in surface water, soil, sediment, and food items.

Relative Bioavailablility

The TRVs for wildlife are expressed in units of ingested dose. However, the toxicity from an ingested dose depends on how much of the ingested dose is actually absorbed, which in turn depends on the properties of both the contaminant and the exposure medium. Ideally, toxicity studies would be available that establish empiric TRVs for all site media of concern (water, food, soil, sediment). However, most laboratory tests use either food or water as the exposure medium, and essentially no studies use soil or sediment. Therefore, in cases where a TRV is based on a study in which the oral absorption fraction is different that what would be expected for a site medium, it is necessary to adjust the TRV to account for the difference in absorption.

The ratio of absorption from the study medium compared to absorption from site medium is referred to as the relative bioavailability (RBA). For inorganic COPCs, available data on cadmium and manganese suggest that absorption from the diet is about half that from water (IRIS 2002). Based on this, when toxicity data for inorganic COPCs are available from studies in food or water, but not both, the RBA for a contaminant in food compared to that for water or other soluble forms (e.g., capsule) is assumed to be 0.5 (50%). That is:

$$TRV_{water} = TRV_{diet} \cdot 0.50$$
$$TRV_{diet} = TRV_{water\ or\ capsule} / 0.50$$

In the absence of any site specific data, it is assumed that contaminants in soil and sediment are absorbed to the same degree as contaminants in food. It is considered likely that this approach may tend to overestimate exposure and risk from ingestion of soil, but this is not known for certain.

7.1.4 Risk Calculations

Calculation of Total Hazard Indices for Riparian Exposure Reaches

Tables 7-3a through 7-3f present the total HIs for each wildlife receptor for each COPC within each exposure reach. Detailed calculations are provided in Appendix E. The HIs are interpreted as follows:

- Exposure reaches with HI values that are all less than or equal to one are classified as having no risk.
- For exposure reaches where some HI values are greater than one but the HI values are similar to those calculated for the reference reaches, the risks are identified as being associated with reference conditions. Risks are not identified for these reaches.
- For exposure reaches where some HQ values are greater than one, potential risks are identified and specific exposure pathway associated with the risks are discussed.

The results are provided in Appendix E and are summarized in Table 7-3a through 7-3f. Inspection of the appendix and tables reveals the following main conclusions:

<u>Masked Shrew- Strawberry Creek</u>. As shown in Table 7-3a, aluminum, cadmium, and lead, contribute HI values above a level of concern for the masked shrew at Strawberry Creek. Risks are associated with the ingestion of aluminum in surface water; and cadmium, and lead in soils and soil invertebrates. HI values are also greater than 1 for

antimony, arsenic, barium, chromium, copper, manganese, mercury, nickel, selenium, thallium, vanadium and zinc; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Masked Shrew-HooDoo Gulch. As shown in Table 7-3a, risks are below a level of concern for the masked shrew at HooDoo Gulch. All HI values are less than or equal to 1.

Masked Shrew- Ruby Gulch. As shown in Table 7-3a, aluminum, and cadmium contribute to HI values above a level of concern (greater than 1) for the masked shrew at Ruby Gulch. Risks are associated with the ingestion of aluminum in surface water and cadmium in soil invertebrates. HI values are also greater than 1 for antimony, arsenic, barium, chromium, copper, manganese, mercury, nickel, selenium, thallium, vanadium and zinc; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Masked Shrew-downstream Bear Butte Creek. As shown in Table 7-3a, cadmium and lead contribute to HI values above a level of concern (greater than 1) for the masked shrew at downstream Bear Butte Creek. Risks are associated with the ingestion of cadmium, and lead in soil invertebrates. HI values are also greater than 1 for aluminum, antimony, arsenic, barium, chromium, copper, manganese, mercury, nickel, selenium, thallium, vanadium and zinc; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Robin- Strawberry Creek. As shown in Table 7-3b, arsenic, cadmium, lead and selenium contribute to HI values above a level of concern (greater than 1) for the robin at Strawberry Creek. Risks are associated with ingestion of arsenic, cadmium, lead and selenium in soil invertebrates and the incidental ingestion of arsenic and lead in soils. HI values are also greater than 1 for aluminum, barium, chromium and zinc; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Robin - HooDoo Gulch. As shown in Table 7-3a, risks are below a level of concern for the robin at HooDoo Gulch. All HI values are less than or equal to 1.

Robin- Ruby Gulch. As shown in Table 7-3b, cadmium and chromium contribute to an HI value above a level of concern (greater than 1) for the robin at Ruby Gulch. Risks are associated with the ingestion cadmium and chromium in soil invertebrates. HI values are also greater than 1 for aluminum, barium, lead and zinc; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Robin- downstream Bear Butte Creek. As shown in Table 7-3b, arsenic, cadmium, lead and vanadium contribute to HI values above a level of concern (greater than 1) for the robin at downstream Bear Butte Creek. Risks are associated with ingestion of these COPCs in soil and soil invertebrates. HI values are also greater than 1 for aluminum, barium, chromium, and zinc; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Deer Mouse- Strawberry Creek. As shown in Table 7-3c, aluminum, antimony, arsenic, and thallium contribute to HI values above a level of concern (greater than 1) for the Deer mouse at Strawberry Creek. Risks are associated with ingestion of aluminum in surface water, and antimony, arsenic and thallium in plants. HI values are also greater than 1 for aluminum (soil), manganese and vanadium; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Deer Mouse - HooDoo Gulch. As shown in Table 7-3a, risks are below a level of concern for the Deer mouse at HooDoo Gulch. All HI values are less than or equal to 1.

Deer Mouse- Ruby Gulch. As shown in Table 7-3c, aluminum and antimony contribute to an HI value above a level of concern (greater than 1) for the deer mouse at Ruby Gulch. Risks are associated with ingestion of aluminum in surface water and antimony in plants. HI values are also greater than 1 for vanadium; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Deer Mouse- downtream Bear Butte Creek. As shown in Table 7-3c, antimony and arsenic contribute to HI values above a level of concern (greater than 1) for the Deer mouse at downstream Bear Butte Creek. Risks are associated with ingestion of these COPCs in plants. HI values are also greater than 1 for aluminum, manganese, thallium and vanadium; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Quail- Strawberry Creek. As shown in Table 7-3d, aluminum, and lead contribute to HI values above a level of concern (greater than 1) for the quail at Strawberry Creek. Risks are associated with ingestion of aluminum in surface water and ingestion of lead in plants. HI values are also greater than 1 for chromium; however, this value is similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Quail - HooDoo Gulch. As shown in Table 7-3a, risks are below a level of concern for the quail at HooDoo Gulch. All HI values are less than or equal to 1.

Quail- Ruby Gulch. As shown in Table 7-3d, risks to the quail at Ruby Gulch are below a level of concern for all COPCs. HI values are greater than 1 for aluminum and chromium; however these HI values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and risks are not considered to be site-related.

Quail- downstream Bear Butte Creek. As shown in Table 7-3d, lead contributes to an HI values above a level of concern (greater than 1) for the quail at downstream Bear Butte Creek. Risks are associated with ingestion of lead in plants. HI values are also greater than 1 for aluminum, and chromium; however, these values are similar to those observed for reference reaches (upstream Bear Butte Creek and/or Butcher Gulch) and are risks are not considered to be site-related.

Kingfisher. As shown in Table 7-3e, risks to the kingfisher are below a level of concern for all COPCs for all exposure reaches. HI values are greater than 1 for chromium, mercury and zinc related to the ingestion of the COPCs in fish; however, these HI values are similar to those observed for the reference reach (upstream Bear Butte Creek) and risks are not considered to be site-related.

Mink. As shown in Table 7-3f, risks to the mink are below a level of concern for all COPCs for all exposure reaches. HI values are greater than 1 for aluminum, mercury and selenium; however, these HI values are similar to those observed for reference reaches and risks are not considered to be site-related.

Based on this line of evidence, the following risks are concluded for wildlife receptors from site-related COPCs:

- Risks are above a level of concern in Strawberry Creek for ingestion of aluminum in surface water; incidental ingestion of arsenic, and lead in soil; ingestion of arsenic, cadmium, lead, selenium, and thallium in soil invertebrates; and ingestion of antimony, arsenic, lead, and thallium in plants.

- Risks are above a level of concern in Ruby Gulch for ingestion of aluminum in surface water; and ingestion of cadmium and chromium in soil invertebrates and antimony in plants.

- Risks are below a level of concern in HooDoo Gulch for all wildlife receptors.

- Risks are above a level of concern in downstream Bear Butte Creek for ingestion of antimony, and lead in plants; and ingestion of arsenic, cadmium, lead, and vanadium in soil invertebrates.

Calculation of Hazard Quotients for Mine Source Area

Figures 7-1a through 7-1q provide graphs showing the distribution of the HQ values for two wildlife receptors (quail and deer mouse) for each COPC for incidental ingestion. Figure 7-2a through 7-2q provide HQ values for wildlife for ingestion of COPCs in plants. In each figure, the results are presented for each sample type (surface soil, soil, fill material and wasted rock). Figures 3-5, 3-6 and 3-7 show the locations of these samples. Note that the results in these figures are plotted on a log-scale, so large differences between HQ values are somewhat compressed. The points are plotted with different symbols corresponding to the sample investigation and waste type. Also plotted are the range (minimum and maximum) of respective background soil concentrations reported in Shacklette & Boerngen (1984) for the state of South Dakota. Inspection of the results in Figures 7-1a through 7-1q reveals the following:

- Some location specific HQs for surface soil or fill material samples are within a level of concern (> 1) for arsenic, manganese, selenium, vanadium, lead, and zinc. These HQs are higher than those associated with the range of possible background soil concentrations. Risks are associated with the ingestion of manganese, selenium, vanadium, lead, and zinc in plants and the incidental ingestion of arsenic in the soil and/or fill material.

- Some location specific HQs for for antimony, chromium, molybdenum, and lead in waste rock samples are within a level of concern (HQ >1) but are not within a level of concern for the other waste types (surface soil, soil, fill material). These HQs are higher than those associated with the range of possible background soil concentrations. Risks are associated with the ingestion of antimony, chromium and molybdenum in plants and the incidental ingestion of antimony and lead in waste rock.

- HQs for all remaining COPCs for all samples and sample types are below a level of concern. Either HQ values are all ≤ 1 or the HQ values are less than HQ values a background conditions.

7.2 Evaluation of Site-Specific Toxicity Tests

No site-specific toxicity tests for wildlife receptors are available for the Gilt Edge Mine site.

7.3 Evaluation of Wildlife Surveys

No wildlife evaluations are available for the Gilt Edge Mine site.

7.4 Weight of Evidence

Only one line of evidence (the HI approach) is available to evaluate risks to wildlife receptors from in water, soil, and the diet. The findings from this line of evidence are summarized below:

Weight of Evidence for Riparian Exposure Reaches	
Line of Evidence	**Findings**
HI calculations based on COPC concentrations measured in soil, water and diet	For Strawberry Creek (Riparian area) risks are above a level of concern for ingestion of aluminum in surface water; incidental ingestion of arsenic and lead in soil; and ingestion of arsenic, cadmium, lead, selenium, and thallium in soil invertebrates and ingestion of antimony, arsenic, lead and thallium in plants. For Ruby Gulch (Riparian area) risks are above a level of concern for ingestion of aluminum in surface water; ingestion of cadmium and chromium in soil invertebrates; and ingestion of antimony in plants. For Hoodoo Gulch (Riparian area) risks are above a level of concern for incidental ingestion of aluminum in sediment. For downstream Bear Butte Creek risks are above a level of concern for ingestion of antimony and lead in plants; and ingestion of arsenic, cadmium, lead, and vanadium in soil invertebrates.
HQ calculations based on COPC concentrations measured in surface soil, subsurface soil, fill material, waste rock, and plants.	For the Mine Source Area, risks are above a level of concern for ingestion of manganese, selenium, vanadium, lead, and zinc in plants and the incidental ingestion of arsenic in environmental media (soil, surface soil, waste rock or fill material). For the Mine Source Area, risks are above a level of concern for exposures to waste rock (but not other waste material types) for ingestion of antimony, chromium and molybdenum in plants (growing on the waste rock) and the incidental ingestion of antimony and lead in waste rock.

Based on this line of evidence, it is concluded that risks from site-related COPCs in surface water and soil are of concern to wildlife receptors in the Riparian Area along Strawberry Creek, Ruby Gulch and downstream Bear Butte Creek.

8.0 UNCERTAINTIES

Quantitative evaluation of ecological risks is generally limited by uncertainty regarding a number of important data. This lack of knowledge is usually circumvented by making estimates based on whatever limited data are available, or by making assumptions based on professional judgement when no reliable data are available. Because of these assumptions and estimates, the results of the risk calculations are themselves uncertain, and it is important for risk managers and the public to keep this in mind when interpreting the results of a risk assessment. The following text summarizes the key sources of uncertainty influencing the results of this ERA.

8.1 Uncertainty in the Nature and Extent of Contamination

Representativeness of Samples Collected

Concentration levels of COPCs in environmental media are often quite variable as a function of location, and may also vary significantly as a function of time. Thus, samples collected during a field sampling program may or may not fully characterize the spatial and temporal variability in actual concentration levels. At this site, all of the field samples were collected in accord with sampling and analysis plans that specifically sought to ensure that samples were representative. However, in some locations and for some media, the number of samples collected was relatively small. Thus, without the collection of very large numbers of samples over both space and time, some uncertain remains as to whether the samples collected provide an accurate representation of the distribution of concentration values actually present.

Accuracy of Analytical Measurements

Laboratory analysis of environmental samples is subject to a number of technical difficulties, and values reported by the laboratory may not always be exactly correct. However, all data used in this risk assessment had sufficient accompanying quality assurance data to ensure that results were within acceptable bounds for accuracy and precision. The magnitude of analytical error is usually small compared to other sources of uncertainty, although the relative uncertainty increases for results that are near the detection limit.

8.2 Uncertainty in Exposure Assessment

Exposure Pathways Not Evaluated

Exposure pathways selected for quantitative evaluation in this ERA do not include all potential exposure pathways for all ecological receptors. Exposure pathways not evaluated in this ERA include:

- Ingestion of prey items and sediments by benthic invertebrates
- Ingestion of water, sediment, and prey items by fish
- Dermal exposure of wildlife to soil, sediment, and surface water

Omission of these pathways will tend to underestimate total risk to the exposed receptors. However, as discussed previously, most of these exposure pathways are likely to be minor compared to other pathways that are evaluated, and the magnitude of the underestimation is not likely to be significant. One possible exception is ingestion of prey items by benthic invertebrates. Although the general consensus is that uptake from food is usually less than from water (Clements, 1991), available data are sufficient to establish that the ingestion pathway can be an important source of exposure to some aquatic macroinvertebrates (Timmermans et al., 1992), and that dietary exposures can be capable of limiting growth in at least some cases (Duddridge and Wainwright, 1980). Based on the lack of data on the toxicity of contaminants in food chain items on aquatic invertebrate receptors, quantitative prediction of hazard using the traditional HQ and HI approach is not yet possible. To the extent that dietary exposures tend to be less important than water exposures in at least some species, failure to quantify the hazard from the ingestion pathway may not lead to a substantial underestimation of total hazard. However, the food pathway may be more important than the water pathway for some contaminants and/or some receptor species. Therefore, the inability to quantify hazard from ingestion exposures is a potential source of uncertainty that may tend to underestimate impacts of contamination on aquatic macroinvertebrate receptors.

Contaminants Not Detected

Any contaminant that was never detected in a site medium is not evaluated in exposures of receptors to that medium. However, in some cases, the analytical detection limit is too high to expect the contaminant would be detected even if it were present at a level of concern. Contaminants in this category are assigned to the Qualitative COPC list (Type 2). Appendix C identifies chemicals assigned to this category, and the results are summarized in Table 8-1. As seen, a few of such contaminants exist. Omission of these contaminants could result in an underestimation of risk. However, the magnitude of the error is likely to be low in most cases. This is because if the contaminant is actually site-related or if it is present at a level of substantial concern, it likely occurs at levels above the detection limit at least a few times. Thus, while the hazard from Qualitative Type 2 COPCs is unknown, it is probably not large enough to cause a substantial underestimation of risk.

Exposure Area Concentration Values

For exposures that are based on the average concentration across many samples rather than exposures that are based on individual samples (this is the case for most wildlife species), the desired input parameter is the true mean concentration of a contaminant within a medium, averaged over the area where exposure occurs. In this assessment, rather than using the sample mean, exposure is based on the 95% UCL of the mean, or the maximum value (which ever was lower). This approach is much more likely to overestimate than underestimate true risk, and this is a source of conservatism in the risk estimates.

Wildlife Exposure Factors

The intake (ingestion) rates for food, soil, water, and sediment used to estimate exposure of wildlife at the site are derived from literature reports of intake rates, average body sizes, dietary compositions, consumption rates, and metabolic rates by receptors at other locations or from measurements of laboratory-raised organisms. These values may or may not serve as appropriate models for site-specific intake rates of wild receptors at this site. Moreover, the actual dietary composition of an organism will vary daily and seasonally. In addition, some wildlife receptor-specific intake rates are estimated by extrapolation from data on a closely related species or by use of allometric scaling equations (scaling of intake rates based on body weights). This introduces further uncertainty into the exposure and risk estimates. These uncertainties could either under- or overestimation the actual exposures of wildlife to COPCs in water, sediment, soil, and diet.

Absorption From Ingested Doses

The toxicity of an ingested contaminant depends on how much of the contaminant is absorbed from the gastrointestinal tract into the body. However, the actual extent of contaminant absorption from ingested media (soil, sediment, food, and water) is usually not known. The hazard from an ingested dose is estimated by comparing the dose to an ingested dose that is believed to be safe, based on tests in a laboratory setting. Thus, if the absorption is the same in the laboratory test and the exposure in the field, then the prediction of hazard will be accurate. However, if the absorption of contaminant from the site medium is different (usually lower) than occurred in the laboratory study, then the hazard estimate will be incorrect (usually too high). In this assessment, estimates of wildlife exposure due to incidental soil and sediment ingestion conservatively assume a relative bioavailability of 100% for all contaminants. This assumption is expected to overestimate contaminant doses to wildlife, since absorption efficiencies for many contaminants (especially metals) are lower in site media (especially soil and sediment) than in most laboratory studies.

8.3 Uncertainties in Effects (Toxicity) Assessment

Representativeness of Receptors Evaluated

Risk characterizations for aquatic receptors are based on a generalized set of species found in freshwater aquatic communities. However, not all of these species are likely to occur at this site. Thus, HQ values above 1E+00 may reflect risks to species that are absent at the site, and risks to species that are actually present at the site may be lower.

Risks to wildlife are assessed for a small subset of the species likely to be present in the areas surrounding the Gilt Edge Mine. The representative wildlife species used for quantitative evaluation at this site was selected to represent a range of taxonomic groups and life history types of species likely to occur in the area. These species may not, however, represent the full range of sensitivities present. The species selected may be either more or less sensitive to contaminant exposures than typical species located within the area.

Absence of Toxicity Data for Some Contaminants

As discussed in Section 4, no reliable toxicity benchmark could be located for a number of contaminants detected in one or more samples of site media. Contaminants in this category are assigned to the Qualitative COPC list (Type 1). Appendix C identifies contaminants assigned to this category, and the results are summarized in Table 8-1. As seen, a number of such contaminants exist. The inability to evaluate hazard from these contaminants could result in an underestimation of risk, but the magnitude of the error is likely to be low. This is because absence of a toxicity benchmark for a contaminant is often due to the fact that toxicological concern over that contaminant is low. That is, contaminants that lack benchmarks are often considered to be relatively less hazardous that those for which benchmarks do exist. To the extent that this is true (even though there are likely some exceptions to this rule), risks from Qualitative Type 1 COPCs at this site are likely not of substantial concern.

Extrapolation of Toxicity Data Between Receptors

Toxicity data are not available for all of the species of potential concern at the site. Thus, it is sometimes necessary to estimate toxicity values for a receptor by extrapolating toxicity data across similar species. This extrapolation may either overestimate or underestimate the risk to the actual receptor, depending on whether the actual receptor is less sensitive or more sensitive that the species for which data are available. The direction of the error introduced by this extrapolation is unknown, but could be significant in some cases.

Extrapolation of Toxicity Data Across Dose or Duration

In some cases, TRV data are available only for high dose exposures, and extrapolation to low doses (similar to those that actually occur at the site) is a source of uncertainty. Likewise, some TRVs are based on relatively short-term exposures, and extrapolation to long-term conditions is uncertain, especially for chemicals that tend to build up in the exposed organism. When such extrapolations are necessary, it is customary to include an "uncertainty factor" in the derivation of the benchmark to account for the extrapolation. In general, the "uncertainty factor" is likely to be somewhat too large, so the benchmarks derived in this way are often conservative (overly protective).

Extrapolation of Toxicity Data from Laboratory to Field Conditions

Even when data are available for a species of concern at the site, the data are usually generated under laboratory conditions and extrapolation of those data to free-living receptors in the field is uncertain. In some cases, site-specific factors may tend to modify (often decrease) the toxicity of contaminants in surface water, sediments, and soil. For example, metals in surface water may be bound to soluble organic materials that reduce the tendency for the metal to bind to respiratory structures of fish or benthic organisms. Similarly, the presence of organic matter in soil, along with other substances, may have a significant influence on actual toxicity. Thus, risks based on literature-derived toxicity factors may sometimes overestimate risk from site media.

8.4 Uncertainties in Risk Characterization

Interactions Among Contaminants

Most toxicity benchmark values are derived from studies of the adverse effects of a single contaminant. However, exposures to ecological receptors usually involve multiple contaminants, raising the possibility that synergistic or antagonistic interactions might occur. However, data are not adequate to permit any quantitative adjustment in toxicity values or risk calculations based on inter-contaminant interactions. In accordance with USEPA guidance, effects from different COPCs are not added unless reliable data are available to indicate that the two (or more) chemicals act on the same target tissue by the same mode of action. At this site, HQ values for each COPC are not added across different contaminants. If any of the other COPCs at the site act by a similar mode of action, total risks could be higher than estimated.

Estimation of Population-Level Impacts

Assessment endpoints for the receptors at this site are based on the sustainability of exposed populations, and risks to some individuals in a population may be acceptable if the population is expected to remain healthy and stable. However, even if it is possible to accurately characterize the distribution of risks or effects across the members of the exposed population, estimating the impact of those effects on the population is generally difficult and uncertain. The relationship between adverse effects on individuals and effects on the population is complex, depending on the demographic and life history characteristics of the receptor being considered as well as the nature, magnitude and frequency of the contaminant stresses and associated adverse effects. Thus, the actual distribution of HQ values that will lead to population-level adverse effects will vary from receptor to receptor, and use of a single criterion (80% below 1E+00) may not be appropriate. For this ERA, risks are estimated for the individual organism and as such may overestimate risks for the population.

8.5 Summary of Uncertainties

Table 8-2 summarizes the various sources of uncertainty in this ERA, along with a qualitative estimate of the direction and magnitude of the likely errors attributable to the uncertainty. Based on all of these considerations, the HQ and HI values calculated and presented in this ERA should be viewed as having substantial uncertainty. Because of the inherent conservatism in the derivation of many of the exposure estimates and toxicity benchmarks, these HQ and HI values should generally be viewed as being more likely to be high than low, and should be interpreted in a weight-of evidence approach based on other types of available information as well.

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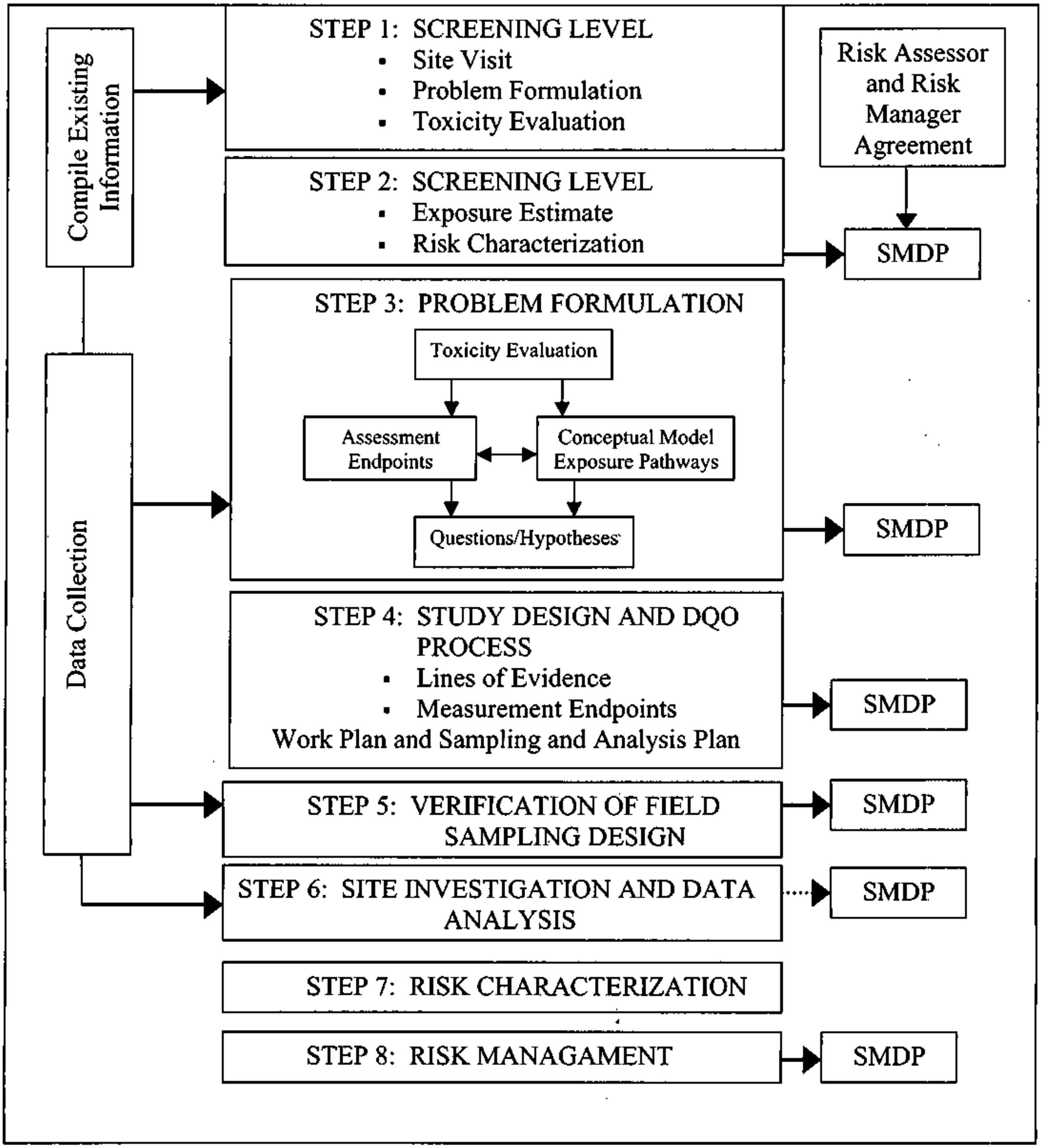
Figure 1-1
Location of Gilt Edge Mine Site

Ecological Risk Assessment for the Gilt Edge Mine Site

Figure 1-2
Eight Step Process Recommended in Ecological Risk Assessment Guidance for Superfund (ERAGs) (USEPA, 1997)



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Color Map(s)

The following pages contain color that does not appear in the scanned images.

To view the actual images, please contact the Superfund Records Center at (303) 312-6473.

Figure 2-1 Mine Operations Map
Gilt Edge Mine, South Dakota

Figure 2-2
Historical Gilt Edge Mine Operations Process

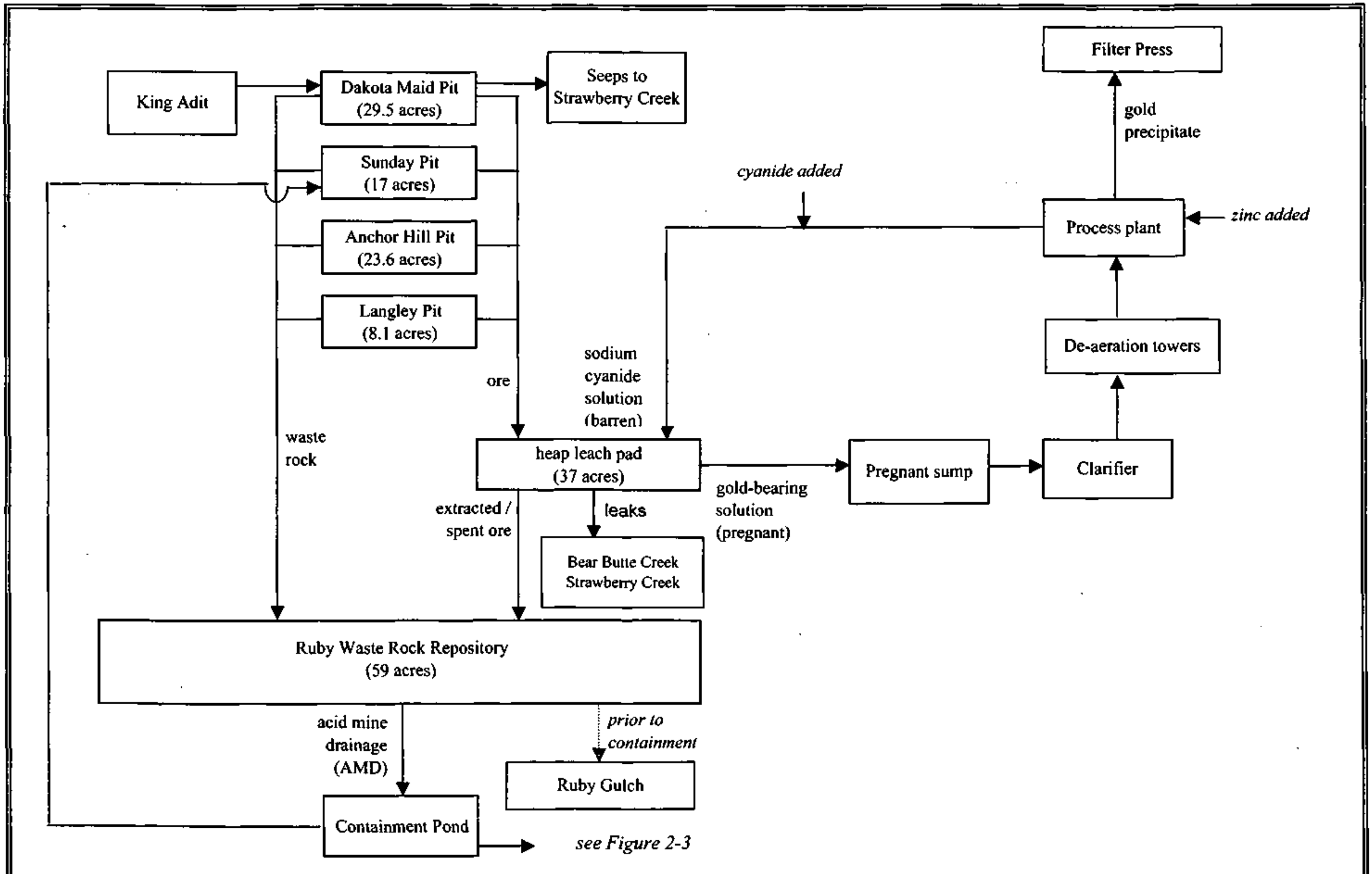
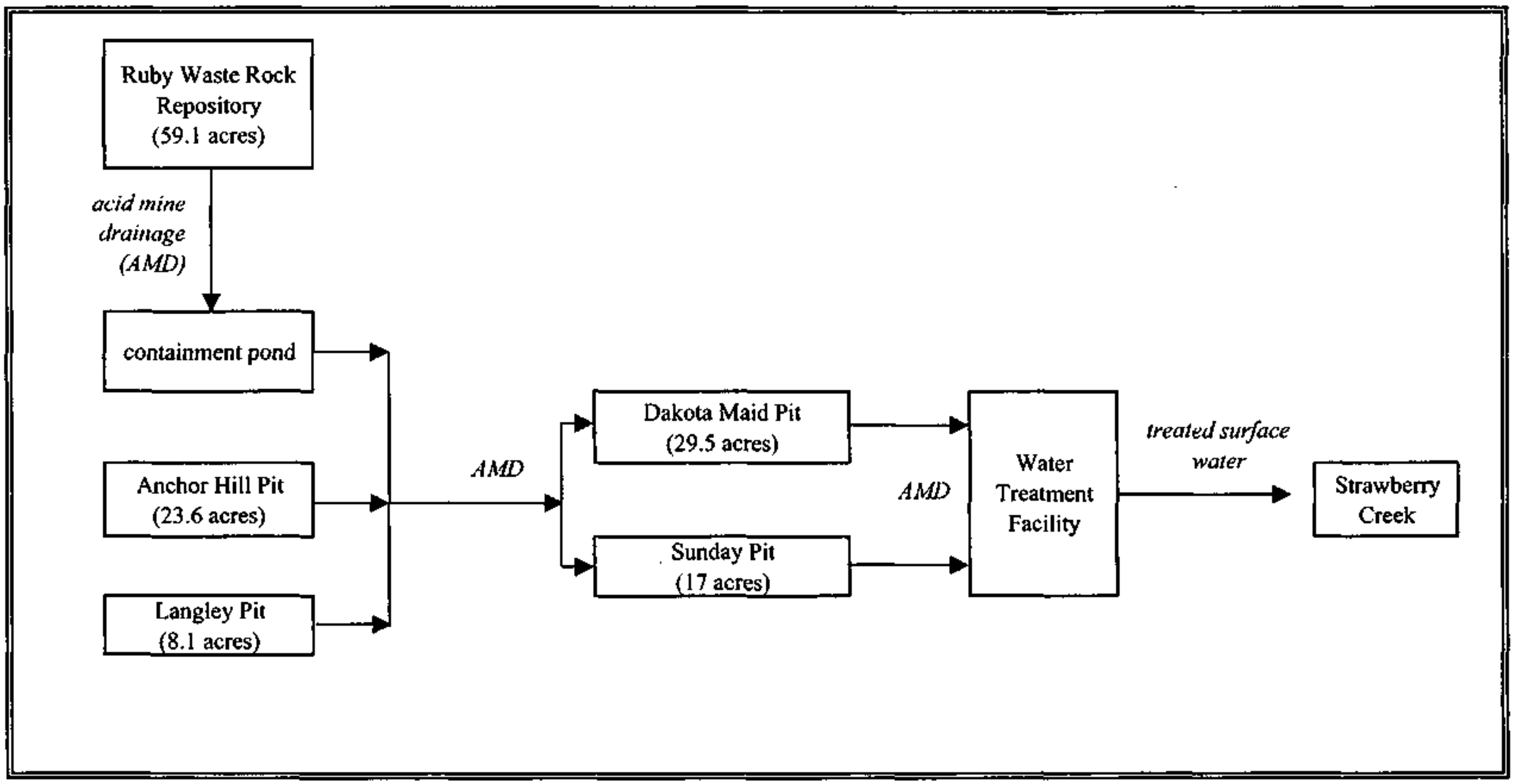


Figure 2-3
Acid Mine Drainage (AMD) Treatment Process



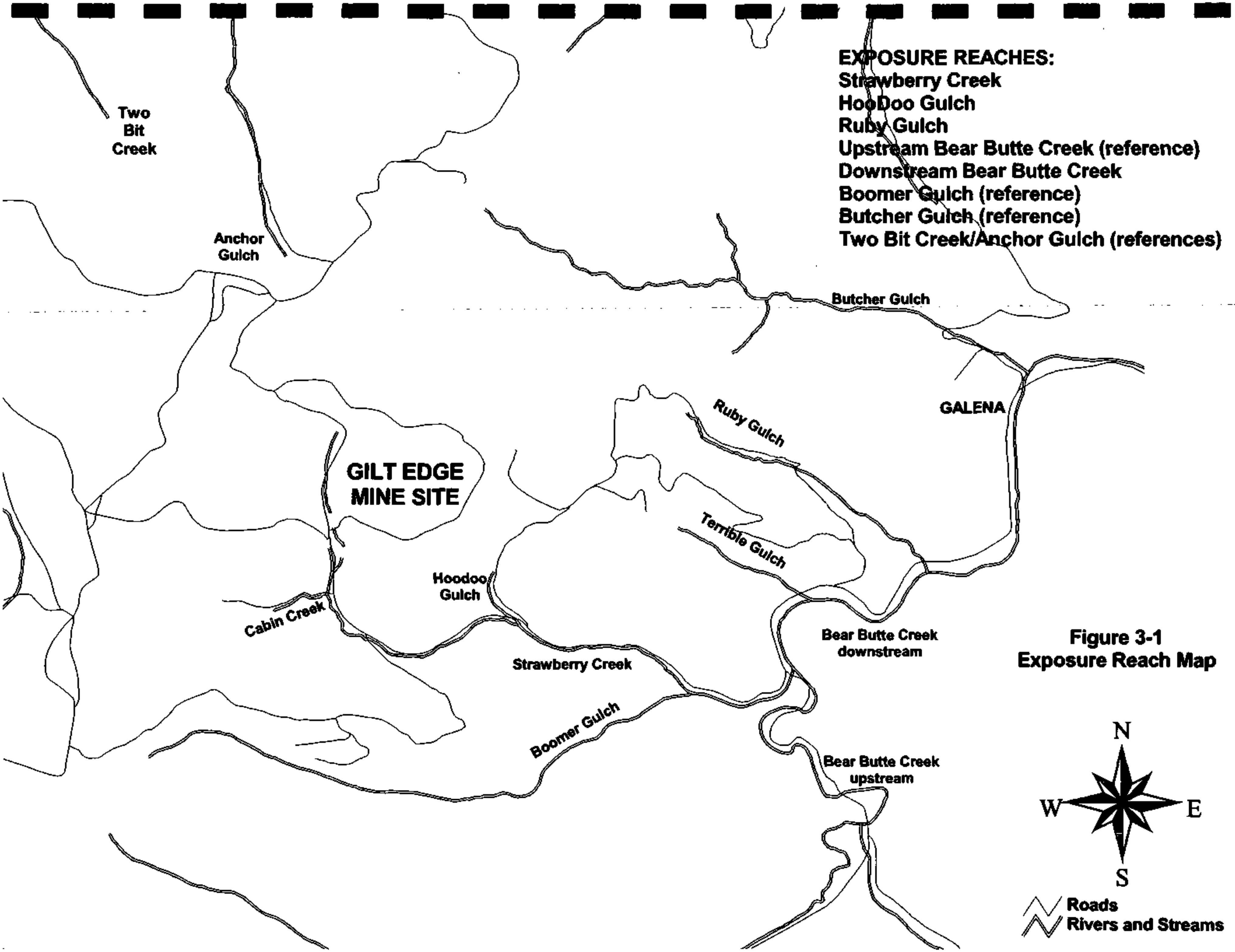


Figure 3-1
Exposure Reach Map

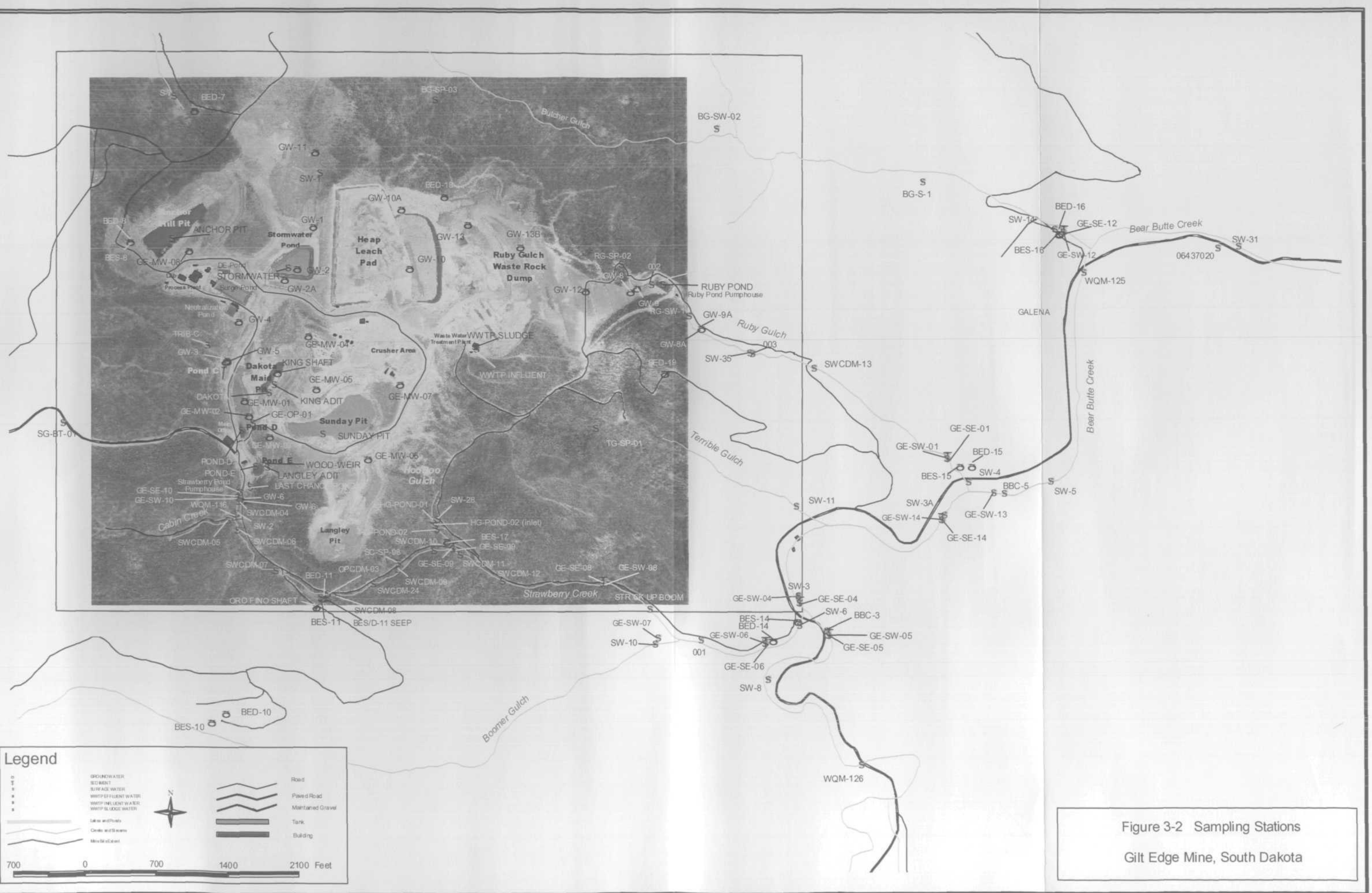
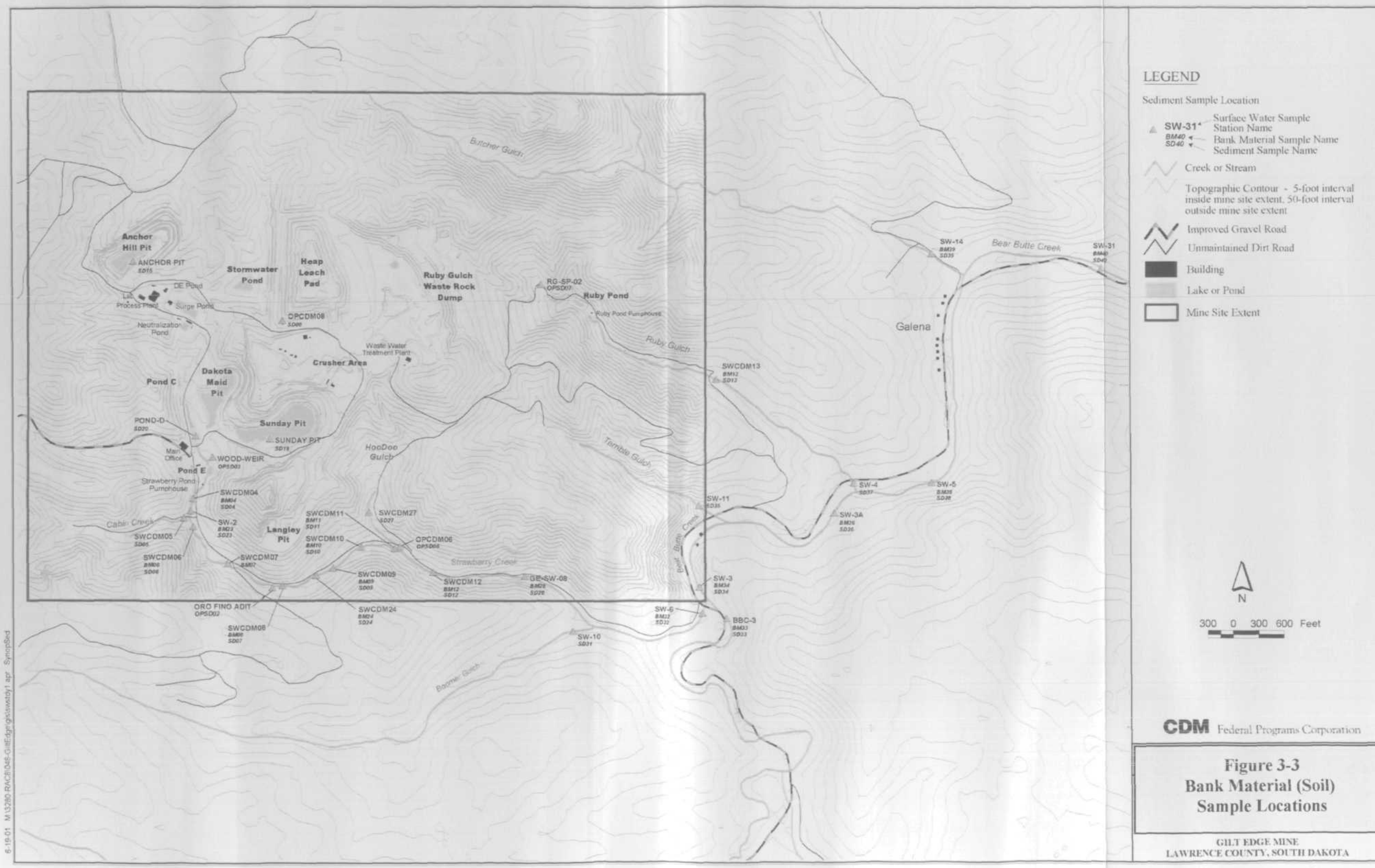


Figure 3-2 Sampling Stations

Gilt Edge Mine, South Dakota



CDM Federal Programs Corporation

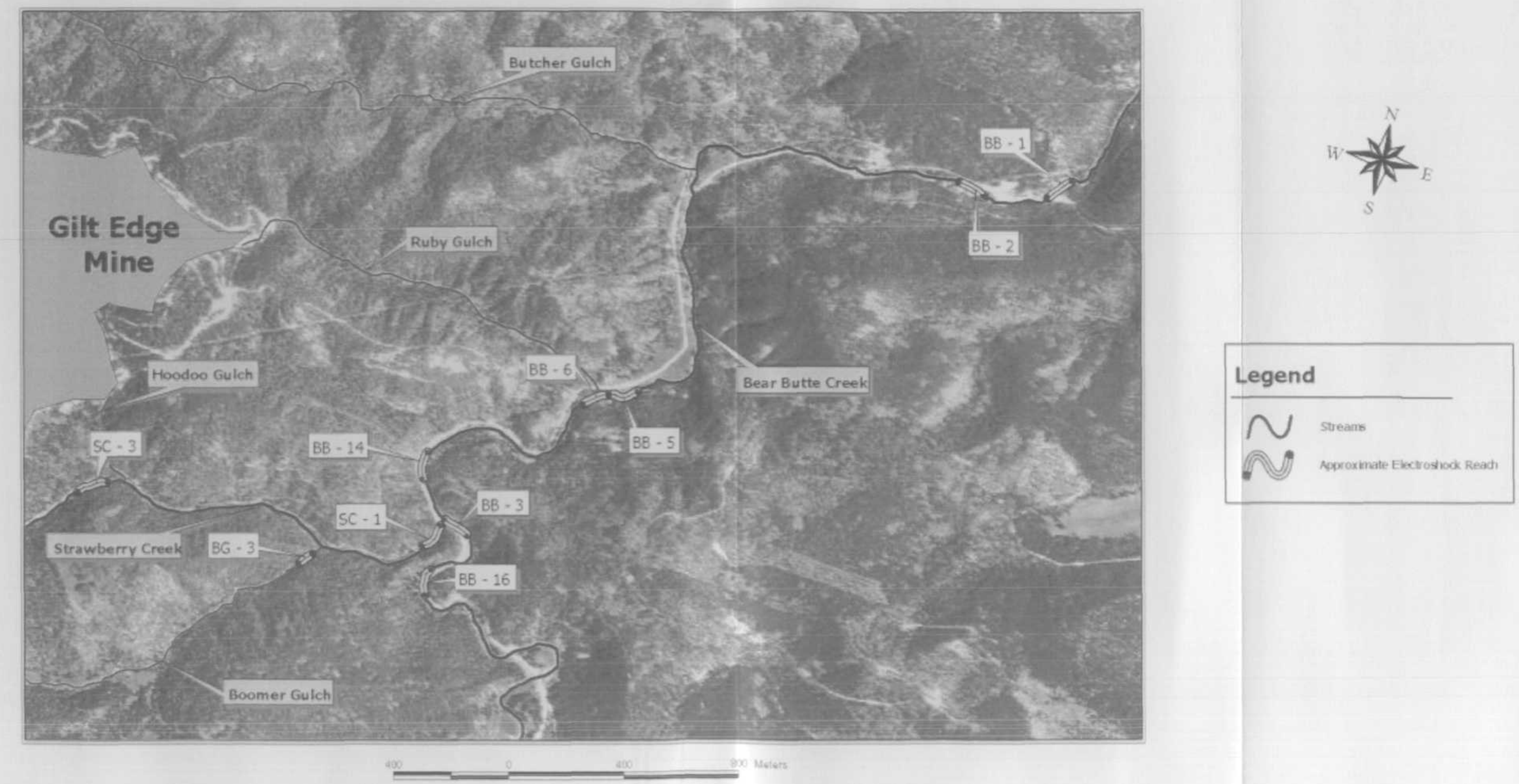
Figure 3-3
Bank Material (Soil) Sample Locations

GILT EDGE MINE
LAWRENCE COUNTY, SOUTH DAKOTA

6-19-01 M:\3280-RAC8\045-GiltEdge\gisweb\y1.apr Synopfsed

Gilt Edge Mine Site

Fish Electroshock Reaches



U.S. EPA Environmental Response Team Center
Response Engineering and Analytical Contract
68-C99-223
W.A.# R1A00154

Figure 3-4

Fish Electroshock Reaches

Gilt Edge Mine Site
Lawrence County, South Dakota

Figure 3-5
Mine Source Area Sample Locations for the Robertson GeoConsultants Waste Rock Study

Gilt Edge Mine
Lawrence County, South Dakota

12-11-01

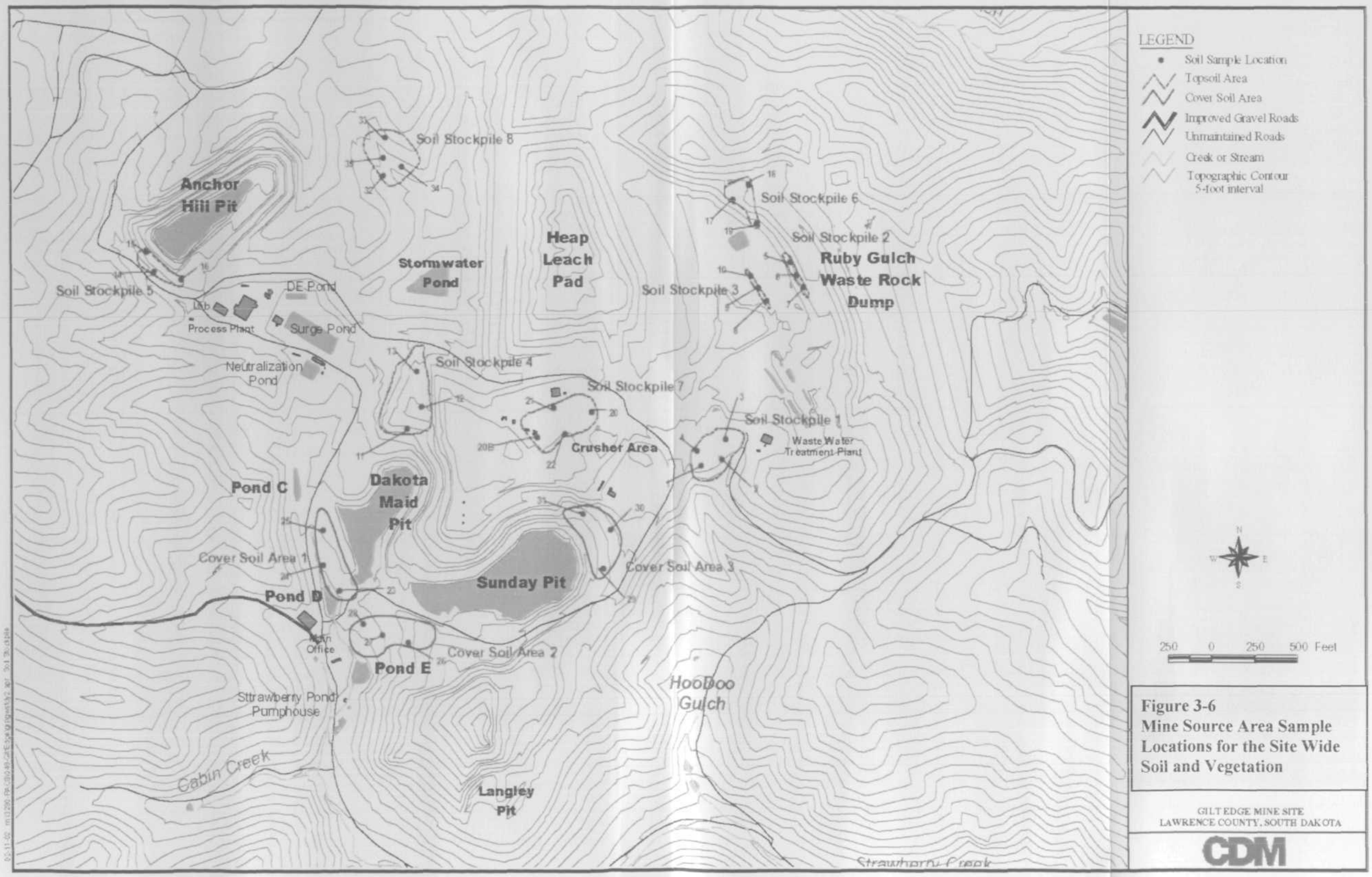


Figure 3-6
Mine Source Area Sample Locations for the Site Wide Soil and Vegetation

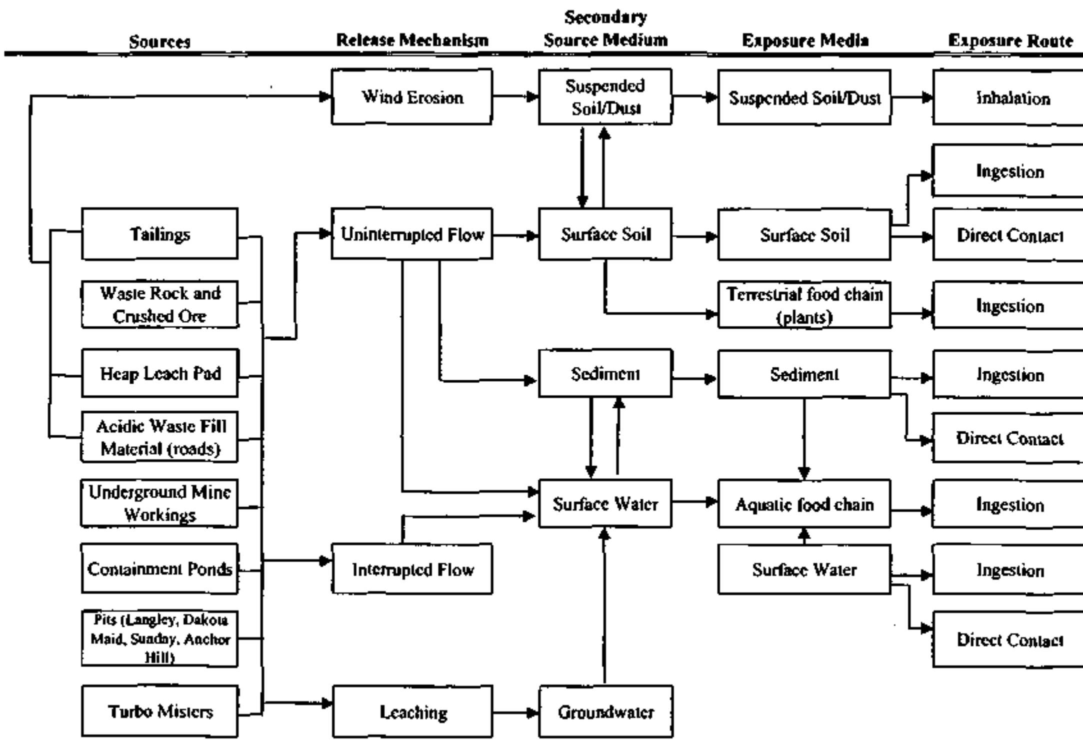
GILT EDGE MINE SITE
LAWRENCE COUNTY, SOUTH DAKOTA

CDM

Figure 3-7
On-Site Sample Locations for the Site Wide Fill Material Investigation and Human Health Risk Assessment Support Study

Figure 4-1
Ecological Site Conceptual Model

Baseline Ecological Risk Assessment for the Gilt Edge Mine Site



Exposure Media	Exposure Route	Fish	Benthics	Terrestrial Wildlife	Semi-Aquatic Wildlife	Reptiles	Amphibians	Plants & Soil Invertebrates
Suspended Soil/Dust	Inhalation			X	X	○	○	
Surface Soil	Ingestion			●	X[b]	○	○	
Surface Soil	Direct Contact			X	X[b]	○	○	●
Terrestrial food chain (plants)	Ingestion			●	X[b]	○	○	
Sediment	Ingestion	X	X		●	○	○	
Sediment	Direct Contact		●		X	○	○	
Aquatic food chain	Ingestion	X	X		●	○	○	
Surface Water	Ingestion			●	●	○	○	
Surface Water	Direct Contact	●	●	X	X	○	●[a]	

Legend:

●	Pathway complete and selected for quantitative evaluation
○	Pathway complete, but exposure and/or toxicity data are lacking to complete quantitative evaluation
X	Pathway complete, but considered to be insignificant compared to other exposure pathways
	Pathway not complete; no evaluation

Notes:

a Amphibian surface water exposures are based on the most sensitive aquatic lifestage (tadpole, larval).
b Direct contact and ingestion of sediment for semi-aquatic wildlife is assessed rather than soils.

Terrestrial Wildlife On-site: Deer Mouse, Bobwhite Quail
Terrestrial Wildlife Off-site: Masked Shrew, American Robin
Semi-aquatic Wildlife Off-site: Mink, Belted Kingfisher

Figure 4-1 Eco SCM.xls: Eco SCM
1/23/2003

Figure 4-2. Conceptual Approach for Categorizing Risks

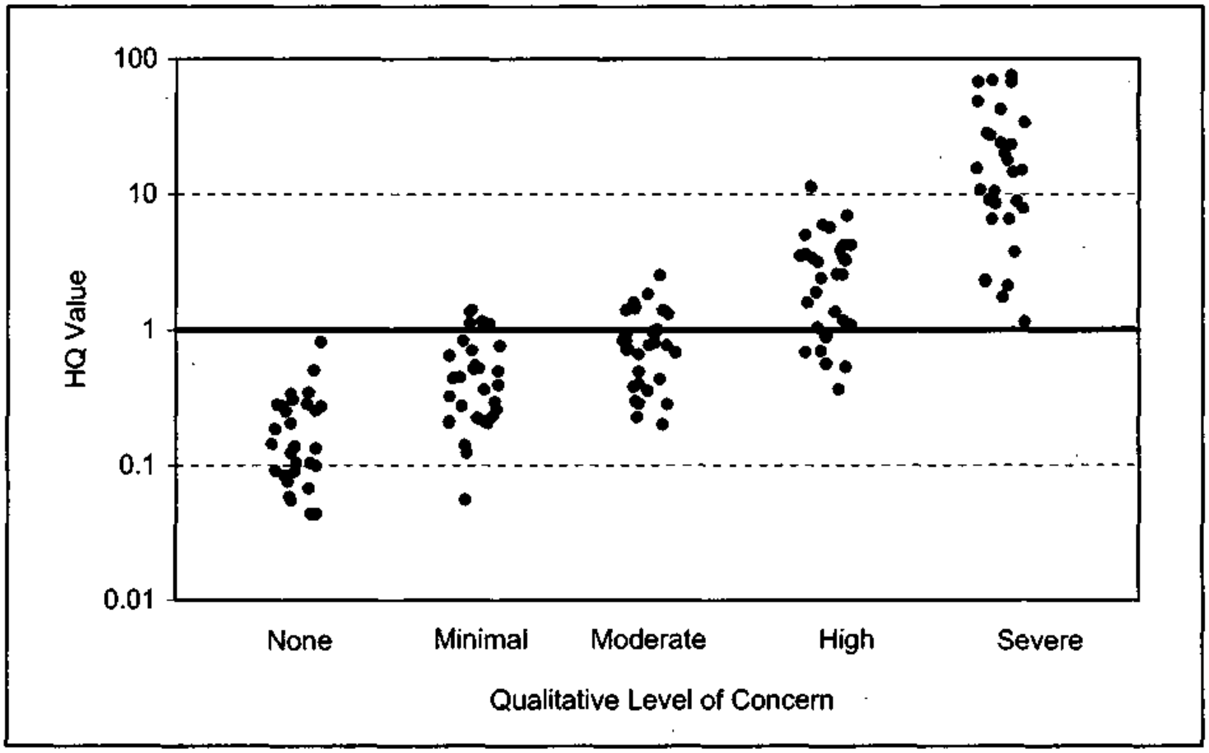
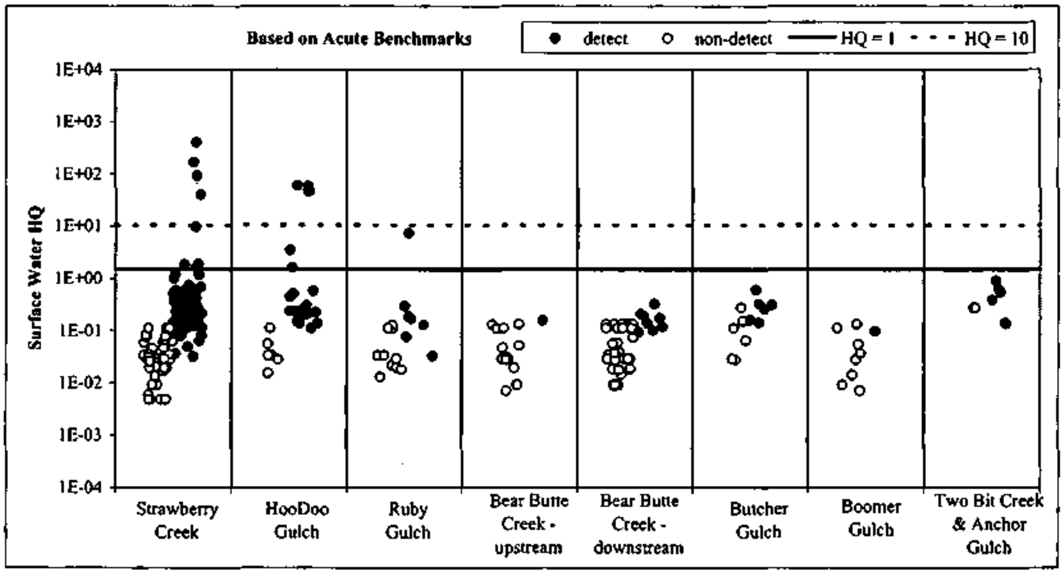
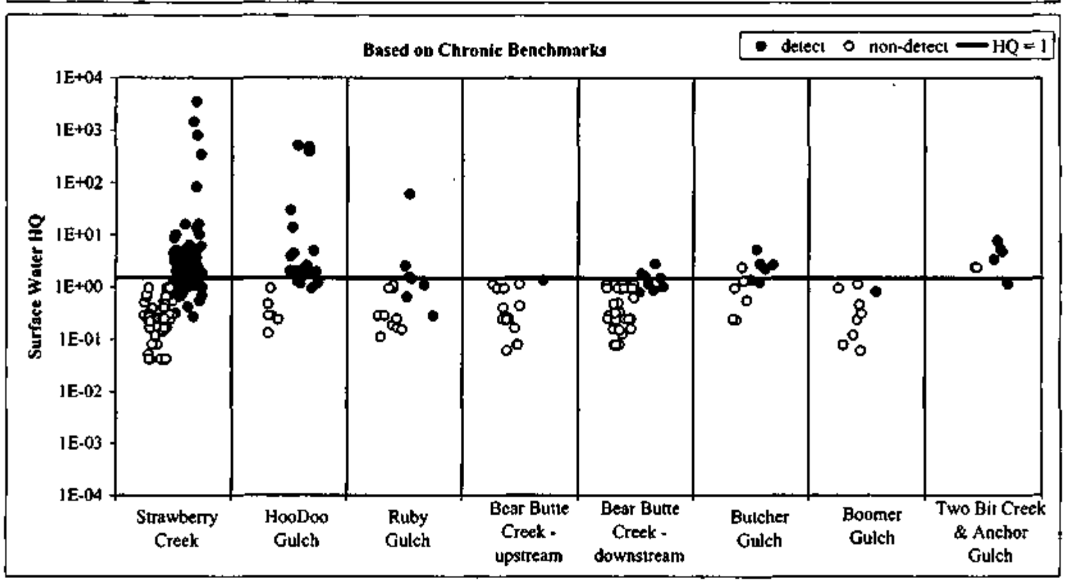


Figure 5-1a
Summary of Surface Water HQs for Aquatic Receptors

ALUMINUM

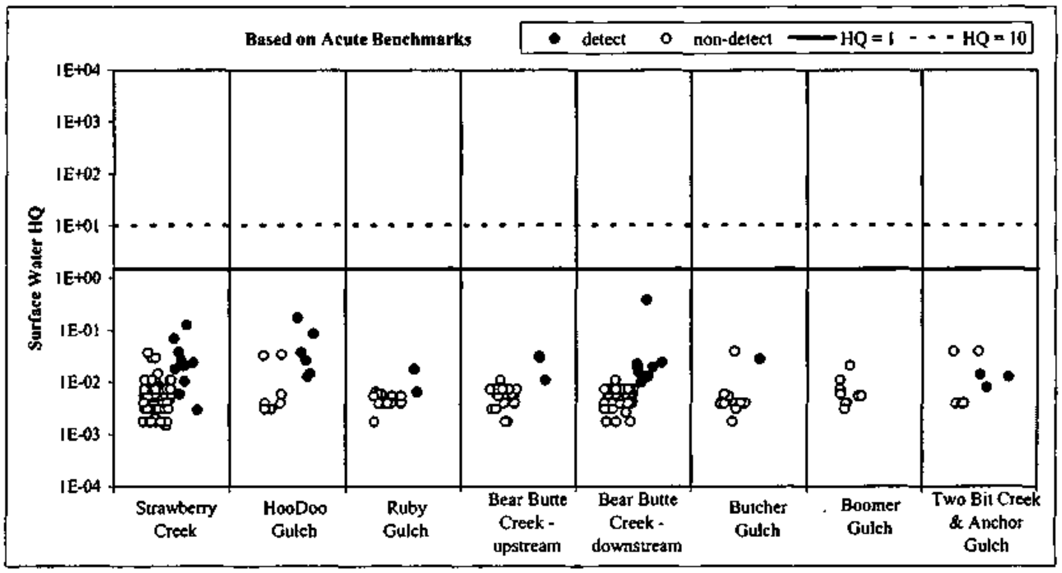


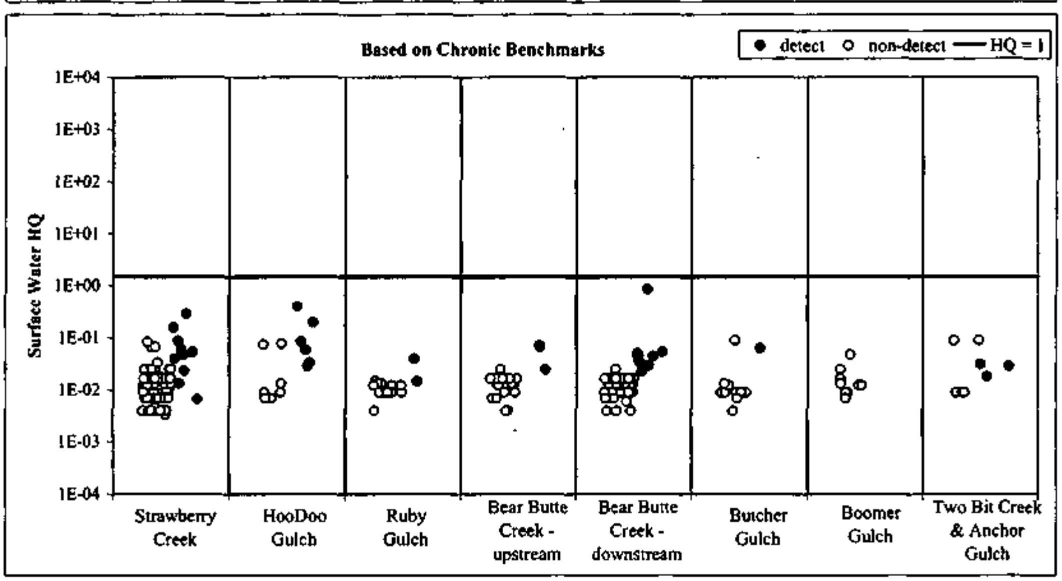


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	95	21	7	1	8	6	1	6
Total Samples:	148	27	18	15	40	12	9	8
ACUTE								
HQs > 1:	8	6	1	0	0	0	0	0
HQs ≤ 1:	140	21	17	15	40	12	9	8
HQs > 1:	5%	22%	6%	0%	0%	0%	0%	0%
HQs ≤ 1:	95%	78%	94%	100%	100%	100%	100%	100%
# HQs > 10	4	4	0	0	0	0	0	0
Category:	severe	severe	moderate	none	none	none	none	none
CHRONIC								
HQs > 1:	65	16	3	0	3	4	0	4
HQs ≤ 1:	83	11	15	15	37	7	9	2
HQs > 1:	44%	59%	17%	0%	8%	33%	0%	50%
HQs ≤ 1:	56%	41%	83%	100%	93%	58%	100%	25%
Category:	moderate	high	minimal	none	minimal	moderate	none	moderate

Figure 5-1b
Summary of Surface Water HQs for Aquatic Receptors

ARSENIC

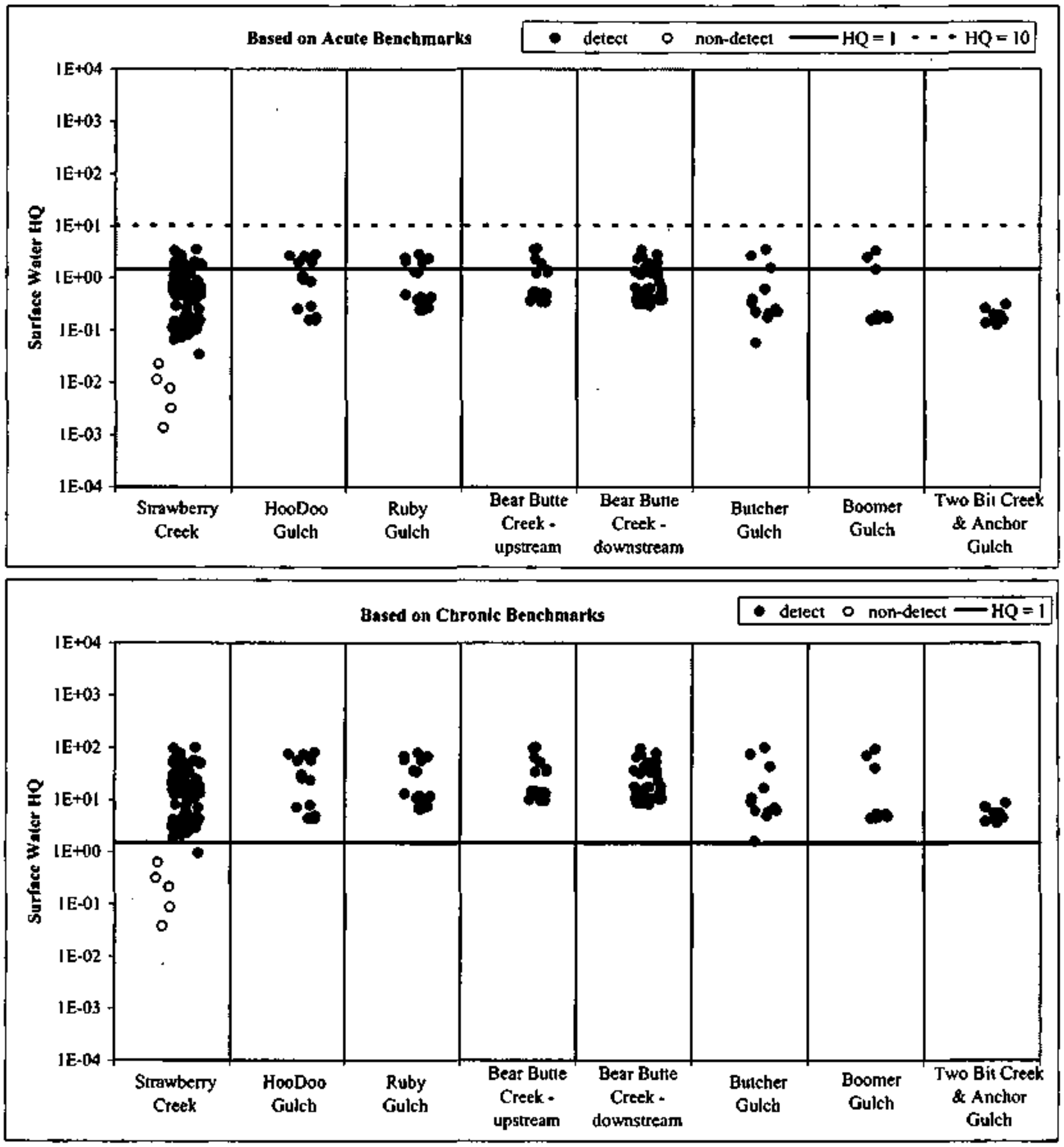




	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	11	6	2	3	10	1	0	3
Total Samples:	131	13	16	30	55	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	131	13	16	30	55	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	none	none	none	none	none	none	none	none
CHRONIC								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	131	13	16	30	55	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
Category:	none	none	none	none	none	none	none	none

Figure 5-1c
Summary of Surface Water HQs for Aquatic Receptors

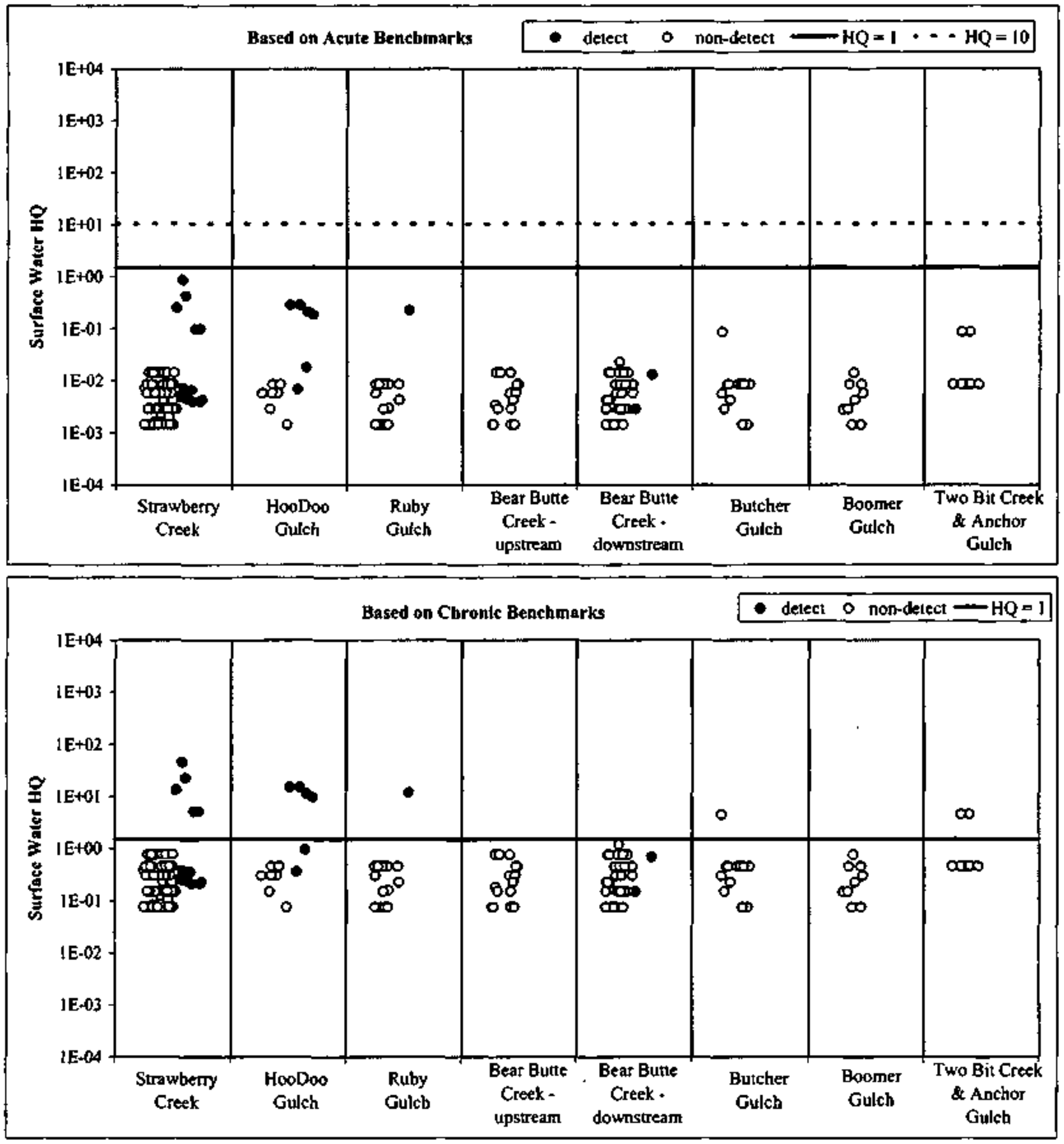
BARIUM



	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	89	13	16	15	40	12	9	8
Total Samples:	94	13	16	15	40	12	9	8
ACUTE								
HQs > 1:	15	5	5	4	7	3	2	0
HQs ≤ 1:	79	8	11	11	33	9	7	8
HQs > 1:	16%	38%	31%	27%	18%	25%	22%	0%
HQs ≤ 1:	84%	62%	69%	73%	83%	75%	78%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	moderate	high	high	high	moderate	high	high	none
CHRONIC								
HQs > 1:	88	13	16	15	40	12	9	8
HQs ≤ 1:	6	0	0	0	0	0	0	0
HQs > 1:	94%	100%	100%	100%	100%	100%	100%	100%
HQs ≤ 1:	6%	0%	0%	0%	0%	0%	0%	0%
Category:	severe	severe	severe	severe	severe	severe	severe	severe

Figure 5-1d
Summary of Surface Water HQs for Aquatic Receptors

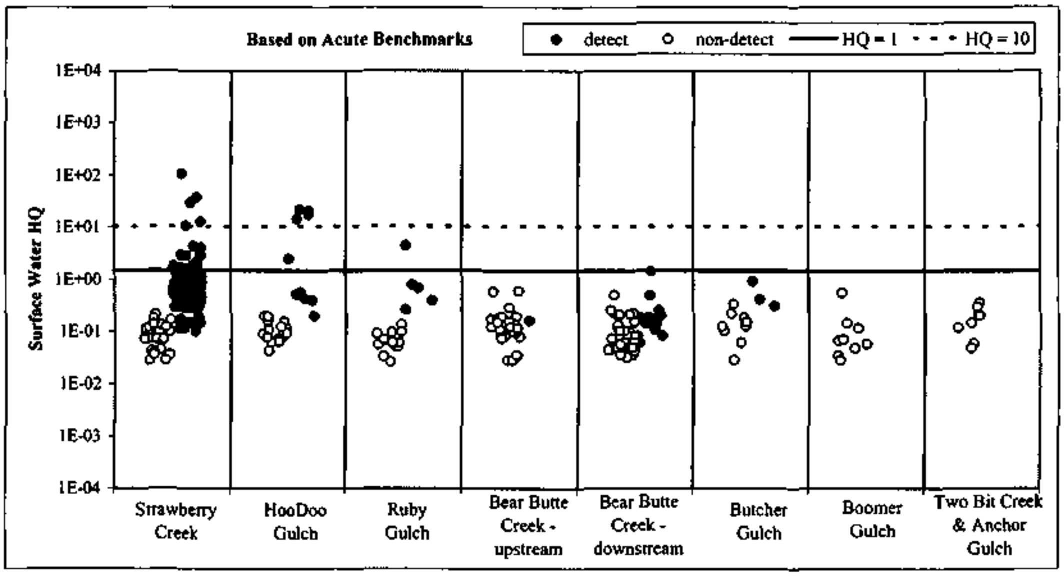
BERYLLIUM

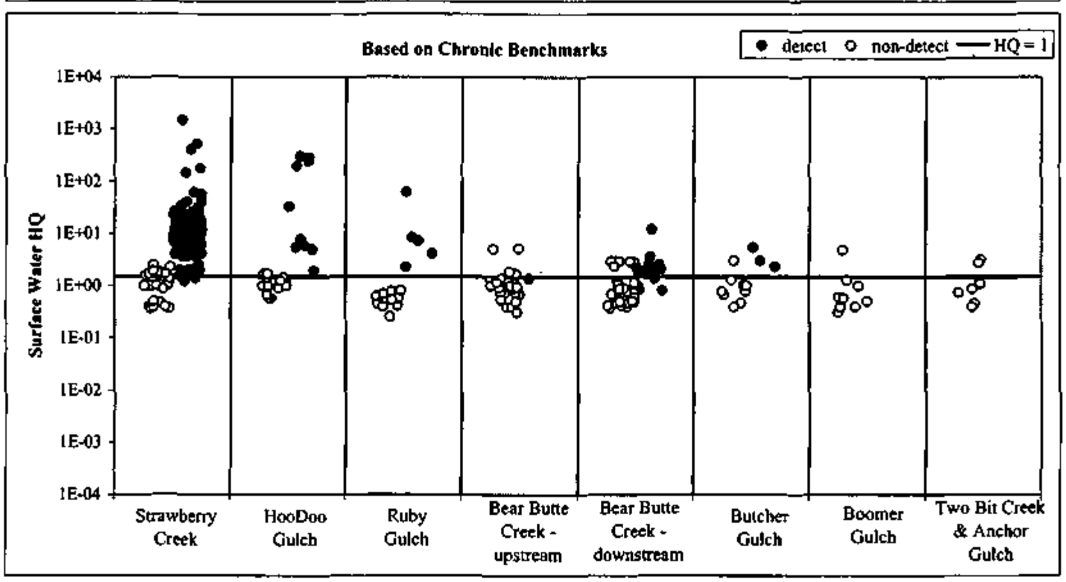


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	14	6	1	0	2	0	0	0
Total Samples:	96	13	16	15	40	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	96	13	16	15	40	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	none	none	none	none	none	none	none	none
CHRONIC								
HQs > 1:	5	4	1	0	0	0	0	0
HQs ≤ 1:	91	9	15	15	40	11	9	6
HQs > 1:	5%	31%	6%	0%	0%	0%	0%	0%
HQs ≤ 1:	95%	69%	94%	100%	100%	92%	100%	75%
Category:	minimal	moderate	minimal	none	none	none	none	none

Figure 5-1e
Summary of Surface Water HQs for Aquatic Receptors

CADMIUM

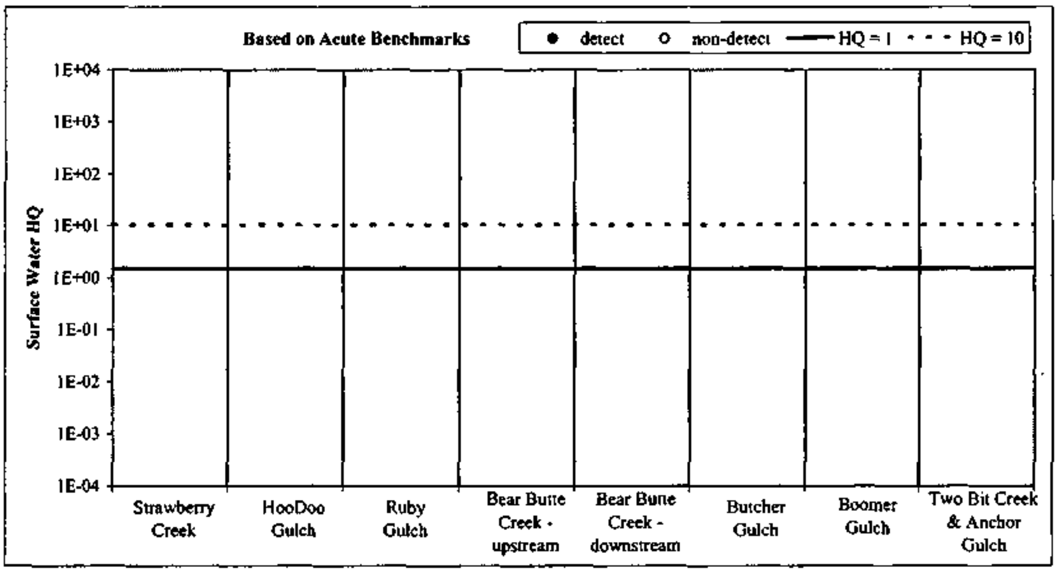


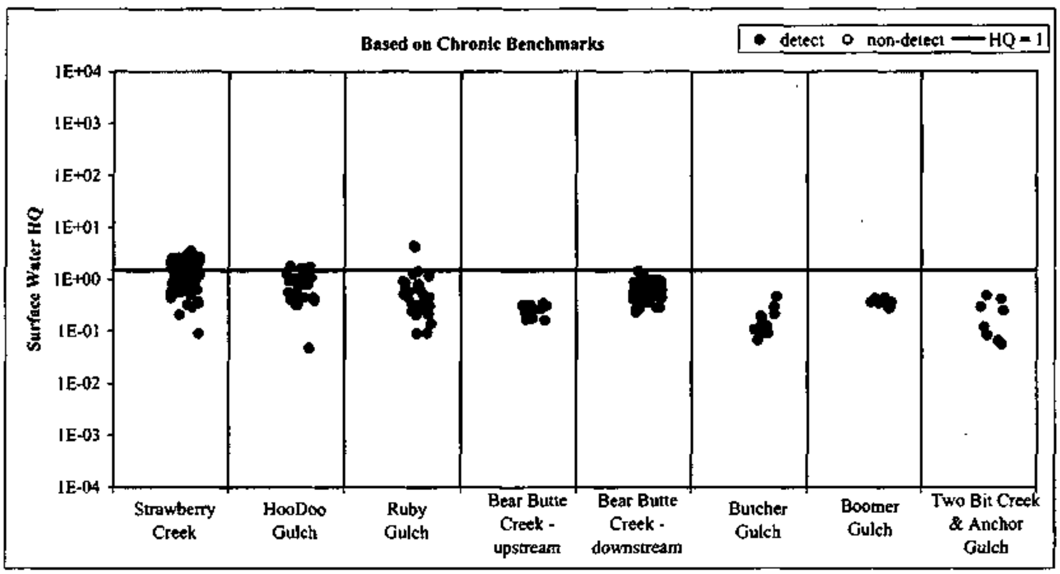


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	171	11	5	1	15	3	0	0
Total Samples:	198	27	18	30	55	12	9	8
ACUTE								
HQs > 1:	25	5	1	0	0	0	0	0
HQs ≤ 1:	173	22	17	30	55	12	9	8
HQs > 1:	13%	19%	6%	0%	0%	0%	0%	0%
HQs ≤ 1:	87%	81%	94%	100%	100%	100%	100%	100%
# HQs > 10	4	4	0	0	0	0	0	0
Category:	severe	severe	moderate	none	none	none	none	none
CHRONIC								
HQs > 1:	178	11	5	0	11	3	0	0
HQs ≤ 1:	20	14	13	26	37	8	8	6
HQs > 1:	90%	41%	28%	0%	20%	25%	0%	0%
HQs ≤ 1:	10%	52%	72%	87%	67%	67%	89%	75%
Category:	severe	moderate	moderate	none	minimal	moderate	none	none

Figure 5-1f
Summary of Surface Water HQs for Aquatic Receptors

CALCIUM

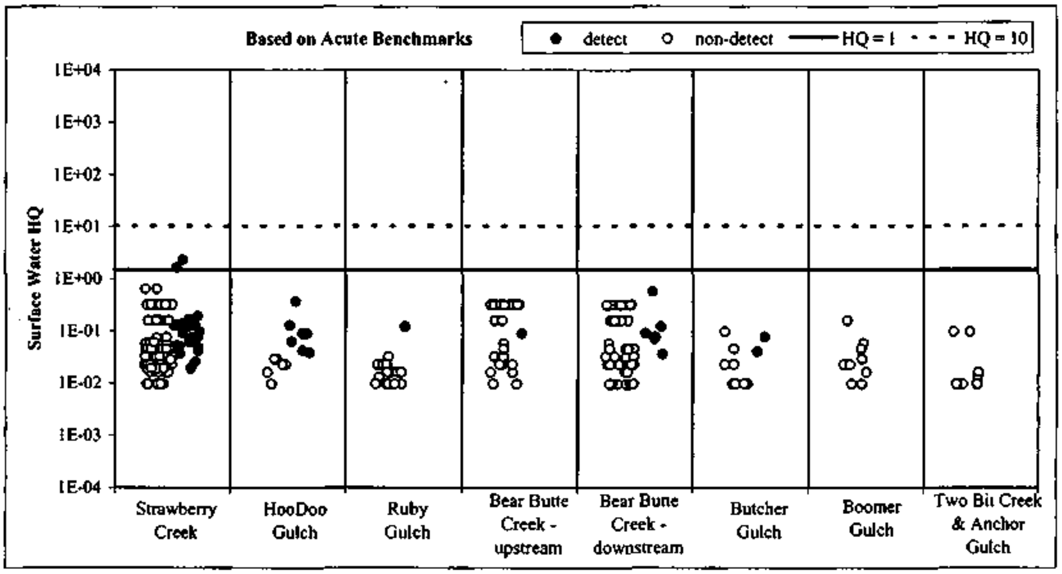


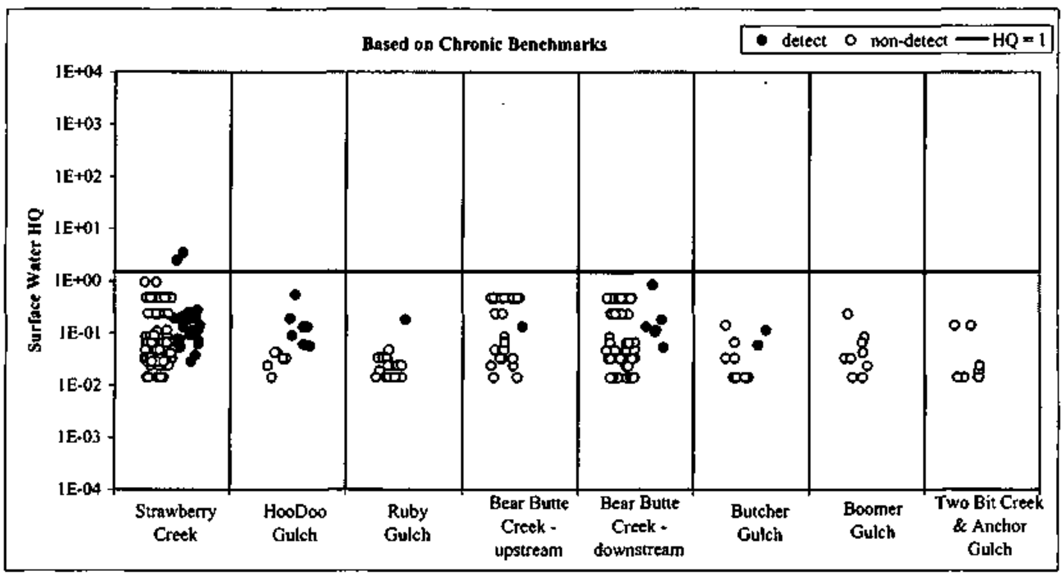


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	221	29	32	16	59	12	9	8
Total Samples:	221	29	32	16	59	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	221	29	32	16	59	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	221	29	32	16	59	12	9	8
Category:	severe	severe	severe	severe	severe	severe	severe	severe
CHRONIC								
HQs > 1:	160	3	2	0	0	0	0	0
HQs ≤ 1:	61	26	30	16	59	12	9	8
HQs > 1:	72%	10%	6%	0%	0%	0%	0%	0%
HQs ≤ 1:	28%	90%	94%	100%	100%	100%	100%	100%
Category:	high	minimal	minimal	none	none	none	none	none

Figure 5-1g
Summary of Surface Water HQs for Aquatic Receptors

CHROMIUM

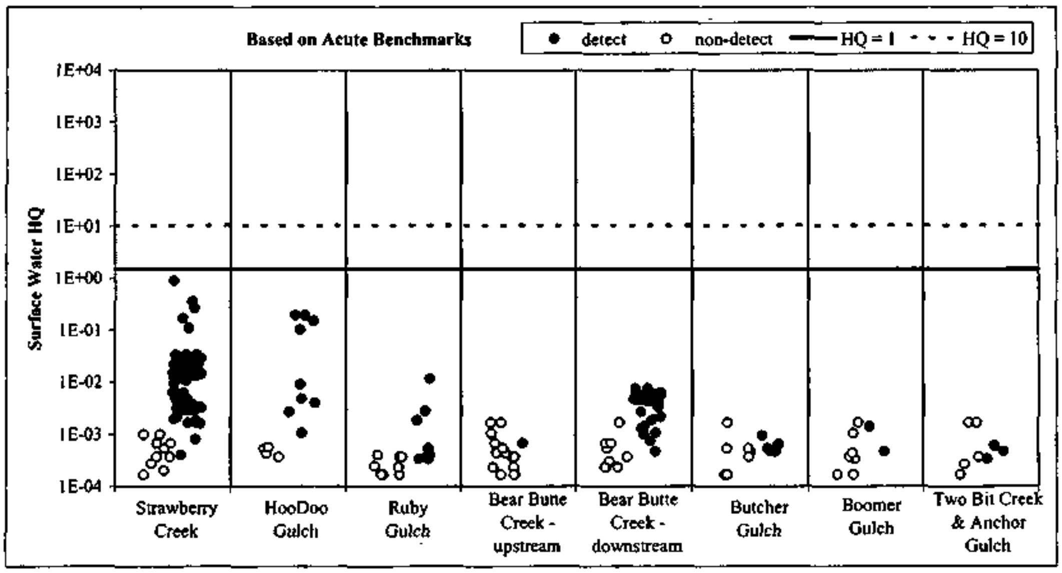


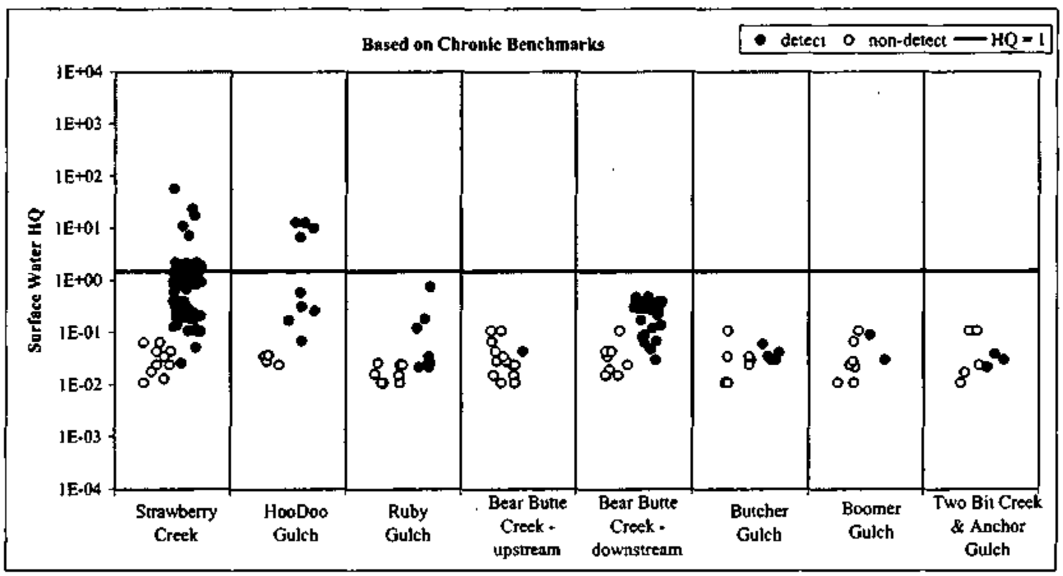


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	24	7	1	1	6	2	0	0
Total Samples:	130	13	16	30	55	12	9	8
ACUTE								
HQs > 1:	2	0	0	0	0	0	0	0
HQs ≤ 1:	128	13	16	30	55	12	9	8
HQs > 1:	2%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	98%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	moderate	none	none	none	none	none	none	none
CHRONIC								
HQs > 1:	2	0	0	0	0	0	0	0
HQs ≤ 1:	128	13	16	30	55	12	9	8
HQs > 1:	2%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	98%	100%	100%	100%	100%	100%	100%	100%
Category:	minimal	none	none	none	none	none	none	none

Figure 5-1h
Summary of Surface Water HQs for Aquatic Receptors

COBALT

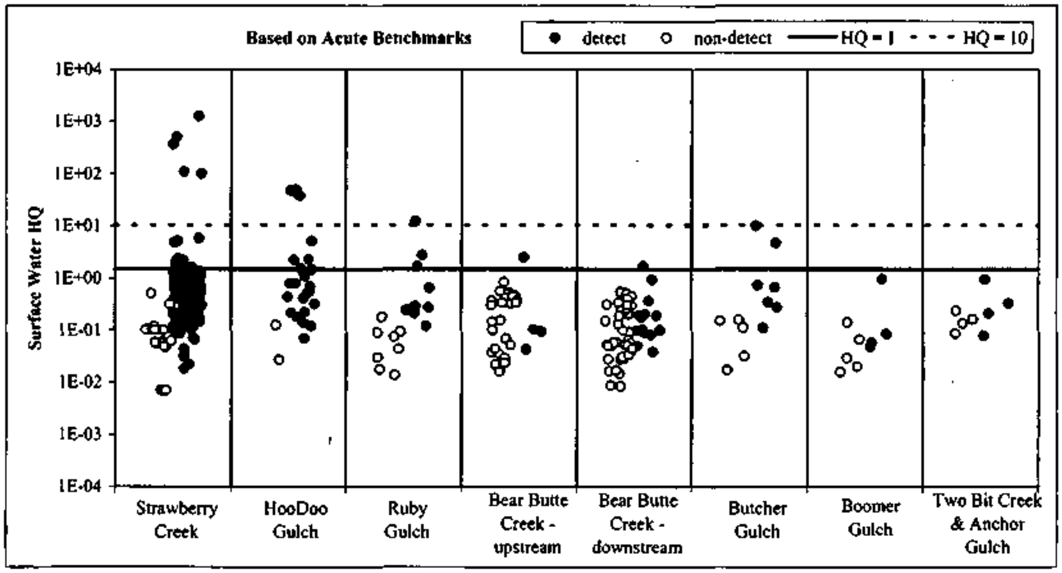


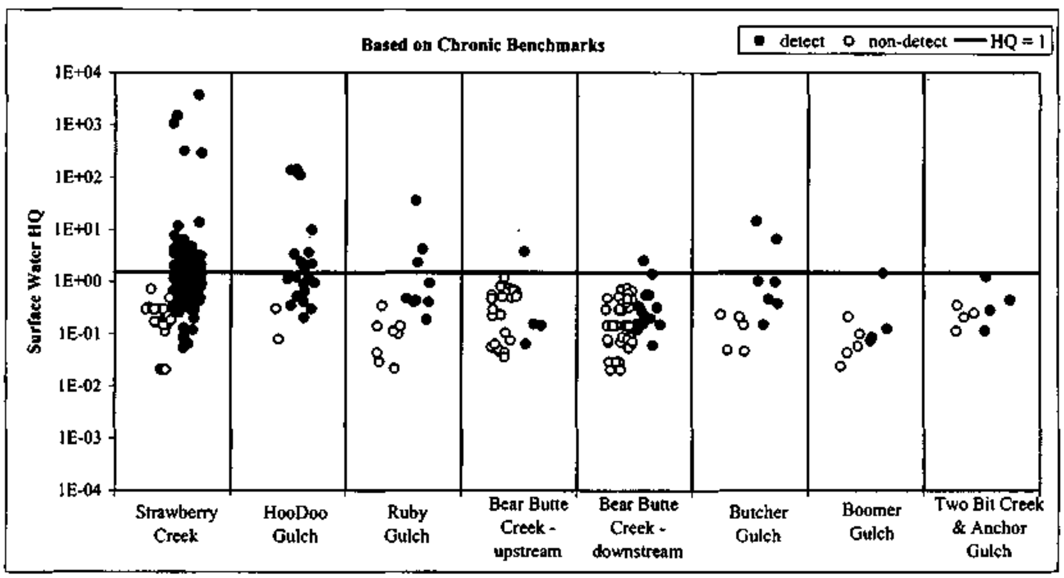


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	85	9	8	1	31	6	2	3
Total Samples:	95	13	16	15	40	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	95	13	16	15	40	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	none	none	none	none	none	none	none	none
CHRONIC								
HQs > 1:	22	4	0	0	0	0	0	0
HQs ≤ 1:	73	9	16	15	40	12	9	8
HQs > 1:	23%	31%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	77%	69%	100%	100%	100%	100%	100%	100%
Category:	moderate	moderate	none	none	none	none	none	none

Figure 5-1i
Summary of Surface Water HQs for Aquatic Receptors

COPPER

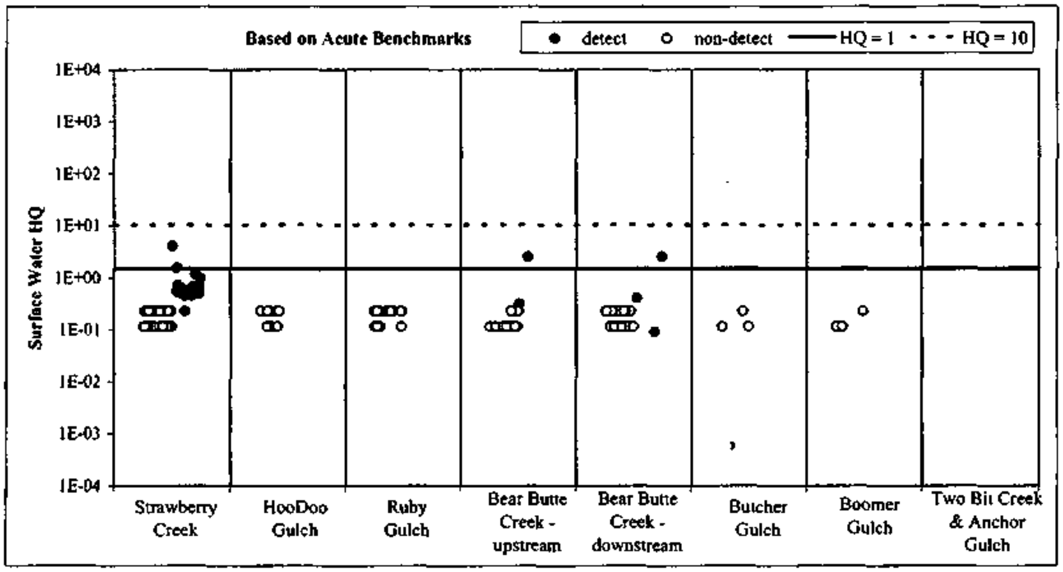


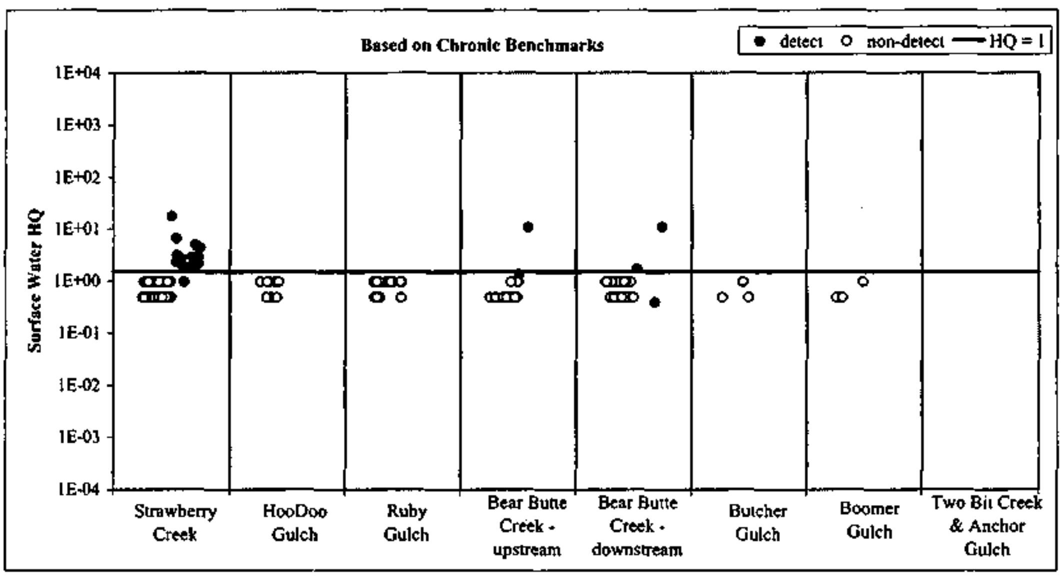


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	172	25	10	4	14	7	4	4
Total Samples:	198	27	18	30	55	12	9	8
ACUTE								
HQs > 1:	17	8	3	1	1	2	0	0
HQs ≤ 1:	181	19	15	29	54	10	9	8
HQs > 1:	9%	30%	17%	3%	2%	17%	0%	0%
HQs ≤ 1:	91%	70%	83%	97%	98%	83%	100%	100%
# HQs > 10	5	4	1	0	0	0	0	0
Category:	severe	severe	moderate	moderate	moderate	moderate	none	none
CHRONIC								
HQs > 1:	80	11	3	1	1	2	0	0
HQs ≤ 1:	118	16	15	29	54	10	9	8
HQs > 1:	40%	41%	17%	3%	2%	17%	0%	0%
HQs ≤ 1:	60%	59%	83%	97%	98%	83%	100%	100%
Category:	moderate	moderate	minimal	minimal	minimal	minimal	none	none

