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NAVAL WEAPONS STATION
CONCORD, CALIFORNIA

QUALITATIVE ECOLOGICAL ASSESSMENT
LITIGATION AREA

FINAL
WORK PLAN

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ABBREVIATIONS AND ACRONYMS

AC	Area of contamination
AET	Apparent effects threshold
APE	Area of potential exposure
ARAR	Applicable or relevant and appropriate requirements
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient water quality criteria
BCF	Bioconcentration factors
BCR	Baseline conditions report
bgs	Below ground surface
CCMVCD	Contra Costa Mosquito and Vector Control District
COPC	Chemicals of potential concern
CTO	Contract Task Order
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichorodiphenyltrichorethane
DTSC	Department of Toxic Substances Control
ED	Exposure duration
EPA	U.S. Environmental Protection Agency
ER-L	Effects range - low
ER-M	Effects range - median
ERA	Ecological risk assessment
FSP	Field sampling plan
HI	Hazard index
HQ	Hazard quotient
HSDB	Hazardous Substances Data Bank
IAS	Initial assessment study
ICA	International Copper Association
Koc	Carbon partitioning coefficient
Kow	Octanol-water partitioning coefficient
LOAEL	Lowest observable adverse effect level
LOEL	Lowest observable effect level
MCL	Maximum contaminant level
ug/L	Micrograms per liter
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
NAS	National Academy of Sciences
NOAA	National Oceanographic and Atmospheric Administration
NOAEL	No observable adverse effect level
NOEL	No observable effect level
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
ppb	Parts per billion
ppm	Parts per million
ppt	Parts per thousand
PRC	PRC Environmental Management, Inc.
QAPjP	Quality assurance project plan

QEA	Qualitative ecological assessment
QEAWP	Qualitative ecological assessment work plan
RASS	Remedial action subsites
RI/FS	Remedial investigation/feasibility study
ROD	Record of decision
RWQCB	San Francisco Regional Water Quality Control Board
SMP	Site monitoring protocol
SOP	Standard operating procedure
STLC	Soluble threshold limit concentration
SUF	Site use factor
SVOC	Semivolatile organic compounds
TOC	Total organic carbon
TPH	Total petroleum hydrocarbons
TRV	Toxicity reference value
TTLC	Total threshold limit concentration
USFWS	U.S. Fish and Wildlife Service
VOC	Volatile organic compounds
WES	Waterways Experiment Station, U.S. Army Corps of Engineers
WET	Waste extraction test
WPNSTA	Naval weapons station

CHAPTER 1
INTRODUCTION

The Department of the Navy, Engineering Field Activity West, Naval Facilities Engineering Command, is conducting an ecological risk assessment at four sites in the Litigation Area of Naval Weapons Station (WPNSTA) Concord, California. The Navy has authorized PRC Environmental Management, Inc. (PRC) under Contract No. N62474-88-D-5086, Contract Task Order (CTO) No. 0295, to prepare a qualitative ecological assessment (QEA). A QEA is a non-probablistic approach to assessing risk to ecological receptors and ranking risk-producing conditions at a site. Quantitative data are collected and used to assess exposure to and potential toxic effects of contaminants to assessment endpoints. Sites can then be defined in qualitative terms as posing 1) little or no risk, 2) significant immediate risk, or 3) potential or unknown risk. The QEA at the Litigation Areas is really a post-remediation validation study to determine if remedial activities have removed significant risk to important ecological receptors. If significant risk is determined to be present at these sites, additional feasibility studies may need to be completed.

Task 3 of the CTO requires PRC to prepare a qualitative ecological assessment work plan (QEAWP). The QEAWP, field sampling plan (FSP), and quality assurance project plan (QAPjP) are companion documents supporting the ecological assessment activities. The QEAWP summarizes the existing data and presents the conceptual approach for the ecological assessment. The FSP describes the sampling design and methods, analyses to be conducted, and the analysis and interpretation of chemical and biological data. It also includes the project-specific health and safety plan. The QAPjP provides the details of chemical analyses, laboratory quality assurance, and standard operating procedures (SOP) for all measurements.

The four remedial action subsites (RASS) in the Litigation Area are contaminated by at least six heavy metals, including arsenic, cadmium, copper, lead, selenium, and zinc, and are undergoing remediation. The QEA will further characterize the nature and extent of contamination and qualitatively assess the risk of the remaining contaminants to ecological receptors. This QEAWP describes the rationale and methods to be used in the QEA, beginning with the following descriptions of the ecological risk framework.