Figure 5-1j
Summary of Surface Water HQs for Aquatic Receptors

CYANIDE (WAD)

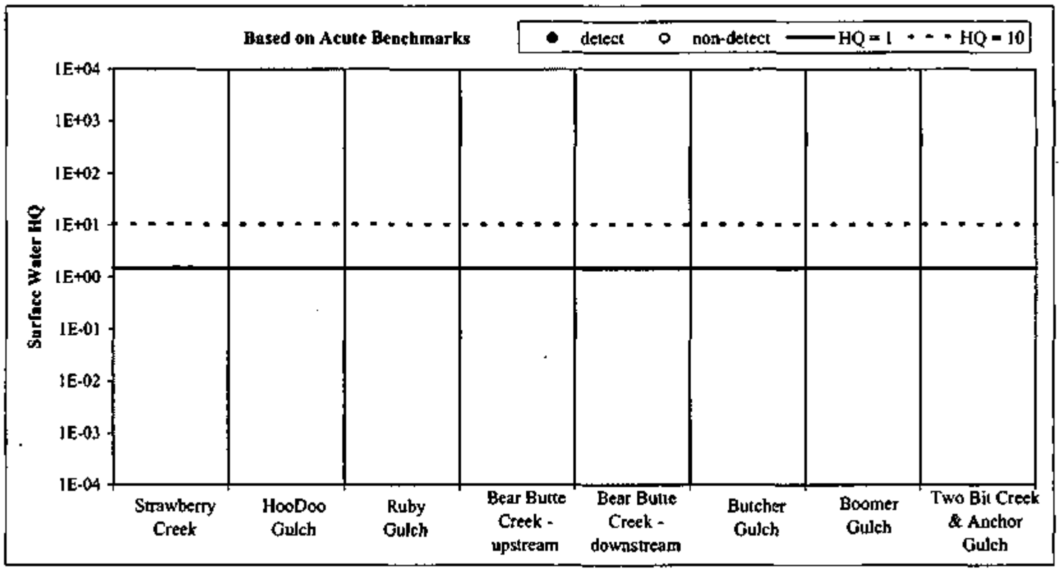


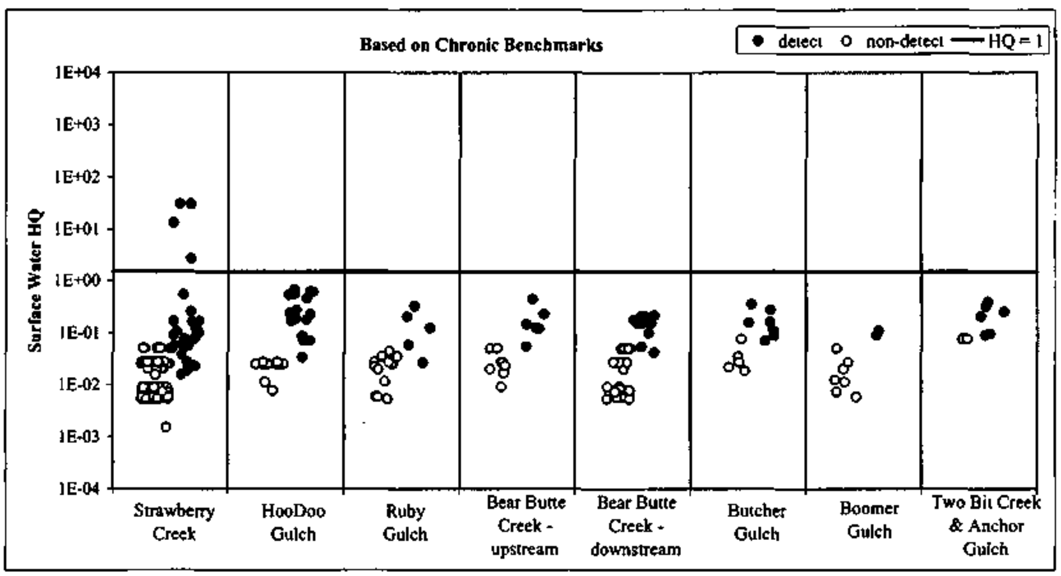


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	14	0	0	3	3	0	0	0
Total Samples:	97	9	15	17	41	3	3	0
ACUTE								
HQs > 1:	2	0	0	1	1	0	0	0
HQs ≤ 1:	95	9	15	16	40	3	3	0
HQs > 1:	2%	0%	0%	6%	2%	0%	0%	na
HQs ≤ 1:	98%	100%	100%	94%	98%	100%	100%	#DIV/0!
# HQs > 10	0	0	0	0	0	0	0	0
Category:	moderate	none	none	moderate	moderate	none	none	na
CHRONIC								
HQs > 1:	13	0	0	1	2	0	0	0
HQs ≤ 1:	84	9	15	16	39	3	3	0
HQs > 1:	13%	0%	0%	6%	5%	0%	0%	na
HQs ≤ 1:	87%	100%	100%	94%	95%	100%	100%	#DIV/0!
Category:	minimal	none	none	minimal	minimal	none	none	na

Figure 5-1k
Summary of Surface Water HQs for Aquatic Receptors

IRON

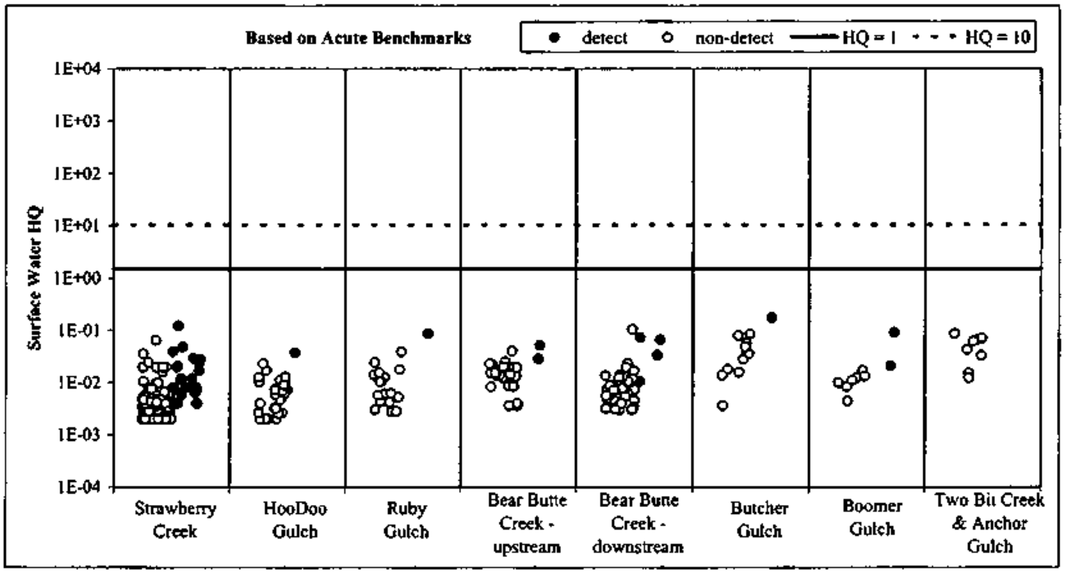


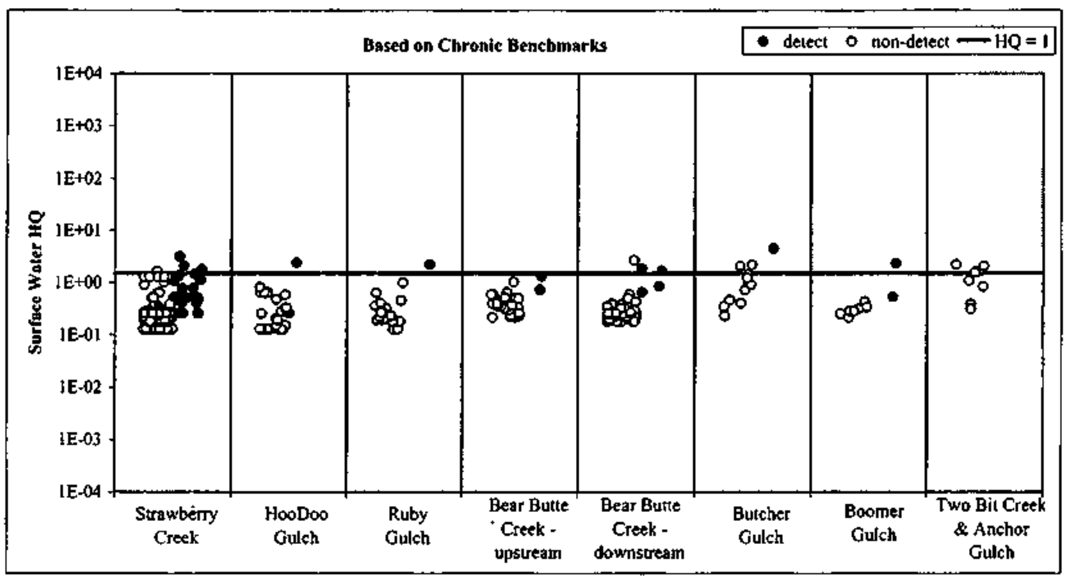


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	27	16	5	6	10	7	2	6
Total Samples:	151	27	18	15	40	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	151	27	18	15	40	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	151	27	18	15	40	12	9	8
Category:	severe	severe	severe	severe	severe	severe	severe	severe
CHRONIC								
HQs > 1:	4	0	0	0	0	0	0	0
HQs ≤ 1:	147	27	18	15	40	12	9	8
HQs > 1:	3%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	97%	100%	100%	100%	100%	100%	100%	100%
Category:	minimal	none	none	none	none	none	none	none

Figure 5-11
Summary of Surface Water HQs for Aquatic Receptors

LEAD

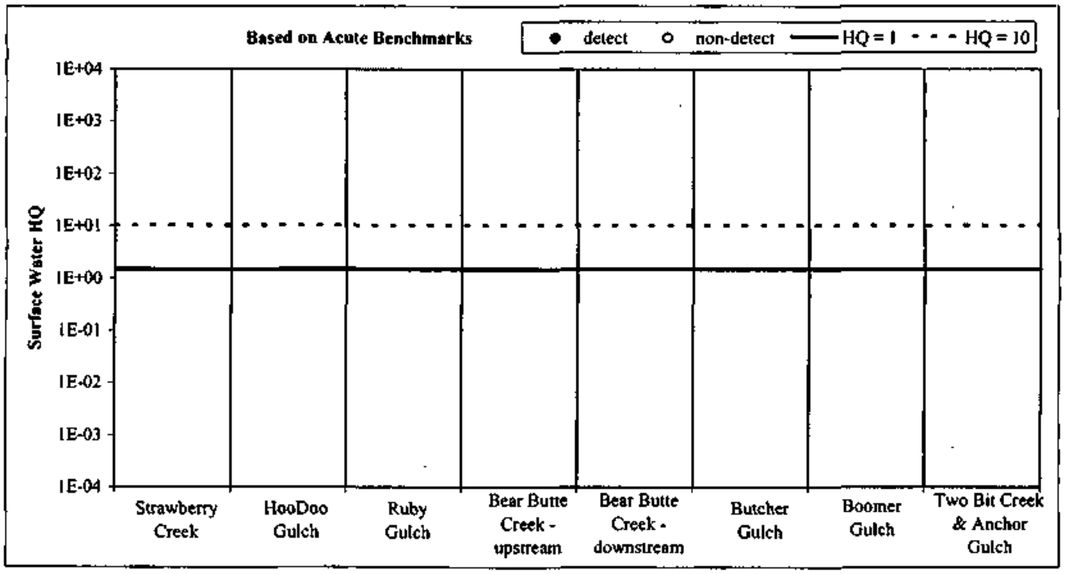


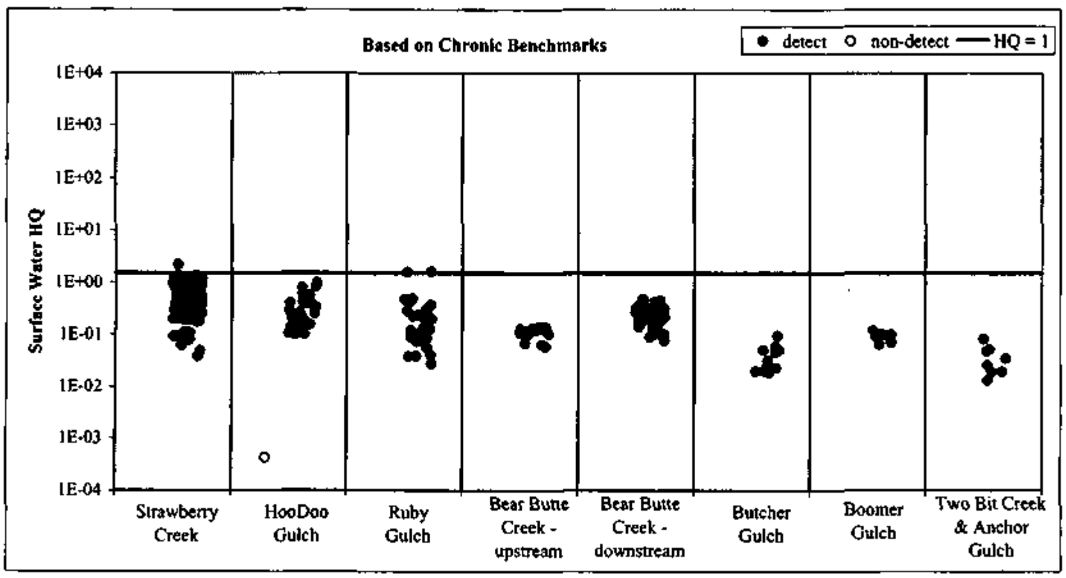


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	26	2	1	2	4	1	2	0
Total Samples:	181	27	18	30	55	12	9	8
				ACUTE				
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	181	27	18	30	55	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	none	none	none	none	none	none	none	none
				CHRONIC				
HQs > 1:	5	1	1	0	2	1	1	0
HQs ≤ 1:	176	26	17	30	52	9	8	4
HQs > 1:	3%	4%	6%	0%	4%	8%	11%	0%
HQs ≤ 1:	97%	96%	94%	100%	95%	75%	89%	50%
Category:	minimal	minimal	minimal	none	minimal	minimal	minimal	none

Figure 5-1m
Summary of Surface Water HQs for Aquatic Receptors

MAGNESIUM

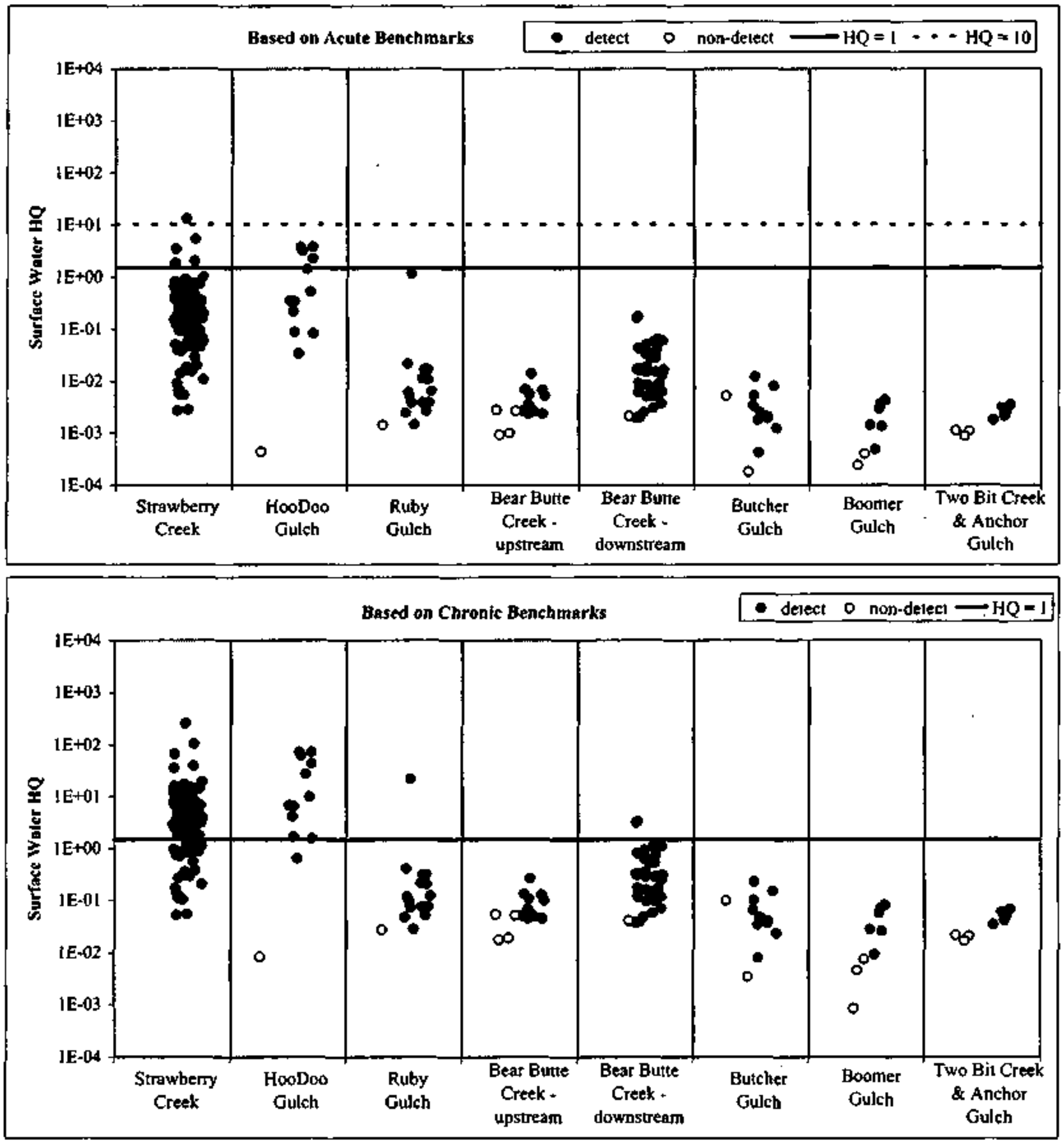




	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	244	28	32	16	59	12	9	8
Total Samples:	244	29	32	16	59	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	244	29	32	16	59	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	244	29	32	16	59	12	9	8
Category:	severe	severe	severe	severe	severe	severe	severe	severe
CHRONIC								
HQs > 1:	1	0	2	0	0	0	0	0
HQs ≤ 1:	243	29	30	16	59	12	9	8
HQs > 1:	0%	0%	6%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	94%	100%	100%	100%	100%	100%
Category:	minimal	none	minimal	none	none	none	none	none

Figure 5-1n
Summary of Surface Water HQs for Aquatic Receptors

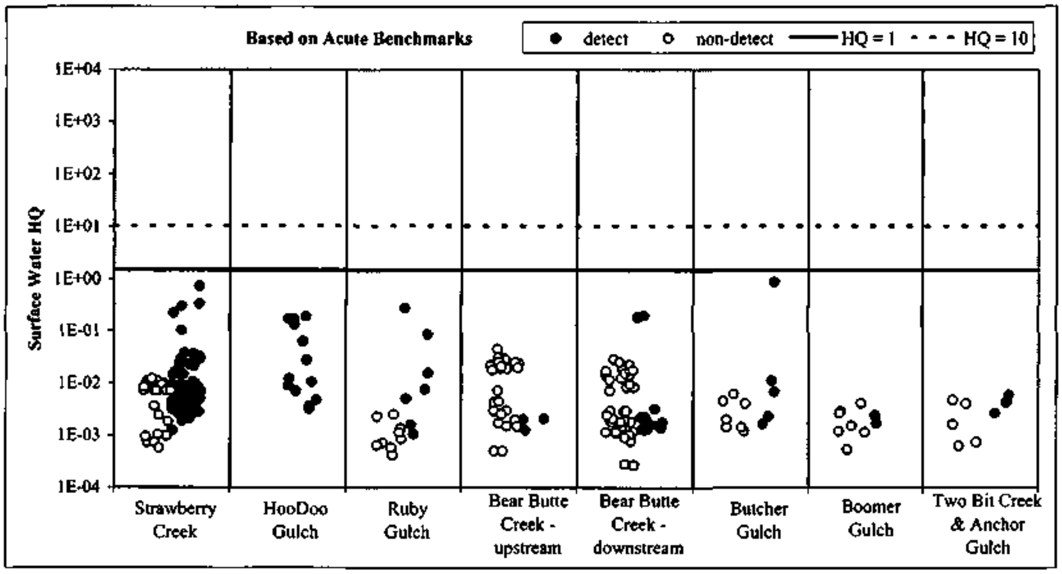
MANGANESE

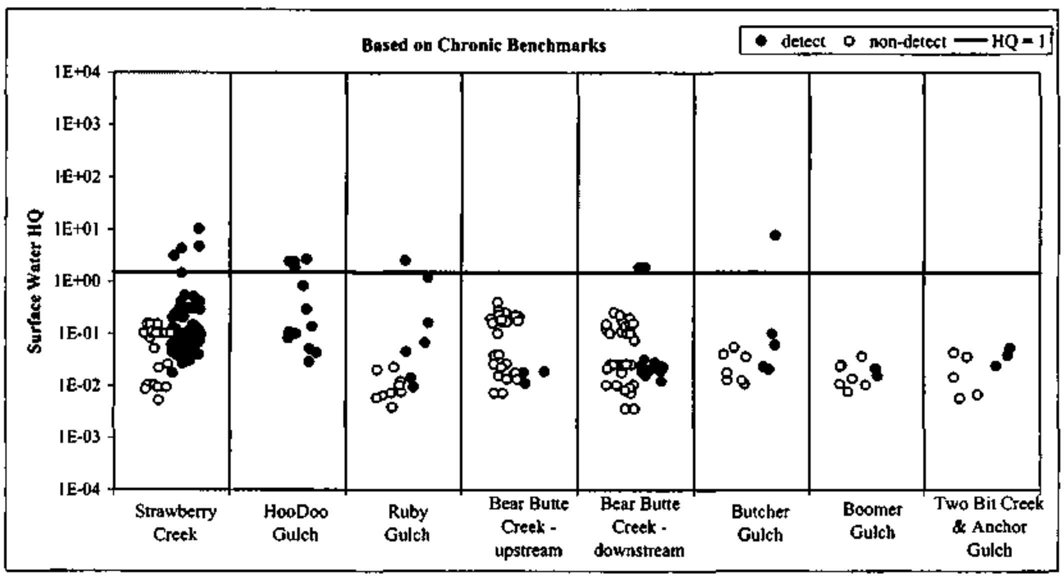


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	100	12	15	11	40	10	6	5
Total Samples:	100	13	16	15	41	12	9	8
ACUTE								
HQs > 1:	5	4	0	0	0	0	0	0
HQs ≤ 1:	95	9	16	15	41	12	9	8
HQs > 1:	5%	31%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	95%	69%	100%	100%	100%	100%	100%	100%
# HQs > 10	1	0	0	0	0	0	0	0
Category:	moderate	high	none	none	none	none	none	none
CHRONIC								
HQs > 1:	73	11	1	0	2	0	0	0
HQs ≤ 1:	27	2	15	15	39	12	9	8
HQs > 1:	73%	85%	6%	0%	5%	0%	0%	0%
HQs ≤ 1:	27%	15%	94%	100%	95%	100%	100%	100%
Category:	high	severe	minimal	none	minimal	none	none	none

Figure 5-1o
Summary of Surface Water HQs for Aquatic Receptors

NICKEL

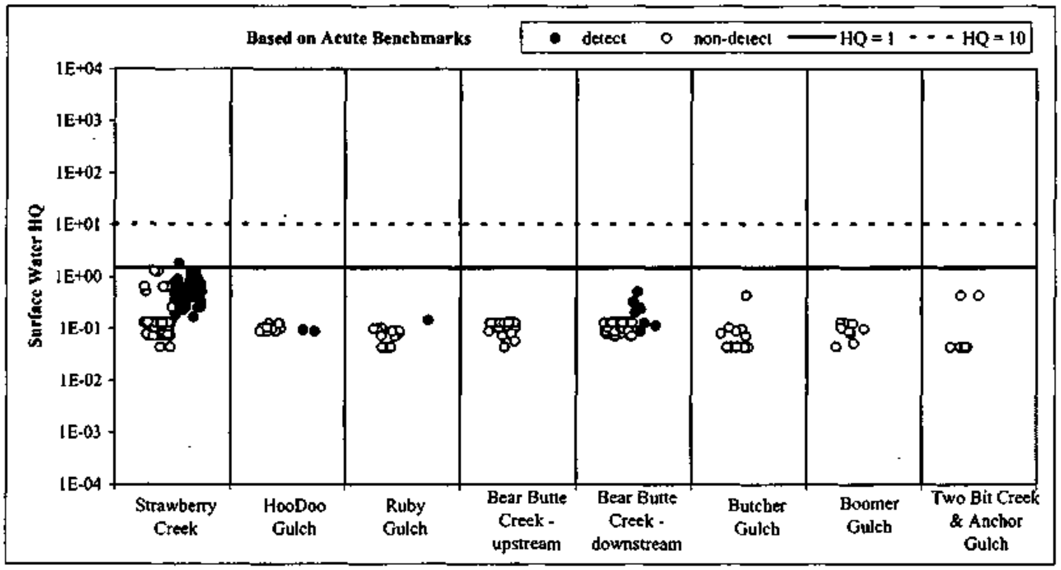


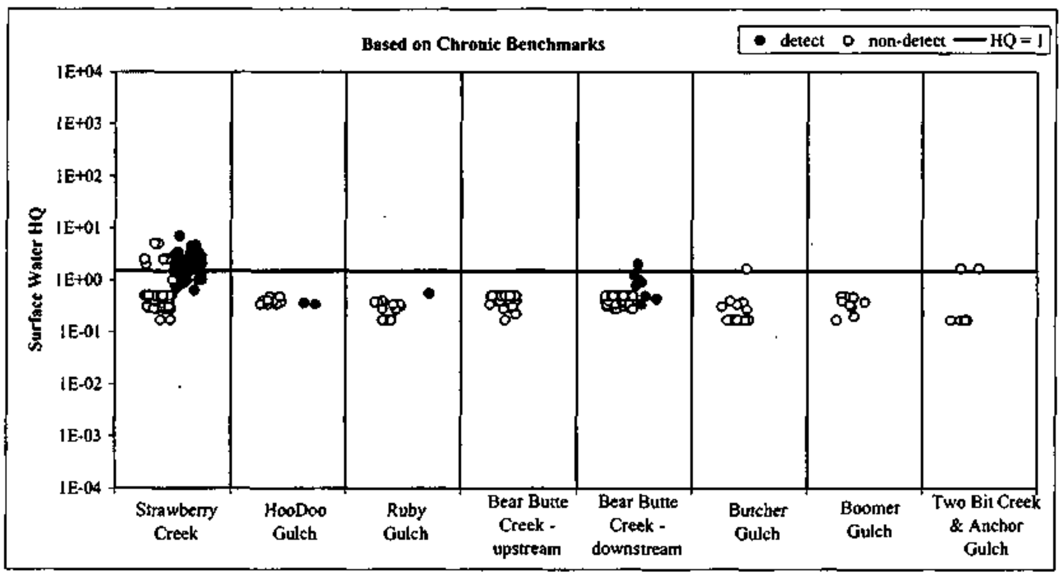


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	103	13	7	3	16	5	2	3
Total Samples:	129	13	16	30	55	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	129	13	16	30	55	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	none	none	none	none	none	none	none	none
CHRONIC								
HQs > 1:	4	4	1	0	2	1	0	0
HQs ≤ 1:	125	9	15	30	53	11	9	8
HQs > 1:	3%	31%	6%	0%	4%	8%	0%	0%
HQs ≤ 1:	97%	69%	94%	100%	96%	92%	100%	100%
Category:	minimal	moderate	minimal	none	minimal	minimal	none	none

Figure 5-1p
Summary of Surface Water HQs for Aquatic Receptors

SELENIUM

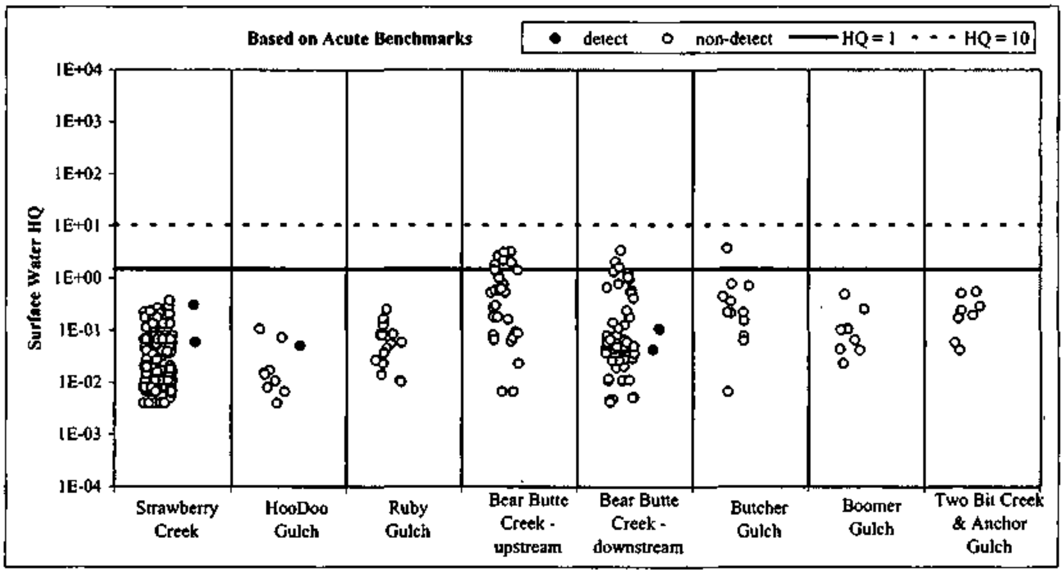


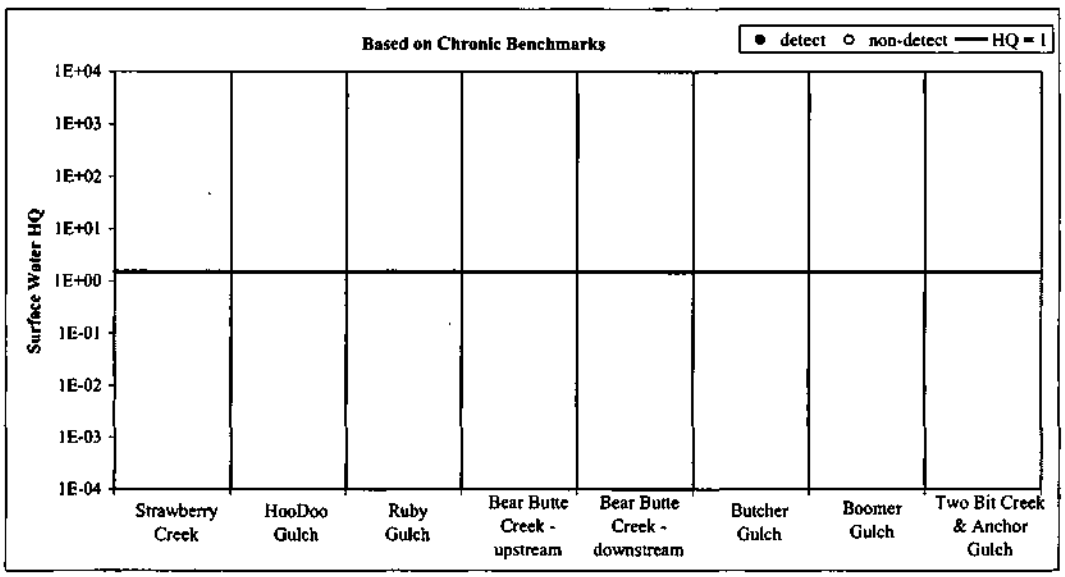


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	61	2	1	0	9	0	0	0
Total Samples:	121	13	16	30	55	12	9	8
ACUTE								
HQs > 1:	1	0	0	0	0	0	0	0
HQs ≤ 1:	120	13	16	30	55	12	9	8
HQs > 1:	1%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	99%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	moderate	none	none	none	none	none	none	none
CHRONIC								
HQs > 1:	46	0	0	0	1	0	0	0
HQs ≤ 1:	75	13	16	30	54	11	9	6
HQs > 1:	38%	0%	0%	0%	2%	0%	0%	0%
HQs ≤ 1:	62%	100%	100%	100%	98%	92%	100%	75%
Category:	moderate	none	none	none	minimal	none	none	none

Figure 5-1q
Summary of Surface Water HQs for Aquatic Receptors

SILVER

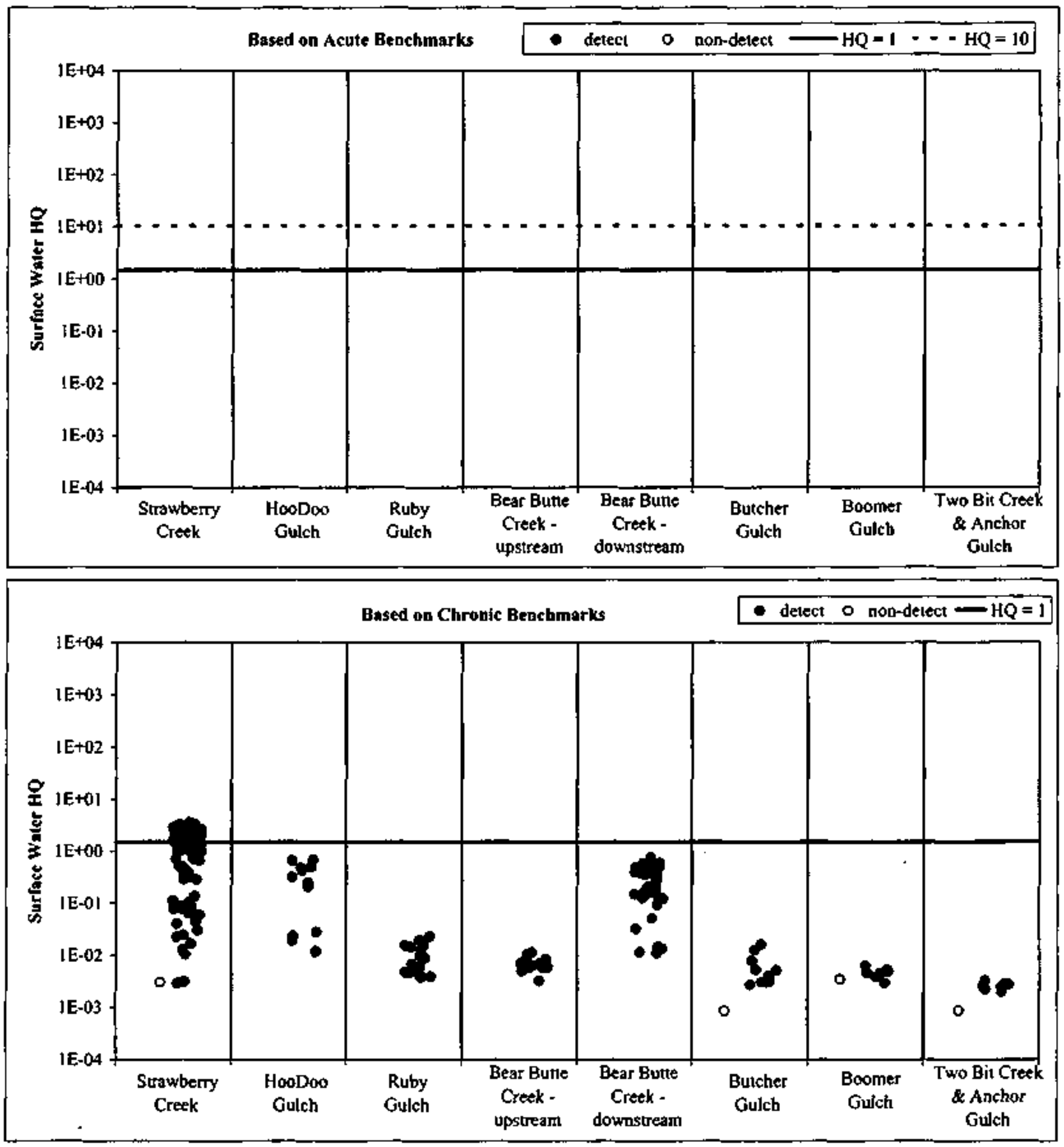




	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	2	1	0	0	2	0	0	0
Total Samples:	126	10	16	30	54	12	8	8
ACUTE								
HQs > 1:	0	0	0	6	3	1	0	0
HQs ≤ 1:	126	10	16	24	51	11	8	8
HQs > 1:	0%	0%	0%	20%	6%	8%	0%	0%
HQs ≤ 1:	100%	100%	100%	80%	94%	92%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	none	none	none	moderate	moderate	moderate	none	none
CHRONIC								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	126	10	16	30	54	12	8	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
Category:	none	none	none	none	none	none	none	none

Figure 5-1r
Summary of Surface Water HQs for Aquatic Receptors

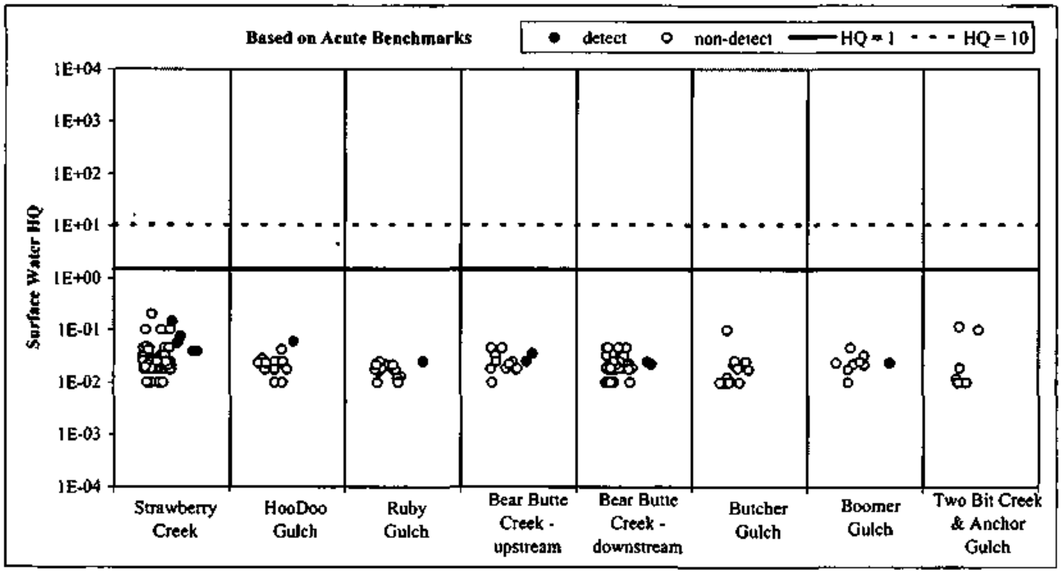
SODIUM

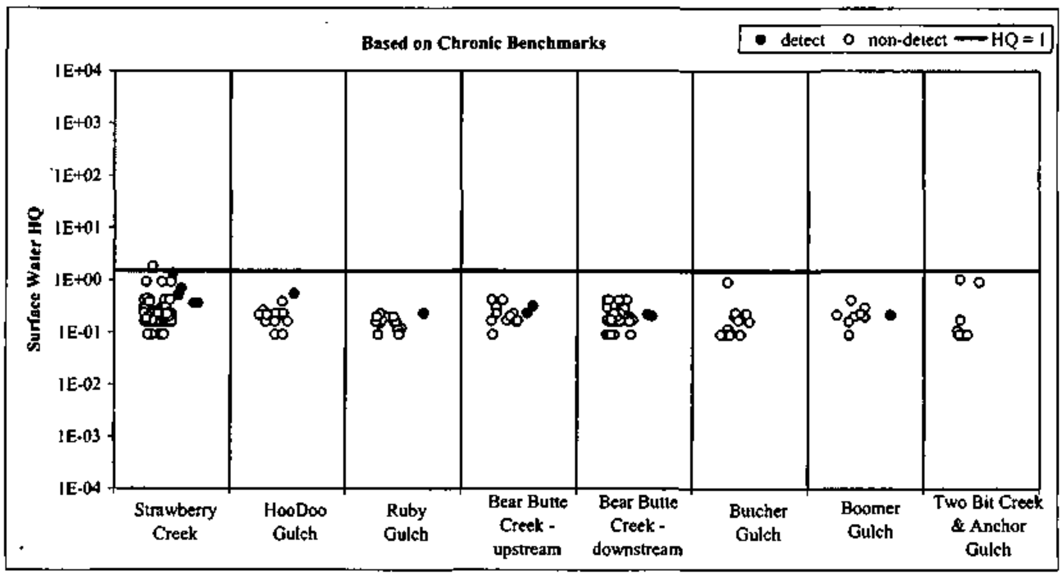


	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	97	13	16	15	40	11	8	7
Total Samples:	98	13	16	15	40	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	98	13	16	15	40	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	98	13	16	15	40	12	9	8
Category:	severe	severe	severe	severe	severe	severe	severe	severe
CHRONIC								
HQs > 1:	38	0	0	0	0	0	0	0
HQs ≤ 1:	60	13	16	15	40	12	9	8
HQs > 1:	39%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	61%	100%	100%	100%	100%	100%	100%	100%
Category:	moderate	none	none	none	none	none	none	none

Figure 5-1s
Summary of Surface Water HQs for Aquatic Receptors

THALLIUM

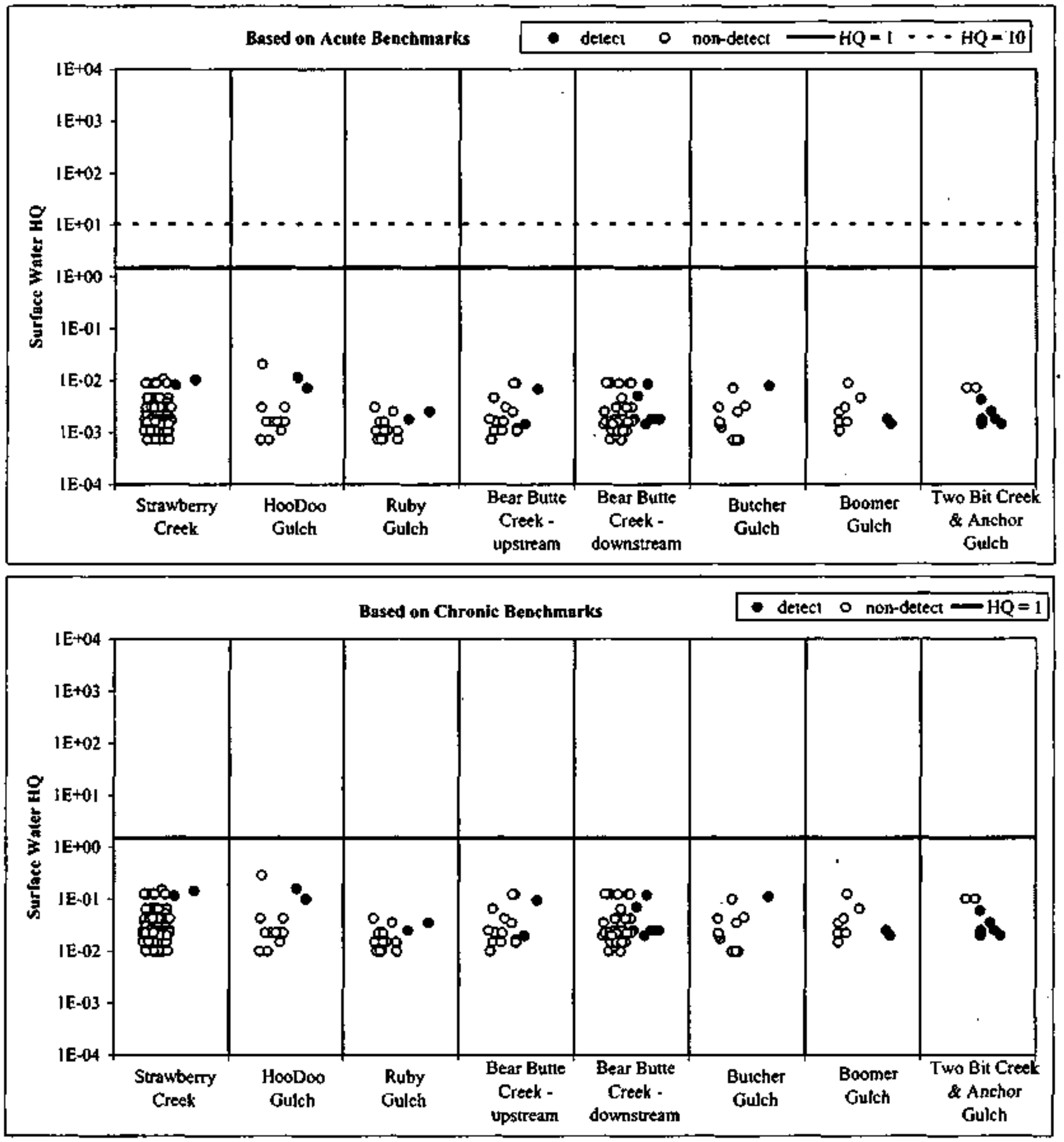




	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	5	1	1	2	2	0	1	0
Total Samples:	93	13	16	15	40	12	9	8
ACUTE								
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	93	13	16	15	40	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	none	none	none	none	none	none	none	none
CHRONIC								
HQs > 1:	1	0	0	0	0	0	0	0
HQs ≤ 1:	92	13	16	15	40	12	9	8
HQs > 1:	1%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	99%	100%	100%	100%	100%	100%	100%	100%
Category:	minimal	none	none	none	none	none	none	none

Figure 5-1t
Summary of Surface Water HQs for Aquatic Receptors

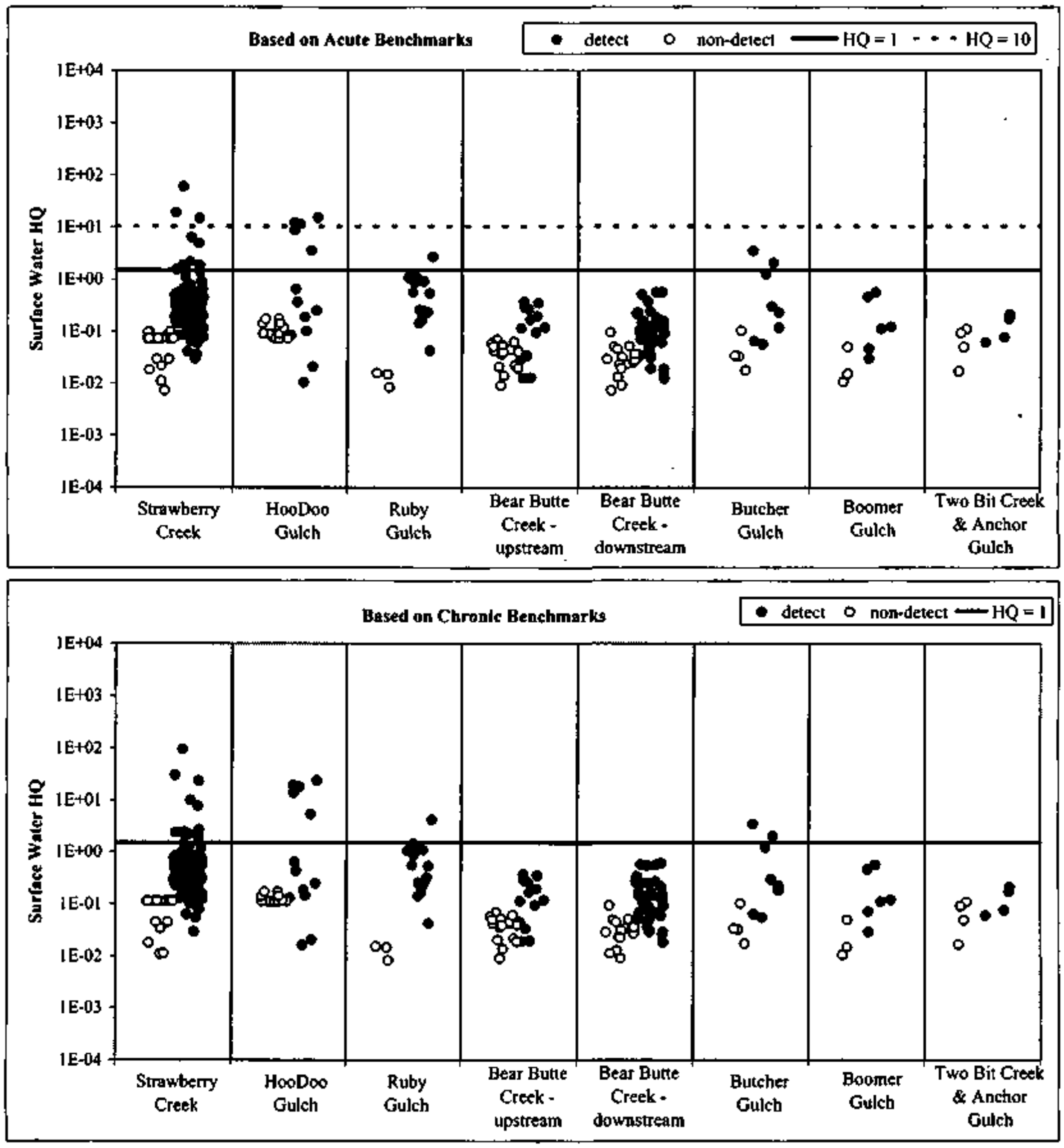
VANADIUM



	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	2	2	2	2	7	1	2	6
Total Samples:	95	13	16	15	40	12	9	8
				ACUTE				
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	95	13	16	15	40	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
# HQs > 10	0	0	0	0	0	0	0	0
Category:	none	none	none	none	none	none	none	none
				CHRONIC				
HQs > 1:	0	0	0	0	0	0	0	0
HQs ≤ 1:	95	13	16	15	40	12	9	8
HQs > 1:	0%	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%	100%
Category:	none	none	none	none	none	none	none	none

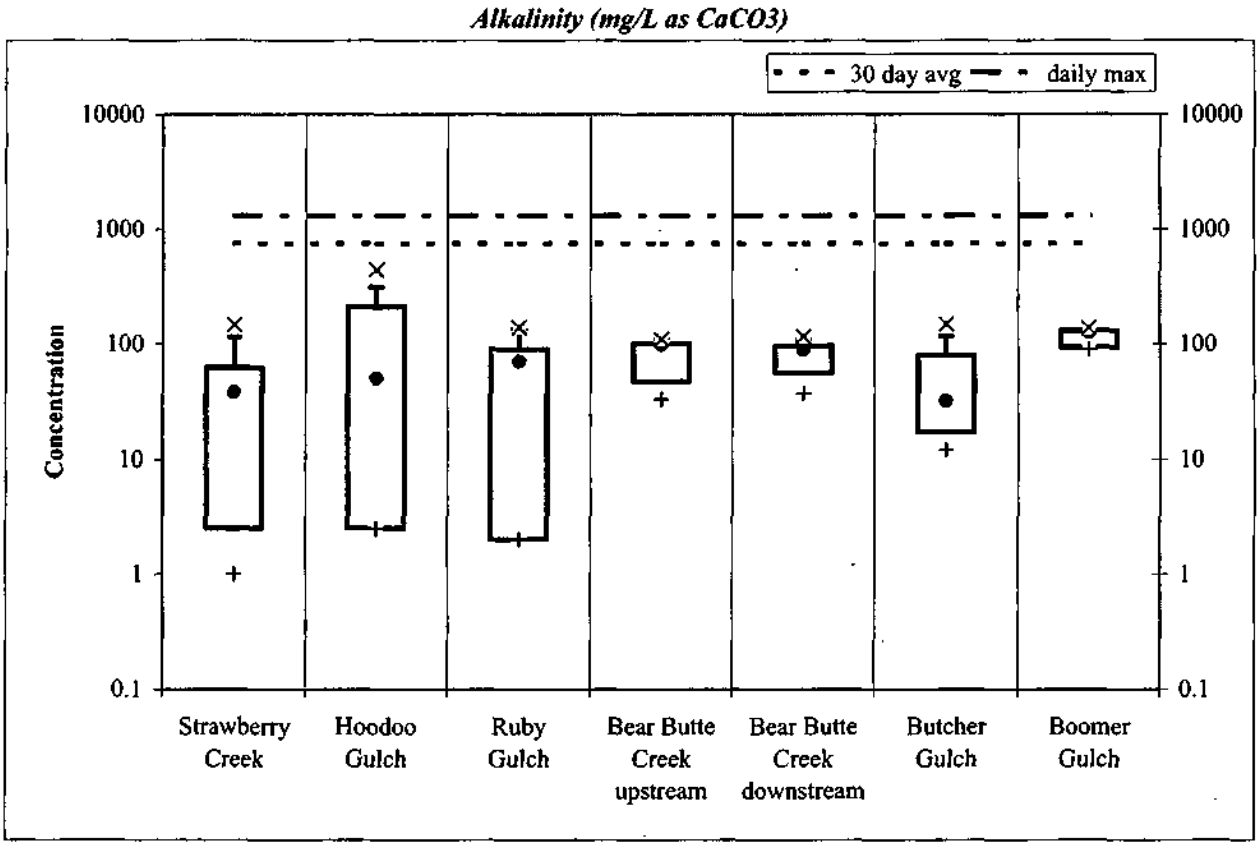
Figure 5-1u
Summary of Surface Water HQs for Aquatic Receptors

ZINC



	Site	Site	Site	Reference	Site	Reference	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch	2Bit&Anchor
Detect Samples:	175	13	15	13	40	8	6	4
Total Samples:	199	27	18	30	55	12	9	8
ACUTE								
HQs > 1:	10	5	1	0	0	2	0	0
HQs ≤ 1:	189	22	17	30	55	10	9	8
HQs > 1:	5%	19%	6%	0%	0%	17%	0%	0%
HQs ≤ 1:	95%	81%	94%	100%	100%	83%	100%	100%
# HQs > 10	3	3	0	0	0	0	0	0
Category:	severe	severe	moderate	none	none	moderate	none	none
CHRONIC								
HQs > 1:	11	5	1	0	0	2	0	0
HQs ≤ 1:	188	22	17	30	55	10	9	8
HQs > 1:	6%	19%	6%	0%	0%	17%	0%	0%
HQs ≤ 1:	94%	81%	94%	100%	100%	83%	100%	100%
Category:	minimal	minimal	minimal	none	none	minimal	none	none

Figure 5-2a
Summary of Water Quality Data Compared to South Dakota Criteria



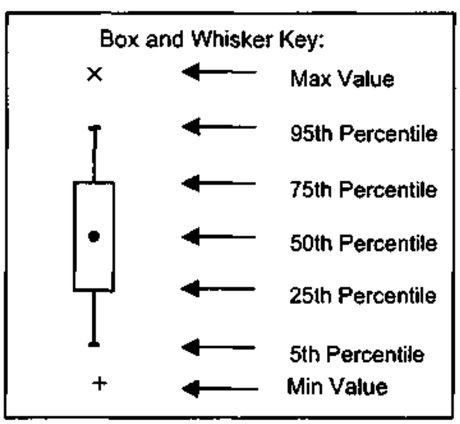
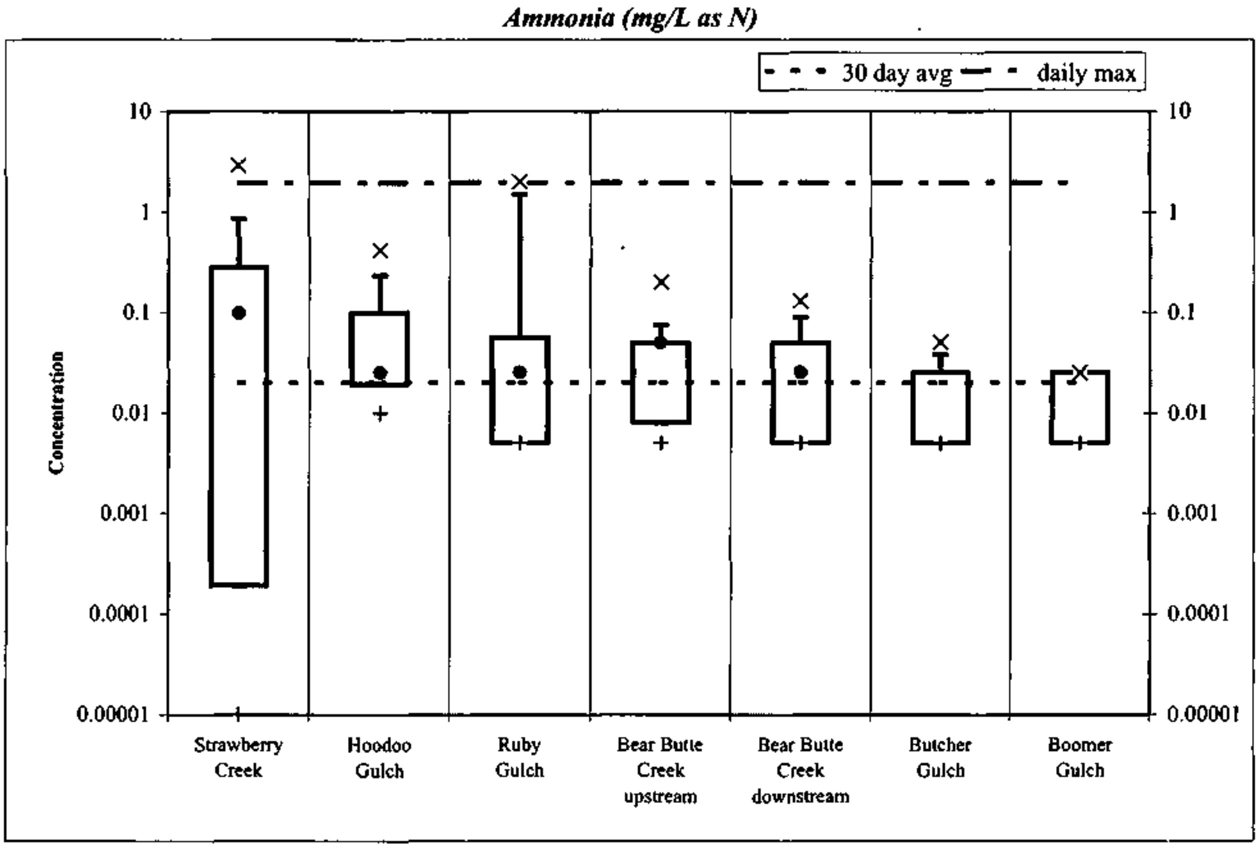
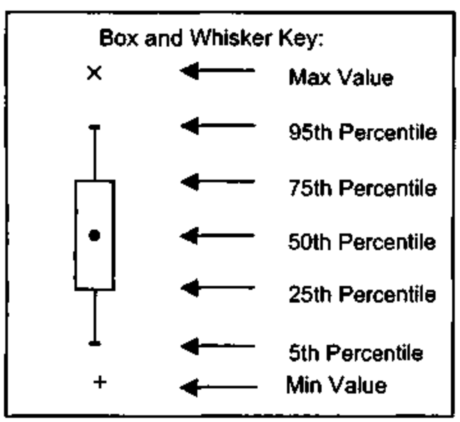


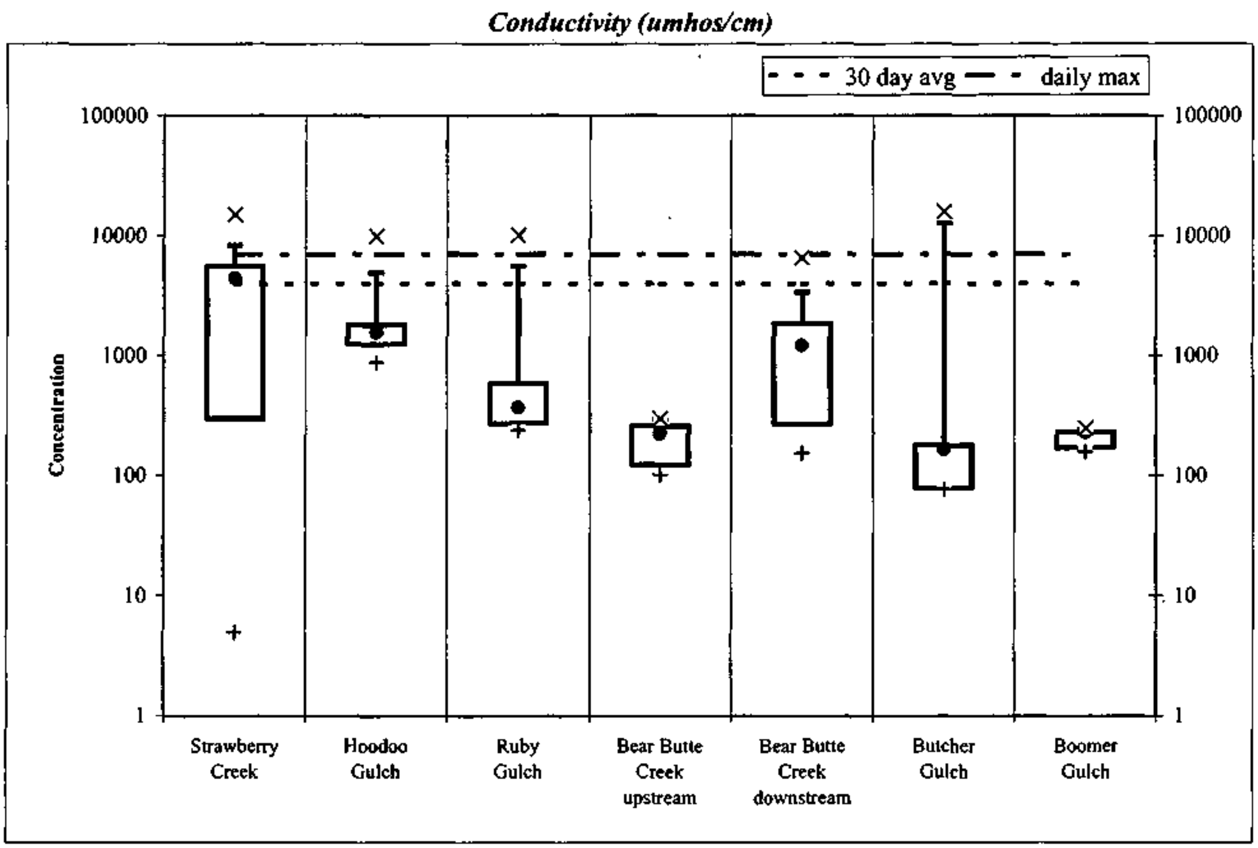
Figure 5-2b
Summary of Water Quality Data Compared to South Dakota Criteria





State WQ COPC Screen.xls: graphs
1/21/2003

Figure 5-2c
Summary of Water Quality Data Compared to South Dakota Criteria



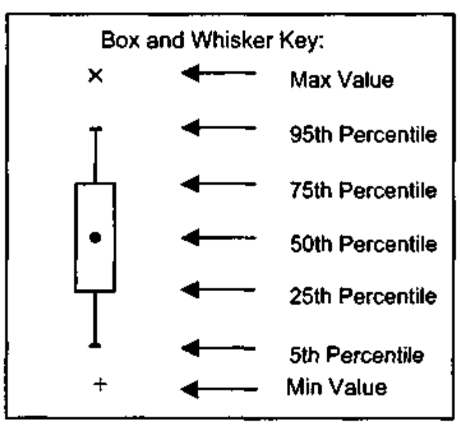
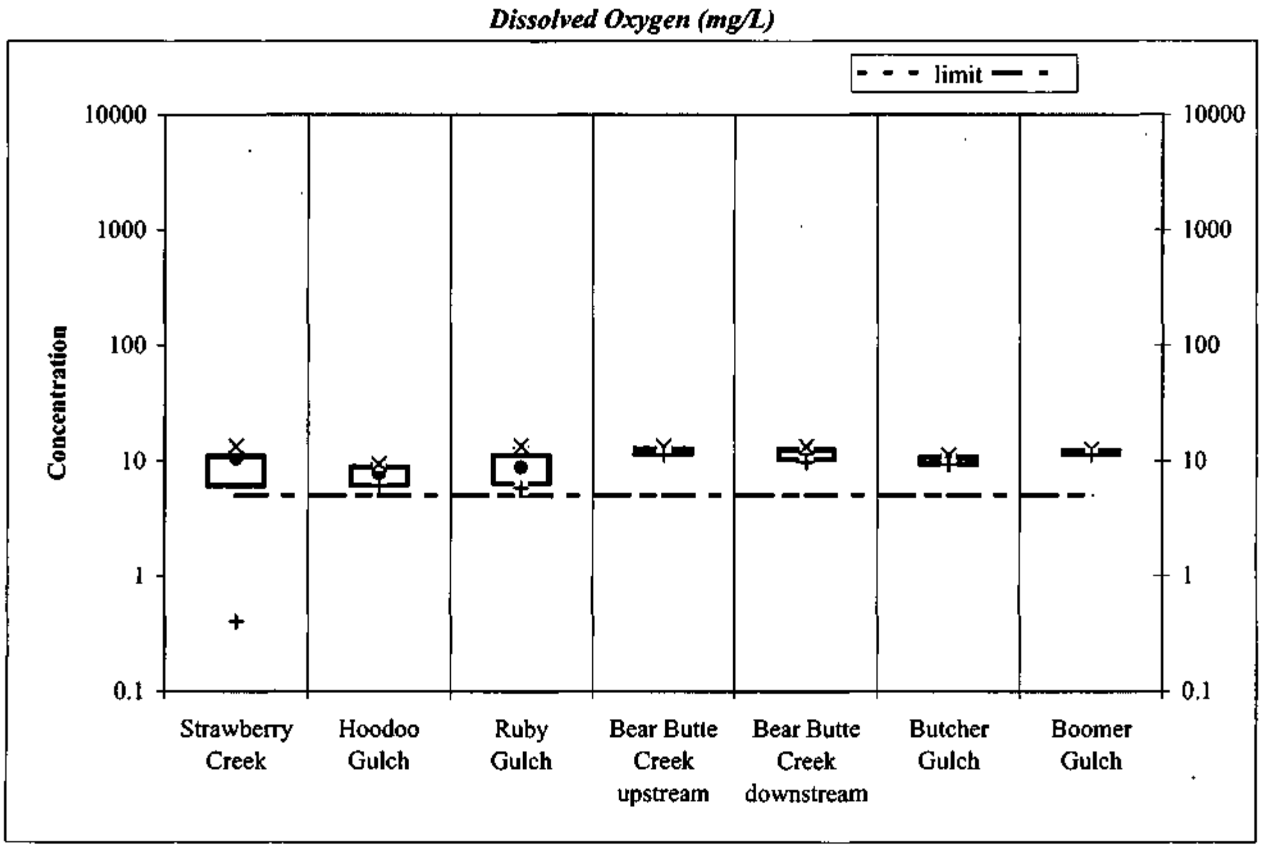
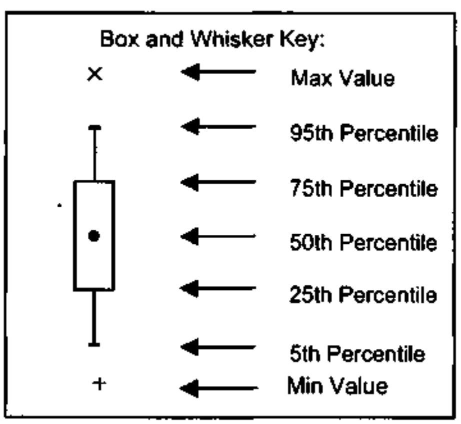


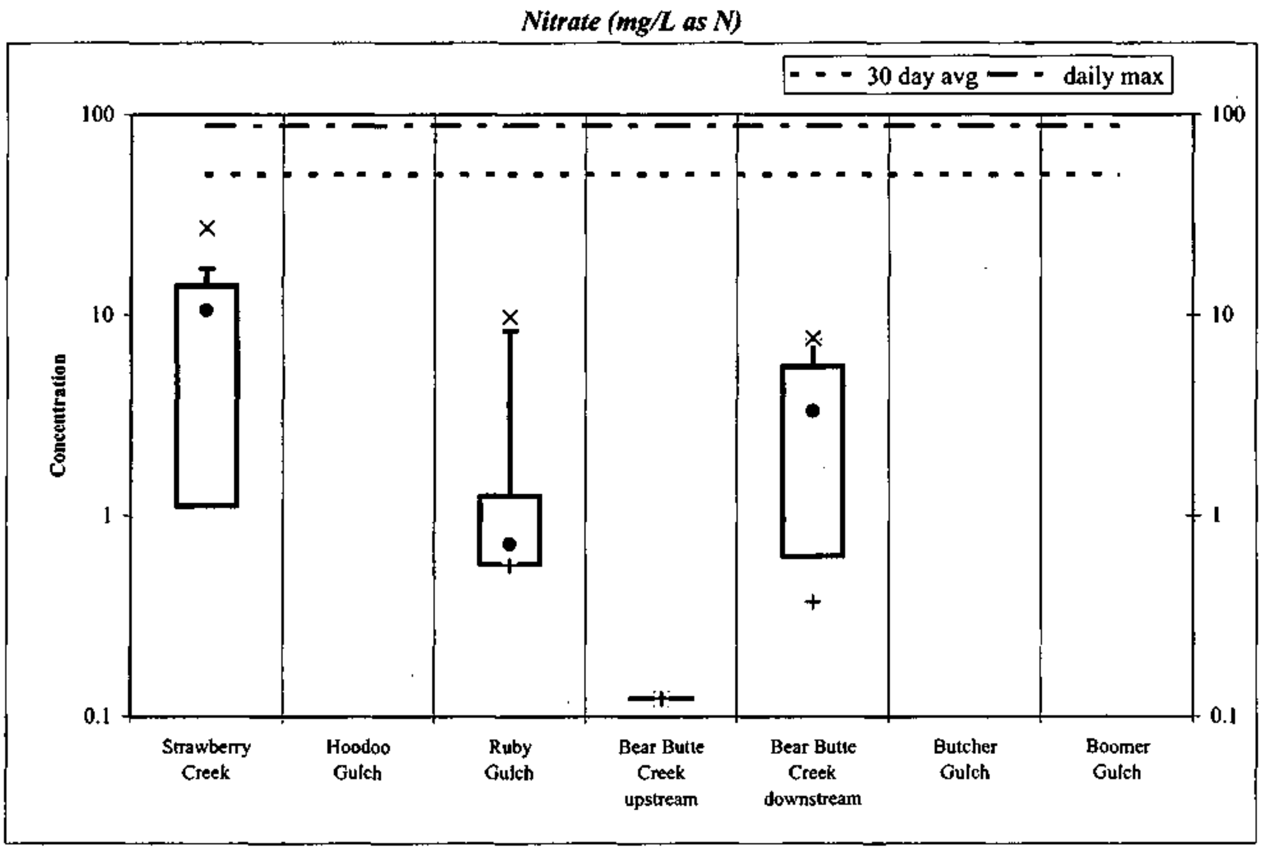
Figure 5-2d
Summary of Water Quality Data Compared to South Dakota Criteria





State WQ COPC Screen.xls: graphs
1/21/2003

Figure 5-2e
Summary of Water Quality Data Compared to South Dakota Criteria



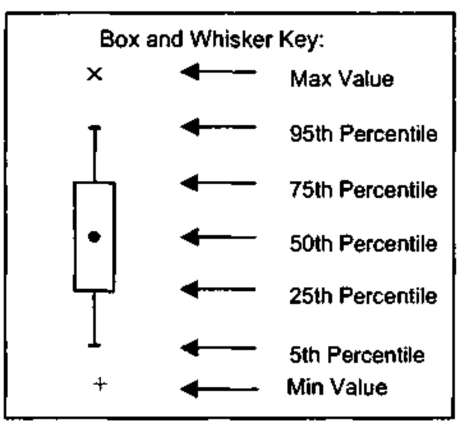
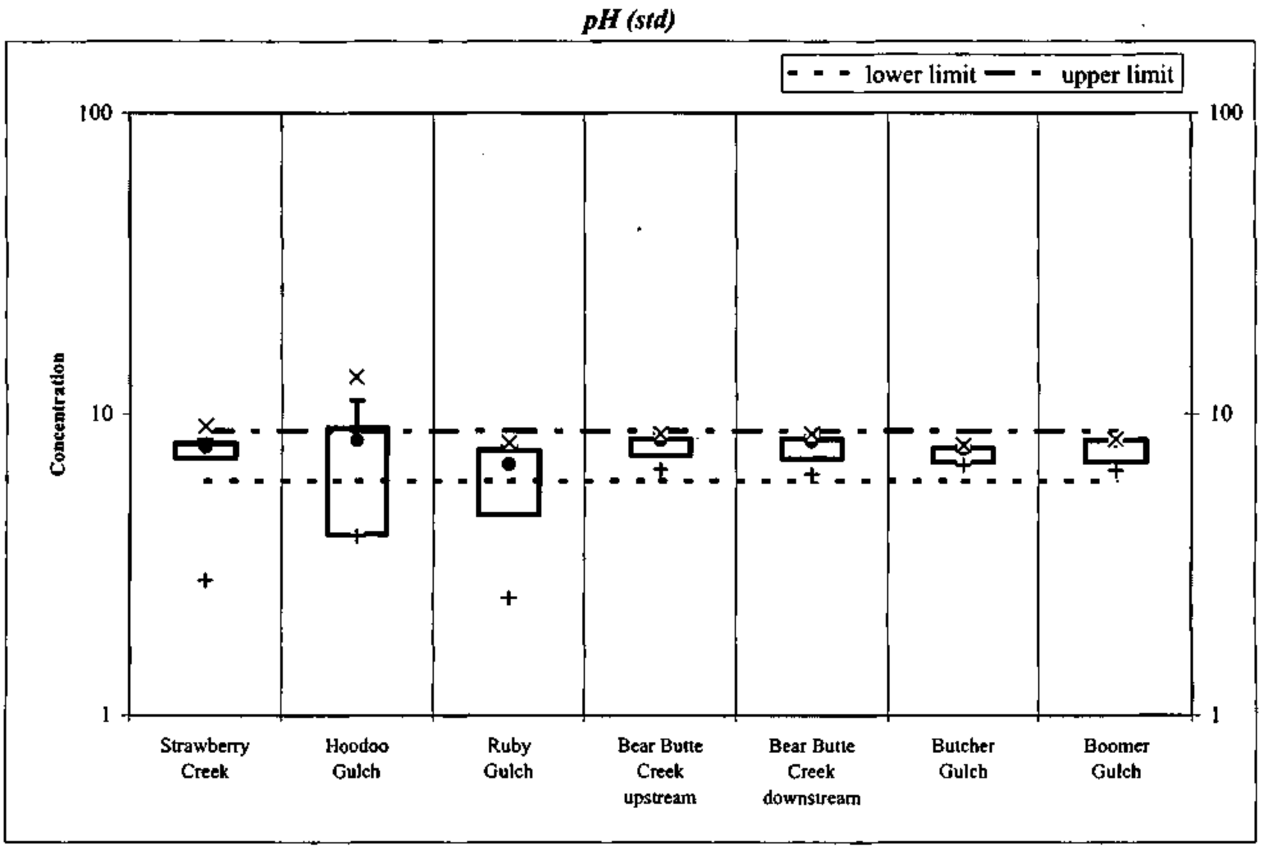


Figure 5-2f
Summary of Water Quality Data Compared to South Dakota Criteria



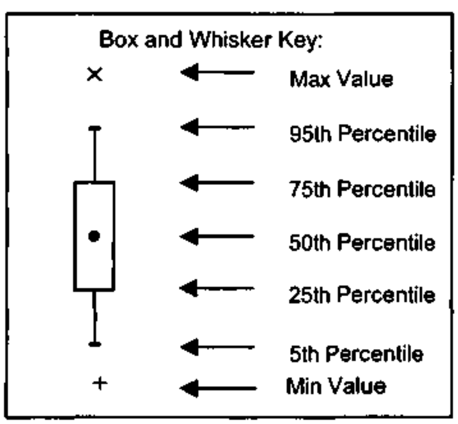
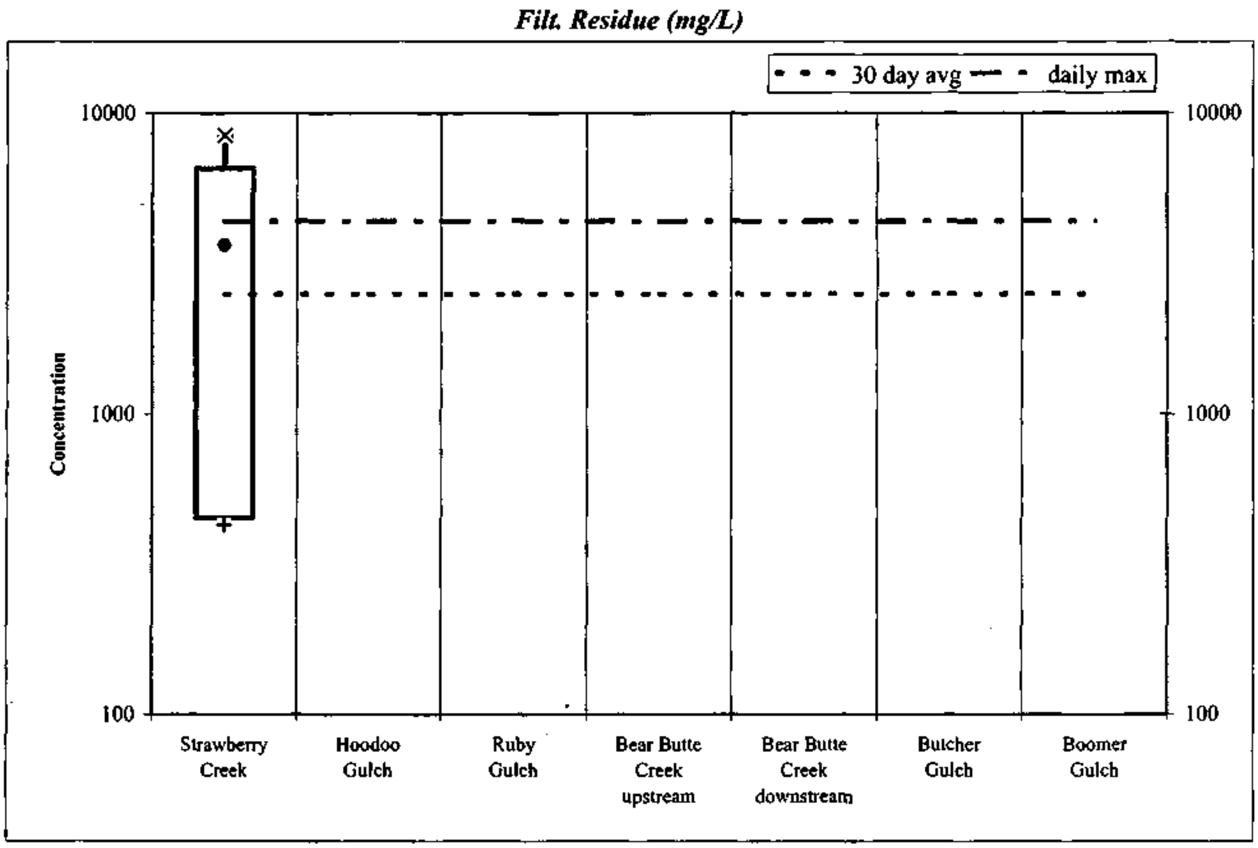
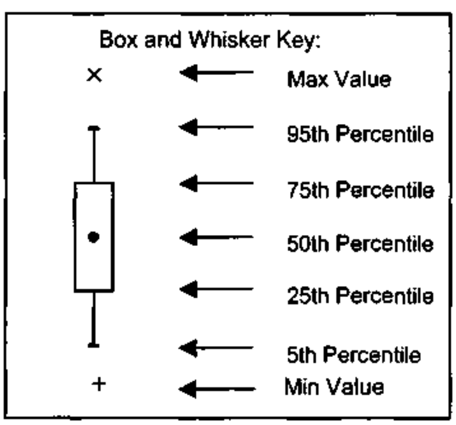


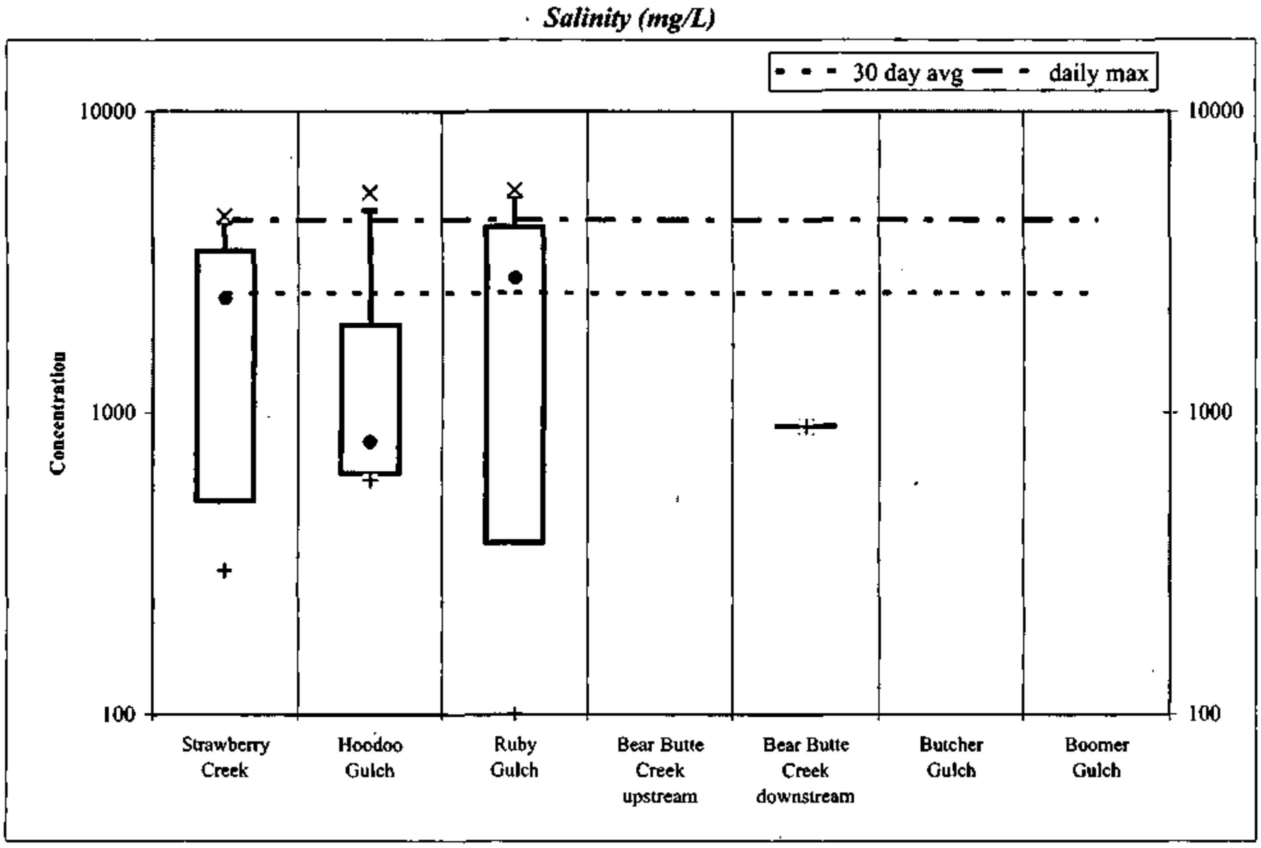
Figure 5-2g
Summary of Water Quality Data Compared to South Dakota Criteria





State WQ COPC Screen.xls: graphs
1/21/2003

Figure 5-2h
Summary of Water Quality Data Compared to South Dakota Criteria



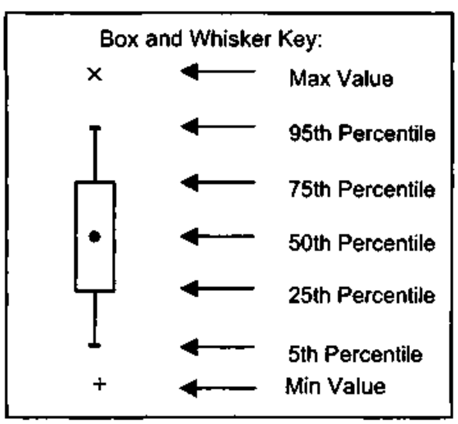
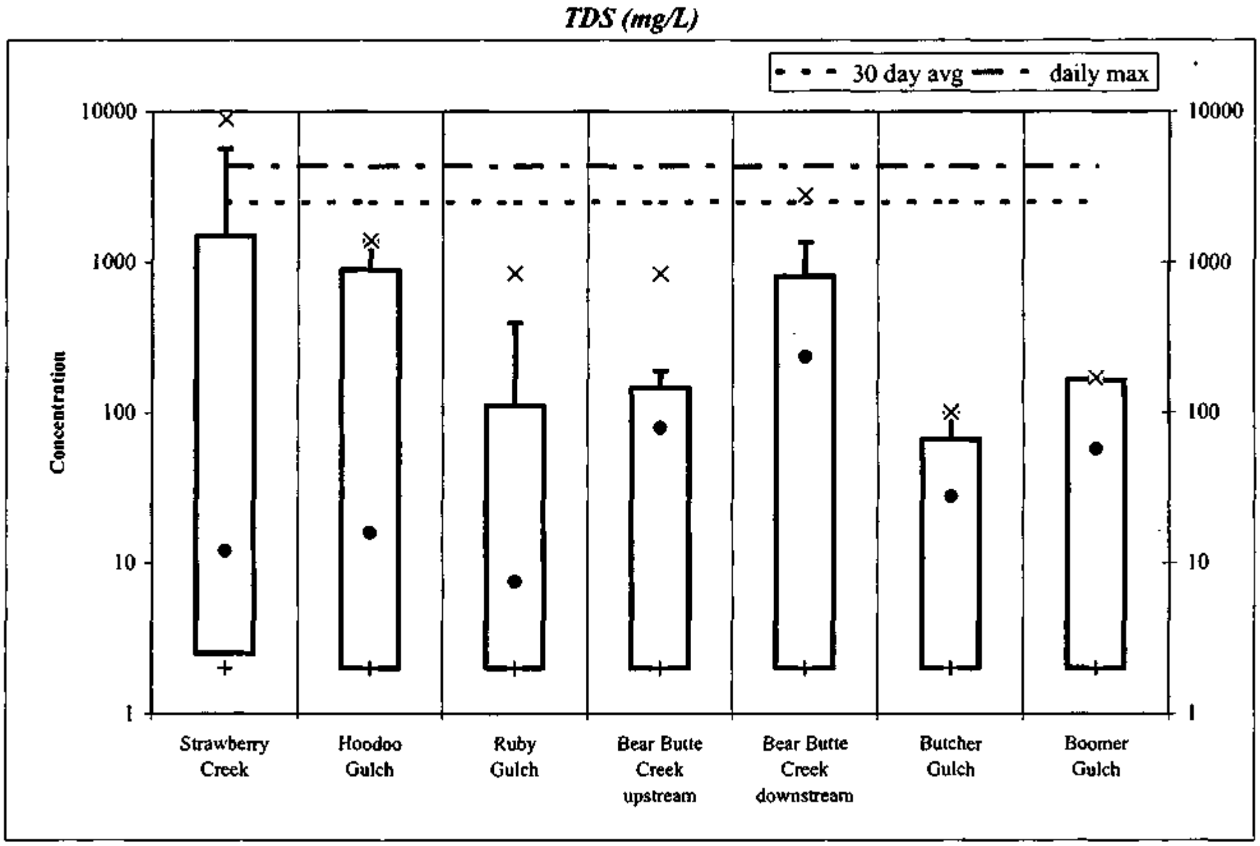


Figure 5-21
Summary of Water Quality Data Compared to South Dakota Criteria



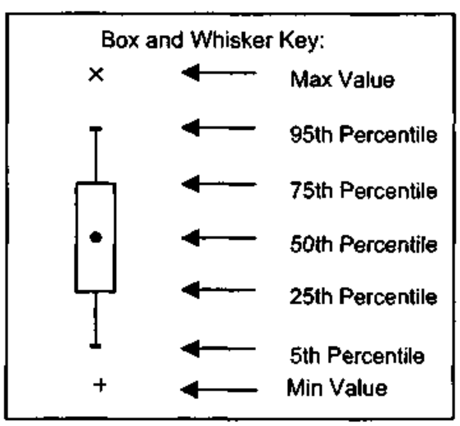
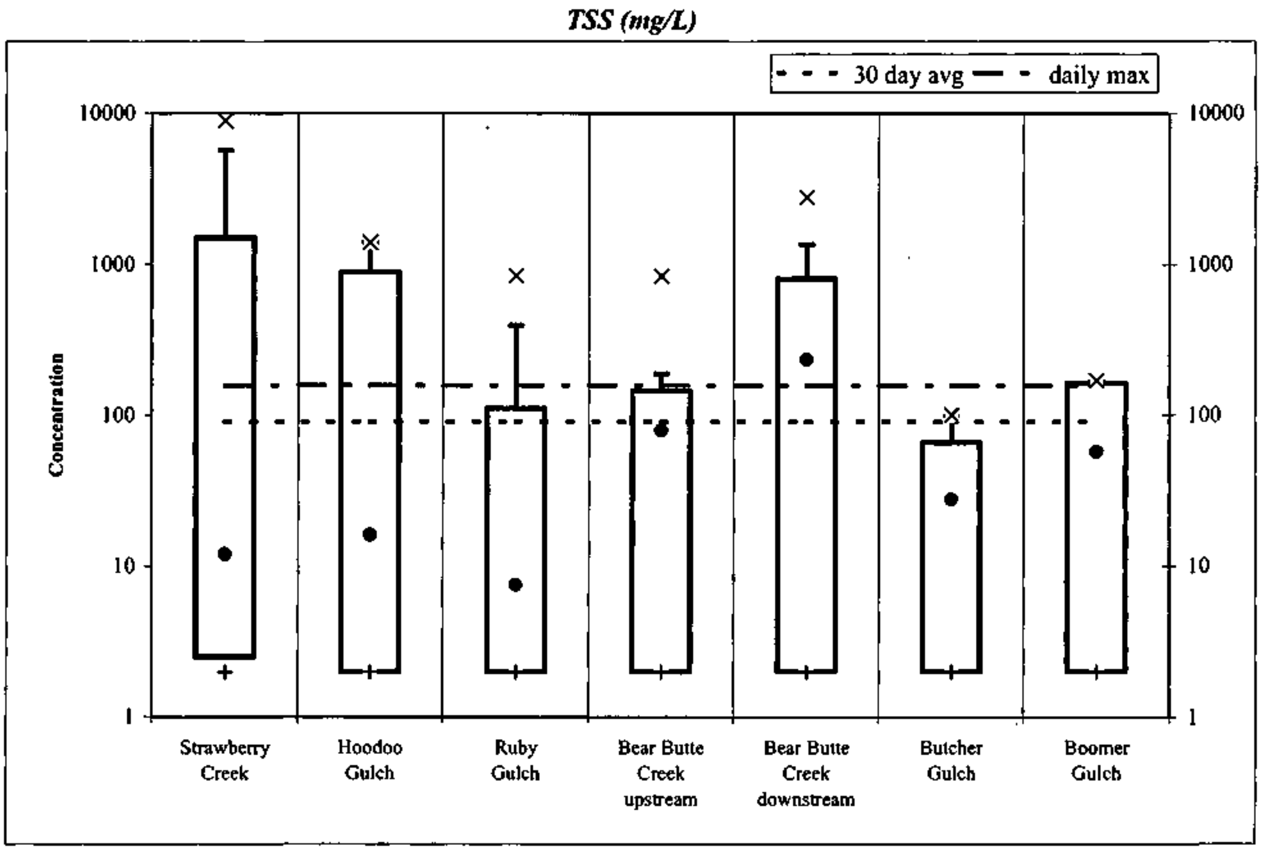


Figure 5-2j
Summary of Water Quality Data Compared to South Dakota Criteria



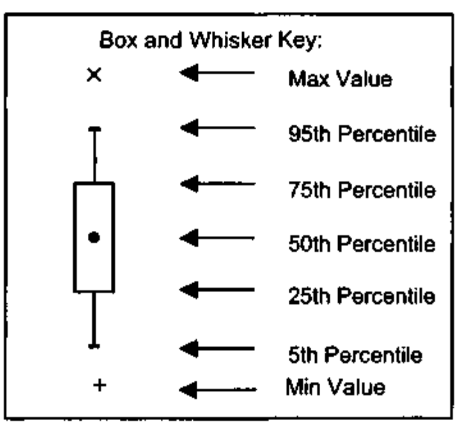
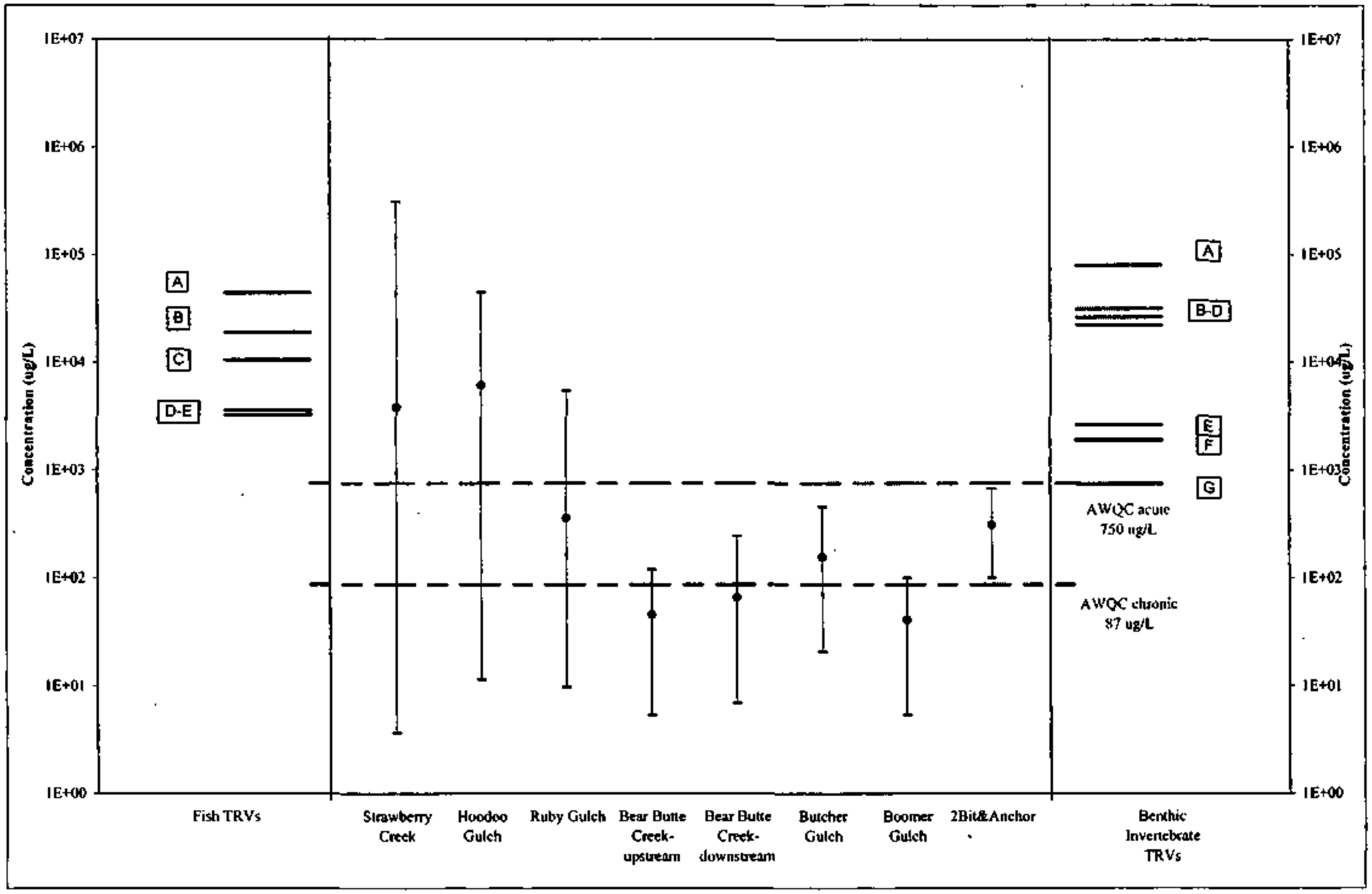


Figure 5-3

Comparison of Aluminum Concentrations with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



FISH TRVs (ug/L)

A	43,797	Fathead Minnow (juv), acute
B	18,900	Fathead Minnow (adult), acute
C	10,394	Rainbow Trout, acute
D	3,600	Brook Trout, chronic
E	3,288	Fathead Minnow, chronic

LEGEND

Maximum Concentration

Average Concentration

Minimum Concentration

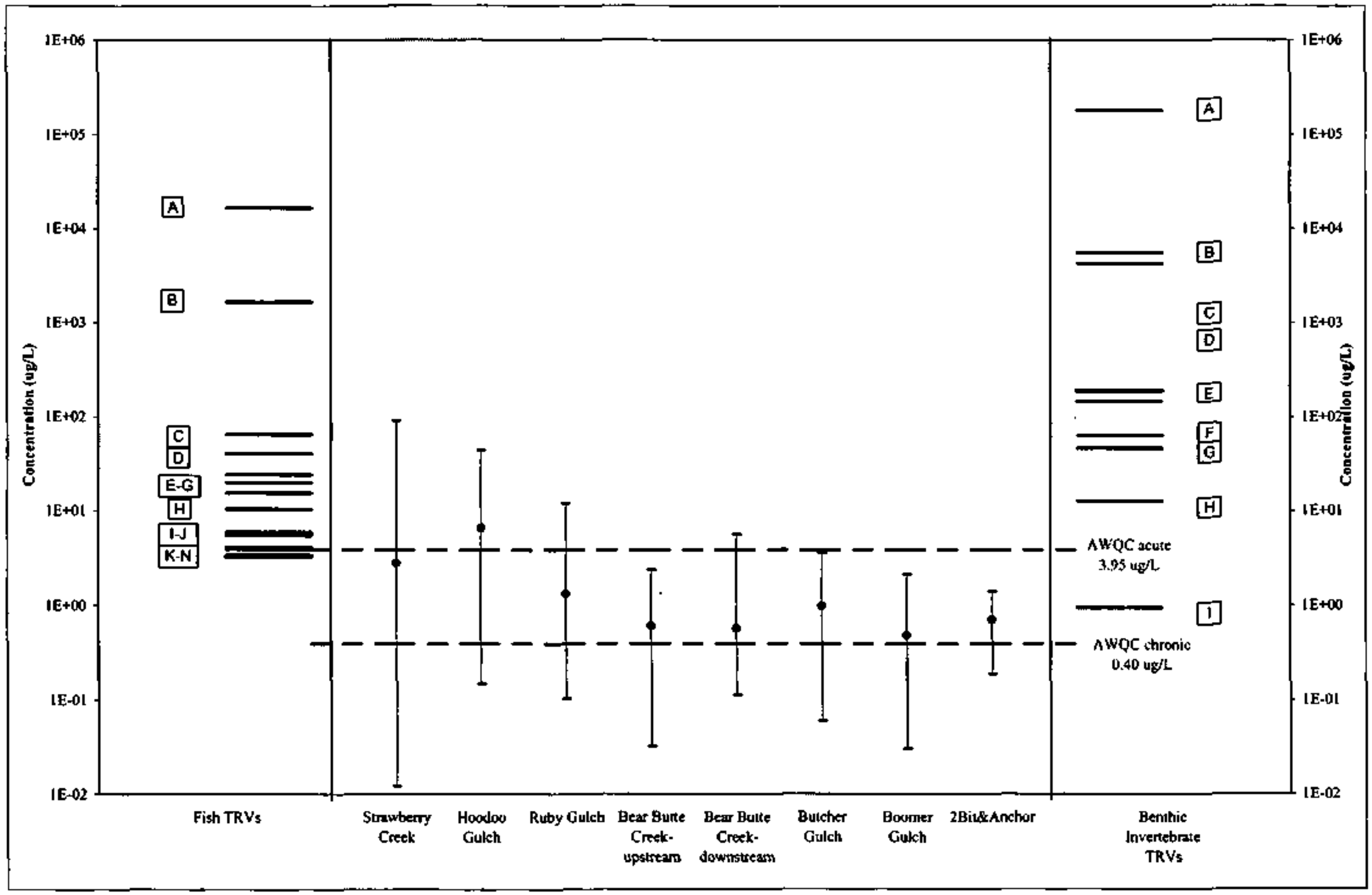
BENTHIC TRVs (ug/L)

A	79,900	Midge, acute
B	31,088	Daphnia, acute
C	26,054	Snail, acute
D	22,000	Amphipod (Gammarus sp.), acute
E	2,648	Ceriodaphnia, acute
F	1,908	Ceriodaphnia, chronic
G	742	Daphnia, chronic

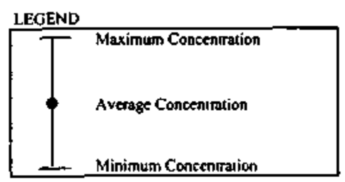
Aluminum toxicity not hardness dependant, no hardness normalization required.

SW Thermometer Plots_Alv2.xls: Al Graph
1/21/2003

Figure 5-4
Comparison of Cadmium Concentrations with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



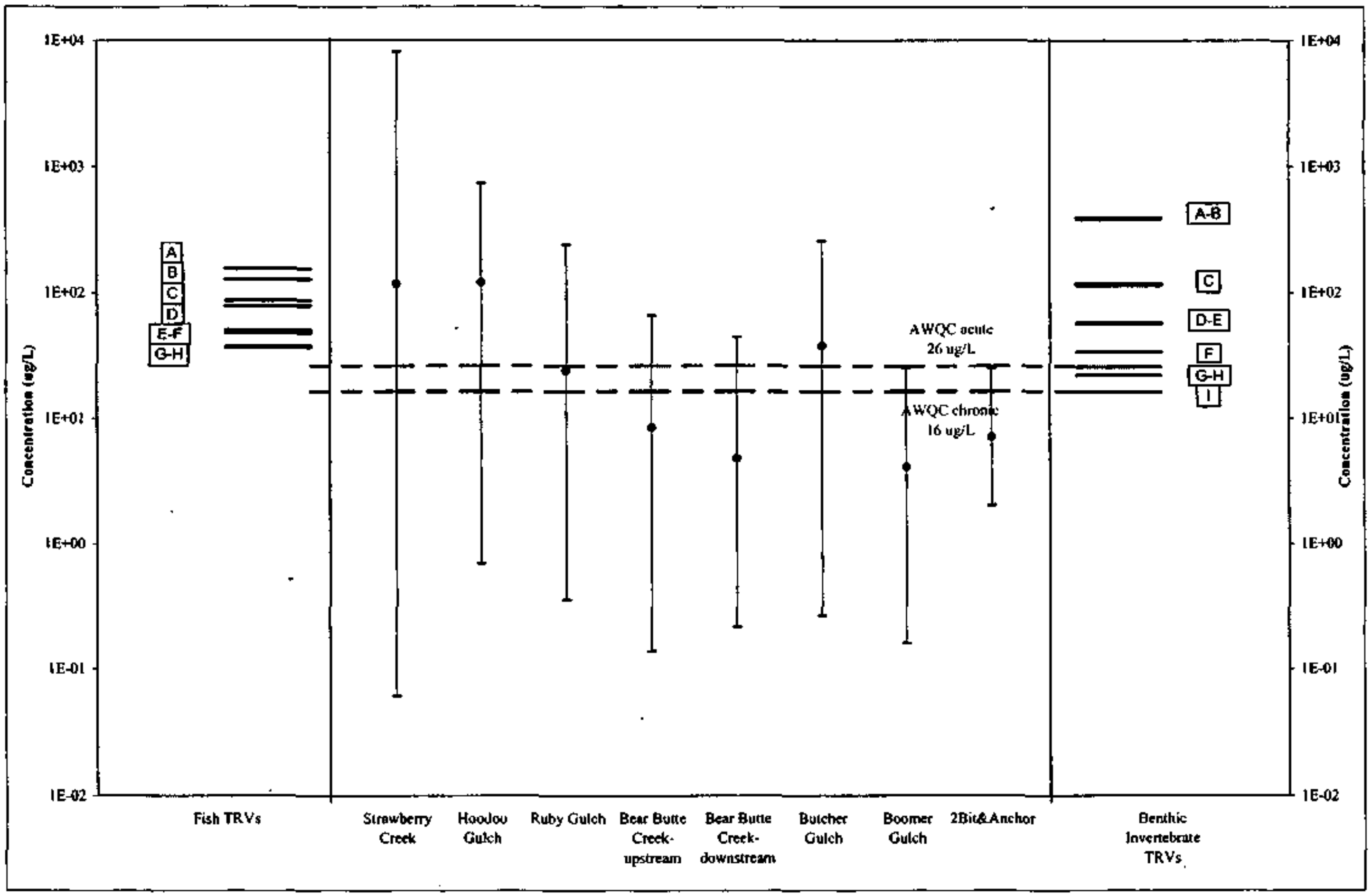
	FISH TRVs (ug/L)	
A	16,592	White Sucker (NR), acute
B	1,660	Fathead Minnow (juv/adult), acute
C	65	Fathead Minnow (larvae), acute
D	40	Fathead Minnow, chronic
E	24	Rainbow Trout (larvae), acute
F	20	White Sucker (NR), chronic
G	15	Brown Trout (NR), chronic
H	10	Colo. Squawfish (larvae/juv), acute
I	6.0	Brook Trout (NR), chronic
J	5.6	Bull Trout (adult), acute
K	4.2	Rainbow Trout (adult), acute
L	4.0	Brook Trout (NR), acute



All measured concentrations and TRVs normalized to a hardness of 200 mg/L.

	BENTHIC TRVs (ug/L)	
A	181,418	Midge, acute
B	5,584	Tubificid Worm, acute
C	4,266	Mayfly, acute
D	191	Snail, acute
E	147	Amphipod (Gammarus sp.), acute
F	63	Ceriodaphnia, acute
G	47	Daphnia, acute
H	13	Snail, chronic
I	0.9	Daphnia, chronic

Figure 5-5
Comparison of Copper Concentrations with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



FISH TRVs (ug/L)

A	154	Fathead Minnow, acute
B	127	Brown Trout, chronic
C	86	White Sucker, chronic
D	78	Rainbow Trout, chronic
E	51	Brook Trout, chronic
F	48	Rainbow Trout, acute
G	37	Fathead Minnow, chronic
H	37	N. Squawfish, acute

LEGEND

Maximum Concentration

Average Concentration

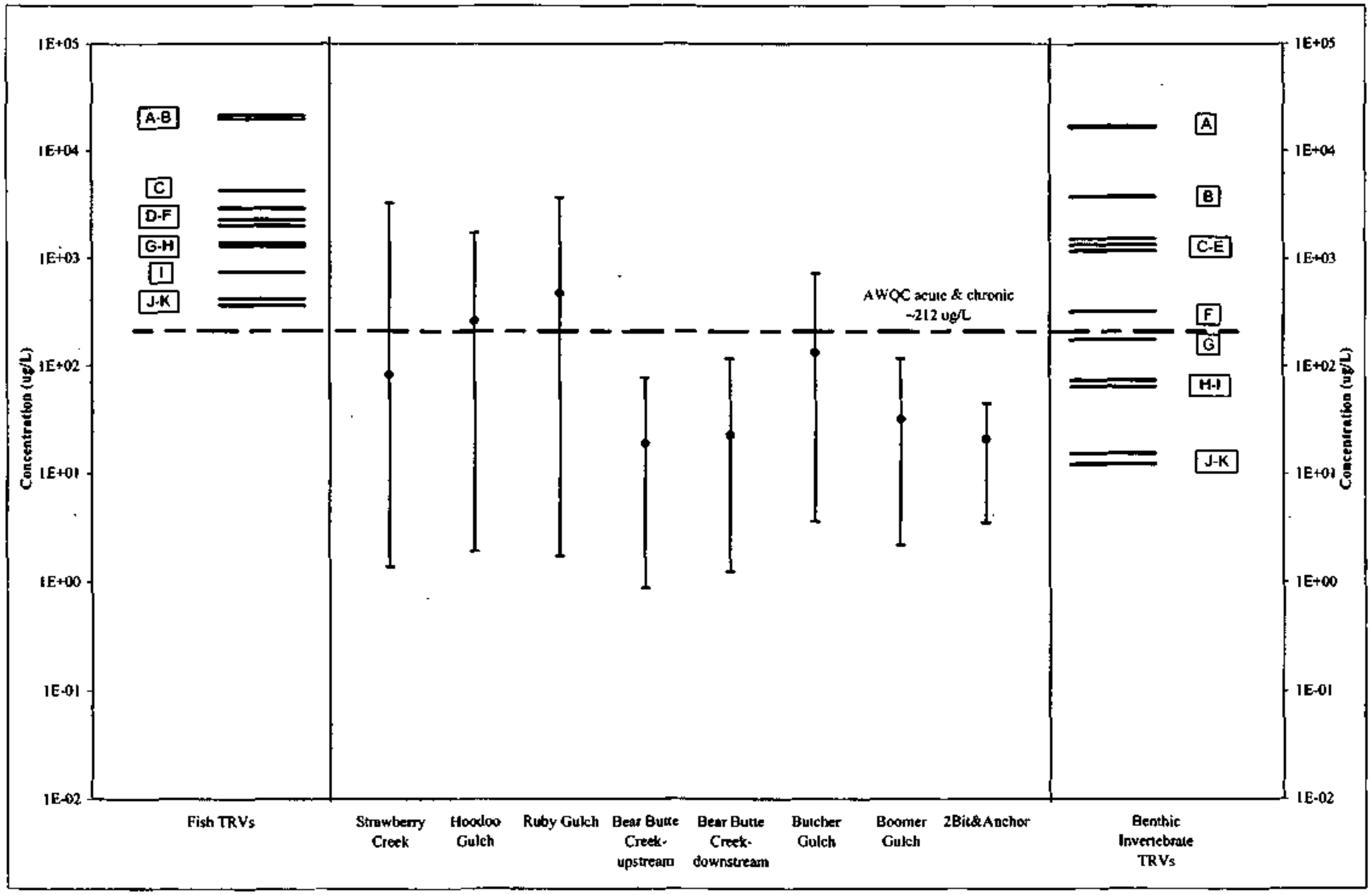
Minimum Concentration

All measured concentrations and TRVs normalized to a hardness of 200 mg/L.

BENTHIC TRVs (ug/L)

A	397	Snail, acute
B	383	Midge, acute
C	116	Tubificid Worm, acute
D	58	Amphipod (Gammarus sp.), acute
E	56	Snail, chronic
F	34	Daphnia, acute
G	25	Amphipod (Gammarus sp.), chronic
H	22	Ceriodaphnia, acute
I	16	Daphnia, chronic

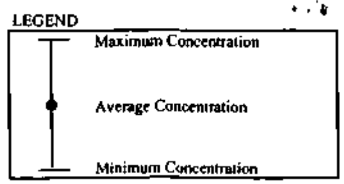
Figure 5-6
Comparison of Zinc Concentrations with Acute and Chronic Toxicity Values for Fish and Benthic Invertebrates



FISH TRVs (ug/L)

A	21,314.96	Northern Squawfish (juvenile), acute
B	19,667.39	White Sucker, acute
C	4,243.20	Fathead Minnow (juv/adult), acute
D	2,909.12	Brook Trout (life cycle), chronic
E	2,288.10	Rainbow Trout (early life-stage), chronic
F	2,022	Brook Trout (juvenile), acute
G	1,392.07	Rainbow Trout (adult), acute
H	1,299.22	Rainbow Trout (larvae), acute
I	741.84	Rainbow Trout (juvenile), acute
J	416.52	Fathead Minnow (larvae), acute
K	361.14	Fathead Minnow (life cycle), chronic

LEGEND



All measured concentrations and TRVs normalized to a hardness of 200 mg/L.

BENTHIC TRVs (ug/L)

A	17,066.4	Midge, acute
B	3,792.94	Tubificid Worm, acute
C	1,548.6	Snail (Physa sp.), acute
D	1,357	Mayfly, acute
E	1,192	Amphipod (Gammarus sp.), acute
F	324	Amphipod (Hyalella sp.), acute
G	179	Daphnia, acute
H	74.2507462	Daphnia, chronic
I	65	Ceriodaphnia, acute
J	15.55	Snail (Aplexa sp.), chronic
K	12	Ceriodaphnia, chronic

SW Thermometer Plots_Zn.xls: Zn Graph
1/21/2003

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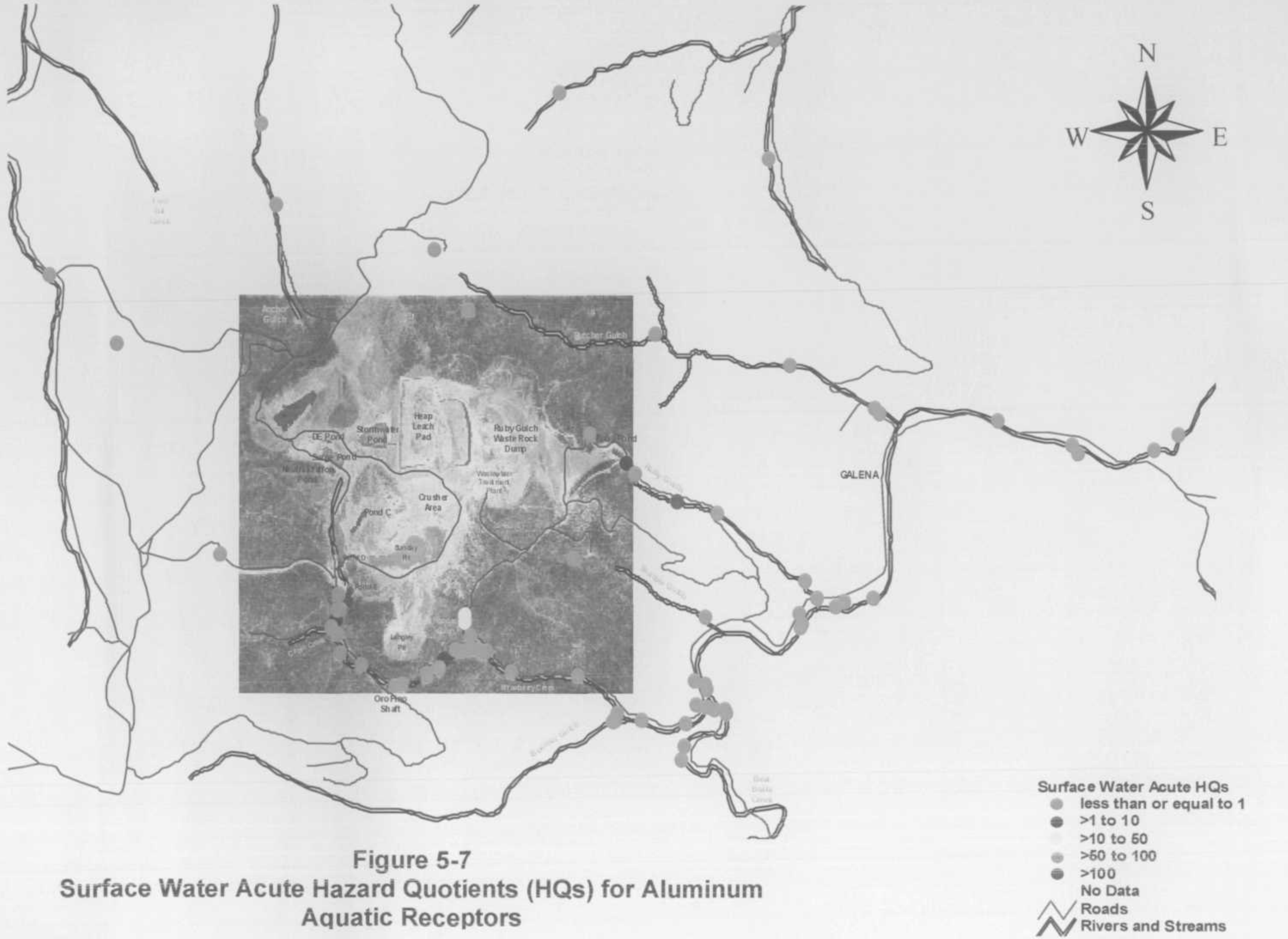


Figure 5-7
Surface Water Acute Hazard Quotients (HQs) for Aluminum Aquatic Receptors

acute sw HQ maps2.doc (gem_revised2.apr)

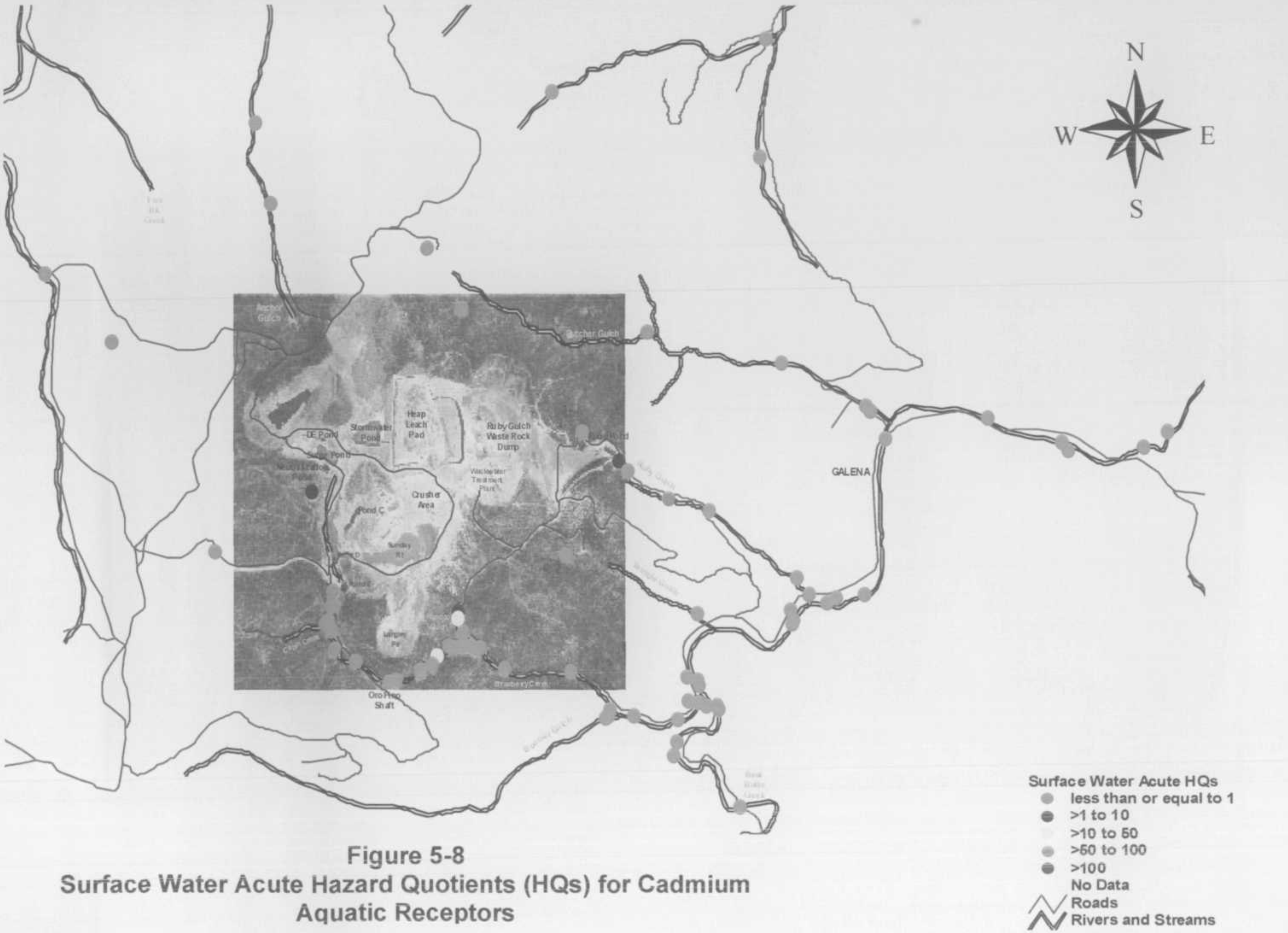


Figure 5-8
Surface Water Acute Hazard Quotients (HQs) for Cadmium Aquatic Receptors

acute sw HQ maps2.doc (gem_revised2.apr)

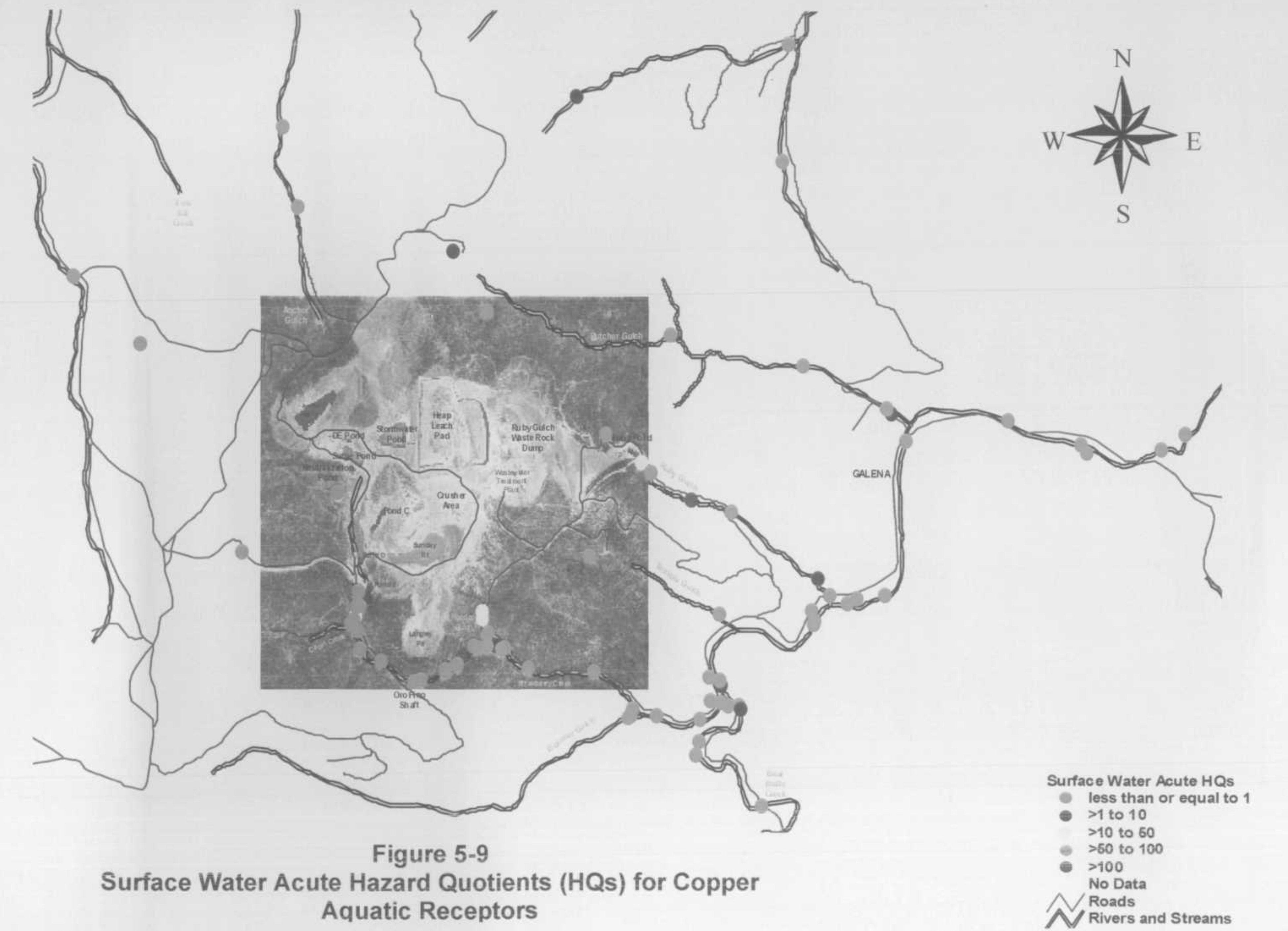


Figure 5-9
Surface Water Acute Hazard Quotients (HQs) for Copper Aquatic Receptors

acute sw HQ maps2.doc (gem_revised2.apr)

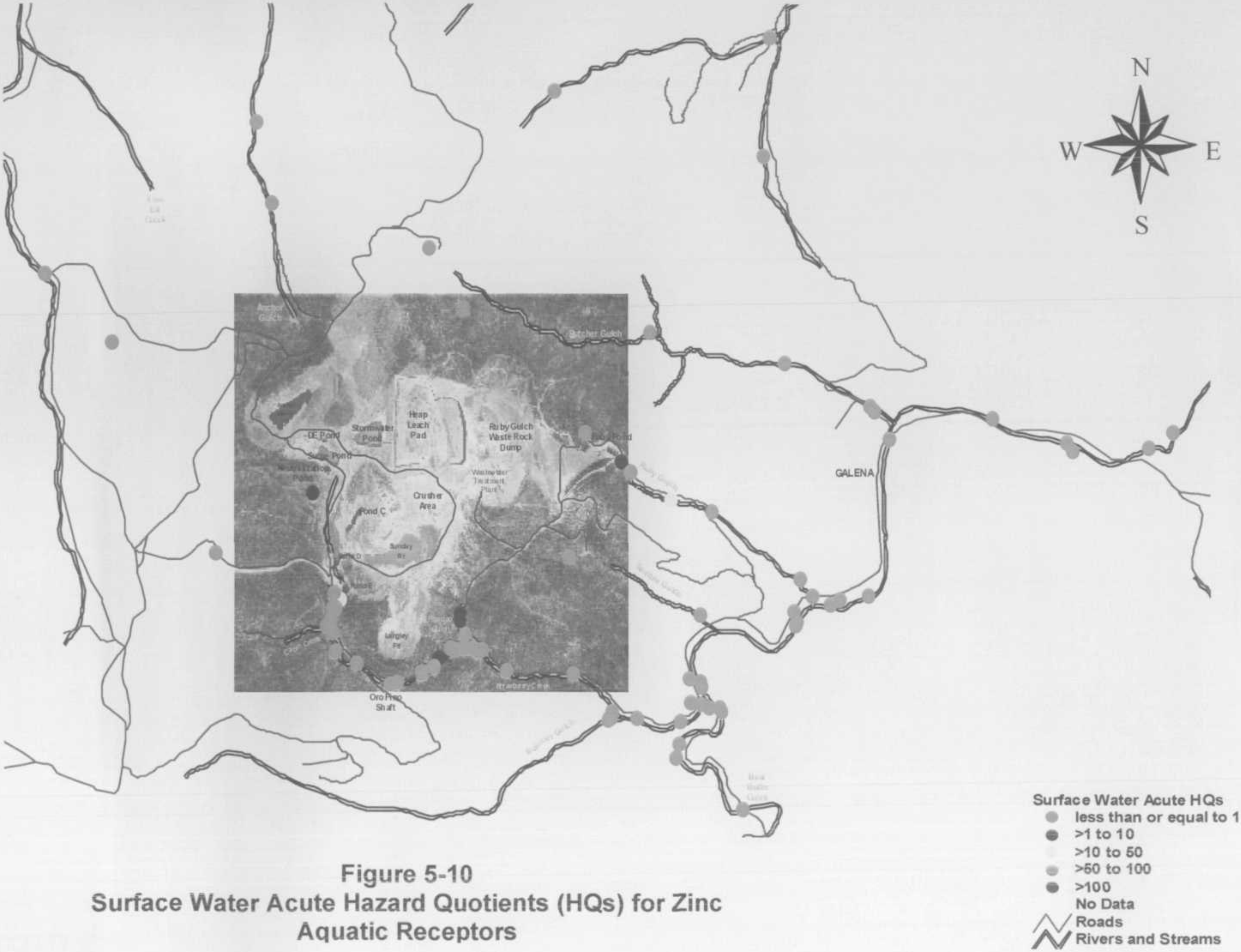


Figure 5-10
Surface Water Acute Hazard Quotients (HQs) for Zinc Aquatic Receptors

acute sw HQ maps2.doc (gem_revised2.apr)

Figure 5-11
Surface Water Chronic Hazard Quotients (HQs) for Aluminum Aquatic Receptors

chronic sw HQ maps2.doc (gem_revised2.apr)

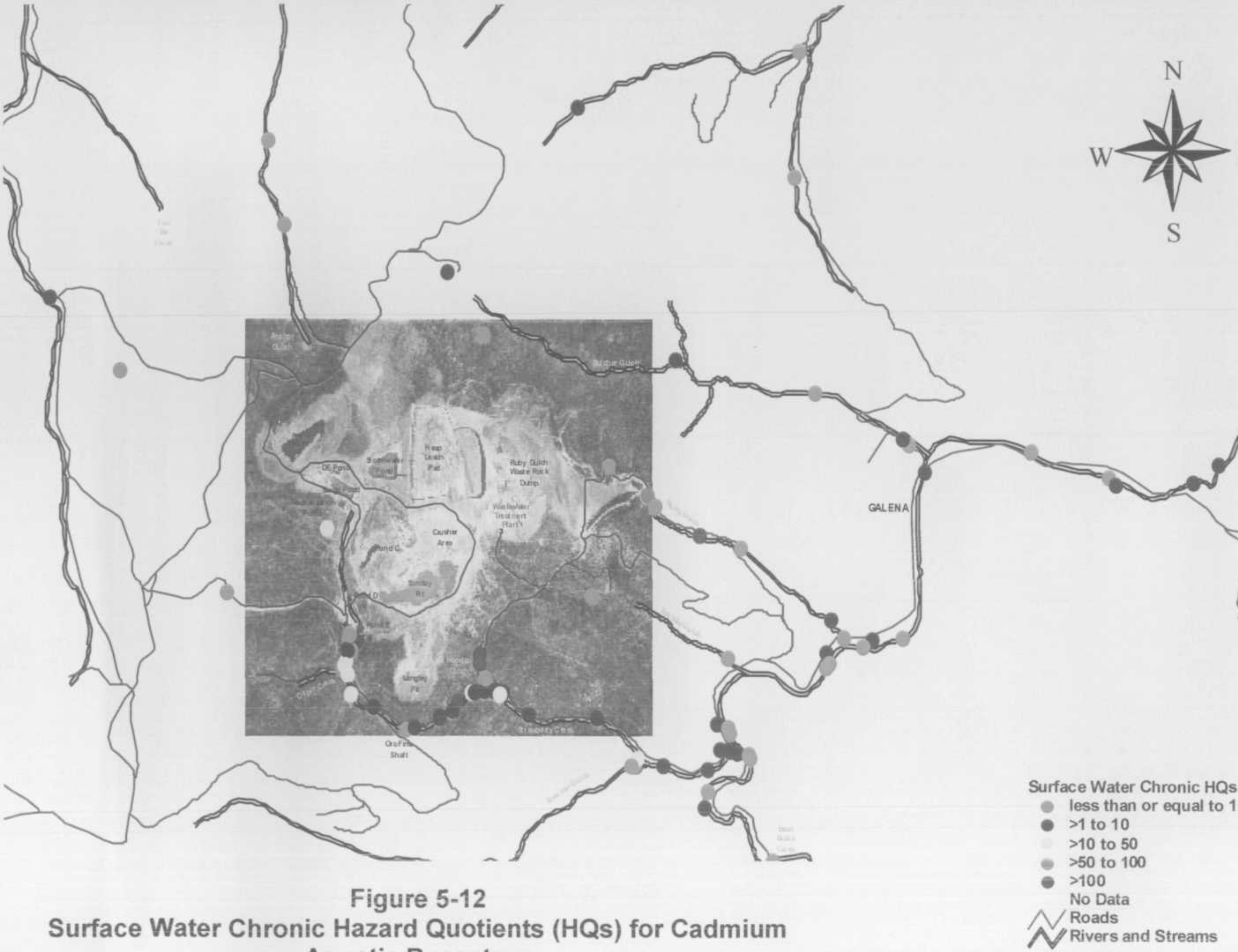


Figure 5-12
Surface Water Chronic Hazard Quotients (HQs) for Cadmium Aquatic Receptors

chronic sw HQ maps2.doc (gem_revised2.apr)

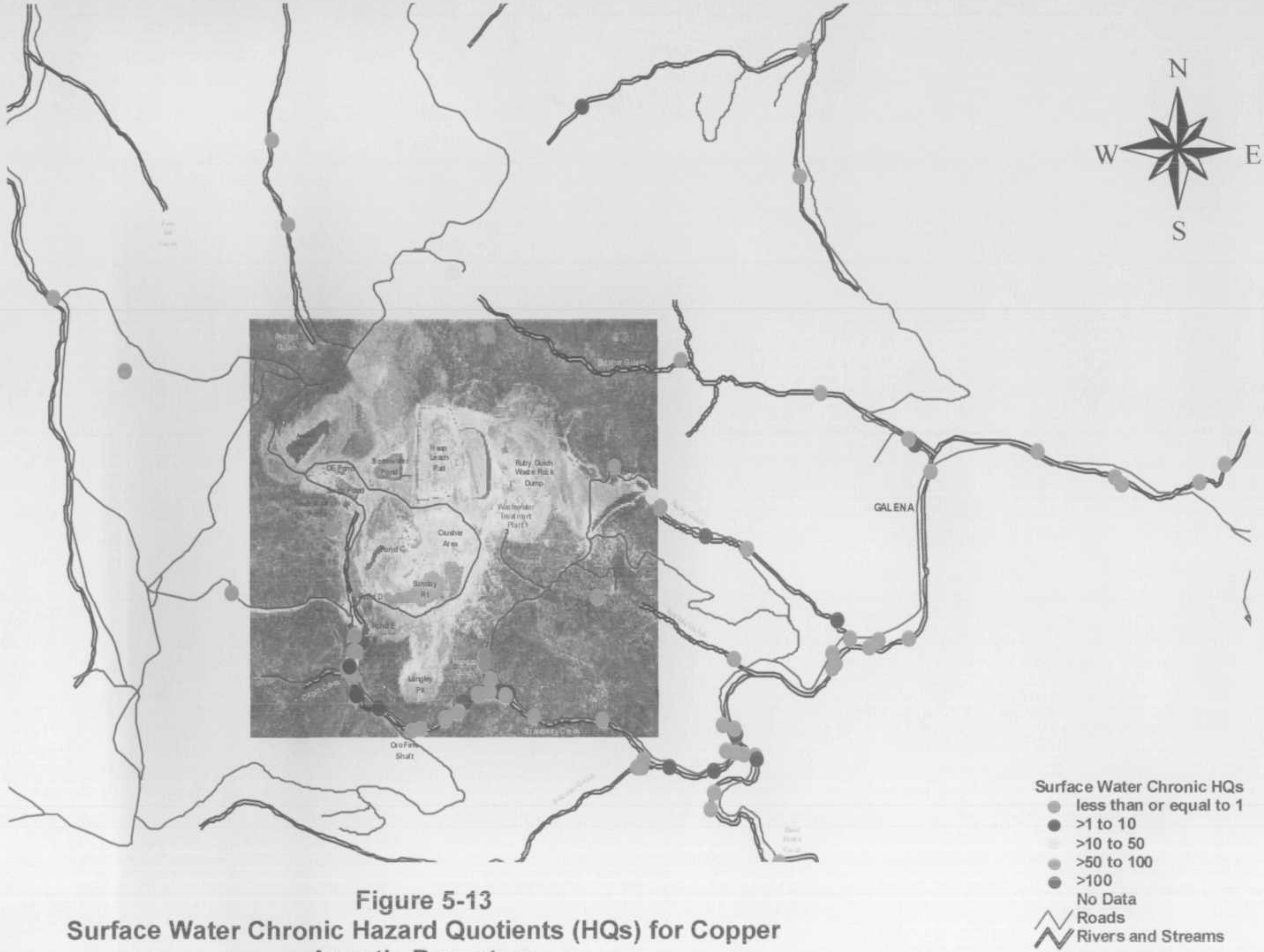


Figure 5-13
Surface Water Chronic Hazard Quotients (HQs) for Copper Aquatic Receptors

chronic sw HQ maps2.doc (gem_revised2.apr)

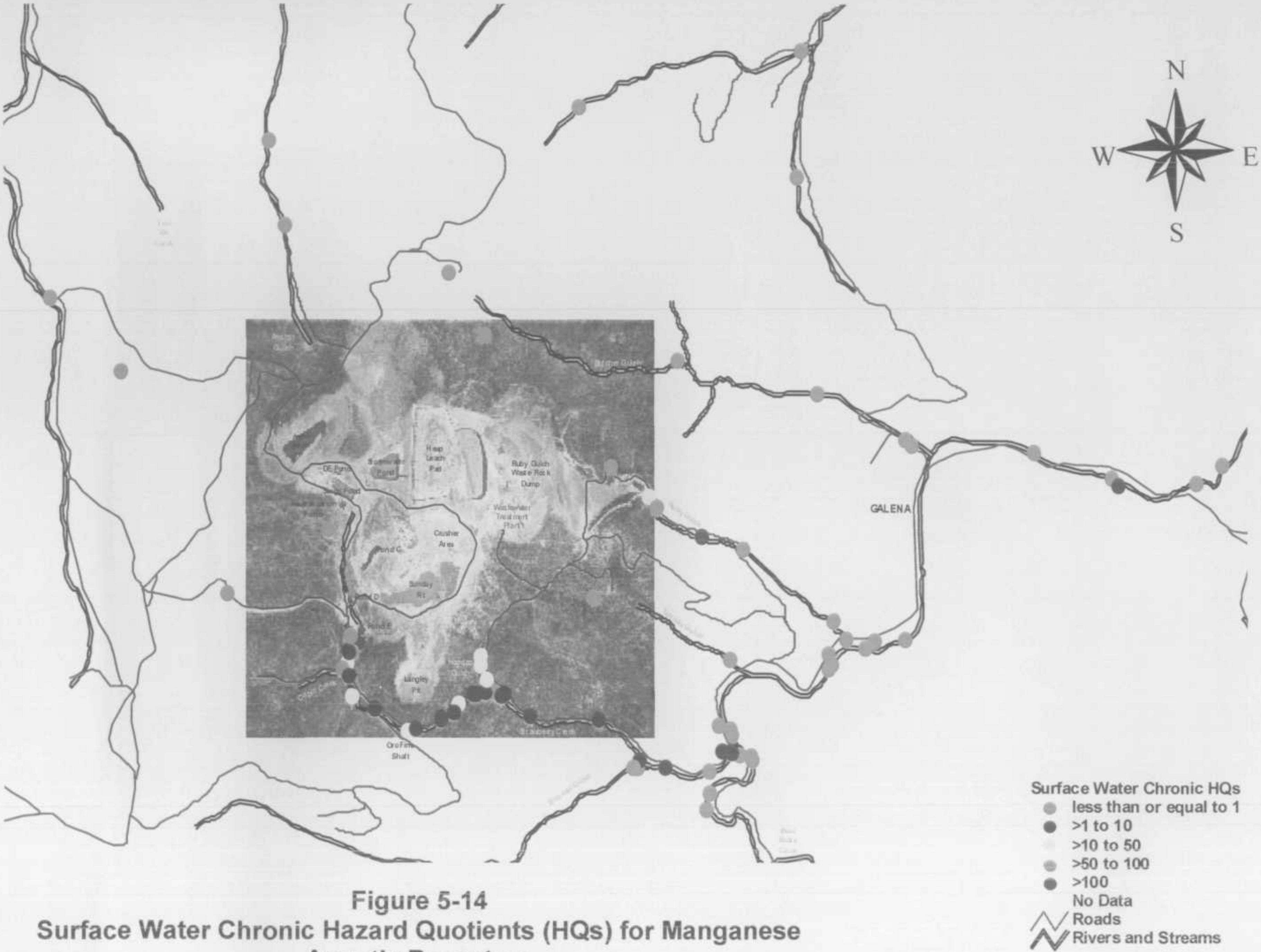


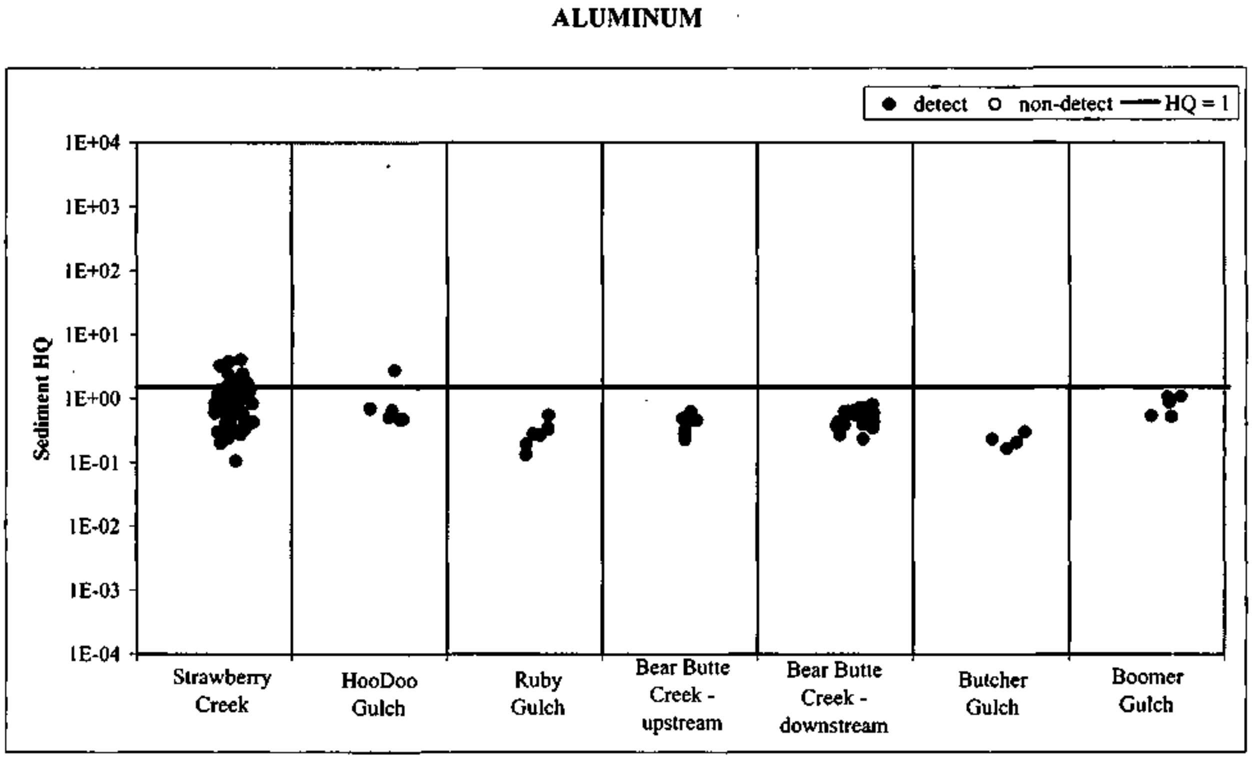
Figure 5-14
Surface Water Chronic Hazard Quotients (HQs) for Manganese Aquatic Receptors

chronic sw HQ maps2.doc (gem_revised2.apr)

Figure 5-15
Surface Water Chronic Hazard Quotients (HQs) for Zinc Aquatic Receptors

chronic sw HQ maps2.doc (gem_revised2.apr)

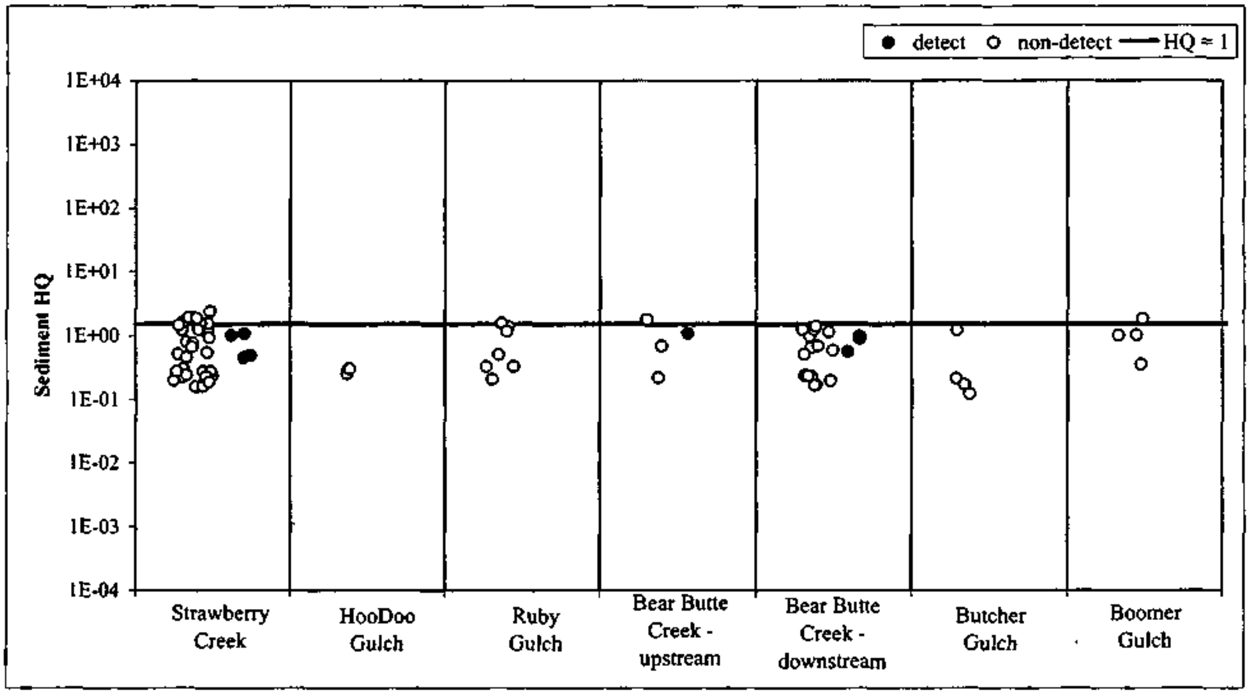
Figure 5-16a
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	13	1	0	0	0	0	0
HQs ≤ 1:	36	5	7	9	23	4	5
HQs > 1:	27%	17%	0%	0%	0%	0%	0%
HQs ≤ 1:	73%	83%	100%	100%	100%	100%	100%
Category:	moderate	minimal	none	none	none	none	none

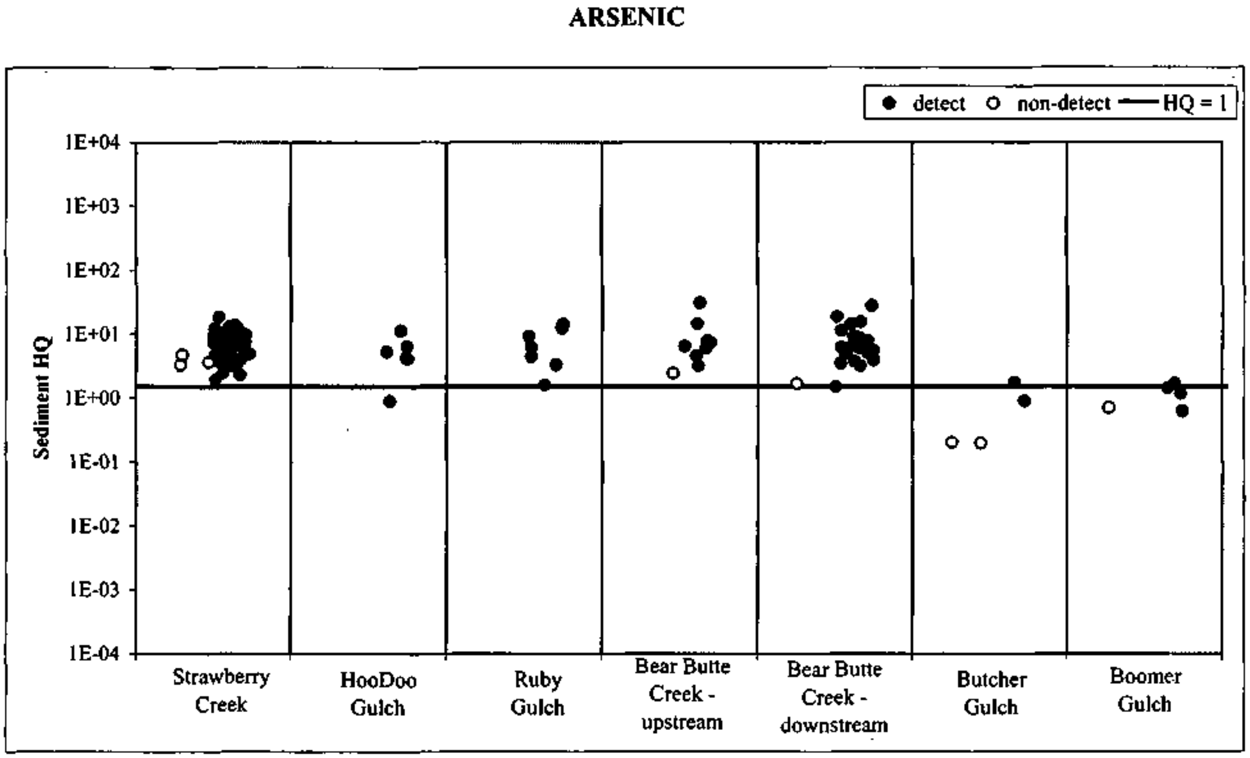
Figure 5-16b
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment

ANTIMONY



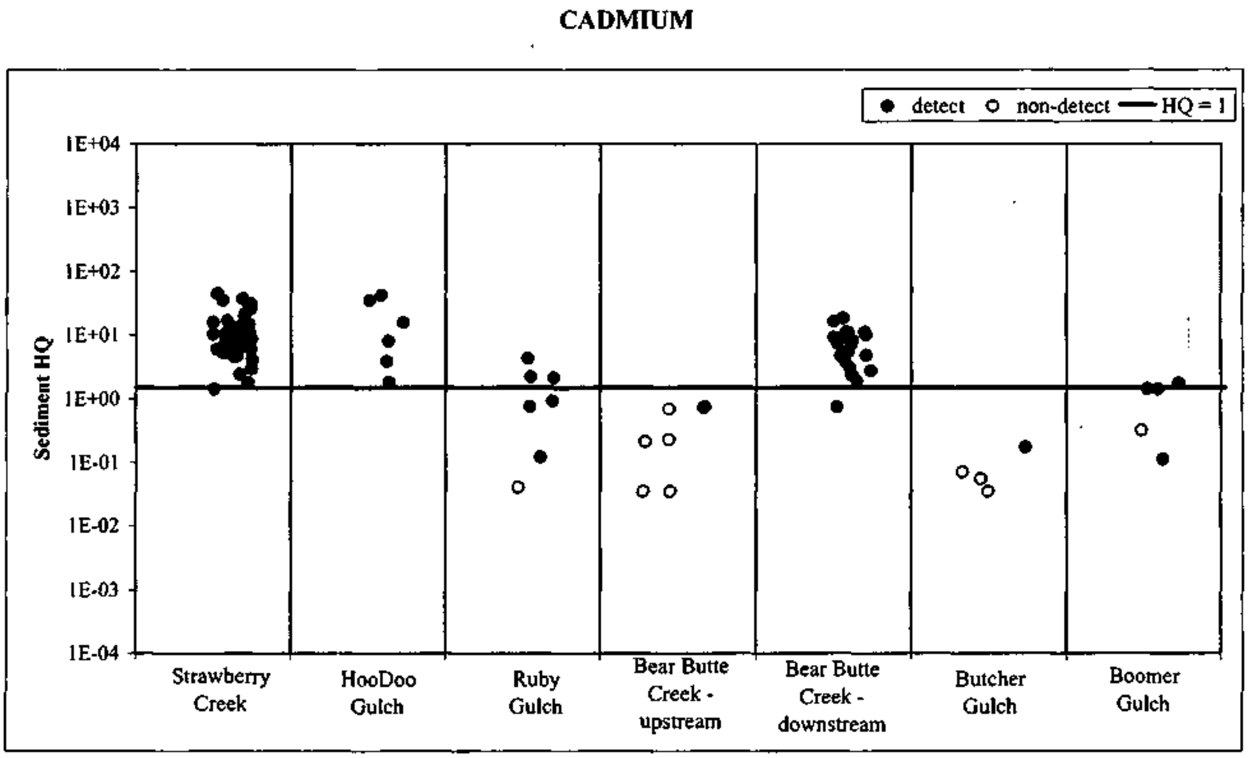
	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	4	0	0	1	3	0	0
Total Samples:	35	3	7	4	19	4	4
HQs > 1:	6	0	1	1	0	0	1
HQs ≤ 1:	29	3	6	3	19	4	3
HQs > 1:	17%	0%	14%	25%	0%	0%	25%
HQs ≤ 1:	83%	100%	86%	75%	100%	100%	75%
Category:	minimal	none	minimal	moderate	none	none	moderate

Figure 5-16c
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	46	6	7	8	22	2	4
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	49	5	7	9	22	1	1
HQs ≤ 1:	0	1	0	0	1	3	4
HQs > 1:	100%	83%	100%	100%	96%	25%	20%
HQs ≤ 1:	0%	17%	0%	0%	4%	75%	80%
Category:	severe	severe	severe	severe	severe	moderate	minimal

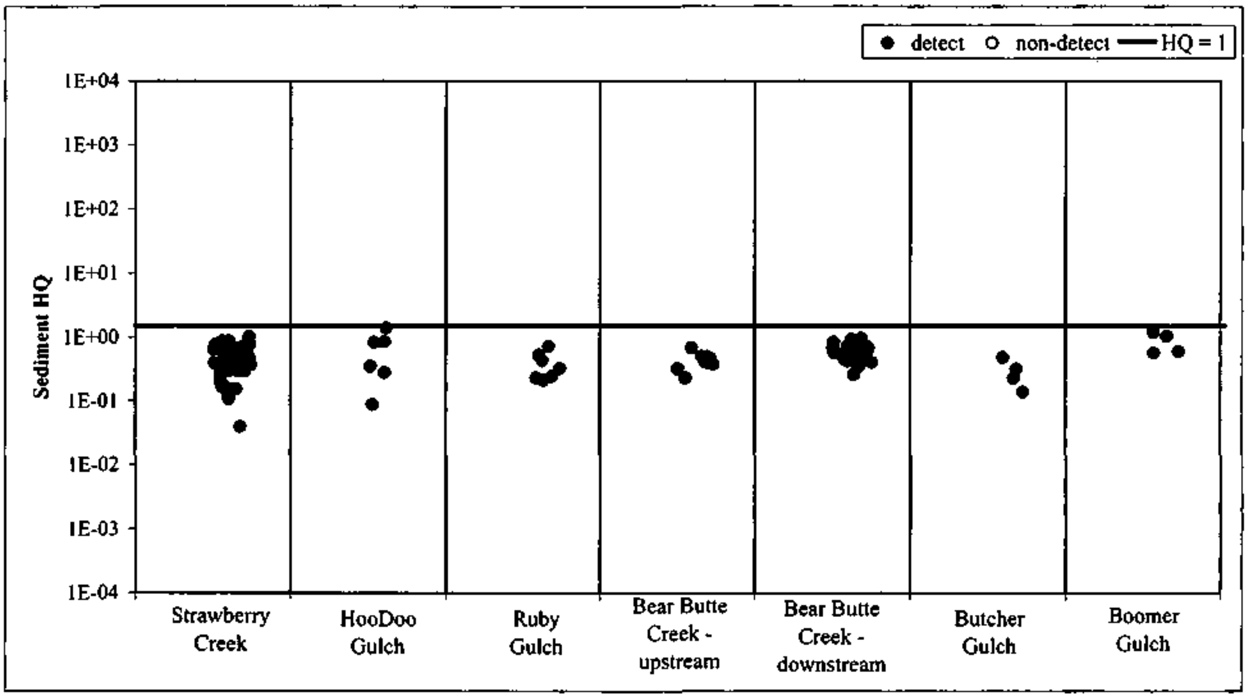
Figure 5-16d
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	6	2	23	1	4
Total Samples:	49	6	7	7	23	4	5
HQs > 1:	48	6	3	0	22	0	1
HQs ≤ 1:	1	0	4	7	1	4	4
HQs > 1:	98%	100%	43%	0%	96%	0%	20%
HQs ≤ 1:	2%	0%	57%	100%	4%	100%	80%
Category:	severe	severe	moderate	none	severe	none	minimal

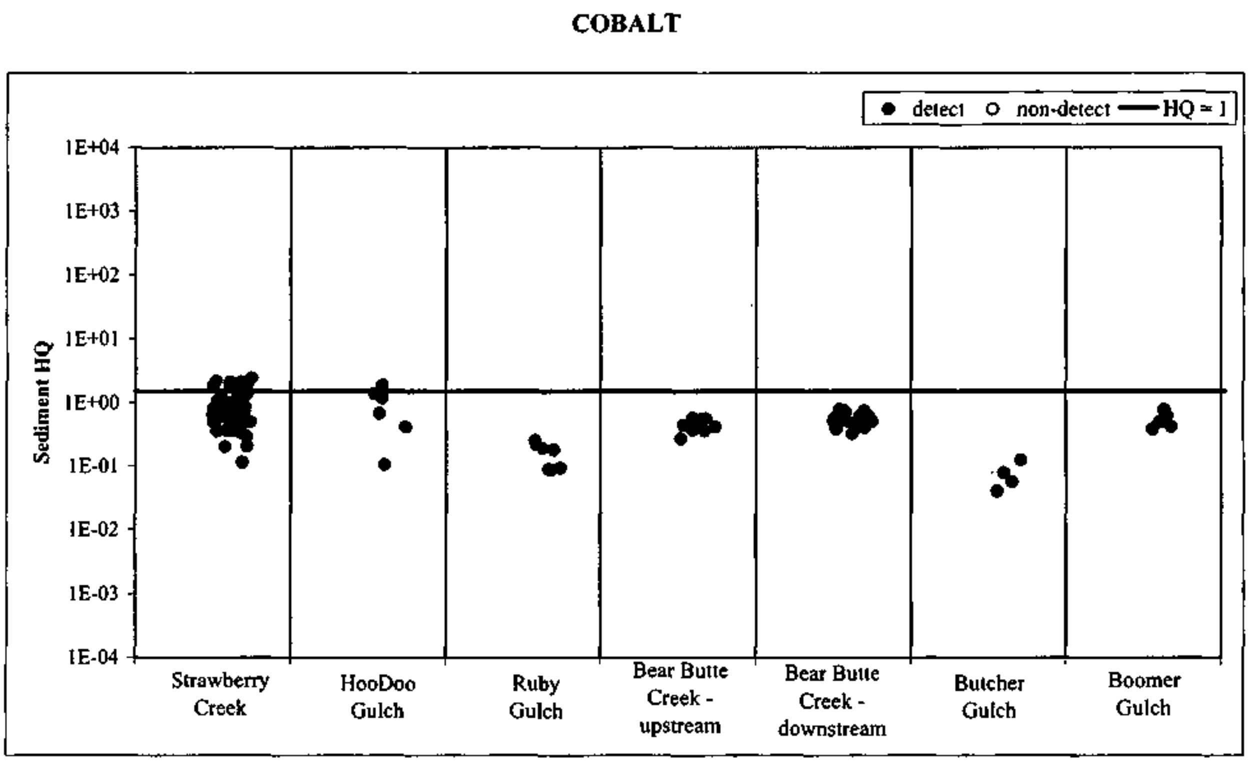
Figure 5-16e
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment

CHROMIUM



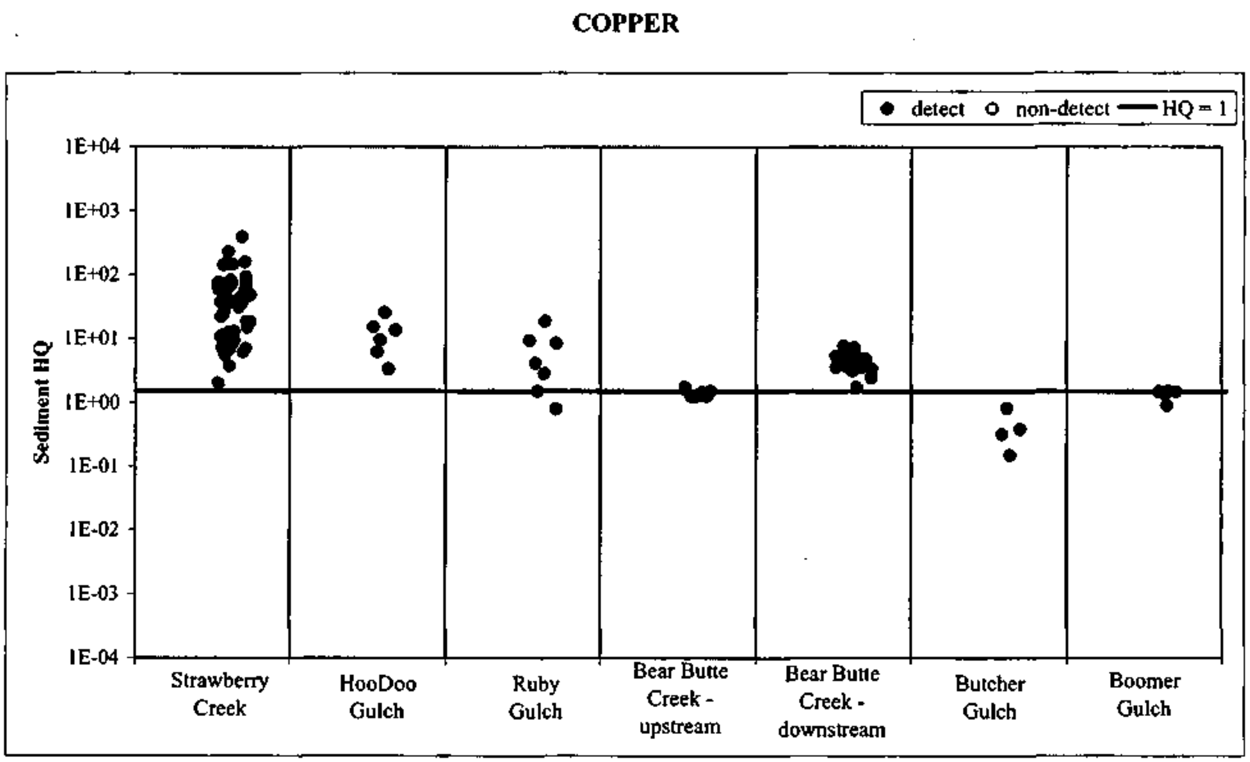
	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	0	0	0	0	0	0	0
HQs ≤ 1:	49	6	7	9	23	4	5
HQs > 1:	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%
Category:	none	none	none	none	none	none	none

Figure 5-16f
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



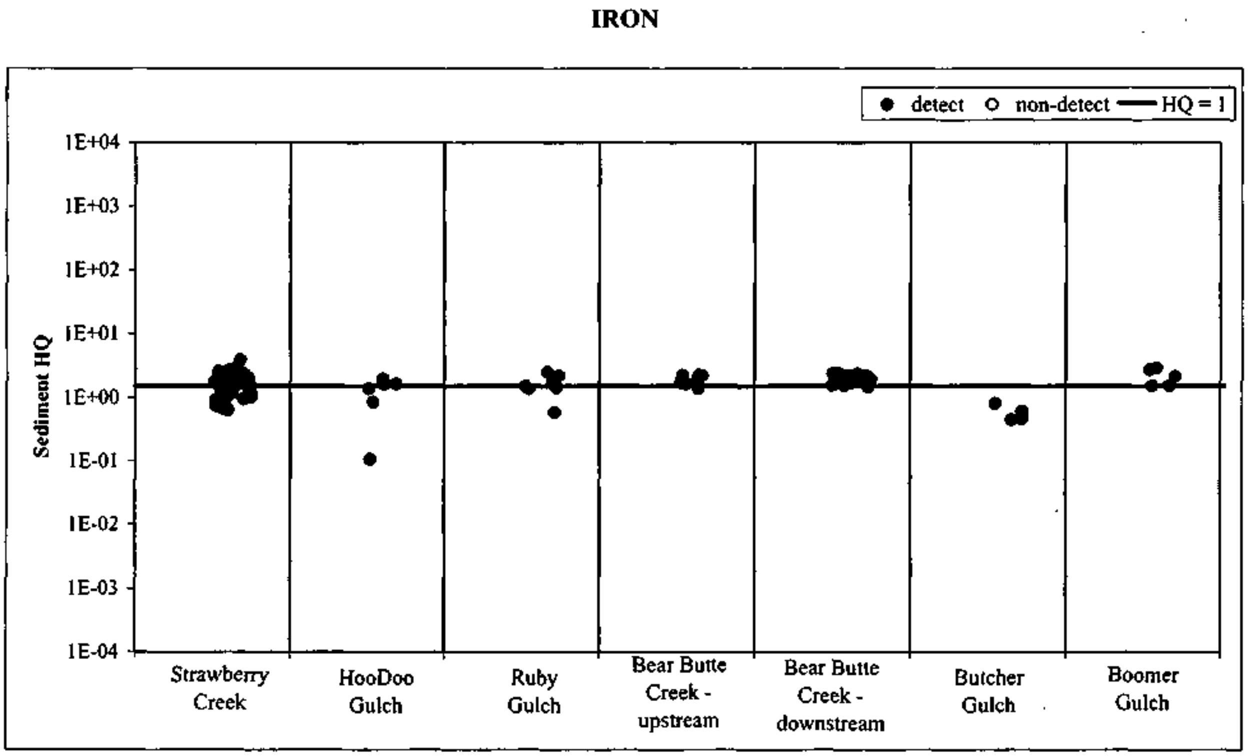
	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	8	1	0	0	0	0	0
HQs ≤ 1:	41	5	7	9	23	4	5
HQs > 1:	16%	17%	0%	0%	0%	0%	0%
HQs ≤ 1:	84%	83%	100%	100%	100%	100%	100%
Category:	minimal	minimal	none	none	none	none	none

Figure 5-16g
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	49	6	5	3	23	0	0
HQs ≤ 1:	0	0	2	6	0	4	5
HQs > 1:	100%	100%	71%	33%	100%	0%	0%
HQs ≤ 1:	0%	0%	29%	67%	0%	100%	100%
Category:	severe	severe	high	moderate	severe	none	none

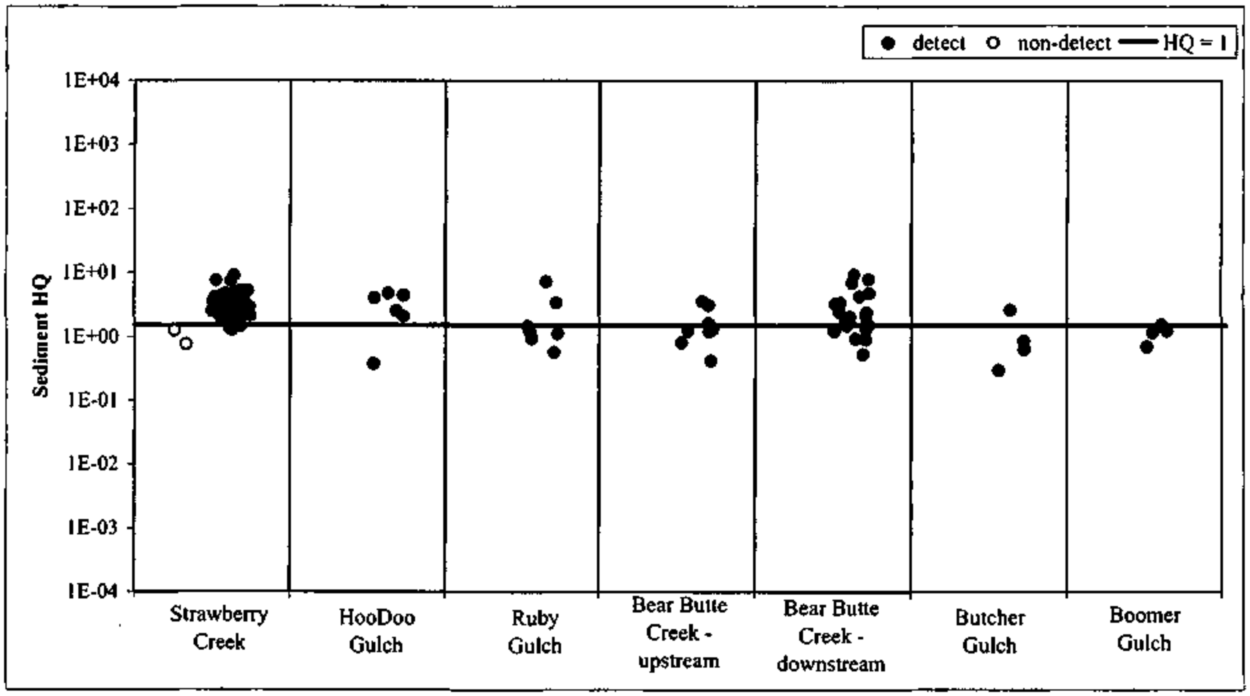
Figure 5-16h
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	33	3	3	8	22	0	5
HQs ≤ 1:	16	3	4	1	1	4	0
HQs > 1:	67%	50%	43%	89%	96%	0%	100%
HQs ≤ 1:	33%	50%	57%	11%	4%	100%	0%
Category:	high	moderate	moderate	severe	severe	none	severe

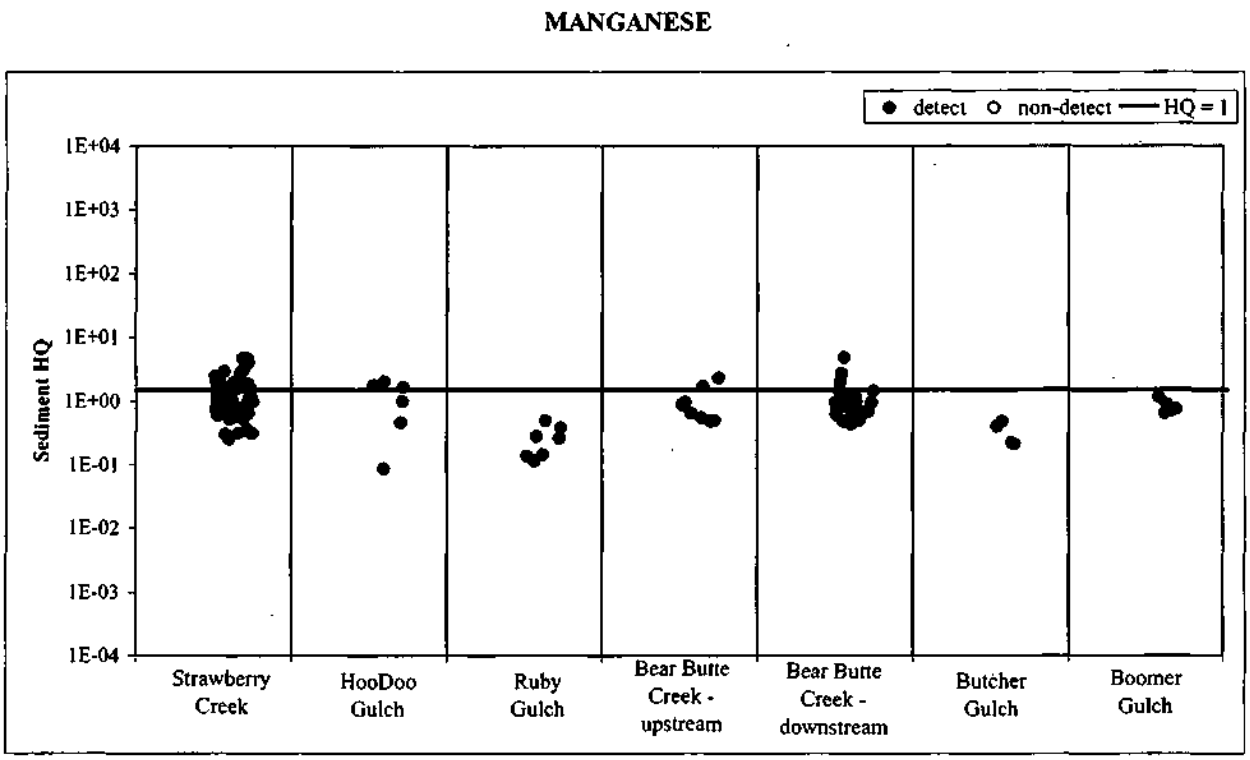
Figure 5-16i
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment

LEAD



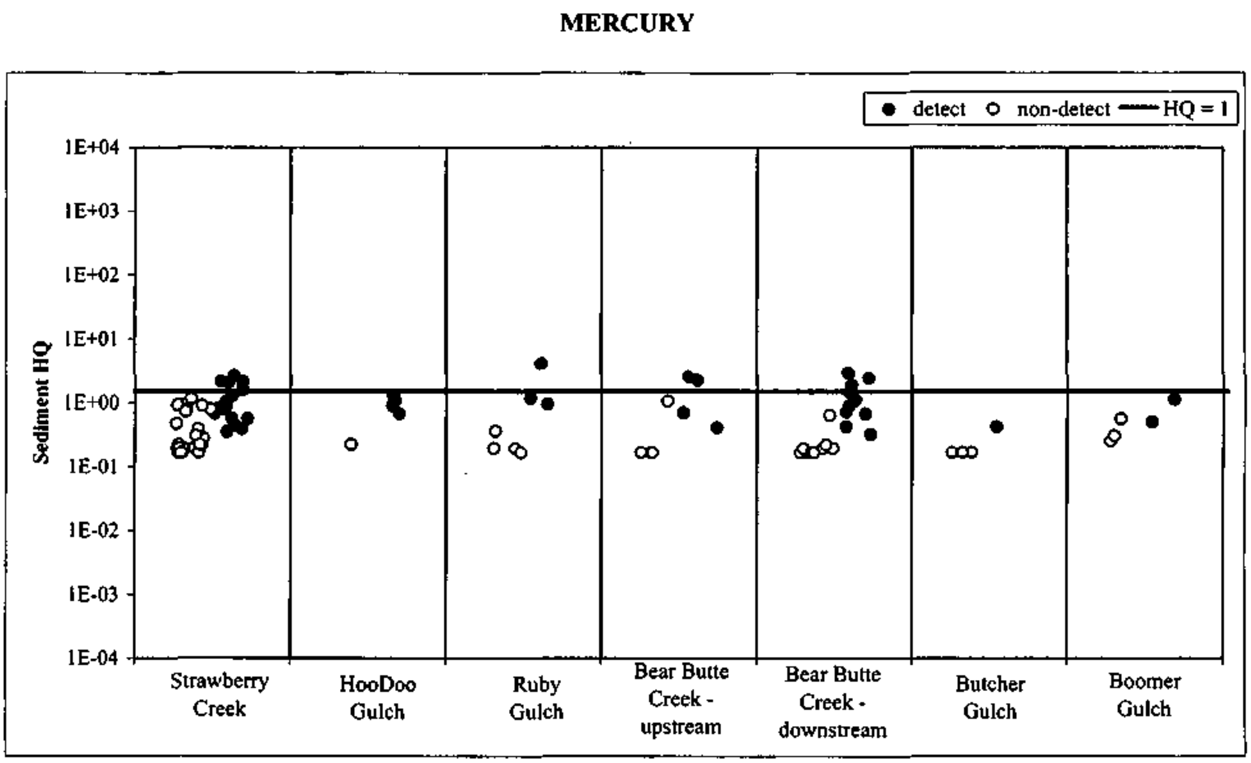
	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	47	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	43	5	2	3	14	1	1
HQs ≤ 1:	6	1	5	6	9	3	4
HQs > 1:	88%	83%	29%	33%	61%	25%	20%
HQs ≤ 1:	12%	17%	71%	67%	39%	75%	80%
Category:	severe	severe	moderate	moderate	high	moderate	minimal

Figure 5-16j
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



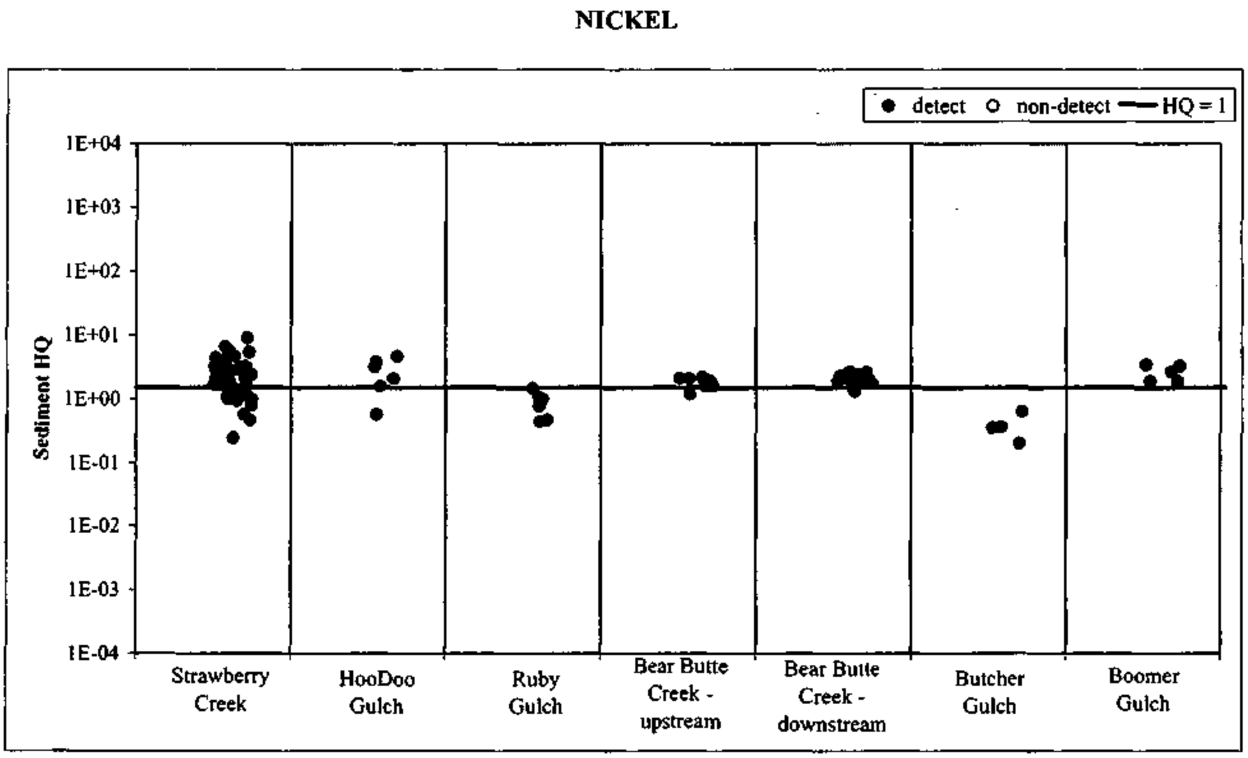
	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	18	3	0	2	3	0	0
HQs ≤ 1:	31	3	7	7	20	4	5
HQs > 1:	37%	50%	0%	22%	13%	0%	0%
HQs ≤ 1:	63%	50%	100%	78%	87%	100%	100%
Category:	moderate	moderate	none	moderate	minimal	none	none

Figure 5-16k
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	16	4	3	4	11	1	2
Total Samples:	38	5	7	8	22	4	5
HQs > 1:	5	0	1	2	3	0	0
HQs ≤ 1:	33	5	6	6	19	4	5
HQs > 1:	13%	0%	14%	25%	14%	0%	0%
HQs ≤ 1:	87%	100%	86%	75%	86%	100%	100%
Category:	minimal	none	minimal	moderate	minimal	none	none

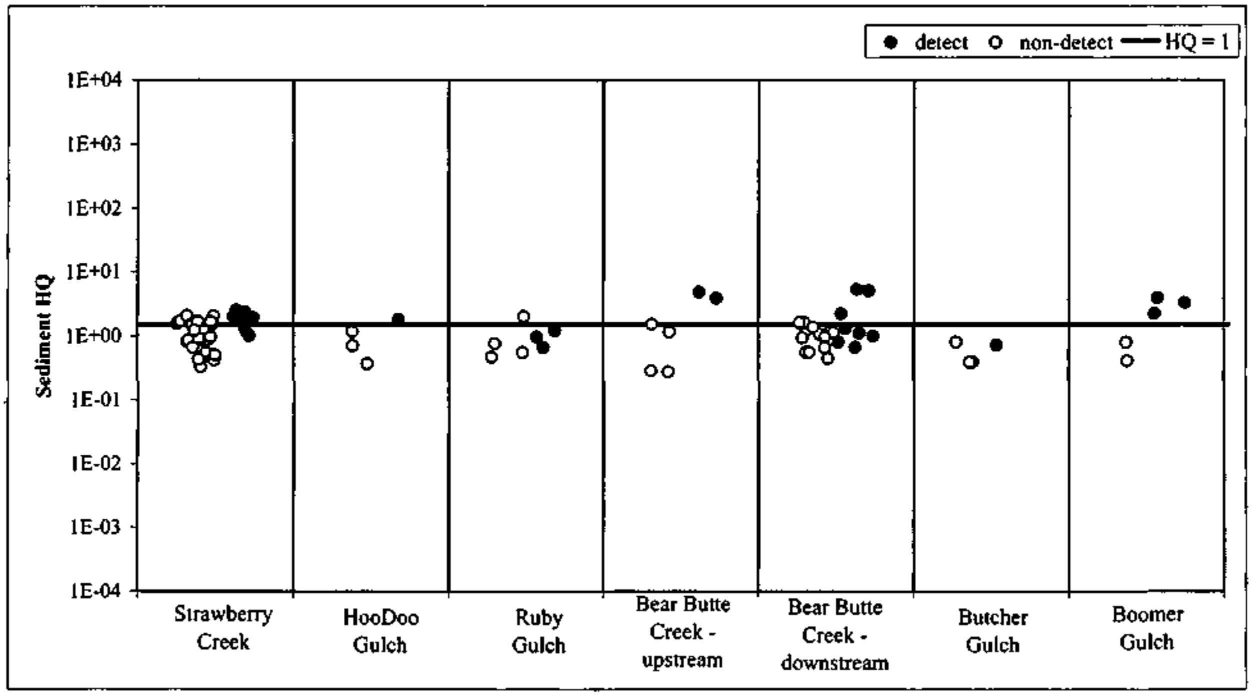
Figure 5-16l
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	33	5	0	8	21	0	5
HQs ≤ 1:	16	1	7	1	2	4	0
HQs > 1:	67%	83%	0%	89%	91%	0%	100%
HQs ≤ 1:	33%	17%	100%	11%	9%	100%	0%
Category:	high	severe	none	severe	severe	none	severe

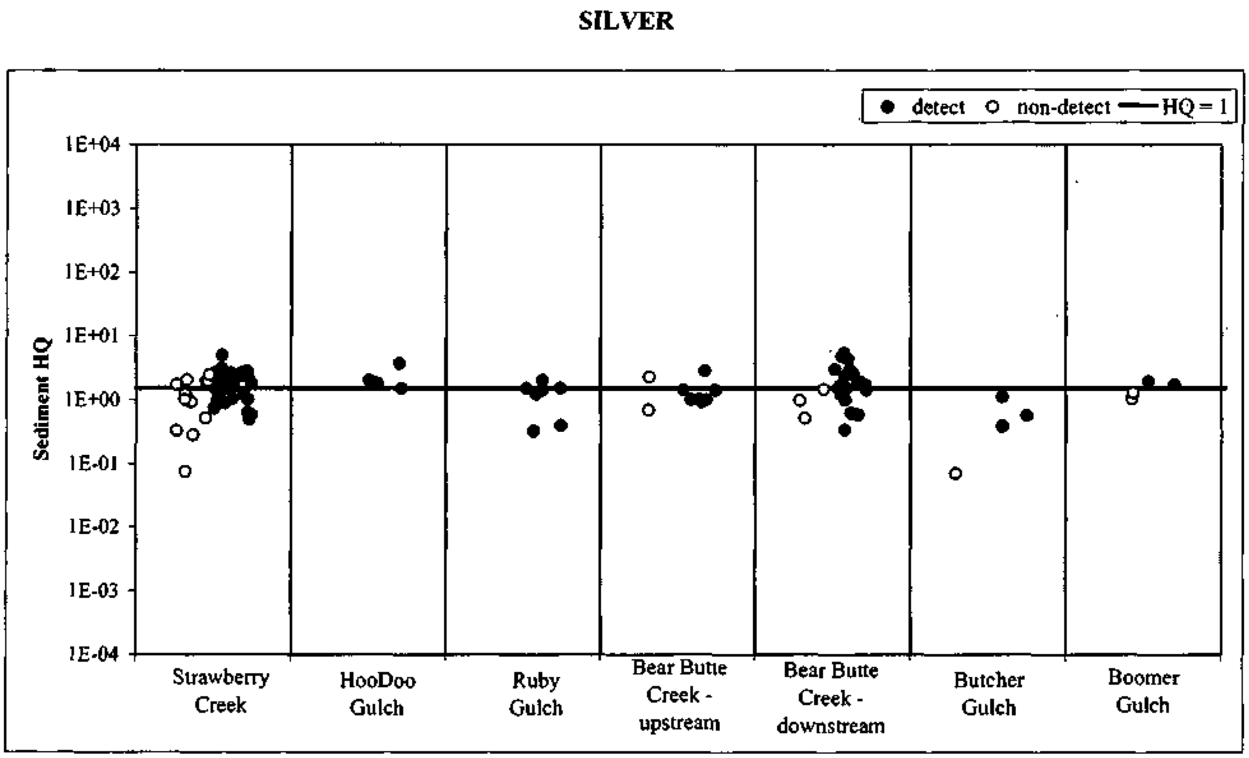
Figure 5-16m
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment

SELENIUM



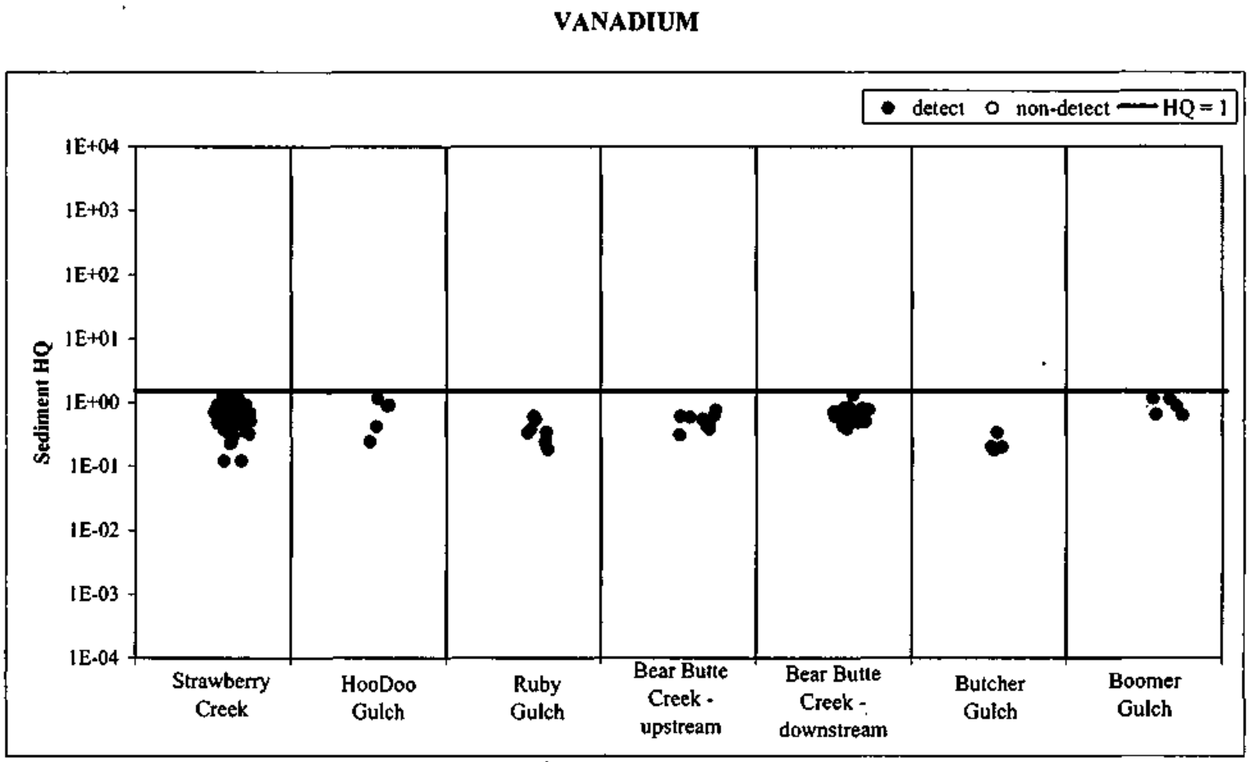
	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	9	1	3	2	8	1	3
Total Samples:	35	4	7	6	22	4	5
HQs > 1:	15	1	1	3	5	0	3
HQs ≤ 1:	20	3	6	3	17	4	2
HQs > 1:	43%	25%	14%	50%	23%	0%	60%
HQs ≤ 1:	57%	75%	86%	50%	77%	100%	40%
Category:	moderate	moderate	minimal	moderate	moderate	none	high

Figure 5-16n
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



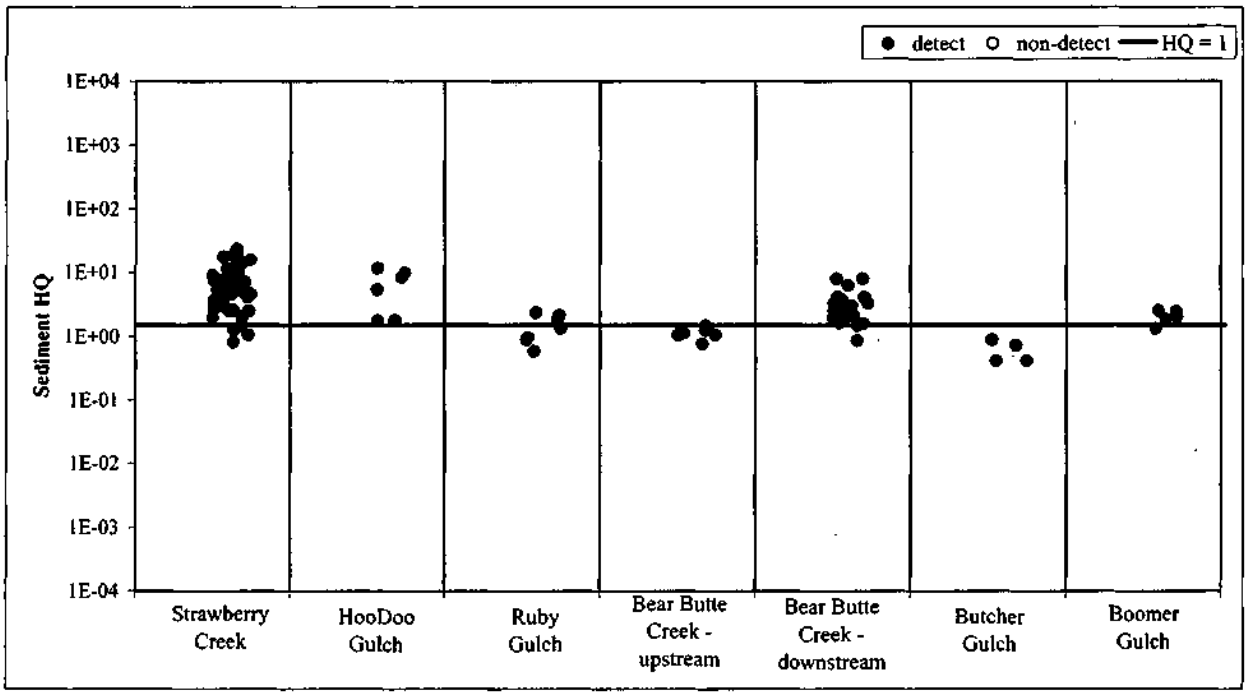
	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	31	4	7	7	20	3	2
Total Samples:	43	4	7	9	23	4	4
HQs > 1:	24	4	3	2	14	0	2
HQs ≤ 1:	19	0	4	7	9	4	2
HQs > 1:	56%	100%	43%	22%	61%	0%	50%
HQs ≤ 1:	44%	0%	57%	78%	39%	100%	50%
Category:	high	severe	moderate	moderate	high	none	moderate

Figure 5-16o
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	5	7	9	23	4	5
Total Samples:	49	5	7	9	23	4	5
HQs > 1:	0	0	0	0	0	0	0
HQs ≤ 1:	49	5	7	9	23	4	5
HQs > 1:	0%	0%	0%	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%	100%	100%	100%
Category:	none	none	none	none	none	none	none

Figure 5-16p
Benthic Invertebrate HQs for Direct Contact with COPCs in Sediment



	Site	Site	Site	Reference	Site	Reference	Reference
	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch	Boomer Gulch
Detect Samples:	49	6	7	9	23	4	5
Total Samples:	49	6	7	9	23	4	5
HQs > 1:	45	6	3	0	21	0	4
HQs ≤ 1:	4	0	4	9	2	4	1
HQs > 1:	92%	100%	43%	0%	91%	0%	80%
HQs ≤ 1:	8%	0%	57%	100%	9%	100%	20%
Category:	severe	severe	moderate	none	severe	none	high

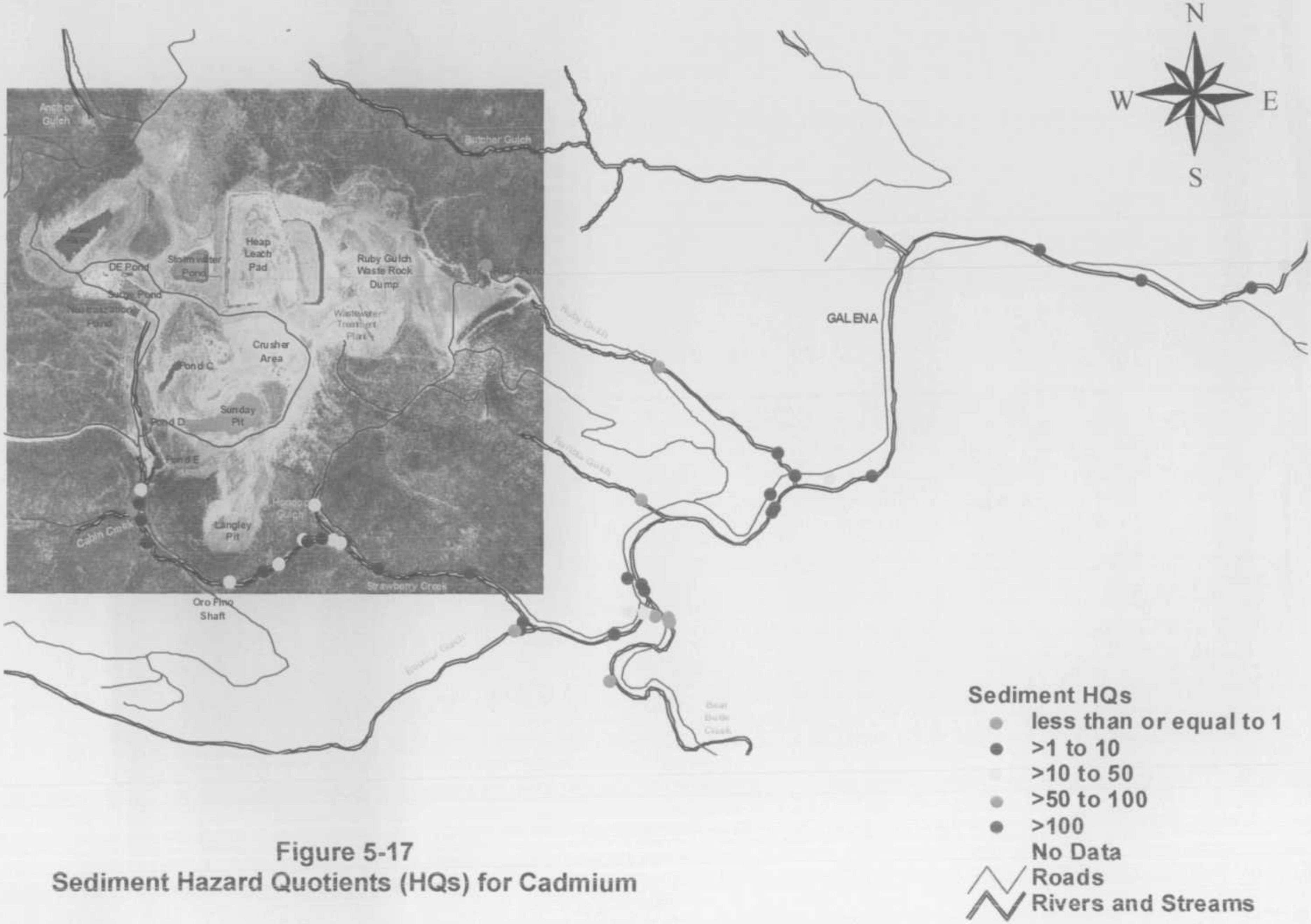


Figure 5-17
Sediment Hazard Quotients (HQs) for Cadmium

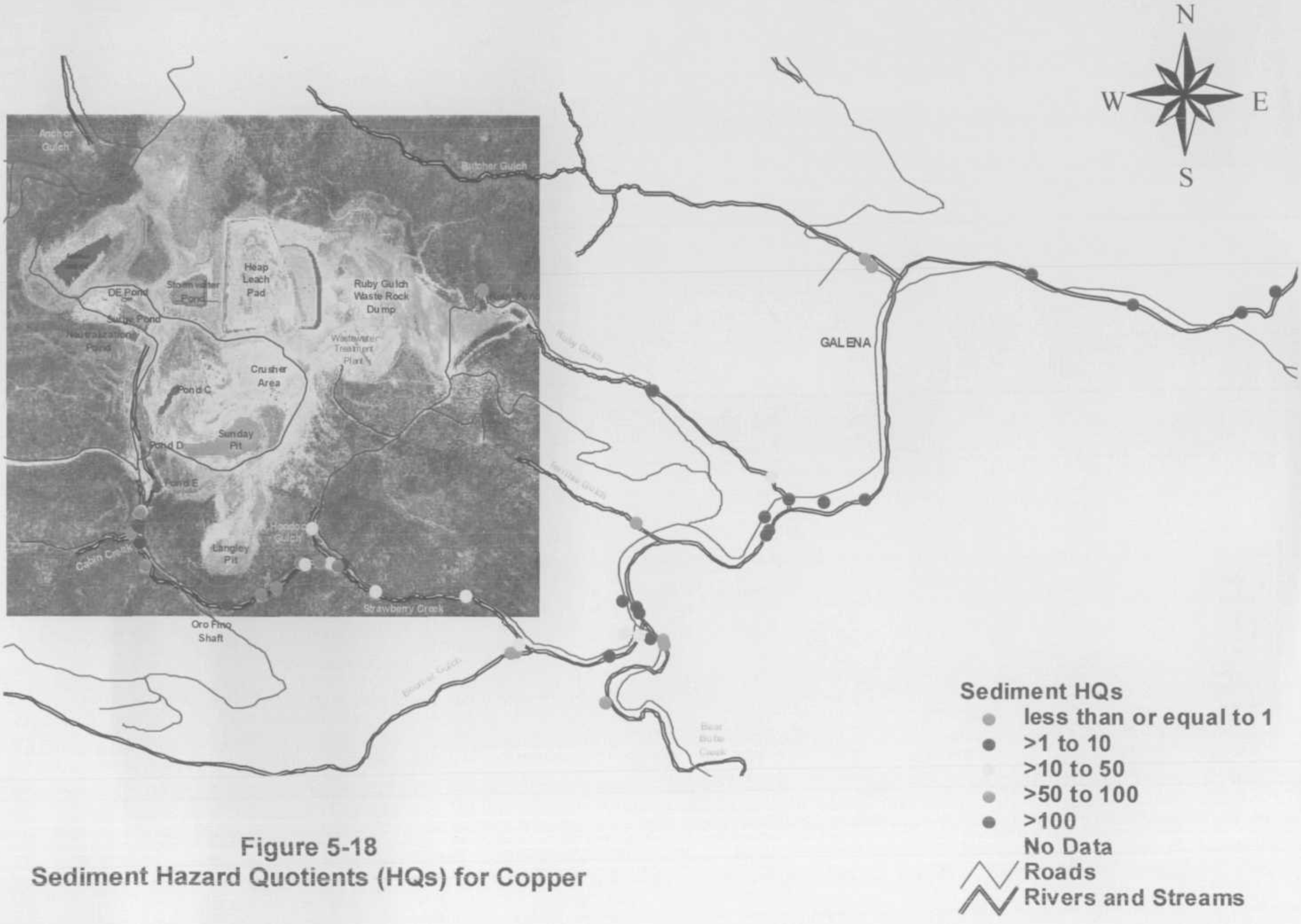


Figure 5-18
Sediment Hazard Quotients (HQs) for Copper

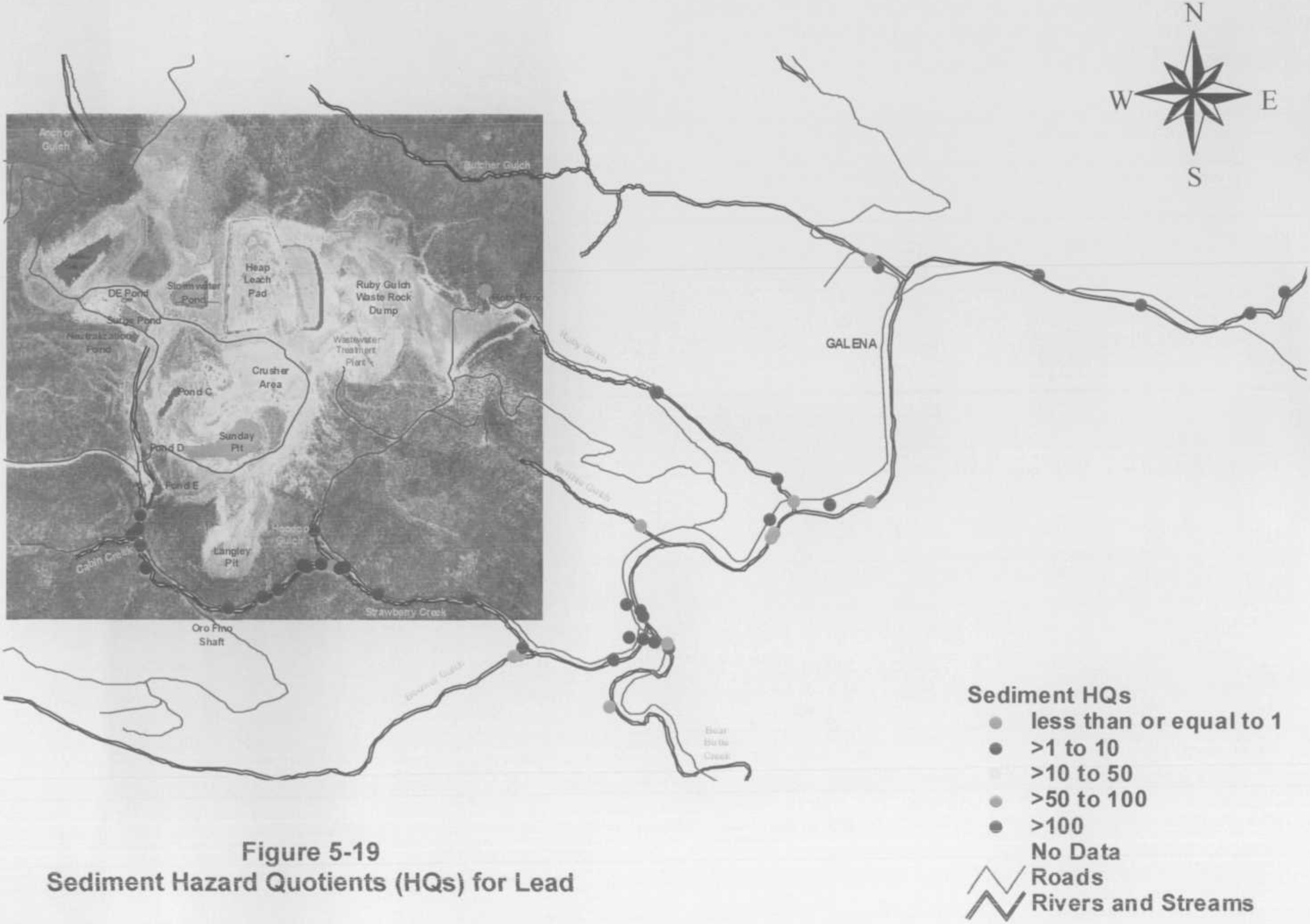


Figure 5-19
Sediment Hazard Quotients (HQs) for Lead

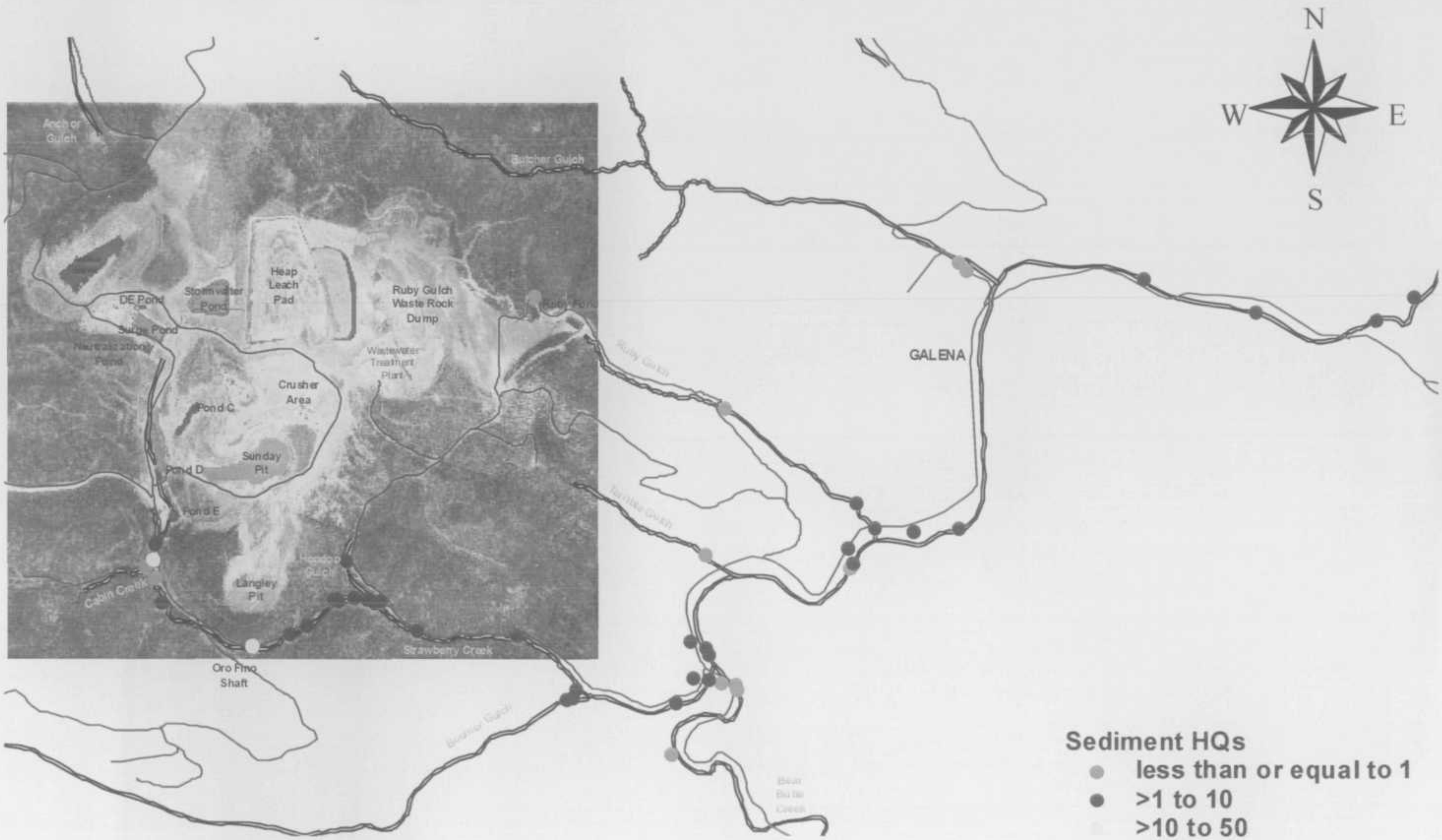
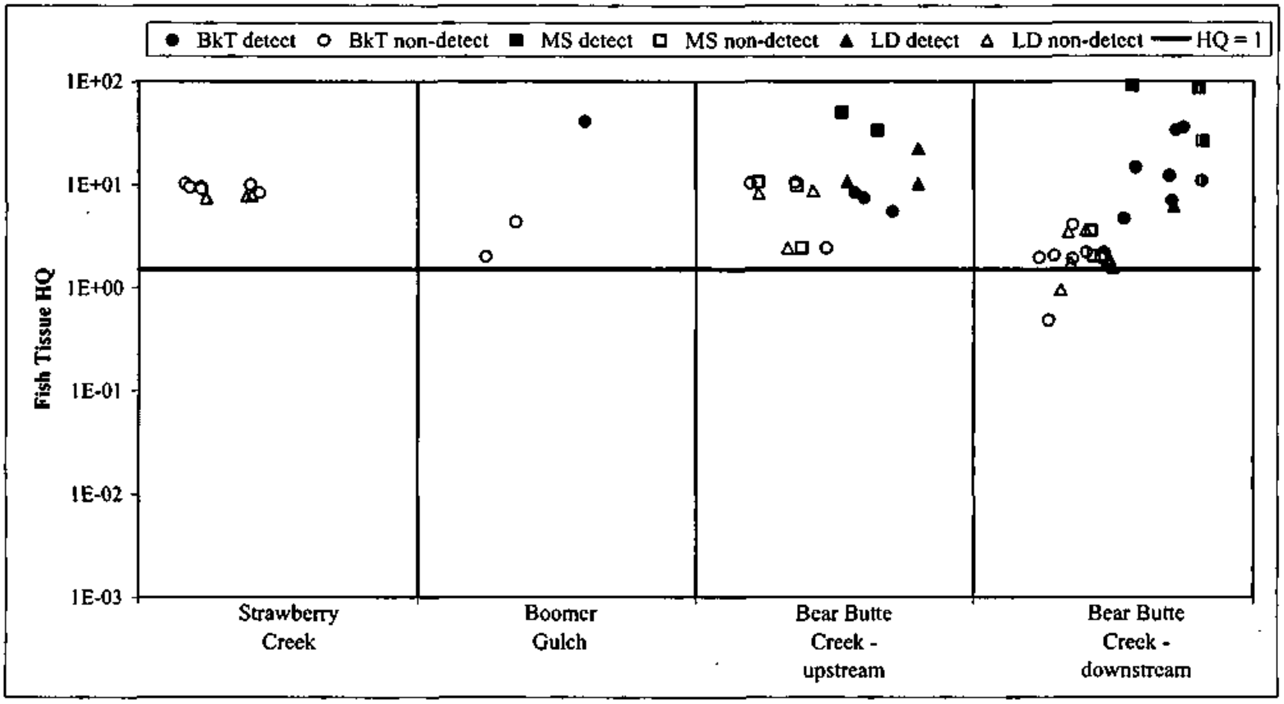


Figure 5-20
Sediment Hazard Quotients (HQs) for Zinc

sediment HQ maps2.doc (gem_revised2.apr)