The U.S. Environmental Protection Agency (EPA) has developed a framework for ecological risk assessment (ERA) that consists of four phases (EPA 1992a):

Problem formulation: The first step involves identifying key factors to be considered in the ERA and compiling available information and data on the sites. In the preliminary analysis, chemicals of potential concern are identified, and biological species and endpoints to be considered in the ERA are determined. This information is used to identify the scope of the ERA and the additional information needed to conduct the ERA. This step also includes the identification of applicable policy and regulatory issues.

Exposure assessment: In the second step, the biological receptors likely to encounter the chemical stressors are identified. The likely exposure routes (for example, dermal contact or ingestion) and the spatial and temporal variation in exposure at the sites are identified.

Ecological effects assessment: The potential adverse effects of exposure to chemical stressors on ecological receptors is then evaluated. The relationship between the amount of exposure and ecological effects is assessed using field measures and available ecotoxicological literature.

Risk characterization: In the final step, information gained during the exposure assessment and the ecological effects assessment are combined to evaluate the relationship between environmental concentrations of chemical stressors and adverse biological effects. The degree of confidence in the risk assessment is evaluated by identifying important sources of uncertainty, as well as underlying assumptions used in the analysis.

This framework, along with the State of California's draft protocol (California Department of Toxic Substances Control 1994), will be used as guidance for the QEA at the WPNSTA Concord Litigation Area. While this is a qualitative assessment, much quantitative information is already available for these sites based on the site monitoring protocol (SMP) (PRC 1991) that describes the strategy for monitoring effects of the remedial action. These data appear in the draft baseline conditions report 2(BCR) (PRC 1994a). The BCR will be used to the fullest extent possible; additional data needed to assess ecological risk will be gathered during Task 4, the implementation of the QEAWP.

1.1 OUTLINE OF WORK PLAN

The initial characterization of the Litigation Area is presented in Chapter 2 of this QEAWP. Much of this information is based on previous studies and document reviews on this site.

The ecology of the sites is characterized in Chapter 3 and includes descriptions of the habitats, typical species, species having special conservation status, and trophic linkages among species.

The toxicity characterization (Chapter 4) includes a description of the chemicals of potential concern (COPC) at the site, a review of preliminary data on the concentration and distribution of metals, a discussion of potential contamination with organic compounds, and a preliminary assessment of the toxicity and potential for bioavailability, bioaccumulation, and biomagnification of contaminants.

The conceptual site models for the three habitats in the Litigation Area are described in Chapter 5. This includes a description of chemical stressors, characterization of ecological receptors and exposure pathways, and a discussion of potential ecological effects of COPCs. This chapter also includes a discussion of fate and transport of contaminants at these sites including hydrologic transport, food chain transfer, and movement of organisms around the area.

Chapter 6 provides an overview of the objectives of the QEA field investigation.

A summary of existing data on the nature and extent of contamination appears in Chapter 7. This chapter presents preliminary sampling strategies and methodologies to further characterize the nature and extent of contamination, based on calculated hazard quotients and indices. A discussion of the appropriate use of baseline chemical data, preliminary statistical analyses of existing data, and criteria for selecting proposed reference stations are included.

Chapter 8 focuses on characterization of ecological receptors to chemical stressors. The preliminary choices of assessment and measurement endpoints, including the rationale for their selection, are introduced. Chapter 9 presents the methodology for characterization of exposure of contaminants to receptors. Proposed measures of bioavailability; factors affecting the potential for receptors to be exposed to contaminants, such as temporal and spatial use of the Litigation Area, ingestion rate and diet, and life history and behavioral characteristics of key species; and the use of exposure modeling are discussed.

The use of existing toxicity data and recommendations for additional toxicity tests are proposed in Chapter 10. Methodologies for characterizing ecological effects and the potential for food chain transfer and bioaccumulation are also discussed.

Chapter 11 presents the proposed methods for characterizing risk to ecological receptors, including threatened and endangered species, using a weight-of-evidence approach. Assumptions and uncertainties in the analyses are identified in this chapter.