Figure 5-21a
Summary of Risks to Fish Based on Comparisons to Fish Tissue MATCs

ALUMINUM

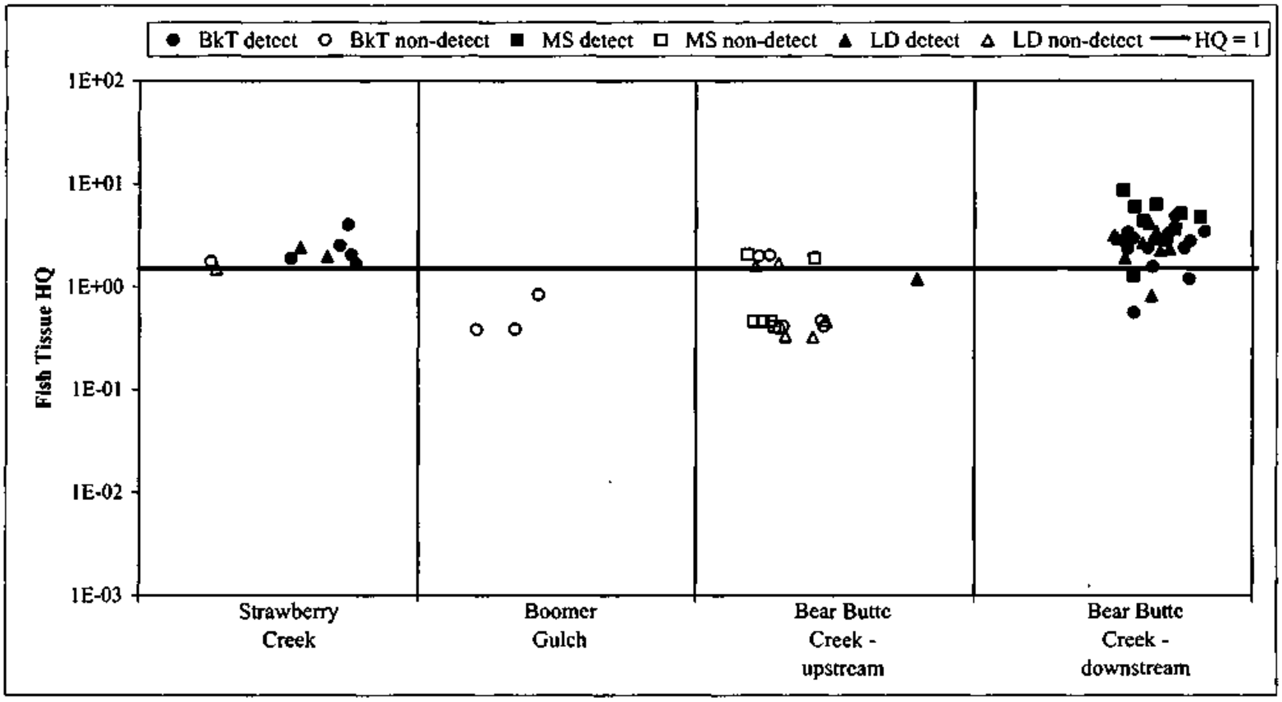


BkT = Brook Trout; MS = Mountain Sucker; LD = Longnose Dace

	Site	Reference	Reference	Site
	Strawberry Creek	Boomer Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream
Detect Samples:	0	1	9	14
Total Samples:	9	3	18	33
HQs > 1:	9	3	18	31
HQs ≤ 1:	0	0	0	2
HQs > 1:	100%	100%	100%	94%
HQs ≤ 1:	0%	0%	0%	6%
Category:	severe	severe	severe	severe

Figure 5-21b
Summary of Risks to Fish Based on Comparisons to Fish Tissue MATCs

CADMIUM

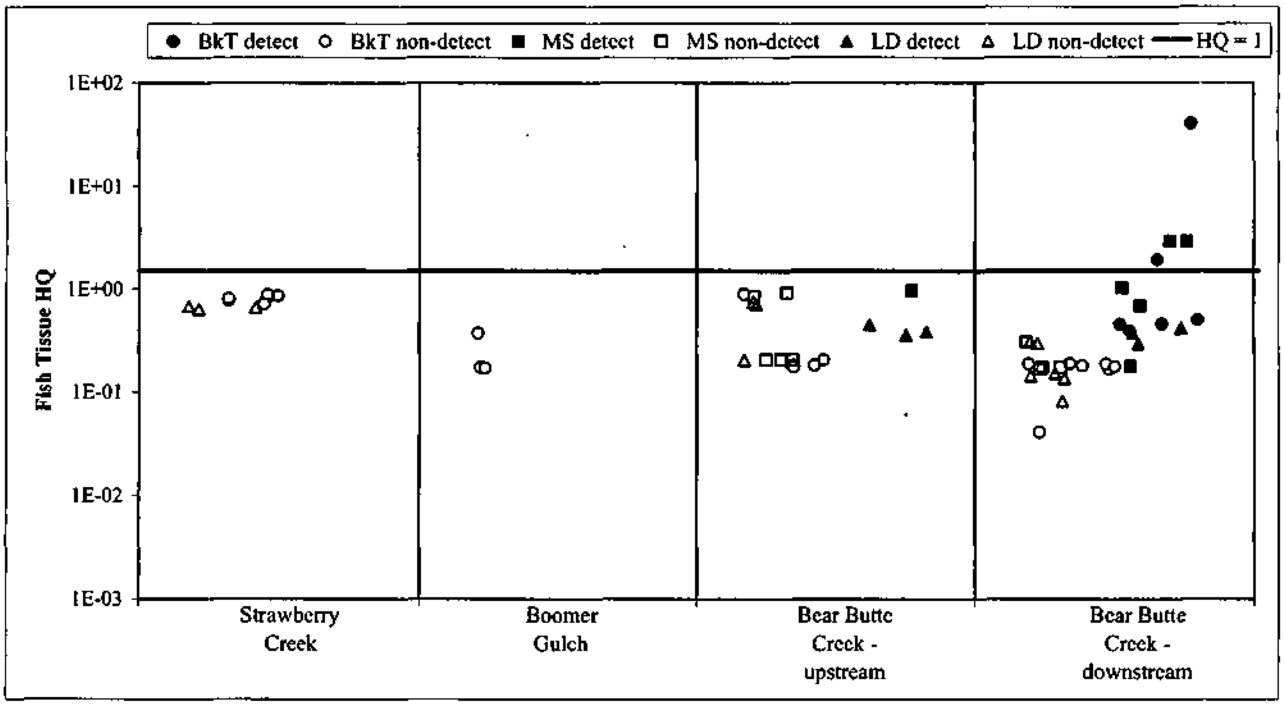


BkT = Brook Trout; MS = Mountain Sucker; LD = Longnose Dace

	Site	Reference	Reference	Site
	Strawberry Creek	Boomer Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream
Detect Samples:	7	0	1	33
Total Samples:	9	3	18	33
HQs > 1:	8	0	6	29
HQs ≤ 1:	1	3	12	4
HQs > 1:	89%	0%	33%	88%
HQs ≤ 1:	11%	100%	67%	12%
Category:	severe	none	moderate	severe

Figure 5-21c
Summary of Risks to Fish Based on Comparisons to Fish Tissue MATCs

CHROMIUM

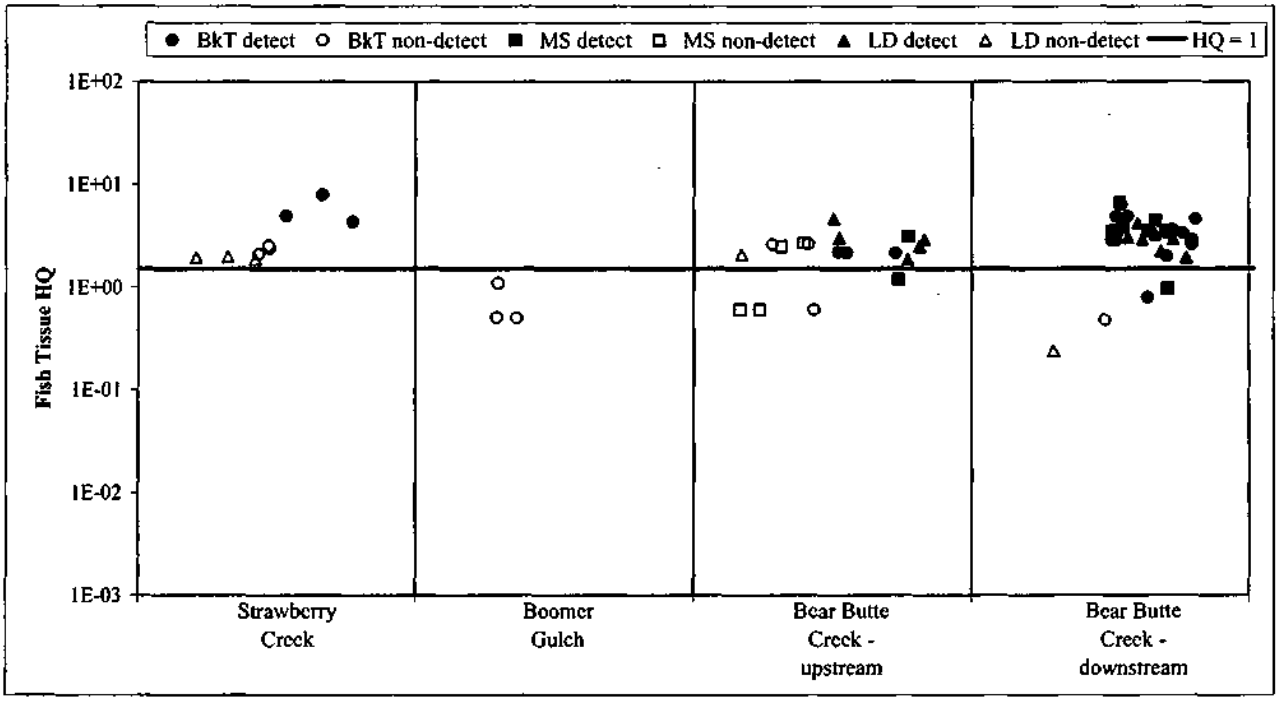


BkT = Brook Trout; MS = Mountain Sucker; LD = Longnose Dace

	Site	Reference	Reference	Site
	Strawberry Creek	Boomer Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream
Detect Samples:	0	0	4	14
Total Samples:	9	3	18	33
HQs > 1:	0	0	0	4
HQs ≤ 1:	9	3	18	29
HQs > 1:	0%	0%	0%	12%
HQs ≤ 1:	100%	100%	100%	88%
Category:	none	none	none	minimal

Figure 5-21d
Summary of Risks to Fish Based on Comparisons to Fish Tissue MATCs

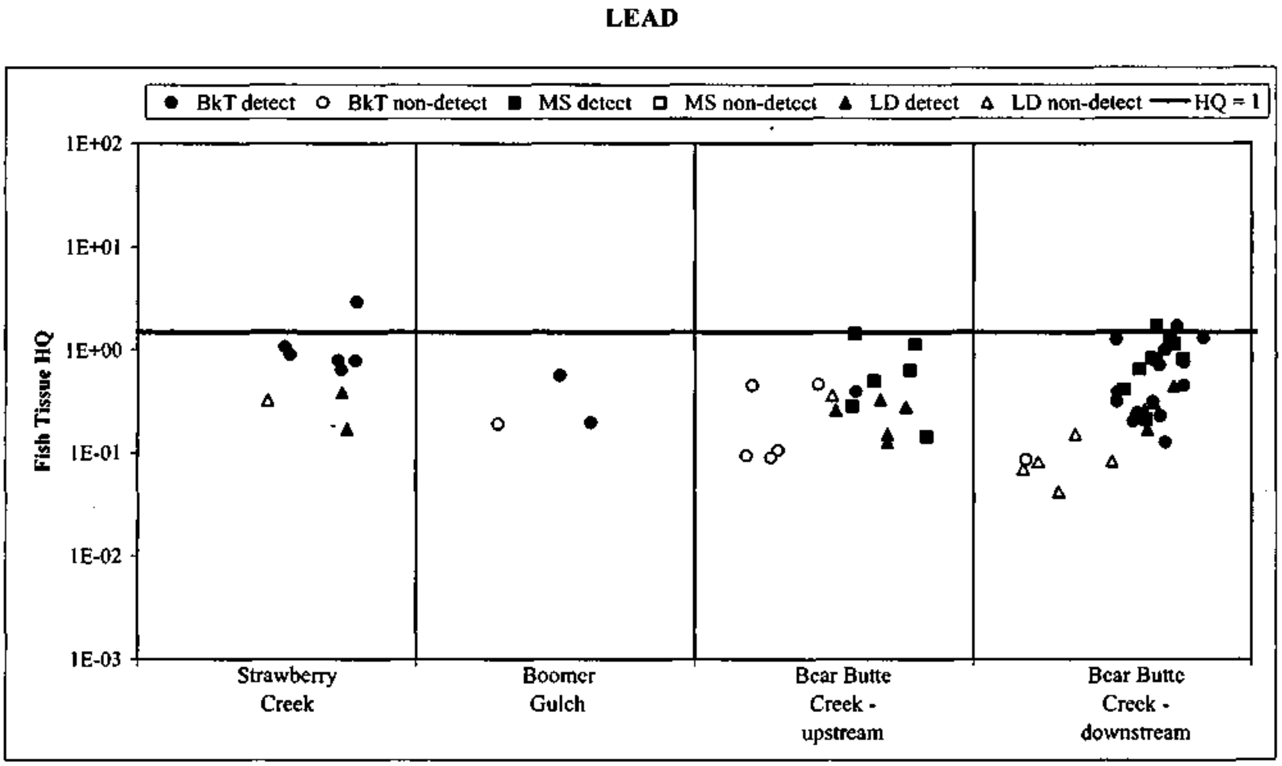
COPPER



BkT = Brook Trout; MS = Mountain Sucker; LD = Longnose Dace

	Site	Reference	Reference	Site
	Strawberry Creek	Boomer Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream
Detect Samples:	3	0	10	31
Total Samples:	9	3	18	33
HQs > 1:	9	0	14	29
HQs ≤ 1:	0	3	4	4
HQs > 1:	100%	0%	78%	88%
HQs ≤ 1:	0%	100%	22%	12%
Category:	severe	none	high	severe

Figure 5-21e
Summary of Risks to Fish Based on Comparisons to Fish Tissue MATCs

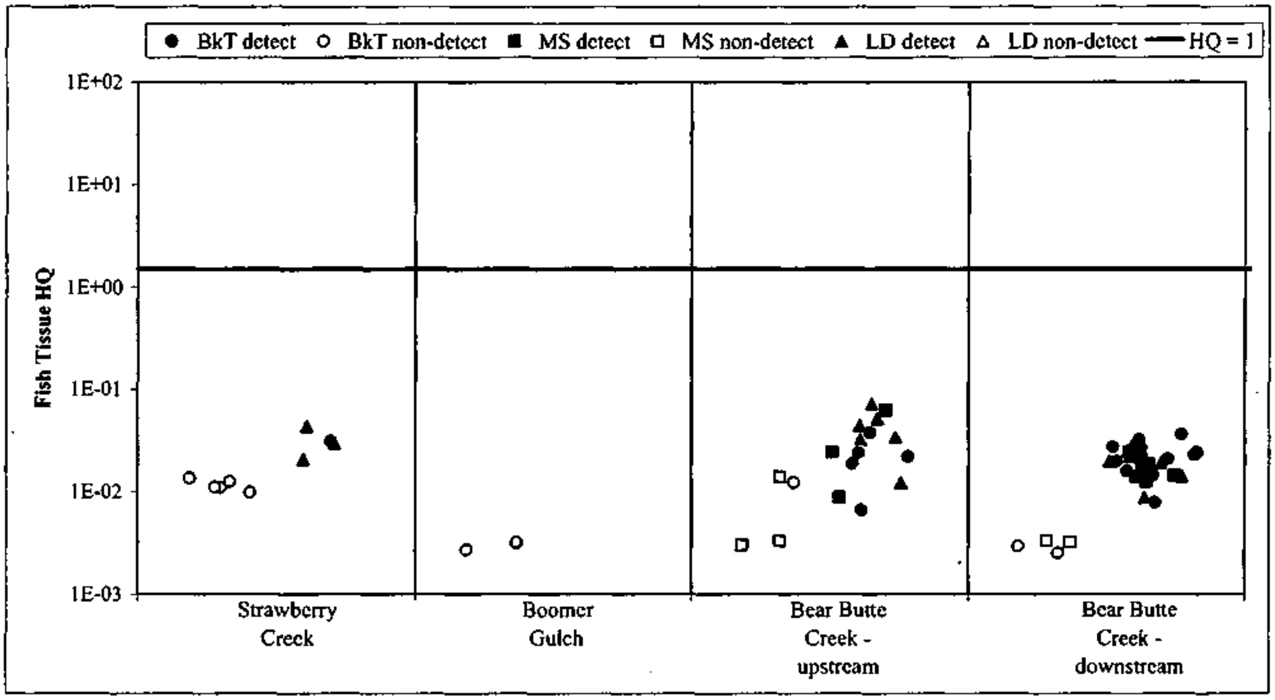


BkT = Brook Trout; MS = Mountain Sucker; LD = Longnose Dace

	Site	Reference	Reference	Site
	Strawberry Creek	Boomer Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream
Detect Samples:	8	2	12	27
Total Samples:	9	3	18	33
HQs > 1:	1	0	0	2
HQs ≤ 1:	8	3	18	31
HQs > 1:	11%	0%	0%	6%
HQs ≤ 1:	89%	100%	100%	94%
Category:	minimal	none	none	minimal

Figure 5-21f
Summary of Risks to Fish Based on Comparisons to Fish Tissue MATCs

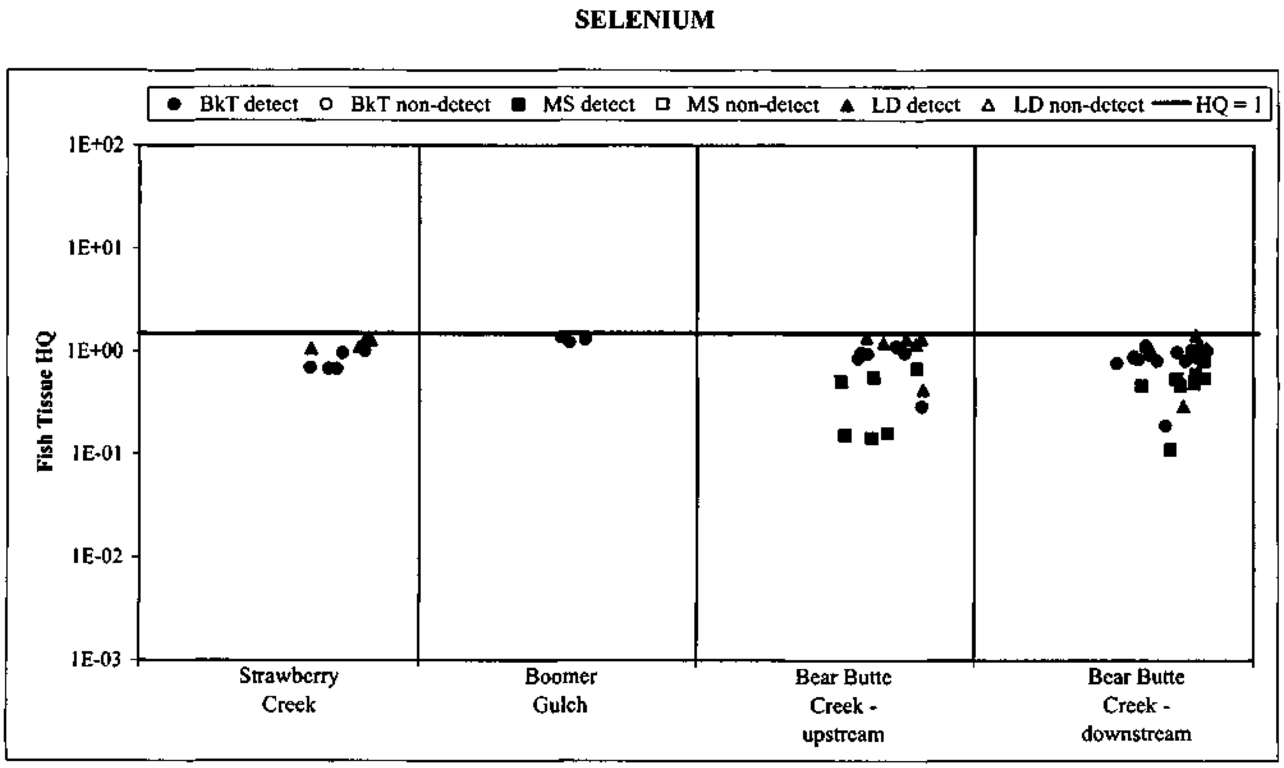
MERCURY



BkT = Brook Trout; MS = Mountain Sucker; LD = Longnose Dace

	Site	Reference	Reference	Site
	Strawberry Creek	Boomer Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream
Detect Samples:	4	0	14	29
Total Samples:	9	3	18	33
HQs > 1:	0	0	0	0
HQs ≤ 1:	9	3	18	33
HQs > 1:	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%
Category:	none	none	none	none

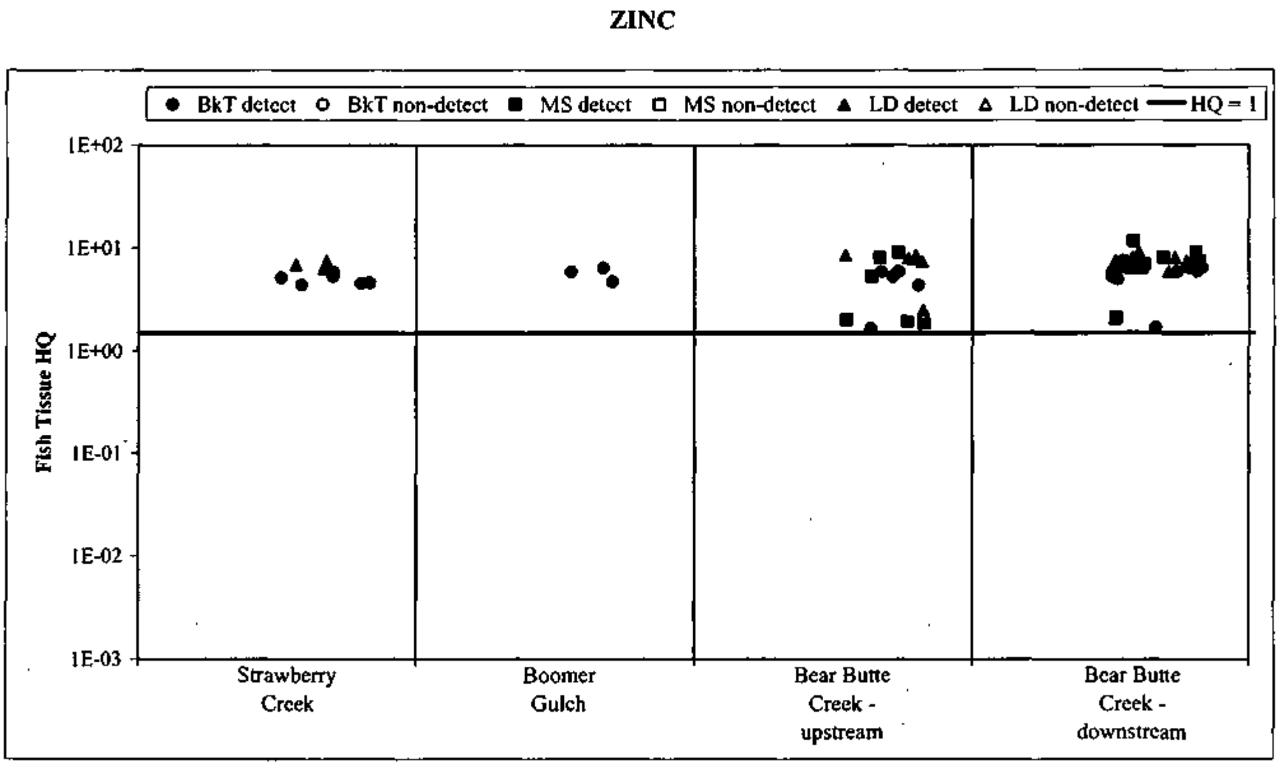
Figure 5-21g
Summary of Risks to Fish Based on Comparisons to Fish Tissue MATCs



BkT = Brook Trout; MS = Mountain Sucker; LD = Longnose Dace

	Site	Reference	Reference	Site
	Strawberry Creek	Boomer Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream
Detect Samples:	9	3	18	33
Total Samples:	9	3	18	33
HQs > 1:	0	0	0	0
HQs ≤ 1:	9	3	18	33
HQs > 1:	0%	0%	0%	0%
HQs ≤ 1:	100%	100%	100%	100%
Category:	none	none	none	none

Figure 5-21h
Summary of Risks to Fish Based on Comparisons to Fish Tissue MATCs



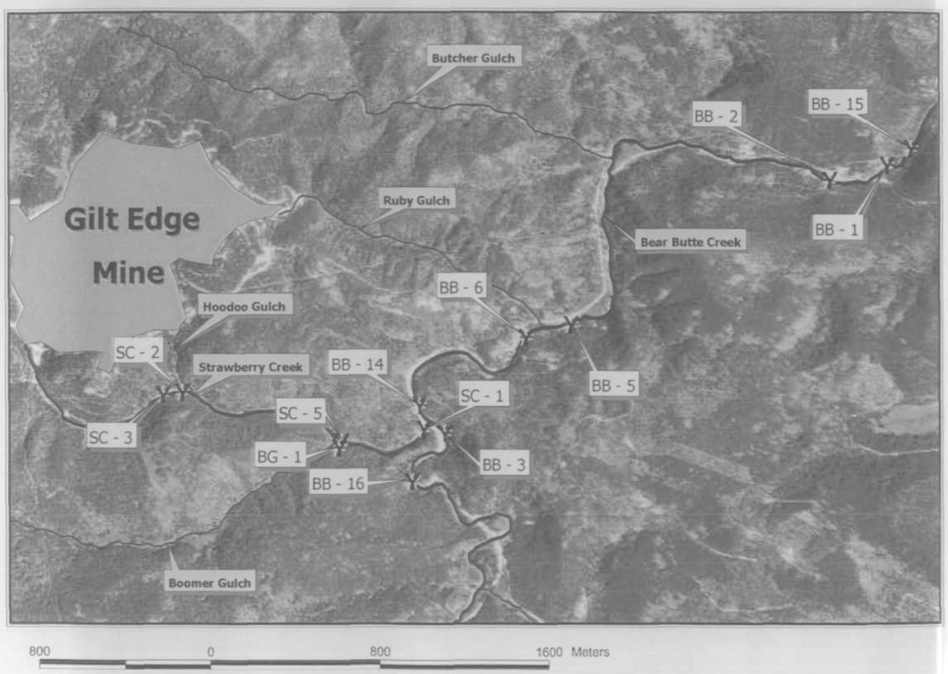
BkT = Brook Trout; MS = Mountain Sucker; LD = Longnose Dace

	Site	Reference	Reference	Site
	Strawberry Creek	Boomer Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream
Detect Samples:	9	3	18	33
Total Samples:	9	3	18	33
HQs > 1:	9	3	18	33
HQs ≤ 1:	0	0	0	0
HQs > 1:	100%	100%	100%	100%
HQs ≤ 1:	0%	0%	0%	0%
Category:	severe	severe	severe	severe

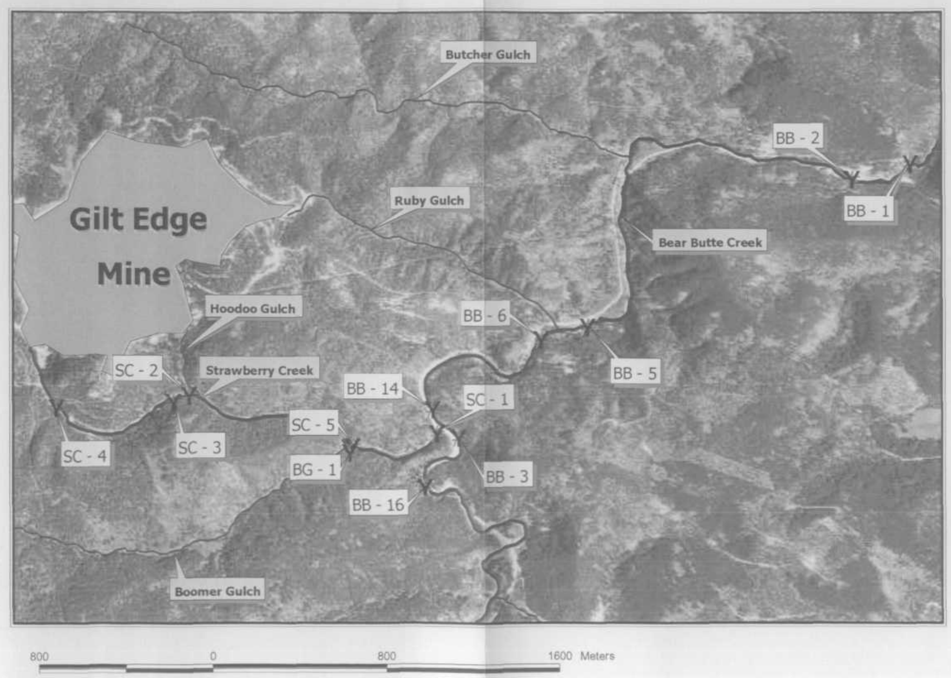
Gilt Edge Mine Site

Sediment and Water Toxicity Sample Locations

Sediment



Water



Legend

- ¥ Water Toxicity Sample Location
- Y Sediment Toxicity Sample Location

Map compiled from USGS air photos, georeferenced to TIGER demography and GPS site location coordinates.

U.S. EPA Environmental Response Team Center
Response Engineering and Analytical Contract
68-C99-223
W.A.# R1A00154

Figure 5-22
Sediment and Water Toxicity Sampling Locations
Gilt Edge Mine Site
Deadwoood, SD

Figure 5-23
Results of Surface Water Toxicity Testing

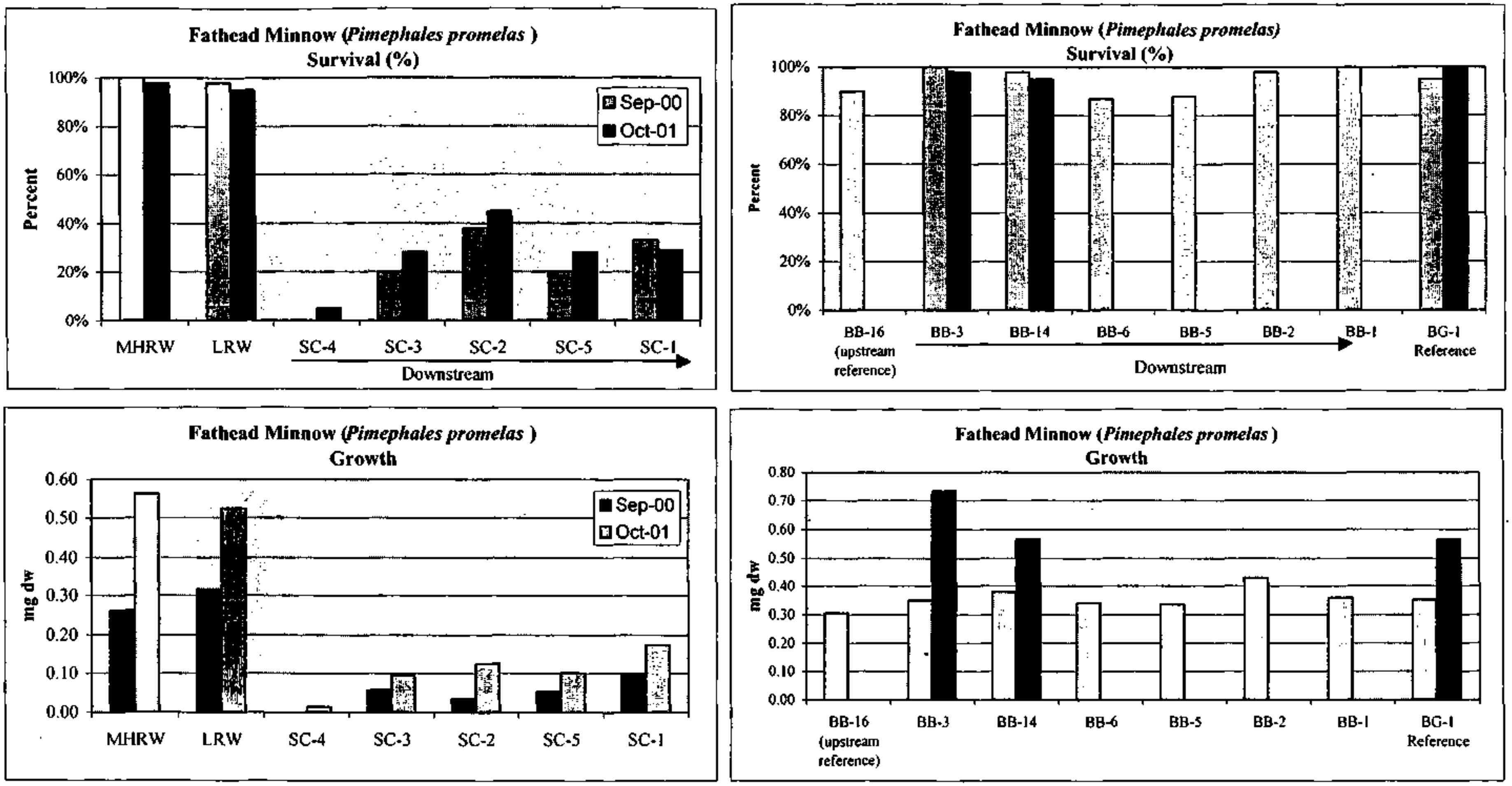
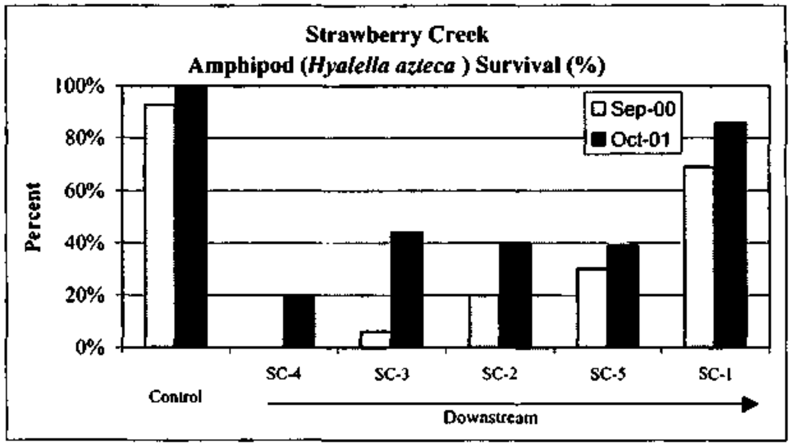
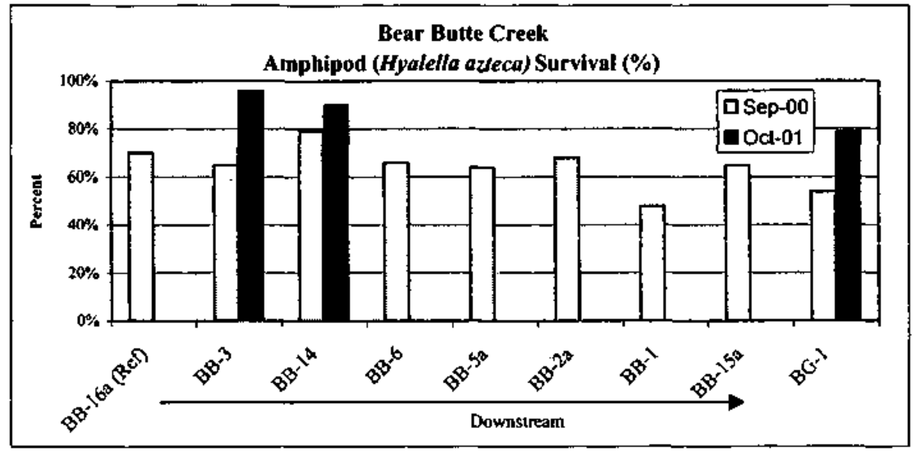
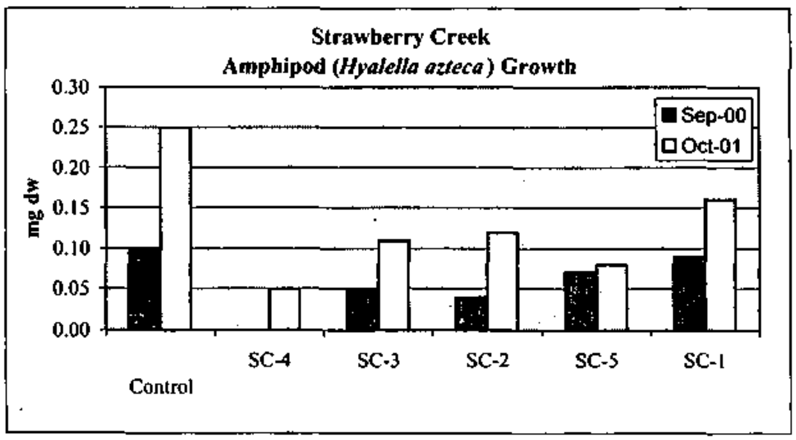
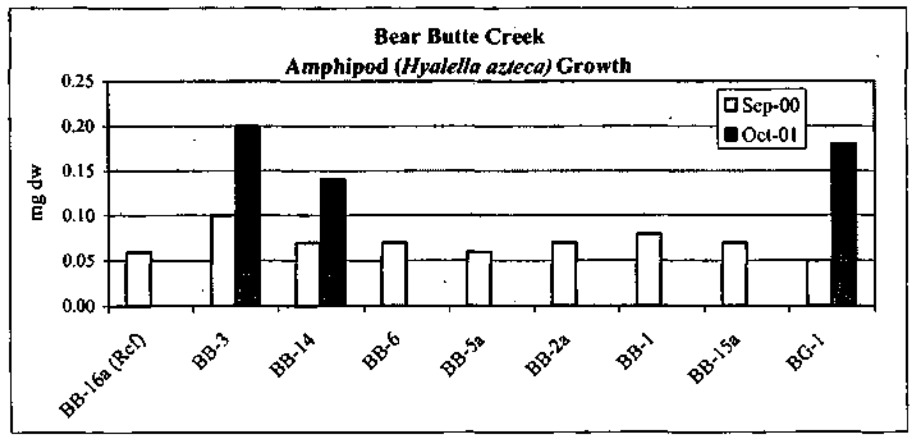


Figure 5-24
Results of Sediment Toxicity Testing









Site-Specific Study

Sampling and Analysis

Metric	Biological Condition Scoring Criteria			
	6	4	2	0
1. Taxa Richness[a]	>80%	60-80%	40-60%	<40%
2. Hilsenhoff Biotic Index (modified)[b]	>85%	70-85%	50-70%	<50%
3. Ratio of Scrapers/Filterers Collectors[a,c]	>50%	35-50%	20-35%	<20%
4. Ratio of EPT and Chironomid Abundances[a]	>75%	50-75%	25-50%	<25%
5. % Contribution of Dominant Taxon[d]	<20%	20-30%	30-40%	>40%
6. EPT Index[a]	>90%	80-90%	70-80%	<70%
7. Community Loss Index[e]	<0.5	0.5-1.5	1.5-4.0	>4.0
8. Ratio of Shredders/Total[a,c]	>50%	35-50%	20-35%	<20%

(a) Score is a ratio of a study site to reference site x 100.
(b) Score is a ratio of reference site to a study site x 100.
(c) Determination of Functional Feeding Group is independent of taxonomic grouping.
(d) Scoring criteria evaluate actual percent contribution, not percent comparability to the reference station.
(e) Range of values obtained. A comparison to the reference station is incorporated in these indices.

BIOASSESSMENT

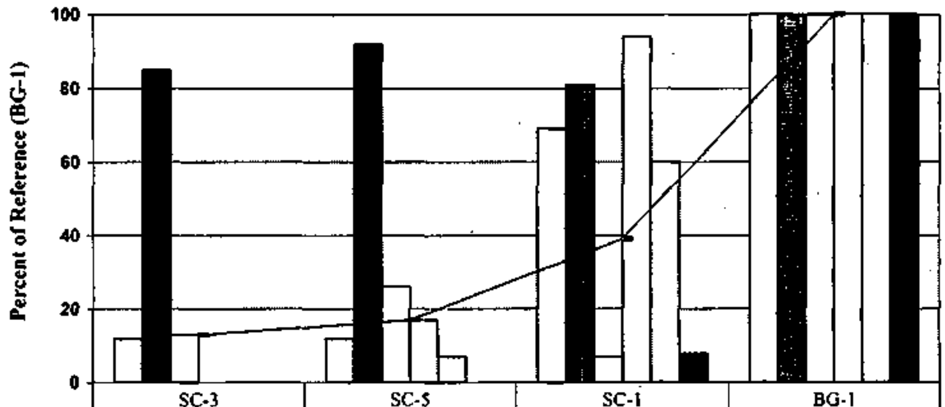
% Comp. to Ref. Score [a]	Biological Condition Category	Attributes
>83%	Not impaired	Comparable to the reference. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.
54-79%	Slightly impaired	Community structure less than expected. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
21-50%	Moderately impaired	Fewer species due to loss of most tolerant forms. Reduction in EPT index.
<17%	Severely impaired	Few species present. If high densities or organisms, then dominated by one or two taxa.

(a) Percentage values that are intermediate to the above ranges are identified in the protcoal to require subjective judgment as to the correct placement. For this risk assessment the judgments are conservative and place the location in the more impaired category.

EPT = Ephemeroptera, Plecoptera, Trichoptera
Source: USEPA, 1989

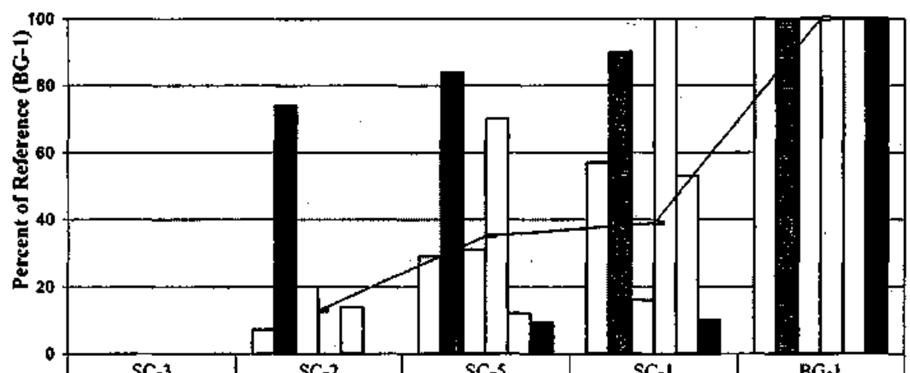
Figure 5-25
Flowchart of Approach for Rapid Bioassessment Protocol (RBP) III

Figure 5-26 Benthic Invertebrate Community Metrics for Strawberry Creek
September 2000



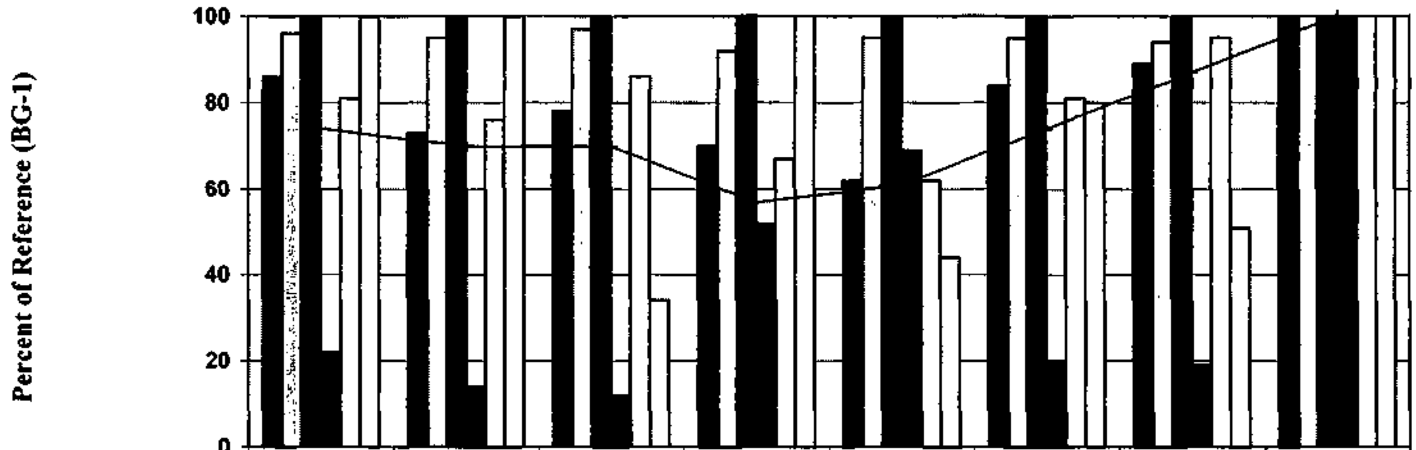
	SC-3	SC-5	SC-1	BG-1
1) Taxa Richness	12	12	69	100
2) HBI Biotic Index	85	92	81	100
3) Scrapers to Filterers	13	26	7	100
4) EPT to Chironomidae	0	17	94	100
6) EPT Index	0	7	60	100
8) Ratio of Shredders to Total	0	0	8	100
Condition Score (% of Reference)	13	17	39	100

October 2001



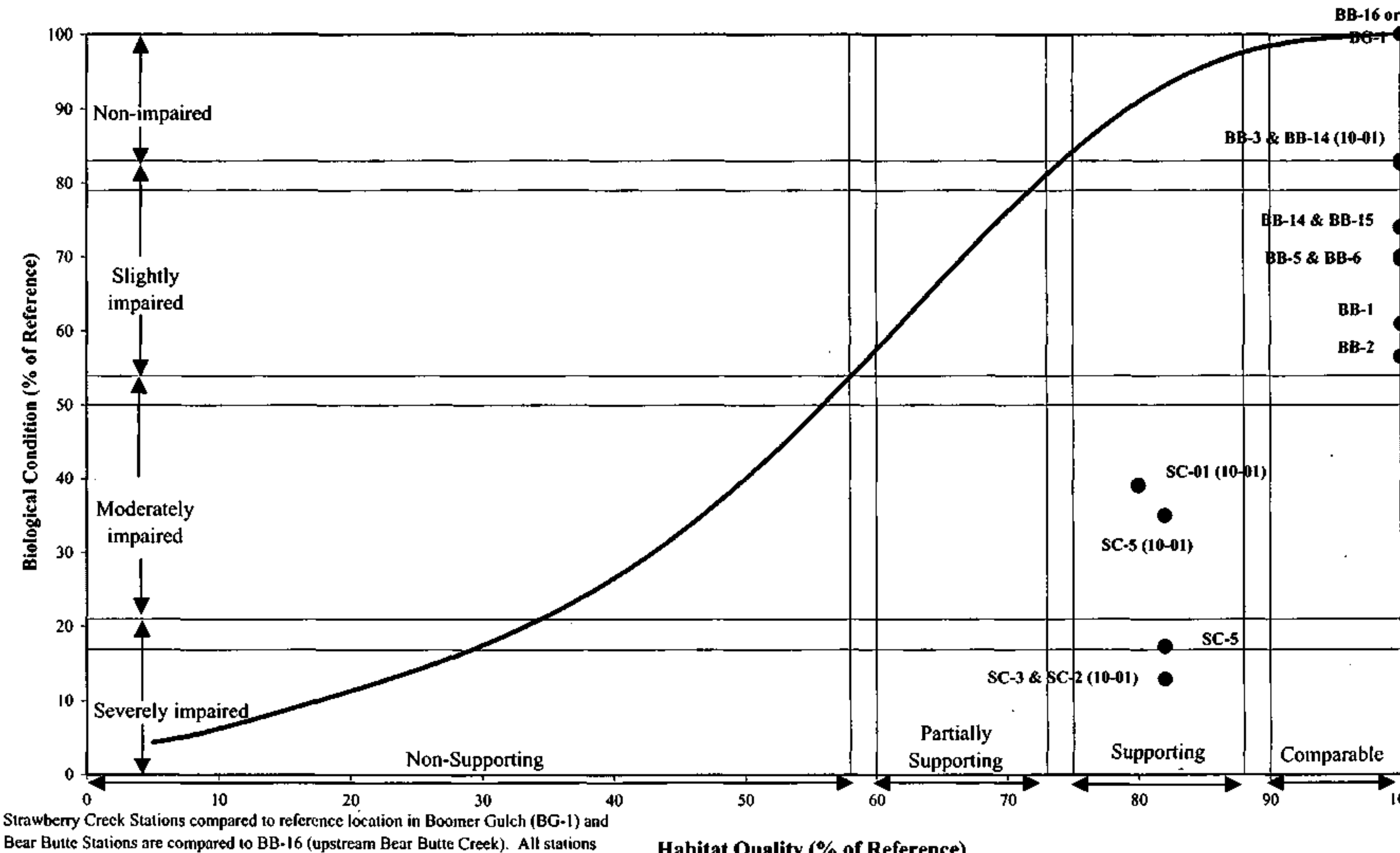
	SC-3	SC-2	SC-5	SC-1	BG-1
1) Taxa Richness		7.1	29	57	100
2) HBI Biotic Index		74	84	90	100
3) Scrapers to Filterers		20	31	16	100
4) EPT to Chironomidae		0	70	100	100
6) EPT Index		14	12	53	100
8) Ratio of Shredders to Total		0	9.5	10	100
Condition Score (% of Reference)		13	35	39	100

Figure 5-27 Benthic Invertebrate Community Metrics for Bear Butte Creek September 2000



	BB-14	BB-6	BB-5	BB-2	BB-1	BB-15	BB-3	BB-16
1) Taxa Richness	86	73	78	70	62	84	89	100
2) HBI Biotic Index	96	95	97	92	95	95	94	100
3) Scrapers to Filterers	100	100	100	100	100	100	100	100
4) EPT to Chironomidae	22	14	12	52	69	20	19	100
6) EPT Index	81	76	86	67	62	81	95	100
8) Ratio of Shredders to Total	100	100	34	100	44	80	51	100
Condition Score (% of Reference)	74	70	70	57	61	74	87	100

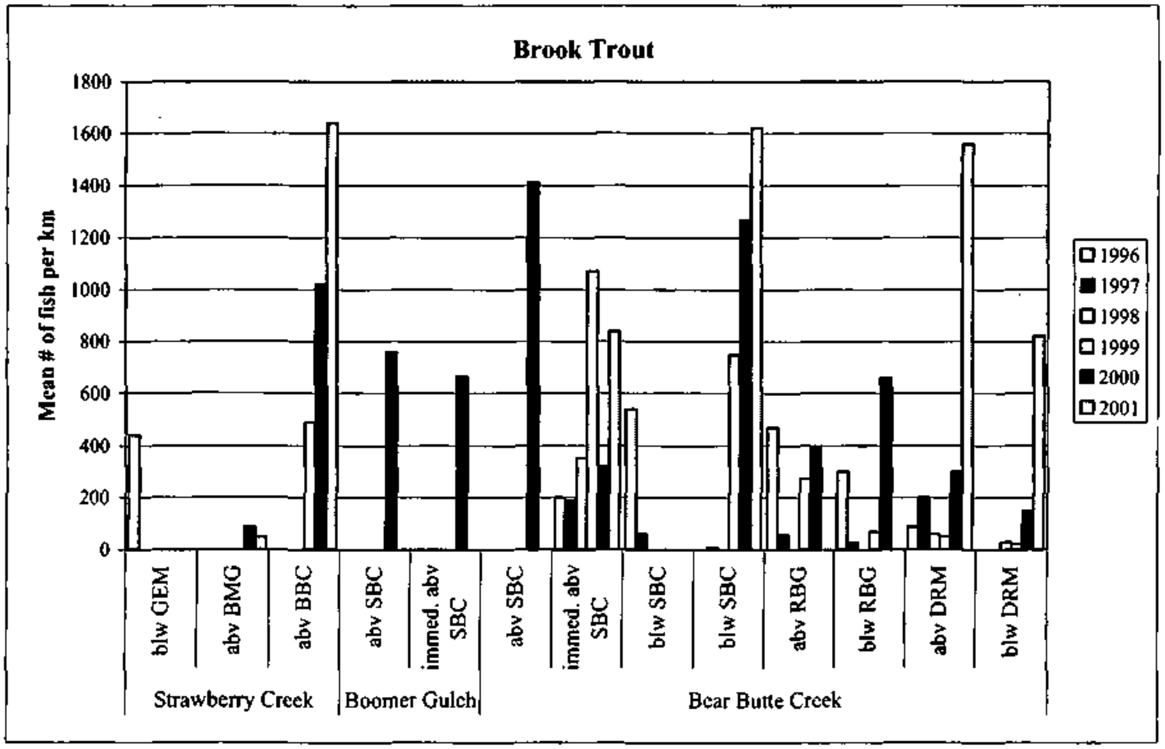
Figure 5-28 Biological Condition of Benthic Macroinvertebrate Communities and Sampling Stations in Strawberry Creek and Bear Butte Creek versus Habitat Quality

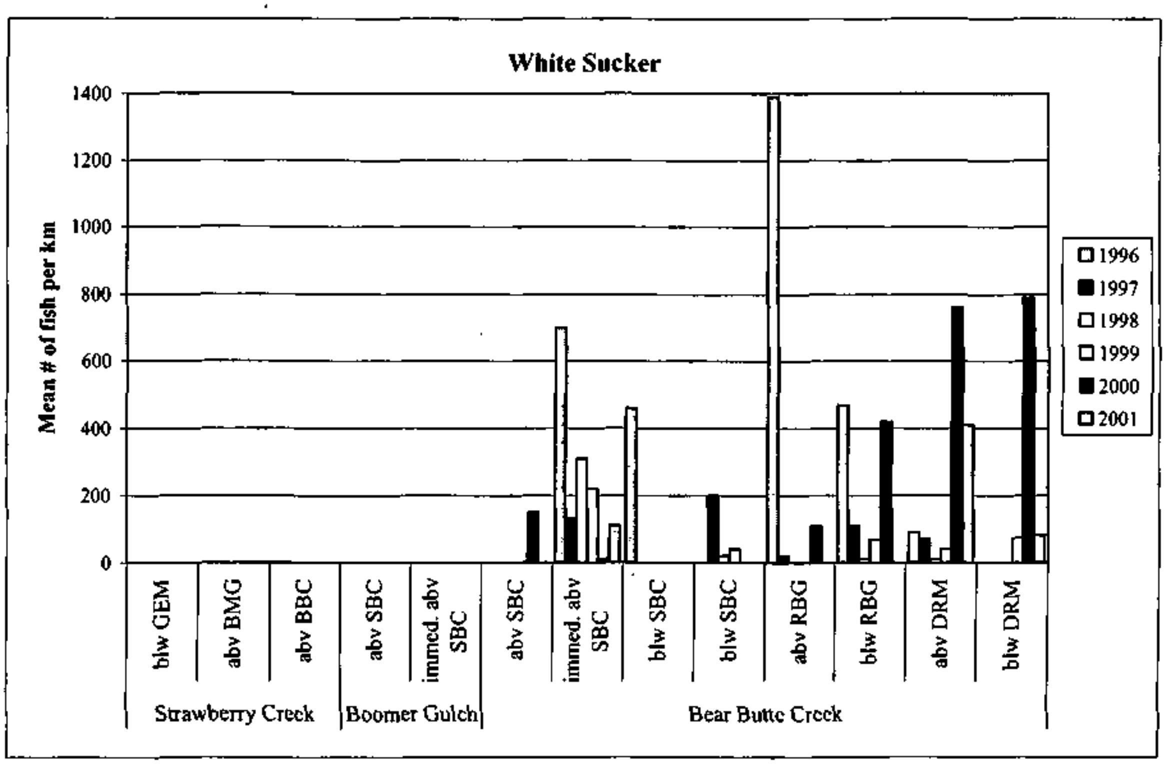


Strawberry Creek Stations compared to reference location in Boomer Gulch (BG-1) and Bear Butte Stations are compared to BB-16 (upstream Bear Butte Creek). All stations sampled September 2000 except where noted for samples collected in October of 2001.

Figure 5-29
Summary of Fish Population Surveys Conducted from 1996 to 2001

Fish Density: Mean Number Per Kilometer

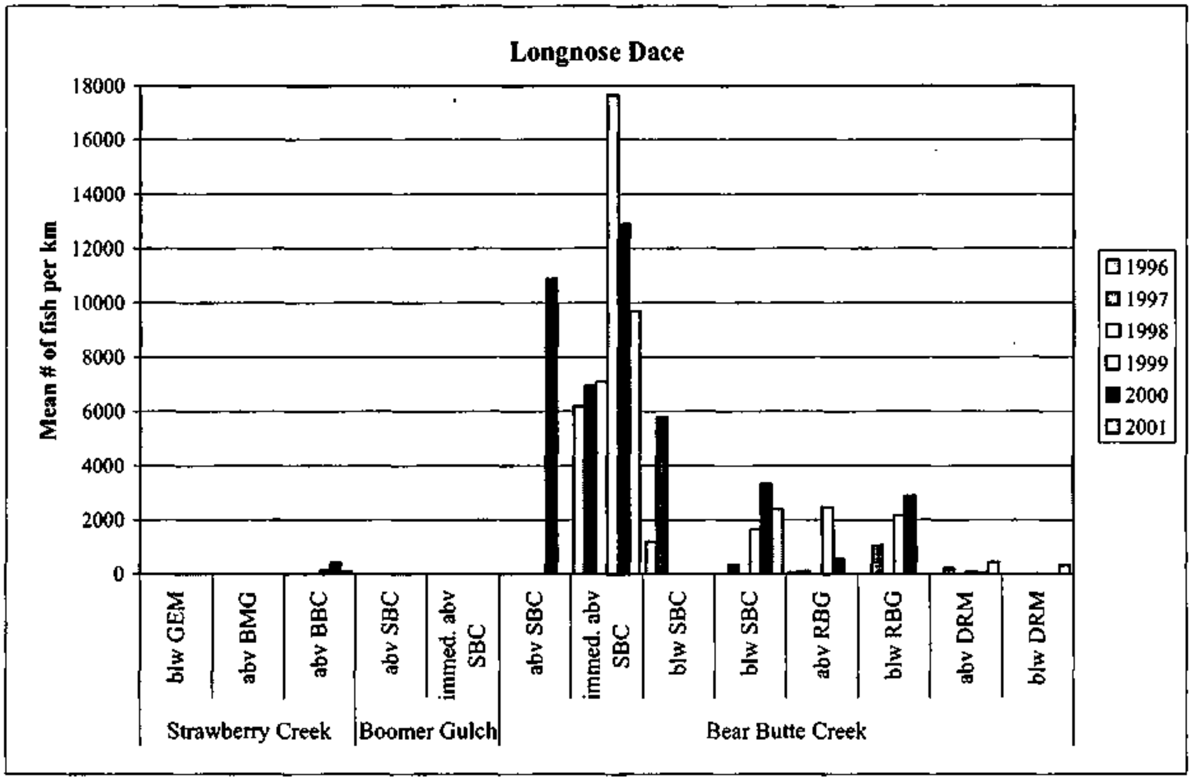




GEM = Gilt Edge Mine; BBC = Bear Butte Creek; SBC = Strawberry Creek; RBG = Ruby Gulch; DRM = Double Rainbow Mine

Figure 5-29
Summary of Fish Population Surveys Conducted from 1996 to 2001

Fish Density: Mean Number Per Kilometer



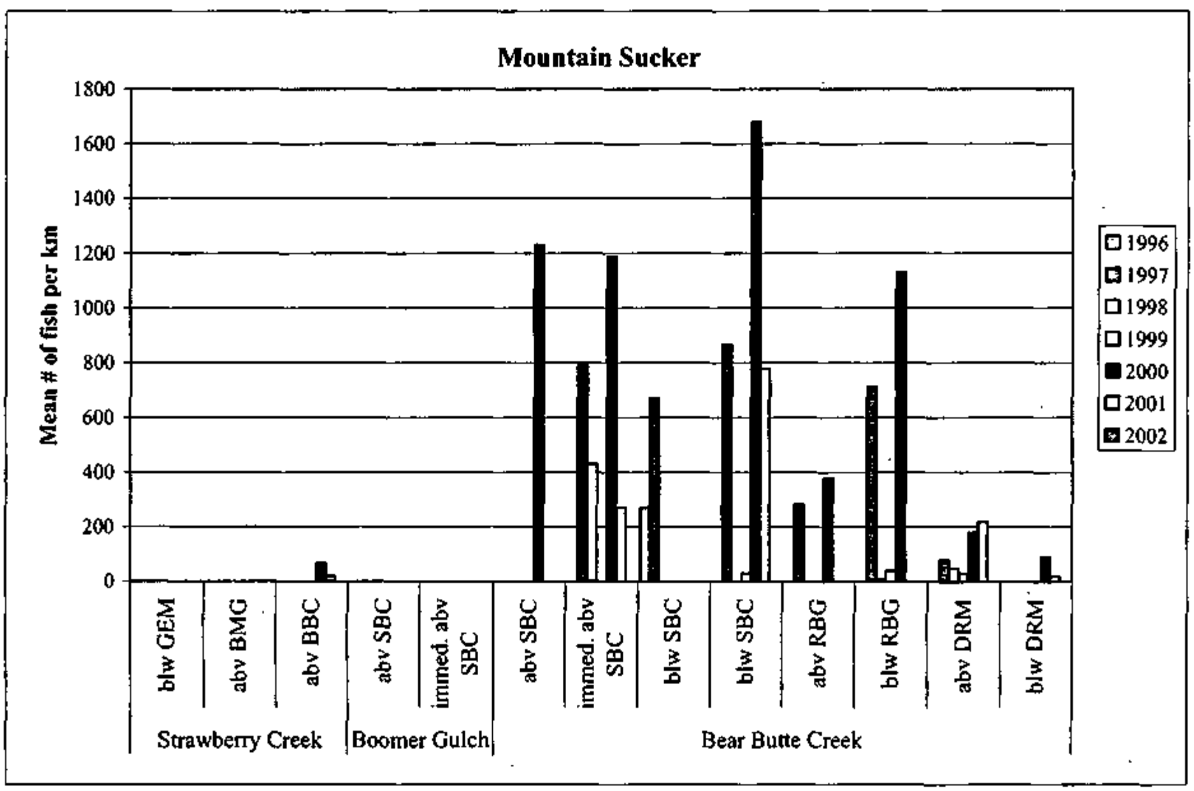
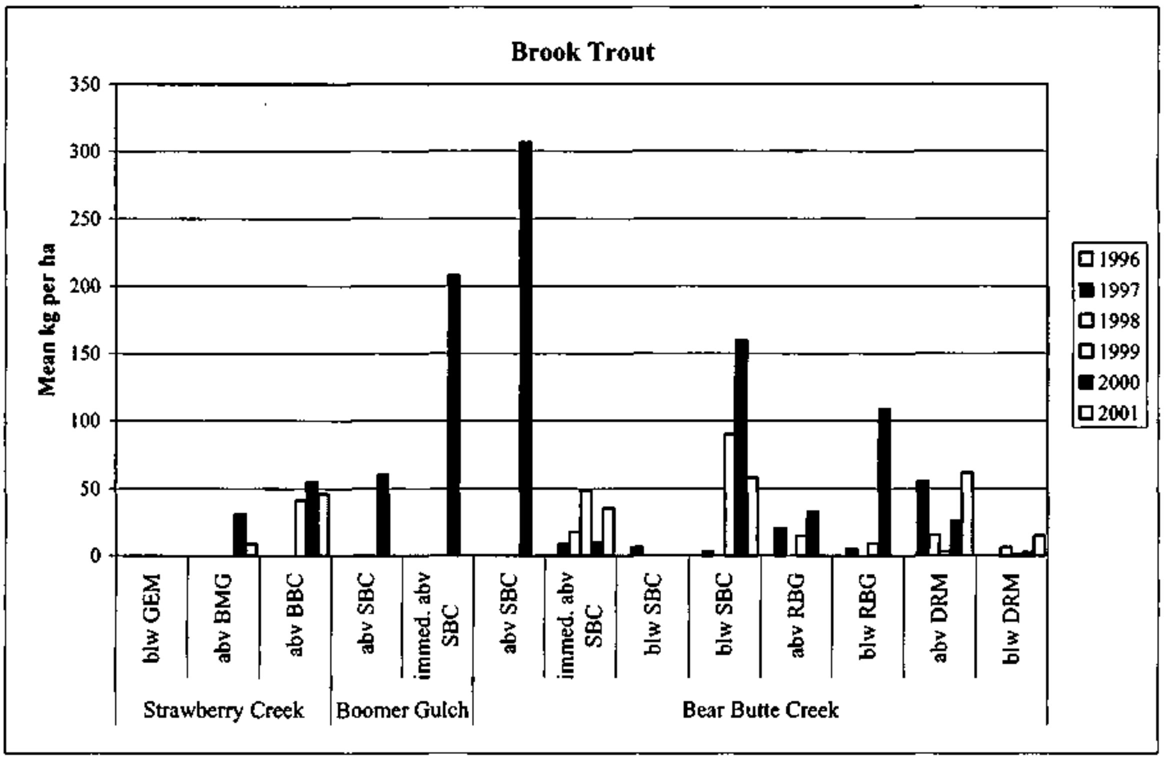
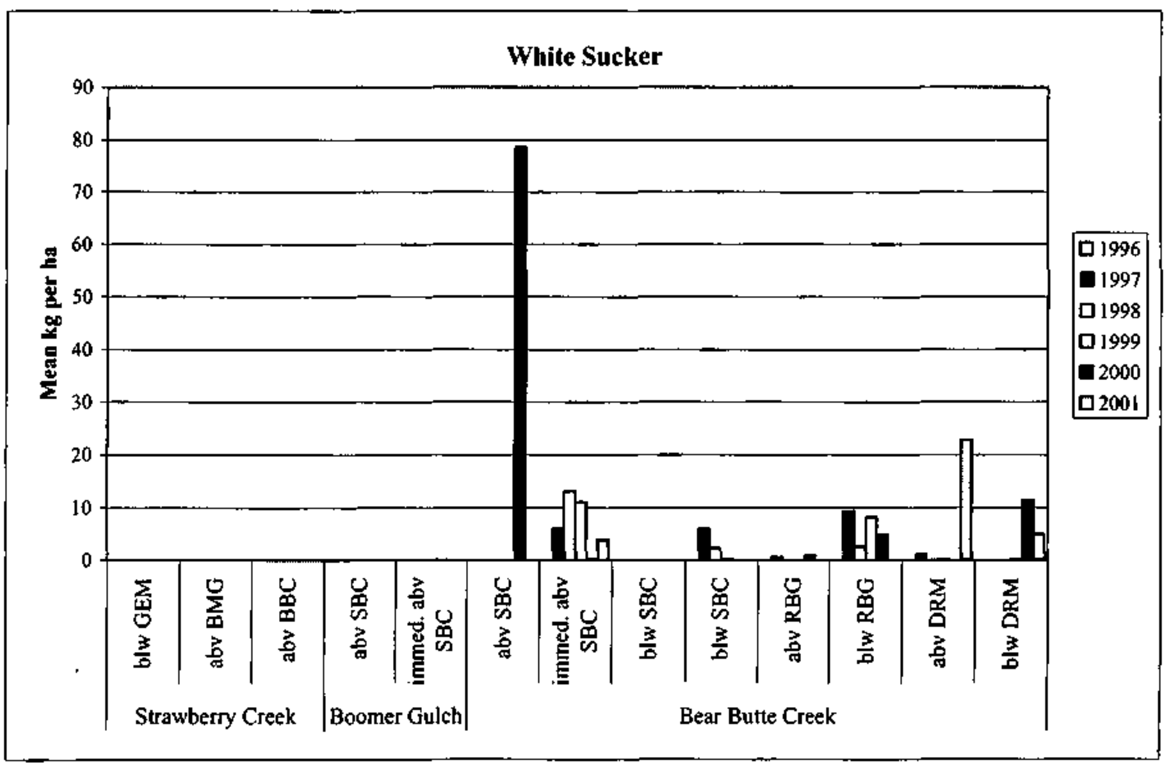


Figure 5-30
Summary of Fish Population Surveys Conducted from 1996 to 2001

Fish Biomass: Mean Kilograms per Hectare

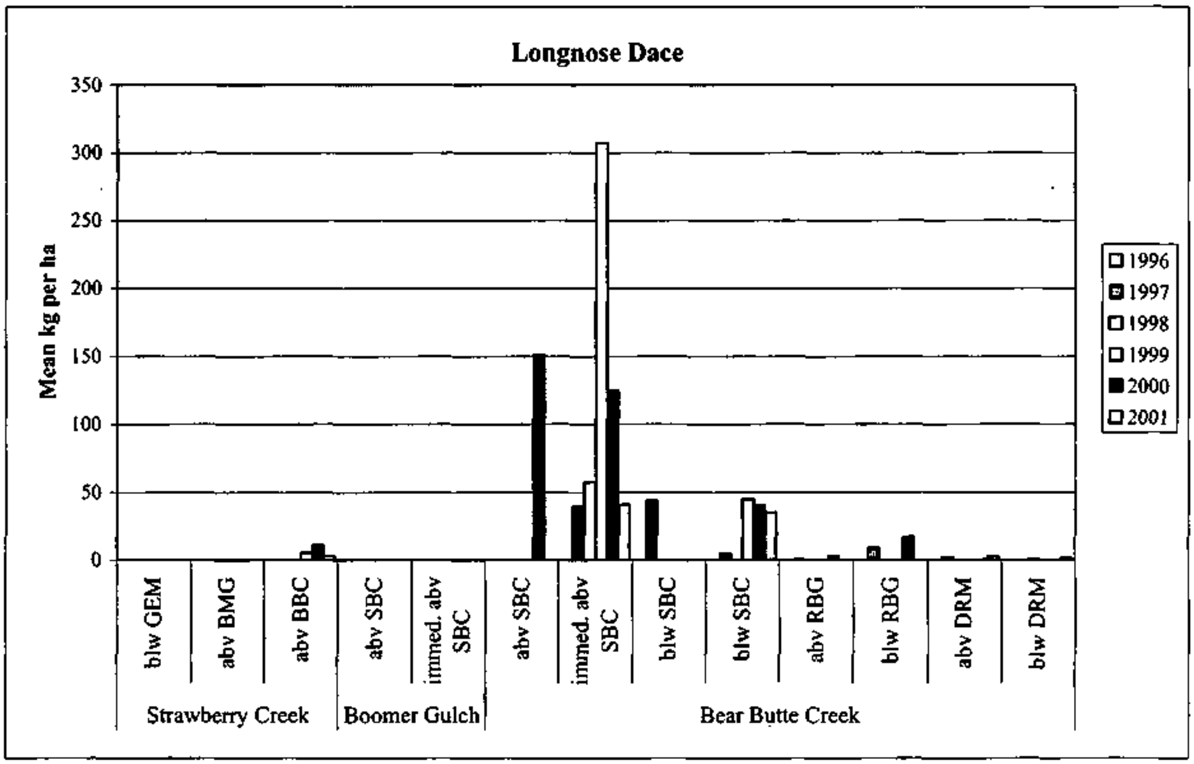


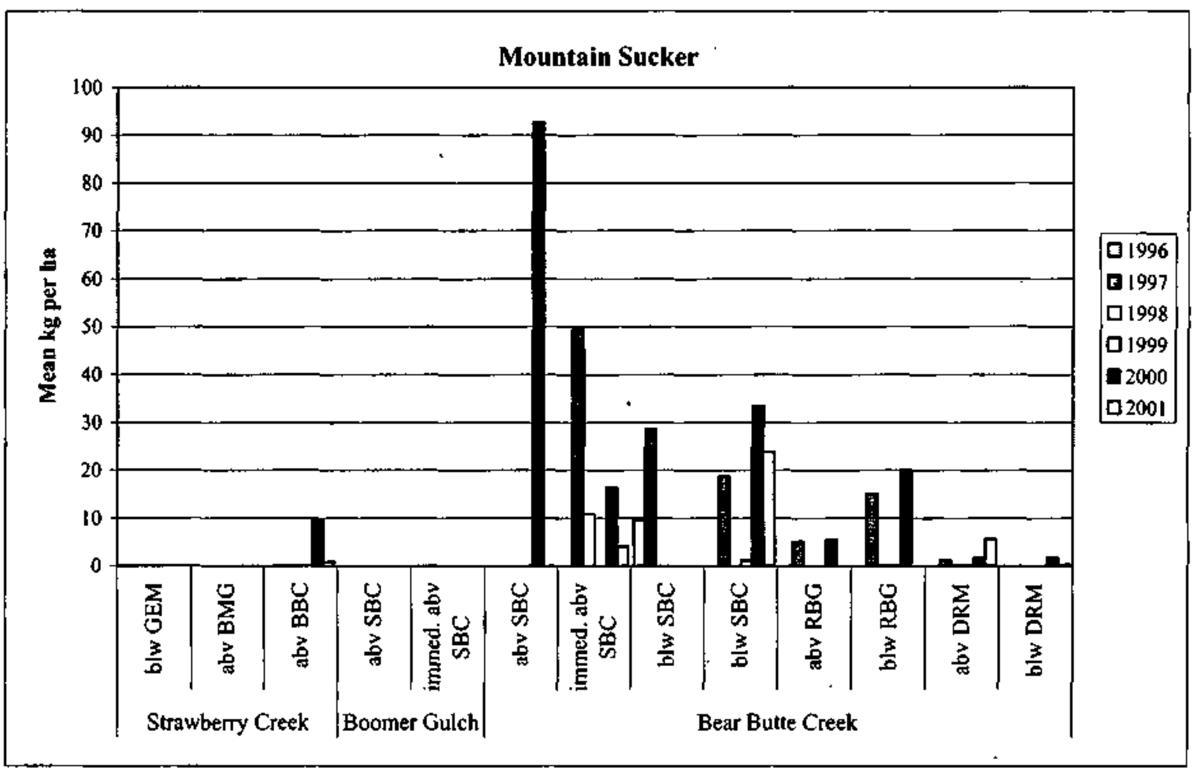


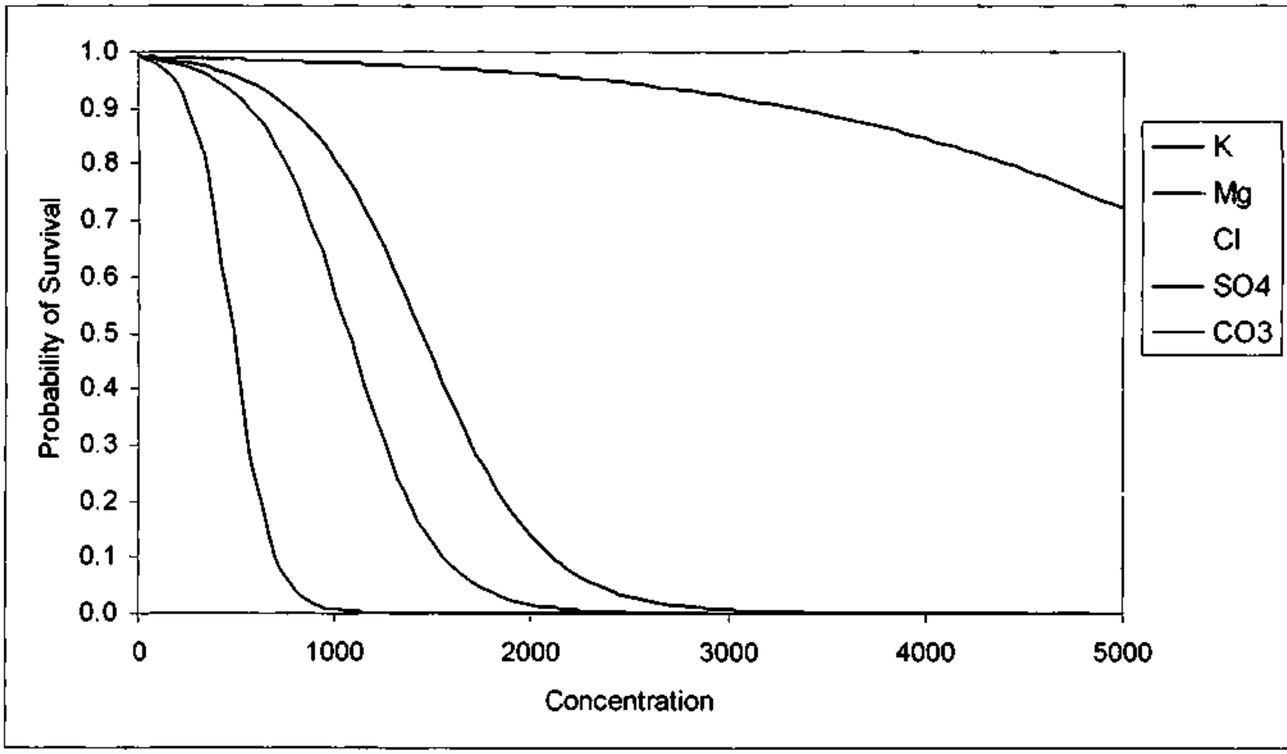
GEM = Gilt Edge Mine; BBC = Bear Butte Creek; SBC = Strawberry Creek; RBG = Ruby Gulch; DRM = Double Rainbow I

Figure 5-30
Summary of Fish Population Surveys Conducted from 1996 to 2001

Fish Biomass: Mean Kilograms per Hectare







Acute Toxicity Model for 96 Hour Survival of the Fathead Minnow (Mount et al., 1997)

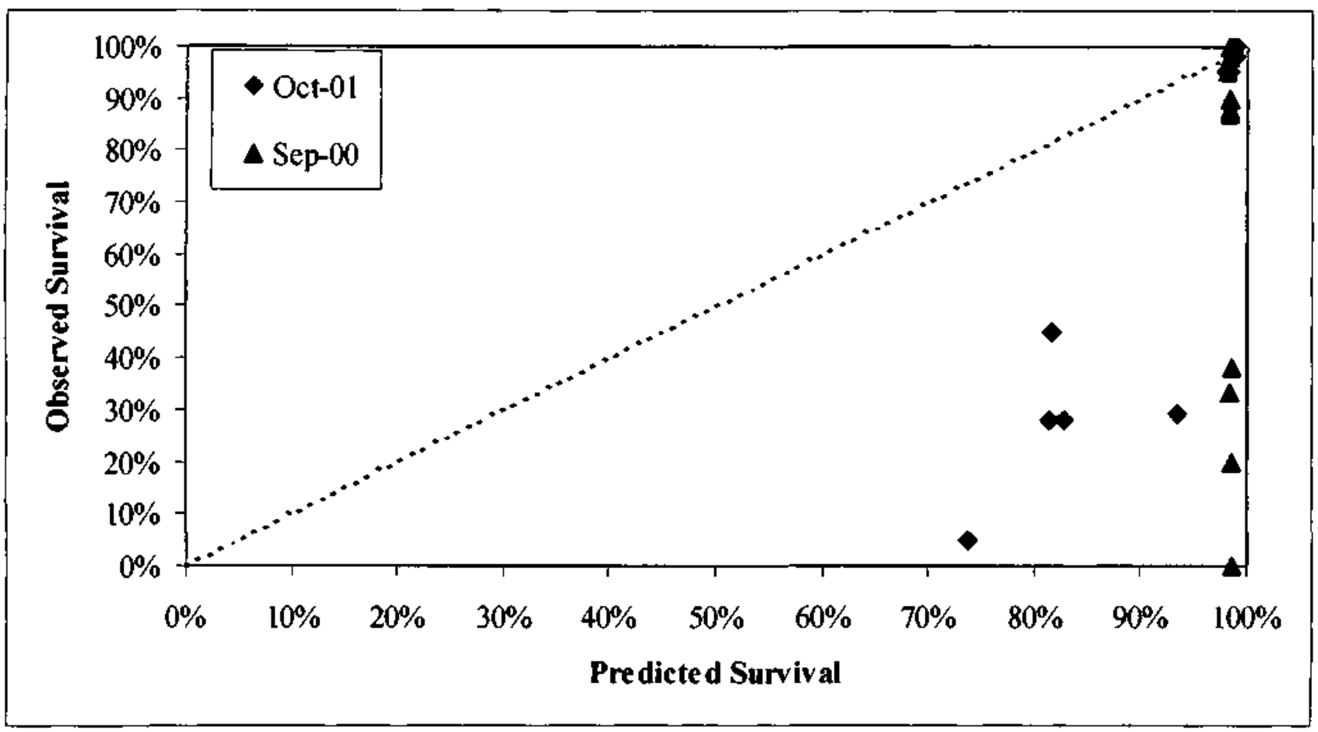


Figure 5-31 Predicted Survival of the Fathead Minnow in Strawberry Creek Surface Water Versus that Predicted by Acute Toxicity Model of Mount et al. (1997)

Color Photo(s)

The following pages contain color that does not appear in the scanned images.

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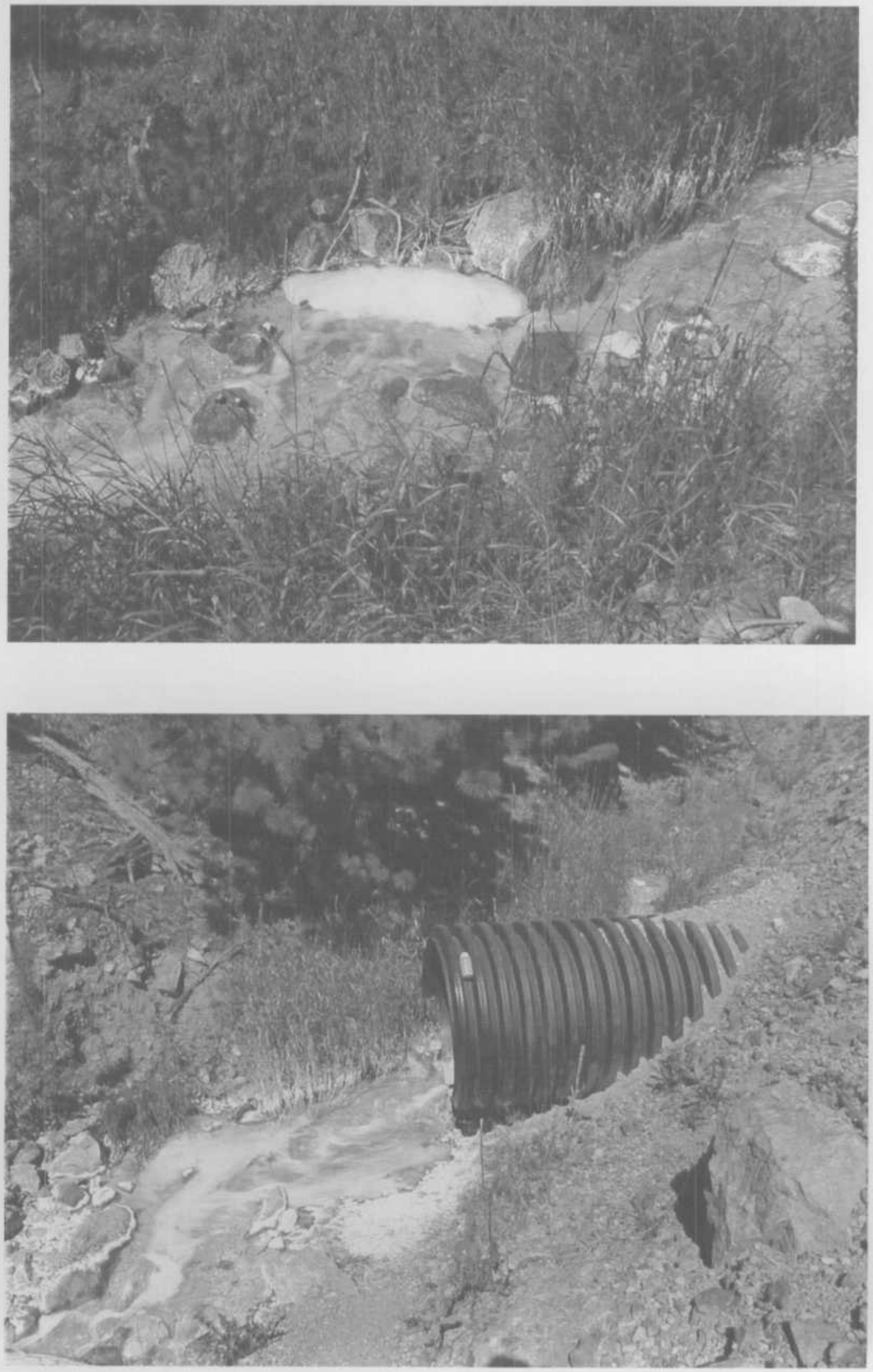
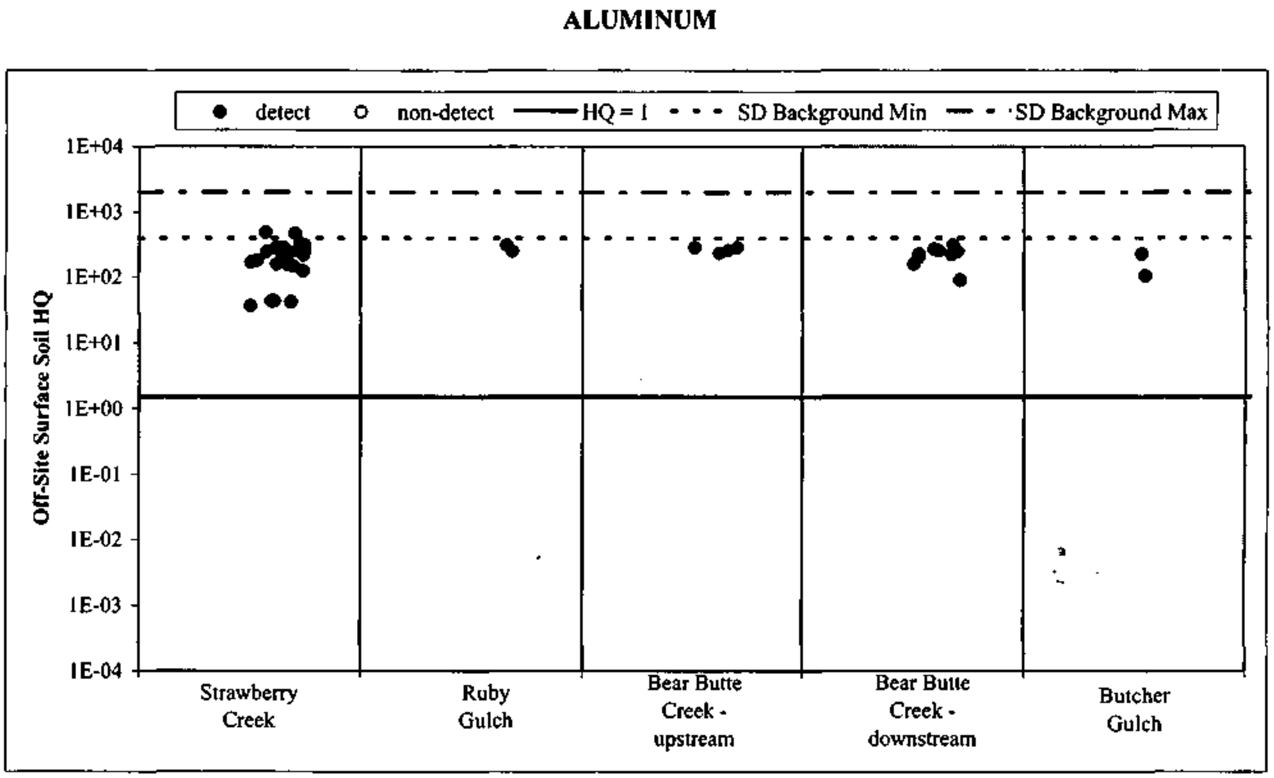


Figure 5-32 Foaming in Strawberry Creek September 2000

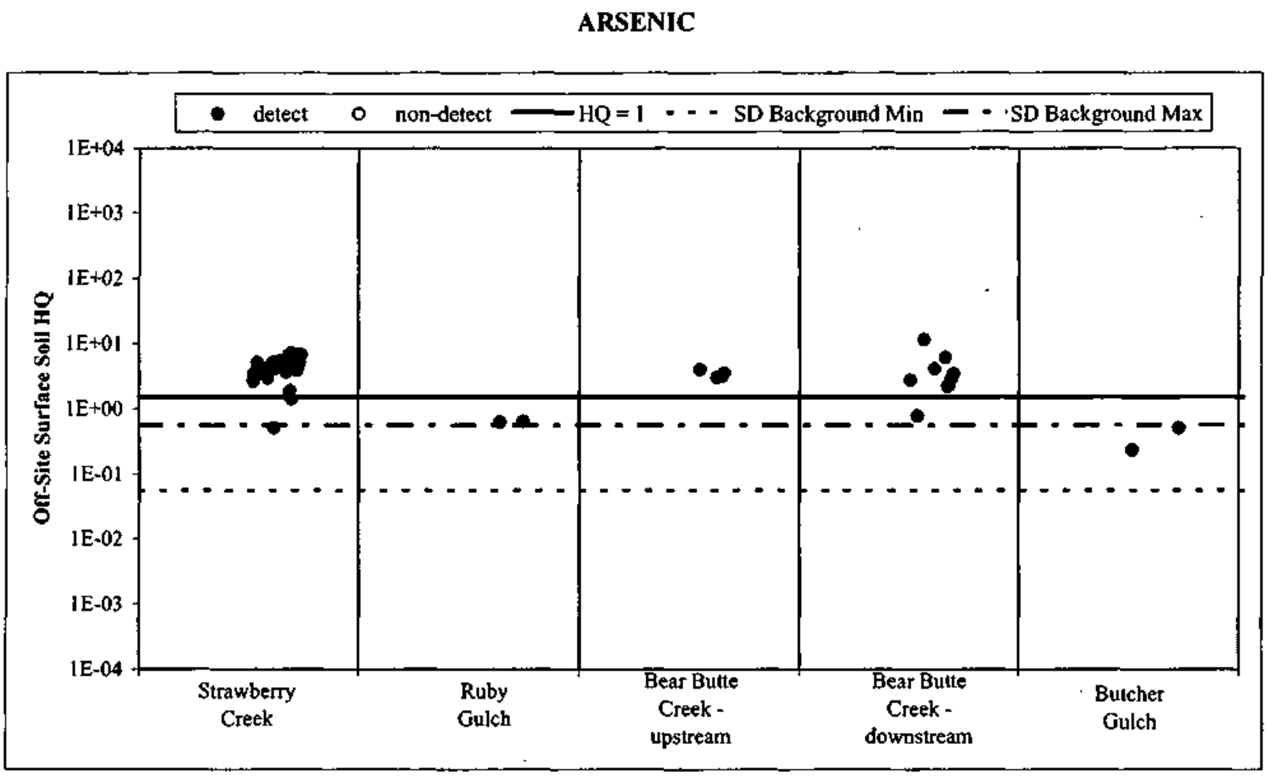
Figure 6-1a
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates



South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	26	2	4	9	2
HQs ≤ 1:	0	0	0	0	0
HQs > 1:	100%	100%	100%	100%	100%
HQs ≤ 1:	0%	0%	0%	0%	0%
Category:	severe	severe	severe	severe	severe

Figure 6-1b
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

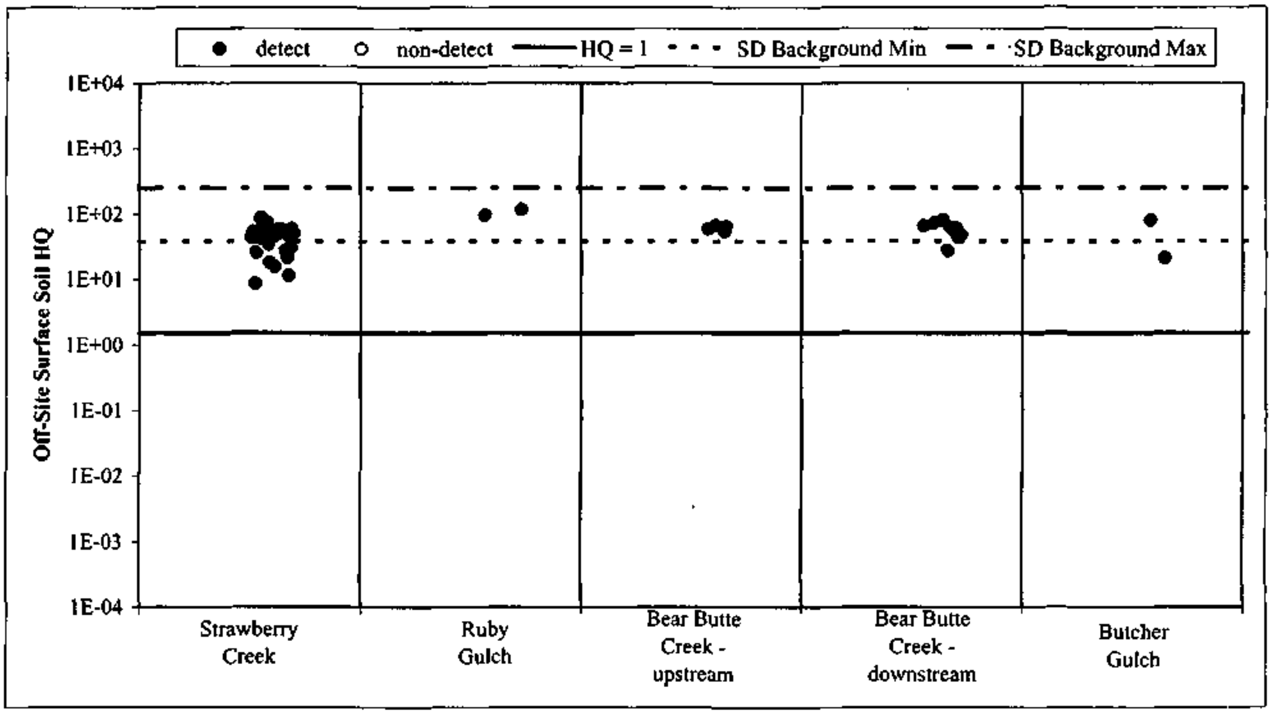


South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	24	0	4	8	0
HQs ≤ 1:	2	2	0	1	2
HQs > 1:	92%	0%	100%	89%	0%
HQs ≤ 1:	8%	100%	0%	11%	100%
Category:	severe	none	severe	severe	none

Figure 6-1c
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

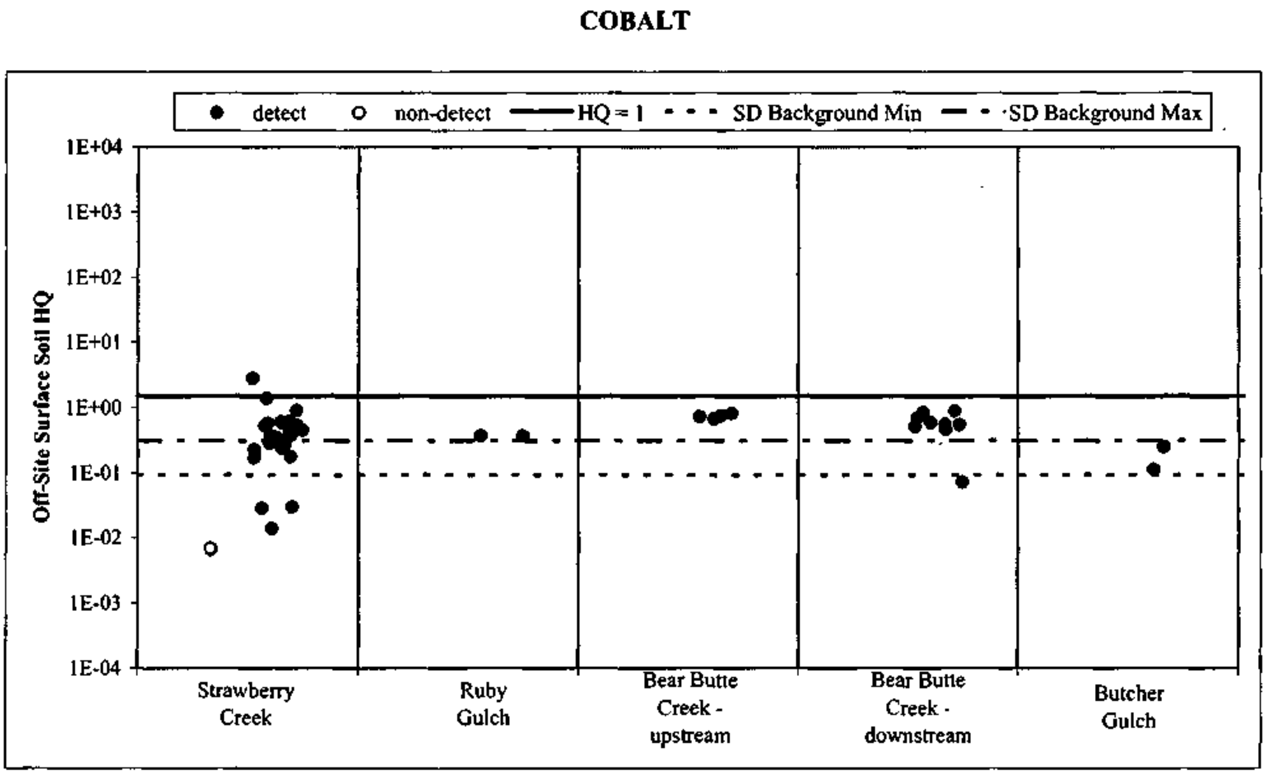
CHROMIUM



South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	26	2	4	9	2
HQs ≤ 1:	0	0	0	0	0
HQs > 1:	100%	100%	100%	100%	100%
HQs ≤ 1:	0%	0%	0%	0%	0%
Category:	severe	severe	severe	severe	severe

Figure 6-1d
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

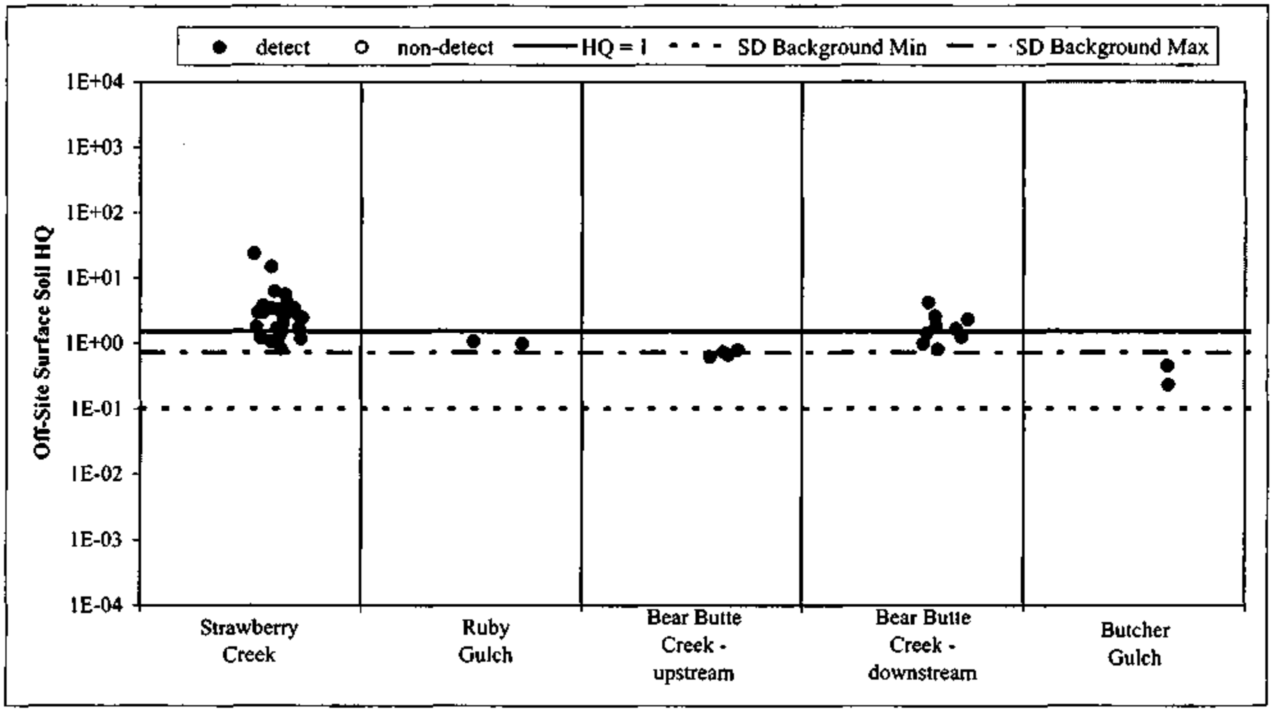


South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	24	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	1	0	0	0	0
HQs ≤ 1:	25	2	4	9	2
HQs > 1:	4%	0%	0%	0%	0%
HQs ≤ 1:	96%	100%	100%	100%	100%
Category:	minimal	none	none	none	none

Figure 6-1e
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

COPPER

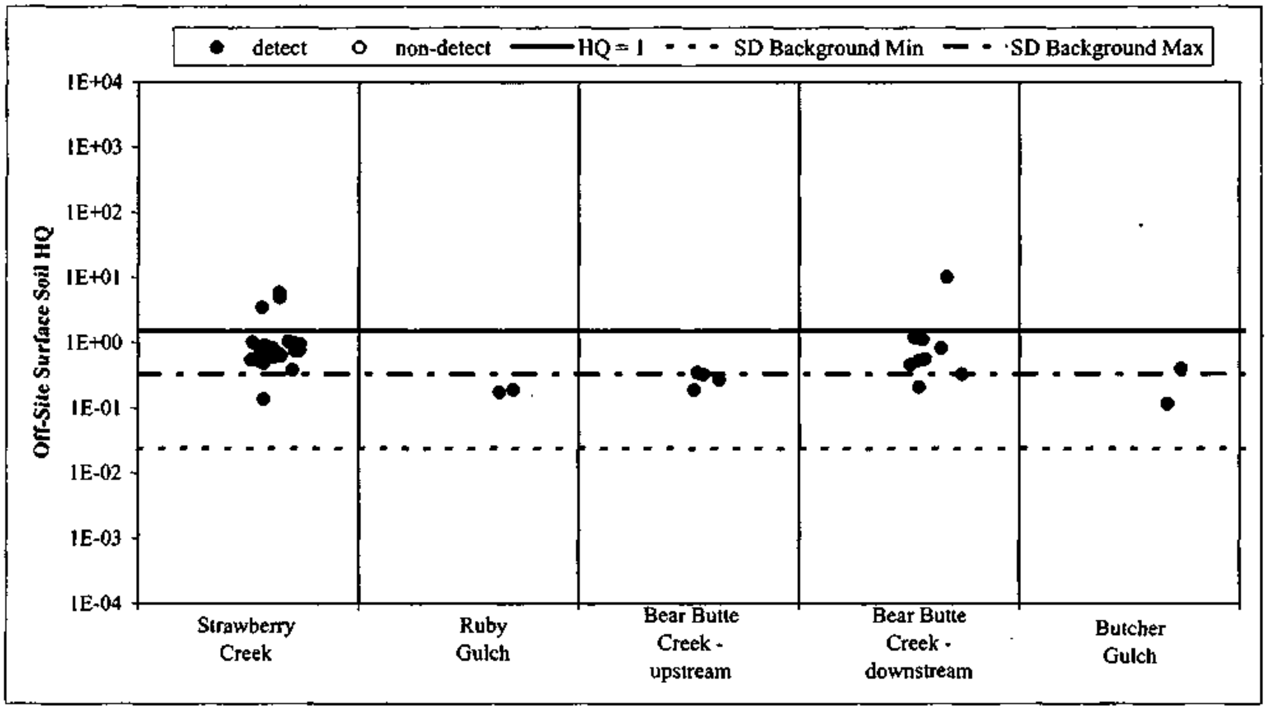


South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	21	0	0	5	0
HQs ≤ 1:	5	2	4	4	2
HQs > 1:	81%	0%	0%	56%	0%
HQs ≤ 1:	19%	100%	100%	44%	100%
Category:	severe	none	none	high	none

Figure 6-1f
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

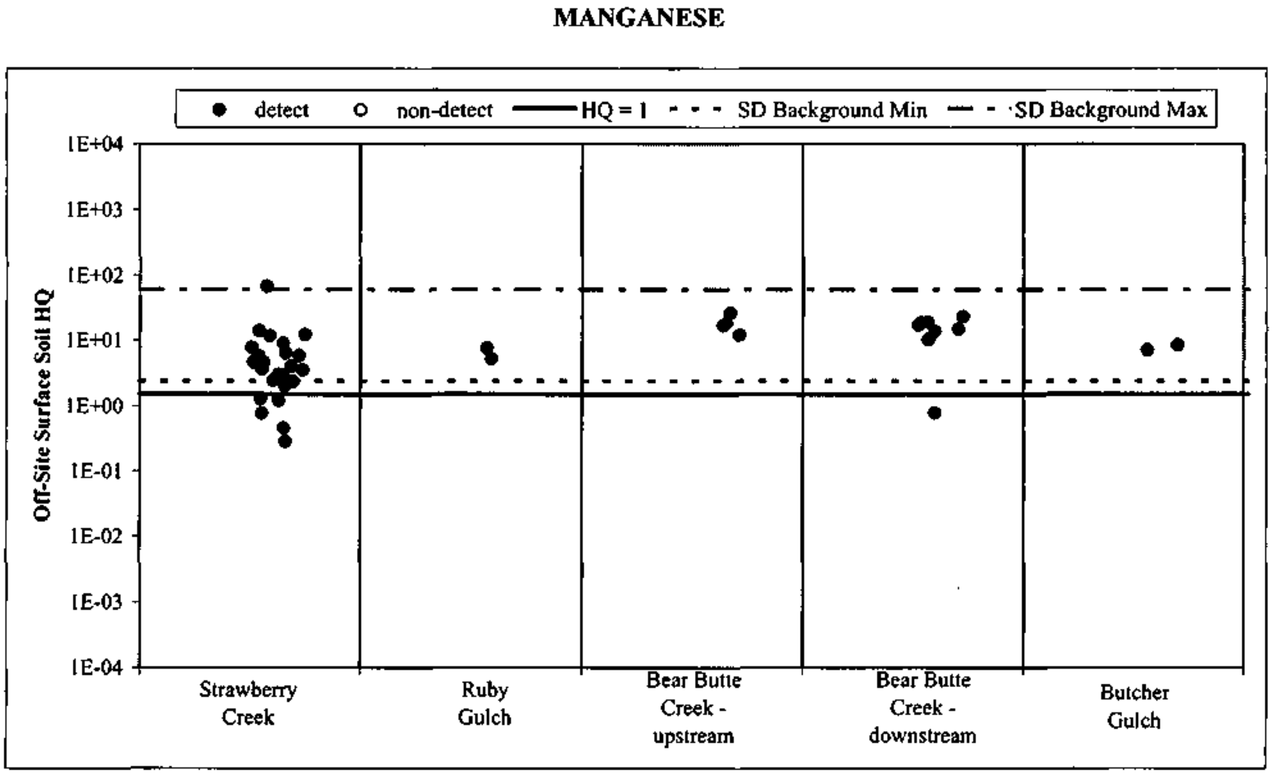
LEAD



South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	3	0	0	1	0
HQs ≤ 1:	23	2	4	8	2
HQs > 1:	12%	0%	0%	11%	0%
HQs ≤ 1:	88%	100%	100%	89%	100%
Category:	minimal	none	none	minimal	none

Figure 6-1g
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

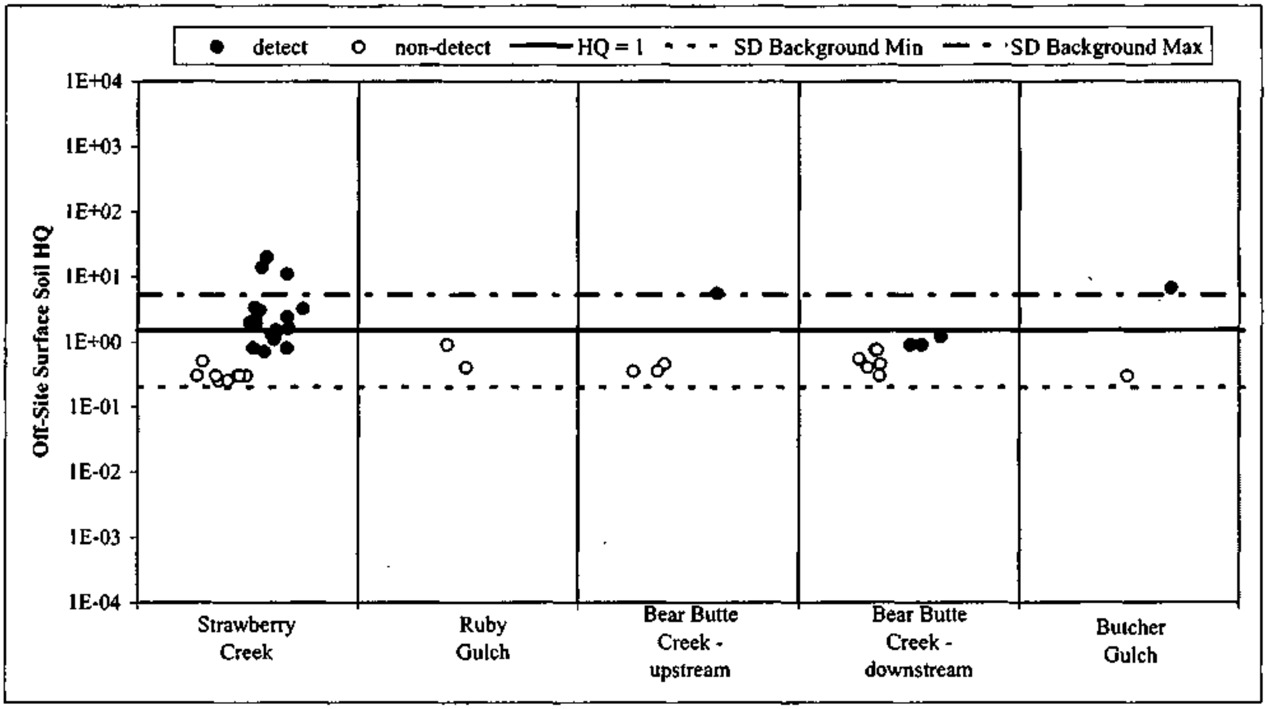


South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	21	2	4	8	2
HQs ≤ 1:	5	0	0	1	0
HQs > 1:	81%	100%	100%	89%	100%
HQs ≤ 1:	19%	0%	0%	11%	0%
Category:	severe	severe	severe	severe	severe

Figure 6-1h
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

MERCURY

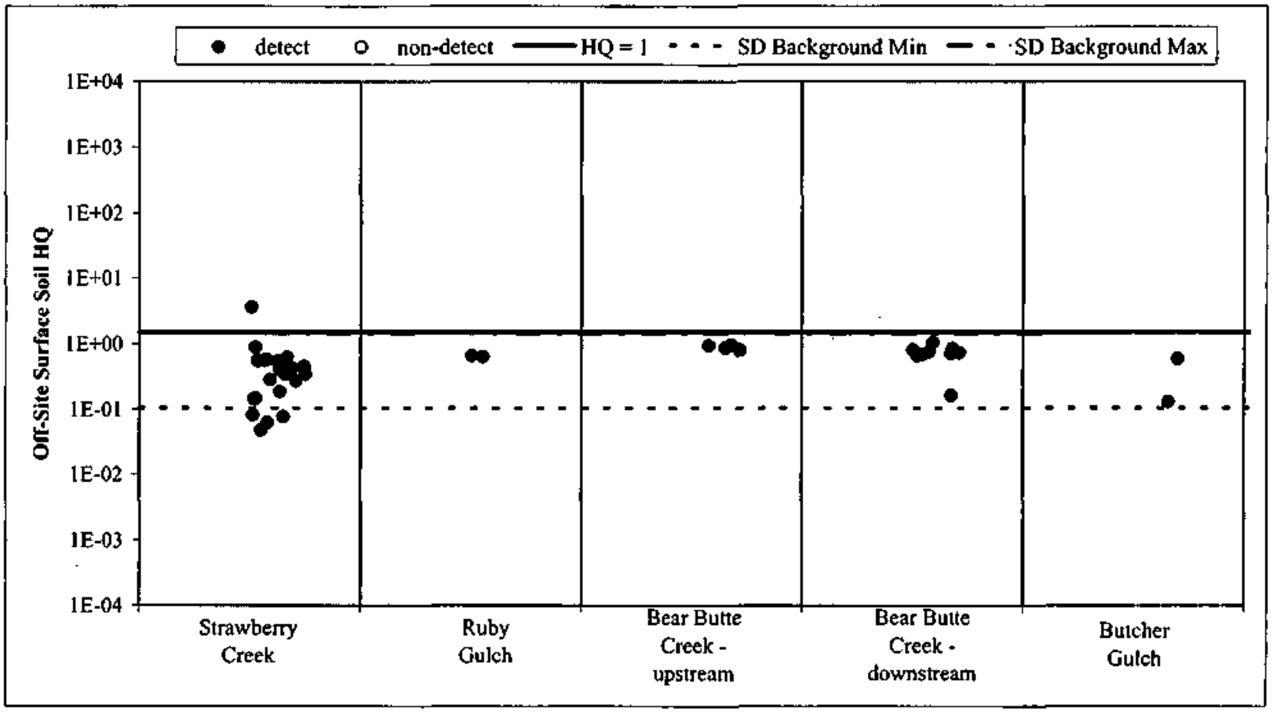


South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	18	0	1	3	1
All Samples:	26	2	4	9	2
HQs > 1:	12	0	1	0	1
HQs ≤ 1:	14	2	3	9	1
HQs > 1:	46%	0%	25%	0%	50%
HQs ≤ 1:	54%	100%	75%	100%	50%
Category:	moderate	none	moderate	none	moderate

Figure 6-1i
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

NICKEL

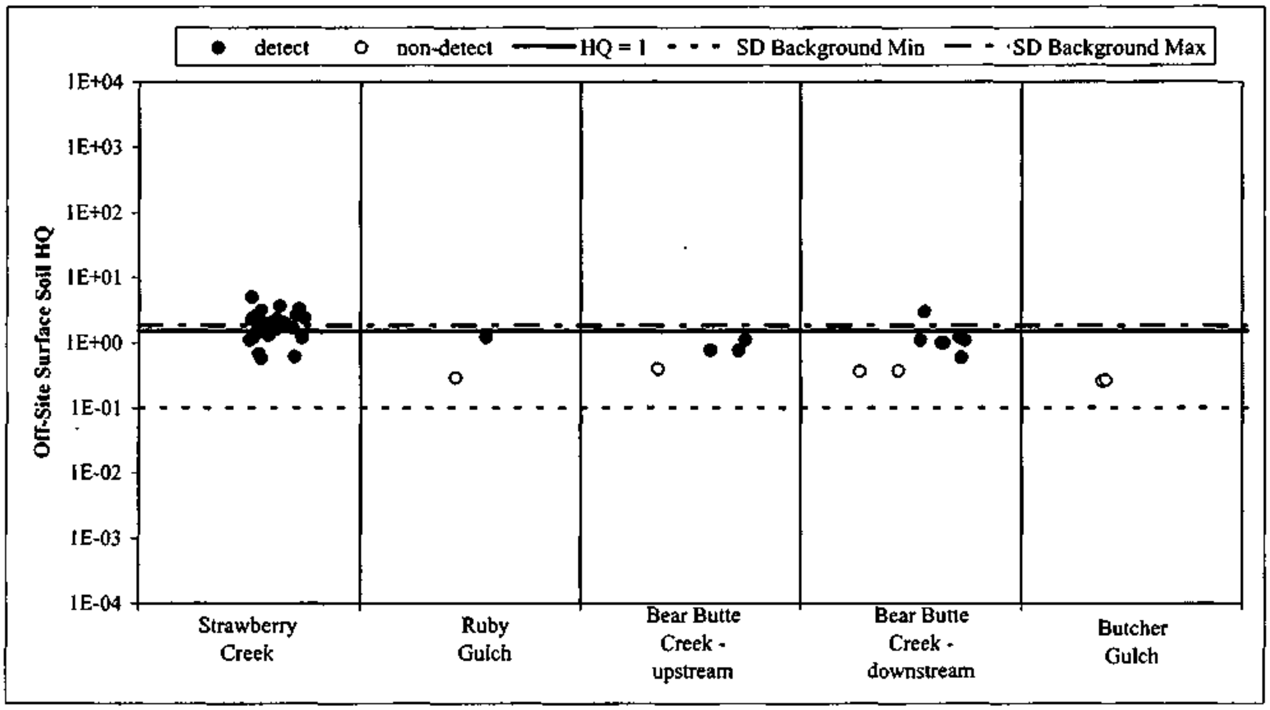


South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	1	0	0	0	0
HQs ≤ 1:	25	2	4	9	2
HQs > 1:	4%	0%	0%	0%	0%
HQs ≤ 1:	96%	100%	100%	100%	100%
Category:	minimal	none	none	none	none

Figure 6-1j
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates

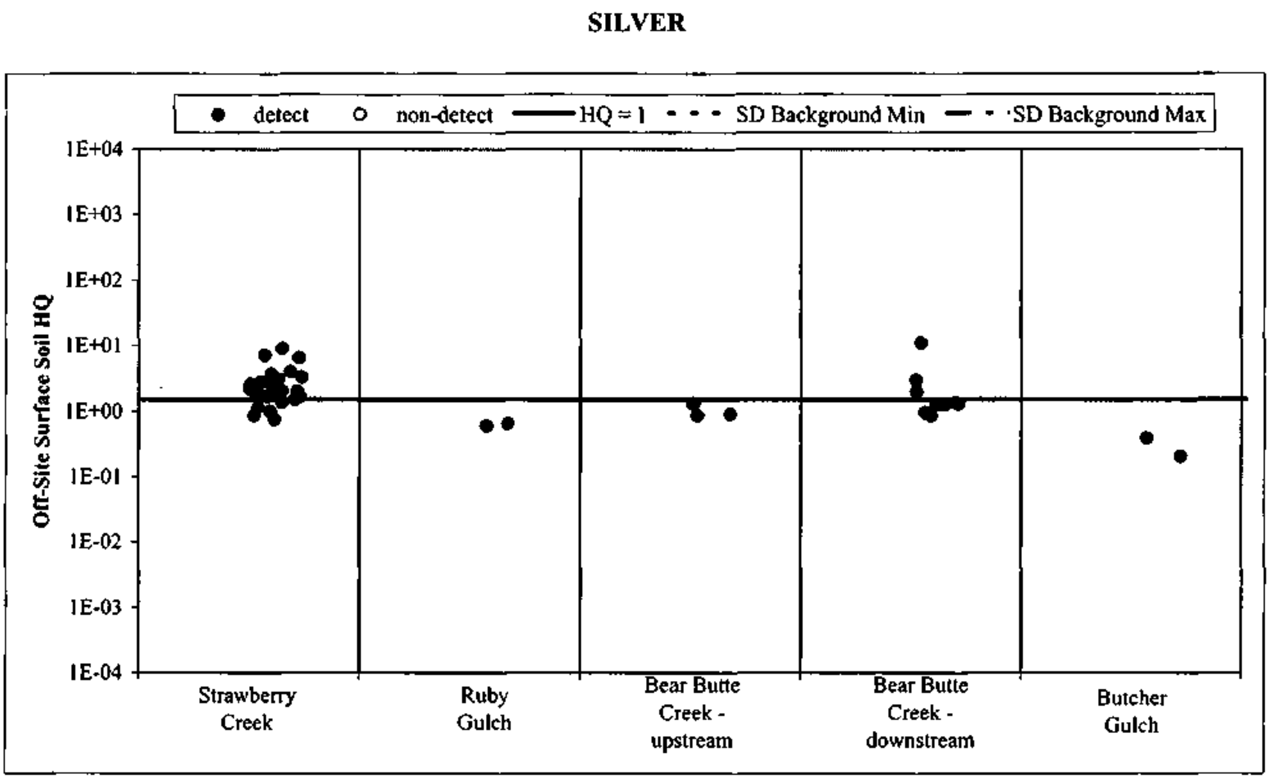
SELENIUM



South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	1	3	7	0
All Samples:	26	2	4	9	2
HQs > 1:	18	0	0	1	0
HQs ≤ 1:	8	2	4	8	2
HQs > 1:	69%	0%	0%	11%	0%
HQs ≤ 1:	31%	100%	100%	89%	100%
Category:	high	none	none	minimal	none

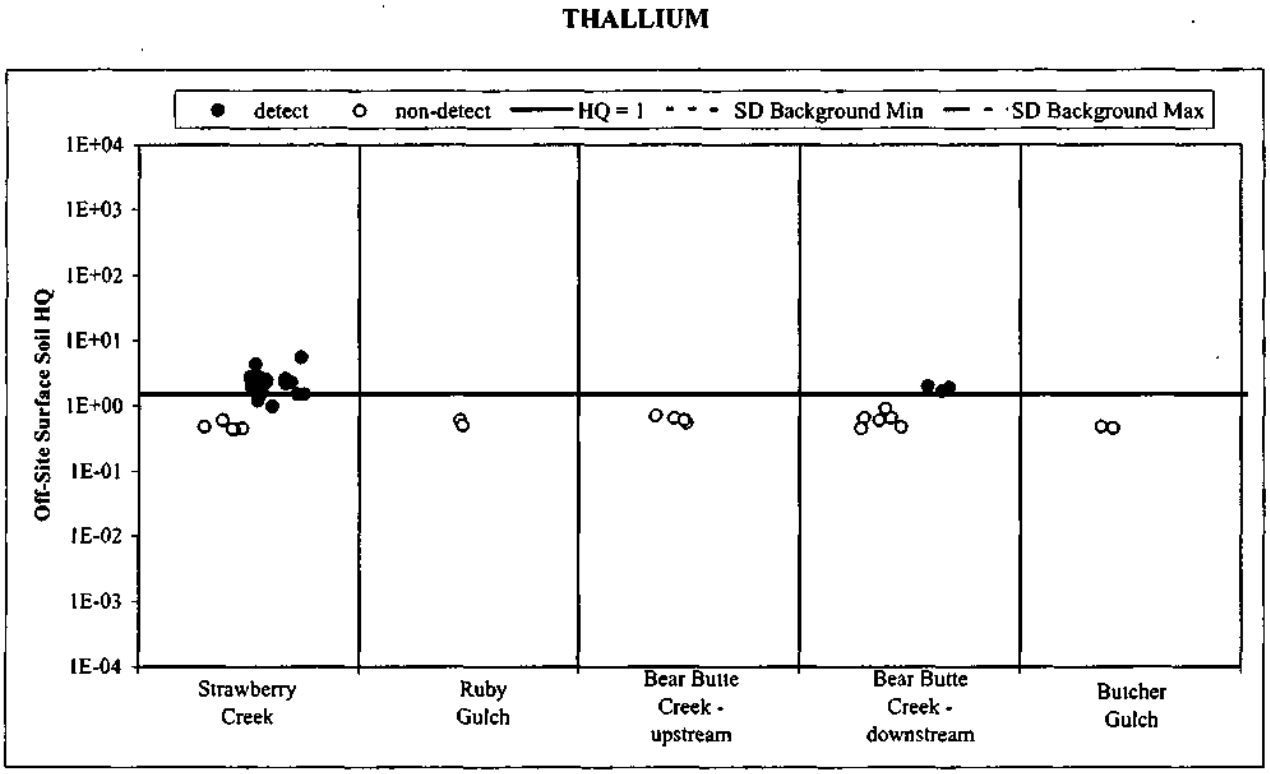
Figure 6-1k
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates



South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	21	0	0	3	0
HQs ≤ 1:	5	2	4	6	2
HQs > 1:	81%	0%	0%	33%	0%
HQs ≤ 1:	19%	100%	100%	67%	100%
Category:	severe	none	none	moderate	none

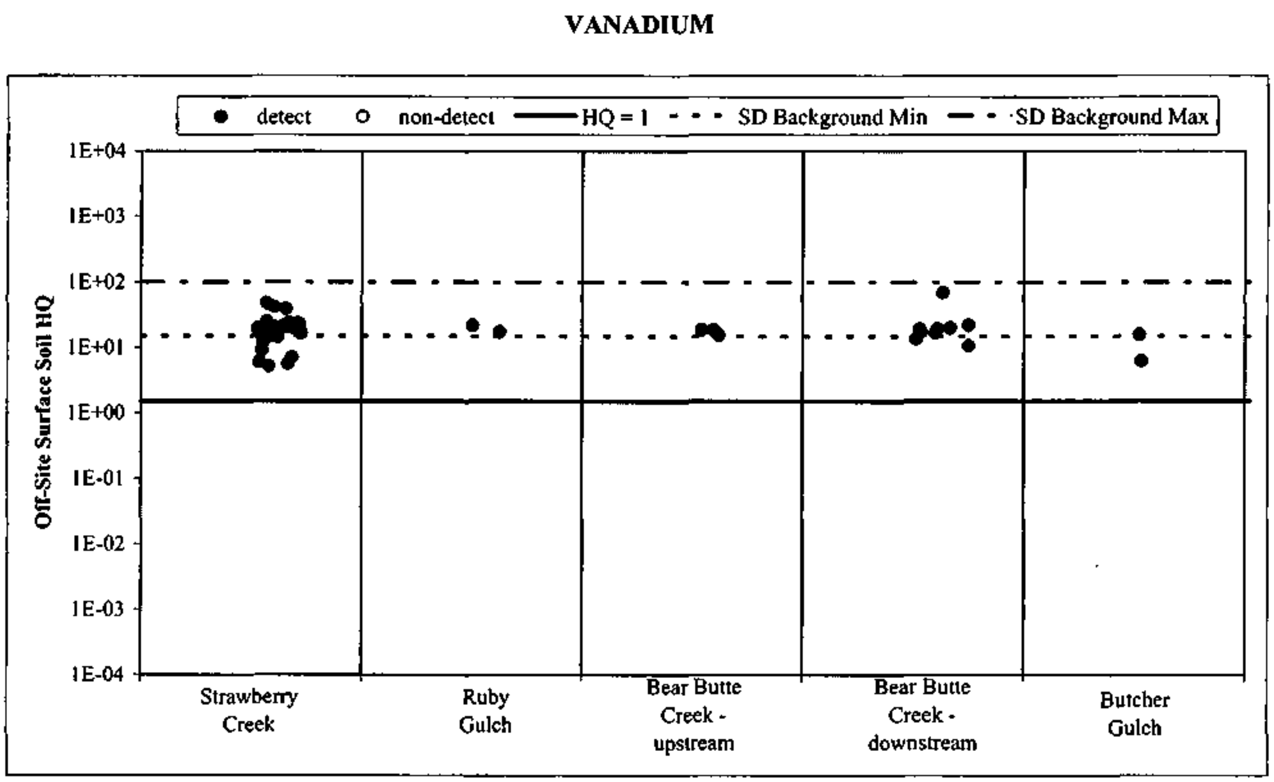
Figure 6-11
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates



South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	21	0	0	3	0
All Samples:	26	2	4	9	2
HQs > 1:	18	0	0	3	0
HQs ≤ 1:	8	2	4	6	2
HQs > 1:	69%	0%	0%	33%	0%
HQs ≤ 1:	31%	100%	100%	67%	100%
Category:	high	none	none	moderate	none

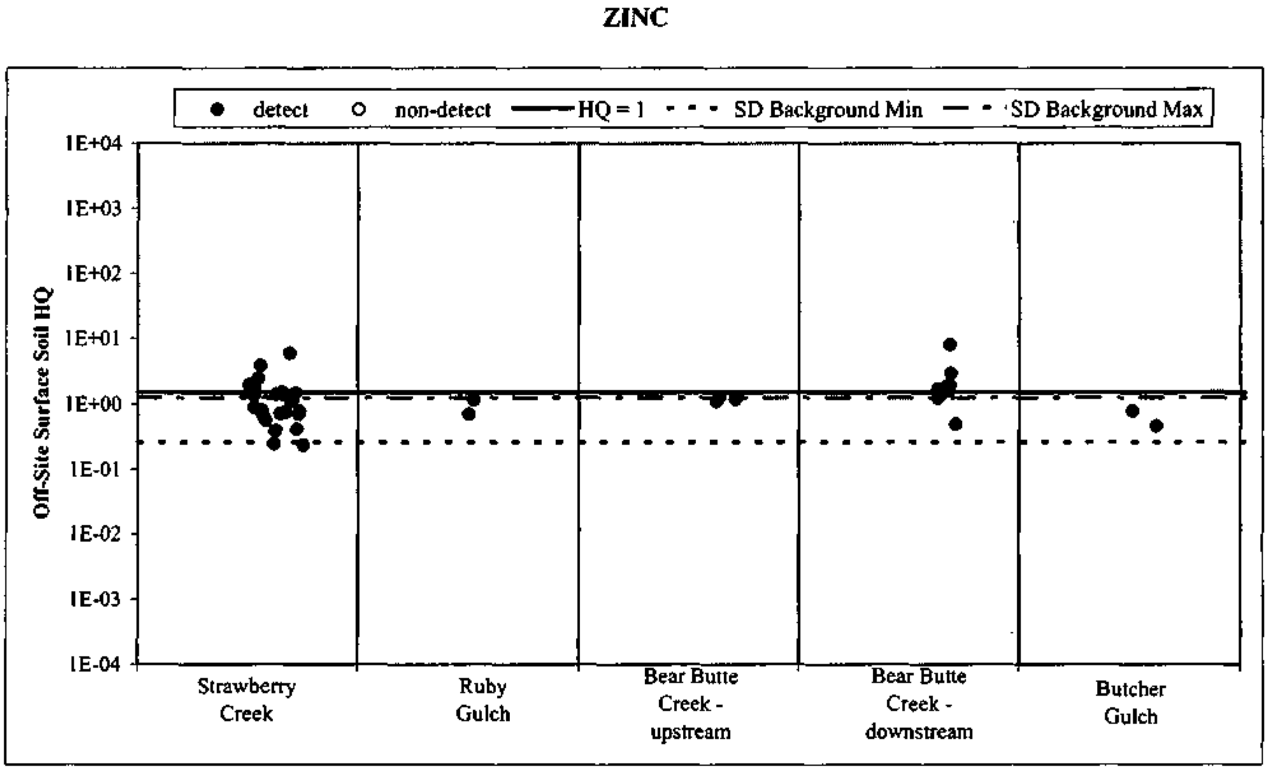
Figure 6-1m
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates



South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	26	2	4	9	2
HQs ≤ 1:	0	0	0	0	0
HQs > 1:	100%	100%	100%	100%	100%
HQs ≤ 1:	0%	0%	0%	0%	0%
Category:	severe	severe	severe	severe	severe

Figure 6-1n
Summary of Riparian Surface Soil HQs for Plants and Soil Invertebrates



South Dakota Background statistics from Shacklette and Boerngen, 1984 (N=30).

	Site	Site	Reference	Site	Reference
	Strawberry Creek	Ruby Gulch	Bear Butte Creek-upstream	Bear Butte Creek-downstream	Butcher Gulch
Detect Samples:	26	2	4	9	2
All Samples:	26	2	4	9	2
HQs > 1:	6	0	0	6	0
HQs ≤ 1:	20	2	4	3	2
HQs > 1:	23%	0%	0%	67%	0%
HQs ≤ 1:	77%	100%	100%	33%	100%
Category:	moderate	none	none	high	none

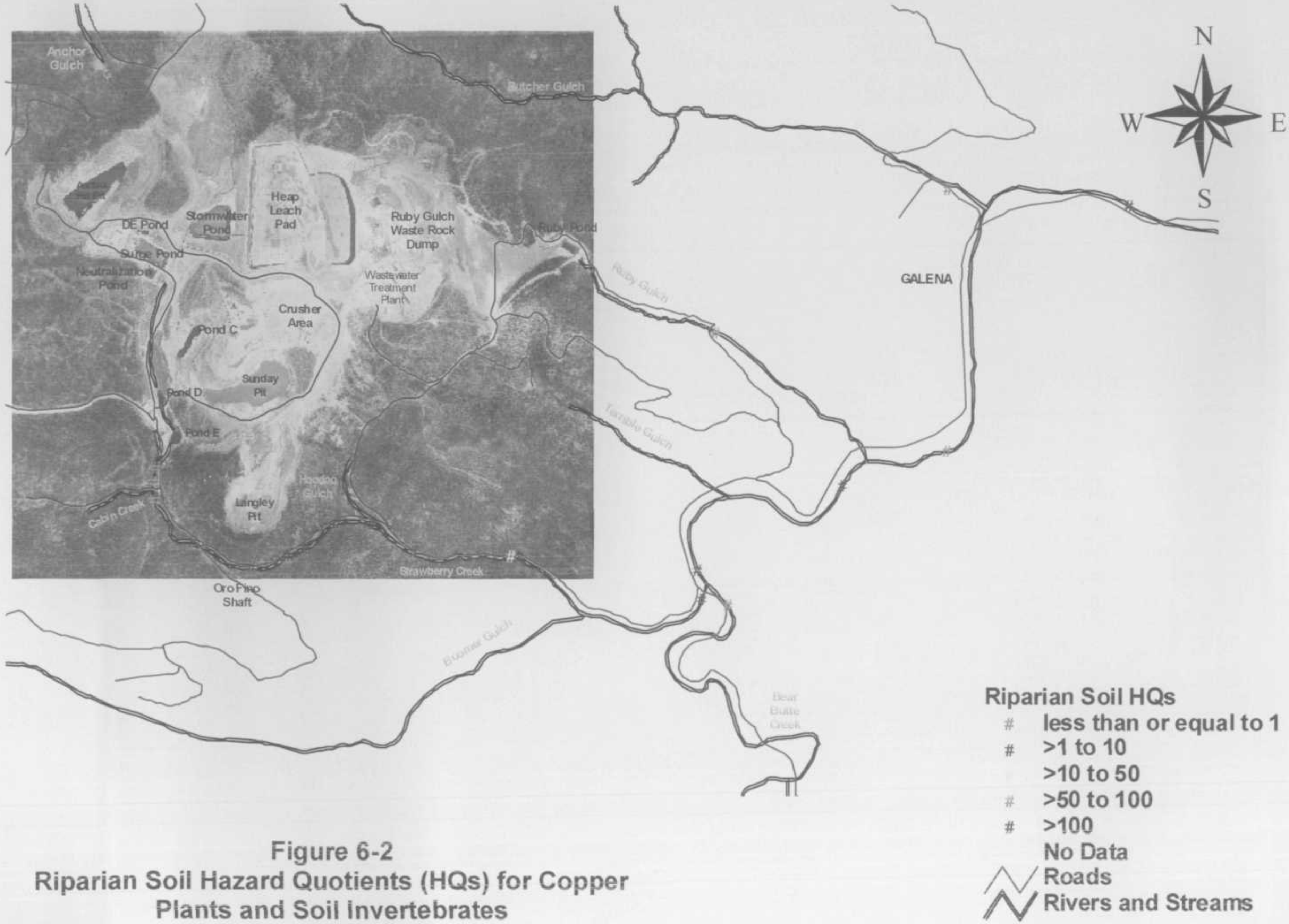


Figure 6-2
Riparian Soil Hazard Quotients (HQs) for Copper Plants and Soil Invertebrates

off-site (riparian) soil HQ maps3.doc (gem_revisedHQs.apr)

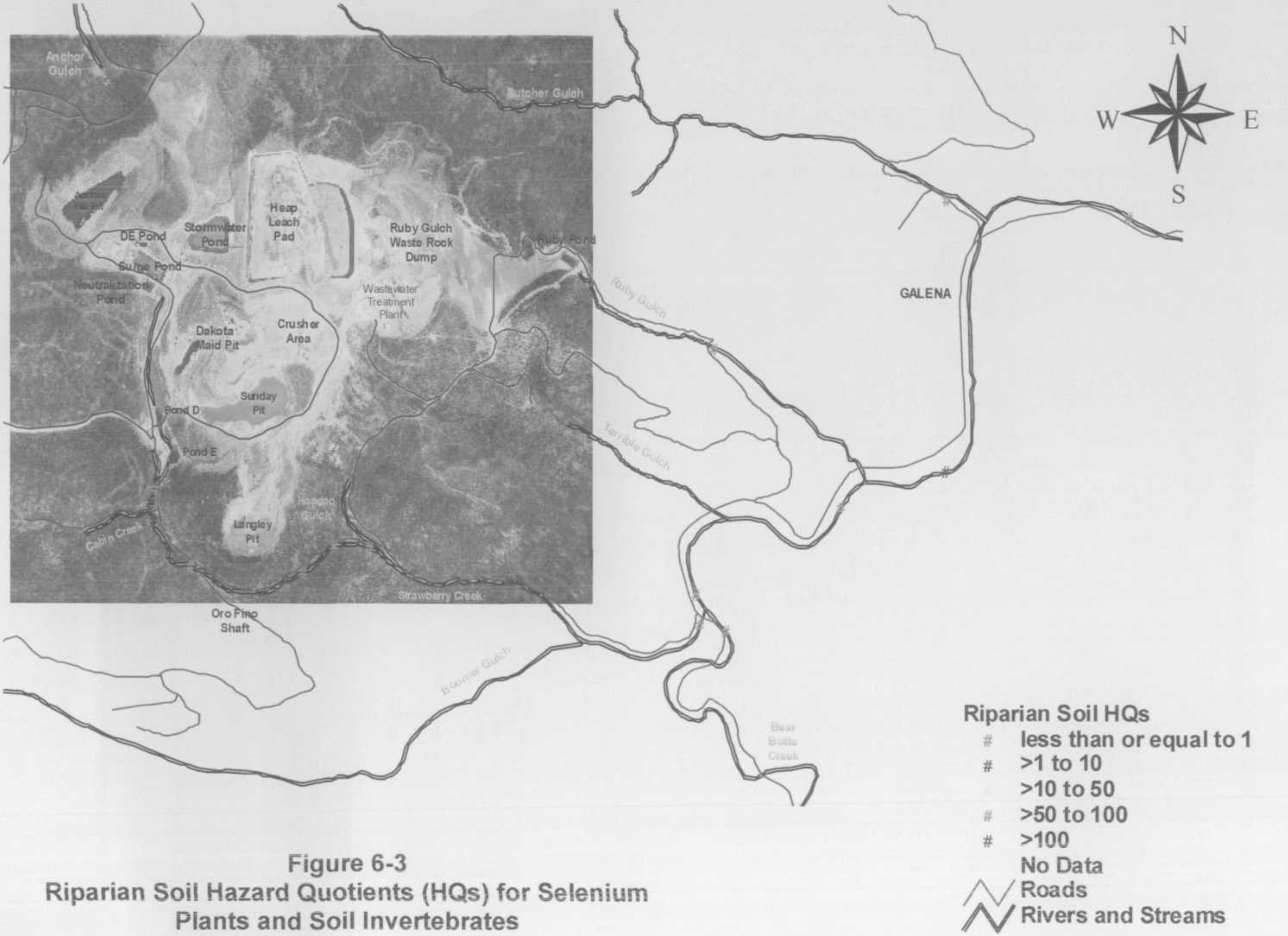


Figure 6-3
Riparian Soil Hazard Quotients (HQs) for Selenium Plants and Soil Invertebrates

off-site (riparian) soil HQ maps3.doc (gem_revisedHQs.apr)

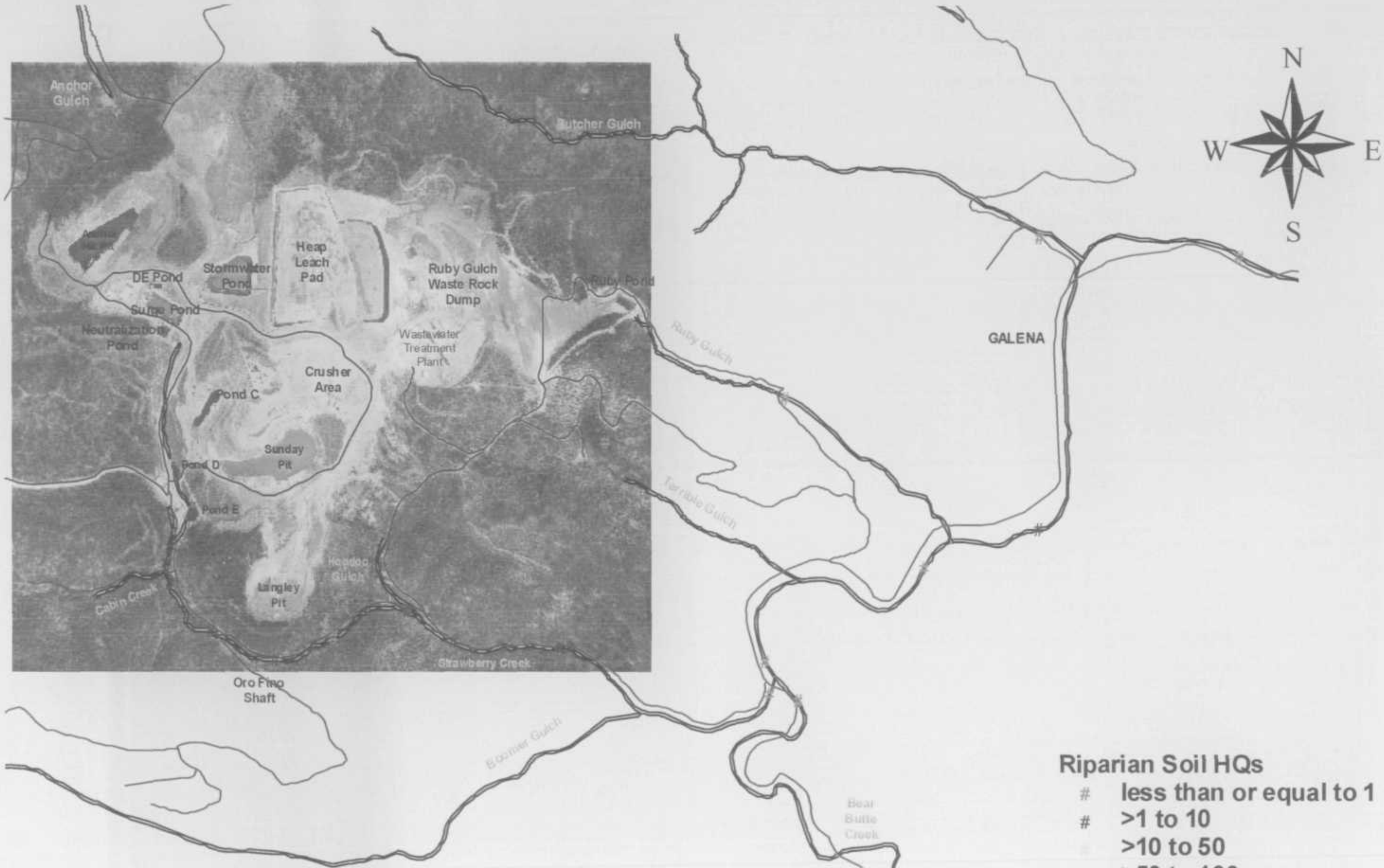


Figure 6-4
Riparian Soil Hazard Quotients (HQs) for Silver Plants and Soil Invertebrates

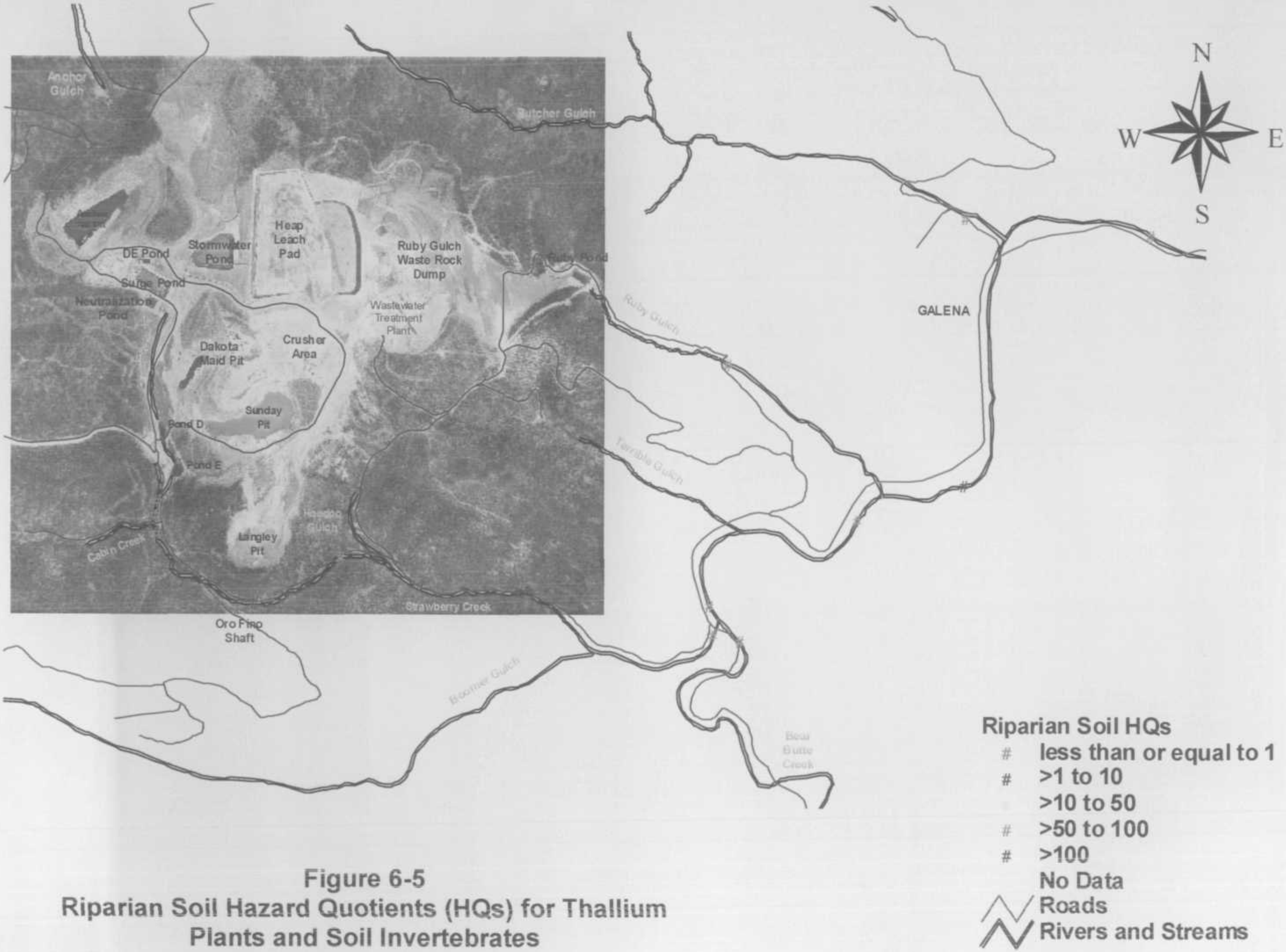


Figure 6-5
Riparian Soil Hazard Quotients (HQs) for Thallium
Plants and Soil Invertebrates

off-site (riparian) soil HQ maps3.doc (gem_revisedHQs.apr)

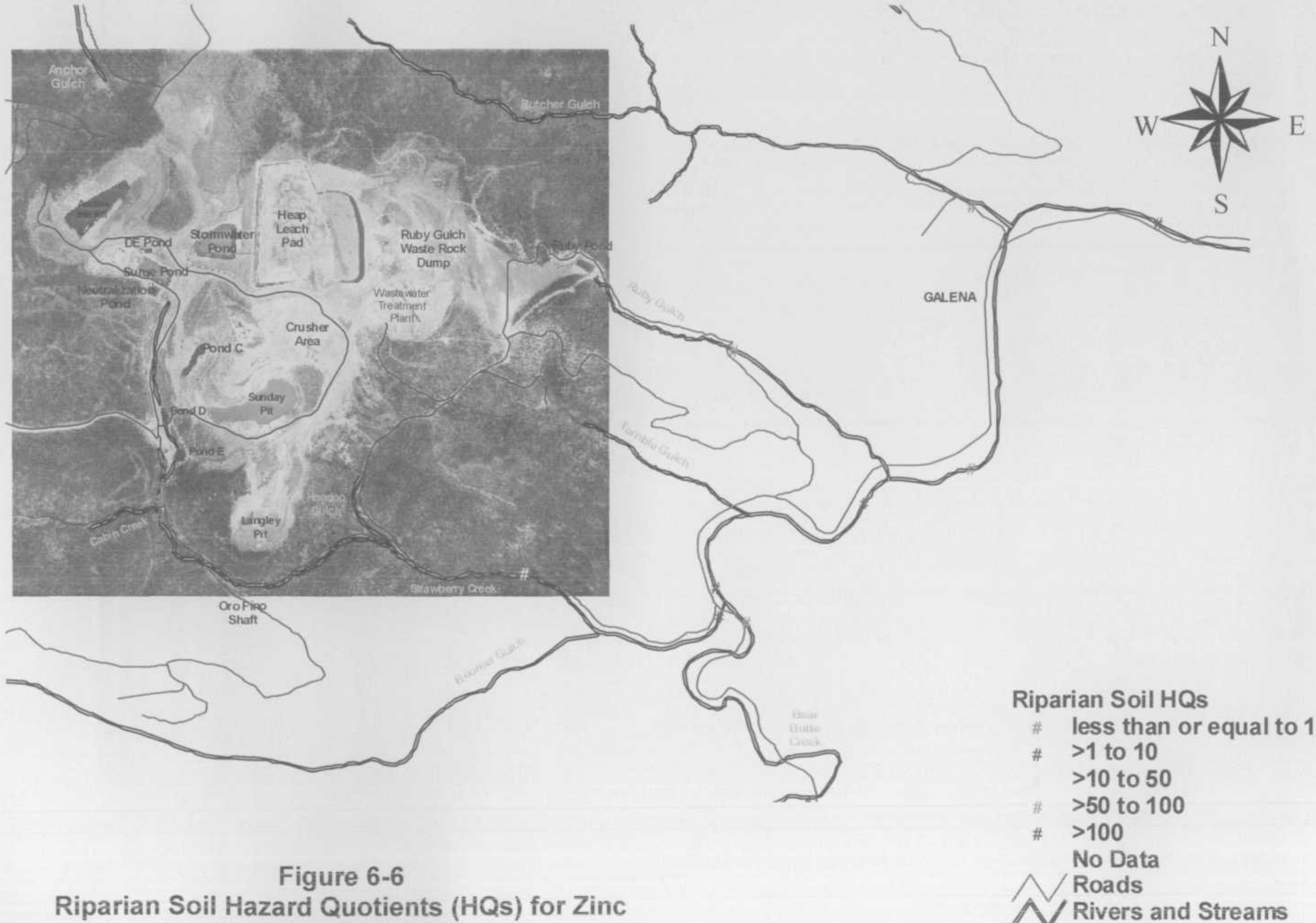
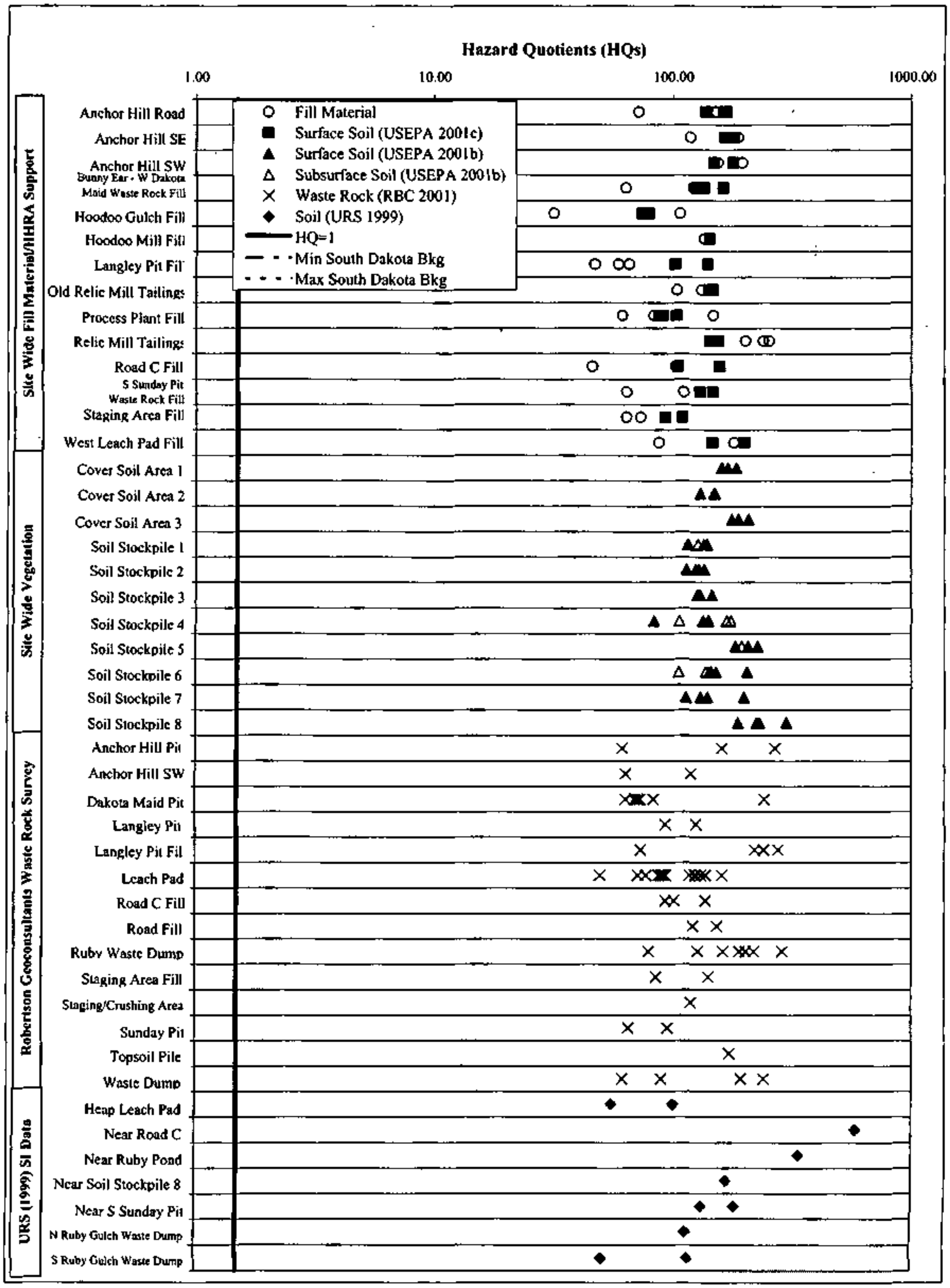


Figure 6-6
Riparian Soil Hazard Quotients (HQs) for Zinc Plants and Soil Invertebrates

off-site (riparian) soil HQ maps3.doc (gem_revisedHQs.apr)

Figure 6-7a
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

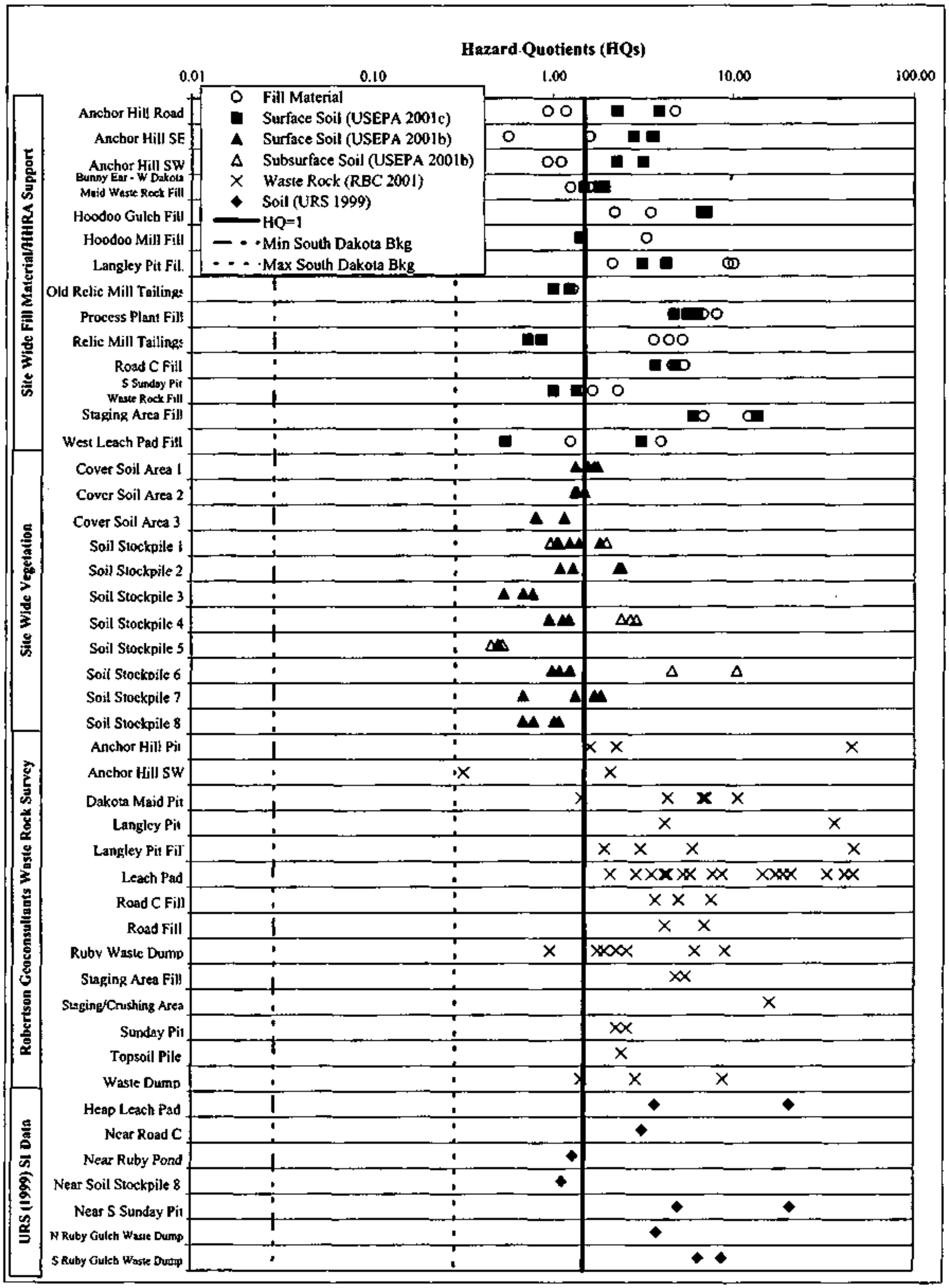
ALUMINUM



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7b
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

ARSENIC

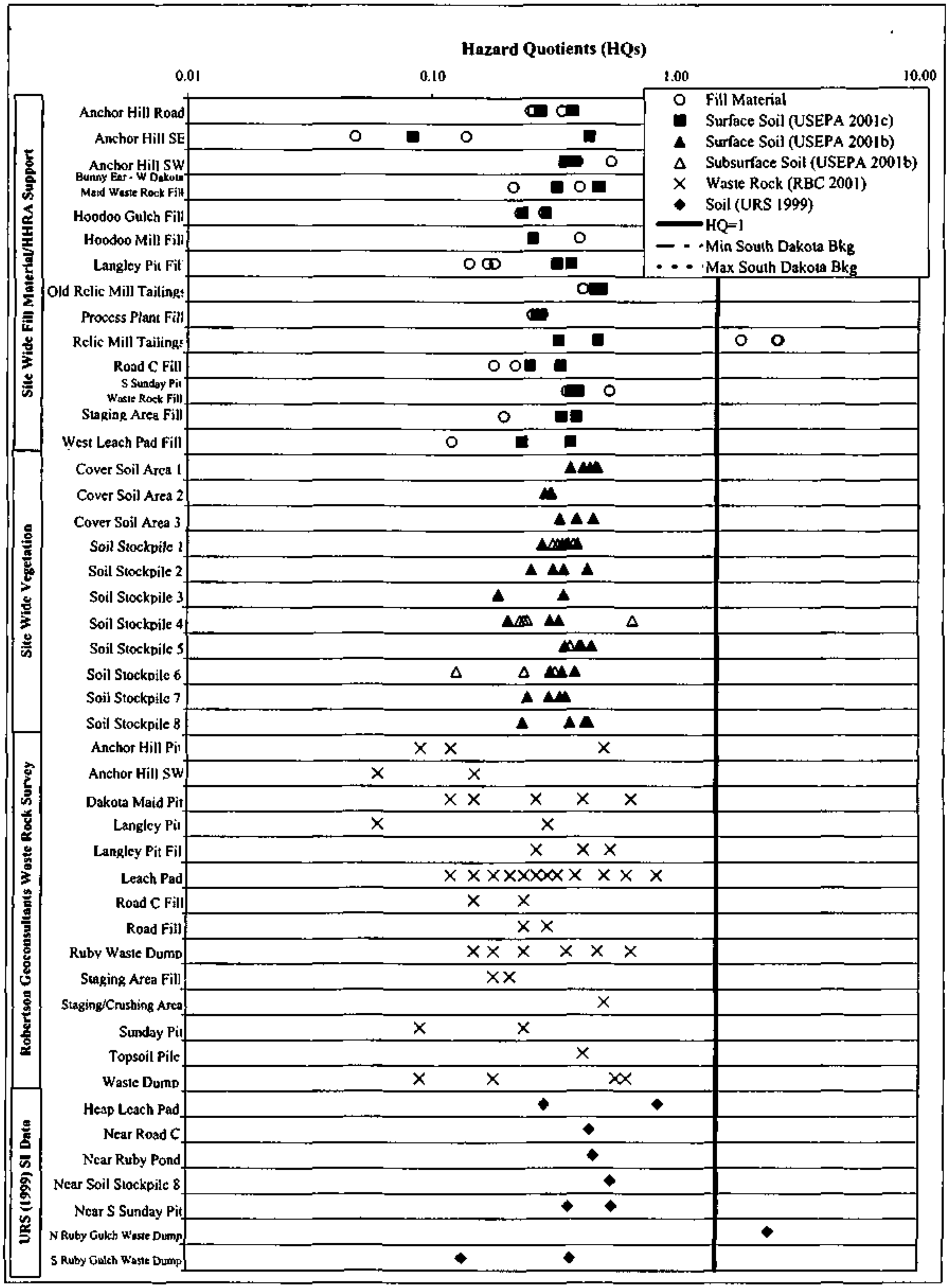


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Terr_Soil Onsite.xls: Graphs
1/21/2003

Figure 6-7c
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

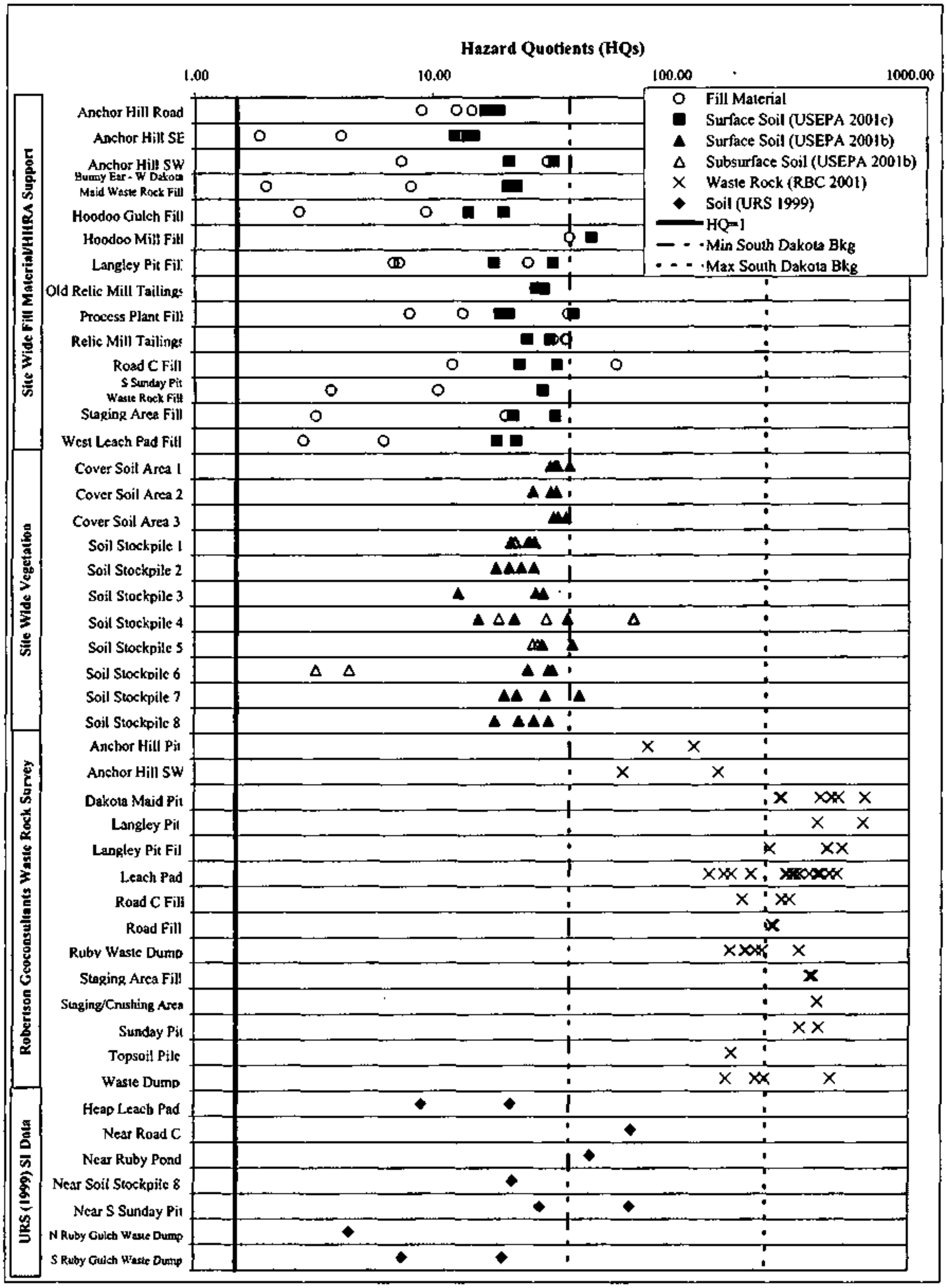
BARIUM



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7d
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

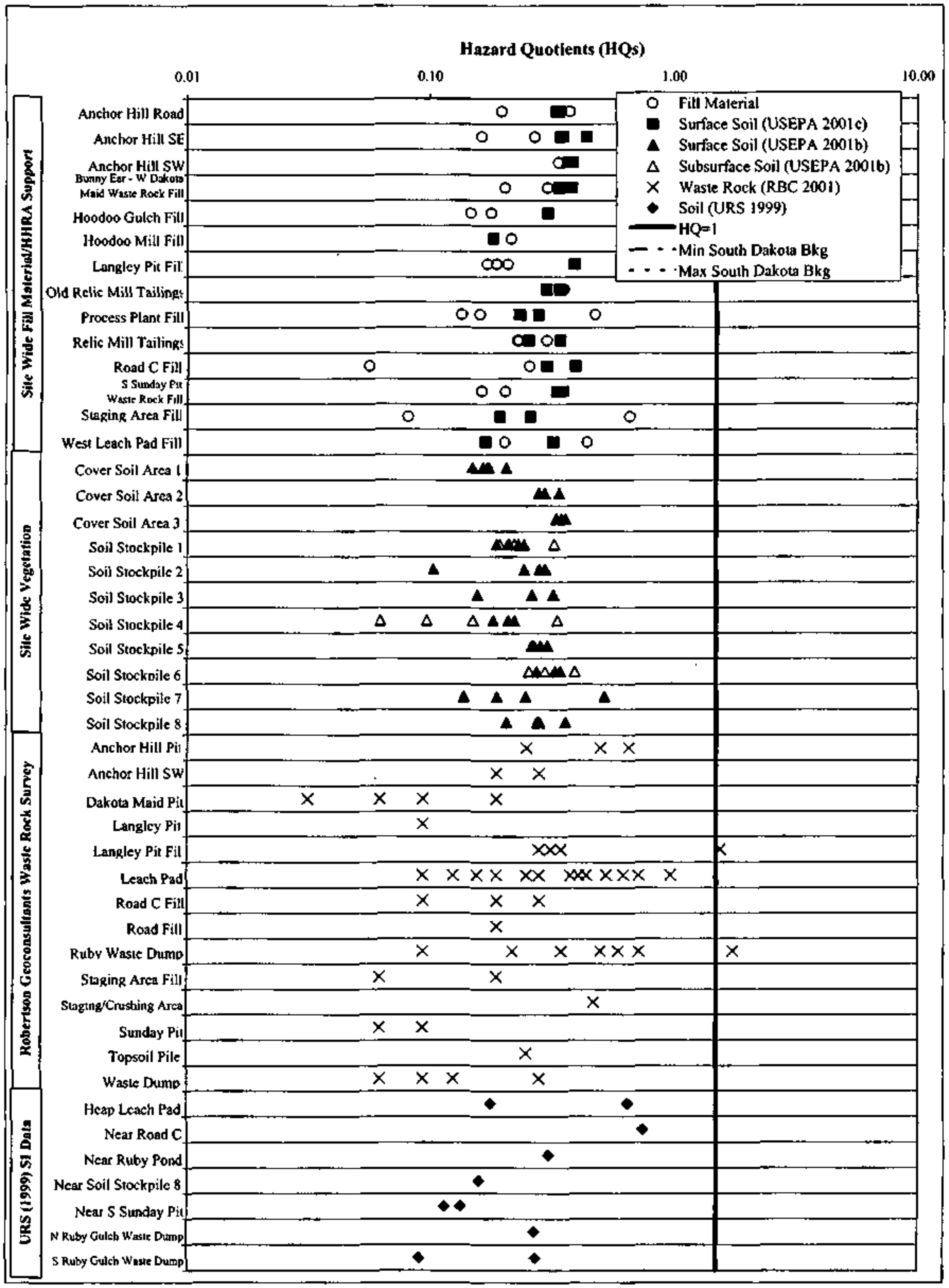
CHROMIUM



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7e
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

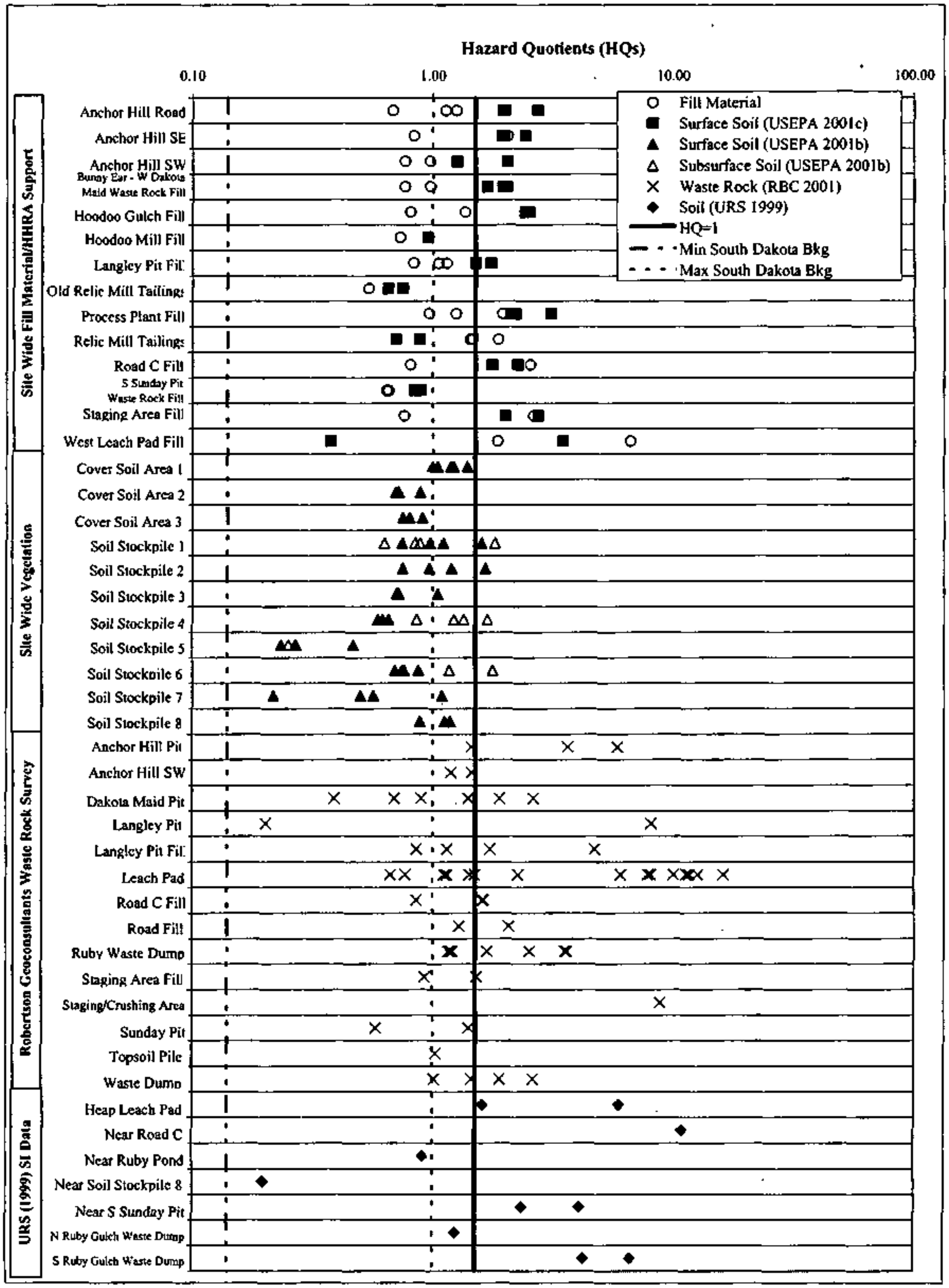
COBALT



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7f
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

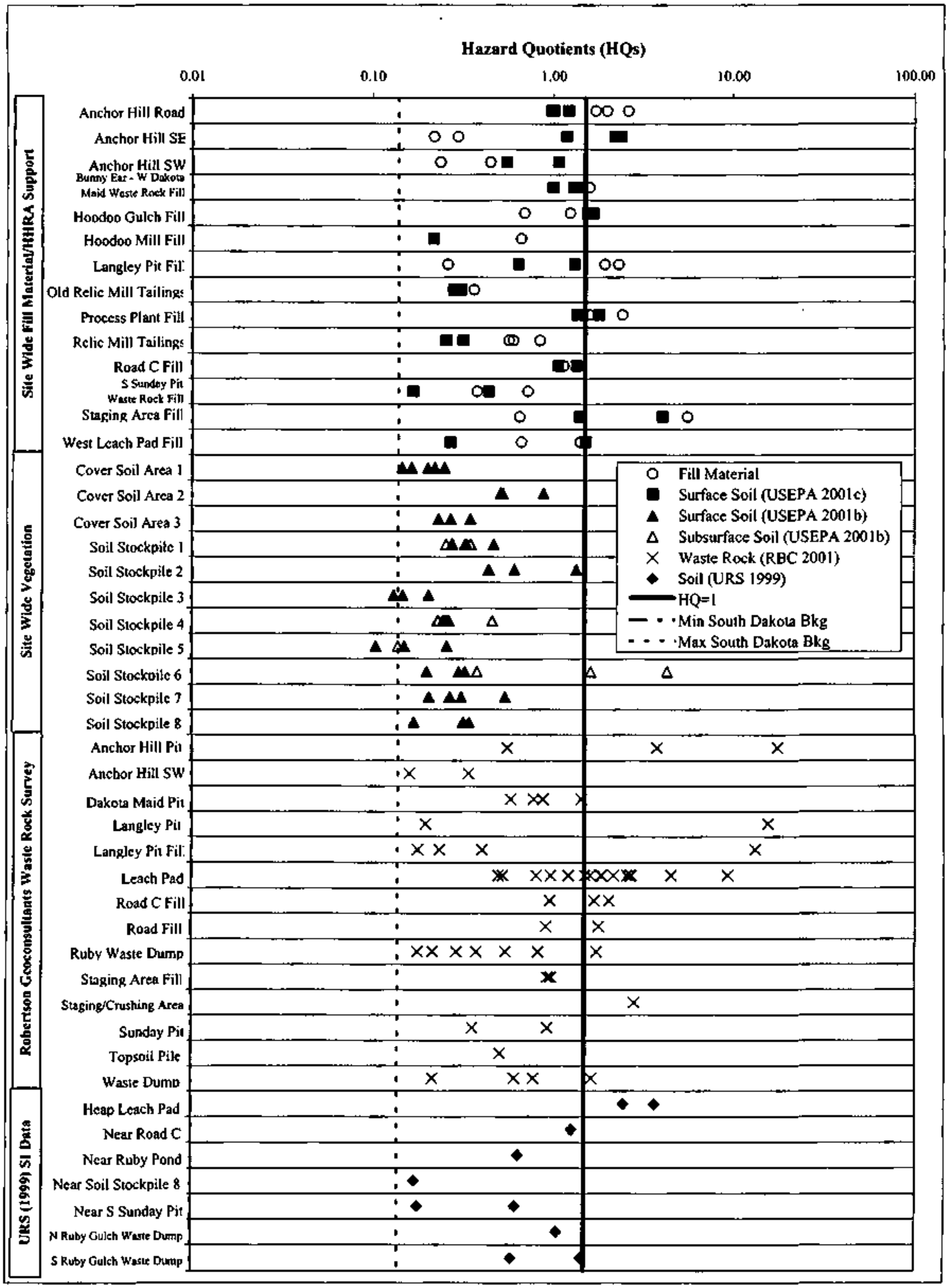
COPPER



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

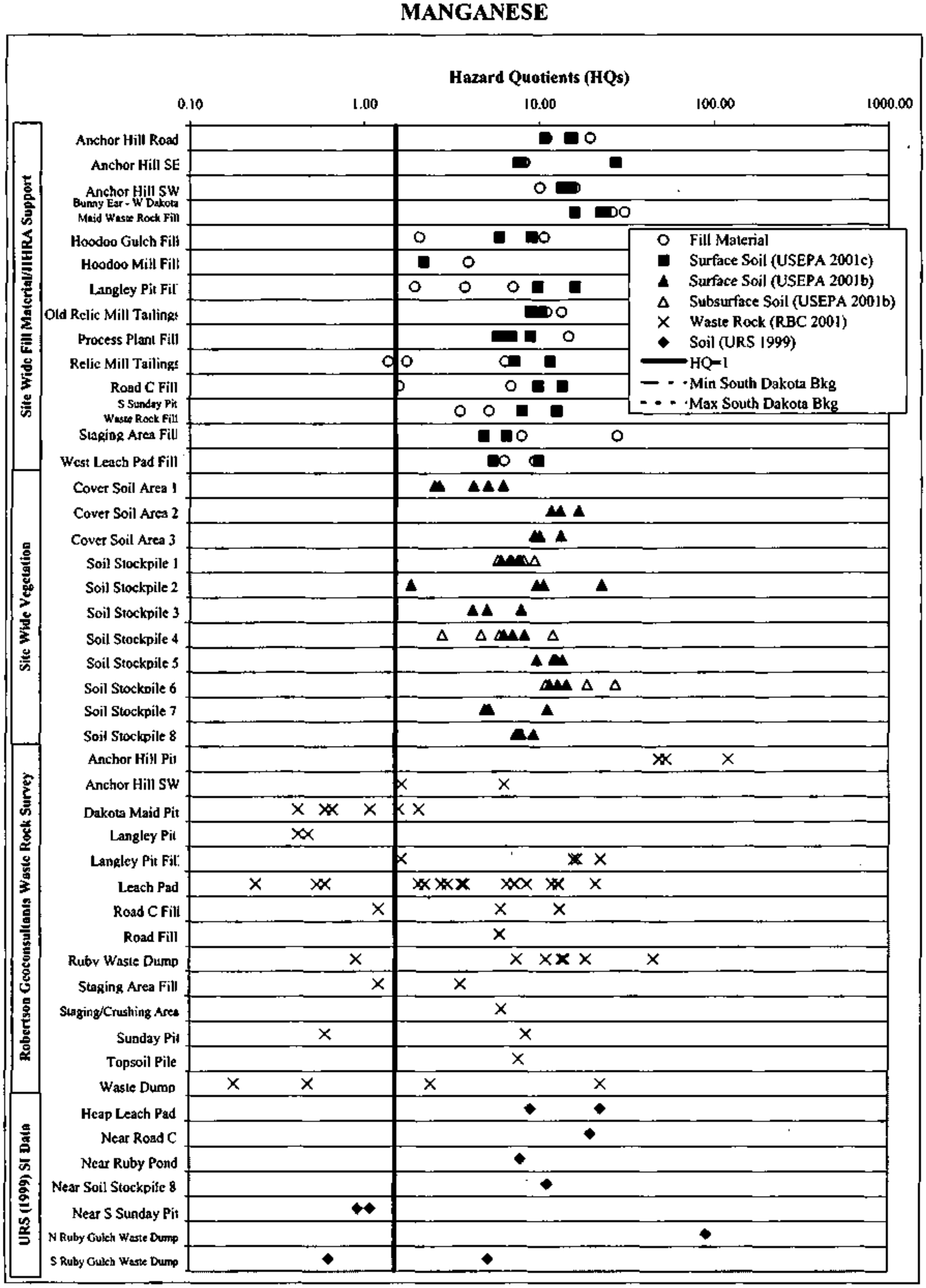
Figure 6-7g
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

LEAD



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

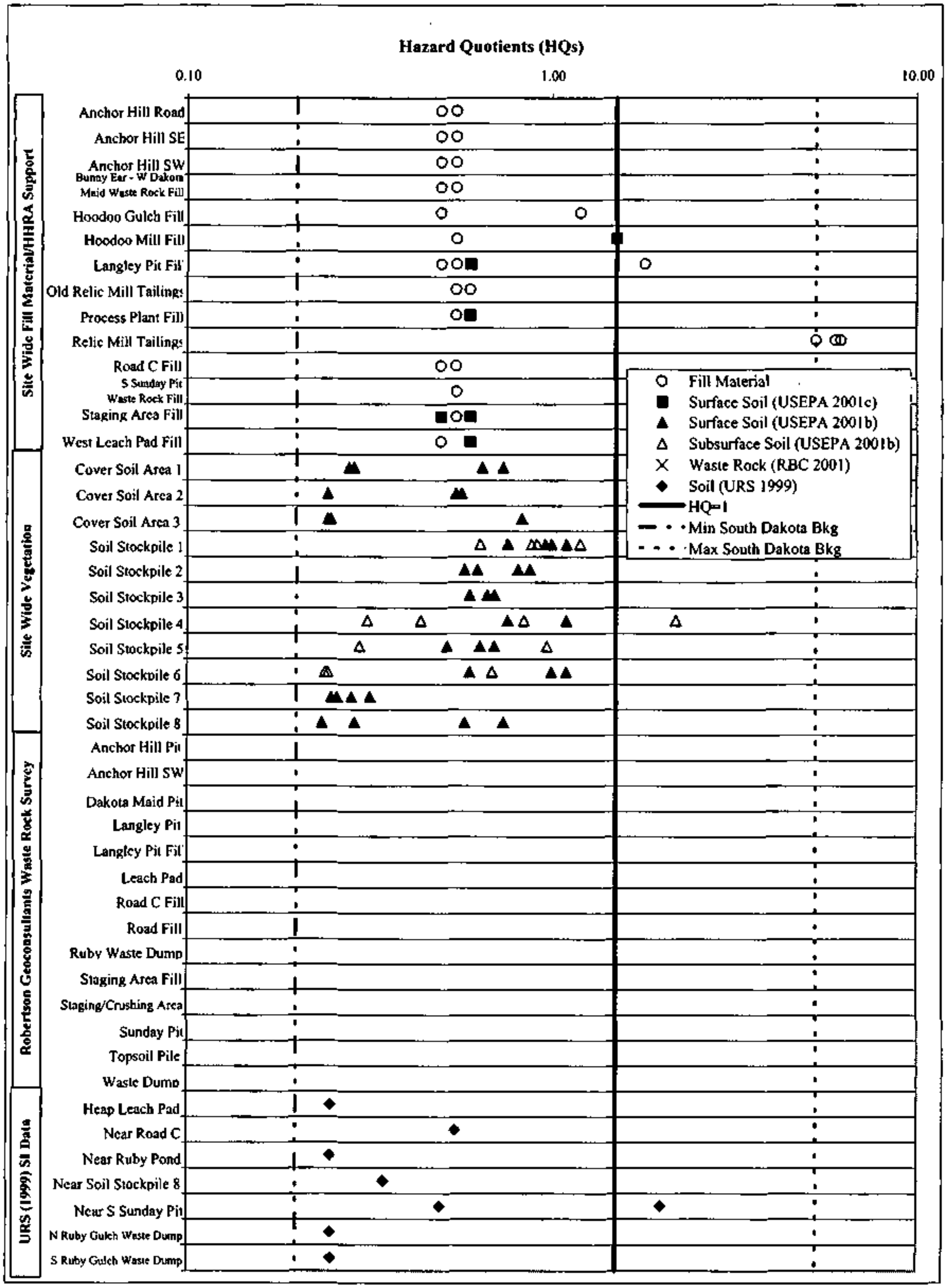
Figure 6-7h
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7i
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

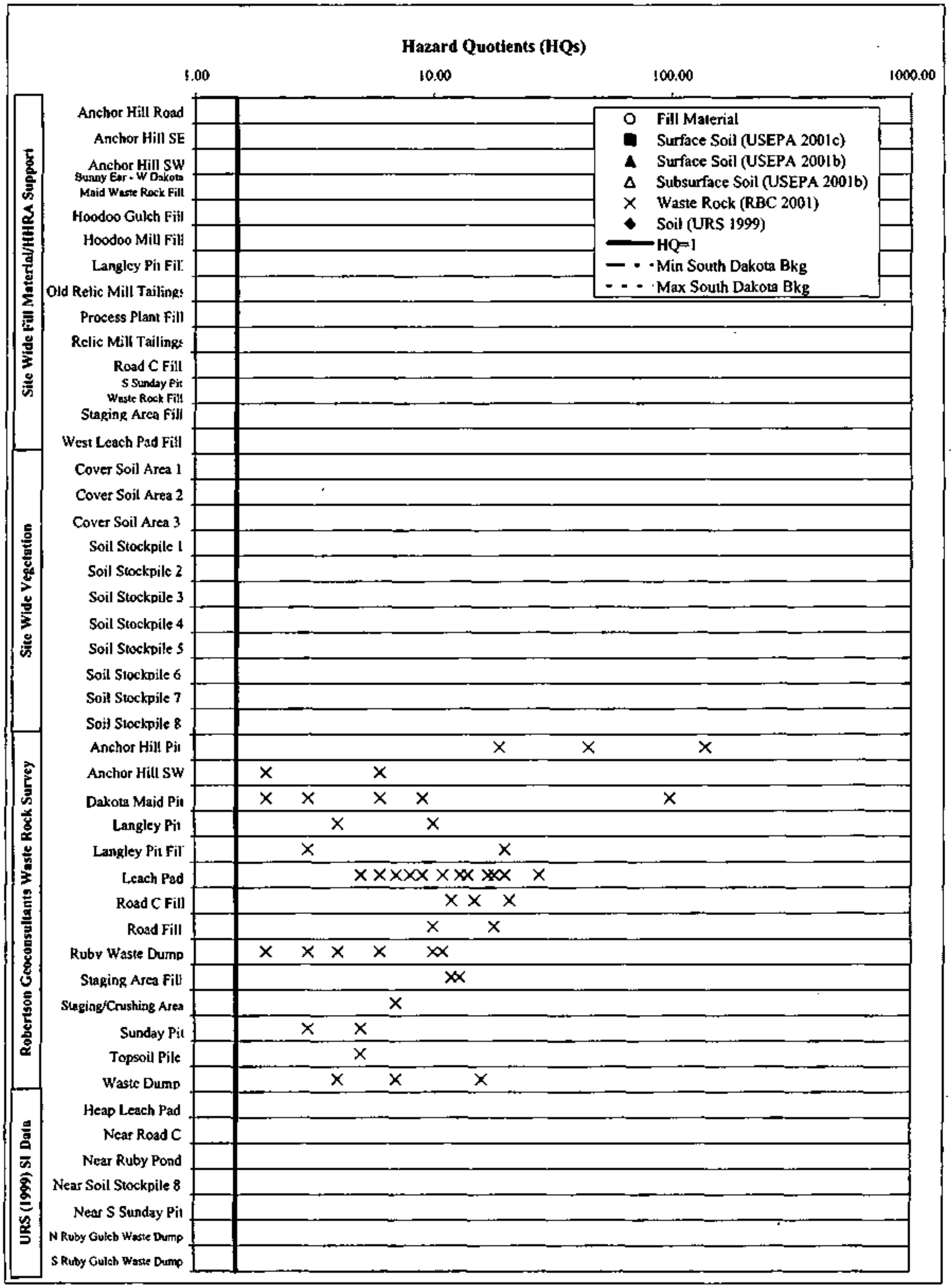
MERCURY



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7j
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

MOLYBDENUM

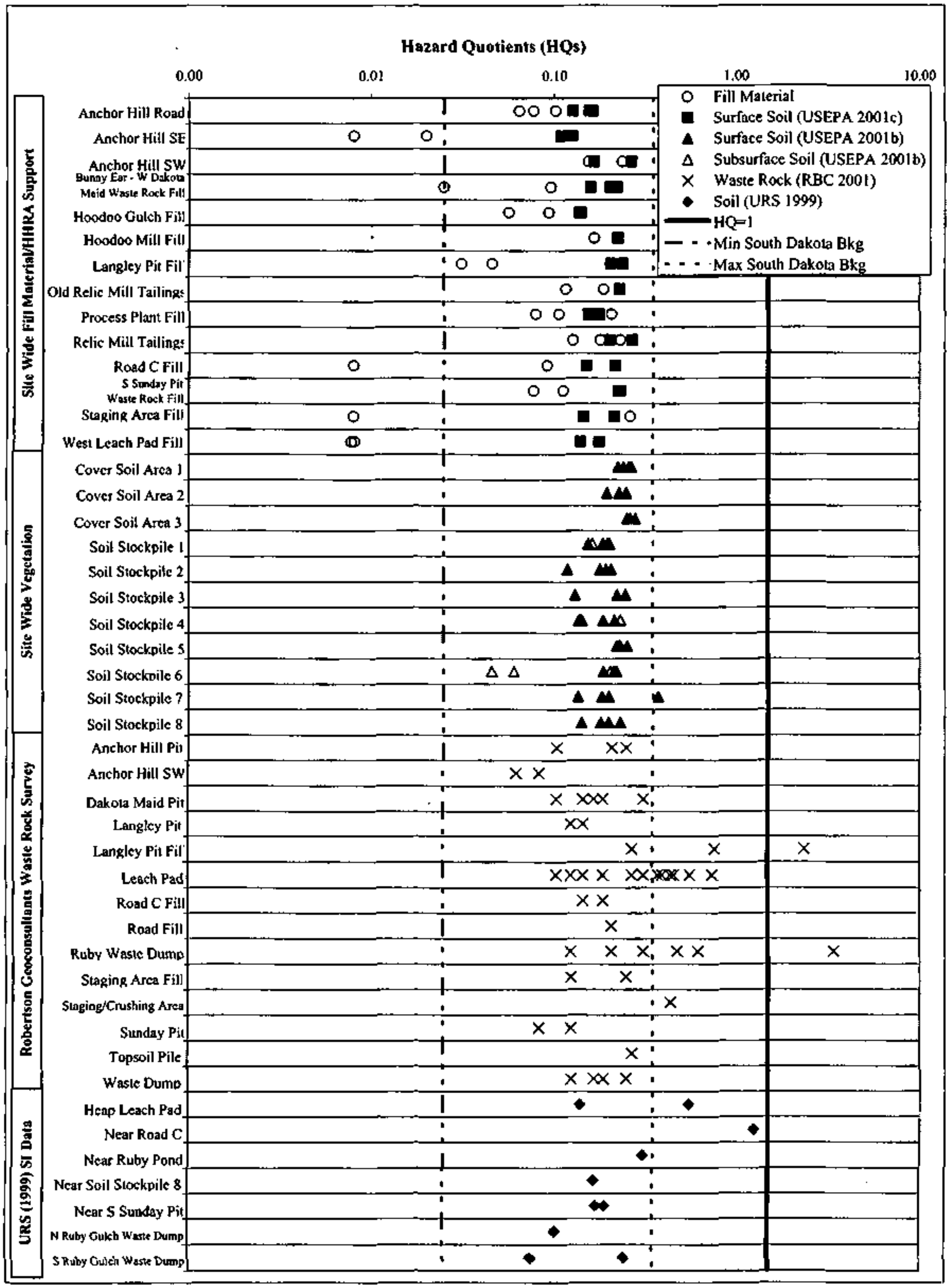


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Terr_Soil Onsite.xls: Graphs
1/21/2003

Figure 6-7k
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

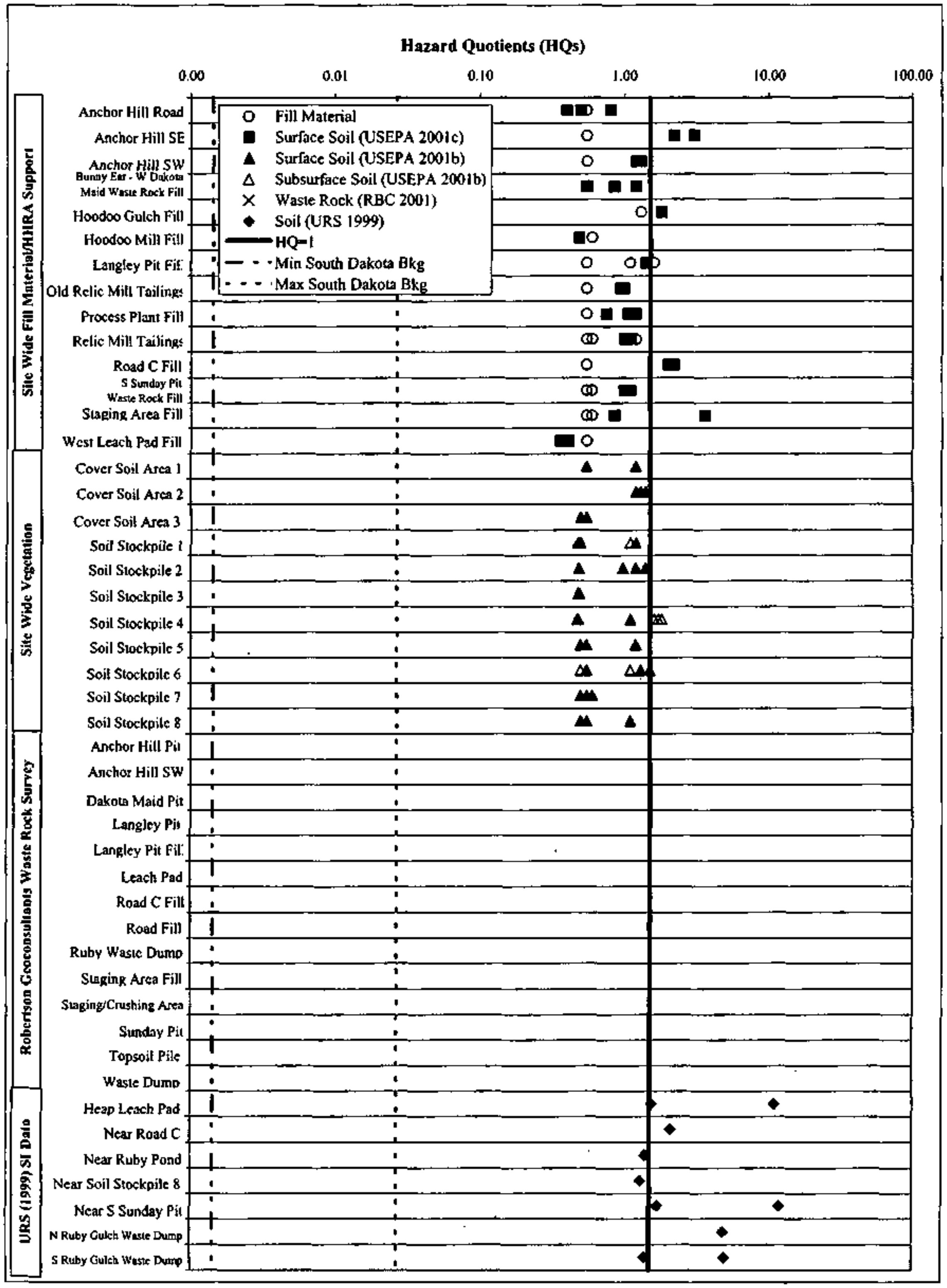
NICKEL



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-71
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

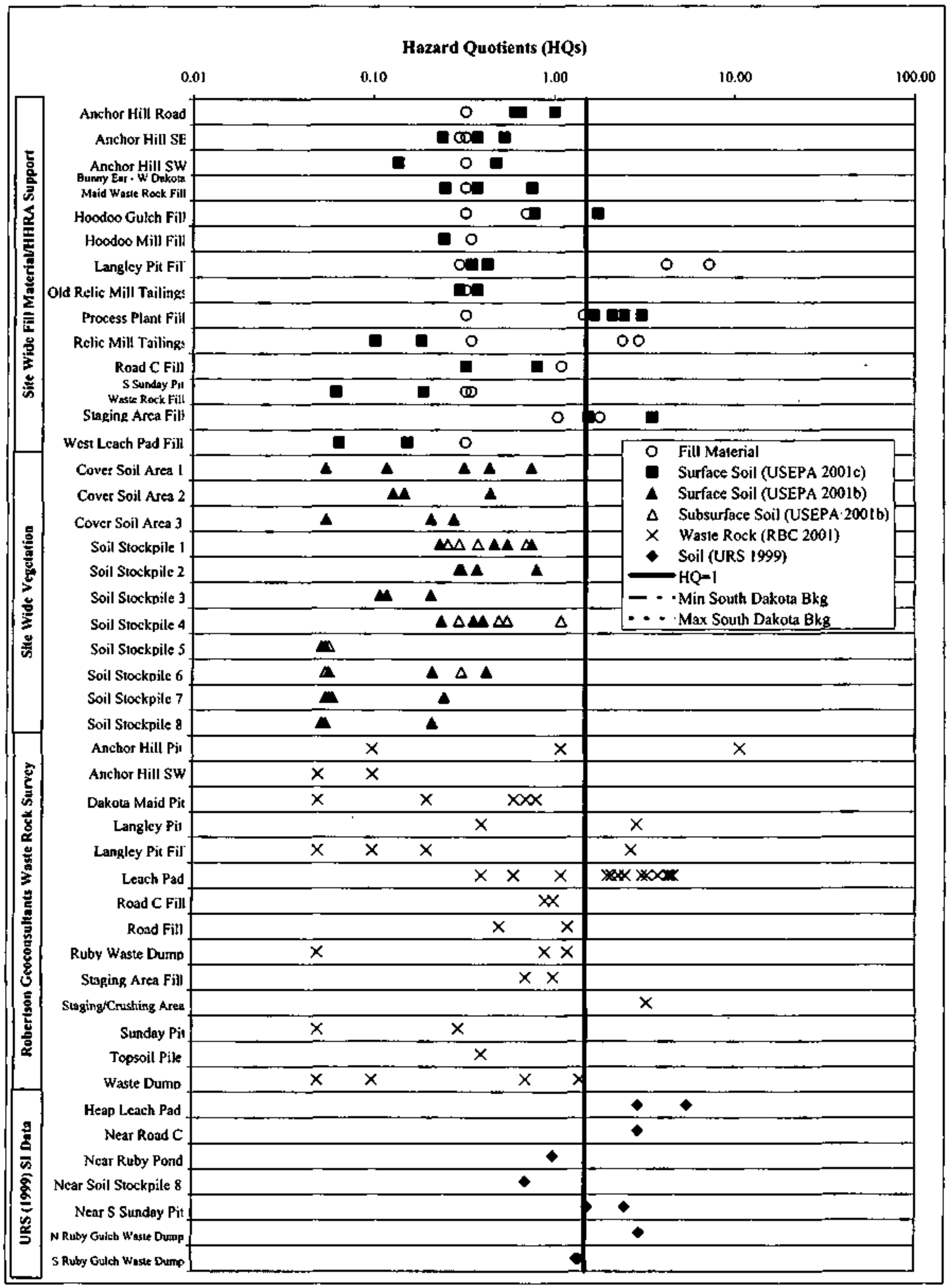
SELENIUM



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7m
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

SILVER

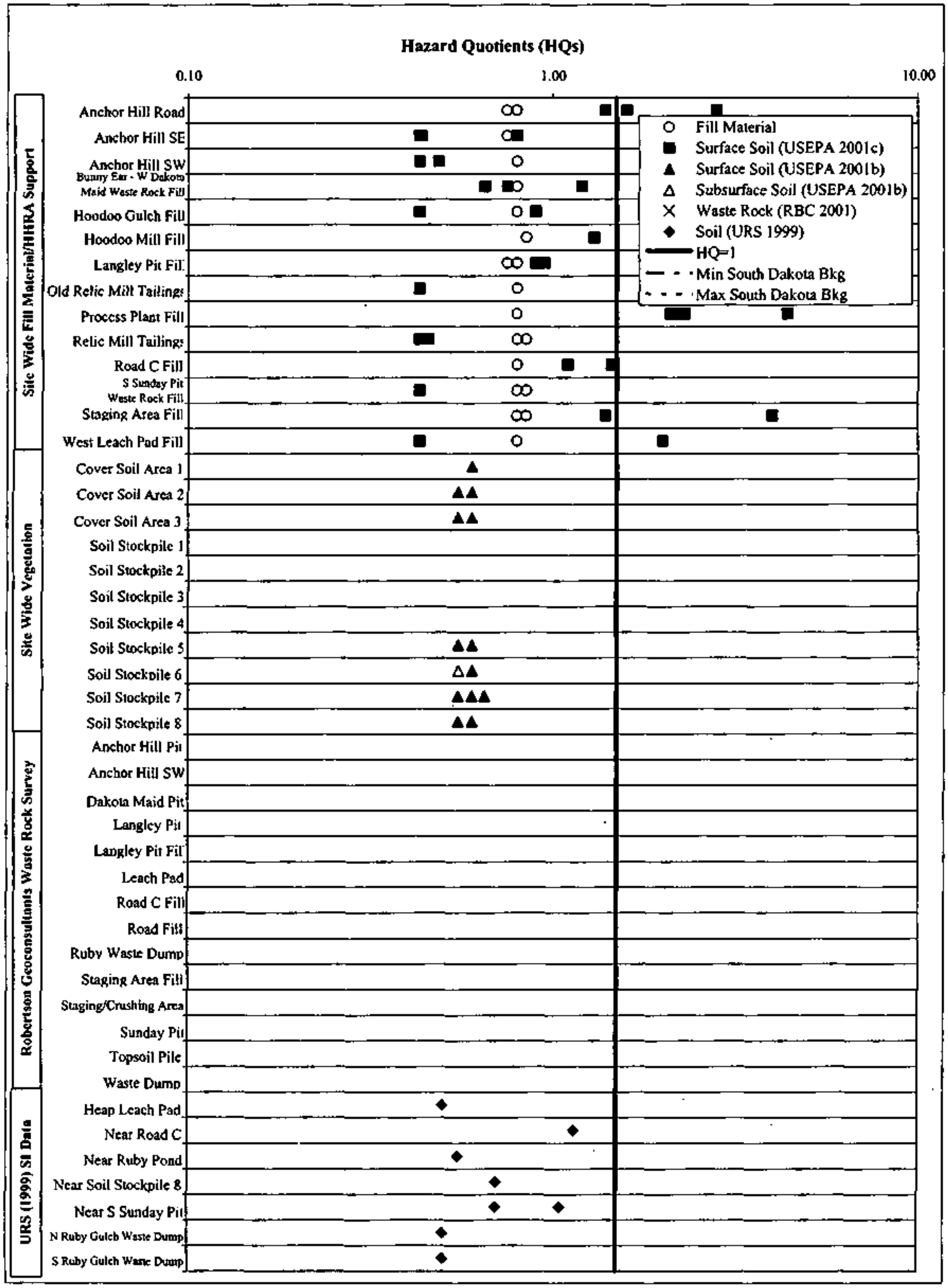


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Terr_Soil Onsite.xls: Graphs
1/21/2003

Figure 6-7n
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

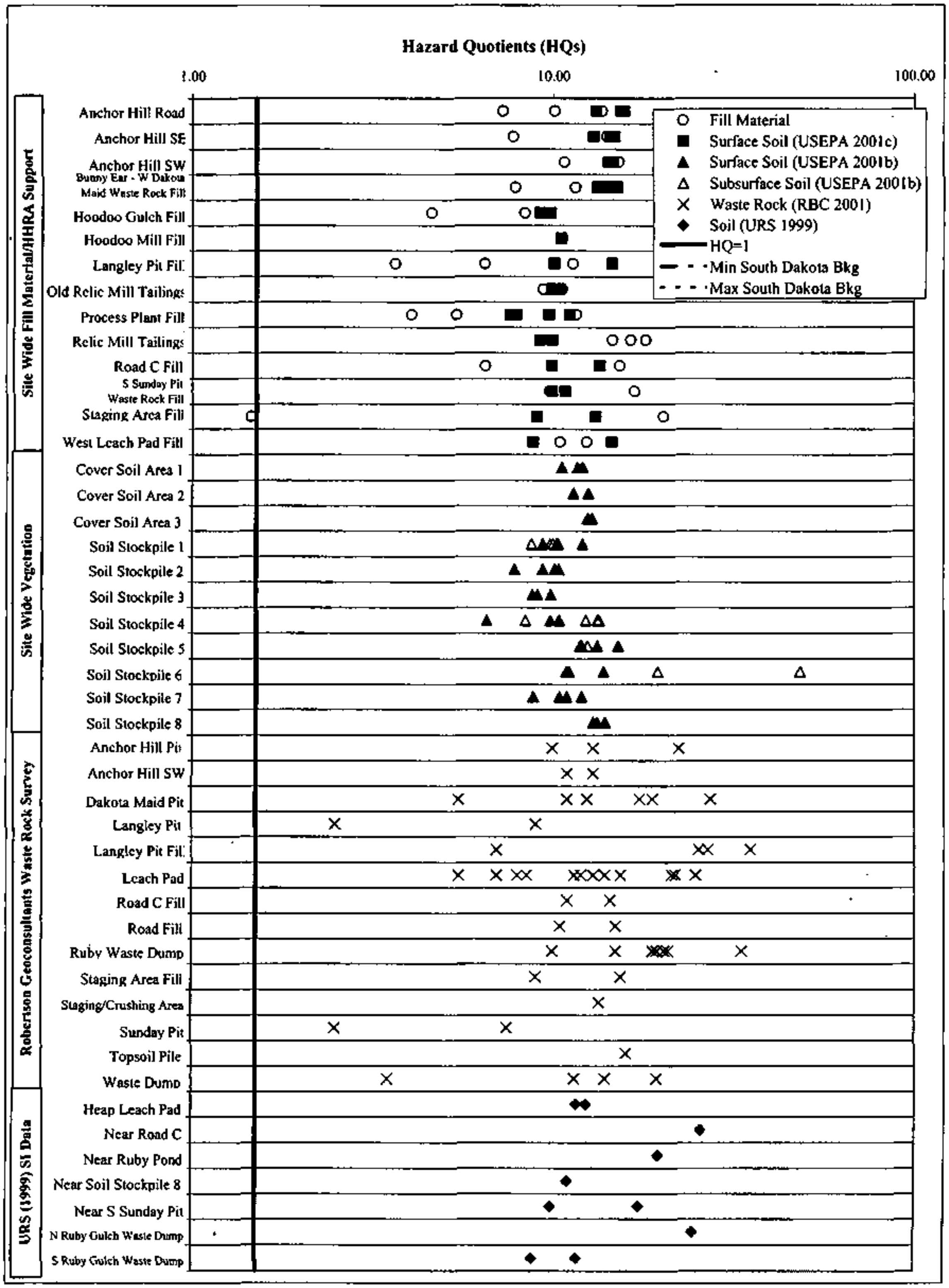
THALLIUM



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7o
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

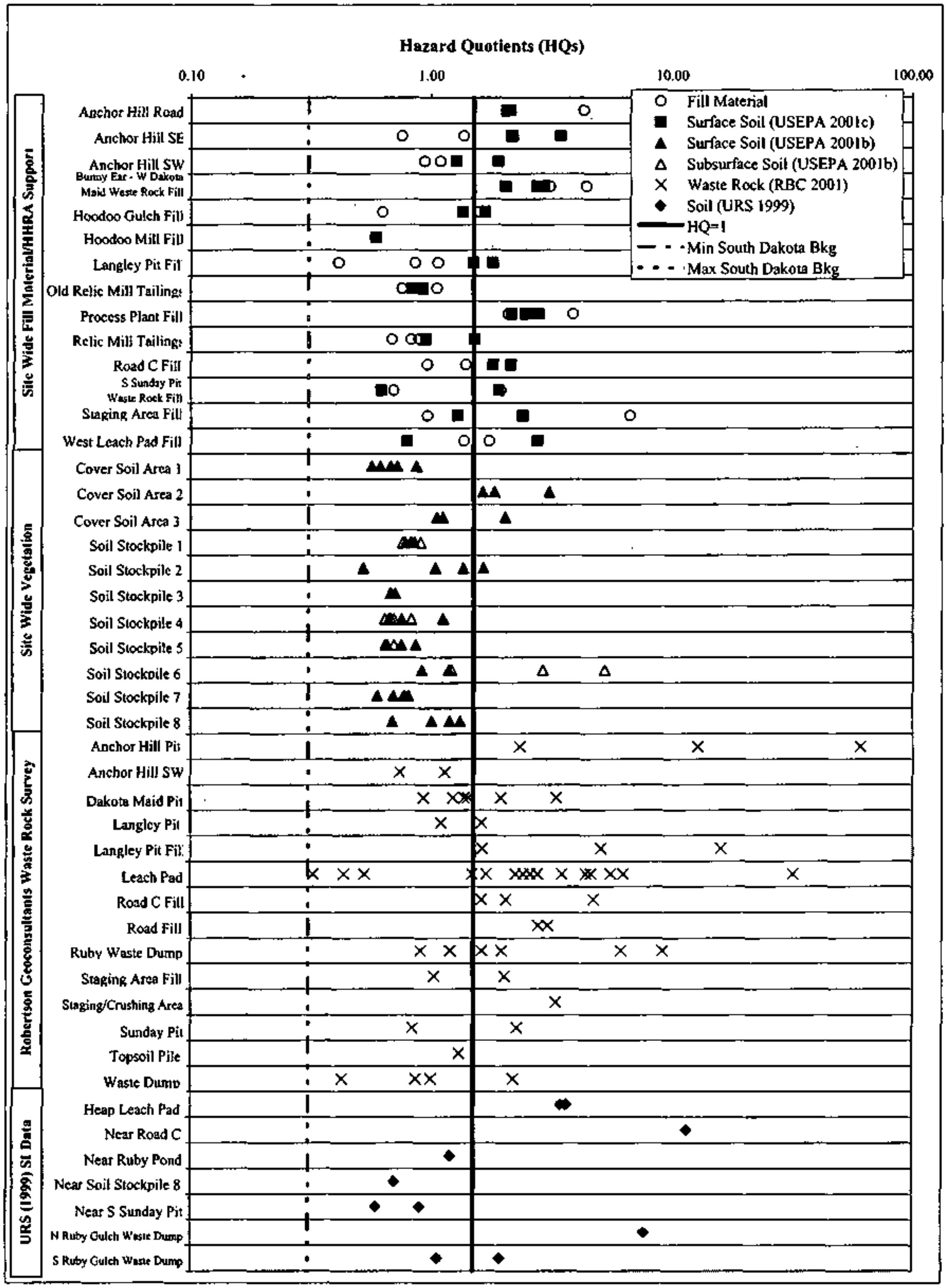
VANADIUM



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 6-7p
Risks to Plants and Soil Organisms from Direct Contact with Mine Source Area Soils

ZINC



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

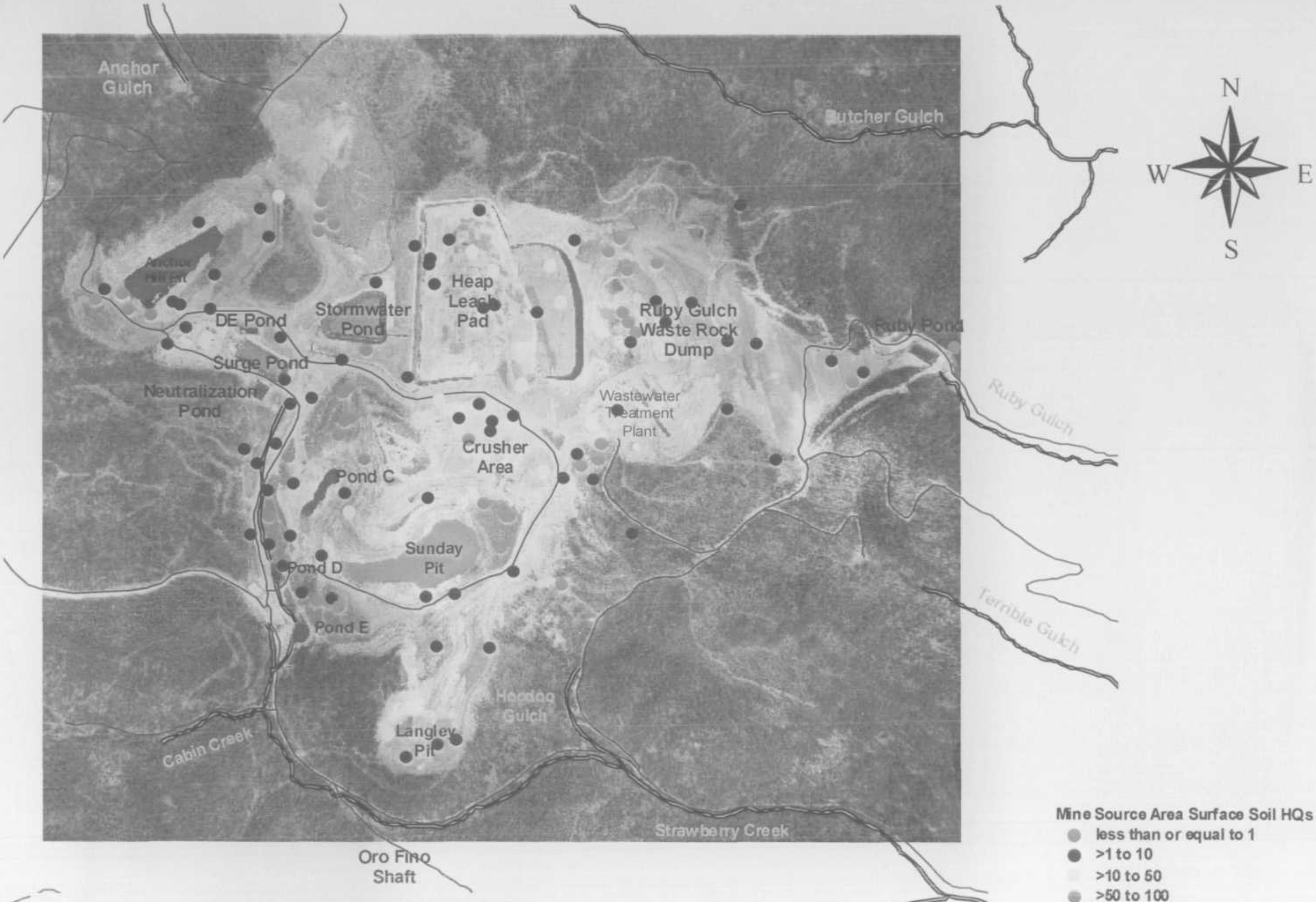


Figure 6-8
Mine Source Area Surface Soil Hazard Quotients (HQs) for Arsenic Plants and Soil Invertebrates

on-site (mine source area) surface soil HQ maps3.doc (gem_revisedHQs.apr)