1.2 SCOPE AND CONTENT OF WORK PLAN

Although this document is called a work plan, it contains elements of a qualitative ecological assessment and a scoping assessment, in addition to those of a work plan. This broad scope is a result of the substantial chemical and biological data collected during the investigation activities in and around the Litigation Area. These data are presented in several reports, the most significant of which are listed below.

- Natural Resource Survey (Jones and Stokes 1982)
- Initial Assessment Study (Ecology & Environment [E&E] 1983)
- Remedial Investigation of Contaminant Mobility (Lee and others 1986)
- Feasibility Study of Contaminant Remediation (Cullinane 1988)
- Remedial Action Subsite Revegetation Plan and Specifications (Harvey 1989)
- Monitoring Plan for Contamination Remediation (Lee and others 1989)
- Revised Protocol, Biological Monitoring, Monitoring Plan Implementation (Harvey, 1991)
- Monitoring Plan Implementation, Site Monitoring Protocol (PRC 1991)
- Concord Weapons Station Vegetation Surveys (Harvey 1992a)
- Concord Naval Weapons Station Invertebrate Characterization (Harvey 1992b)
- Concord Naval Weapons Station Special Status Rail Surveys (Harvey 1992c)
- Final Technical Memorandum (Martin Marietta Energy Systems [MMES] 1993)
- Hydrocarbon Site Investigation Report (PRC 1993a)
- Baseline Conditions Report (PRC 1994a)
- Interim Site Description Report (PRC 1994b)

Reference is made throughout this work plan to the data contained in these reports. Relevant historical data, summarized in this work plan within the context of the ecological assessment at the WPNSTA Concord Litigation Area, provide a foundation from which future ecological investigation activities needed for the QEA are developed.

A companion document, the draft final field sampling plan (FSP) (PRC 1995a), will provide the specific details of the technical approach for the QEAWP and its implementation, including the sample locations, number of samples, analytes, bioassay protocols, and other details relating to the field activities and procedures. Throughout this work plan reference is made to specific details included in the FSP, which should be consulted for such inquiries.

CHAPTER 2
SITE CHARACTERIZATION

Chapter 2 describes the location and climate, site history, physiography, and hydrology of the Litigation Area. A thorough description of the setting is found in the BCR (PRC 1994a) and the interim site description report (PRC 1994b).

2.1 LOCATION AND CLIMATE

WPNSTA Concord is located in the north-central portion of Contra Costa County, California, approximately 30 miles northeast of San Francisco (Figure 1). The installation encompasses approximately 12,900 acres consisting of three holdings: the Tidal Area, the Inland Area, and a radiography facility in Pittsburg, California. This QEA focuses on portions of the Tidal Area, which includes approximately 6,077 acres, including 1,571 acres on seven islands in Suisun Bay (Freeman, Middleground, Roe, Ryer, Snag, and two unnamed islets of the Seal Islands). The Tidal Area is bounded by Suisun Bay to the north and the city of Concord to the south and west, and is separated from the Inland Area by the town of Clyde and a range of hills outside of Navy property. The Litigation Area lies within the Tidal Area and encompasses approximately 308 acres of both wetland and upland portions of the Tidal Area adjacent to Suisun Bay (Figure 2). The area under study is dominated by three habitat types: tidal marsh, uplands, and non-tidal wetlands.

Average local temperature for the area varies from 45 degrees Fahrenheit in January to 75 degrees Fahrenheit in August. The record low of 16 degrees Fahrenheit was recorded in December 1972. The average frost season is about 100 days. The mean precipitation for the area is 14 inches per year. Approximately 84 percent of the rainfall occurs from November to March. Warm, dry summers and moderate rainy winters are the normal weather trend for this area (PRC 1993b, 1993c).

San Francisco Bay and the Carquinez Strait form a wind gap, through which the prevailing winds blow in a westerly direction. This results in a significant influence to the area's microclimate by the Pacific Ocean and Suisun Bay. The westerly winds are most predominant in the summer months and minimal from November through February. A high-pressure ridge carrying high temperatures can occur in the late spring and summer months. Mean wind velocities average 12 miles per hour 65

percent of the time in a southwesterly to west-northwesterly direction. The area has periodic inversions which cause an increase in ambient temperature with altitude.

2.2 SITE HISTORY

This section provides information on the past use of the land at the Litigation Area, designation of the RASSs, and the status of the remediation.