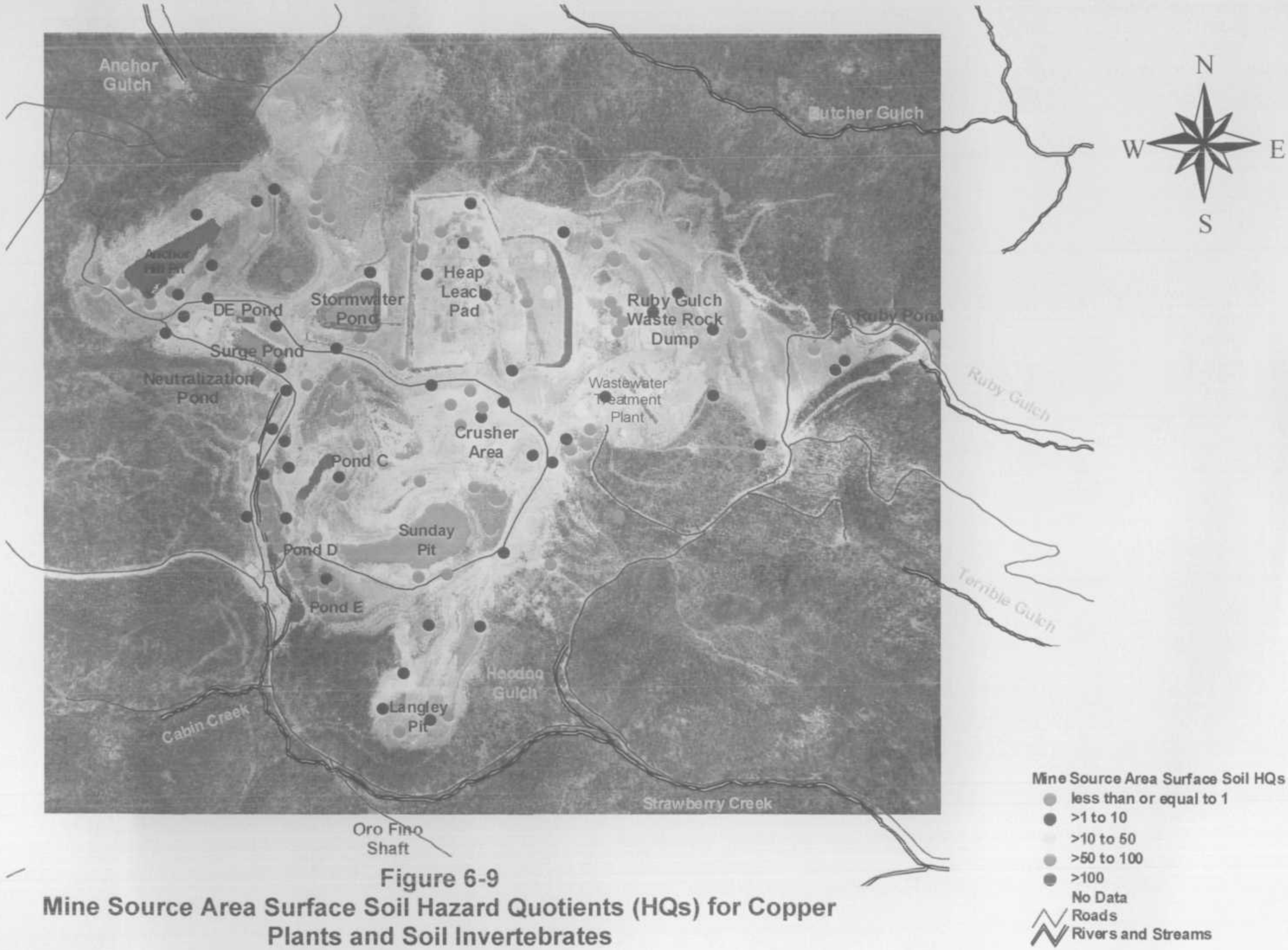


Figure 6-9

Mine Source Area Surface Soil Hazard Quotients (HQs) for Copper Plants and Soil Invertebrates

on-site (mine source area) surface soil HQ maps3.doc (gem_revisedHQs.apr)

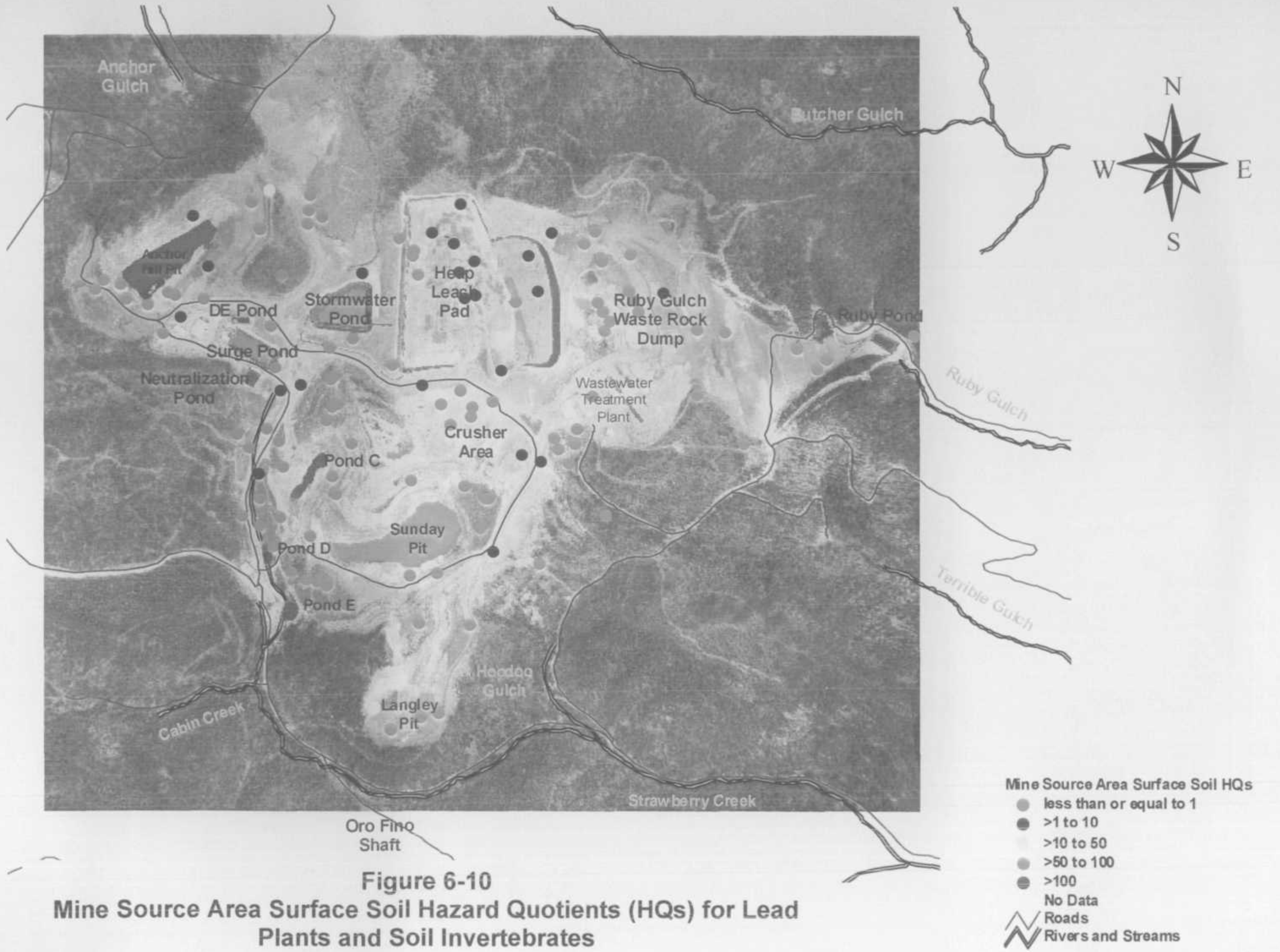


Figure 6-10
Mine Source Area Surface Soil Hazard Quotients (HQs) for Lead Plants and Soil Invertebrates

on-site (mine source area) surface soil HQ maps3.doc (gem_revisedHQs.apr)

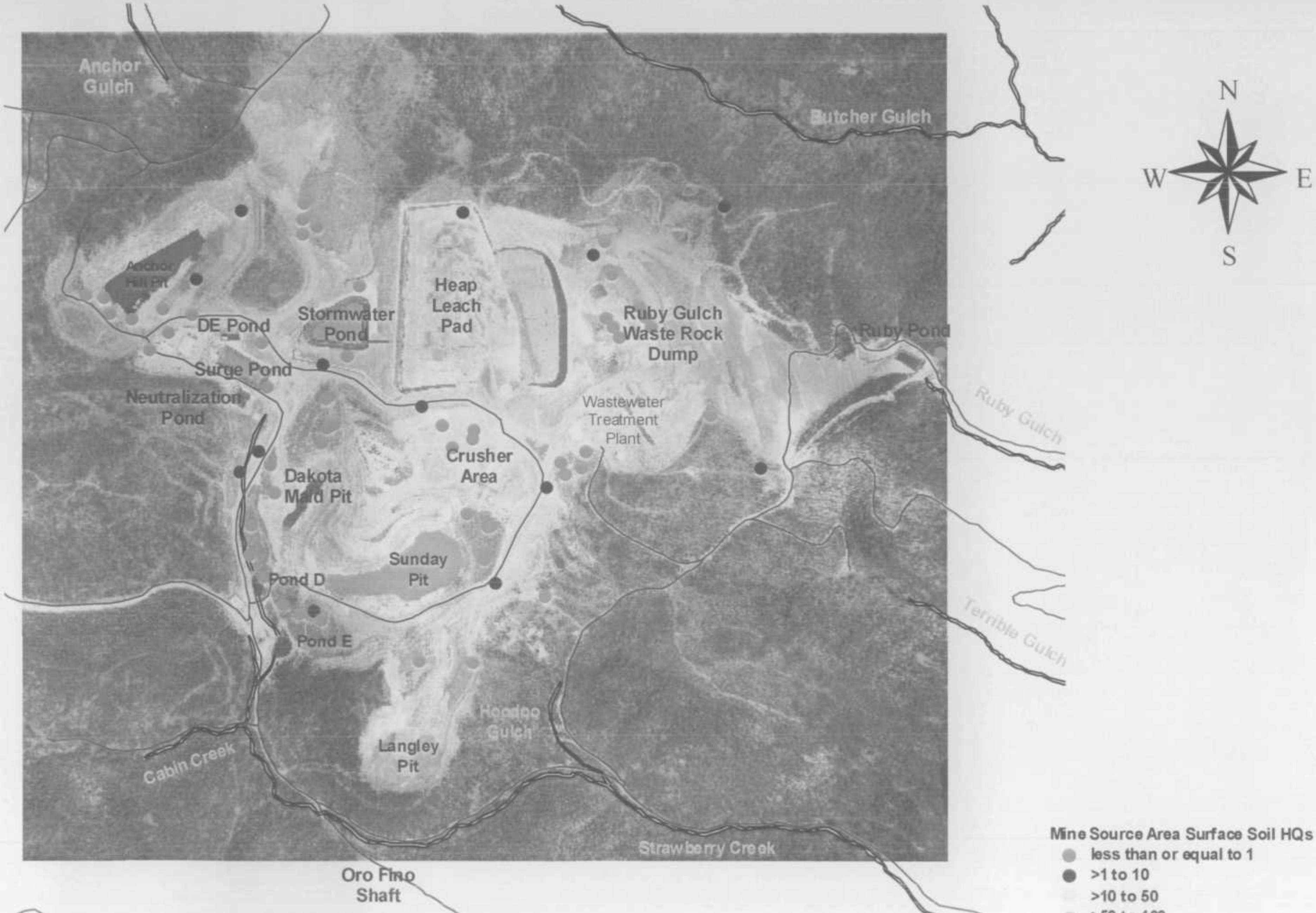


Figure 6-11
Mine Source Area Surface Soil Hazard Quotients (HQs) for Selenium Plants and Soil Invertebrates

on-site (mine source area) surface soil HQ maps3.doc (gem_revisedHQs.apr)

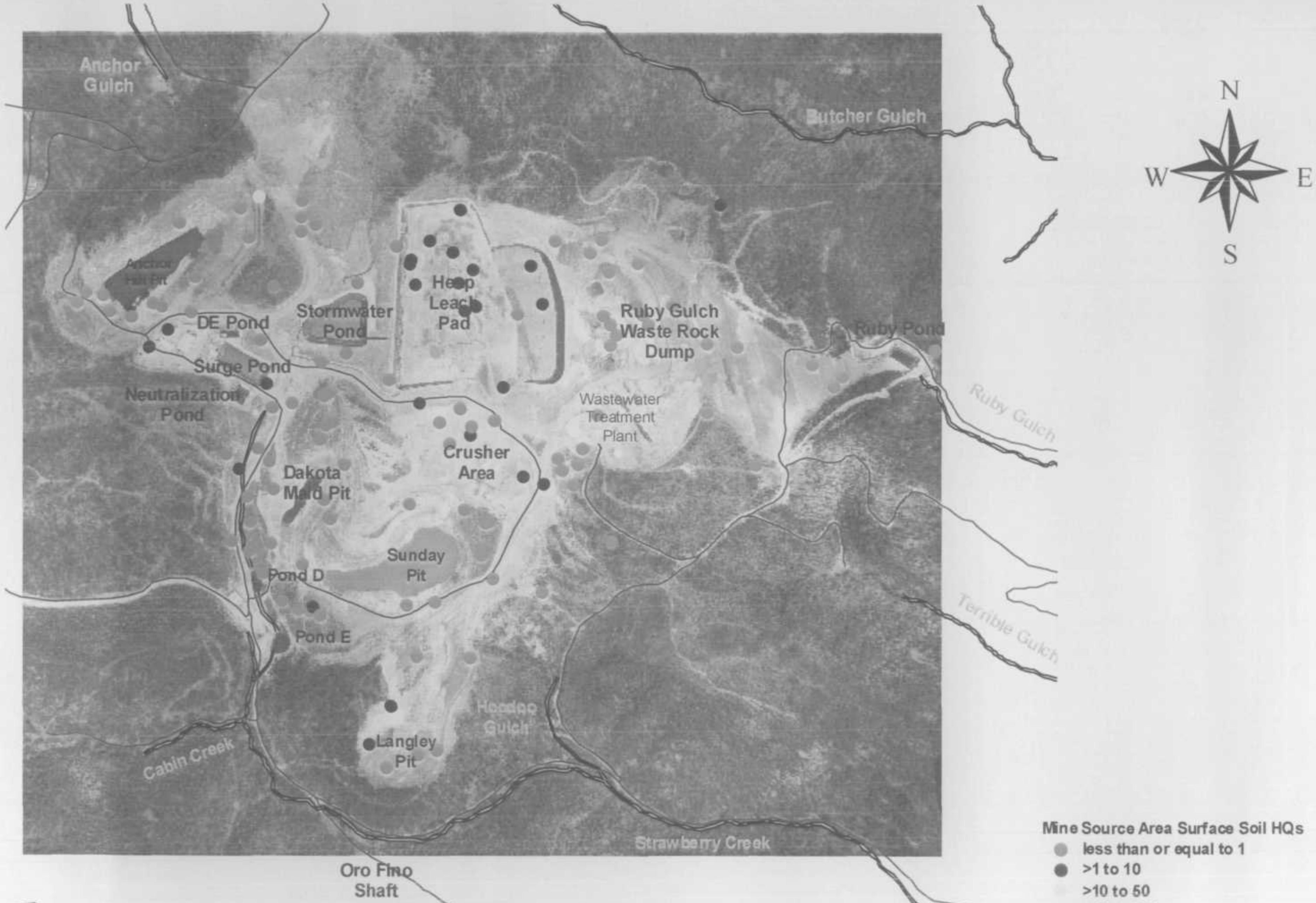


Figure 6-12
Mine Source Area Surface Soil Hazard Quotients (HQs) for Silver Plants and Soil Invertebrates

on-site (mine source area) surface soil HQ maps3.doc (gem_revisedHQs.apr)

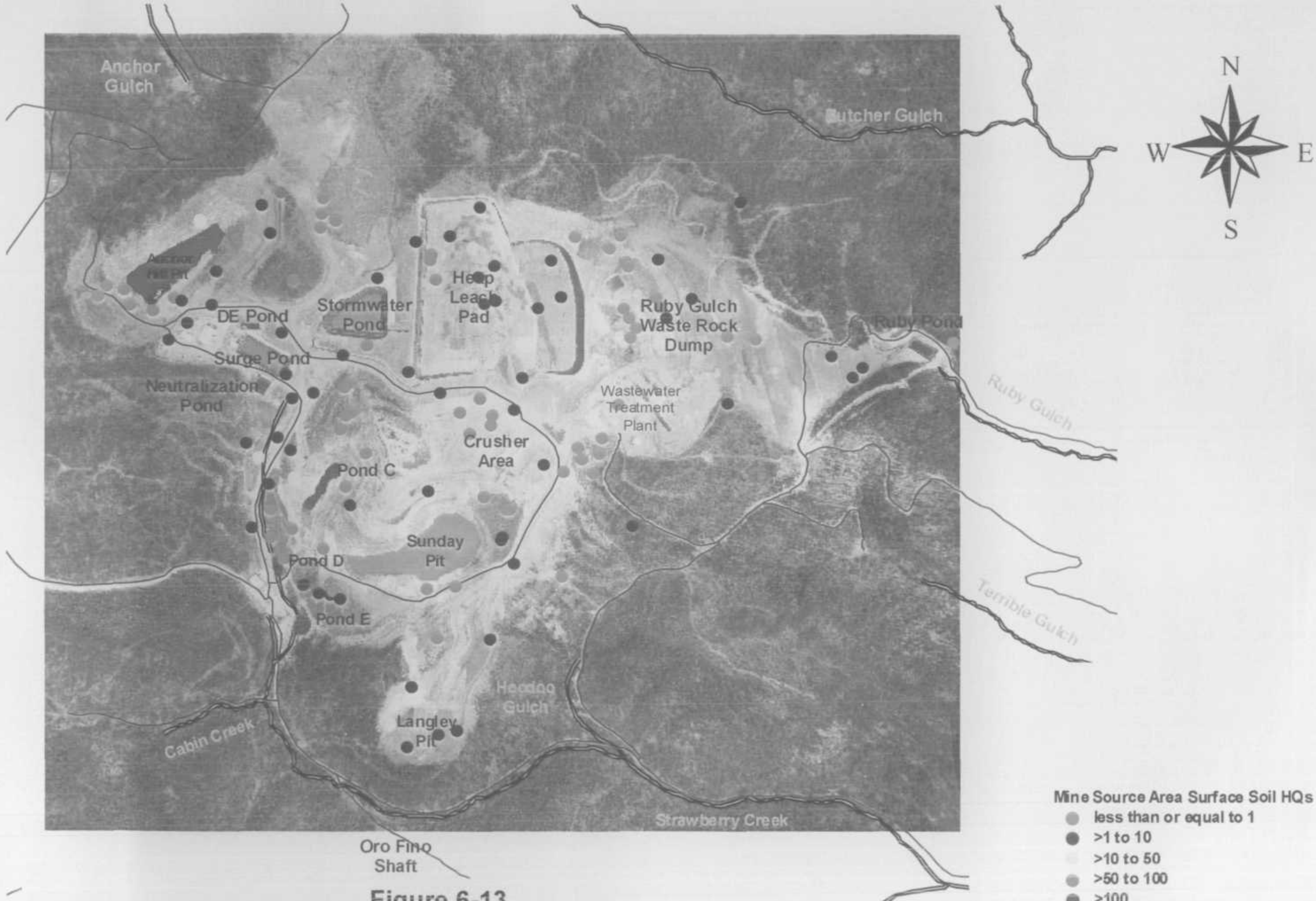


Figure 6-13
Mine Source Area Surface Soil Hazard Quotients (HQs) for Zinc Plants and Soil Invertebrates

on-site (mine source area) surface soil HQ maps3.doc (gem_revisedHQs.apr)

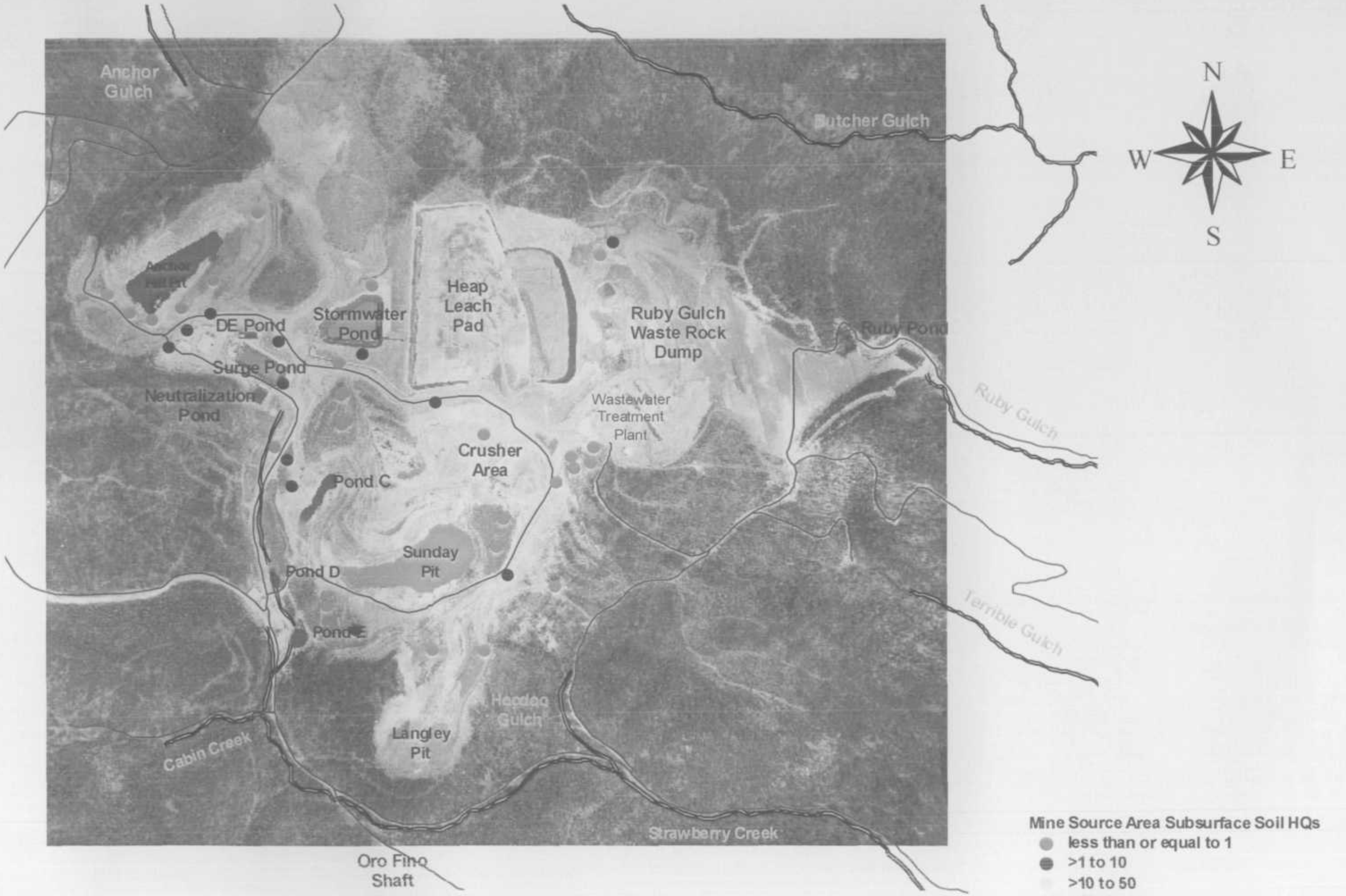


Figure 6-14
Mine Source Area Subsurface Soil Hazard Quotients (HQs) for Arsenic Plants and Soil Invertebrates

on-site (mine source area) subsurface soil HQ maps3.doc (gem_revisedHQs.apr)

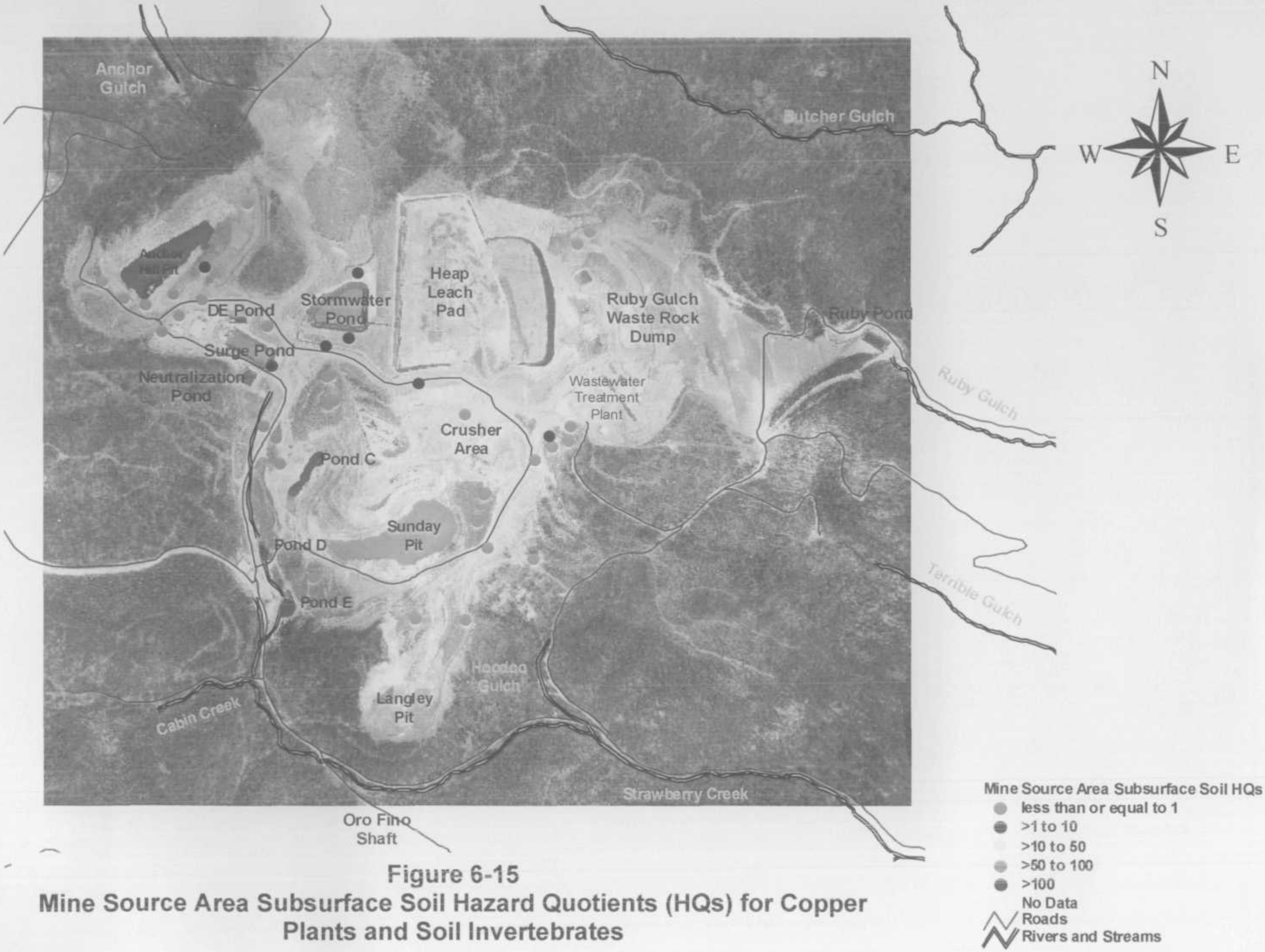


Figure 6-15
Mine Source Area Subsurface Soil Hazard Quotients (HQs) for Copper Plants and Soil Invertebrates

on-site (mine source area) subsurface soil HQ maps3.doc (gem_revisedHQs.apr)

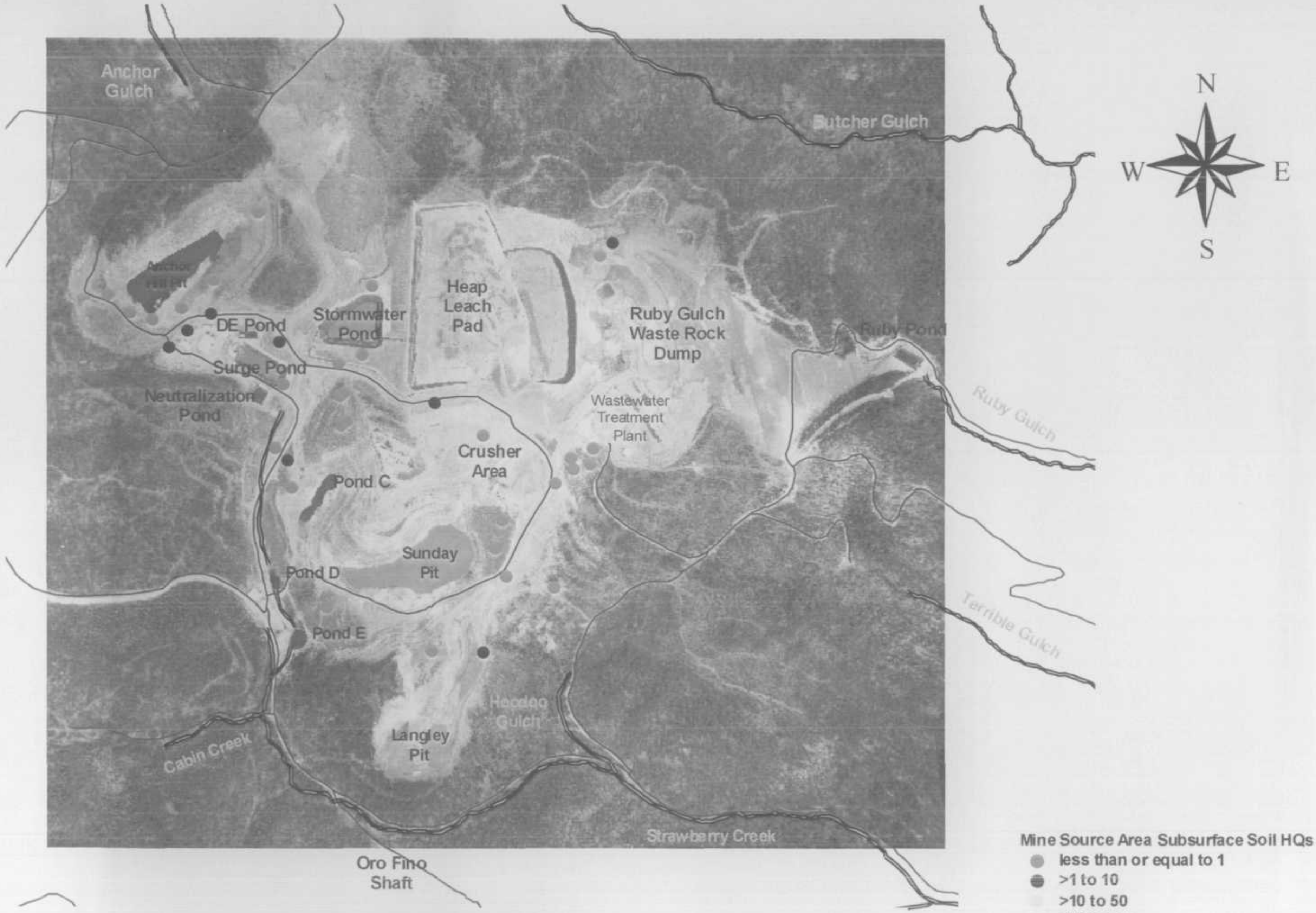


Figure 6-16
Mine Source Area Subsurface Soil Hazard Quotients (HQs) for Lead Plants and Soil Invertebrates

on-site (mine source area) subsurface soil HQ maps3.doc (gem_revisedHQs.apr)

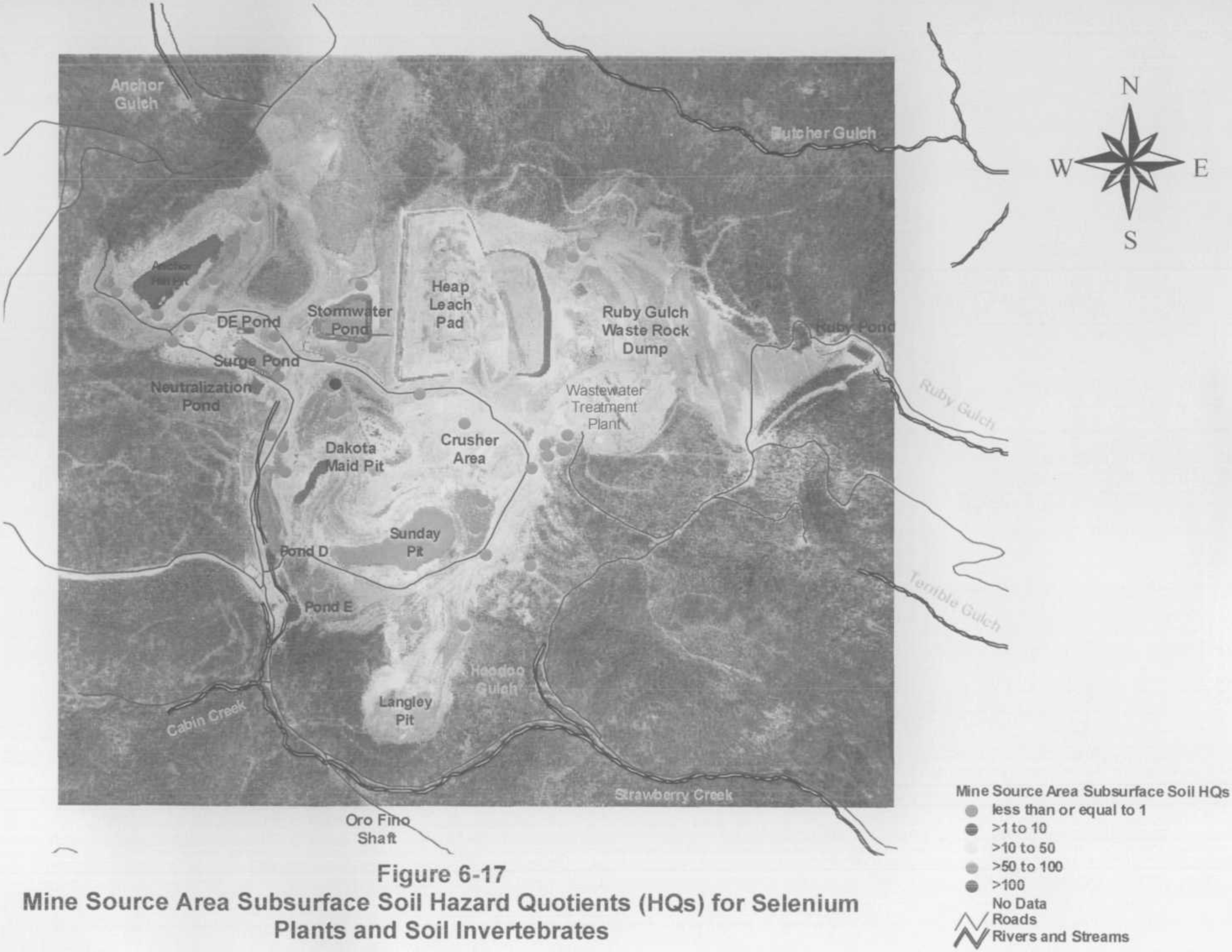


Figure 6-17
Mine Source Area Subsurface Soil Hazard Quotients (HQs) for Selenium Plants and Soil Invertebrates

on-site (mine source area) subsurface soil HQ maps3.doc (gem_revisedHQs.apr)

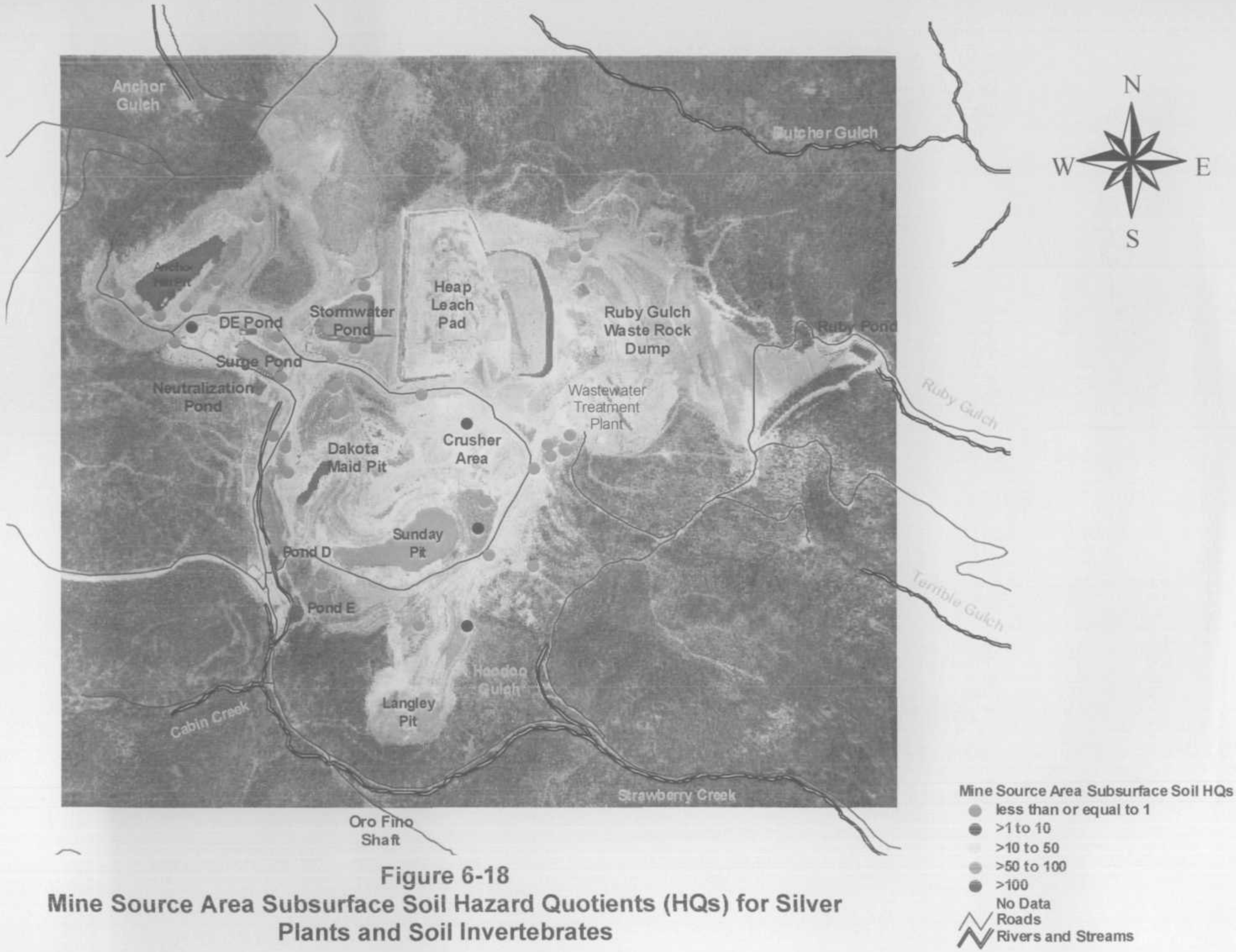


Figure 6-18
Mine Source Area Subsurface Soil Hazard Quotients (HQs) for Silver Plants and Soil Invertebrates

on-site (mine source area) subsurface soil HQ maps3.doc (gem_revisedHQs.apr)

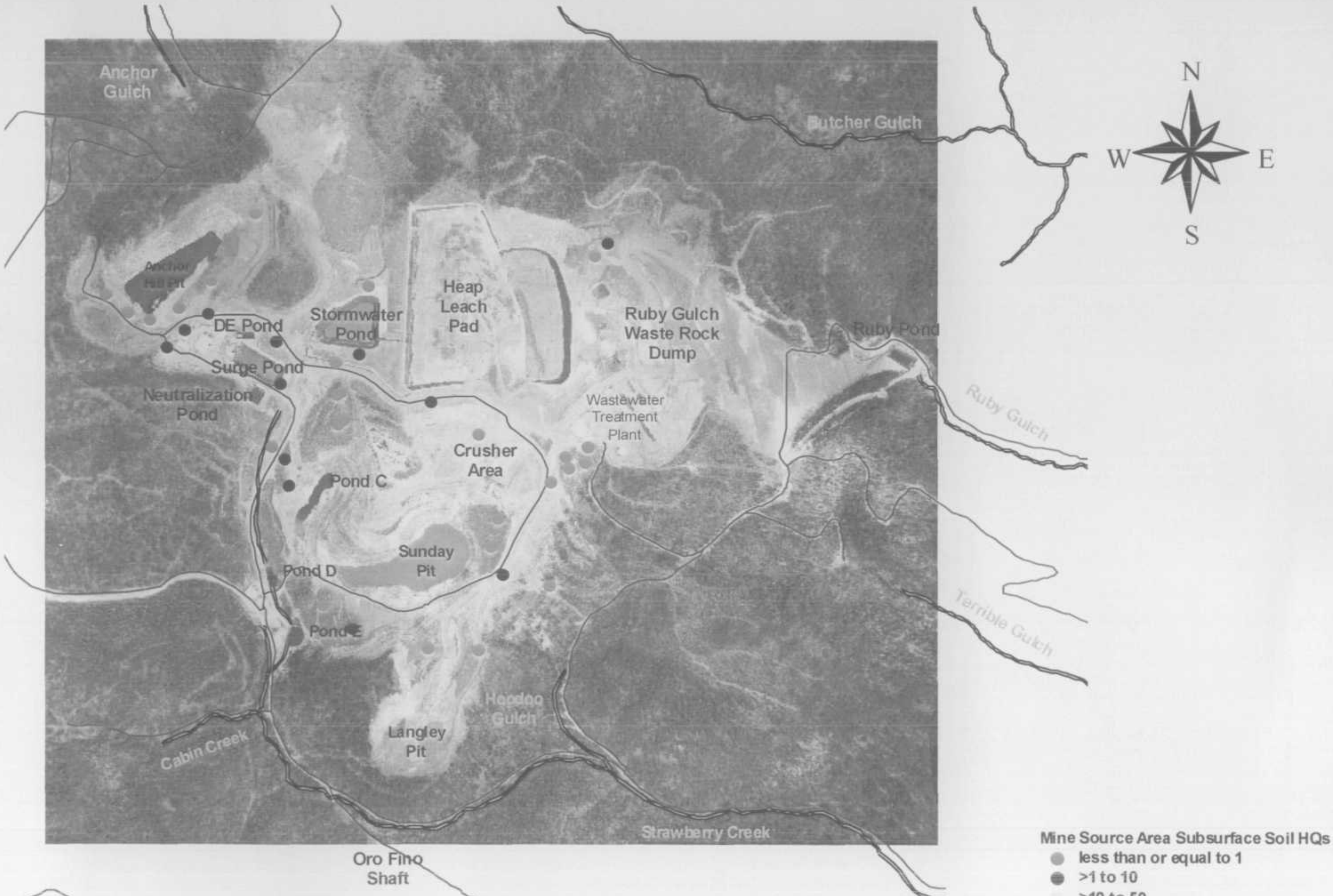
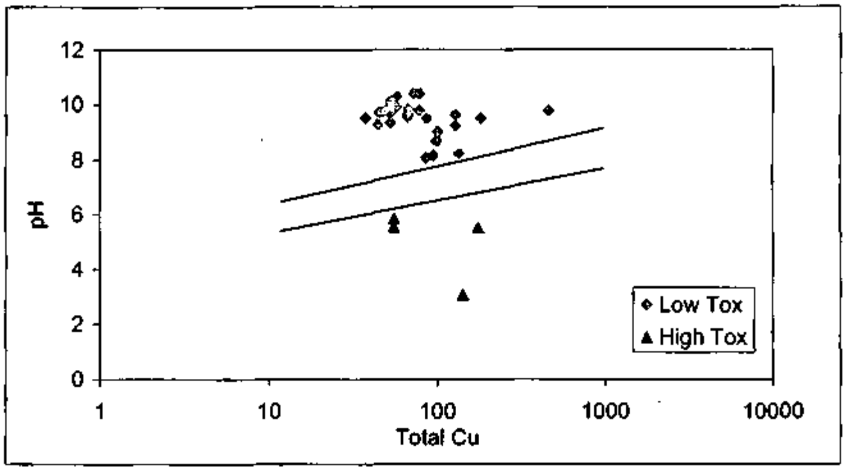


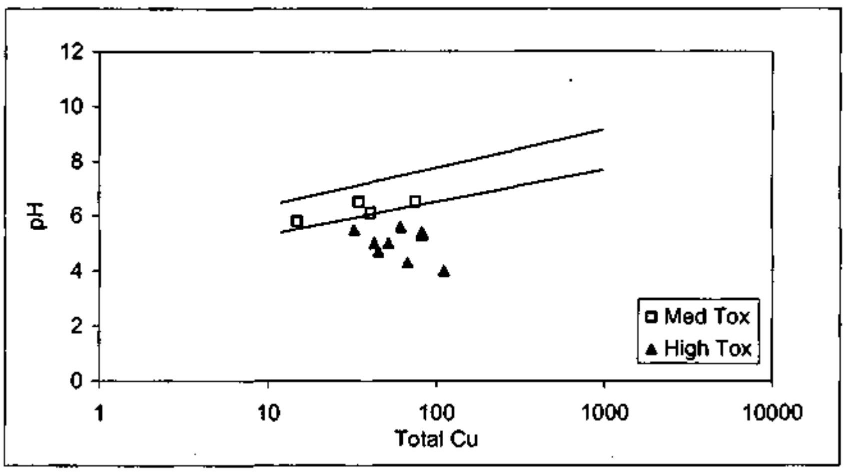
Figure 6-19
Mine Source Area Subsurface Soil Hazard Quotients (HQs) for Zinc Plants and Soil Invertebrates

on-site (mine source area) subsurface soil HQ maps3.doc (gem_revisedHQs.apr)

Fill Material



Soil Stockpiles (Site Wide Vegetation Study)



Waste Rock

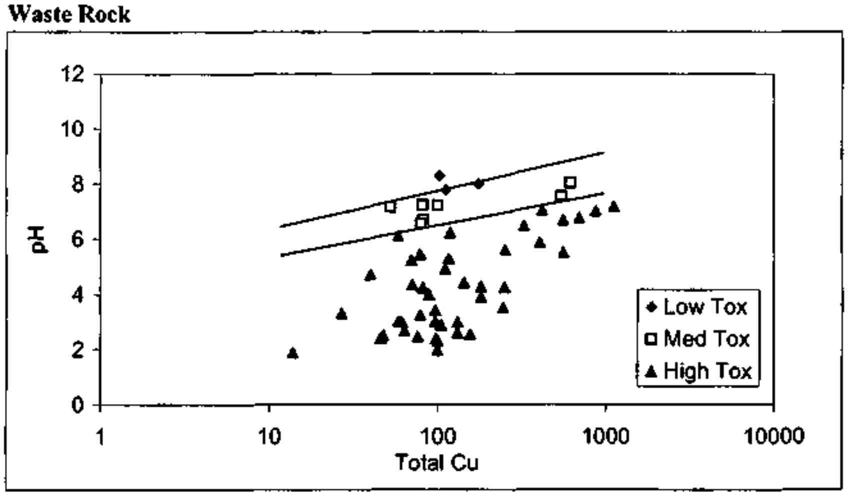
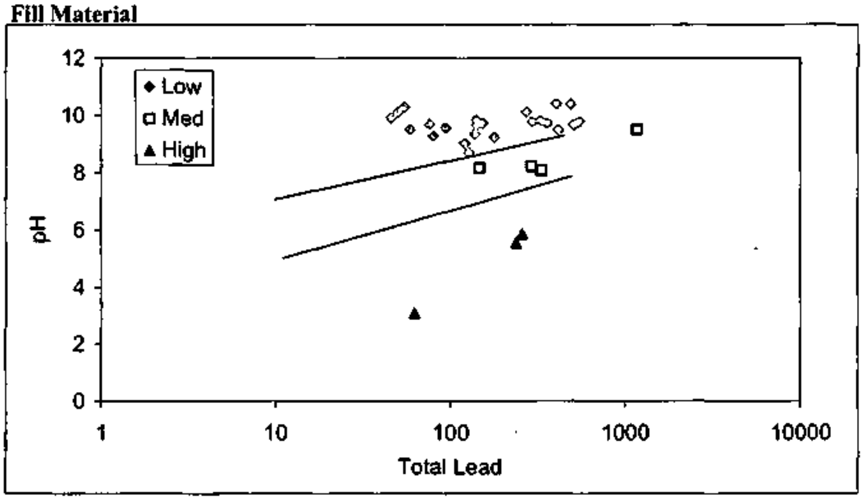
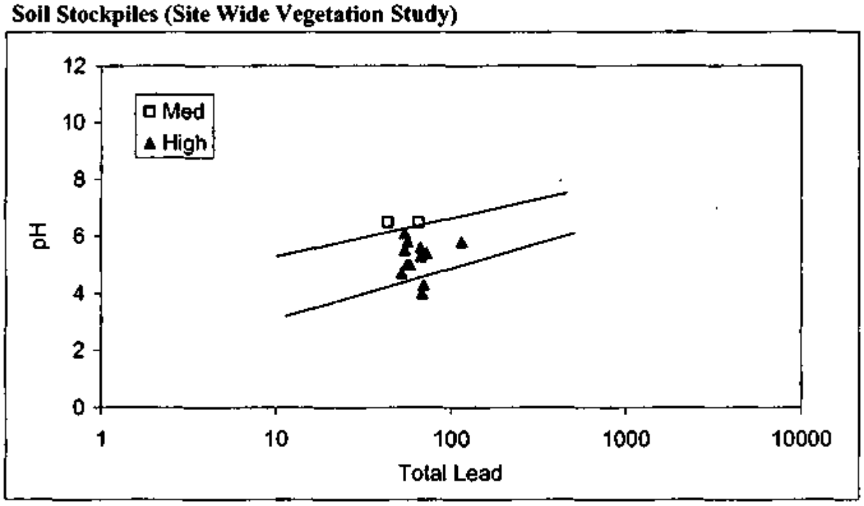


Figure 6-20
Predicted Phytotoxicity of Mine Source Area Samples Due to Copper

Fill Material



Soil Stockpiles (Site Wide Vegetation Study)



Waste Rock

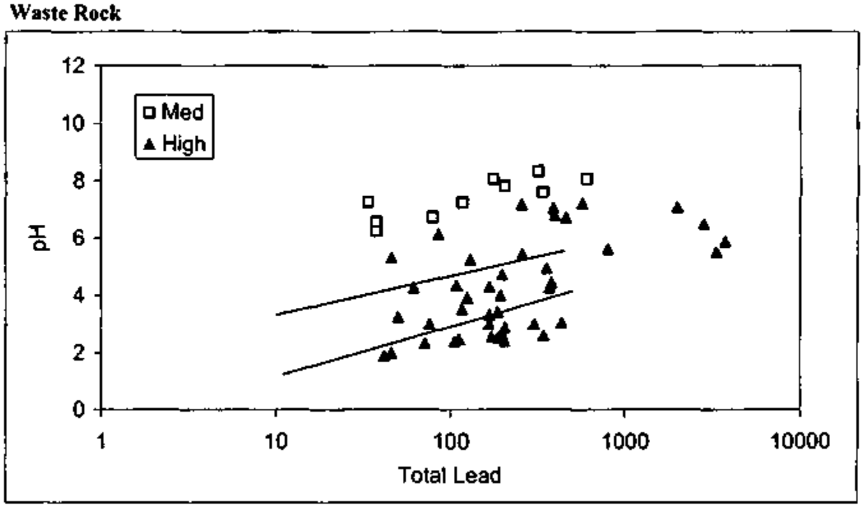
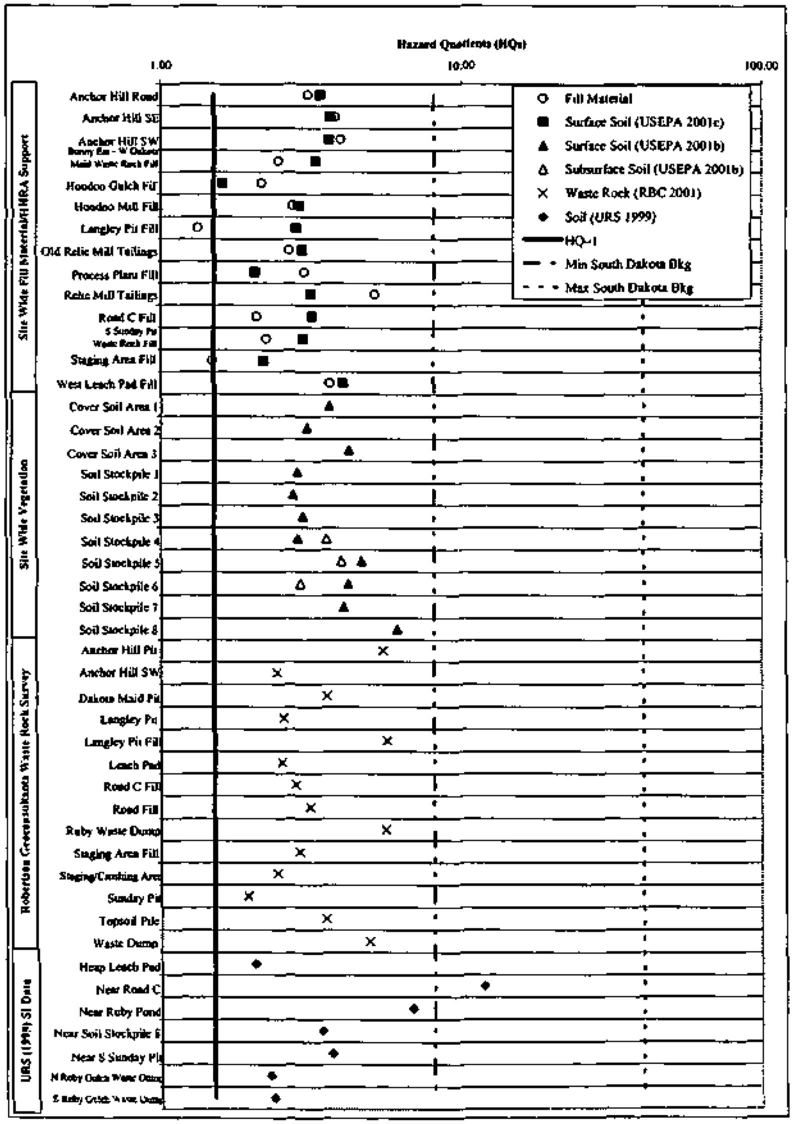


Figure 6-21
Predicted Phytotoxicity of Mine Source Area Samples Due to Lead

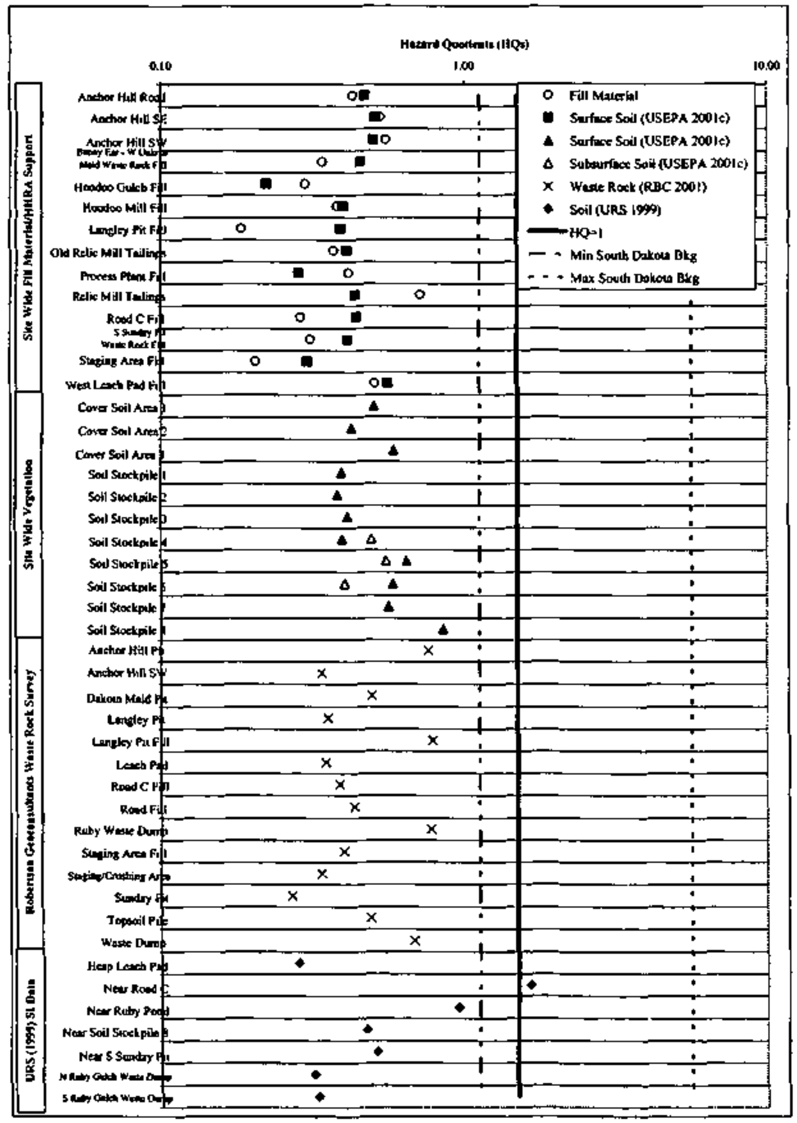
Figure 7-1a
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

ALUMINUM

DEER MOUSE



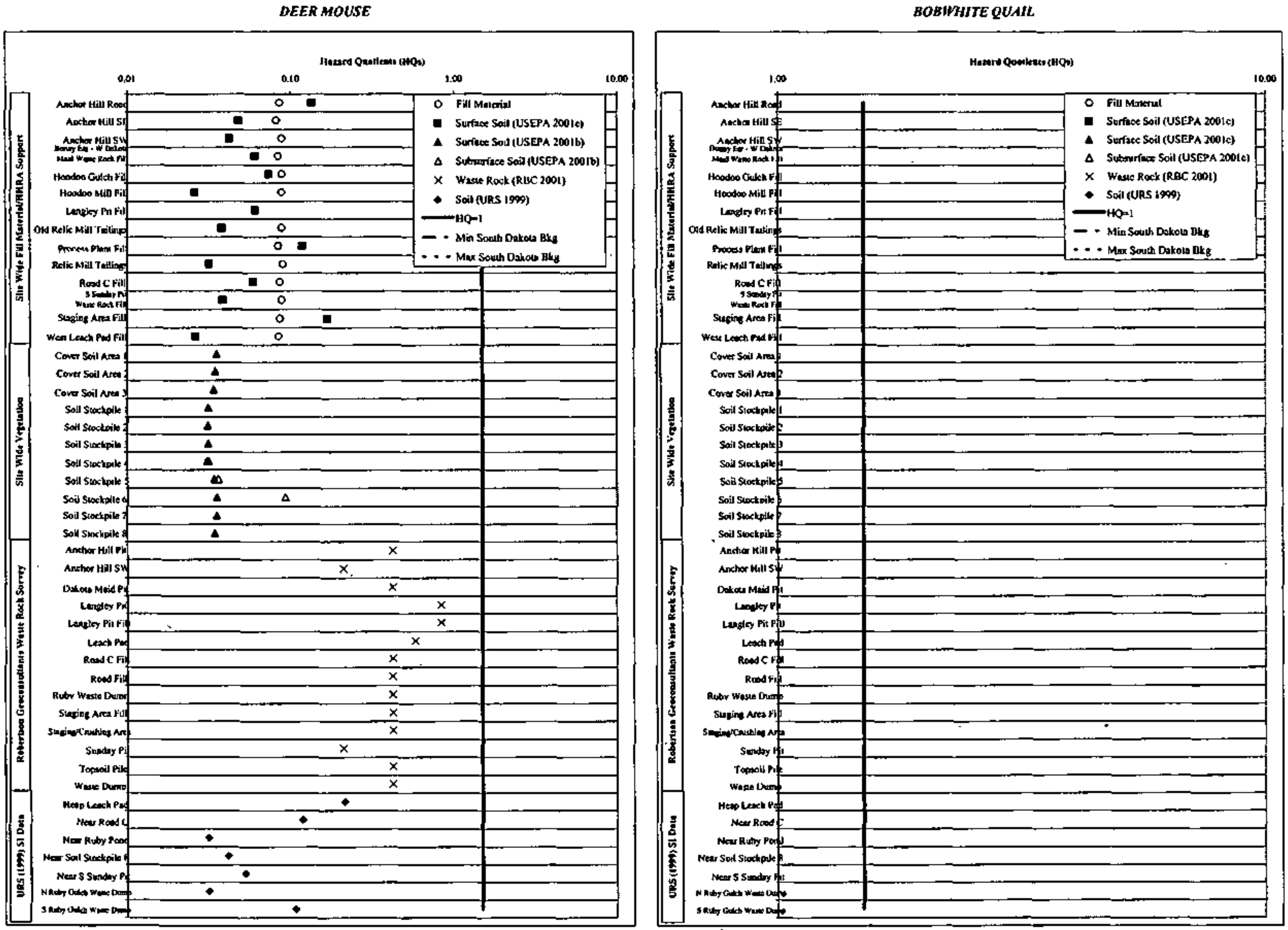
BOBWHITE QUAIL



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 7-1b
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

ANTIMONY

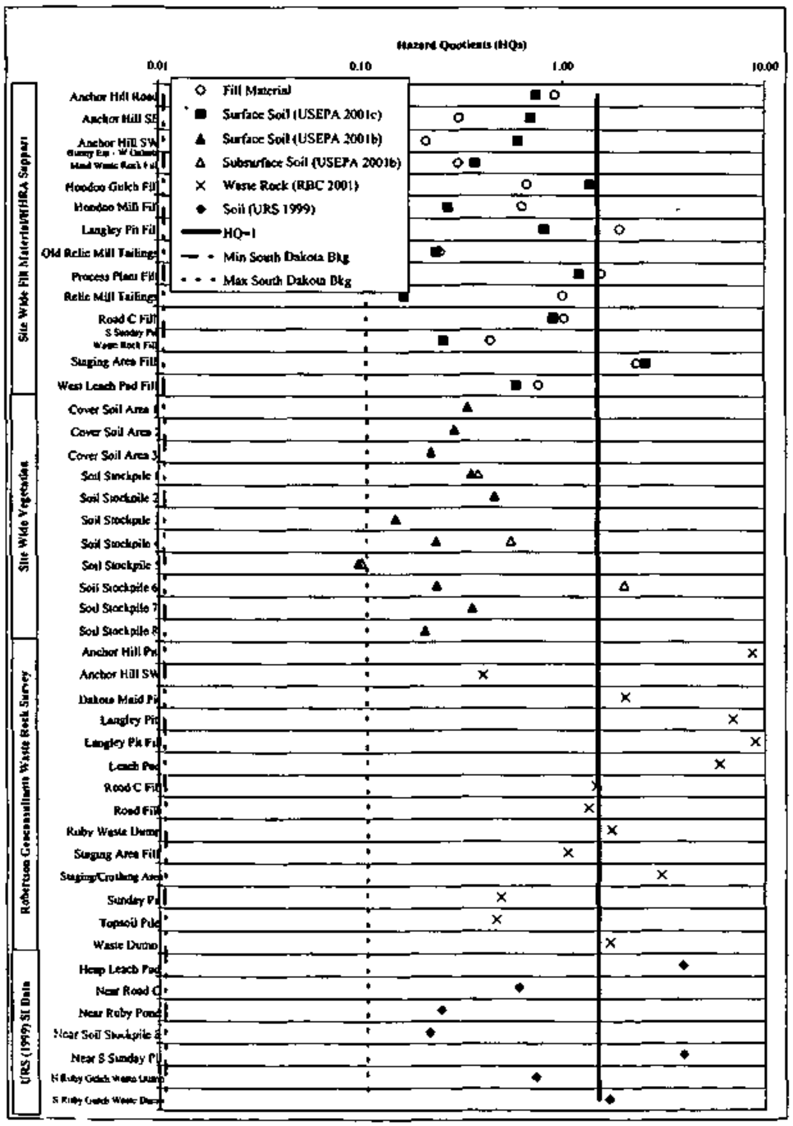


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

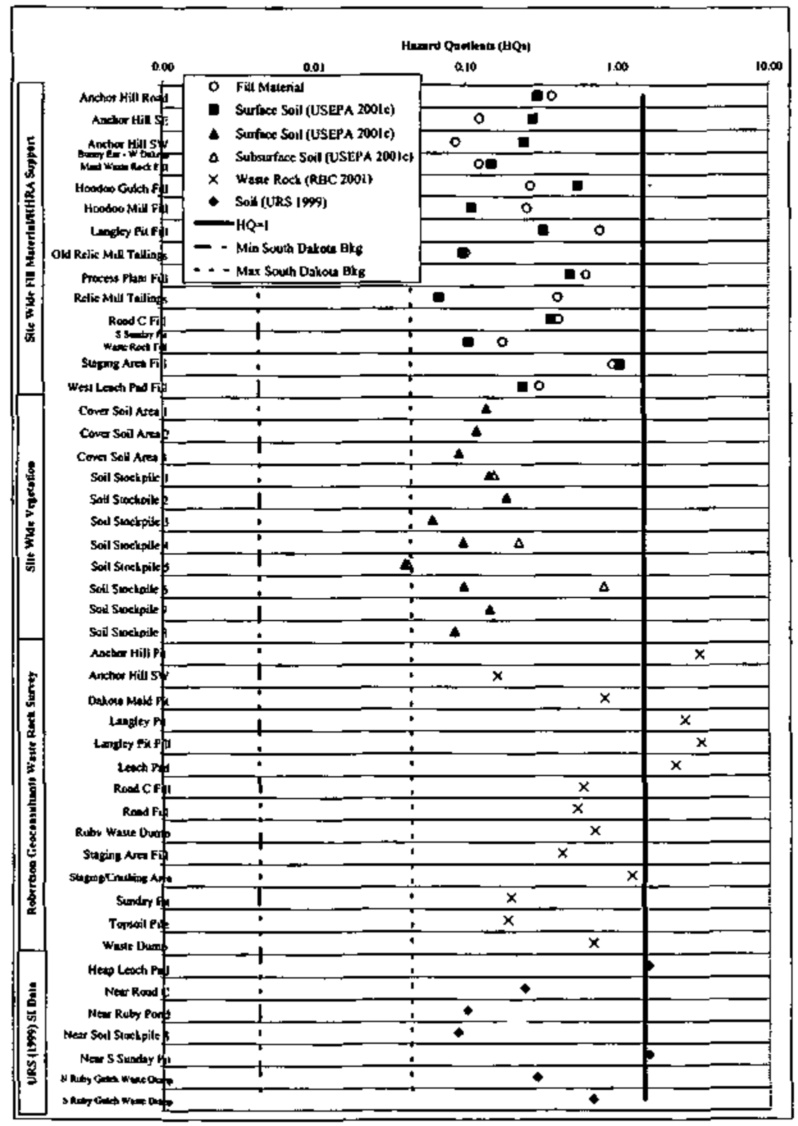
Figure 7-1c
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

ARSENIC

DEER MOUSE



BOBWHITE QUAIL



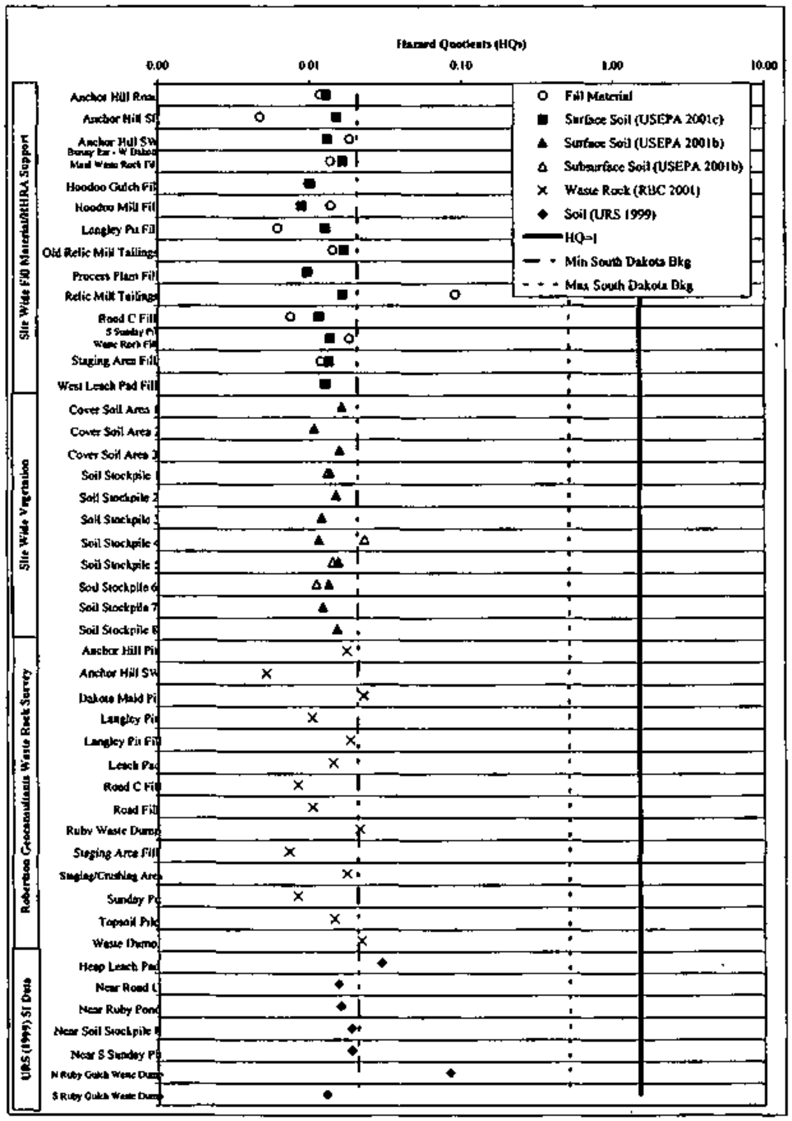
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls: Graphs
1/23/2003

Figure 7-1d
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

BARIUM

DEER MOUSE



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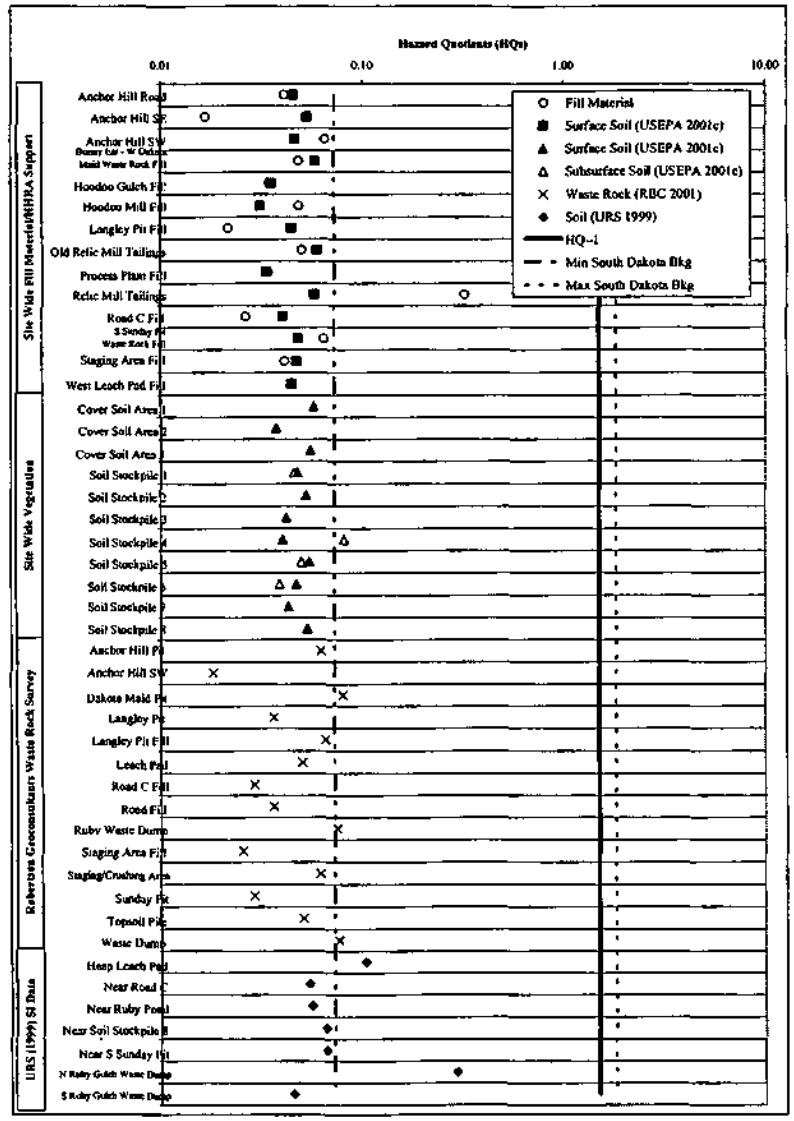
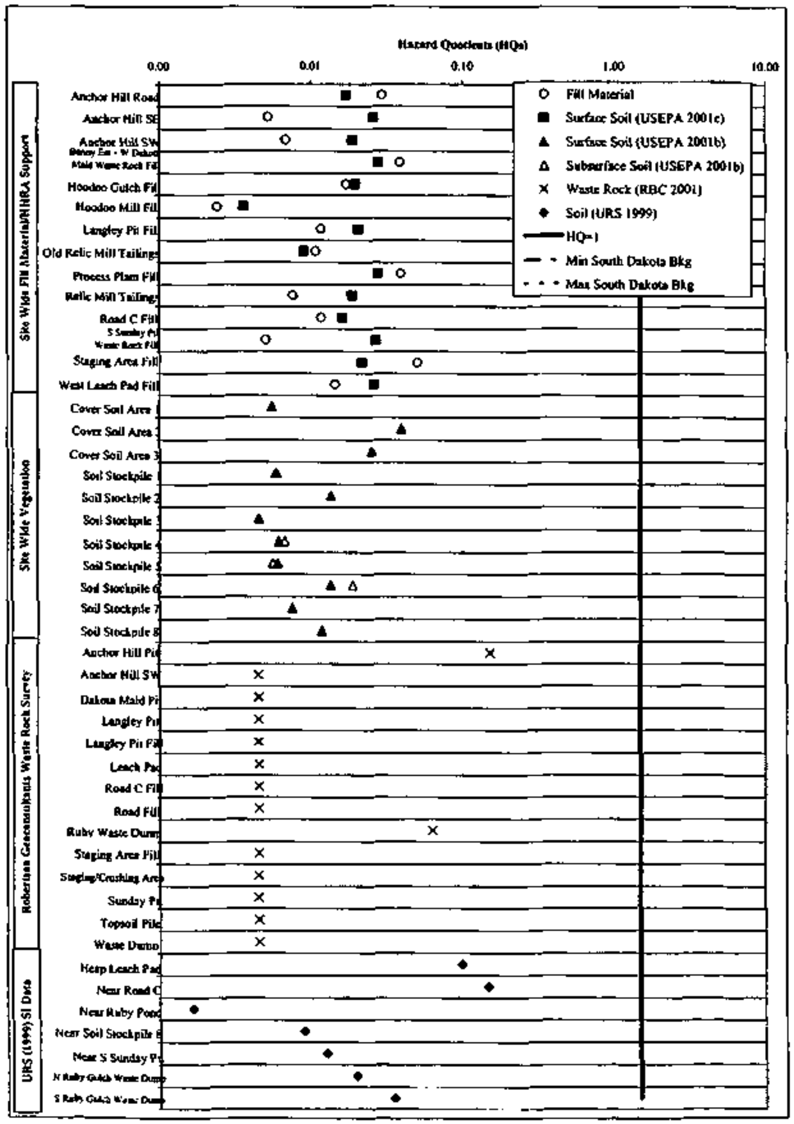


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 7-1e
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

CADMIUM

DEER MOUSE



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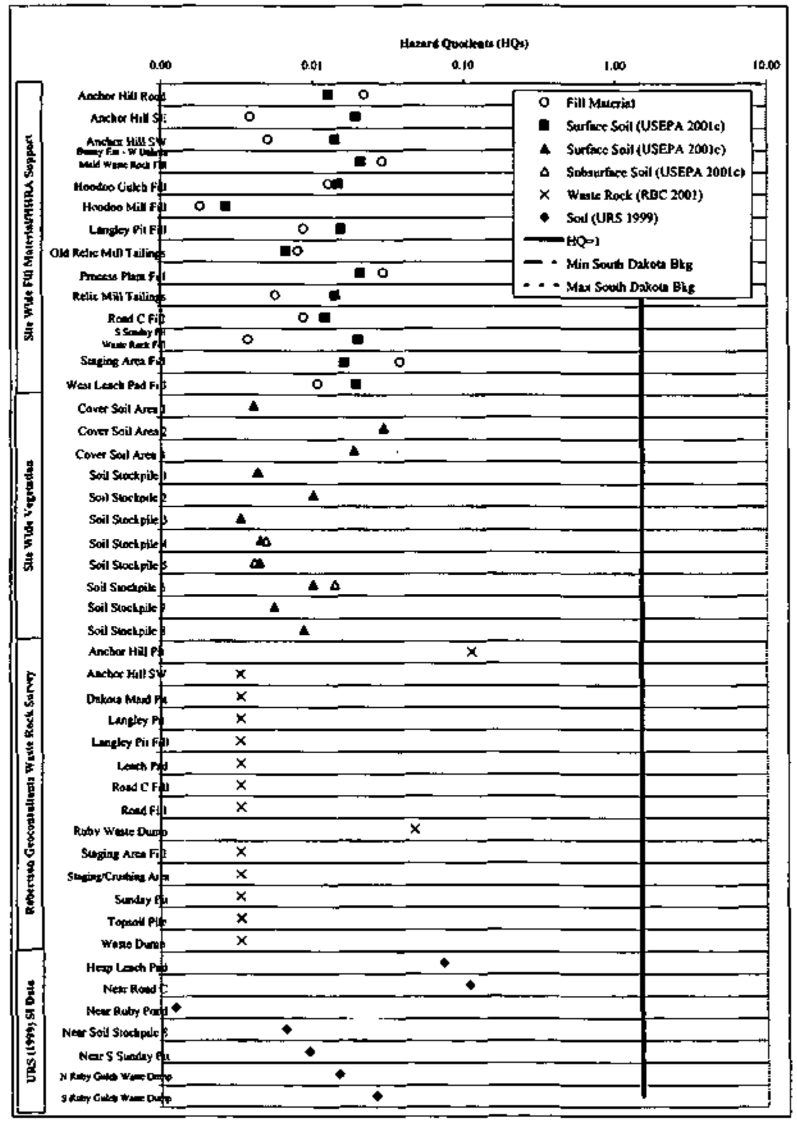
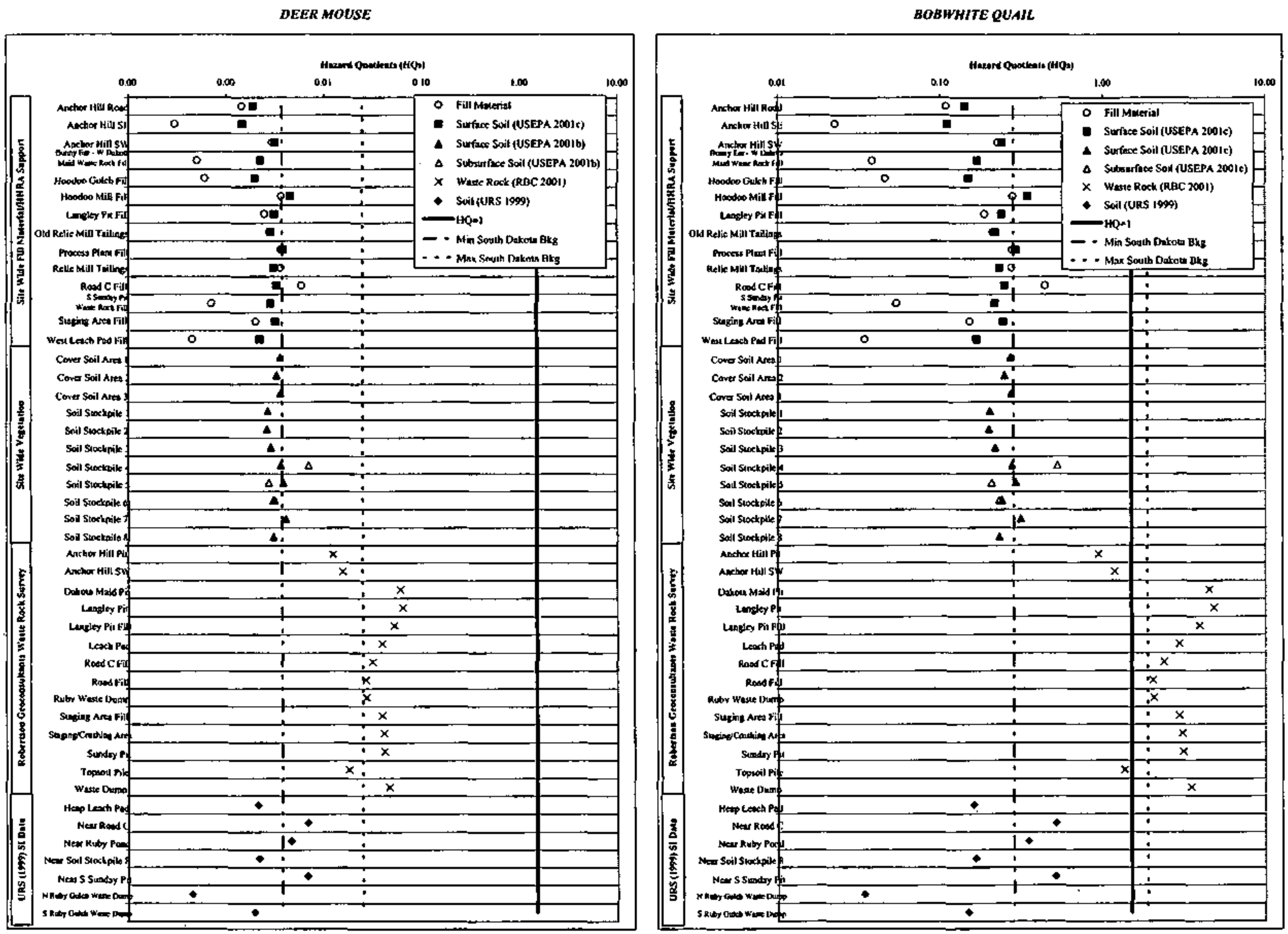


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls: Graphs
1/23/2003

Figure 7-1f
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

CHROMIUM



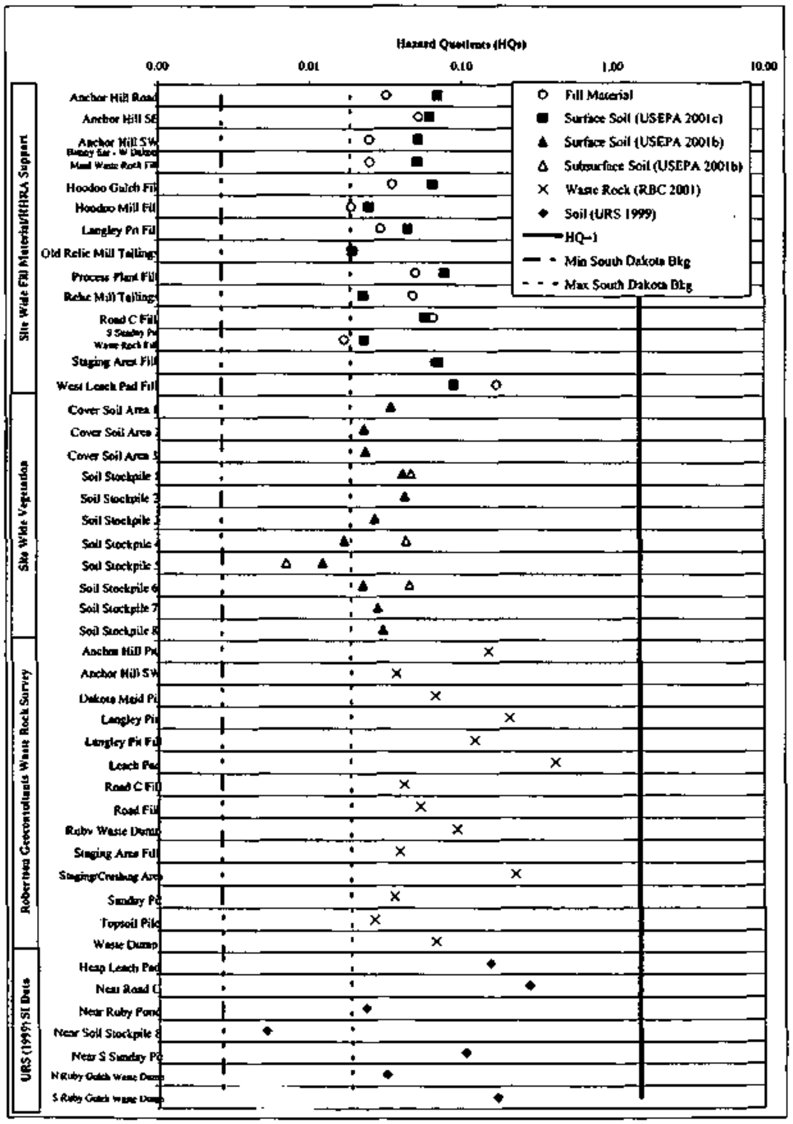
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls- Graphs
1/23/2003

Figure 7-1g
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

COPPER

DEER MOUSE



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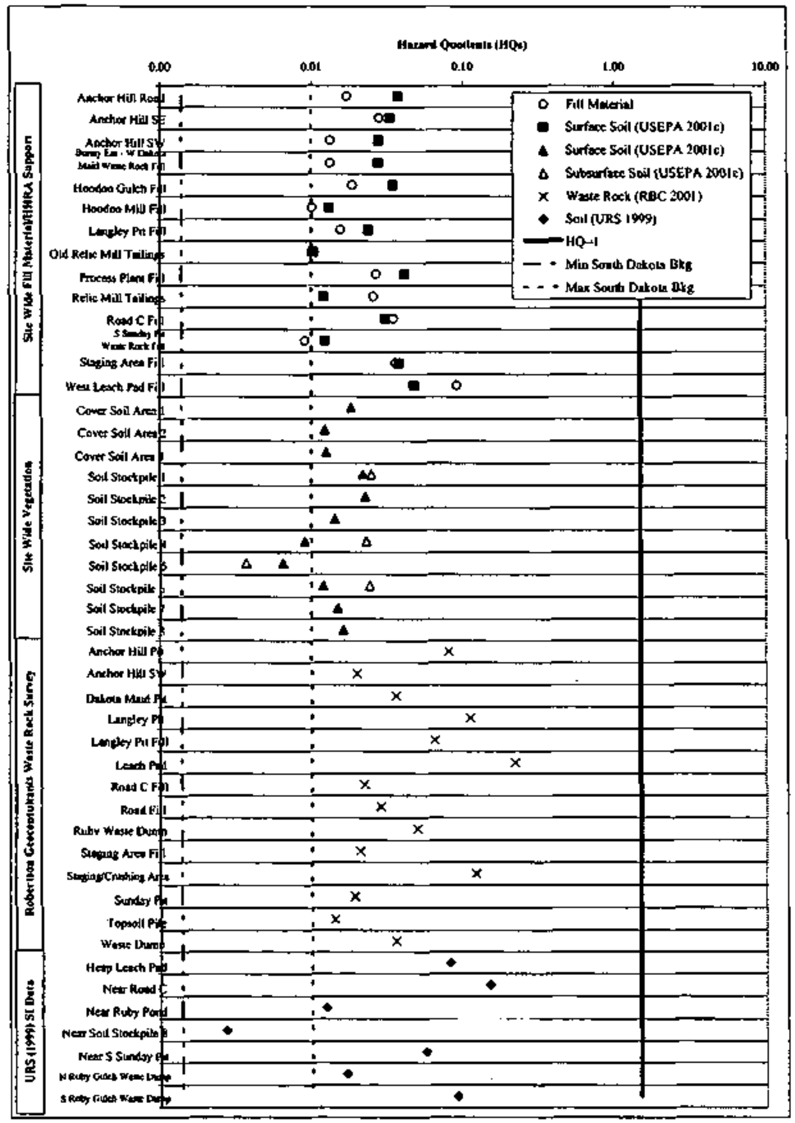


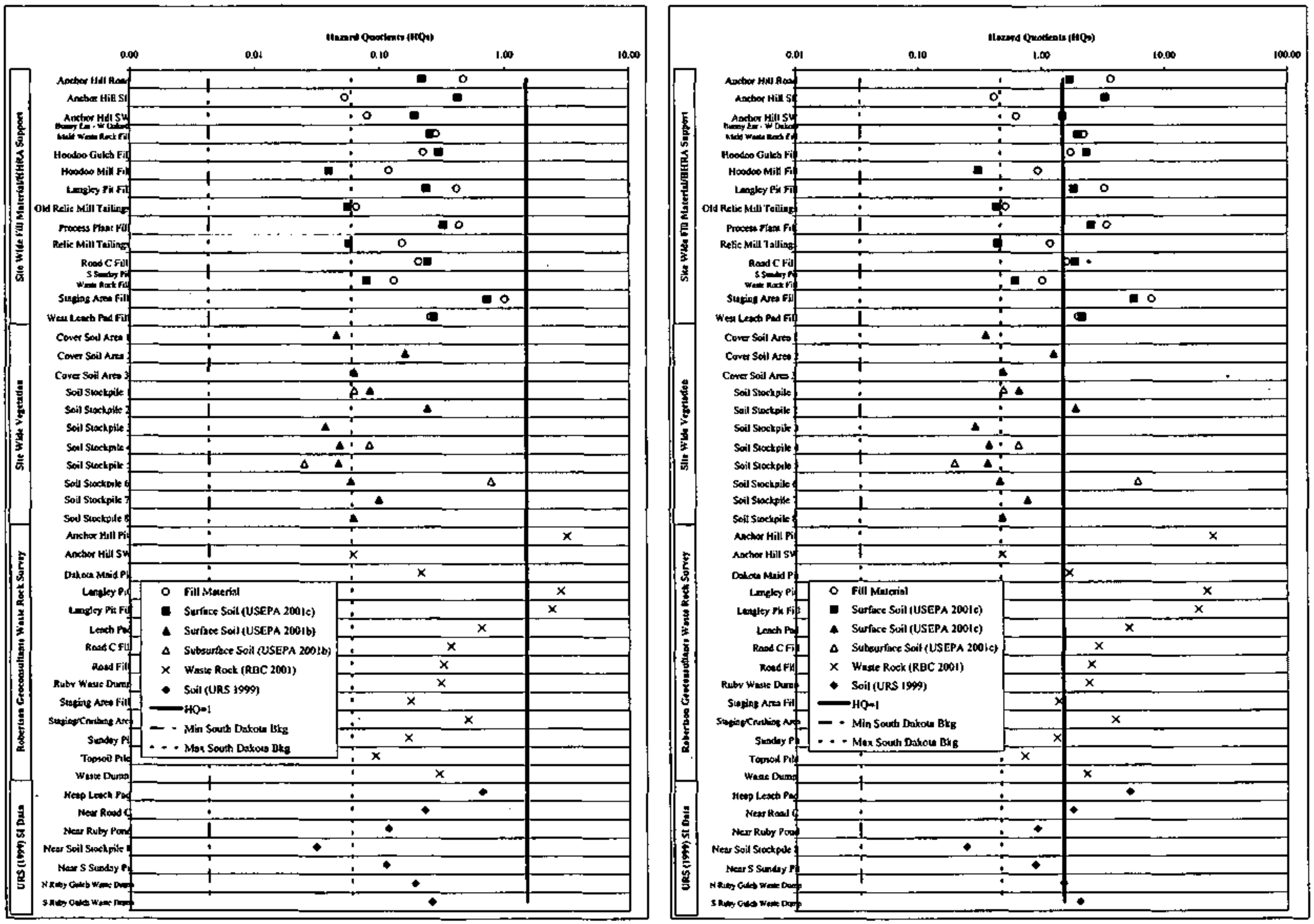
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls: Graphs
1/23/2003

Figure 7-1h
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

LEAD

DEER MOUSE — BOBWHITE QUAIL



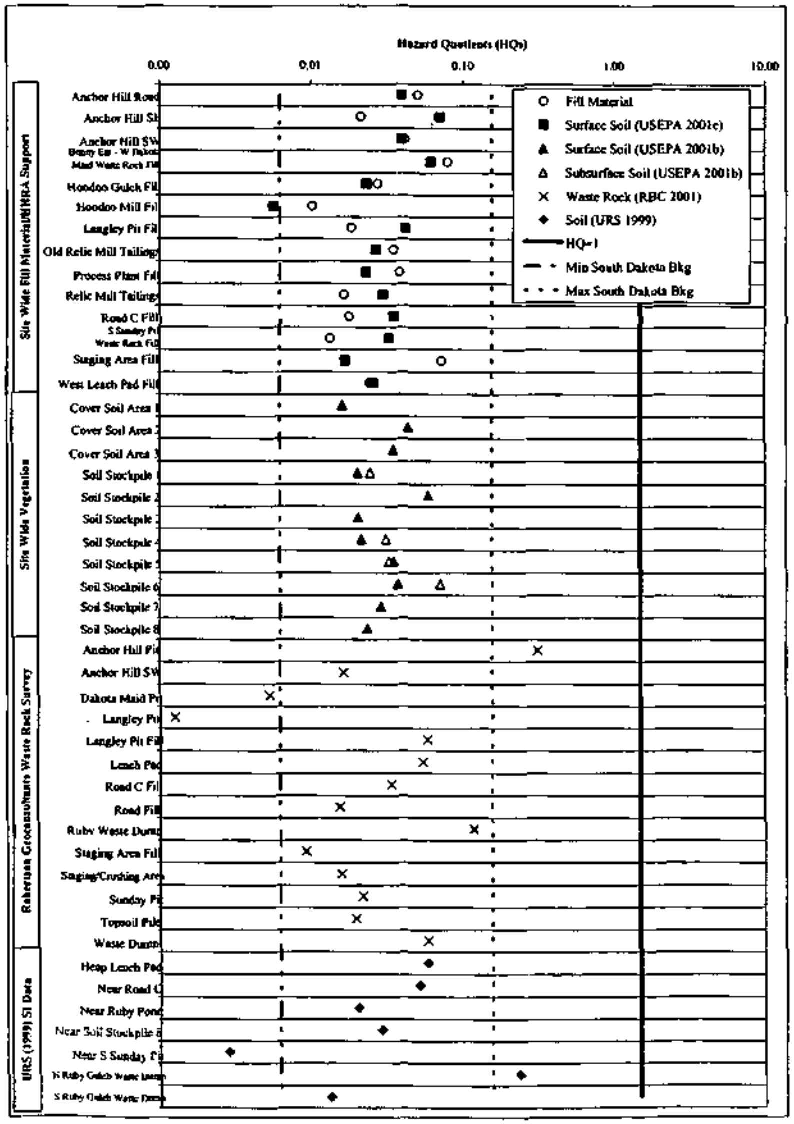
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls: Graphs
1/23/2003

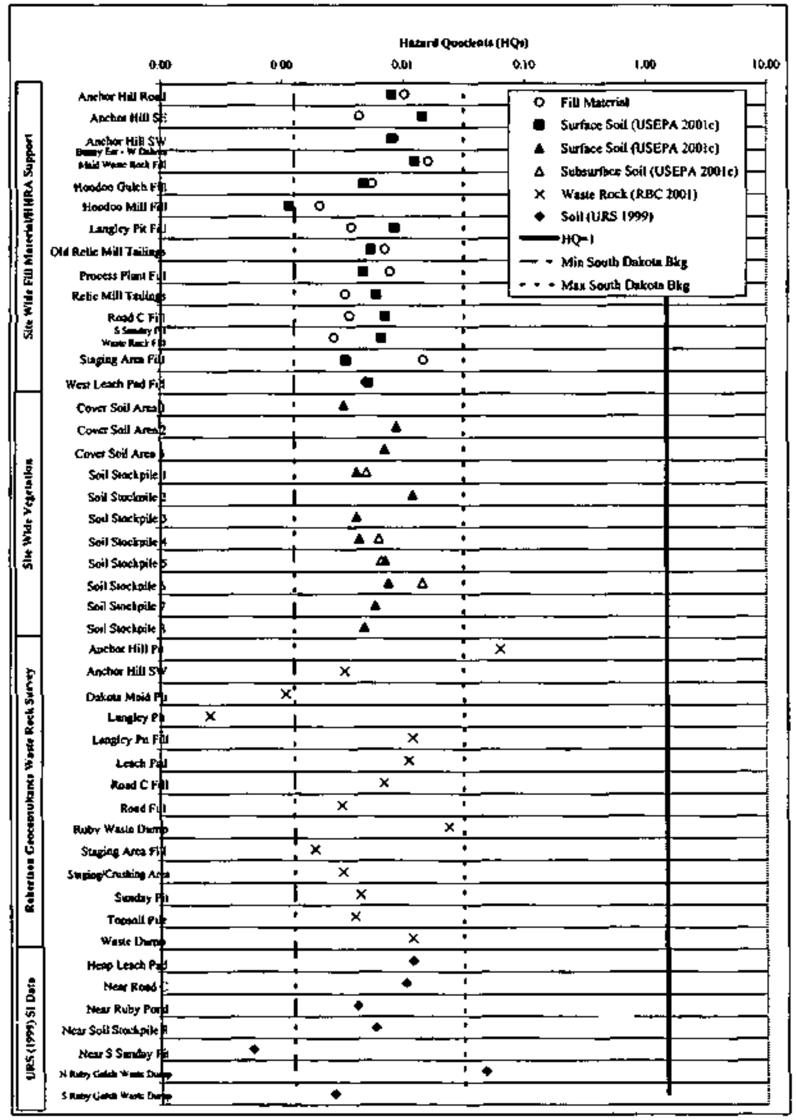
Figure 7-1i
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

MANGANESE

DEER MOUSE



BOBWHITE QUAIL

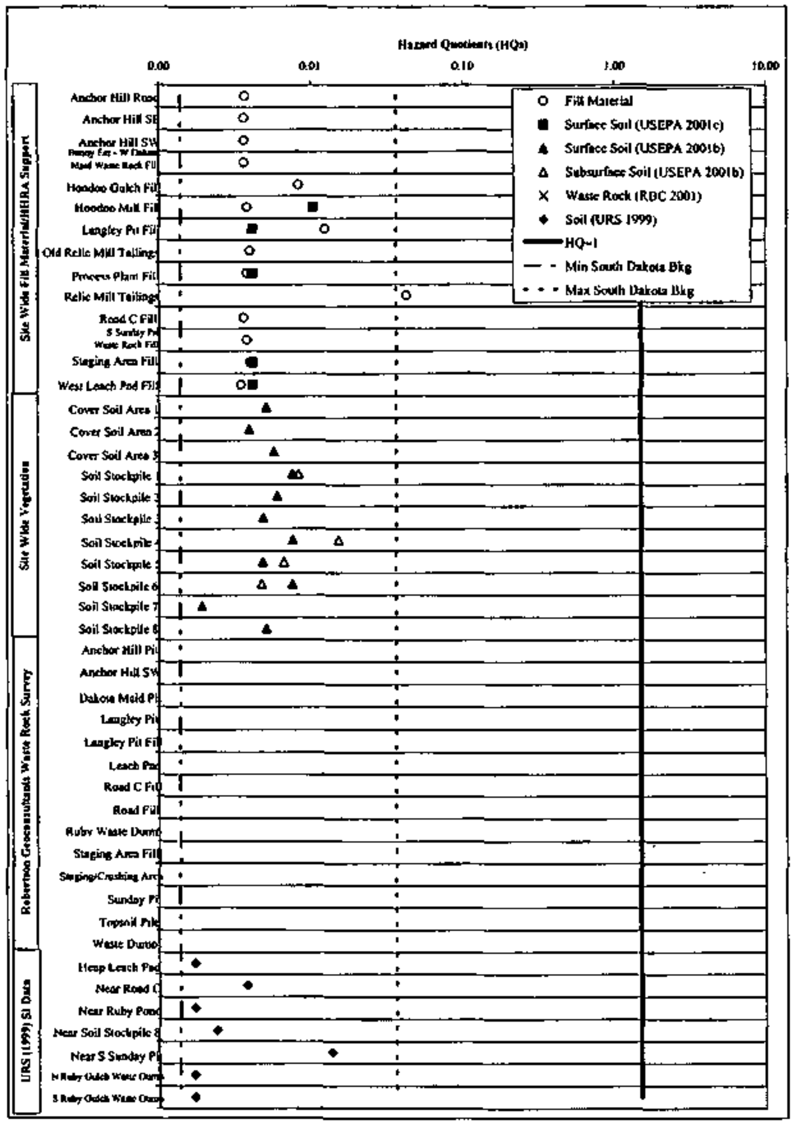


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

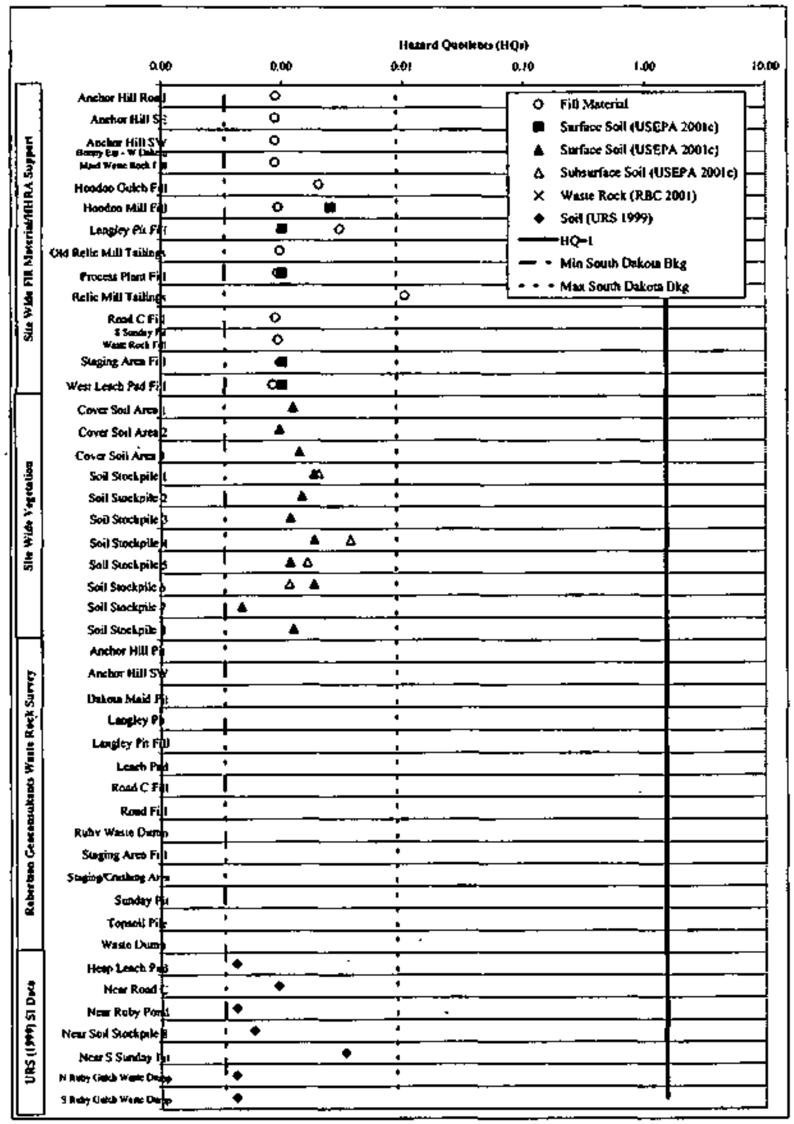
Figure 7-1j
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