2.2.1 Past Use

According to the initial assessment study (IAS) (E&E 1983), the marsh areas at WPNSTA Concord have undergone dramatic change in the past century. Industrial development around 1939 spurred the drainage of over 400 acres of tidal wetlands bounded by Suisun Bay and the town of Port Chicago. Tidal flows were controlled by ditches within and adjacent to the Tidal Area, and the undeveloped wetlands were cut by natural, meandering channels.

Aerial photographs taken in 1959 show additional loss of marsh area due to drainage. From the mid 1970s to the mid 1990s, an additional 25 percent of the marsh was altered for the expansion of administrative and industrial facilities, including the construction of a new magazine to hold munitions.

2.2.2 RASS Designations

The four sites under investigation in the Litigation Area are designated RASSs 1, 2, 3, and 4 (Figure 2). The RASSs include 6 of the 25 sites identified in the IAS (E&E 1983):

Remedial Action Subsite	IAS Site Number	Study Location
1	Sites 4 and 5	Allied Site A and Allied Site B
2	Site 3	Kiln Site, ES Area
3	Sites 25 and 26	K-2 Area and G-1 Area
4	Site 6	Coke Pile Site

During the feasibility study (Cullinane 1988), each RASS was divided into three areas according to the type of remediation required: active, passive, and monitoring. The active and passive remediation areas are those areas determined to be contaminated based on exceedance of total/soluble threshold limit criteria (TTLC/STLC) for one to six of the following metals: arsenic, cadmium, copper, lead, selenium, and zinc. These criteria were developed as screening values for land disposal of contaminated sediment (California Code of Regulations Title 22). Additional portions of each RASS area, bordering the active and passive areas but determined not to be contaminated, were designated the monitoring areas. As part of the remediation process, contaminated soils within the active remediation areas were removed (see Section 2.2.3 for additional details regarding the status of these removals). Although the passive remediation areas were contaminated, soils were not excavated because, as expressed in their Biological Opinion, the U.S. Fish and Wildlife Service (USFWS) was concerned that extending the active remediation into the passive areas would be more destructive to the marsh than actually leaving the contamination in place (USFWS 1988). The monitoring areas were to be observed and monitored for signs of migration of contaminants back into the active remediation areas and from the passive remediation areas to off-site locations.

2.2.3 Status of Remediation

Excavation of contaminated soils in each active remediation area was completed in RASS 4 by June 1994, completed in RASS 3 by July 1994, and completed in RASSs 1 and 2 in November 1994. The active remediation area of RASS 4 was excavated to an average depth of 12 inches, and the remaining soil was graded to restore natural elevations before being revegetated with common cattail (*Typha latifolia*), common tule (*Scirpus acutus*), coyote brush (*Baccharis pilularis*), and grasses (Gramineae spp.). Excavation of the active remediation area of RASS 3 was completed to an average depth of 18 inches; this area was graded in a manner similar to RASS 4, and revegetated with several grasses, including purple stipa (*Stipa pulchra*), California brome (*Bromus carinatus*), California fescue (*Festuca californica*), and wild rye (*Elymus glaucus*). Excavation of the active remediation areas of RASS 1 and RASS 2 was completed to an average depth of about 18 inches in mid-November, 1994. RASSs 1 and 2 were backfilled with material from the Martinez dredge spoil ponds and graded to restore natural elevations; revegetation with pickleweed (*Salicornia virginica*), fat hen (*Atriplex patula hastata*), alkali heath (*Frankenia grandifolia*), beardless wildrye (*Elymus triticoides*), California brome, coyote brush, meadow barley, and purple stipa will proceed through the spring of 1995.

2.2.4 Habitat Designations in the Litigation Area

While the RASS designations were useful during remediation, they have no inherent ecological significance. Although this work plan will refer to RASS areas when appropriate, the QEA is dependent on a description of habitat and ecological receptors exposed to contaminants left in place after remediation, and is organized according to the three habitat types found in the Litigation Area: tidal marsh, uplands, and non-tidal wetlands. Each RASS contains at least two habitat types.

A map delineating habitat boundaries is presented in the FSP (PRC 1995a). The habitat map is based on vegetation maps (PRC 1994a) and visual verification during reconnaissance visits. Much of the preliminary information discussed in this workplan was collected and identified by RASS designations, not by habitat. Future ecological data collection efforts will be focused on habitats, with RASS designations included only for clarity and continuity. The correspondence of RASS to habitat is illustrated below:

Litigation Area RASS/ Reference Designation[1]	Habitat Types
RASS 1	Marsh, Upland
RASS 2	Marsh, Upland
RASS 3	Upland, Pond
RASS 4	Upland, Non-tidal Wetland
Reference 1	Upland
Reference 2	Marsh

1 Active, Passive, and Monitoring remediation activities occur in portions of all RASS in the Litigation Area. Remediation activities are not currently being conducted at either reference site.

2.3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Applicable or relevant and appropriate requirements (ARAR) for the Litigation Area at WPNSTA Concord were discussed with the regulatory agencies at the time the record of decision (ROD) for the Litigation Area was issued by the Navy April 6, 1989. A list of ARARs is provided in the feasibility study report (Cullinane 1988) and is considered to be current. The Navy is in the process of contacting the California Department of Toxic Substances Control to determine if any additions or amendments to the list of ARARs should be considered at this time.

2.4 PHYSIOGRAPHY

The installation originally comprised three distinct land formations: the tidal wetlands along the margin of Suisun Bay (Figure 1), the upland colluvial slope, and the sandstone hills. The area to the south of Contra Costa Canal is characterized by steeply sloping terrain, beginning at the 100-foot elevation and rising to more than 600 feet. The hills are composed of soft sandstone (PRC 1993d).

Due to several northwest tending fault systems, Contra Costa County is divided into large blocks of rocks, including upthrown blocks which form the hills and downthrown blocks which form the broad lowlands floored with thick, unconsolidated Pleistocene-age alluvial sediments eroded from the upthrown blocks. The major active faults in the county are the Antioch, Clayton, Concord, and Pleasanton (PRC 1993d).

2.5 HYDROLOGY

The hydrology of the area is addressed in the following sections on surface water, groundwater, tides, and seasonal changes.

2.5.1 Surface Water

WPNSTA Concord lies approximately 10 miles west of the confluence of the Sacramento and San Joaquin Rivers, which form the Delta Region that drains over 5,000 square miles of the northern central valley. Runoff from WPNSTA Concord drains almost exclusively to the north into Suisun

Bay. Surface water, stored off-site and piped on-site by the Contra Costa Water District, is the source of potable water at WPNSTA Concord.

The Litigation Area lies within the Mount Diablo-Seal Creek Watershed, which has a drainage area of approximately 36 square miles. This watershed is bounded to the north by Suisun Bay and to the south by Mount Diablo's northern peak. It is drained by streams with headwaters on the slopes of Mount Diablo that flow via Mount Diablo Creek through Clayton Valley into Suisun Bay (PRC 1993b, 1993d).

2.5.2 Groundwater

Groundwater is used for agricultural purposes and intermittently for augmenting water resources to wildlife residing on the installation such as the tule elk (*Cervus elaphus nannodes*). The groundwater in the Tidal Area is considered hard and contains high levels of total dissolved solids, chlorides, and iron.

2.5.3 Tides

Suisun Bay averages 14 feet deep and has a tidal range of 4.3 feet. Tides affect the conditions for aquatic organisms at WPNSTA Concord as they alternately accelerate or slow the seaward motion of fresh water. A dredged channel runs through the middle of Suisun Bay.

Winter high tides and heavy rains completely inundate RASS 1, with water from Suisun Bay travelling up the sloughs and mosquito abatement ditches. Parts of RASS 2 are also regularly flooded by tidal flow. The pond in RASS 3, created by excavation during the summer of 1994, appears to be under tidal influence; PRC observed water flowing into the northwest corner of the pond via a channel under the railroad trestle during a field reconnaissance survey in winter 1994 (PRC 1995b).

2.5.4 Seasonal Changes

In winter and during heavy rain, much of the marsh itself is inundated. Additionally, high tides cover much of RASS 1 and 2, occasionally forming ponds in the marsh when the tide recedes. In the

summer, the tides infrequently inundate the marsh and little standing water remains, as tidal flow is mostly restricted to channels through the marsh.

The pattern of tidal flow in and out of RASS 3 is expected to be different this winter due to the recent remedial excavation activity that has created a new pond. The flow in this area will be monitored for its overall effect on the tidal prism of the marsh.