MERCURY

DEER MOUSE



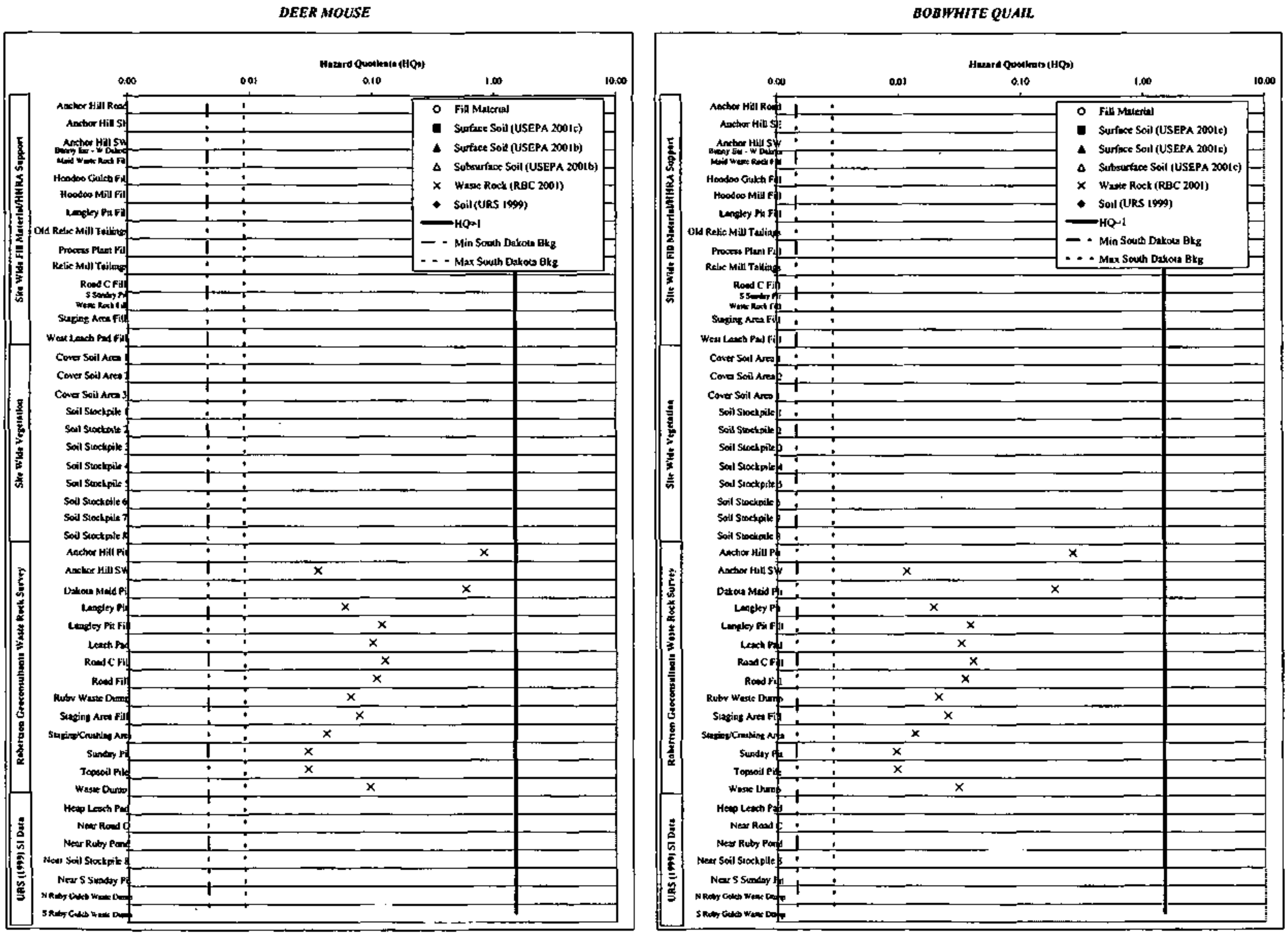
BOBWHITE QUAIL



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 7-1k
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

MOLYBDENUM



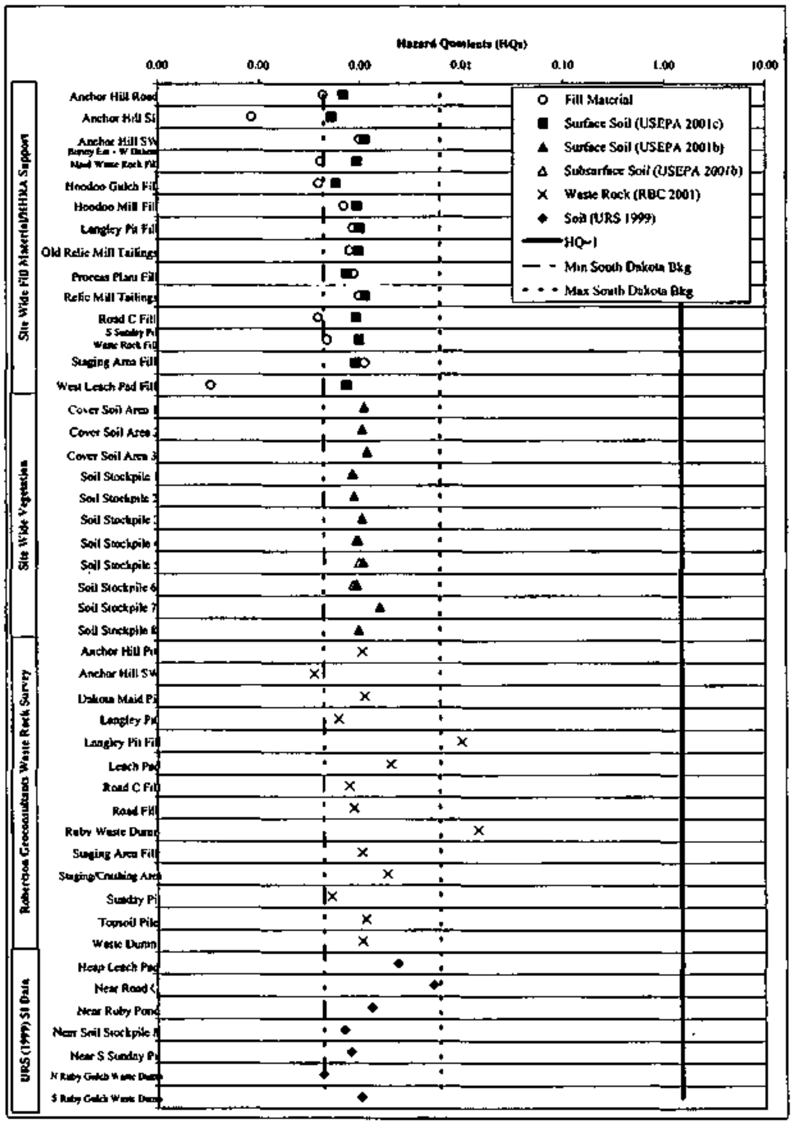
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls, Graphs
1/23/2003

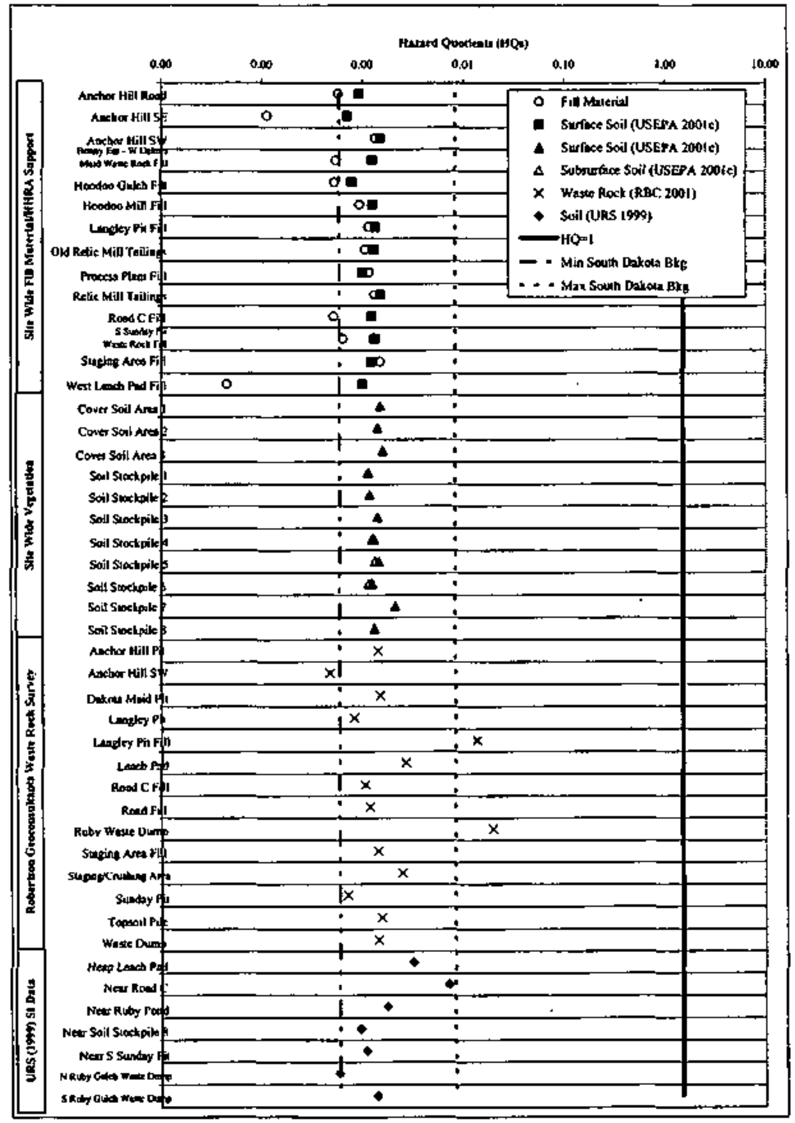
Figure 7-11
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

NICKEL

DEER MOUSE



BOBWHITE QUAIL



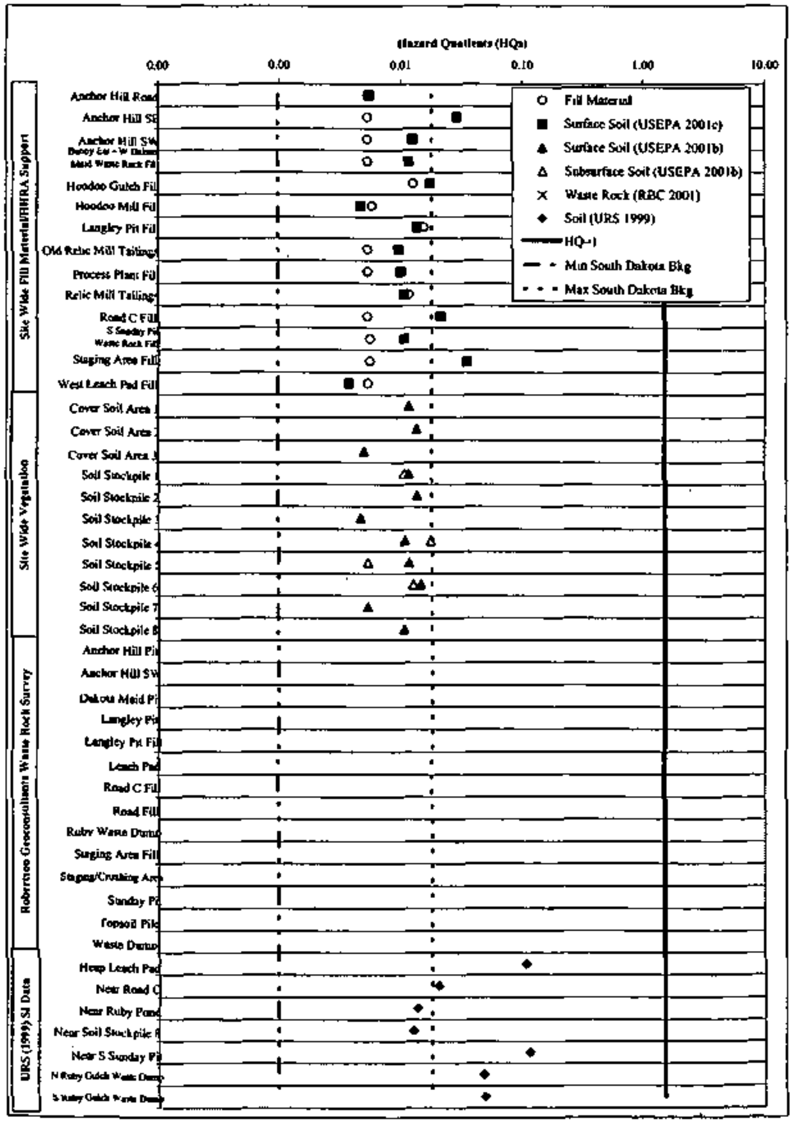
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls: Graphs
1/23/2003

Figure 7-1m
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

SELENIUM

DEER MOUSE



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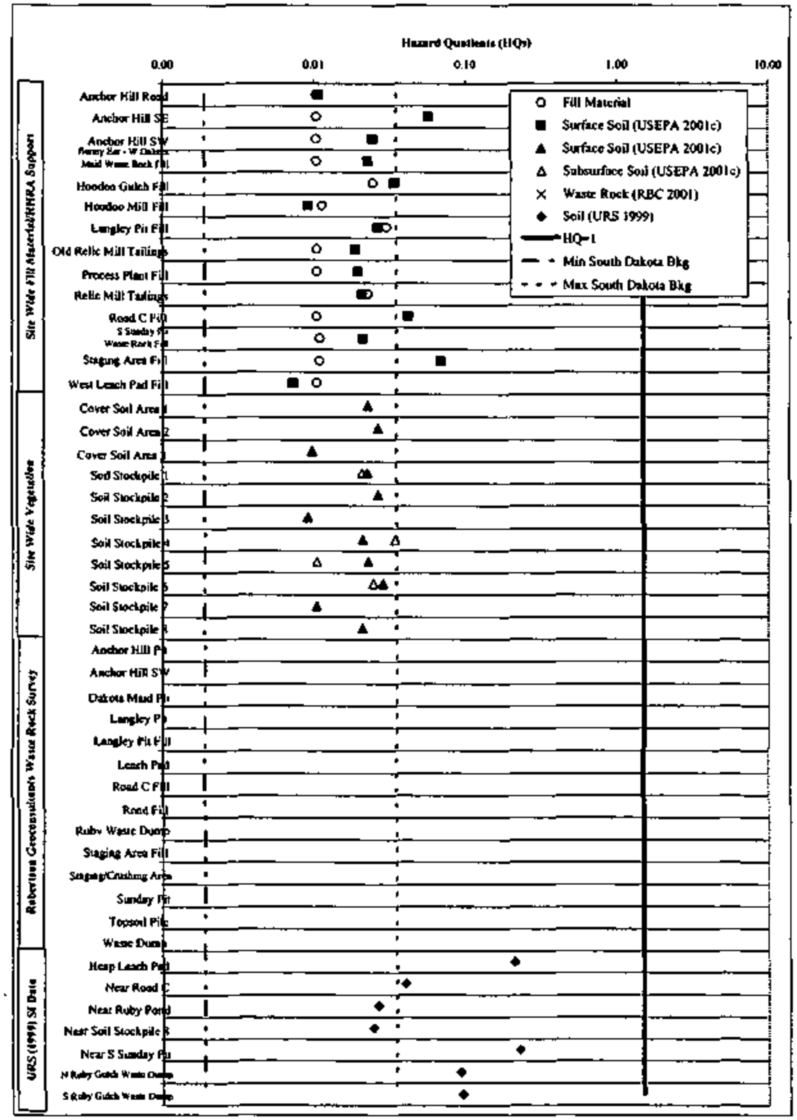
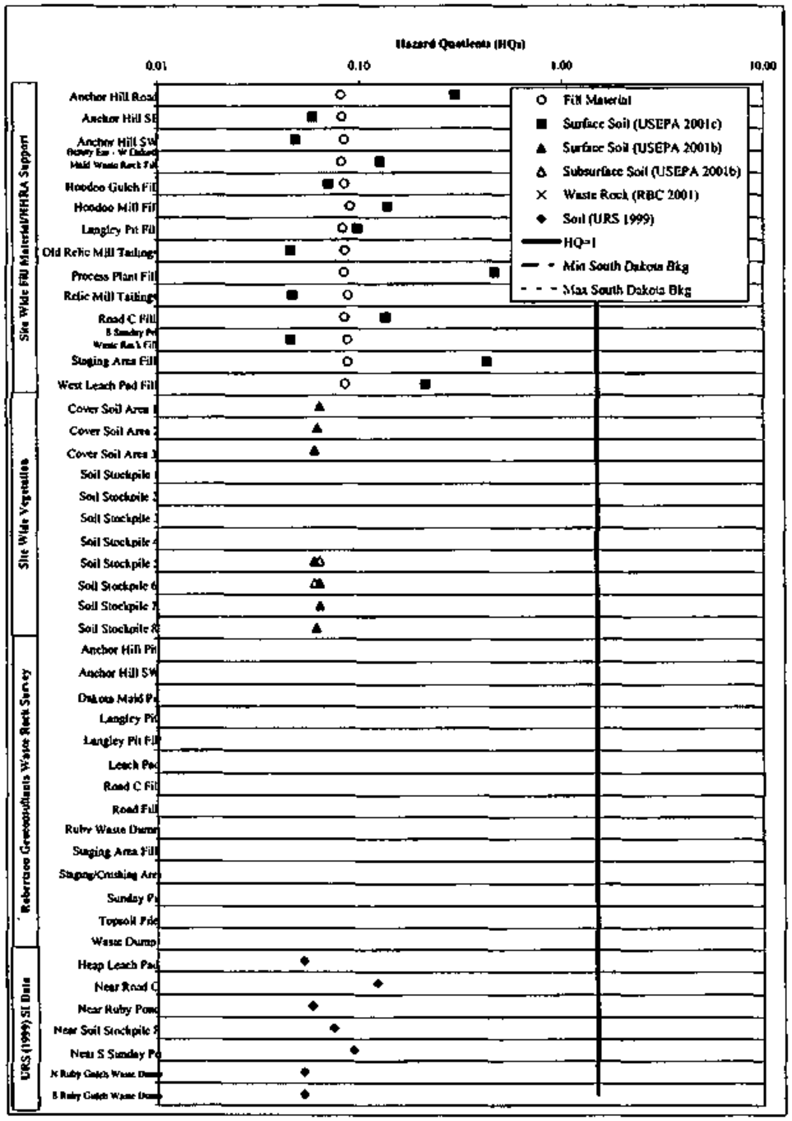
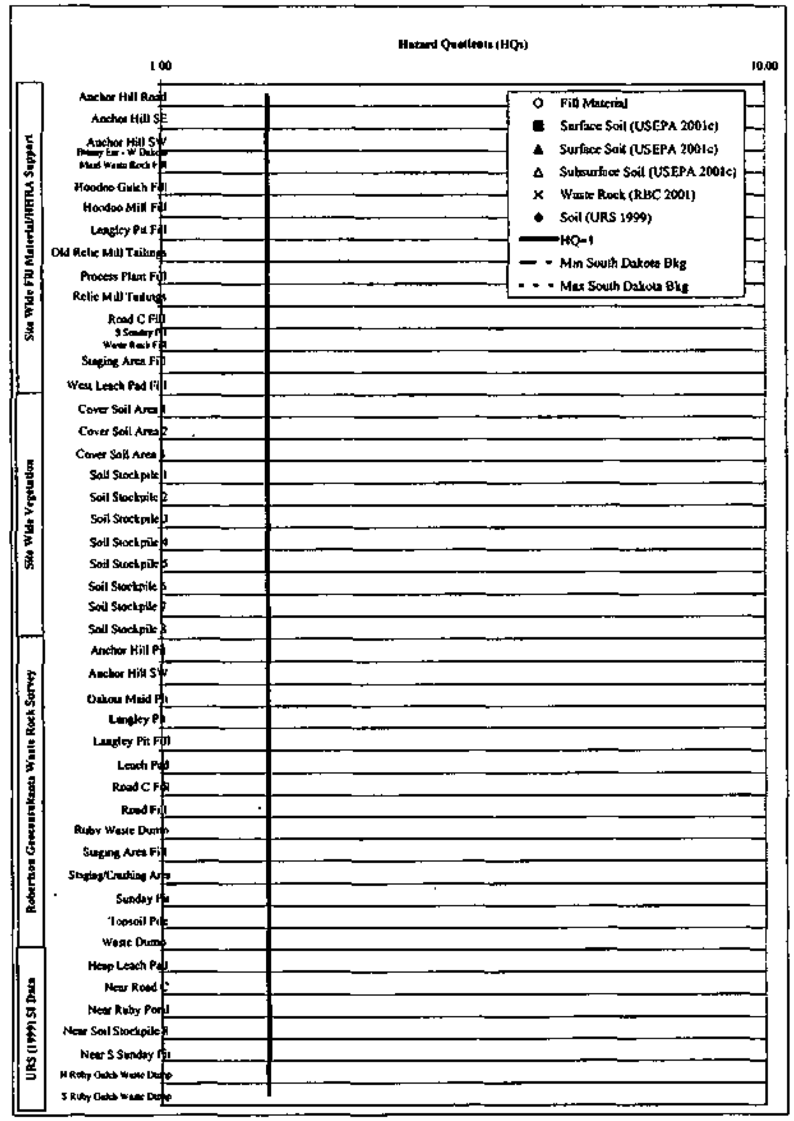


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 7-1n
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

THALLIUM





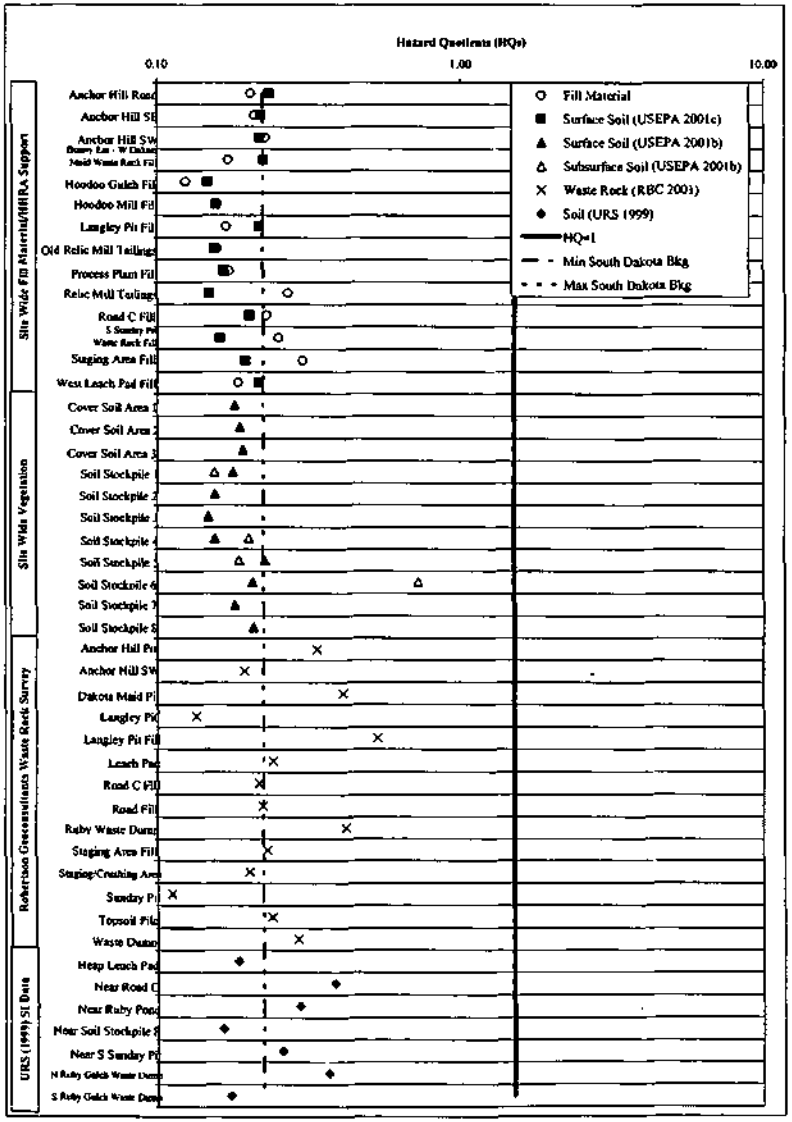
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls: Graphs
1/23/2003

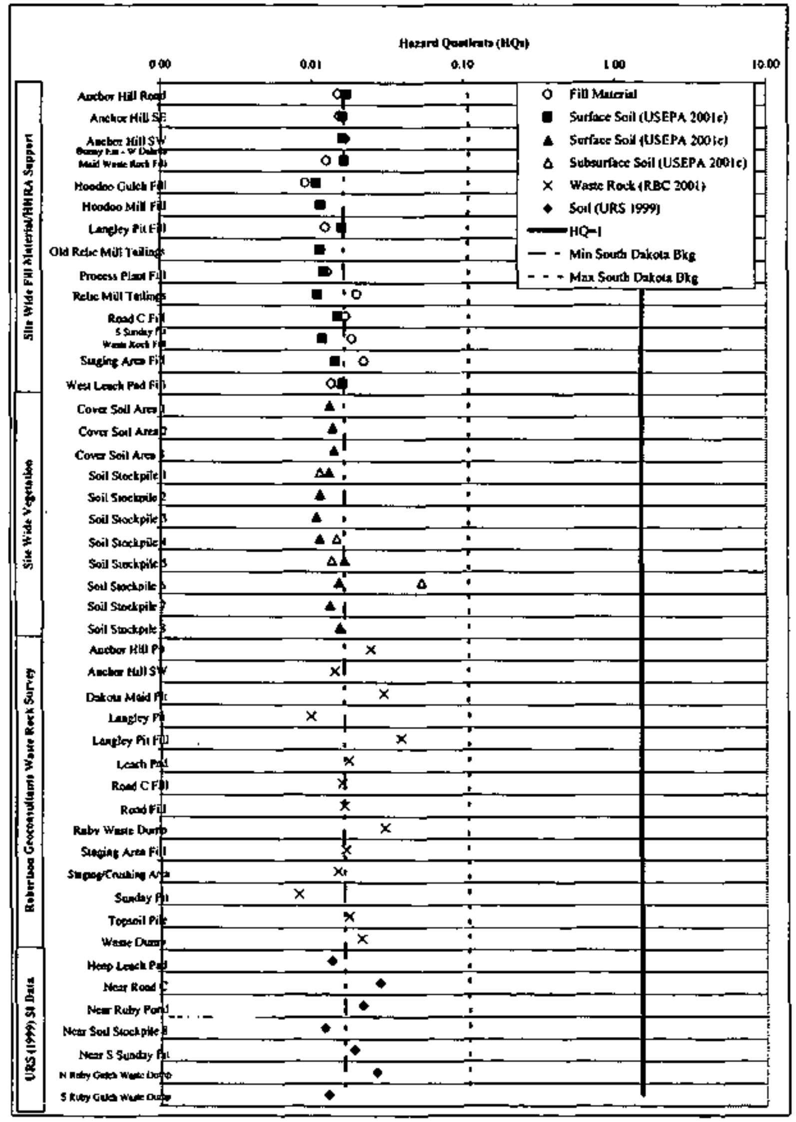
Figure 7-1o
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

VANADIUM

DEER MOUSE



BOBWHITE QUAIL

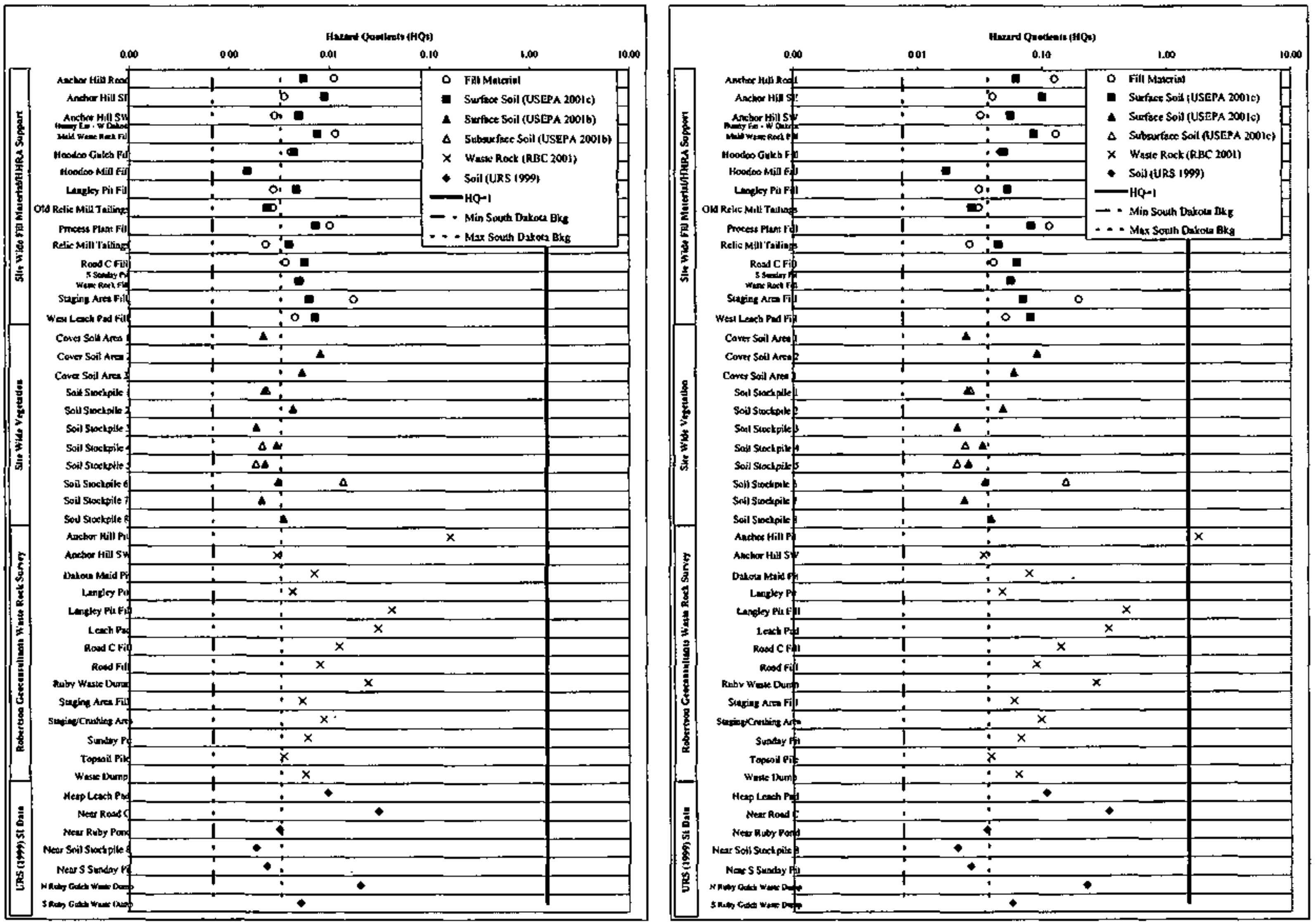


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Figure 7-1p
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

ZINC

DEER MOUSE *BOBWHITE QUAIL*

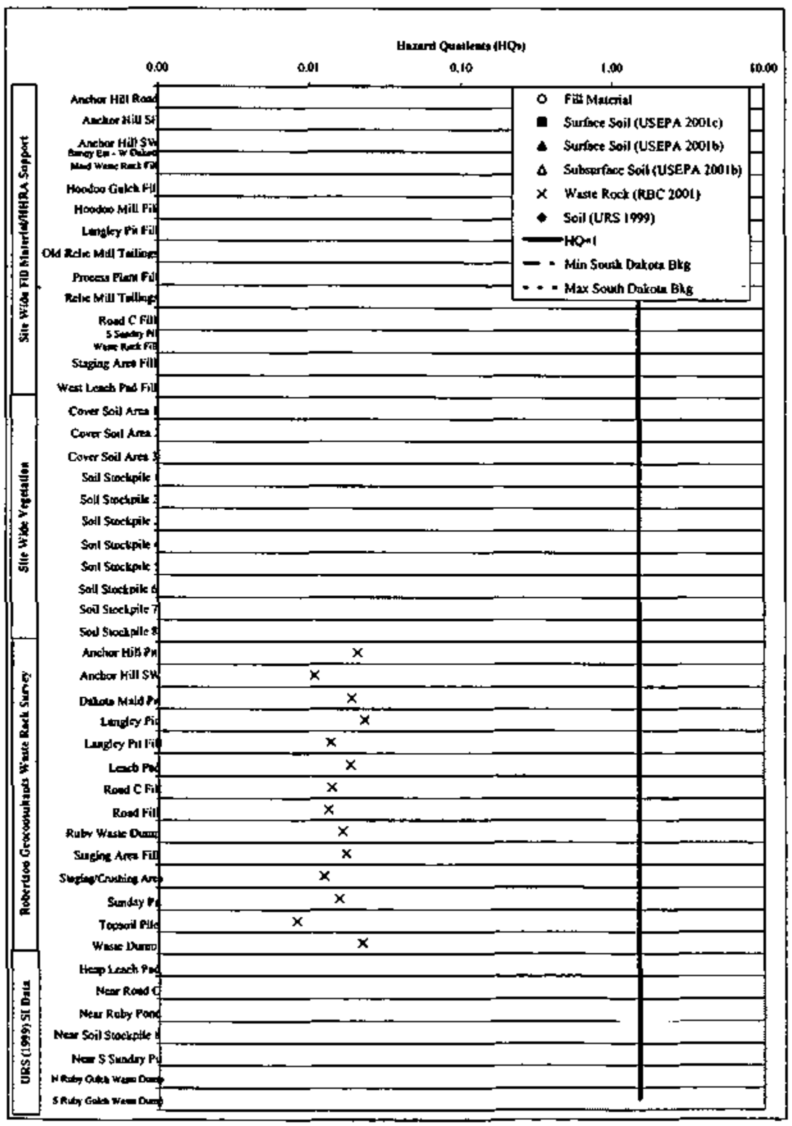


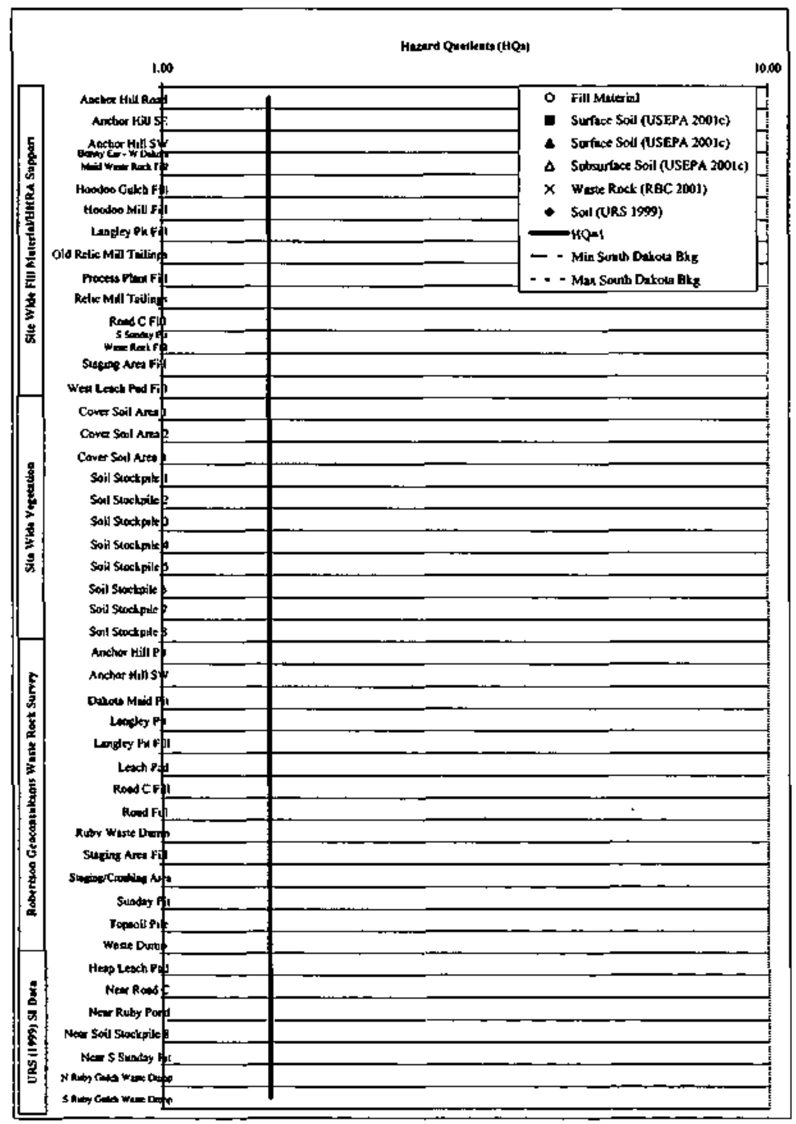
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

Wildlife Soil Onsite.xls: Graphs
1/23/2003

Figure 7-1q
Risks to Wildlife Receptors from Incidental Ingestion of Mine Source Area Soils

ZIRCONIUM



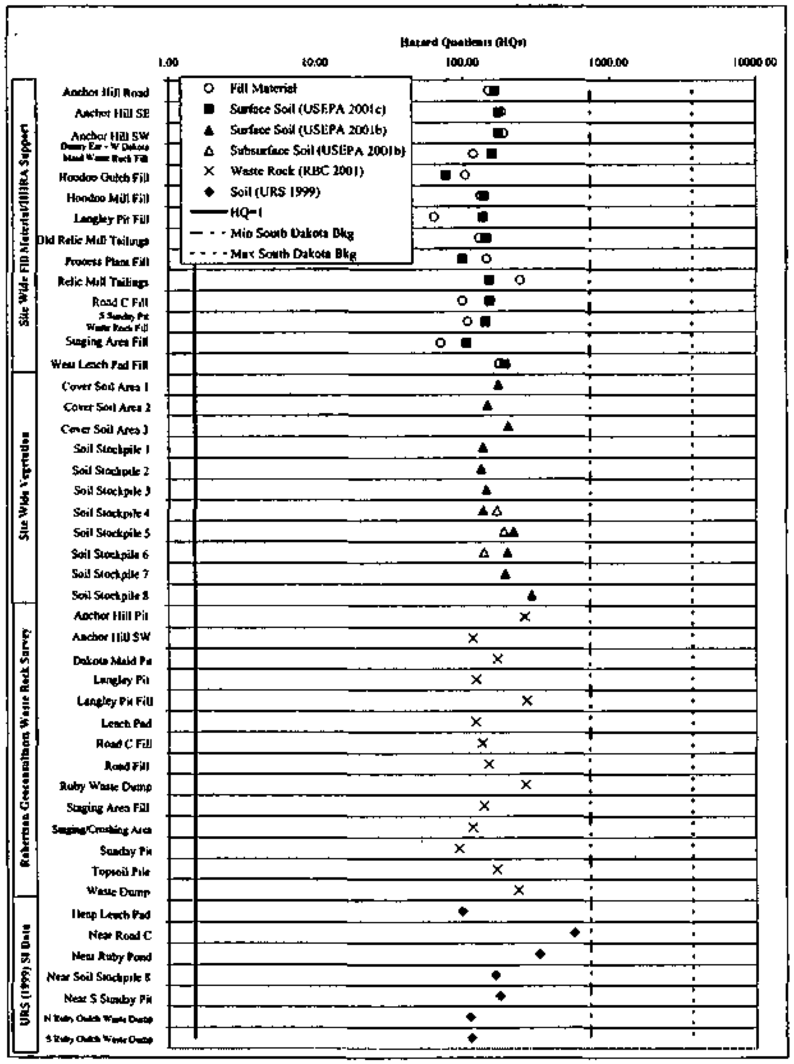


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)

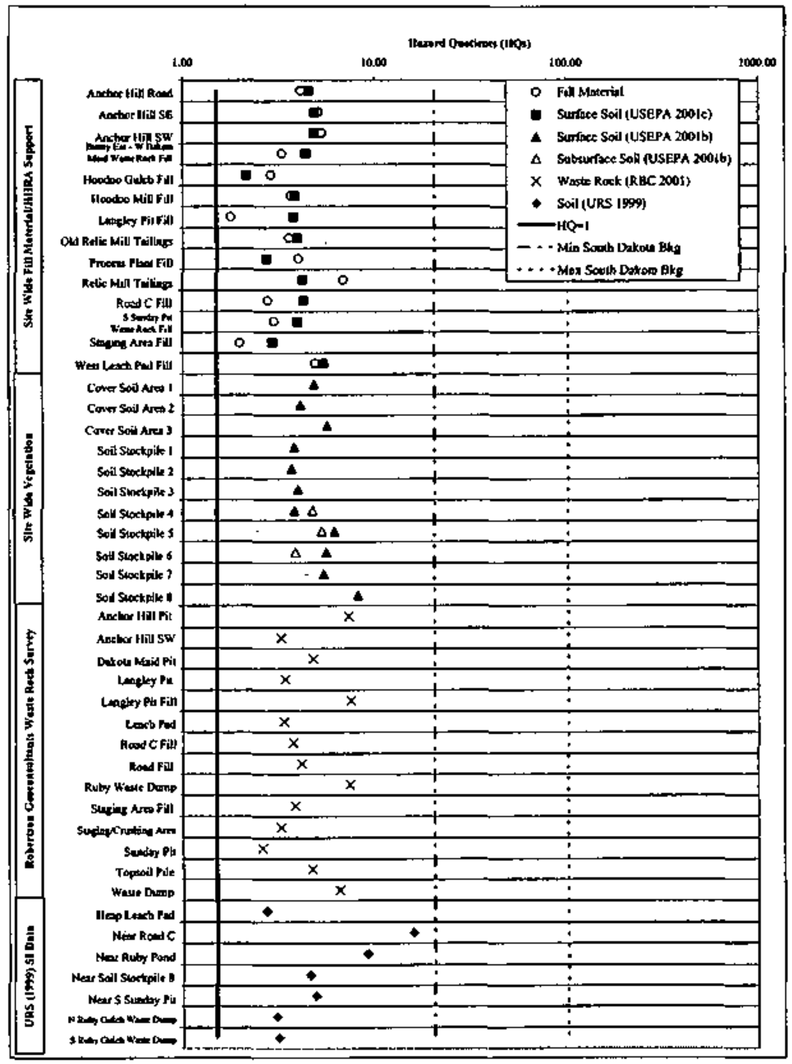
Figure 7-2a
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

ALUMINUM

DEER MOUSE



BOBWHITE QUAIL

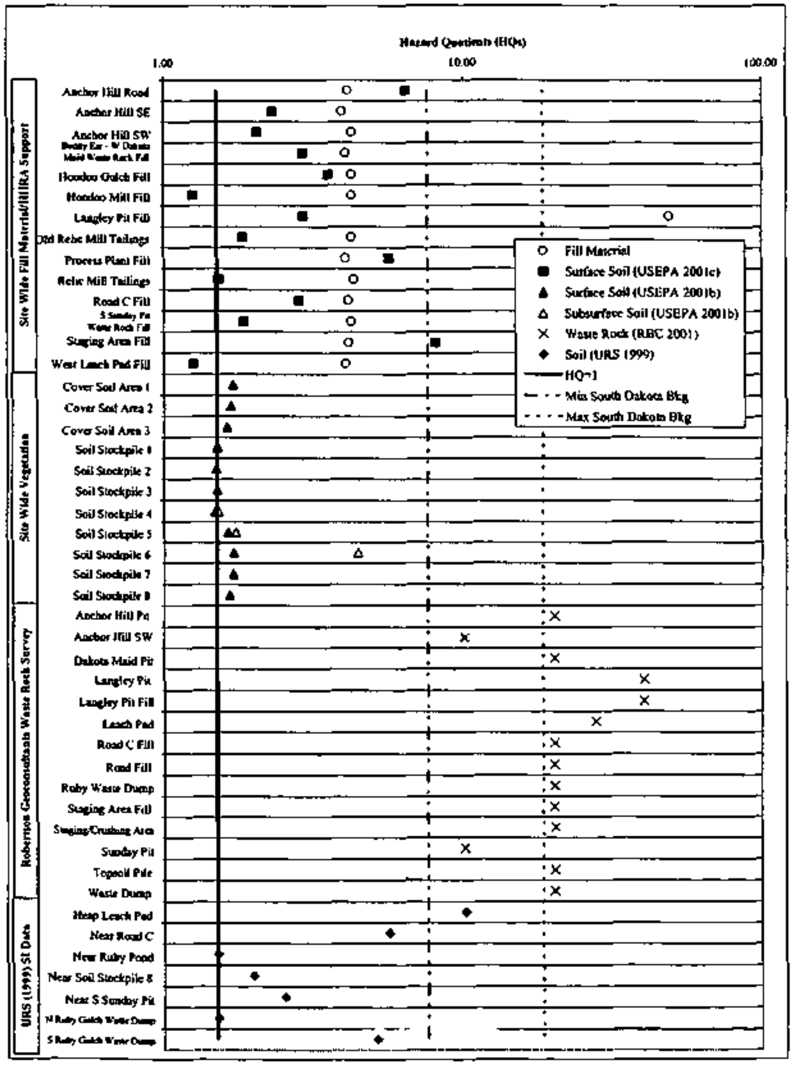


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

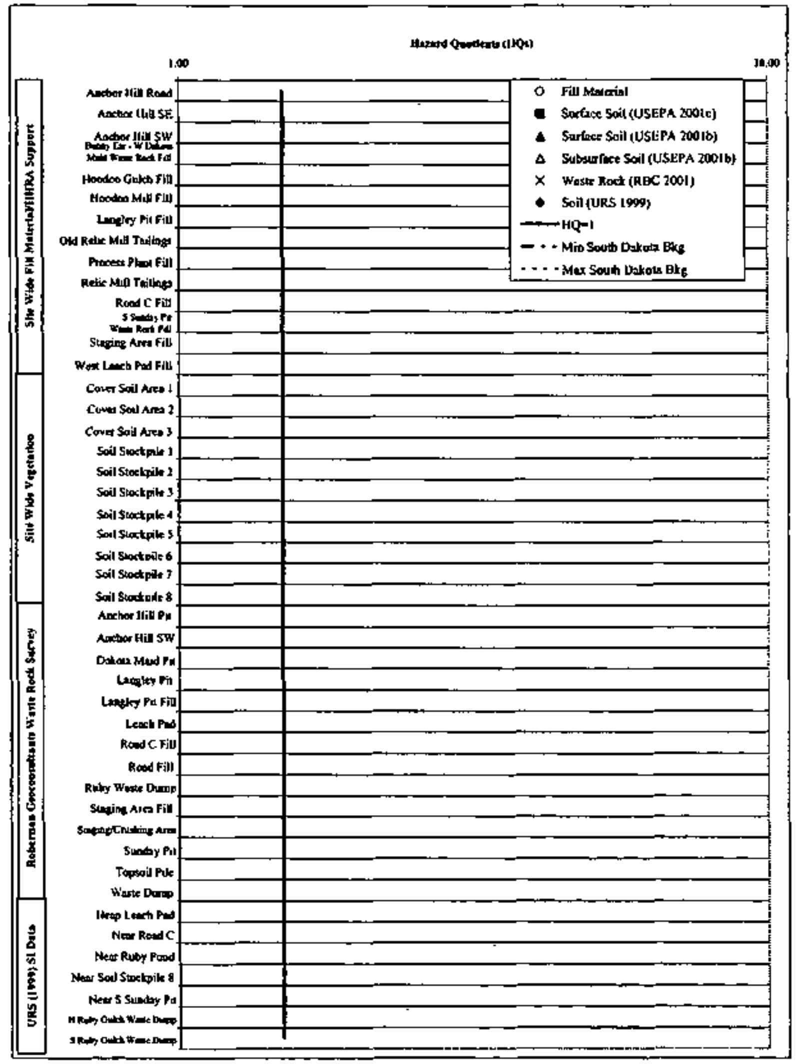
Figure 7-2b
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

ANTIMONY

DEER MOUSE



BOBWHITE QUAIL

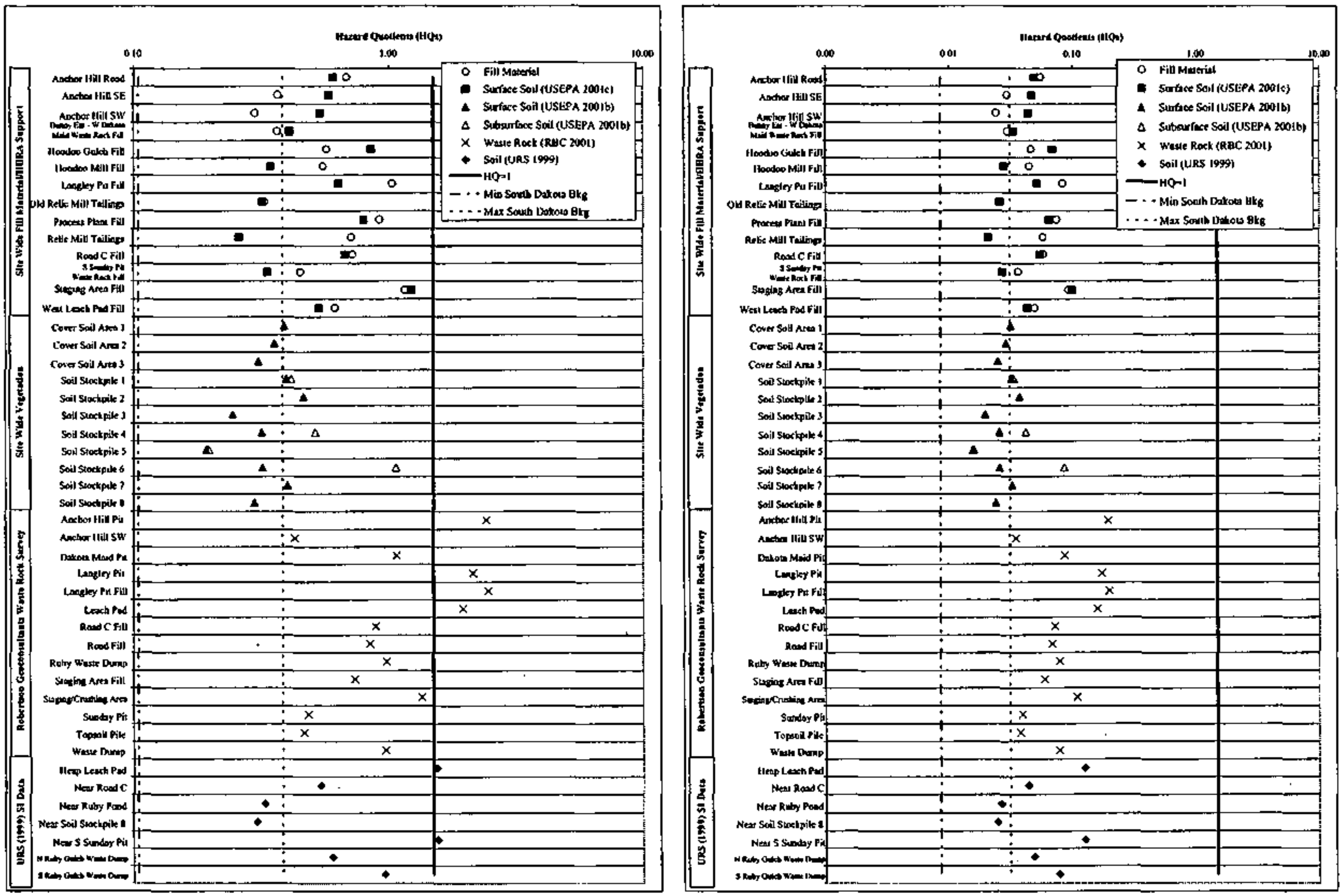


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Figure 7-2c
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

ARSENIC

DEER MOUSE *BOBWHITE QUAIL*

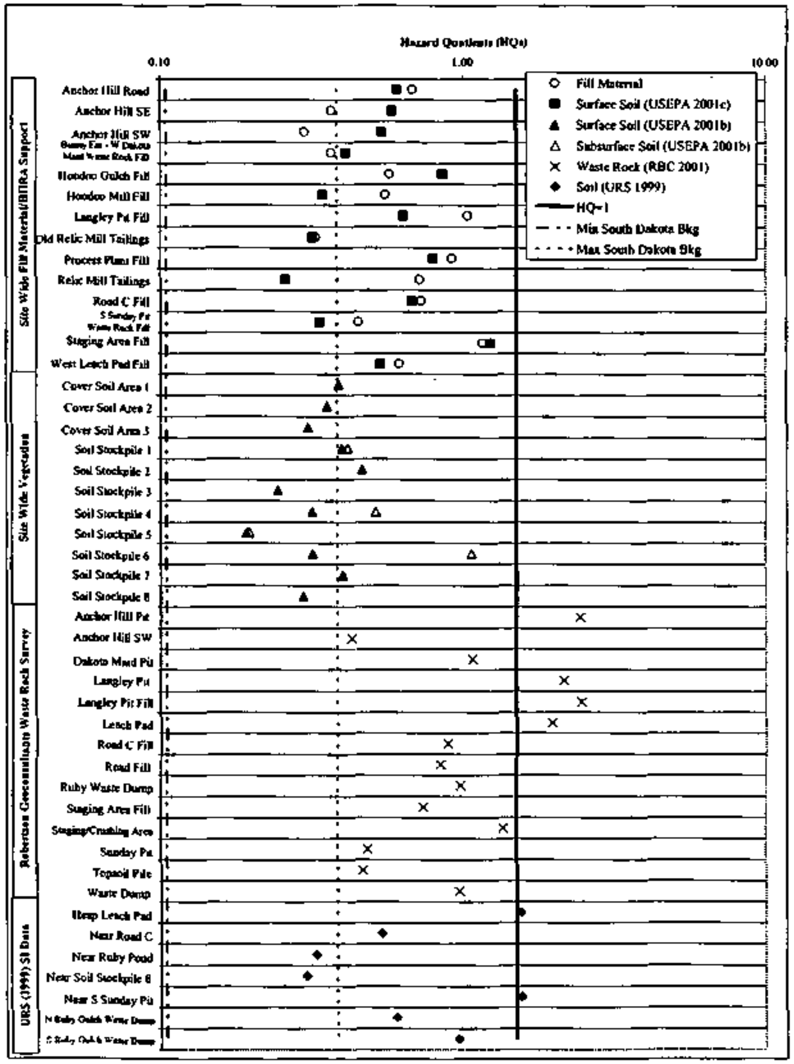


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

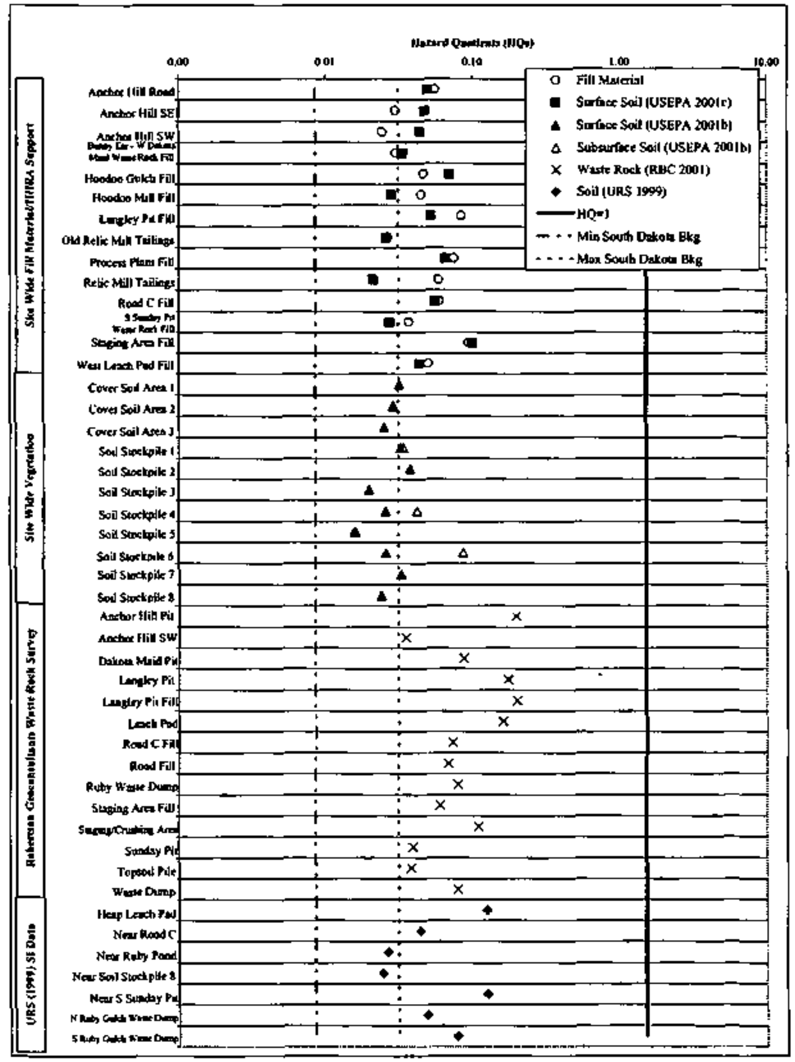
Figure 7-2c
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

ARSENIC

DEER MOUSE



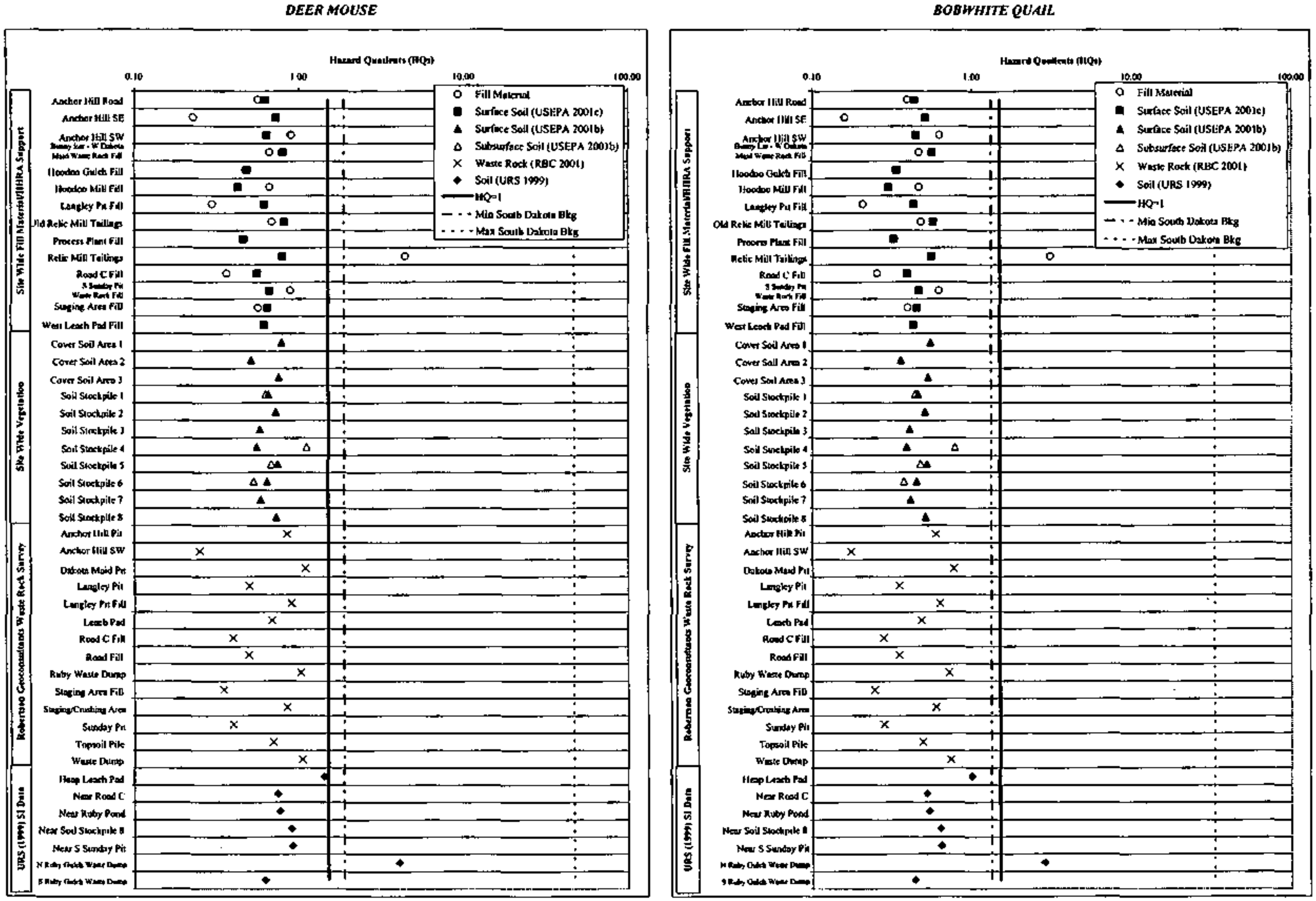
BOBWHITE QUAIL



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Figure 7-2d
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

BARIUM

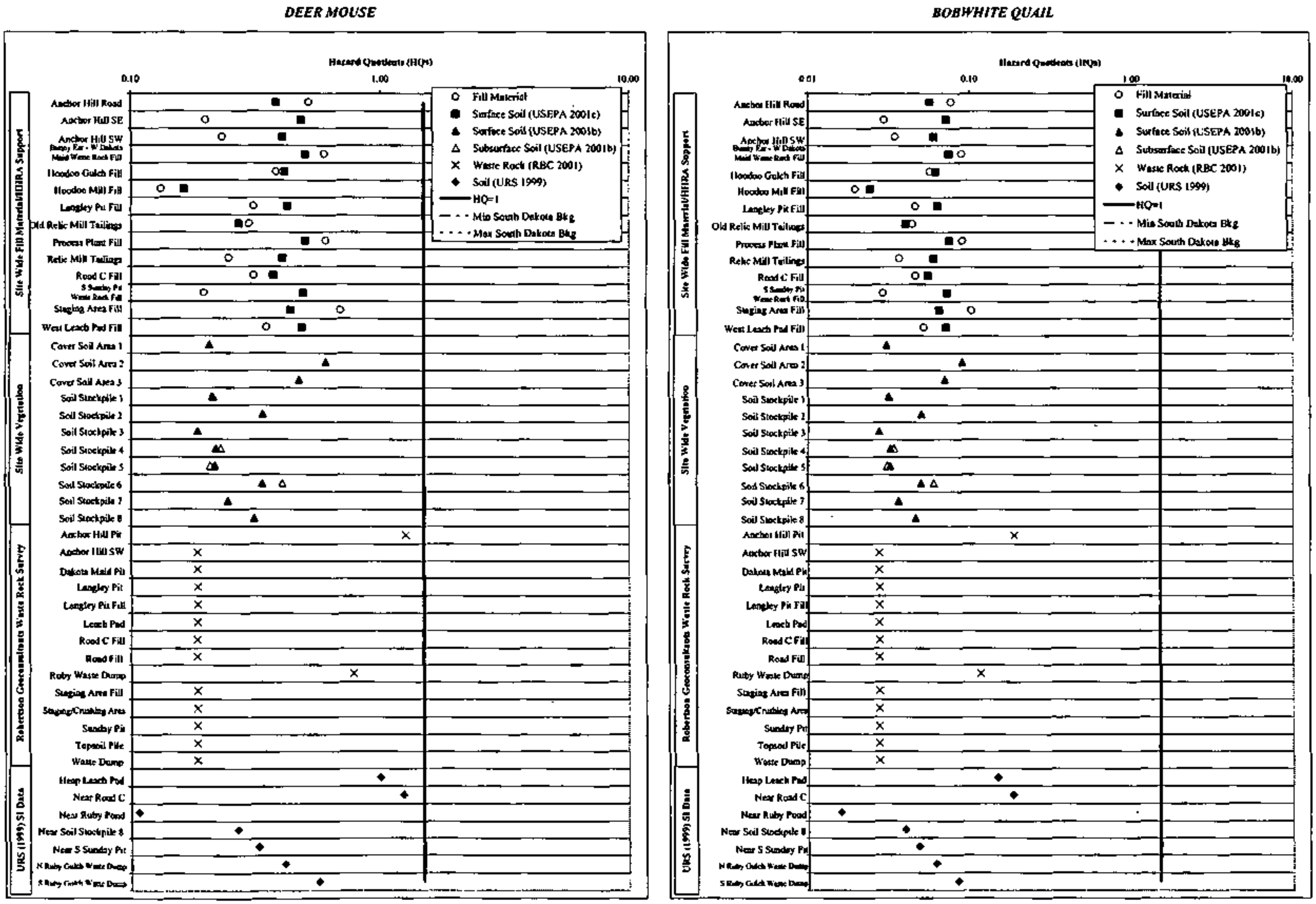


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Wildlife Plants Onsite.xls: Graphs
1/23/2003

Figure 7-2e
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

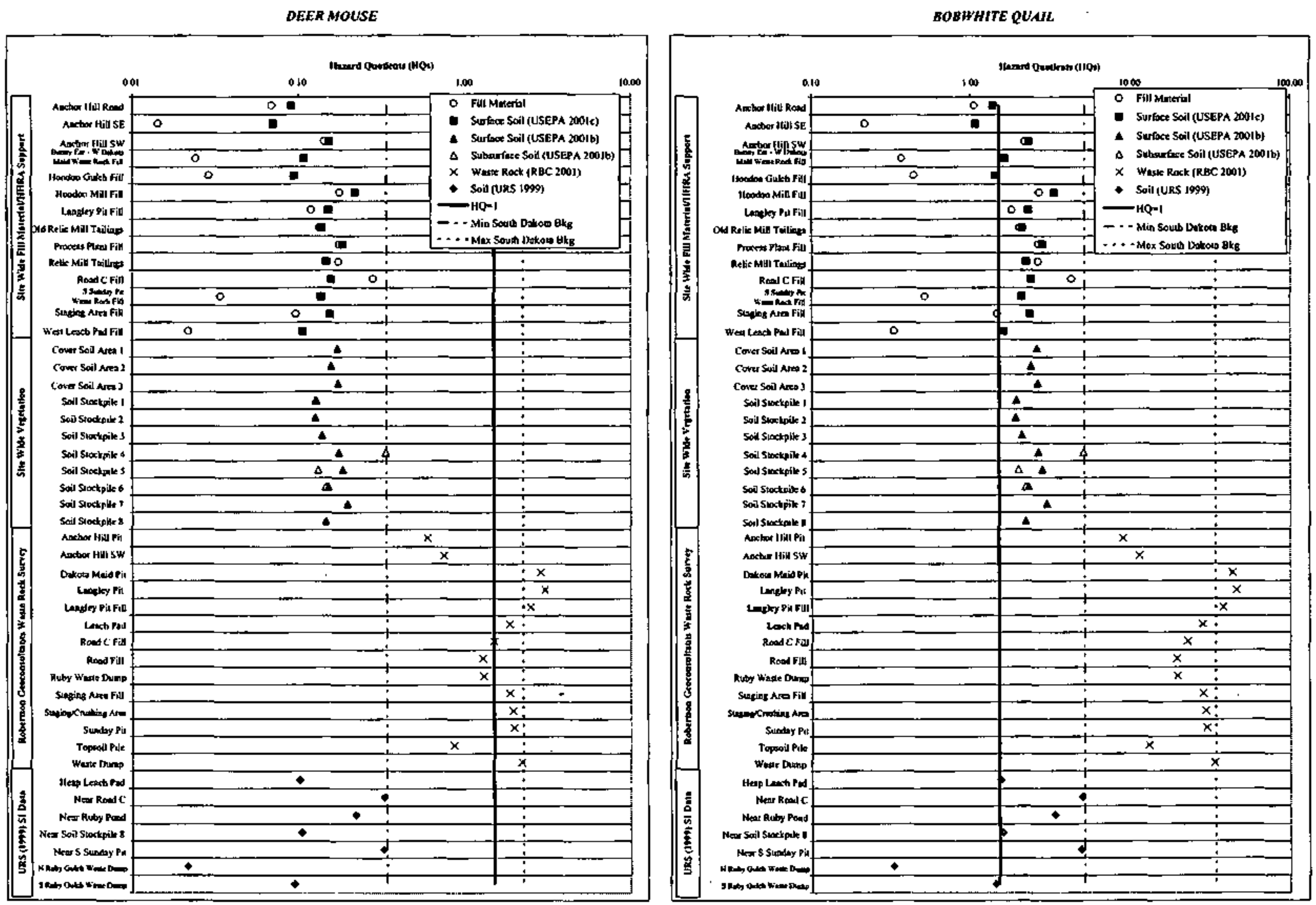
CADMIUM



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors

Figure 7-2f
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

CHROMIUM



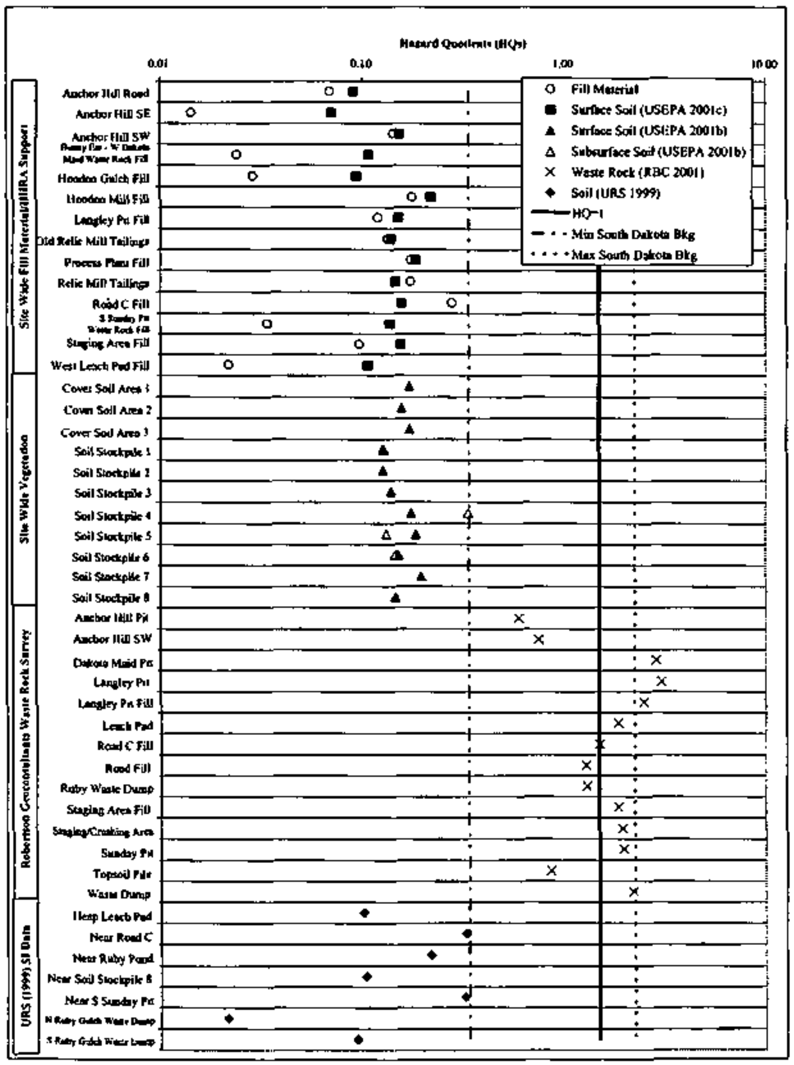
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Wildlife Plants Onsite.xls: Graphs
1/23/2003

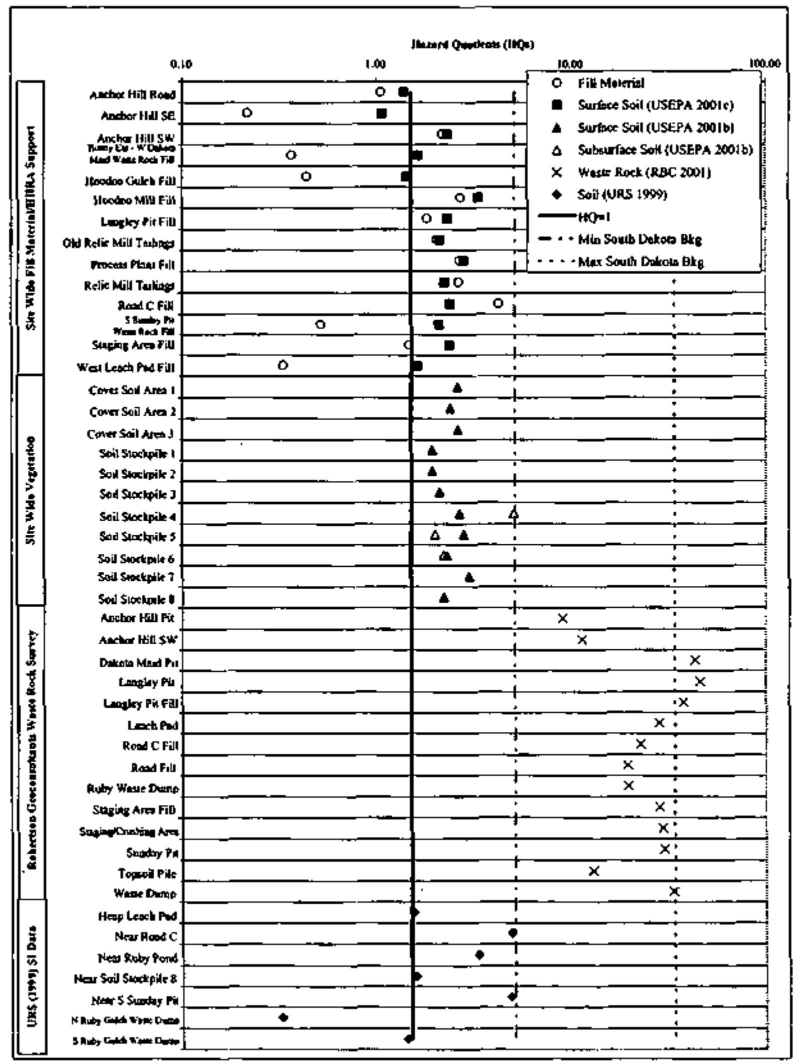
Figure 7-2f
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

CHROMIUM

DEER MOUSE



BOBWHITE QUAIL

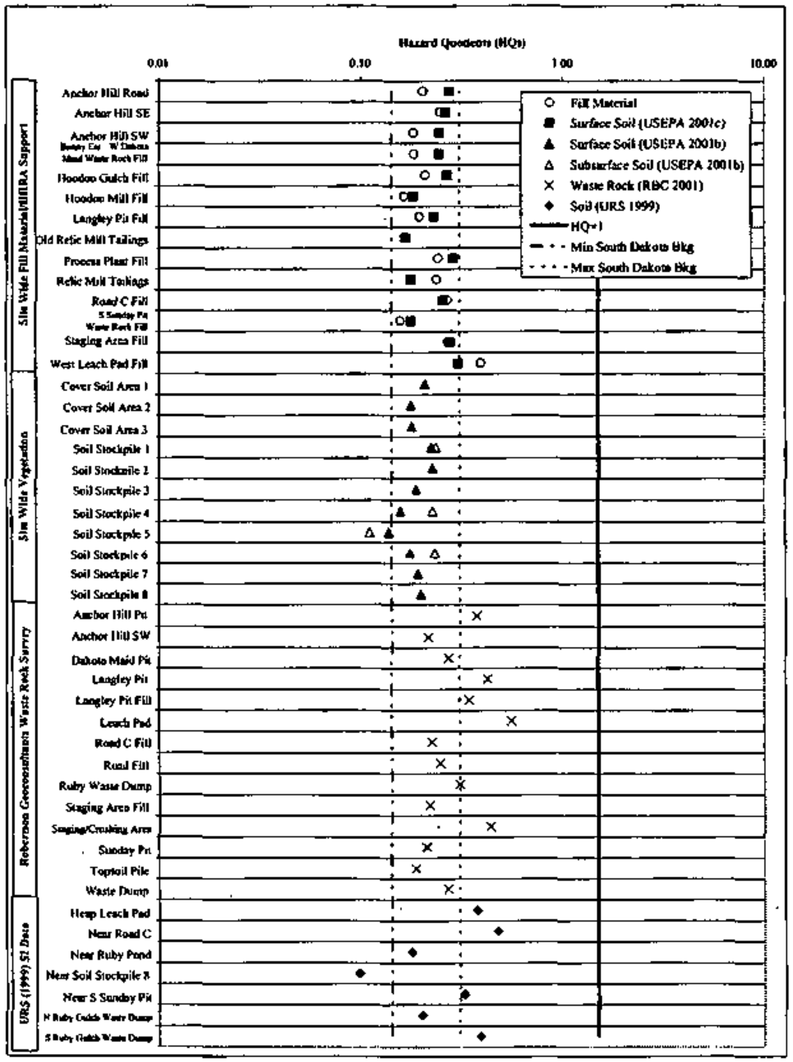


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

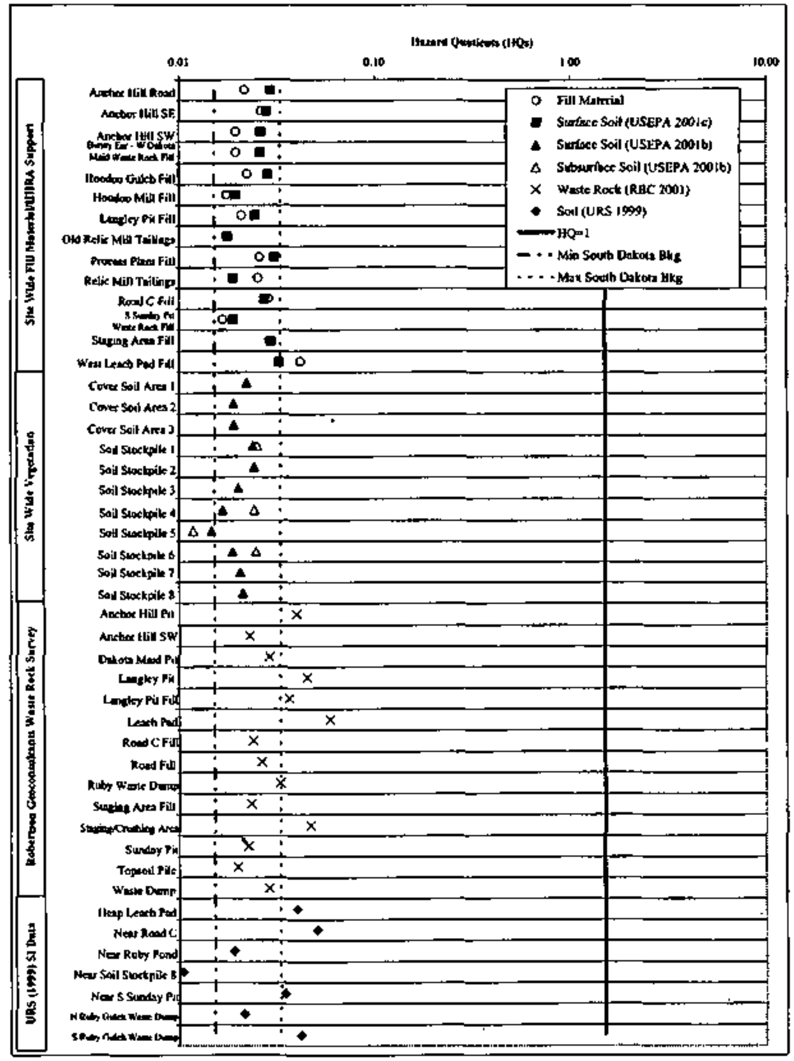
Figure 7-2g
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

COPPER

DEER MOUSE



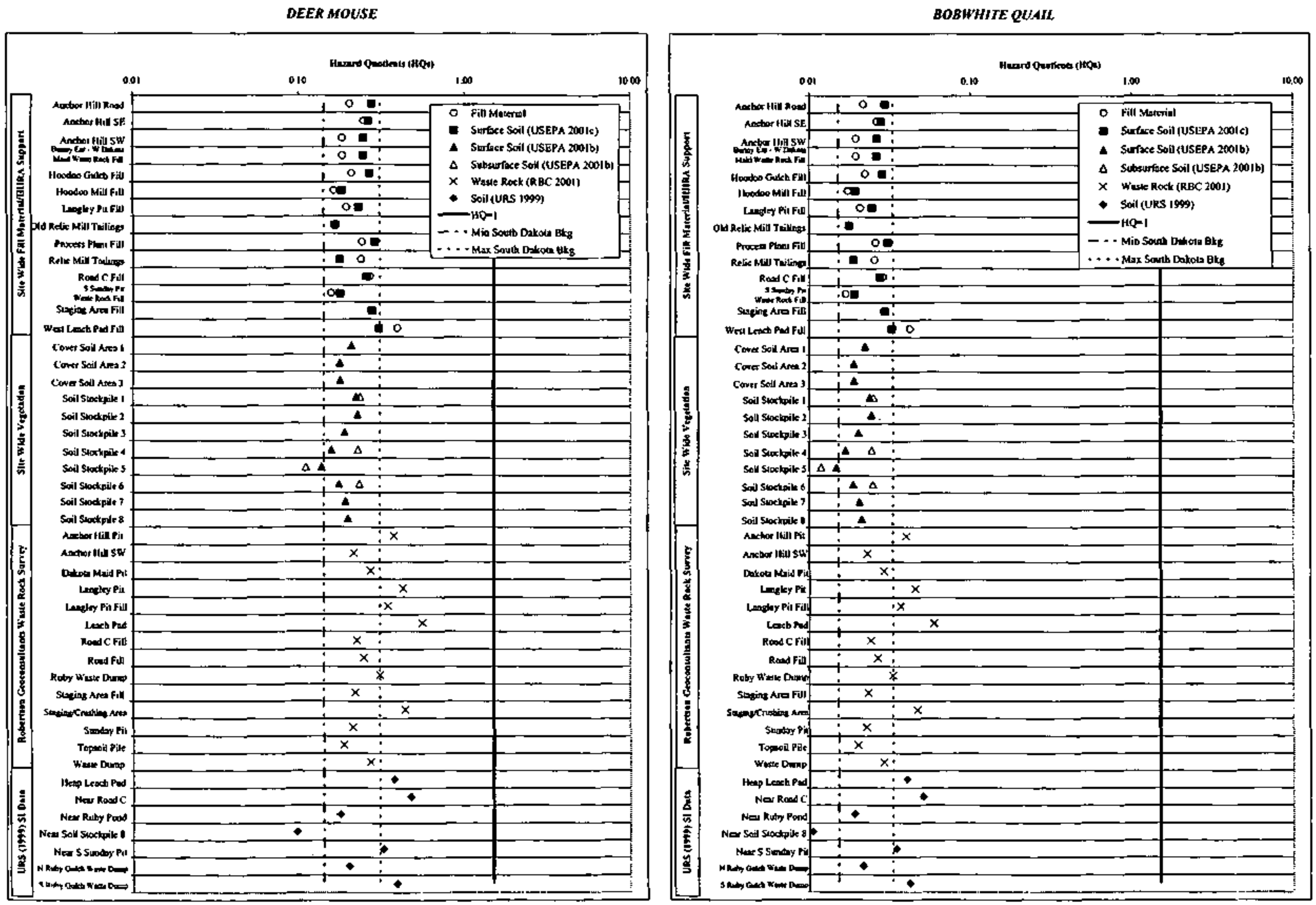
BOBWHITE QUAIL



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Figure 7-2g
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

COPPER



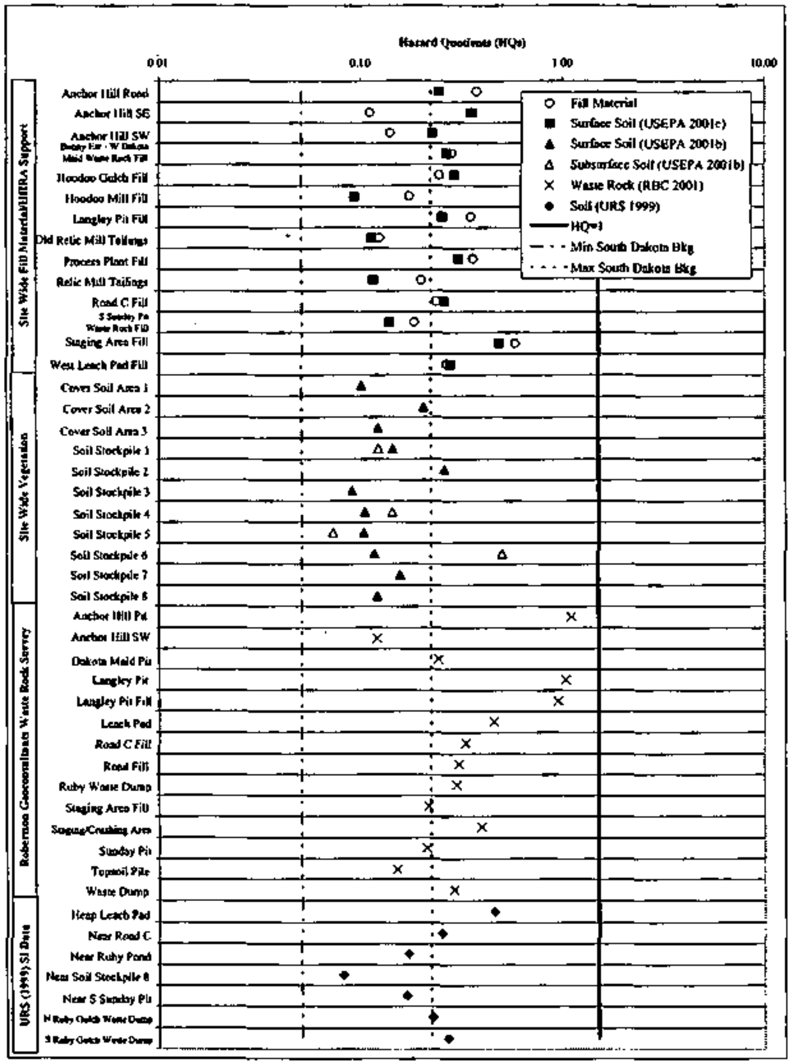
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Wildlife Plants Onsite.xls: Graphs
1/23/2003

Figure 7-2h
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

LEAD

DEER MOUSE



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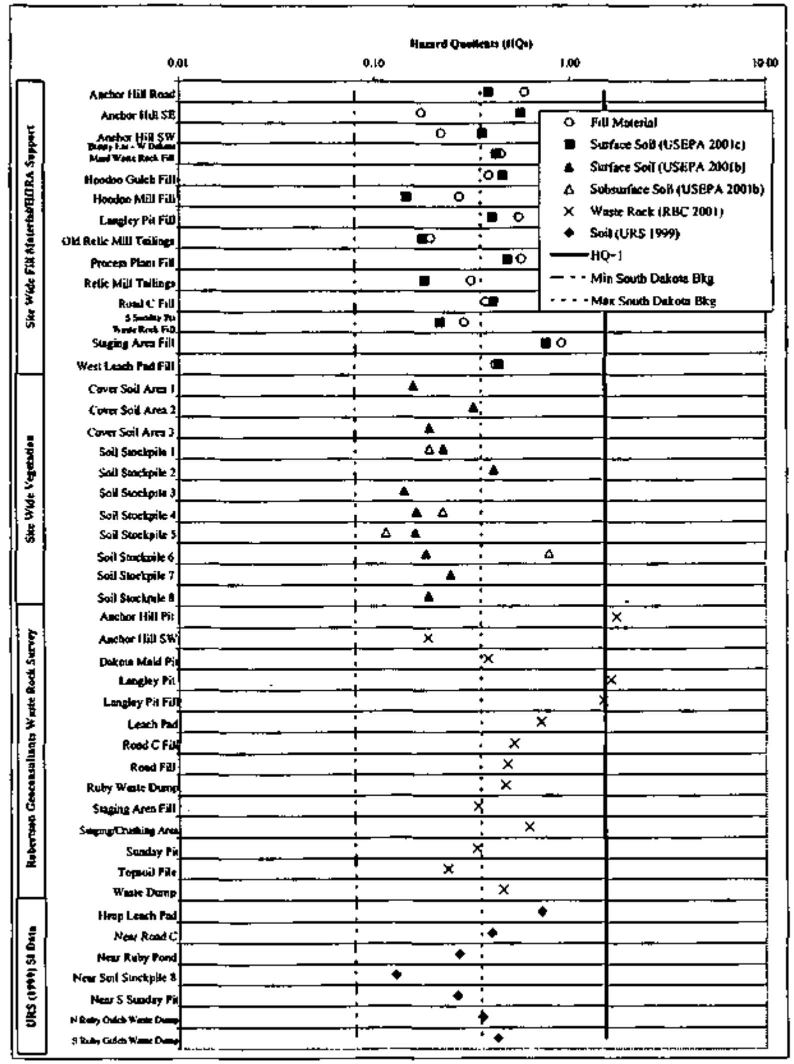


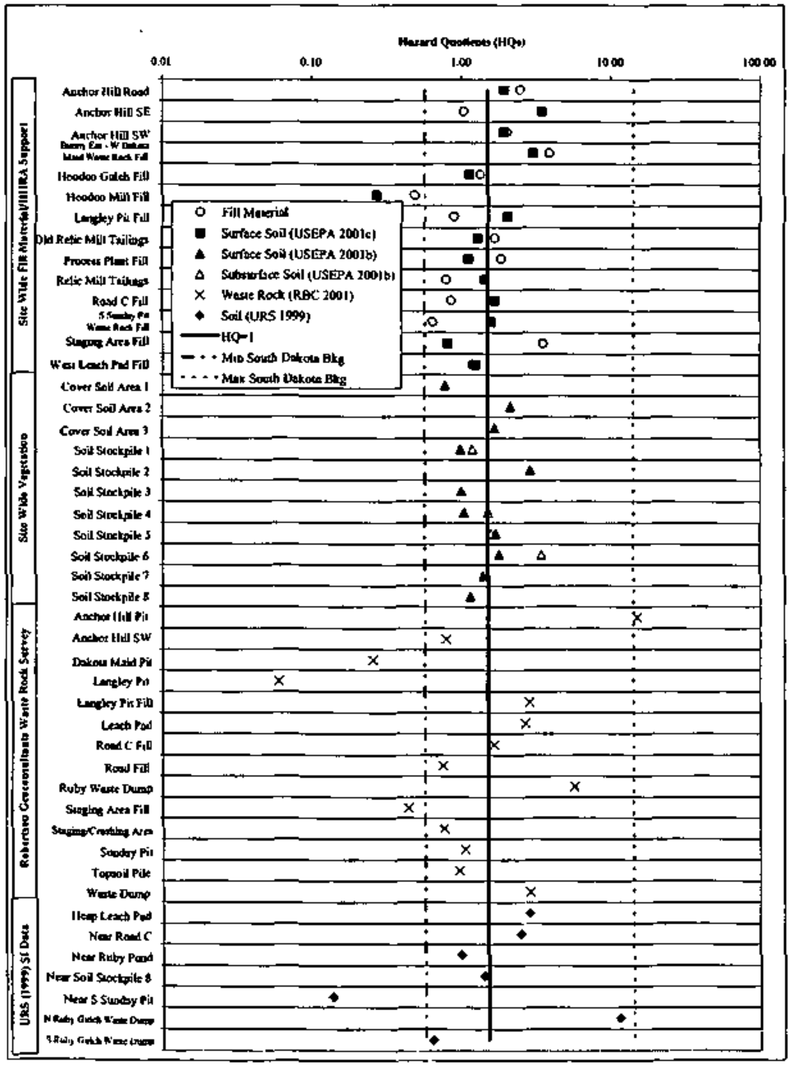
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Wildlife Plants Onsite.xls: Graphs
1/23/2003

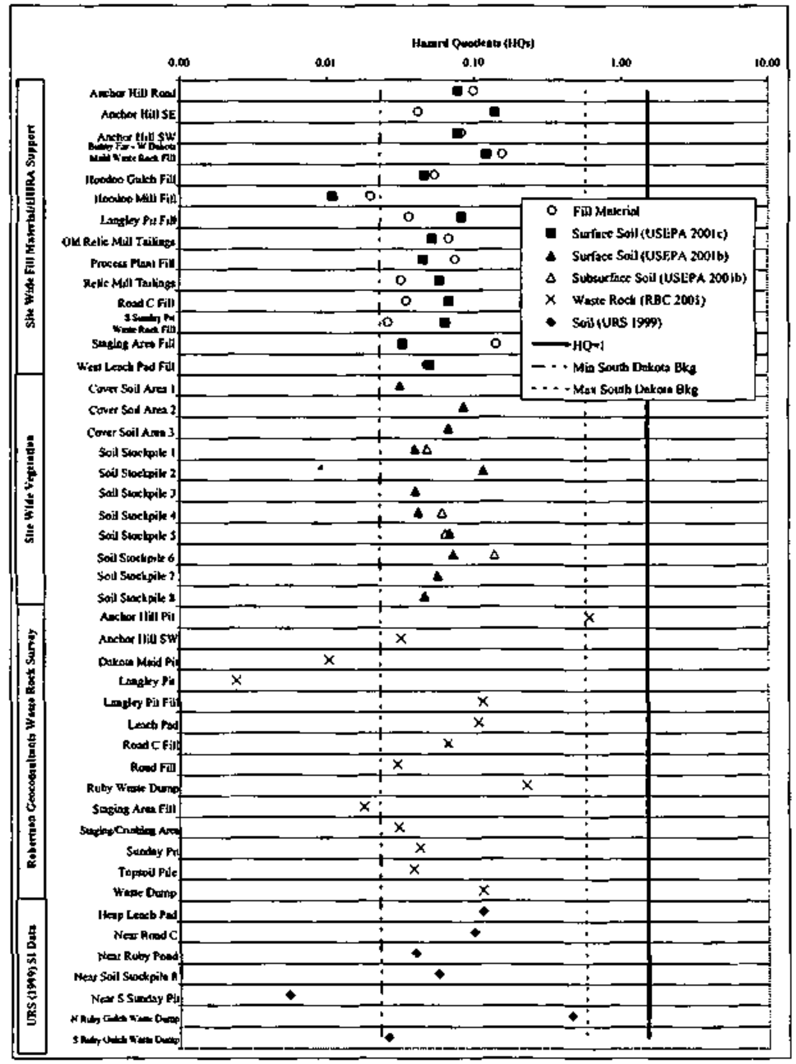
Figure 7-2i
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

MANGANESE

DEER MOUSE



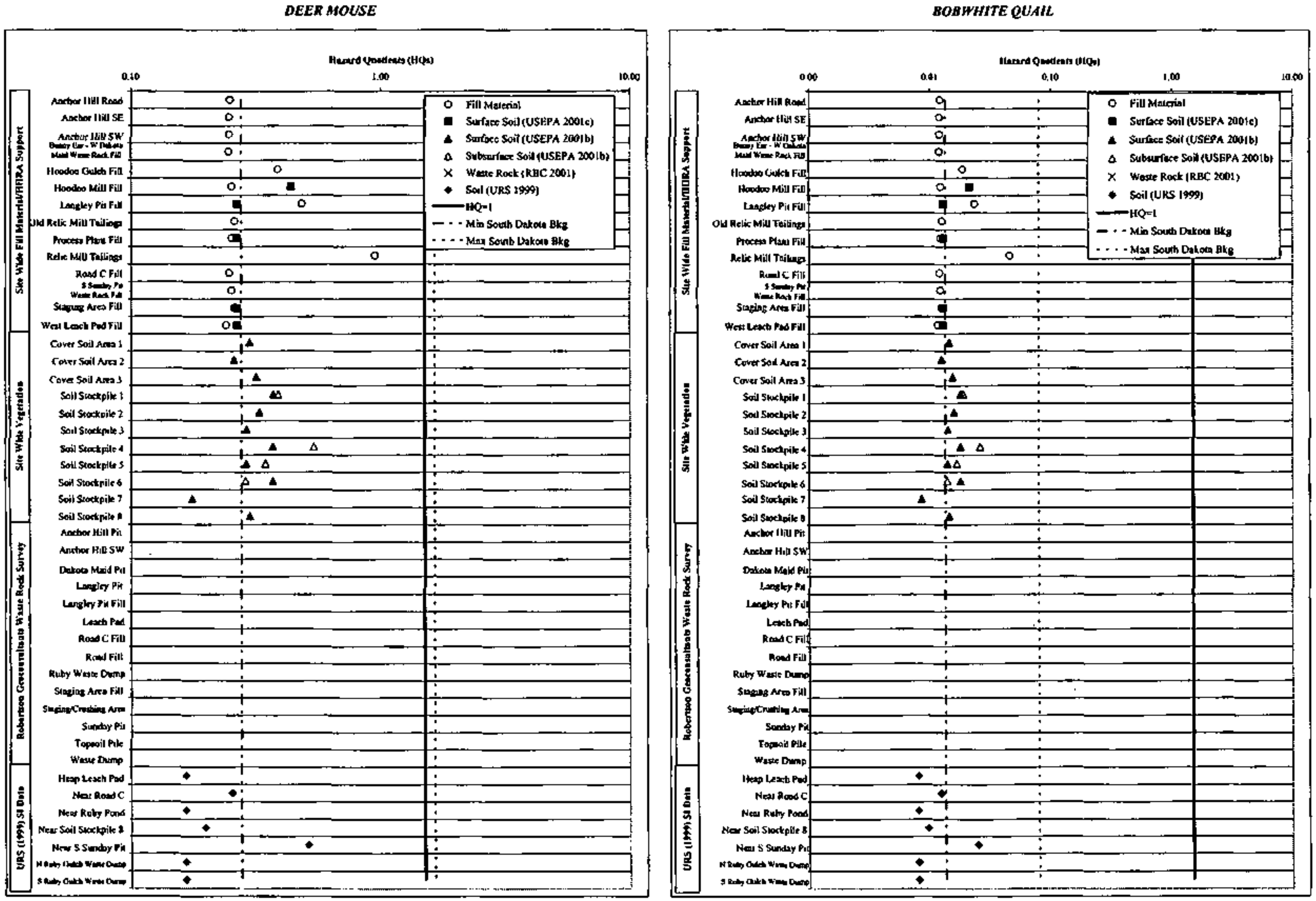
BOBWHITE QUAIL



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Figure 7-2j
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

MERCURY



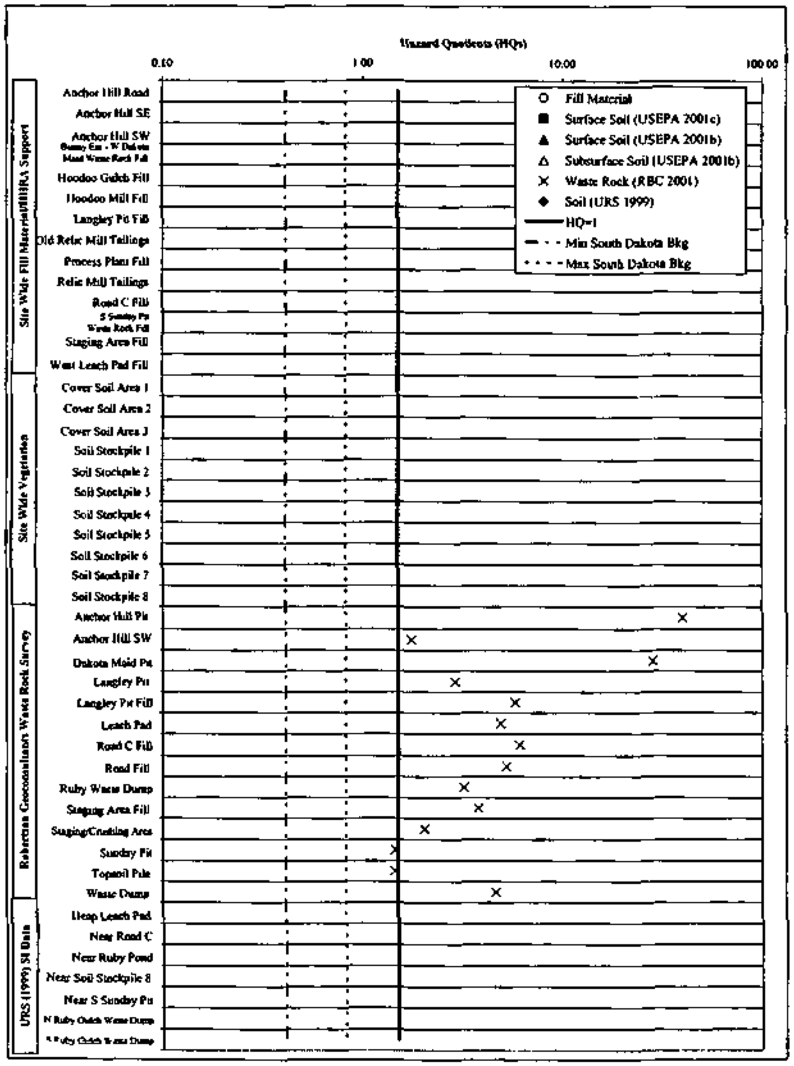
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Wildlife Plants Onsite.xls: Graphs
1/23/2003

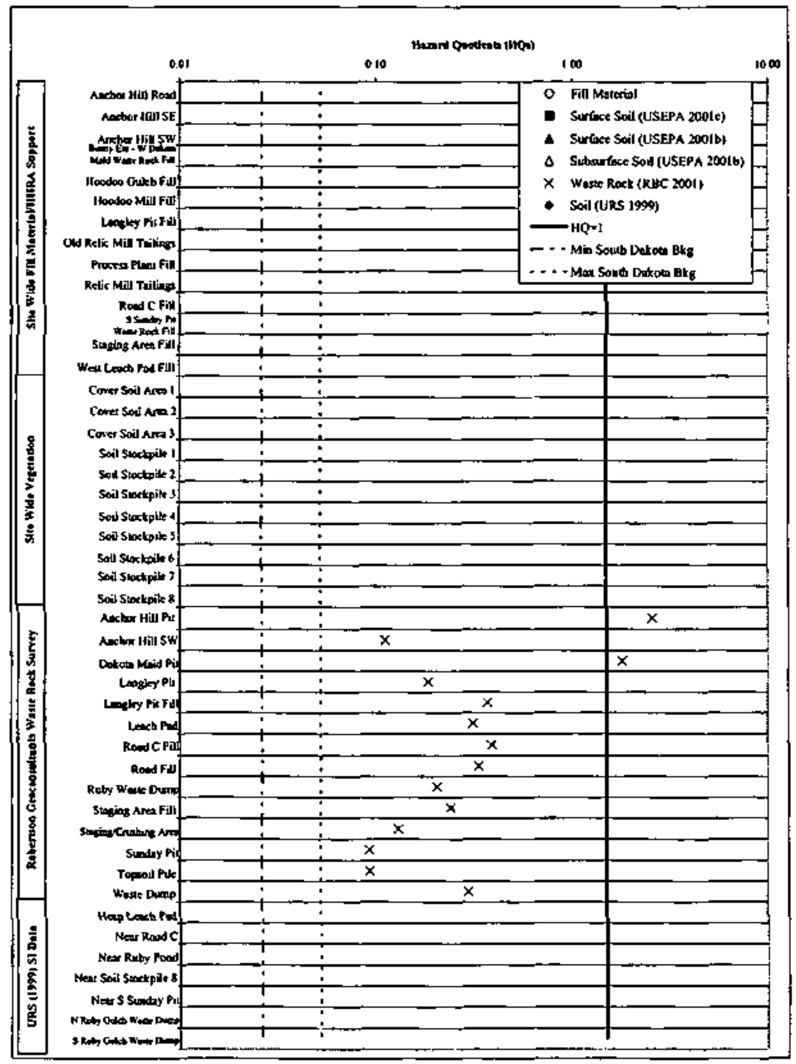
Figure 7-2k
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

MOLYBDENUM

DEER MOUSE



BOBWHITE QUAIL

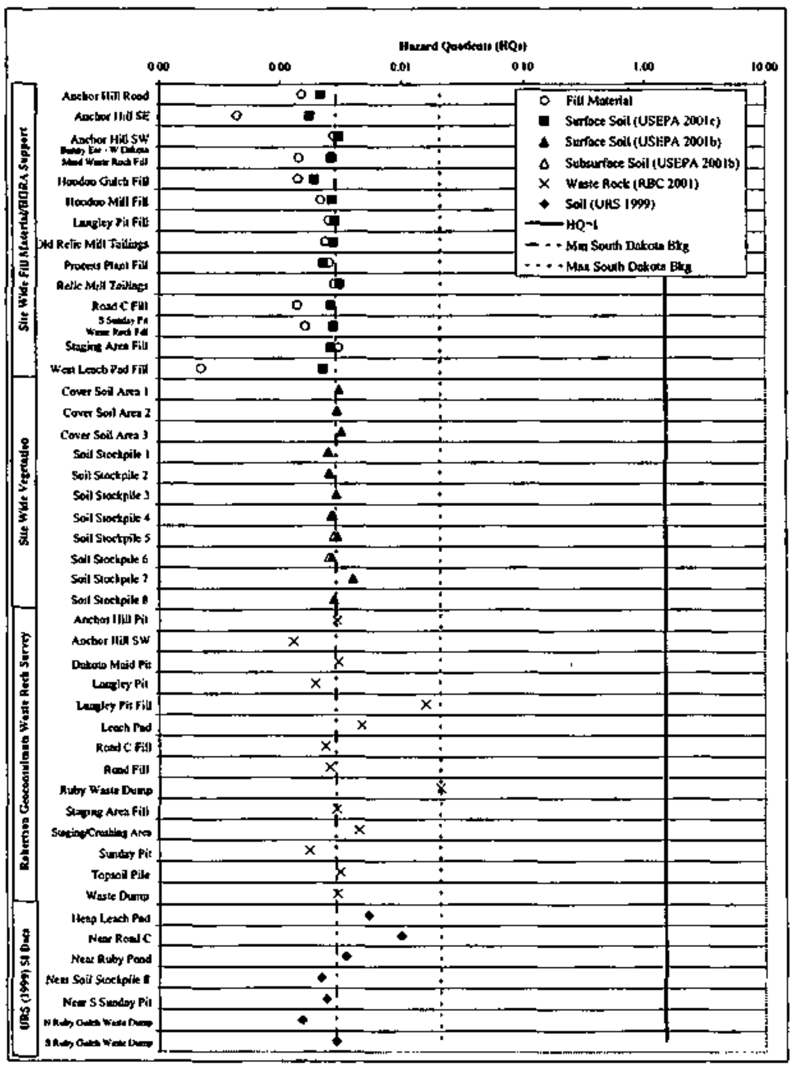


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

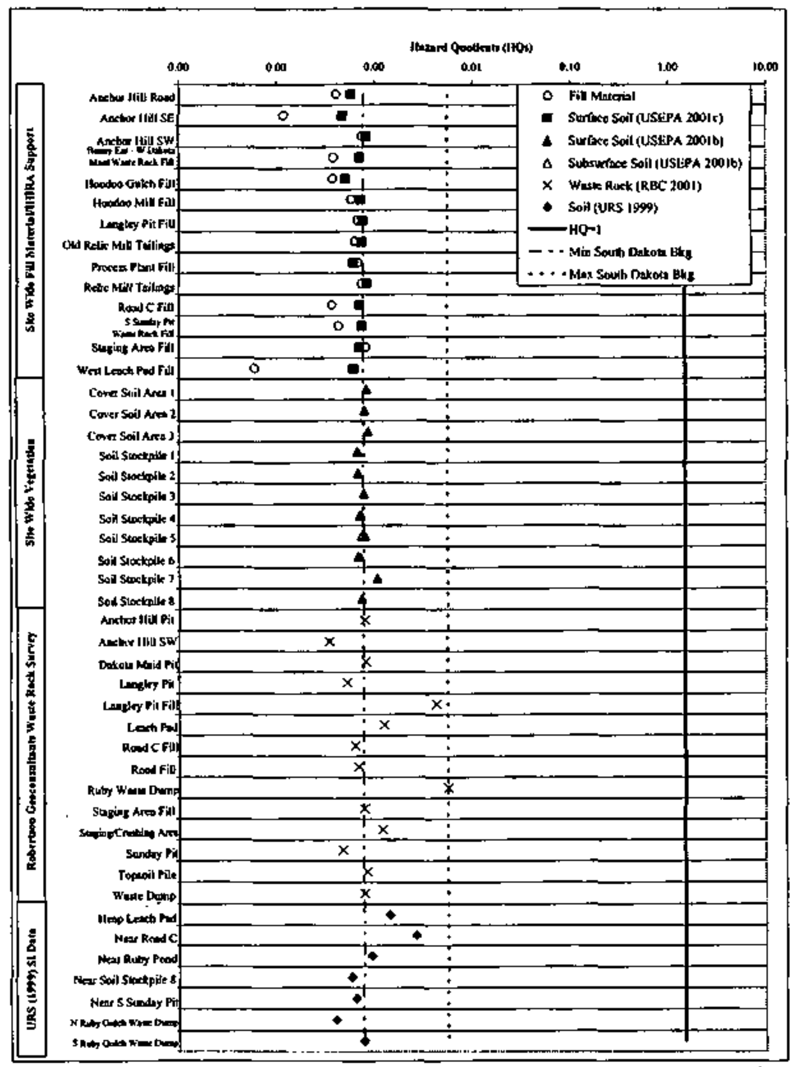
Figure 7-21
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

NICKEL

DEER MOUSE



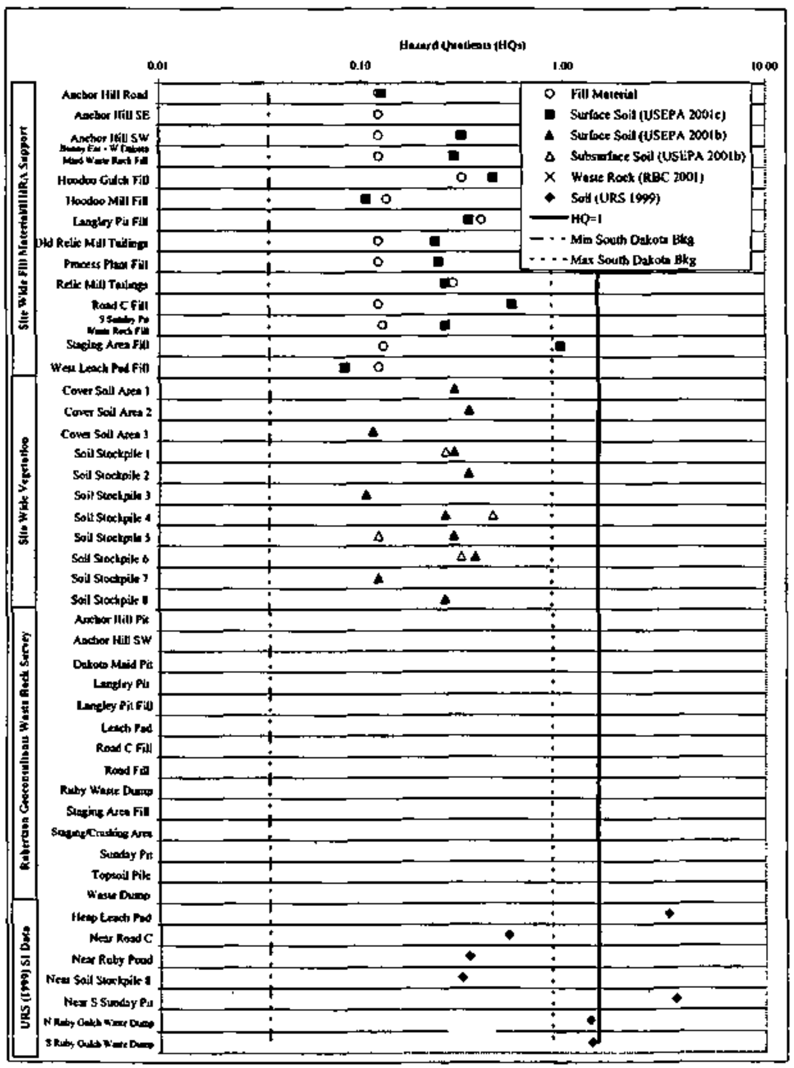
BOBWHITE QUAIL

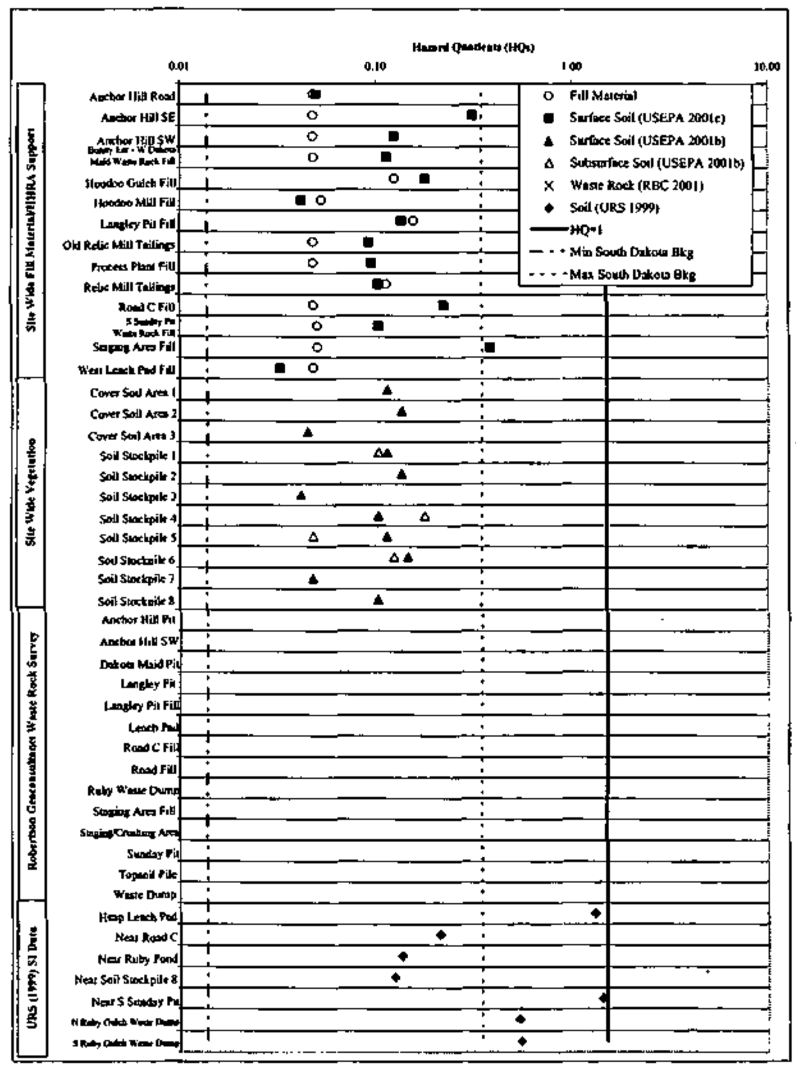


South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Figure 7-2m
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

SELENIUM

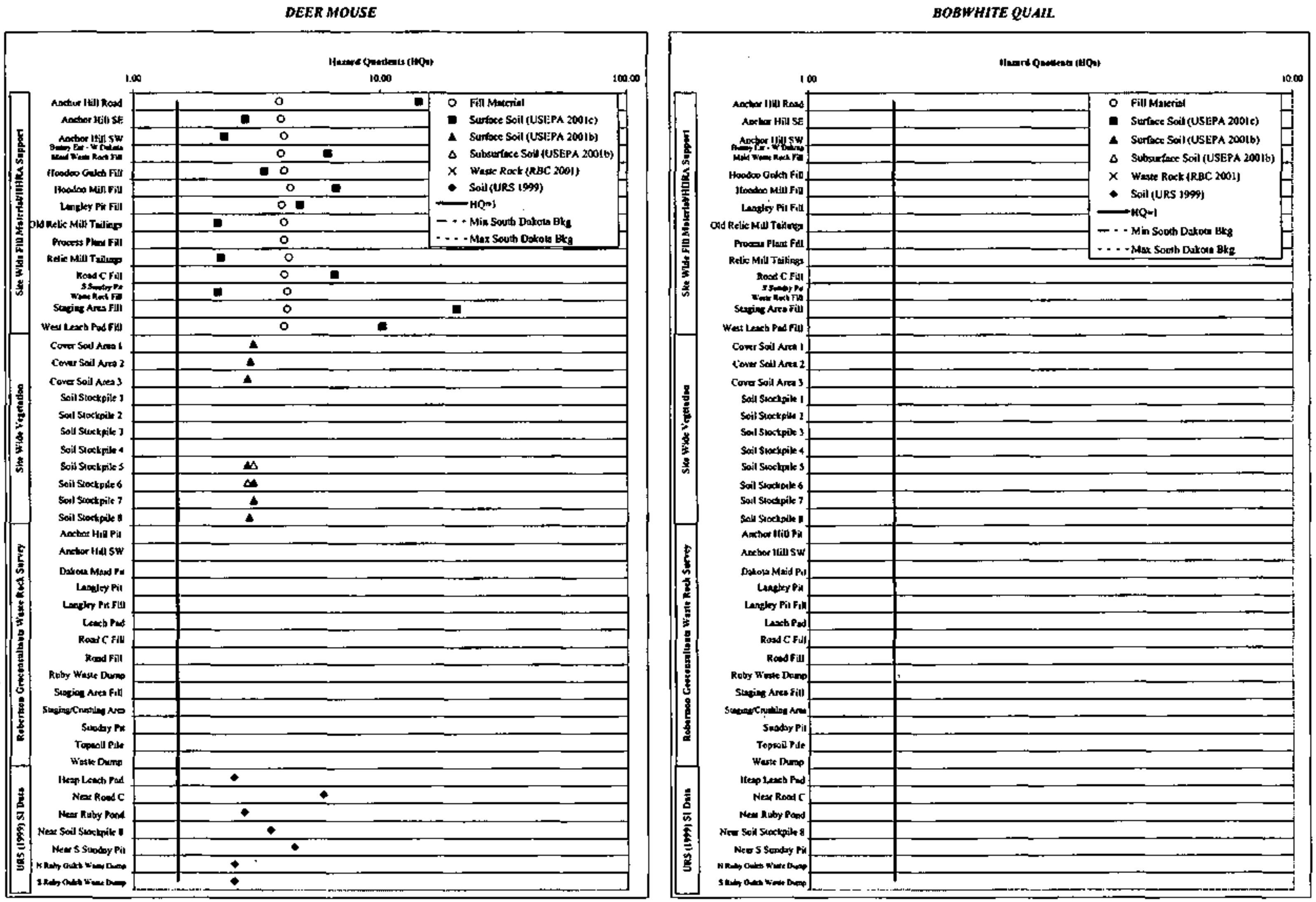




South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Figure 7-2n
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

THALLIUM



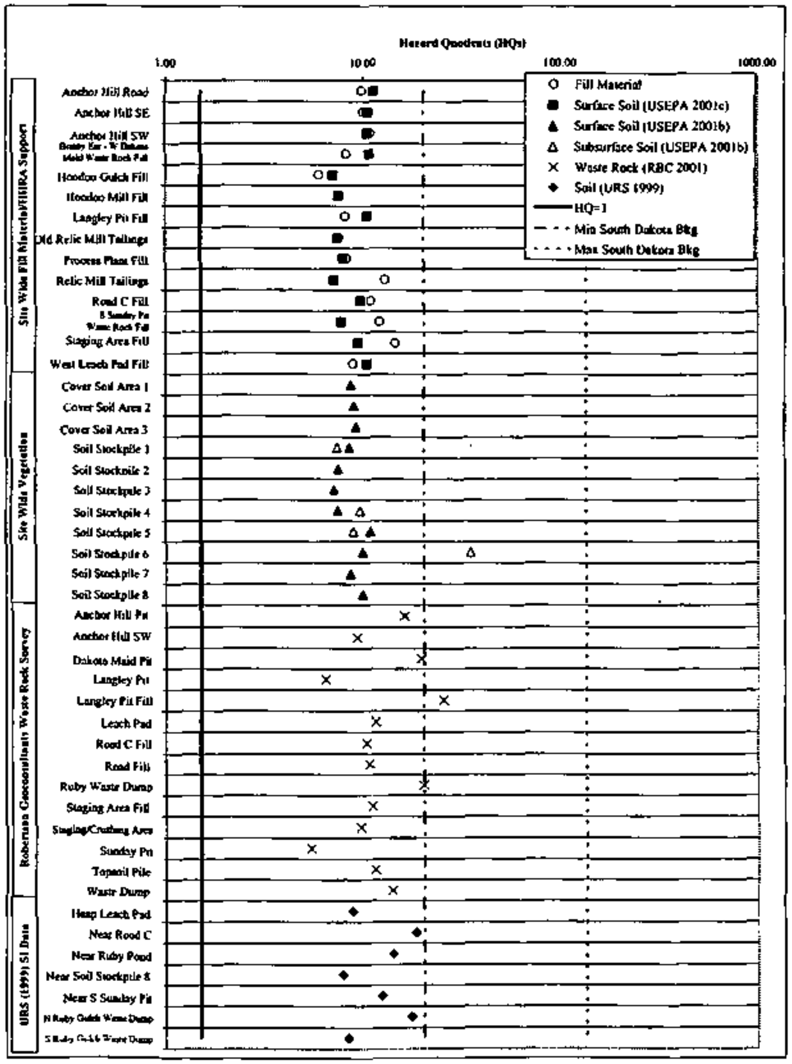
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Wildlife Plants Onsite.xls: Graphs
1/23/2003

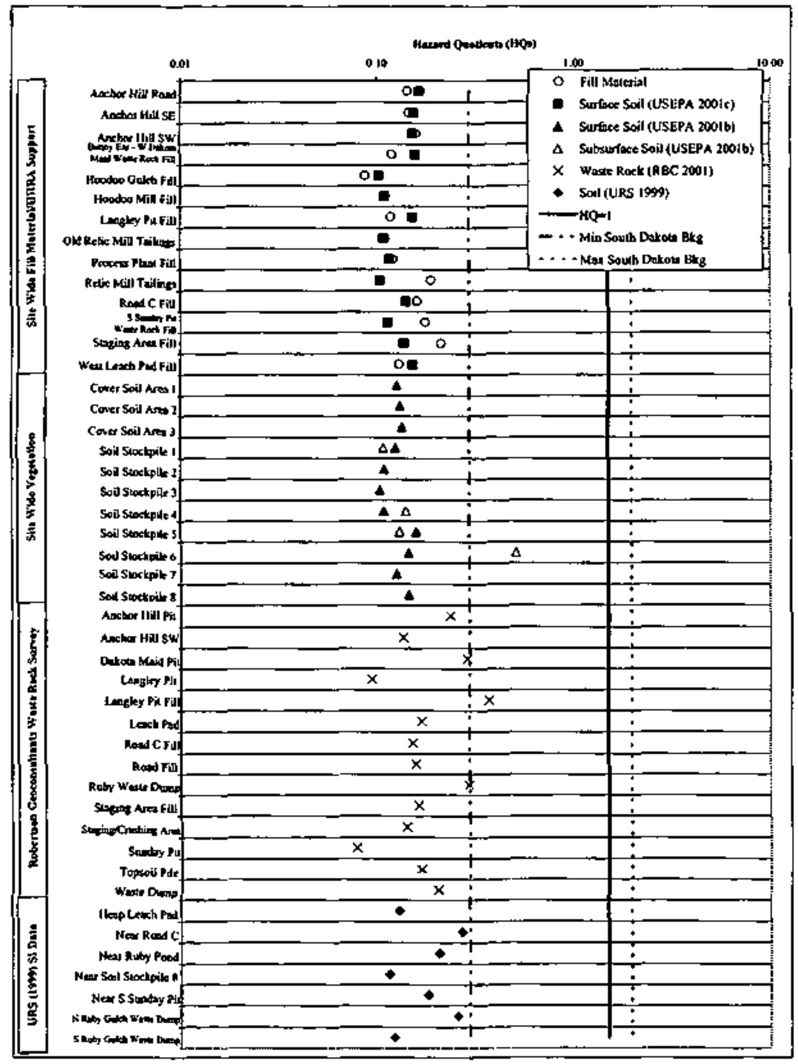
Figure 7-2o
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

VANADIUM

DEER MOUSE



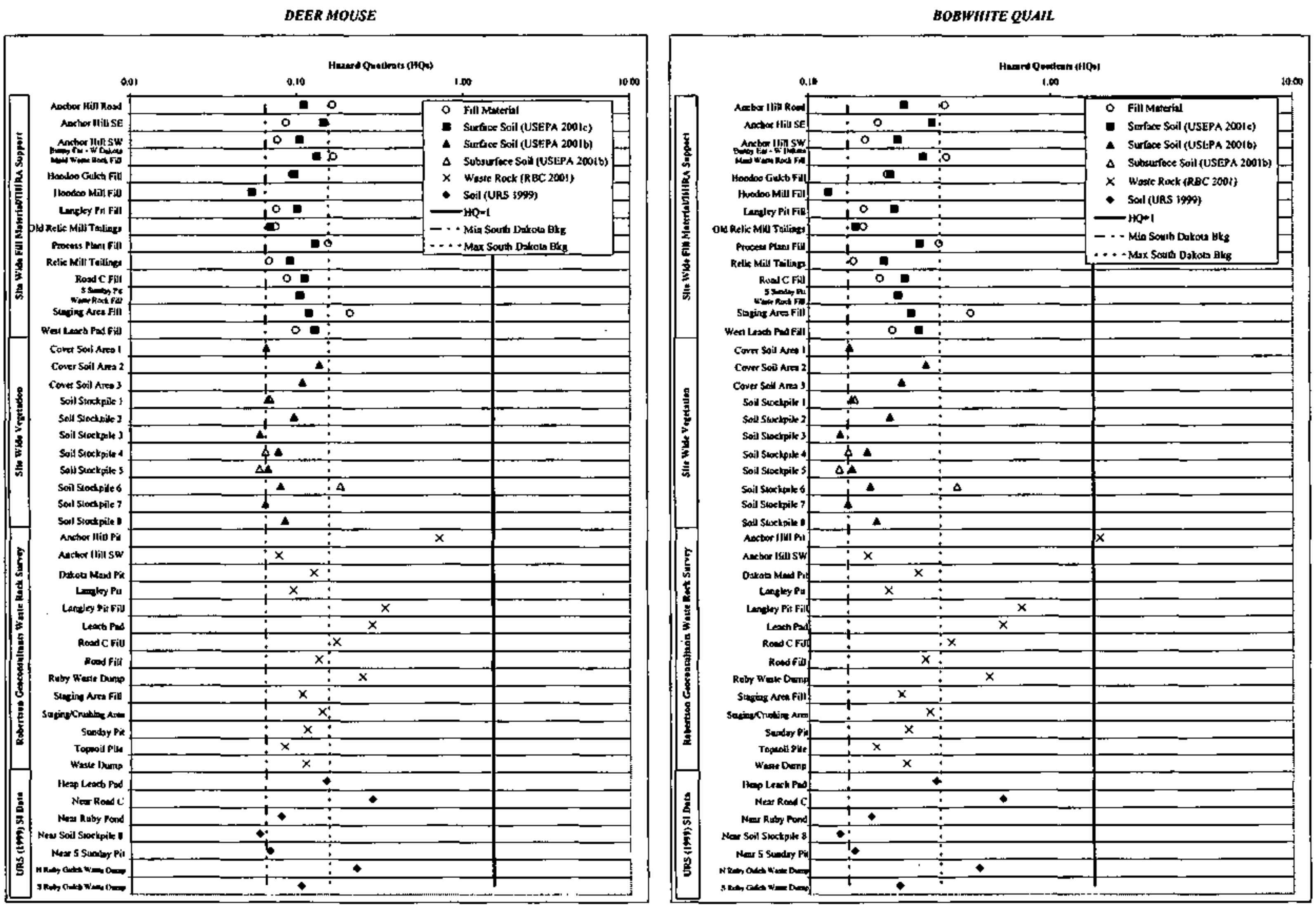
BOBWHITE QUAIL



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Figure 7-2p
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

ZINC



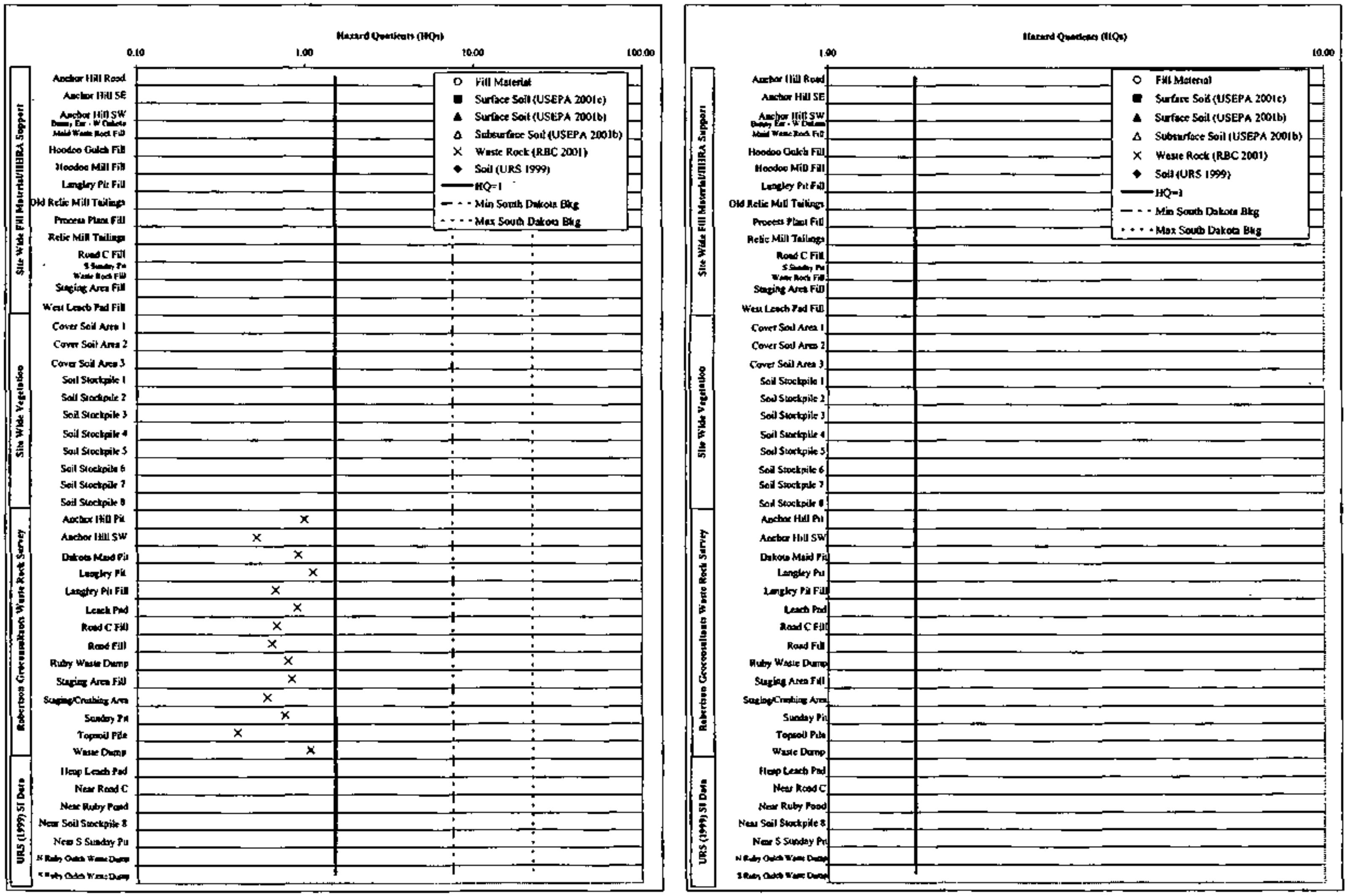
South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Wildlife Plants Onsite.xls: Graphs
1/23/2003

Figure 7-2q
Risks to Wildlife Receptors from Ingestion of Mine Source Area Plants (a)

ZIRCONIUM

DEER MOUSE ***BOBWHITE QUAIL***



South Dakota Background Statistics from Shacklette & Boerngen, 1984 (N = 30)
(a) Plant tissue concentrations estimated from measured soil using bioaccumulation factors.

Wildlife Plants Onsite.xls: Graphs
1/23/2003

Table 2-1 Timeline of Mining Activities and Regulatory History of the Gilt Edge Mine Site Area	
Date	**Activity**
1876	Joe King locates the Gilt Edge and Dakota Maid claims (SDDENR, 1999).
1893-1940	Mining operations take place in the area (URS, 1999a).
1898	Gilt Edge and Dakota Maid claims are owned by Colonel Lee M. Day (SDDENR, 1999).
1900	Hoodoo-Union Hill Mine group is active (URS, 1999a).
1900-1902	Gilt Edge and Dakota Maid claims are consolidated by the Gilt Edge Maid Mining Company and mining operations occur (SDDENR, 1999; URS, 1999a).
1905-1916	Gilt Edge-Maid Gold Mining Company operates its mines, producing silver and gold (URS, 1999a; SDDENR, 1999).
1909	120-stamp mill active for Hoodoo-Union mine group (URS, 1999a).
1916-1935	Mine is owned and operated by C.B. "Bart" Harris (SDDENR, 1999).
Mid 1930s-1941	Mine tailings are discharged down Strawberry Creek into Bear Butte Creek. When mine closes in 1941, piles of acidic tailings are left along Strawberry Creek. These tailings discharged acid and metal-laden water into the creek until they were removed by Brohm Mining Corp. in 1993 (USEPA, 2000).
1935	Gilt Edge Mining company is incorporated in South Dakota (URS, 1999a).
1935-1941	Mine is owned by Mrs. Leslie Sansom and operates under Gilt Edge Mines, Inc. (SDDENR, 1999).
1937-1940	Gilt Edge Mining company mining operations take place (URS, 1999a).
1938	Gilt Edge Mine milling operations use cyanidization gold extraction process (URS, 1999a).
1939, Fall	Landowners along Bear Butte Creek lobby the South Dakota Water Pollution Commission to allow Gilt Edge Mine to allow their mine tailings to wash into Strawberry Creek, which flows into Bear Butte Creek so sands might migrate into Bear Butte Creek and seal the creek bottom to prevent water in the creek from disappearing into the bedrock and allow surface water to flow further downstream and recharge alluvial aquifers. The resolution to allow this discharge is signed on December 19, 1939 (SDDENR, Minerals & Mining Program, misc. files).
1940	Two, five-stamp batteries operate as part of the Anchor Hill mine (URS, 1999a).
January 17, 1940	Mine milling process stops using cyanide (SDDENR, 1999).
February 1941	Gilt Edge stops mining operations (SDDENR, 1999).

Table 2-1 Timeline of Mining Activities and Regulatory History of the Gilt Edge Mine Site Area	
Date	**Activity**
June-September, 1941	Tungsten is mined and milled (SDDENR, 1999).
1941-1969	Property owned by Commonwealth Mining Company, but not operational (Brohm Mining Corp., 1988).
1969-1971	Congdon and Carey drill about 10,000 feet in 11 test holes to investigate copper-molybdenum potential of the property (SDDENR, 1999).
1975	Congdon-Carey (Co-Ca) and Cyprus (Amoco) initiate an extensive drilling program to outline the mineralized area (SDDENR, 1999).
Early 1980's	Cyprus/Amoco conduct a test heap leach on ore from the site under an exploration permit (SDDENR, 1999).
1983	Gilt Edge, Inc. enters into a joint venture with Amoco-CoCa to further evaluate and develop the property (Brohm Mining Corp., 1988; SDDENR, 1999).
1984 - present	Biological monitoring takes place at five sampling stations on Bear Butte Creek and a station on Strawberry Creek, downstream of Boomer Gulch (OEA, 1998).
November 1986	State of South Dakota issues Mining and Milling permit No. 439 to Lacana for the Gilt Edge Project for the production of gold and silver (SDDENR, Mining and Mineral Program, 1998, personal communication; SDDENR, 1999).
1987	Preliminary work prior to actual mining operations begins (construction of the open-pit mine and cyanide heap leaching facilities) (USEPA, 2000).
January 1988	Brohm submits a permit amendment application to the original permit (SDDENR, 1999).
1988	Mining begins (Brohm Mining Corp., 1988; SDDENR, 1999).
1989	Leach pad is retrofitted with a very low-density polyethylene (VLDPE) liner to improve the integrity of the primary liner (URS, 1999a).
June 20-21, 1991	Cyanide leaks from the cyanide heap leach pad and is released into Strawberry Creek and Bear Butte Creek. Sodium cyanide is used in the heap leach process to extract gold from crushed ore (USEPA, 2000).
May 19, 1992	EPA conducts an NPDES Inspection and finds two areas that are discharging without a permit: 1) water seeping from the toe of Ruby Repository, and 2) pollutants from several point sources entering Strawberry Creek diversion culvert through sedimentation ponds. The pH of the water from the toe of Ruby Repository is low and contains the following pollutants: AMD, Al, Cd, Cu, Pb and Zn. The pH of the water discharged to Strawberry Creek is also low and contains the following pollutants: AMD, Al, Cd, Cu, Fe, Pb and Zn (USEPA, 2000).
August 10, 1992	EPA transmits an inspection report to Brohm requiring application for a NPDES permit (USEPA, 2000).

Table 2-1
Timeline of Mining Activities and Regulatory History of the Gilt Edge Mine Site Area

Date	Activity
November 24, 1992	EPA issues Findings of Violation and Order of Compliance setting forth monitoring requirements and interim performance standards for Strawberry Creek and Ruby Gulch (USEPA, 2000).
1992	Mining ends temporarily when oxide ore reserves in the Sunday and Dakota Maid pits are exhausted (SDDENR, 1999).
1993	Brohm Mining removes 150,000 tons of tailings from the upper reaches of Strawberry Creek (URS, 1999a).
1993	Biological monitoring stations are established above and below Ruby Gulch (OEA, 1998).
April 19, 1993	SDDENR issues a Notice of Violation based on low pH and concentrations of sulfate, aluminum, copper, iron, manganese, and zinc in the Ruby Gulch discharge (USEPA, 2000).
September 14, 1993	EPA executes an Order of Compliance on Consent, which supercedes the November 24, 1992 order (USEPA, 2000).
September 15, 1993	EPA issues NPDES permit Number SD-0026891 to Brohm (USEPA, 2000).
1994	Amended tailings are capped with a low permeability clay liner (URS, 1999a).
February 15, 1994	SSDENR issues a letter regarding NPDES permit violations at Compliance Point 002 in Ruby Gulch for pH, Al, Cu and Zn) (USEPA, 2000).
March 31, 1994	EPA issues a Notice of Proposed Assessment of Class II Civil Penalty on NPDES permit Number SD-0026891 (USEPA, 2000).
March 31, 1994-January 31, 2000	Numerical violations of NPDES permit limits at Compliance Points 001 and 002 (USEPA, 2000).
Summer 1994	More than 4,000 cubic yards of remaining tailings are removed from the stream channels and banks of Strawberry Creek (OEA, 1998). The tailings were amended with fly ash and placed on-site.
August 25, 1994	EPA issues a Consent Order based on permit violations including February 1994 violations in Ruby Gulch (USEPA, 2000).
October 1994 & May 1995	Heavy rains occur, which cause severe erosion and flooding throughout the region and devastate the area's stream channels and aquatic life (OEA, 1998).
1995	Brohm submits a permit application for the Anchor Hill Pit (Brohm Mining Corp., 1995; SDDENR, 1999).
1995	Macroinvertebrate communities at all stations on Bear Butte Creek downstream of Strawberry Creek are rated as either not impaired or slightly impaired (OEA, 1997).
1995	Monitoring station is sampled on Bear Butte Creek, above Double Rainbow Mine (OEA, 1998).

Table 2-1 Timeline of Mining Activities and Regulatory History of the Gilt Edge Mine Site Area	
Date	**Activity**
1995-present	Aquatic biology is monitored on Two Bit Creek (OEA, 1998).
1996	Large-scale mining permit for the Anchor Hill deposit is issued by the State of South Dakota (USEPA, 2000).
1996	Full-scale mining resumes in the Anchor Hill Pit on private land (SDDENR, 1999).
May 1996-August 1997	Mining of Anchor Hill Phase I deposit and Langley area occur (USEPA, 2000).
September 1996	Monitoring stations sample on Strawberry Creek, Two Bit Creek, and Bear Butte Creek (OEA, 1997).
August 1997	Mining ends because of delays in getting approval to expand the Anchor Hill Pit onto Forest Service land (Brohm Mining Corp., 1997c; SSDENR, 1999).
November 1997	Phase II of Anchor Hill approved and stripping of waste rock begins (USEPA, 2000).
February 1998	Forest Service withdraws its approval of Phase II and mining ceases (USEPA, 2000).
May 1998a	Dakota Mining Company informs State of South Dakota that it intends to abandon the site (Janklow, 2000).
May 1998b	Temporary restraining order issued to prevent abandonment of site (Janklow, 2000).
June 5, 1998	Preliminary injunction is issued to extend temporary restraining order indefinitely (Janklow, 2000).
September 5, 1998	SSDENR issues a Notice of Violation and Order for Compliance for NPDES permit violations (including cadmium, copper, zinc) at Strawberry Creek Compliance Point 001 in 1996, 1997, and 1998 (USEPA, 2000).
July 8, 1999	Dakota Mining Company files for Bankruptcy (Janklow, 2000).
July 1999	State of South Dakota involuntarily takes over waste water treatment of the mine (Janklow, 2000).
February 18, 2000	Governor of South Dakota requests in a letter to EPA Region VIII Regional Administrator that the Brohm Mining site water treatment be taken over by EPA and the site be placed on the National Priorities List (NPL) (Janklow, 2000).
March 11, 2000	Gilt Edge Mine Site is proposed to NPL (EPA, 2000).

Table 3-1
Surface Water Sample Stations Used for Riparian Area Ecological Risk Assessment

Reach	Designation	Station Identification
Two Bit Creek	Reference for Strawberry Creek	AG-SW-01
		DB-SW-01
		DB-SW-02
		DB-SW-03
		S-7
		SW-34
		SW-36
Upstream Bear Butte Creek	Reference for Downstream Bear Butte Creek	BB-16
		BB-3
		BBC-03
		GE-SW-05
		SW-08
		WQM-126
Boomer Gulch	Reference for Strawberry Creek	BG-1
		BOOMER GULC
		GE-SW-07
		SW-10
Butcher Gulch	Reference for Strawberry Creek	BG-S-1
		BG-SP-03
		BG-SW-01
		BG-SW-02
		GE-SW-12
		SW-14
Hoodoo Gulch	Site	AC HOO DOO
		HG-POND-01
		HG-POND-02
		HG-POND-02 (INLET)
		HOODOO-BOR01
		OPCDM-06
		SW-28
		SWCDM-25
		SWCDM-27
Ruby Gulch	Site	003
		GE-SW-01
		OPCDM09
		RG-SP-02
		RG-SW-1
		SW-35
		SW-04
		SWCDM-13
Strawberry Creek	Site	001
		BES/D-11 SEEP
		GE-SW-06
		GE-SW-08
		GE-SW-09
		GE-SW-10
		LAST CHANCE POND
		OPCDM11
		ORA FINO
		ORO FINO ADIT
		SC-1
		SC-2
		SC-3
		SC-4
		SC-5
		SC-SP-08
		SC-SP-91
		SG-BT-01
		STR CK UP BOOM
		SW-02
		SW-06
		SWCDM-04
		SWCDM-06
		SWCDM-07
		SWCDM-08
		SWCDM-09
		SWCDM-10
		SWCDM-11
		SWCDM-12
		SWCDM-22
		SWCDM-24
		TRIB-C
		WQM-116
Downstream Bear Butte Creek	Site	BB-1
		BB-14
		BB-15
		BB-17
		BB-2
		BB-5
		BB-6
		GE-SW-04
		GE-SW-13
		GE-SW-14
		Seep-1
		SW-03
		SW-31
		SW-03A
		SW-05
		SWCDM-36
		WQM-125

Table 3-2
Sediment Sample Stations Used for Riparian Area Ecological Risk Assessment

Reach	Designation	Station Identification
Upstream Bear Butte Creek	Reference for Downstream Bear Butte Creek	BB-16
		BB-3
		GE-SE-05
		SD33
Boomer Gulch	Reference for Strawberry Creek	BG-1
		SD31
		GE-SE-12
		SD39
Hoodoo Gulch	Site	OPSD06
		SD27
Ruby Gulch	Site	GE-SE-01
		OPSD07
		SD13
		SD37
Strawberry Creek	Site	GE-SE-06
		GE-SE-08
		GE-SE-09
		GE-SE-10
		OPSD02
		SC-1
		SC-2
		SC-3
		SC-5
		SD04
		SD06
		SD07
		SD09
		SD10
		SD11
		SD12
		SD23
		SD24
		SD28
		SD32
ownstream Bear Butte Cre	Site	BB-14
		BB-15
		BB-17
		BB-2
		BB-5
		BB-6
		GE-SE-04
		GE-SE-14
		SD34
		SD36
		SD38
		SD40
		BB-1

Table 3-3
Soil Sample Stations Used for Riparian Area Ecological Risk Assessment

Reach	Designation	Station Identification	Investigation
Upstream Bear Butte Creek	Reference for downstream Bear Butte Creek	BM33-L	CDM (2001)
		BM33-R	CDM (2001)
Butcher Gulch	Reference for Strawberry Creek	BM39-L	CDM (2001)
		BM39-R	CDM (2001)
Strawberry Creek	Site	BM04-L	CDM (2001)
		BM04-R	CDM (2001)
		BM06-L	CDM (2001)
Downstream Bear Butte Creek	Site	BM34-L	CDM (2001)
		BM34-R	CDM (2001)
		BM36-L	CDM (2001)
		BM36-R	CDM (2001)
		BM38-L	CDM (2001)
		BM38-R	CDM (2001)
		BM40-L	CDM (2001)
		BM40-R	CDM (2001)
Ruby Gulch	Site	BM13-L	CDM (2001)
		BM13-R	CDM (2001)
Strawberry Creek	Site	BM06-R	CDM (2001)
		BM07-L	CDM (2001)
		BM07-R	CDM (2001)
		BM08-L	CDM (2001)
		BM08-R	CDM (2001)
		BM09-L	CDM (2001)
		BM09-R	CDM (2001)
		BM10-L	CDM (2001)
		BM10-R	CDM (2001)
		BM11-L	CDM (2001)
		BM11-R	CDM (2001)
		BM12-L	CDM (2001)
		BM12-R	CDM (2001)
		BM23-L	CDM (2001)
		BM23-R	CDM (2001)
		BM24-L	CDM (2001)
		BM24-R	CDM (2001)
		BM28-L	CDM (2001)
		BM28-R	CDM (2001)
		BM32-L	CDM (2001)
		BM32-R	CDM (2001)

Table 3-4
Fish Tissue Samples Collected in September 2000 (USEPA, 2002)

Exposure Reach (total number of samples (n) per reach)	Location	Number of Fish Samples [1]Analyzed		
		Brook Trout	Mountain Sucker	Longnose Dace
Bear Butte Creek- Upstream	BB-16	3	3	3
	BB-3	3	3	3
Bear Butte Creek- Downstream	BB-14	3	3	3
	BB-6	3	3	3
	BB-5	3	3	3
	BB-2	3	3	NS
	BB-1	3	NS	NS
Strawberry Creek	SC-1	3	NS	3
	SC-3	3	NS	NS
Boomer Gulch	BG-3	3	NS	NS

[1]A "Fish Sample" is equal to one composite with enough mass for analyses
NS = Not sampled

Table 3-5
Surface Water Sample Locations Used for Ecological Risk Assessment for Mine Source Area

Mine Feature	Sample Location Identification
Anchor Pit	A. PIT
	ANCHOR PIT
Dakota Maid Pit	DAKOTA
	DAKOTA MAID PIT
King Adit	KING ADIT
Langley Adit	LANGLEY ADIT
Heap Leach Pad	PAD EFFL
Pond A	POND A
Pond C	POND C
	POND C CUL
	POND C IN
	POND-C
Pond D	POND-D
Pond E	POND-E
Ruby Waste Rock Repository	RUBY DUMP
	RUBY POND
Sunday Pit	SUNDAY PIT
	SUNDAY SUMP
Surge Pond	SURGE POND
Wastewater Treatment Plant Influent	WWTP INFLUENT
Wood Weir	WOOD-WEIR
Location not Specified	2
	PIT WATER
	OPCDMO8
	OPCDM14
	OPCDM15
	GE-OP-01
	GE-SP-01
	GE-SP-02
	GE-SP-03
	STORMWATER
	SW-1
	SWCDM29

Table 4-1
Summary of Assessment and Measurement Endpoints

Receptor	Assessment Endpoint	Measurement Endpoint
Aquatic Community	Protection of aquatic invertebrates and fish from adverse effects related to exposure to chemicals in surface water and sediment.	Comparison of sampling location-specific chemical concentrations in surface water to National Ambient Water Quality Criteria (AWQC).
		Comparison of sampling location-specific chemical concentrations in sediment to benthic macroinvertebrate toxicity benchmarks.
		Evaluate the toxicity of site sediment to *Chironomus tenans* and *Hyalella azteca* (growth and survival) through laboratory testing.
		Benthic macroinvertebrate community structure, including density and diversity (taxa richness) of benthic organisms
		Comparison of chemical concentrations in fish tissue to maximum allowable tissue concentration (MATC) toxicity benchmarks for fish.
Terrestrial Community	Protection of terrestrial plants and terrestrial soil invertebrates from adverse effects related to exposure to chemicals in surface soil.	Comparison of sampling location-specific chemical concentrations in soil to toxicity screening benchmarks for terrestrial plants and terrestrial soil invertebrates.
Wildlife Community	Protection of wildlife from adverse effects to growth, reproduction, or survival related to exposure to chemicals in surface water, sediment, soil, benthic macroinvertebrates, and fish.	Comparison of the reach-specific chemical doses estimated from exposure point concentrations (EPCs) in surface water, sediment, soil, and aquatic food items to toxicity reference values (TRVs) for wildlife.

Table 5-1
Summary of Risks to Aquatic Receptors from Direct Contact with COPCs in Riparian Surface Water

COPC	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Downstream Bear Butte Creek
ACUTE				
Aluminum	severe	severe	moderate	none
Arsenic	none	none	none	none
Barium	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Beryllium	none	none	none	none
Cadmium	severe	severe	moderate	none
Calcium	*Acute Benchmark Not Available*			
Chromium	moderate	none	none	none
Cobalt	none	none	none	none
Copper	severe	severe	moderate	moderate
Cyanide (WAD)	Equal to or < Reference	none	none	Equal to or < Reference
Iron	*Acute Benchmark Not Available*			
Lead	none	none	none	none
Magnesium	*Acute Benchmark Not Available*			
Manganese	moderate	high	none	none
Nickel	none	none	minimal	none
Selenium	moderate	none	none	none
Silver	none	none	none	Detection limit higher than acute value for 6% of samples. Silver not detected above benchmark.
Sodium	*Acute Benchmark Not Available*			
Thallium	none	none	none	none
Vanadium	none	none	none	none
Zinc	severe	severe	moderate	none
CHRONIC				
Aluminum	moderate	high	minimal	minimal
Arsenic	none	none	none	none
Barium	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Beryllium	minimal	moderate	minimal	none
Cadmium	severe	moderate	moderate	minimal
Calcium	high	minimal	minimal	none
Chromium	minimal	none	none	none
Cobalt	moderate	moderate	none	none
Copper	moderate	moderate	minimal	minimal
Cyanide (WAD)	Equal to or < Reference	none	none	Equal to or < Reference
Iron	minimal	none	none	none
Lead	minimal	minimal	minimal	minimal
Magnesium	minimal	none	minimal	none
Manganese	high	severe	minimal	minimal
Nickel	minimal	moderate	minimal	minimal
Selenium	moderate	none	none	minimal
Silver	*Chronic Benchmark Not Available*			
Sodium	moderate	none	none	none
Thallium	minimal	none	none	none
Vanadium	none	none	none	none
Zinc	minimal	minimal	minimal	none

Equal to or < Reference	HQ values are less than or equal to those for reference exposure reaches (Figure 5-1)		
Acute		**Chronic**	
none	All HQ values are < or equal to 1.	none	All HQ values are < or equal to 1.
moderate	< 20% of the HQ values are greater than 1.	minimal	< 20% of the HQ values are greater than 1.
high	21 to 50% of the HQ values are greater than 1.	moderate	21 to 50% of the HQ values are greater than 1.
severe	51 to 80% of the HQ values are greater than 1	high	51 to 80% of the HQ values are greater than 1.
severe	> 81% of the HQ values are greater than 1.	severe	> 81% of the HQ values are greater than 1.
severe	Or the acute HQ for any three or more samples is greater than 10.		

Table 5-2
Summary of Risks to Benthic Invertebrates from Direct Contact with Sediment

COPC	Strawberry Creek	Hoodoo Gulch	Ruby Gulch	Downstream Bear Butte Creek
Aluminum	moderate	minimal	none	none
Antimony	Equal to or < Reference	none	Equal to or < Reference	none
Arsenic	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Cadmium	severe	severe	moderate	severe
Chromium	none	none	none	none
Cobalt	minimal	minimal	none	none
Copper	severe	severe	high	severe
Iron	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Lead	severe	severe	Equal to or < Reference	high
Manganese	moderate	moderate	none	minimal
Mercury	Equal to or < Reference	none	Equal to or < Reference	Equal to or < Reference
Nickel	Equal to or < Reference	Equal to or < Reference	none	Equal to or < Reference
Selenium	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Silver	high	severe	Equal to or < Reference	high
Vanadium	none	none	none	none
Zinc	severe	severe	Equal to or < Reference	severe

Equal to or < Reference	HQ values are less than or equal to those for reference exposure reaches (Figure 5-15)
none	All HQ values are < or equal to 1.
minimal	< 20% of the HQ values are greater than 1.
moderate	21 to 50% of the HQ values are greater than 1.
high	51 to 80% of the HQ values are greater than 1.
severe	> 81% of the HQ values are greater than 1.

Table 5-3
Summary of *Pimephales promelas* Toxicity Test Results (Survival and Growth)

SEPTEMBER 2000

Parameter	Controls		Strawberry Creek					Bear Butte Creek							Boomer Gulch
	MHRW	LRW	SC-4	SC-3	SC-2	SC-5	SC-1	BB-16 (upstream reference)	BB-3	BB-14	BB-6	BB-5	BB-2	BB-1	BG-1
Toxicity Test Results															
Survival Mean (%)	100	98	0*	20*	38*	20*	33*	90	100	98	87	88	98	100	95
Weight Mean (mg dw)	0.262	0.316	NA	0.058 *	0.035 *	0.053 *	0.095 *	0.305	0.35	0.378	0.341	0.336	0.428	0.359	0.352
Measured Filtered Surface Water Concentrations(ug/l)															
Aluminum		U	1400	550	390	310	230	U	U	U	U	U	U	U	U
Antimony		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic		U	U	U	U	U	U	U	U	U	U	U	U	6.48	U
Barium		U	U	12.3	12.6	17.7	22.3	56.3	53.1	42.8	50.1	51.4	69.2	67.5	21
Beryllium		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Cadmium		U	11.6	8.9	8.85	7.08	3.91	U	U	U	U	U	U	U	U
Calcium		28,000	360,000	290,000	290,000	290,000	220,000	36,000	34,000	97,000	110,000	110,000	110,000	110,000	42,000
Chromium		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Cobalt		U	45.8	33.8	33.5	28.4	21.1	U	U	8.58	9.61	9.58	8.91	8.62	U
Copper		U	8.24	14.9	14.9	8.83	6.04	U	U	U	U	U	U	U	U
Iron		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Lead		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Magnesium		25,000	81,000	62,000	62,000	61,000	47,000	9,500	9,200	22,000	24,000	24,000	25,000	26,000	7,400
Manganese		U	2,100	1,400	1300	900	360	8.12	16	120	63.2	63.3	16.1	19.3	8.31
Mercury		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Nickel		U	5.54	7.53	7.71	6.27	U	U	U	U	U	U	U	U	U
Potassium		1,800	3,100	3,500	3,700	4,000	3,600	2,700	2,700	3,000	3,100	3,200	3,590	3,500	1,500
Selenium		U	12.7	11.3	9.39	10.1	U	U	U	U	U	U	U	U	U
Silver		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Sodium		54,000	2,000,000	1,400,000	1,400,000	1,300,000	970,000	4,660	4,600	330,000	370,000	380,000	351,000	340,000	3,600
Thallium		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Vanadium		U	U	U	U	U	U	U	U	U	U	U	U	U	U
Zinc		U	U	50.5	51.7	48.2	24.6	U	U	U	U	U	U	36.6	U
Conductivity (uS/cm)	307	485.5	9021	7018	6914	6472	2979	259.6	231.5	2298	2654	2351	2203	2150	279

OCTOBER 2001

Parameter	Controls		Strawberry Creek					Bear Butte Creek		Boomer Gulch
	MHRW	LRW	SC-4	SC-3	SC-2	SC-5	SC-1	BB-3	BB-14	BG-1
Toxicity Test Results										
Mean % Survival	98	95	5**	28**	45**	28**	29**	98	95	100
Mean Dry Weight (mg)	0.562	0.524	0.014	0.097	0.125	0.102	0.174	0.734	0.567	0.564
Measured Filtered Surface Water Concentrations(ug/l)										
Aluminum		U	405	U	1830	85.8	U	U	U	U
Antimony		U	U	U	476	U	U	U	U	U
Arsenic		U	U	U	39.9	U	U	U	U	U
Barium		U	U	7.3	1870	9.8	13.7	58.4	43.1	20.6
Beryllium		U	U	U	41.8	U	U	U	U	U
Cadmium		U	3.7	3.2	47.4	3	2	U	0.84	U
Calcium		28000	244,000	224,000	220,000	215,000	167,000	35,700	86,500	42,700
Chromium		U	U	U	171	U	U	U	U	U
Cobalt		U	46.3	35.5	470	31.8	19.7	U	9.2	U
Copper		U	52.7	11.1	231	9.4	4.3	U	U	U
Iron		U	U	U	822	U	U	U	U	U
Lead		U	U	U	17.3	U	U	2.5	U	U
Magnesium		25000	53,200	50,300	48,400	49,700	39,400	10,400	21,700	7,500
Manganese		U	812	586	963	394	216	11.9	76.2	6.8
Mercury		U	U	U	0.92	U	U	U	U	U
Nickel		U	9.3	8.5	444	6.8	5.1	U	U	U
Potassium		1800	2,970	4,570	4,600	5,240	4,530	2,160	4,160	1,150
Selenium		U	18.2	11.6	22.8	11.8	7.8	U	U	U
Silver		U	U	U	21.7	U	U	U	U	U
Sodium		54000	2,280,000	1,750,000	1,750,000	1,740,000	1,150,000	4,320	399,000	3,130
Thallium		U	U	U	47.5	U	U	U	U	U
Vanadium		U	U	U	439	U	U	U	U	U
Zinc		U	41.5	72.6	562	68.1	48.5	24.9	31.6	17.1
Conductivity (uS/cm)	309	522.5	8024	6933	6733	6764	4802	276	1971	268

MHRW = Moderately Hard Reconstituted Water
LRW = Laboratory Reconstituted Water
SC = Strawberry Creek; BB = Bear Butte Creek; BG = Boomer Gulch
* = Statistically significant difference from lab controls
** = Statistically significant difference from lab controls and upstream reference (BB-3)
Locations presented from upstream to downstream

Table 5-4
Survival and Growth Results for Pimephales promelas Definitive Tests with Strawberry Creek Surface Water

Location SC-4 September 2000: IC_{25}=19.5%						
Concentration	**Rep A**	**Rep B**	**Rep C**	**Rep D**	**Mean % Survival**	**Mean Dry Weight (mg)**
MHRW (control)	10	10	10	10	100	0.392
LRW (control)	10	8	10	10	95	0.356
6.25%	10	9	9	10	95	0.344
12.5%	10	9	10	10	98	0.408
25%	8	7	5	7	68*	0.229
50%	1	0	1	3	13*	0.04
100%	1	0	1	2	10*	0.036

Location SC-4 October 2001: IC_{25}=29.6%						
Concentration	**Rep A**	**Rep B**	**Rep C**	**Rep D**	**Mean % Survival**	**Mean Dry Weight (mg)**
MHRW (control)	9	10	10	10	98	0.321
LRW (control)	9	10	10	9	95	0.266
6.25%	9	10	RL	RL	95	0.329
12.5%	9	9	10	10	95	0.336
25%	8	8	10	RL	87	0.271
50%	3	2	2	4	28*	0.048
100%	1	0	0	0	3*	0.002

Location SC-3 October 2001: IC_{25}=42.4%						
Concentration	**Rep A**	**Rep B**	**Rep C**	**Rep D**	**Mean % Survival**	**Mean Dry Weight (mg)**
MHRW (control)	9	10	10	10	98	0.321
LRW (control)	9	10	10	9	95	0.266
6.25%	10	10	10	10	100	0.347
12.5%	10	9	9	9	93	0.34
25%	10	10	10	10	100	0.32
50%	9	RL	8	8	77*	0.204
100%	1	3	2	2	20*	0.08

Location SC-2 October 2001: IC_{25}=59.9%						
Concentration	**Rep A**	**Rep B**	**Rep C**	**Rep D**	**Mean % Survival**	**Mean Dry Weight (mg)**
MHRW (control)	9	10	10	10	98	0.321
LRW (control)	9	10	10	9	95	0.266
6.25%	8	10	10	10	95	0.302
12.5%	10	8	9	9	90	0.269
25%	10	10	10	9	98	0.328
50%	7	8	8	9	80*	0.266
100%	0	2	1	1	10*	0.025

Location SC-5 October 2001: IC_{25}=47.9%						
Concentration	**Rep A**	**Rep B**	**Rep C**	**Rep D**	**Mean % Survival**	**Mean Dry Weight (mg)**
MHRW (control)	9	10	10	10	98	0.321
LRW (control)	9	10	10	9	95	0.266
6.25%	9	10	9	10	95	0.348
12.5%	8	10	9	10	93	0.271
25%	9	9	7	9	85	0.338
50%	9	9	6	6	75*	0.223
100%	0	2	0	1	8*	0.012

* = statistically different from the control (LRW and MHRW)
MHRW = Moderately Hard Reconstituted Water
LRW = Laboratory Reconstituted Water
mg = milligrams
Rep = replicate
Tests conducted September 2000 and October 2001
RL = replicate lost
IC_{25} = The toxicant concentration causeing a 25 percent reduction in growth.

Table 5-5
Summary of *Hyalella azteca* Toxicity Test Results (Survival and Growth)

SEPTEMBER 2000

		Strawberry Creek				Bear Butte Creek								Boomer Gulch
Parameter	**West Bearskin (Control)**	**SC-3**	**SC-2**	**SC-5**	**SC-1**	**BB-16a (upstream reference)**	**BB-3**	**BB-14**	**BB-6**	**BB-5a**	**BB-2a**	**BB-1**	**BB-15a**	**BG-1**
Toxicity Test Results														
Survival Mean (%)	93	6**	20**	30*	69	70	65	79	66	64	68	48*	65	54*
Growth Mean (mg dw)	0.1±0.02	0.05*	0.04*	0.07*	0.09	0.06*	0.1	0.07*	0.07*	0.06*	0.07*	0.08*	0.07*	0.05*
Measured Sediment Concentrations (mg/kg, unless indicated otherwise)														
Aluminum	5400	49000	32000	15000	17200	14000	16000	19000	18000	18000	15000	16000	16000	27000
Antimony	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Arsenic	U	91	47.6	60.1	48.4	30.8	140	59.3	59	51	110	270	180	11.3
Barium	31	120	70.2	66.2	98.2	230	180	160	160	180	140	160	150	270
Beryllium	U	3.2	1.96	1.37	1.65	1.19	1.28	1.54	1.49	1.56	1.38	1.37	1.4	1.57
Cadmium	U	11.1	6.66	8.67	16.6	U	U	5.21	7.09	18	9	9	11	U
Calcium	2900	7800	5300	2700	3400	11000	4700	4600	4200	6200	4100	13000	7400	11000
Chromium	17	43.6	25.8	21.7	32.8	21.6	29.2	40	36.2	29.8	26.2	34.1	24.4	51.2
Cobalt	4.8	48.7	29.7	33.9	39.2	21.8	26.3	30.3	30.4	37.8	28.3	27	26	30.8
Copper	18	2200	1400	470	270	39.9	54.3	110	110	120	150	140	170	47.3
Cyanide, Total	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Iron	13000	47000	26000	31000	36000	37000	44000	47000	43000	40000	44000	47000	38000	54000
Lead	21	130	70.9	99.3	88.7	28.4	110	55.9	85.8	59	150	330	280	55
Magnesium	2600	11000	6400	4900	8200	5000	7100	10000	8800	6600	6200	11000	6300	14000
Manganese	510	1500	970	3100	3500	1400	800	2000	1600	4500	1400	1600	970	1900
Mercury	U	0.14	U	0.229	0.103	0.126	0.074	0.058	0.077	0.161	0.333	0.521	0.43	U
Nickel	18	66.5	40.5	45.5	61.4	39.2	47.7	59.2	51.5	56	47	46	39.4	73.2
Potassium	800	6000	3600	3100	5100	3800	4700	6600	5900	4500	3800	4800	3800	7300
Selenium	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Silver	U	U	U	U	U	U	U	U	U	U	1.73	4.26	5.29	U
Sodium	U	5600	4200	2200	1800	393.5	227	1100	192	1800	225	1300	1500	336
Thallium	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Vanadium	24	62.1	36.6	35.2	41.4	35	43	47.2	45.1	41	40.7	42.9	36.7	64.2
Zinc	63	1000	650	550	580	150	160	310	320	450	490	950	740	300
TOC (%)	3.1	1.5	1.2	0.73	0.29	2.3	2.8	0.9	1.3	2.3	1.7	2.6	2	5.1
Solids (%)	32	26	35	66	58.28	32	44	57.94	51	32.94	44.78	49.22	42	30

OCTOBER 2001

		Strawberry Creek					Bear Butte Creek		Boomer Gulch
Parameter	West Bearskin (Control)	SC-4	SC-3	SC-2	SC-5	SC-1	BB-3	BB-14	BG-1
October 2001									
Survival Mean (%)	100	20***	44***	40***	39***	86	96	90	79*
Growth Mean (mg dw)	0.25	0.05	0.11	0.12	0.08	0.16***	0.2*	0.14***	0.18*
Measured Sediment Concentrations (mg/kg, unless indicated otherwise)									
Aluminum	5400	21,000	29200	34400	34700	17800	12400	20000	13200
Antimony	U	U	U	302	U	U	U	U	U
Arsenic	U	40.4	97	121	82.5	73.8	76.5	48.8	16.2
Barium	31	46.7	107	1590	107	117	288	217	161
Beryllium	U	1.8	U	34.3	U	U	U	U	U
Cadmium	U	5.5	10.1	45	11.3	25.1	0.71	8.1	1.4
Calcium	2900	7,140	5,990	7,550	7,330	7,170	6,510	6,200	8,660
Chromium	17	8.9	32.6	170	29.1	27.3	21.4	41.4	24.4
Cobalt	4.8	47.4	54.3	384	66.7	60.1	28.2	37	20.7
Copper	18	2380	1520	2090	2300	584	49.9	188	46.2
Cyanide, Total	U	NM	NM	NM	NM	NM	NM	NM	NM
Iron	13000	18200	46000	43300	37500	36400	43200	42400	30200
Lead	21	59	125	147	139	126	52	53	46
Magnesium	2600	1,870	7,780	8,240	6270	6400	5070	10300	6090
Manganese	510	1070	2430	2890	3150	4890	1450	2400	1250
Mercury	U	U	U	1.4	U	U	U	U	U
Nickel	18	44.1	67.2	403	72.8	71	47	60.3	42.7
Potassium	800	845	4150	4630	3470	3620	3020	6890	3020
Selenium	U	U	U	5.6	U	U	4.8	U	2.2
Silver	U	U	U	18	U	U	U	U	U
Sodium	U	2560	4520	4290	5730	3070	321	999	U
Thallium	U	U	U	34	U	U	U	U	U
Vanadium	24	13	47	375	43	41	34	46	36
Zinc	63	687	922	1280	1140	932	178	400	238
TOC (%)	3.1	4.58	9.34	6.27	12.85	7.28	9.36	5.2	16.57
Solids (%)	32	NA	NA	NA	NA	NA	NA	NA	NA

a Location survival without replicates containing Megaloprura larvae
-- = not evaluated
* = Statistically significant reduction compared with laboratory control
** = Statistically significant reduction compared with laboratory control and BB -16 upstream reference
*** = Statistically significant reduction compared with laboratory control and BB-3 upstream reference
Locations presented from upstream to downstream
SC=Strawberry Creek; BB = Bear Butte Creek; BG = Boomer Gulch
NM = not measured
NA = not available in preliminary dataset

Table 5-6
Habitat Characteristics of Bear Butte Creek, Strawberry Creek, and Boomer Gulch (September 2000)

Stream Name	Location	Stream Order	Width (Ft.)	Depth (In.)	Flow (ft./s)	Canopy (%)	Dominant Substrate	Score[1] (%)	Score[2] (%)	Notes
Bear Butte Creek	BB-15	3rd	30	6--36	0.5	25	boulder cobble	145	145	Shallow riffles separated by deep pools, white crust on exposed rocks, large boulders in stream, some sedimentation in pools
	BB-1	3rd	15--30	2--24	0.5	25	boulder cobble	114	114	Mix of riffles and pools, shallow depositional areas, white crust on exposed rocks, minor bank undercuts
	BB-2	3rd	15--30	2--24	0.5	25	boulder cobble	114	114	Mix of riffles and pools, shallow depositional areas, white crust on exposed rocks
	BB-5	3rd	10--15	2--24	0.5	100	cobble gravel	109	109	Shallow riffles, maintained lawn along left bank with narrow riparian zone, Ruby Gulch dry, white crust
	BB-6	3rd	10--15	2--24	0.5	100	cobble gravel	103	103	Shallow riffles, some pools shallow depositional areas, bldg. foundation close to left bank, white crust
	BB-14	3rd	20	2--12	0.5	10	cobble gravel	100	100	Shallow riffles, no pools, left bank/riparian zone impacted by earthmoving activities (although vegetated), white crust
	BB-3	3rd	20	2--12	0.5	10	cobble gravel	100	100	Shallow riffles, no pools, left bank/riparian zone impacted by earth moving activities (vegetated), no white crust
	BB-16	3rd	20	2--12	<0.1	10	cobble gravel	100	100	Shallow riffles, small pools, no crust on exposed rocks
Strawberry Creek	SC-1	2nd	5	2–4	<0.1	100	gravel sand	80	67	Very shallow, left bank impacted by road grading activities, no vegetation on left bank, white crust on rocks, no flocculent
	SC-5	2nd	3	2–4	<0.1	100	gravel silt	82	70	Sediment covered with flocculent (>6"), thick leaf packs, very small, shallow riffles, no apparent flow except in riffle areas, low gradient
	SC- 2	2nd	3	2–4	<0.1	100	gravel silt	82	70	Sediment covered with flocculent (>6"), thick leaf packs, very small, shallow riffles, no apparent flow except in riffle areas, low gradient

Table 5-6
Habitat Characteristics of Bear Butte Creek, Strawberry Creek, and Boomer Gulch (September 2000)

Stream Name	Location	Stream Order	Width (Ft.)	Depth (In.)	Flow (ft./s)	Canopy (%)	Dominant Substrate	Score[1] (%)	Score[2] (%)	Notes
	SC-3	1st	3	2-4	<0.1	100	gravel silt	82	67	Sediment covered with flocculent (>6"), thick leaf packs, very small, shallow riffles, no apparent flow except in riffle areas, low gradient
	SC-4	1st	2	2--4	<0.1	50	gravel silt	NA	NA	Not sampled due to thick flocculent covering the substrate and heavy white crust on the rocks. Location downstream of treatment discharge
Boomer Gulch	BG-1	1st	1--2	2-4	<0.1	100	cobble gravel	100	86	Very small, shallow creek, shallow riffle areas, higher gradient than SC-2, SC-3, and SC-5, no crust or flocculent

Score 1-Location BB-16 used as the Reference Location for scoring Bear Butte Creek and Location BG-1 used as the Reference Location for scoring Strawberry Creek
Score 2-Location BB-16 used as the Reference Location for scoring all creek locations

Table 5-7
Benthic Macroinvertebrate Community Metrics and Biological Condition Scores
September 2000

Sampling Station	**BG-1 Ref**	**SC-3**	**SC-5**	**SC-1**	**BB-16 Ref**	**BB-3**	**BB-14**	**BB-6**	**BB-5**	**BB-2**	**BB-1**	**BB-15**
Step 1: Statistics Used to Derive Metrics												
Number of Organisms per Sample (average of replicates)	213.3	1.3	1.7	218.3	309.3	280.0	291.7	288.0	275.0	248.3	261.0	261.7
Functional Feeding Groups												
Total Scrapers at Station (sum across replicates)	194.0	2.0	2.0	227.0	311.0	313.0	406.0	410.0	485.0	560.0	584.0	566.0
Total Filterers at Station (sum across replicates)	25.0	0.0	1.0	404.0	328.0	250.0	367.0	318.0	179.0	70.0	107.0	136.0
Total Shredders at Station (sum across replicates)	195.0	0.0	0.0	16.0	56.0	26.0	54.0	76.0	17.0	50.0	21.0	38.0
EPT Abundance (sum across replicates)	429	0	1	457	589	492	529	461	371	166	270	268
Chironomid Abundance (sum across replicates)	149.0	2.0	2.0	169.0	3.0	13.0	12.0	17.0	16.0	4.0	2.0	7.0
H' Diversity (average of replicates)	2.3	0.2	0.0	1.5	2.5	2.5	1.8	2.1	2.2	1.8	1.9	1.8

Step 2: Calculate Metrics

1) Taxa Richness (Number of Taxa across replicates)	26	3	3	18	37	33	32	27	29	26	23	31
2) Hillsenhoff's Biotic Index (average across replicates)	3.7	4.3	4.0	4.5	3.5	3.3	3.7	3.7	3.6	3.8	3.7	3.7
3) Ratio of Scrapers to Filterers/Collectors (Scrapers/Filterers)	7.8	1.0	2.0	0.6	0.9	1.3	1.1	1.3	2.7	8.0	5.5	4.2
4) Ratio of EPT and Chironomid Abundance (EPT Abundance/Chironomid Abundance)	2.9	0.0	0.5	2.7	196.3	37.8	44.1	27.1	23.2	41.5	135.0	38.3
5) % Contribution Dominant Taxon (average across replicates)	23.6	83.3	100.0	46.0	23.4	25.1	40.9	28.8	27.3	52.2	45.1	51.7
6) EPT Index (number of taxa at station across replicates)	15	0.0	1.0	9.0	21	20	17	16	18	14	13	17
7) Community Loss Index*	NA	11.7	11.3	1.3	NA	0.18	0.29	0.56	0.45	0.58	0.7	0.42
8) Ratio of Shredders to Total (Total Shredders/Average Number per Sample)	0.9	0.0	0.0	0.1	0.2	0.1	0.2	0.3	0.1	0.2	0.1	0.1

	Strawberry Creek							
	BG-1		SC-3		SC-5		SC-1	
Step 3: Calculate Biological Condition Score **	% of Ref	Score	% of Ref	Score	% of Ref	Score	% of Ref	Score
1) Taxa Richness***		6	12%	0	12%	0	69%	4
2) Hillsenhoff's Biotic Index (Reference/Site * 100)***		6	85%	6	92%	6	81%	4
3) Ratio of Scrapers to Filterers/Collectors***		6	13%	0	26%	2	7%	0
4) Ratio of EPT and Chironomid Abundance ***		6	0%	0	17%	0	94%	6
5) % Contribution Dominant Taxon		6	83%	0	100%	0	46%	0
6) EPT Index***		4	0%	0	7%	0	60%	0
7) Community Loss Index		6	12	0	11.3	0	1.3	4
8) Ratio of Shredders to Total ***		6	0%	0	0%	0	8%	0
Biological Condition Score		46		6		8		18
Biological Condition Score % Compared to Reference			13%		17%		39.1%	
Biological Condition Category			Severe		Severe		Moderate	

	Bear Butte Creek															
	BB-16		BB-3		BB-14		BB-6		BB-5		BB-2		BB-1		BB-15	
Step 3: Calculate Biological Condition Score **	% of Ref	Score	% of Ref	Score	% of Ref	Score	% of Ref	Score	% of Ref	Score	% of Ref	Score	% of Ref	Score	% of Ref	Score
1) Taxa Richness***		6	89%	6	86%	6	73%	4	78%	4	70%	4	62%	4	84%	6
2) Hillsenhoff's Biotic Index (Reference/Site * 100)***		6	94%	6	96%	6	95%	6	97%	6	92%	6	95%	6	95%	6
3) Ratio of Scrapers to Filterers/Collectors***		6	>100%	6	>100%	6	>100%	6	>100%	6	>100%	6	>100%	6	>100%	6
4) Ratio of EPT and Chironomid Abundance ***		6	19%	0	22%	0	14%	0	12%	0	21%	0	69%	4	20%	0
5) % Contribution Dominant Taxon		6	25%	4	41%	0	29%	4	27%	4	52%	0	45%	0	52%	4
6) EPT Index***		4	95%	6	81%	4	76%	2	86%	4	67%	0	62%	0	81%	0
7) Community Loss Index		6	0.18	6	0.29	6	0.56	4	0.45	6	0.58	4	0.74	4	0.42	6
8) Ratio of Shredders to Total ***		6	51%	6	>100%	6	>100%	6	34%	2	>100%	6	44%	4	80%	6
Biological Condition Score		46		40		34		32		32		26		28		34
Biological Condition Score % Compared to Reference			87%		74%		70%		70%		57%		61%		74%	
Biological Condition Category			Not Impaired		Slight		Slight		Slight		Slight		Slight		Slight	

*Community Loss Index equals

**Biological Condition Scoring Criterion listed in Figure 5-4.

*** Relative to BG-1 for Strawberry Creek locations and BB-16 for Bear Butte locations.

Data from (USEPA, 2002a)

Locations correspond to those on Figure 5-22.

Table 5-8
Benthic Macroinvertebrate Community Metrics and Biological Condition Scores
October 2001

Step 1: Statistics Used to Derive Metrics — Sampling Station	BG-1	SC-2	SC-5	SC-1	BB-3	BB-14
	Reference				Reference	
Number of Organisms per Sample (average of replicates)	240.3	2.0	8.3	182.3	255.0	345.7
Functional Feeding Groups						
Total Scrapers at Station (sum across replicates)	135.0	1.0	10.0	188.0	131.0	413.0
Total Filterers at Station (sum across replicates)	38.0	0.0	9.0	325.0	107.0	474.0
Total Shredders at Station (sum across replicates)	302.0	0.0	1.0	24.0	45.0	76.0
EPT Abundance (sum across replicates)	556	0	12	447	566	636
Chironomid Abundance (sum across replicates)	97.0	0.0	3.0	24.0	19.0	86.0
H' Diversity (average of replicates)	2.1	0.7	1.5	1.5	2.5	2.0

Step2: Calculate Metrics	BG-1	SC-2	SC-5	SC-1	BB-3	BB-14
1) Taxa Richness (Number of Taxa across replicates)	28	2	8	16	39	32
2) Hillsenhoff's Biotic Index (average across replicates)	3.3	4.5	3.9	3.7	3.4	3.9
3) Ratio of Scrapers to Filterers/Collectors (Scrapers/Filterers)	3.6	>1	1.1	0.6	1.2	0.9
4) Ratio of EPT and Chironomid Abundance (EPT Abundance/Chironomid Abundance)	5.7	0.0	4.0	18.6	29.8	7.4
5) % Contribution Dominant Taxon (average across replicates)	29.6	50.0	37.2	54.2	25.4	35.6
6) EPT Index (number of taxa at station across replicates)	17	0	2	9	21	17
7) Community Loss Index*	n/a	14	3	1.1	n/a	0.34
8) Ratio of Shredders to Total (Total Shredders/Average Number per Sample)	1.3	0.0	0.12	0.13	0.18	0.22

Step 3: Calculate Biological Condition Score**	BG-1	SC-2		SC-5		SC-1		BB-3		BB-14	
	% of Reference	% of Reference	Score	% of Reference	Score	% of Reference	Score	% of Reference	Score	% of Reference	Score
1) Taxa Richness***		7.1%	0	29%	0	57%	2		6	82%	6
2) Hillsenhoff's Biotic Index (Reference/Site * 100)***		74%	6	84%	6	90%	6		6	89%	6
3) Ratio of Scrapers to Filterers/Collectors***		<20%	0	31%	2	16%	0		6	71%	6
4) Ratio of EPT and Chironomid Abundance ***		0%	0	70%	4	>100%	6		6	25%	2
5) % Contribution Dominant Taxon		50%	0	37%	2	54%	0		4	36%	2
6) EPT Index***		0%	0	12%	0	53%	0		6	81%	4
7) Community Loss Index		14	0	3.0	2	1.1	4		6	0.34	6
8) Ratio of Shredders to Total ***		0.00%	0	9.5%	0	10%	0		6	>100%	6
Biological Condition Score			6		16		18		46		38
Biological Condition Score % Compared to Reference		**13.0%**		**35%**		**39.1%**				**83%**	
Biological Condition Category		**Severe**		**Moderate**		**Moderate**				**Not Impaired**	

*Community Loss Index equals

**Biological Condition Scoring Criterion listed in Figure 5-4.

*** Relative to BG-1 for Strawberry Creek locations and BB-3 for Bear Butte locations.

Data from (USEPA, 2002a)

Table 5-9

***Pimephales promelas* Toxicity Test Results (Survival and Growth) Compared to Surface Water Concentrations**

	September 2000				October 2001			
	Survival Mean (%)		Weight Mean (mg dw)		Survival Mean (%)		Weight Mean (mg dw)	
Analyte	p value	R2	p value	R2	p value	R2	p value	R2
TAL Metals								
Aluminum	3.50E-03	0.522	9.80E-03	0.439	1.80E-01	0.240	2.22E-01	0.204
Antimony	Not Detected		Not Detected		Not Detected		Not Detected	
Arsenic	8.81E-01	0.002	7.63E-01	0.008	Not Detected		Not Detected	
Barium	6.47E-03	0.474	2.09E-03	0.560	6.00E-02	0.418	1.38E-02	0.604
Beryllium	Not Detected		Not Detected		Not Detected		Not Detected	
Cadmium	2.89E-05	0.779	8.18E-06	0.821	1.63E-02	0.586	6.85E-03	0.672
Chromium	Not Detected		Not Detected		Not Detected		Not Detected	
Cobalt	7.79E-08	0.917	1.29E-06	0.868	2.05E-04	0.876	1.29E-04	0.891
Copper	4.13E-03	0.510	1.18E-03	0.598	5.45E-02	0.432	9.27E-02	0.351
Iron	Not Detected		Not Detected		Not Detected		Not Detected	
Lead	Not Detected		Not Detected		2.49E-01	0.184	3.16E-01	0.143
Manganese	6.31E-06	0.828	1.94E-05	0.793	1.04E-03	0.805	1.12E-03	0.801
Mercury	Not Detected		Not Detected		Not Detected		Not Detected	
Nickel	1.94E-02	0.378	6.32E-03	0.476	3.01E-03	0.738	1.02E-03	0.806
Selenium	2.06E-05	0.791	7.28E-05	0.743	2.43E-03	0.753	1.87E-03	0.770
Silver	6.34E-01	0.019	5.34E-01	0.033	Not Detected		Not Detected	
Thallium	Not Detected		Not Detected		Not Detected		Not Detected	
Vanadium	Not Detected		Not Detected		Not Detected		Not Detected	
Zinc	4.28E-02	0.299	1.60E-02	0.395	1.57E-02	0.589	7.00E-03	0.670
Total Dissolved Solids (TDS) and Primary TDS Components								
TDS/Salinity	7.28E-06	0.824	5.55E-05	0.755	8.59E-05	0.903	2.92E-05	0.929
Calcium	1.37E-07	0.909	5.12E-06	0.834	5.98E-05	0.912	3.01E-05	0.928
Magnesium	4.01E-07	0.891	3.70E-06	0.843	1.70E-04	0.882	2.69E-05	0.930
Potassium	6.37E-02	0.258	1.03E-01	0.206	5.93E-02	0.419	5.06E-02	0.442
Sodium	8.95E-08	0.915	3.47E-06	0.844	3.15E-05	0.927	3.19E-05	0.927
Sulfate	Not Analyzed				3.56E-04	0.897	6.34E-05	0.942

Shaded cells indicate p <0.01 and/or R2 >0.6

Table 6-1

Summary of Risks to Plants and Soil Invertebrates from Direct Contact with Riparian Surface Soils

COPC	Strawberry Creek	Ruby Gulch	Downstream Bear Butte Creek
Aluminum	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Arsenic	Equal to or < Reference	none	none
Chromium	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Cobalt	minimal	none	none
Copper	severe	none	high
Lead	minimal	none	minimal
Manganese	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Mercury	moderate	none	none
Nickel	minimal	none	none
Selenium	high	none	minimal
Silver	severe	none	moderate
Thallium	high	none	moderate
Vanadium	Equal to or < Reference	Equal to or < Reference	Equal to or < Reference
Zinc	moderate	none	high

Equal to or < Reference	HQ values are less than or equal to those for reference exposure reaches (Figure 6-1)
none	All HQ values are < or equal to 1.
minimal	< 20% of the HQ values are greater than 1.
moderate	21 to 50% of the HQ values are greater than 1.
high	51 to 80% of the HQ values are greater than 1.
severe	> 81% of the HQ values are greater than 1.

Table 7-1
Riparian Area Exposure Point Concentrations (EPCs) for Wildlife Receptors

Reach	COPC	Surface Water (Total) EPC (mg/L)	Sediment (Total) EPC (mg/kg)	Soil (Total) EPC (mg/kg)	Plant EPC (mg/kg ww)	Soil Invertebrate EPC (mg/kg ww)	Fish EPC (mg/kg ww)
Strawberry Creek	Aluminum	6.7E+02	3.9E+04	1.5E+04	8.0E+03	5.3E+03	3.7E+01
	Antimony	6.4E-02	2.1E+00	2.9E+00	1.5E+00	1.0E+00	NA
	Arsenic	2.3E-02	7.9E+01	1.7E+02	1.3E+00	3.2E+00	3.6E+00
	Barium	4.5E-01	9.3E+01	1.2E+02	6.6E+01	4.4E+01	NA
	Beryllium	7.0E-02	2.5E+00	NA	NA	NA	NA
	Cadmium	1.4E-01	1.5E+01	2.3E+00	5.2E-01	5.6E+00	1.5E+00
	Chromium	4.6E-02	2.5E+01	2.3E+01	1.2E+01	2.6E+01	1.8E+00
	Copper	1.1E+01	3.1E+03	3.9E+02	1.1E+01	9.0E+00	NA
	Lead	4.2E-01	1.3E+02	3.4E+02	3.7E+00	3.1E+01	NA
	Lithium	1.6E+01	NA	NA	NA	NA	NA
	Manganese	9.5E+00	3.0E+03	1.1E+03	5.7E+02	1.8E+01	8.0E+01
	Mercury	2.3E-04	1.8E-01	5.4E-01	1.4E-01	3.1E-01	1.6E-01
	Molybdenum	1.5E+00	NA	NA	NA	NA	NA
	Nickel	1.0E+00	7.2E+01	3.7E+01	8.5E-01	6.1E+01	NA
	Selenium	4.3E-02	1.6E+00	2.5E+00	7.4E-01	6.3E-01	4.9E+00
	Strontium	8.0E+00	NA	NA	NA	NA	NA
	Thallium	3.5E-03	1.9E+00	2.8E+00	1.5E+00	9.8E-01	NA
	Vanadium	1.1E-01	4.0E+01	4.8E+01	2.6E+01	1.7E+01	NA
	Zinc	1.1E+01	1.1E+03	2.3E+02	5.2E+01	1.8E+02	1.2E+02
HooDoo Gulch	Aluminum	4.7E+01	5.5E+04	NA	NA	NA	NA
	Antimony	2.5E-03	5.7E-01	NA	NA	NA	NA
	Arsenic	5.5E-02	1.1E+02	NA	NA	NA	NA
	Barium	2.3E-02	1.5E+02	NA	NA	NA	NA
	Beryllium	1.1E-02	3.2E+00	NA	NA	NA	NA
	Cadmium	1.4E-01	4.2E+01	NA	NA	NA	NA
	Chromium	1.4E-03	6.0E+01	NA	NA	NA	NA
	Copper	2.6E+00	8.1E+02	NA	NA	NA	NA
	Lead	4.1E-03	1.7E+02	NA	NA	NA	NA
	Lithium	NA	NA	NA	NA	NA	NA
	Manganese	9.0E+00	3.3E+03	NA	NA	NA	NA
	Mercury	7.3E-05	2.2E-01	NA	NA	NA	NA
	Molybdenum	NA	NA	NA	NA	NA	NA
	Nickel	2.5E-01	1.1E+02	NA	NA	NA	NA
	Selenium	2.3E-03	1.8E+00	NA	NA	NA	NA
	Strontium	6.4E-01	NA	NA	NA	NA	NA
	Thallium	3.8E-03	7.3E-01	NA	NA	NA	NA
	Vanadium	4.6E-03	6.5E+01	NA	NA	NA	NA
	Zinc	4.2E+00	1.4E+03	NA	NA	NA	NA
Ruby Gulch	Aluminum	5.7E+00	1.2E+04	1.5E+04	8.2E+03	5.4E+03	NA
	Antimony	1.6E-03	1.5E+00	2.8E+00	1.5E+00	9.6E-01	NA
	Arsenic	2.4E-03	1.4E+02	2.0E+01	3.9E-01	6.9E-01	NA
	Barium	6.6E-02	1.4E+02	1.2E+02	6.5E+01	4.3E+01	NA
	Beryllium	1.5E-03	1.4E+00	NA	NA	NA	NA
	Cadmium	5.7E-03	4.2E+00	1.1E+00	3.5E-01	3.1E+00	NA
	Chromium	6.7E-04	2.7E+01	4.6E+01	2.4E+01	5.1E+01	NA
	Copper	1.4E-01	5.9E+02	7.3E+01	5.6E+00	5.8E+00	NA
	Lead	3.4E-03	2.6E+02	4.0E+01	1.1E+00	5.5E+00	NA
	Lithium	NA	NA	NA	NA	NA	NA
	Manganese	4.6E-01	8.1E+02	6.3E+02	3.3E+02	1.3E+01	NA
	Mercury	1.2E-03	7.3E-01	6.5E-02	4.4E-02	1.5E-01	NA
	Molybdenum	NA	NA	NA	NA	NA	NA
	Nickel	2.2E-02	3.0E+01	3.2E+01	7.6E-01	5.2E+01	NA
	Selenium	2.0E-03	1.2E+00	1.2E+00	3.3E-01	3.7E-01	NA
	Strontium	1.1E+00	NA	NA	NA	NA	NA
	Thallium	1.8E-03	1.9E+00	5.5E-01	2.9E-01	1.9E-01	NA
	Vanadium	9.8E-04	3.1E+01	4.4E+01	2.3E+01	1.5E+01	NA
	Zinc	2.3E-01	2.8E+02	1.4E+02	3.9E+01	1.5E+02	NA

Table 7-1
Riparian Area Exposure Point Concentrations (EPCs) for Wildlife Receptors

Reach	COPC	Surface Water (Total) EPC (mg/L)	Sediment (Total) EPC (mg/kg)	Soil (Total) EPC (mg/kg)	Plant EPC (mg/kg ww)	Soil Invertebrate EPC (mg/kg ww)	Fish EPC (mg/kg ww)
Bear Butte Creek-upstream	Aluminum	3.6E-01	1.4E+04	1.4E+04	7.5E+03	5.0E+03	1.5E+02
	Antimony	2.2E-03	2.2E+00	NA	NA	NA	NA
	Arsenic	3.8E-03	1.9E+02	1.2E+02	1.1E+00	2.5E+00	3.1E+00
	Barium	5.5E-02	3.2E+02	2.3E+02	1.2E+02	7.9E+01	NA
	Beryllium	2.2E-04	1.0E+00	NA	NA	NA	NA
	Cadmium	3.6E-04	7.3E-01	1.1E-01	9.9E-02	5.0E-01	6.4E-01
	Chromium	7.2E-03	2.3E+01	2.7E+01	1.4E+01	2.9E+01	1.7E+00
	Copper	6.6E-03	4.8E+01	5.5E+01	5.0E+00	5.4E+00	NA
	Lead	2.4E-03	1.0E+02	7.3E+01	1.6E+00	9.0E+00	NA
	Lithium	NA	NA	NA	NA	NA	NA
	Manganese	3.7E-02	2.5E+03	2.2E+03	1.2E+03	2.9E+01	1.2E+02
	Mercury	9.0E-05	4.5E-01	5.5E-01	1.4E-01	3.1E-01	2.6E-01
	Molybdenum	NA	NA	NA	NA	NA	NA
	Nickel	8.9E-03	4.6E+01	4.6E+01	1.0E+00	7.7E+01	NA
	Selenium	2.4E-03	4.8E+00	1.1E+00	3.0E-01	3.5E-01	5.5E+00
	Strontium	NA	NA	NA	NA	NA	NA
	Thallium	2.6E-03	1.8E+00	6.3E-01	3.3E-01	2.2E-01	NA
	Vanadium	1.2E-03	3.6E+01	3.8E+01	2.0E+01	1.3E+01	NA
	Zinc	2.4E-02	1.6E+02	1.5E+02	4.2E+01	1.6E+02	1.5E+02
Bear Butte Creek-*downstream*	Aluminum	2.4E-01	1.5E+04	1.5E+04	7.7E+03	5.1E+03	2.6E+02
	Antimony	2.5E-03	1.9E+00	7.2E+00	3.8E+00	2.5E+00	NA
	Arsenic	3.0E-02	1.1E+02	2.5E+02	1.6E+00	4.1E+00	3.2E+00
	Barium	4.9E-02	1.7E+02	1.5E+02	7.9E+01	5.2E+01	NA
	Beryllium	1.5E-04	1.1E+00	NA	NA	NA	NA
	Cadmium	8.7E-04	1.1E+01	2.8E+00	5.8E-01	6.6E+00	2.2E+00
	Chromium	3.5E-03	2.9E+01	2.9E+01	1.5E+01	3.2E+01	9.0E+00
	Copper	1.0E-02	1.6E+02	1.9E+02	8.2E+00	7.5E+00	NA
	Lead	2.9E-03	1.4E+02	1.0E+03	6.9E+00	7.6E+01	NA
	Lithium	NA	NA	NA	NA	NA	NA
	Manganese	9.5E-02	2.5E+03	1.9E+03	1.0E+03	2.7E+01	2.2E+02
	Mercury	9.5E-05	2.3E-01	9.8E-02	5.5E-02	1.7E-01	1.2E-01
	Molybdenum	NA	NA	NA	NA	NA	NA
	Nickel	3.7E-03	5.0E+01	5.0E+01	1.1E+00	8.3E+01	NA
	Selenium	2.6E-03	1.9E+00	2.0E+00	5.7E-01	5.4E-01	4.3E+00
	Strontium	NA	NA	NA	NA	NA	NA
	Thallium	3.4E-03	1.9E+00	1.7E+00	9.2E-01	6.1E-01	NA
	Vanadium	1.3E-03	4.2E+01	6.8E+01	3.6E+01	2.4E+01	NA
	Zinc	3.6E-02	4.9E+02	5.5E+02	8.5E+01	2.4E+02	1.5E+02
Butcher Gulch	Aluminum	2.2E+00	7.6E+03	1.1E+04	6.0E+03	4.0E+03	NA
	Antimony	2.0E-03	8.5E-01	2.2E+00	1.2E+00	7.7E-01	NA
	Arsenic	5.3E-03	1.7E+01	1.6E+01	3.4E-01	5.9E-01	NA
	Barium	5.0E-02	1.3E+02	1.4E+02	7.6E+01	5.0E+01	NA
	Beryllium	5.2E-04	1.1E+00	NA	NA	NA	NA
	Cadmium	3.0E-04	1.7E-01	1.9E-01	1.3E-01	7.7E-01	NA
	Chromium	1.6E-03	2.1E+01	3.2E+01	1.7E+01	3.5E+01	NA
	Copper	7.3E-02	2.6E+01	3.1E+01	4.0E+00	4.6E+00	NA
	Lead	3.9E-03	9.3E+01	8.3E+01	1.7E+00	9.9E+00	NA
	Lithium	NA	NA	NA	NA	NA	NA
	Manganese	2.7E-02	7.9E+02	7.0E+02	3.7E+02	1.4E+01	NA
	Mercury	8.8E-05	7.5E-02	6.7E-01	1.6E-01	3.3E-01	NA
	Molybdenum	NA	NA	NA	NA	NA	NA
	Nickel	2.5E-03	1.4E+01	2.9E+01	7.0E-01	4.7E+01	NA
	Selenium	2.3E-03	7.2E-01	2.6E-01	6.1E-02	1.2E-01	NA
	Strontium	NA	NA	NA	NA	NA	NA
	Thallium	2.5E-03	5.1E-01	4.7E-01	2.5E-01	1.6E-01	NA
	Vanadium	2.0E-03	1.9E+01	3.2E+01	1.7E+01	1.1E+01	NA
	Zinc	4.6E-02	1.1E+02	9.3E+01	3.2E+01	1.3E+02	NA

Table 7-1
Riparian Area Exposure Point Concentrations (EPCs) for Wildlife Receptors

		Surface Water (Total)	Sediment (Total)	Soil (Total)	Plant	Soil Invertebrate	Fish
Reach	COPC	EPC (mg/L)	EPC (mg/kg)	EPC (mg/kg)	EPC (mg/kg ww)	EPC (mg/kg ww)	EPC (mg/kg ww)
Boomer Gulch	Aluminum	2.6E-01	2.7E+04	NA	NA	NA	1.7E+02
	Antimony	2.3E-03	2.1E+00	NA	NA	NA	NA
	Arsenic	2.6E-03	1.6E+01	NA	NA	NA	1.7E+00
	Barium	2.3E-02	2.6E+02	NA	NA	NA	NA
	Beryllium	2.1E-04	1.6E+00	NA	NA	NA	NA
	Cadmium	4.1E-04	1.7E+00	NA	NA	NA	2.9E-01
	Chromium	1.5E-03	5.1E+01	NA	NA	NA	5.8E-01
	Copper	1.2E-02	4.7E+01	NA	NA	NA	NA
	Lead	1.9E-03	5.5E+01	NA	NA	NA	NA
	Lithium	NA	NA	NA	NA	NA	NA
	Manganese	4.4E-02	1.8E+03	NA	NA	NA	2.6E+01
	Mercury	8.3E-05	2.0E-01	NA	NA	NA	1.5E-02
	Molybdenum	NA	NA	NA	NA	NA	NA
	Nickel	1.2E-03	7.7E+01	NA	NA	NA	NA
	Selenium	2.0E-03	3.9E+00	NA	NA	NA	5.7E+00
	Strontium	NA	NA	NA	NA	NA	NA
	Thallium	2.4E-03	1.6E+00	NA	NA	NA	NA
	Vanadium	1.0E-03	6.5E+01	NA	NA	NA	NA
	Zinc	2.0E-02	3.0E+02	NA	NA	NA	1.2E+02
2Bit&Anchor	Aluminum	2.8E+00	NA	NA	NA	NA	NA
	Antimony	1.8E-03	NA	NA	NA	NA	NA
	Arsenic	6.1E-03	NA	NA	NA	NA	NA
	Barium	3.0E-02	NA	NA	NA	NA	NA
	Beryllium	6.0E-04	NA	NA	NA	NA	NA
	Cadmium	2.0E-04	NA	NA	NA	NA	NA
	Chromium	1.9E-03	NA	NA	NA	NA	NA
	Copper	3.6E-03	NA	NA	NA	NA	NA
	Lead	3.0E-03	NA	NA	NA	NA	NA
	Lithium	NA	NA	NA	NA	NA	NA
	Manganese	2.5E-02	NA	NA	NA	NA	NA
	Mercury	1.0E-04	NA	NA	NA	NA	NA
	Molybdenum	NA	NA	NA	NA	NA	NA
	Nickel	1.8E-03	NA	NA	NA	NA	NA
	Selenium	3.2E-03	NA	NA	NA	NA	NA
	Strontium	NA	NA	NA	NA	NA	NA
	Thallium	3.9E-03	NA	NA	NA	NA	NA
	Vanadium	3.1E-03	NA	NA	NA	NA	NA
	Zinc	2.4E-02	NA	NA	NA	NA	NA

Non-detects are evaluated at one-half the detection limit.
NA = Not a COPC or Not Analyzed

Table 7-2
Exposure Factors for Representative Wildlife Species

Class	Type	Receptor	*Genus species*	Body Weight (kg wet weight)	Food Ingestion Rate (kg wet weight/day)	Water Ingestion Rate (L/day)	Sediment Ingestion Rate (kg dry weight/day)	Soil Ingestion Rate (kg dry weight/day)	Assumed Dietary Fraction (df)
Avian	Aquatic Piscivore	Belted Kingfisher	*Ceryle alcyon*	0.14733	0.0737	0.016	0.0004	NA	100% fish; no data for benthics
	Terrestrial Omnivore	Bobwhite Quail	*Colinus virginianus*	0.17183	0.0334	0.181	NA	0.0018	100% plants; estimated from soil data
	Terrestial Omnivore	American Robin	*Turdus migratorius*	0.081	0.098	0.011	NA	0.0016	25% plants, 75% earthworms; estimated from soil data
Mammalian	Terrestrial Insectivore	Masked Shrew	*Sorex cinereus*	0.00487	0.096	0.001	NA	0.0040	100% earthworms; estimated from soil data
	Terrestrial Omnivore	Deer Mouse	*Peromyscus maniculatus*	0.02118	0.010	0.003	NA	0.0001	100% plants; estimated from soil data
	Semi-Aquatic Piscivore	Mink	*Mustela vison*	0.85225	0.116	0.024	0.0003	NA	100% fish; no data for benthics

NA = Not applicable
See Appendix B for detailed information and sources.

Table 7-3a
Summary of Total Hazard Index (HI) Values for the Masked Shrew in Riparian Areas

	Strawberry Creek	HooDoo Gulch	Ruby Gulch	Bear Butte Creek (downstream)
Aluminum	1E+04	≤ 1	1E+04	Equal to or < Reference
Antimony	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Arsenic	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Barium	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Beryllium	≤ 1	≤ 1	≤ 1	≤ 1
Cadmium	2E+02	≤ 1	1E+02	2E+02
Chromium	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Copper	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Lead	2E+02	≤ 1	Equal to or < Reference	4E+02
Lithium	≤ 1	NA	NA	NA
Manganese	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Mercury	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Molybdenum	≤ 1	NC	NA	NA
Nickel	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Selenium	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Strontium	≤ 1	≤ 1	≤ 1	NA
Thallium	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Vanadium	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Zinc	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference

NA = Not Analyzed. Analyte was not analyzed for in this exposure reach.

HI ≤ 1E+00

1E+00 < HI ≤ 1E+01

1E+01 < HI ≤ 1E+02

HI ≥ 1E+02

Table 7-3b

Summary of Hazard Index (HI) Values for the American Robin in Riparian Areas

	Strawberry Creek	HooDoo Gulch	Ruby Gulch	Bear Butte Creek (downstream)
Aluminum	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Antimony	NC	NC	NC	NC
Arsenic	2E+00	≤ 1	≤ 1	2E+00
Barium	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Beryllium	NC	NC	NC	NC
Cadmium	3E+00	≤ 1	2E+00	4E+00
Chromium	Equal to or < Reference	≤ 1	1E+02	Equal to or < Reference
Copper	≤ 1	≤ 1	≤ 1	≤ 1
Lead	2E+01	≤ 1	Equal to or < Reference	6E+01
Lithium	NC	NC	NC	NC
Manganese	≤ 1	≤ 1	≤ 1	≤ 1
Mercury	≤ 1	≤ 1	≤ 1	≤ 1
Molybdenum	≤ 1	NA	NA	NA
Nickel	≤ 1	≤ 1	≤ 1	≤ 1
Selenium	2E+00	≤ 1	≤ 1	≤ 1
Strontium	NC	NC	NC	NC
Thallium	NC	NC	NC	NC
Vanadium	≤ 1	≤ 1	≤ 1	2E+00
Zinc	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference

NC = Not Calculated as TRV is not available.

NA = Not Analyzed. Analyte was not analyzed for in this exposure reach.

HI ≤ 1E+00

1E+00 < HI ≤ 1E+01

1E+01 < HI ≤ 1E+02

HI ≥ 1E+02

Table 7-3c
Summary of Hazard Index (HI) Values for the Deer Mouse in Riparian Areas

	Strawberry Creek	HooDoo Gulch	Ruby Gulch	Bear Butte Creek (downstream)
Aluminum	3E+02	≤ 1	3E+02	Equal to or < Reference
Antimony	1E+01	≤ 1	1E+01	3E+01
Arsenic	2E+00	≤ 1	≤ 1	2E+00
Barium	≤ 1	≤ 1	≤ 1	≤ 1
Beryllium	≤ 1	≤ 1	≤ 1	≤ 1
Cadmium	≤ 1	≤ 1	≤ 1	≤ 1
Chromium	≤ 1	≤ 1	≤ 1	≤ 1
Copper	≤ 1	≤ 1	≤ 1	≤ 1
Lead	≤ 1	≤ 1	≤ 1	≤ 1
Lithium	≤ 1	NA	NA	NA
Manganese	Equal to or < Reference	≤ 1	≤ 1	Equal to or < Reference
Mercury	≤ 1	≤ 1	≤ 1	≤ 1
Molybdenum	≤ 1	NA	NA	NA
Nickel	≤ 1	≤ 1	≤ 1	≤ 1
Selenium	≤ 1	≤ 1	≤ 1	≤ 1
Strontium	≤ 1	≤ 1	≤ 1	NA
Thallium	1E+01	≤ 1	NA	Equal to or < Reference
Vanadium	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Zinc	≤ 1	≤ 1	≤ 1	≤ 1

NA = Not Analyzed. Analyte was not analyzed for in this exposure reach.

	HI ≤ 1E+00
	1E+00 < HI ≤ 1E+01
	1E+01 < HI ≤ 1E+02
	HI ≥ 1E+02

Table 7-3d

Summary of Hazard Index (HI) Values for the Bobwhite Quail in Riparian Areas

	Strawberry Creek	HooDoo Gulch	Ruby Gulch	Bear Butte Creek (downstream)
Aluminum	1E+01	≤ 1	Equal to or < Reference	Equal to or < Reference
Antimony	NC	NC	NC	NC
Arsenic	≤ 1	≤ 1	≤ 1	≤ 1
Barium	≤ 1	≤ 1	≤ 1	≤ 1
Beryllium	NC	NC	NC	NC
Cadmium	≤ 1	≤ 1	≤ 1	≤ 1
Chromium	Equal to or < Reference	≤ 1	Equal to or < Reference	Equal to or < Reference
Copper	≤ 1	≤ 1	≤ 1	≤ 1
Lead	3E+00	≤ 1	≤ 1	8E+00
Lithium	NC	NC	NC	NC
Manganese	≤ 1	≤ 1	≤ 1	≤ 1
Mercury	≤ 1	≤ 1	≤ 1	≤ 1
Molybdenum	≤ 1	NA	NA	NA
Nickel	≤ 1	≤ 1	≤ 1	≤ 1
Selenium	≤ 1	≤ 1	≤ 1	≤ 1
Strontium	NC	NC	NC	NC
Thallium	NC	NC	NC	NC
Vanadium	≤ 1	≤ 1	≤ 1	≤ 1
Zinc	≤ 1	≤ 1	≤ 1	≤ 1

NC = Not Calculated as TRV is not available.

NA = Not Analyzed. Analyte was not analyzed for in this exposure reach.

HI ≤ 1E+00

1E+00 < HI ≤ 1E+01

1E+01 < HI ≤ 1E+02

HI ≥ 1E+02

Table 7-3e

Summary of Hazard Index (HI) Values for Belted Kingfisher in Riparian Areas

	Strawberry Creek	HooDoo Gulch	Ruby Gulch	Bear Butte Creek (downstream)
Aluminum	≤ 1	≤ 1	≤ 1	≤ 1
Antimony	NC	NC	NC	NC
Arsenic	≤ 1	≤ 1	≤ 1	≤ 1
Barium	≤ 1	≤ 1	≤ 1	≤ 1
Beryllium	NC	NC	NC	NC
Cadmium	≤ 1	≤ 1	≤ 1	≤ 1
Chromium	Equal to or < Reference	≤ 1	≤ 1	Equal to or < Reference
Copper	≤ 1	≤ 1	≤ 1	≤ 1
Lead	≤ 1	≤ 1	≤ 1	≤ 1
Lithium	≤ 1	NA	NA	NA
Manganese	≤ 1	≤ 1	≤ 1	≤ 1
Mercury	Equal to or < Reference	≤ 1	≤ 1	Equal to or < Reference
Molybdenum	≤ 1	NA	NA	NA
Nickel	≤ 1	≤ 1	≤ 1	≤ 1
Selenium	≤ 1	≤ 1	≤ 1	≤ 1
Strontium	NC	NC	NC	NC
Thallium	NC	NC	NC	NC
Vanadium	≤ 1	≤ 1	≤ 1	≤ 1
Zinc	≤ 1	≤ 1	≤ 1	Equal to or < Reference

NC = Not Calculated as TRV is not available.

NA = Not Analyzed. Analyte was not analyzed for in this exposure reach.

	HI ≤ 1E+00
	1E+00 < HI ≤ 1E+01
	1E+01 < HI ≤ 1E+02
	HI ≥ 1E+02

Table 7-3f
Summary of Hazard Index (HI) Values for the Mink in Riparian Areas

	Strawberry Creek	HooDoo Gulch	Ruby Gulch	Bear Butte Creek (downstream)
Aluminum	Equal to or < Reference	Equal to or < Reference	≤ 1	Equal to or < Reference
Antimony	≤ 1	≤ 1	≤ 1	≤ 1
Arsenic	≤ 1	≤ 1	≤ 1	≤ 1
Barium	≤ 1	≤ 1	≤ 1	≤ 1
Beryllium	≤ 1	≤ 1	≤ 1	≤ 1
Cadmium	≤ 1	≤ 1	≤ 1	≤ 1
Chromium	≤ 1	≤ 1	≤ 1	≤ 1
Copper	≤ 1	≤ 1	≤ 1	≤ 1
Lead	≤ 1	≤ 1	≤ 1	≤ 1
Lithium	≤ 1	NA	NA	NA
Manganese	≤ 1	≤ 1	≤ 1	≤ 1
Mercury	≤ 1	≤ 1	≤ 1	≤ 1
Molybdenum	≤ 1	NA	NA	NA
Nickel	≤ 1	≤ 1	≤ 1	≤ 1
Selenium	≤ 1	≤ 1	≤ 1	≤ 1
Strontium	≤ 1	≤ 1	≤ 1	NA
Thallium	≤ 1	≤ 1	≤ 1	≤ 1
Vanadium	≤ 1	≤ 1	≤ 1	≤ 1
Zinc	≤ 1	≤ 1	≤ 1	≤ 1

NA = Not Analyzed. Analyte was not analyzed for in this exposure reach.

	HI ≤ 1E+00
	1E+00 < HI ≤ 1E+01
	1E+01 < HI ≤ 1E+02
	HI ≥ 1E+02

Table 8-1
Summary of Qualitative COPCs for Ecological Risk Assessment

	Wildlife Receptors								Terrestrial Receptors (plants, soil organisms)		Aquatic Receptors			
	Surface Water		Sediment		Soil		Aquatic Food Web		Soil		Surface Water		Sediment	
	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2	Type 1	Type 2
Riparian Area	9	0	4	0	2	2	3	0	3	0	1	1	8	0
Mine Source Area	NA	NA	NA	NA	10	1	NA	NA	11	0	NA	NA	NA	NA

NA = Not applicable

Table 8-2
Summary of Uncertainties in the Ecological Risk Assessment

Assessment Component	Description	Likely Direction of Error	Likely Magnitude of Error
Nature and Extent of Contamination	Samples collected may not be fully representative of variability in space or time, especially if the number of samples is small.	Unknown	Probably small
	Analytical results may be imprecise.	Unknown	Probably small
Exposure Assessment	Some exposure pathways are not evaluated.	Underestimate of risk	Probably small, except possibly for dietary ingestion exposure of benthic organisms
	Some contaminants are not evaluated because chemical was never detected, but detection limit was too high to detect the chemical if it were present at a level of concern.	Underestimate of risk	Usually small
	Exposure parameters for wildlife receptors are based on studies at other sites.	Unknown	Probably small
	Exposure point concentrations for wildlife receptors are based on a conservative estimate of the mean concentration in the exposure area.	Overestimate of risks	Possibly significant
	Absorption from site media is assumed to be the same as in laboratory studies.	Probably overestimate risk	Possibly significant
Effects (Toxicity) Assessment	Many chemicals lack reliable toxicity benchmarks for some receptors for some media; these chemicals are not evaluated.	Underestimation of risk	Probably small in most cases
	Available toxicity benchmarks are often based on limited data, and values must be extrapolated across species.	Unknown	Unknown, could be significant
	Wildlife receptors selected as representative species may not capture the full range of sensitivities in site receptors.	Unknown	Probably small
	Aquatic toxicity benchmarks are based on a wide range of species, many of which do not occur at this site.	Likely to overestimate risk	Probably small
Risk Characterization	Interactions between chemicals are difficult to account for; effects of one chemical may increase, decrease, or have no effect on other chemicals.	Unknown	Unknown, but probably small

APPENDICES

Baseline Ecological Risk Assessment for the Gilt Edge Mine Site

November 2003

Appendices are provided electronically in the attached CD.

TARGET SHEET

EPA REGION VIII

SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOCUMENT NUMBER: 1017355

SITE NAME: GILT EDGE MINE

DOCUMENT DATE: 11/01/2003

DOCUMENT NOT SCANNED

Due to one of the following reasons:

- ☐ PHOTOGRAPHS
- ☐ 3-DIMENSIONAL
- ☐ OVERSIZED
- ☑ AUDIO/VISUAL
- ☐ PERMANENTLY BOUND DOCUMENTS
- ☐ POOR LEGIBILITY
- ☐ OTHER
- ☐ NOT AVAILABLE
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DOCUMENT DESCRIPTION:

CD - BASELINE ECOLOGICAL RISK ASSESSMENT, FINAL