CHAPTER 3
ECOLOGICAL CHARACTERIZATION

This chapter characterizes the ecology of the Litigation Area, including habitat types and typical species, special species status, trophic linkages among species, seasonality in use of habitats, and linkages among habitats.

3.1 HABITAT TYPES AND TYPICAL SPECIES

This section describes the three predominant habitats at the Litigation Area (tidal marsh, uplands, and non-tidal wetlands) and identifies some plants and animals commonly occurring in these habitats. Taxa expected to be present at the site are listed in Appendices A-1 through A-5. Throughout the QEA, emphasis will be on habitats rather than RASS designations. This QEA includes habitat area previously designated active, passive, and monitoring, and also includes previously uncharacterized areas in all four RASSs.

3.1.1 Tidal Marsh

Before the Gold Rush of 1849, 544,000 acres of marshlands covered almost two-thirds of the San Francisco Bay estuary (Cohen and Laws 1991). Today, most of the estuary's tidal marshes, about 10,682 acres, representing 12 percent of California's remaining wetlands, are in the northern portion of Suisun Bay (Monroe and others 1992) and are diked off from the tides. Elsewhere in Suisun Bay, 160,000 acres of diked wetlands provide a variety of habitats: fresh-water ponds and lagoons, non-tidal brackish and salt marshes, and seasonal wetlands.

Suisun Bay tidal marshes are influenced by four significant hydrological factors (Lee and others 1986).

- The parallel orientation of the drainage pattern to the shoreline allows wave action to build up sediment and debris at a higher elevation along the shoreline than along the plain and creates indirect drainage of tidal waters to Suisun Bay.
- Sea level is rising at the rate of 0.5 foot per 100 years.

- Hydraulic mining in the Sierra Nevada during the last 100 years increased the flow of sediments to the bay system and subsequent shoaling and filling of intertidal areas.

- Increased grazing in adjacent upland areas caused sediment influx to the marsh of WPNSTA Concord.

The wetlands in the northern part of the region along Suisun Bay are underlain by estuarine and riverine deposits. The wetlands and adjacent uplands at WPNSTA Concord are formed from alluvium of three different ages and modes of deposition. The terrace remnants of Pleistocene alluvial fans and floodplain deposits consist of irregularly interstratified sand, gravel, silt, and clay (MMES 1993). The Pleistocene deposits are overlain by Holocene floodplain deposits consisting of irregularly interstratified sand, silt, gravel, and clay. These deposits are overlain at the bay margin by bay mud, consisting of unconsolidated silt and clay with admixed organic material. The Pleistocene and Holocene alluvial deposits are up to 500 feet thick and make up a locally important aquifer with highly variable permeability. According to the National Cooperative Soil Survey, the wetland soils are acidic clastic, euic, and thermic *Terric Medisaprists* (MMES 1993).

Permanent or semi-permanent surface water in the Litigation Area is limited to the slough channels and ditches of the marsh areas, and small ponds or wetlands in RASS 3 and 4. During high tide, especially in winter, much of the marsh is inundated by Suisun Bay. Nichols Creek flows through the upland habitat of RASS 3 and along the western boundary of RASS 2 to Middle Point Marsh. Pier 4 Slough lies along the western boundary of RASS 1. The marsh in the Litigation Area has a relatively low density of tributary slough channels (Waterways Experiment Station [WES] and IT Corporation 1986). The first alteration of tidal drainage occurred sometime after 1888, and probably in the early 20th century (Lee and others 1986). Channels were dredged southward from the shoreline, and the naturally occurring slough channels connected to these. This action probably increased tidal action in the marsh, resulting in higher highs and lower lows of the tidal range. Until 1959, the local mosquito abatement district excavated a network of ditches in Middle Point Marsh in RASS 1 for mosquito control (PRC 1994c).

Although debris and sediment has built up the shoreline relative to the elevation of the rest of the marshy plain (Lee and others 1986), extreme tides caused by the superimposition of storm surges on

normal high tides can cover the marsh area in winter months. A 10-year high tide will flood the marsh plain at WPNSTA Concord to depths of about 2.5 feet.

Vegetation in the brackish tidal marshes of the San Francisco Bay Area typically includes pickleweed, saltgrass (*Distichlis spicata var.*), fat hen, marsh gum plant (*Grindelia humilis*), alkali bulrush (*Scirpus robustus*), and California bulrush (*Scirpus californicus*) (Cohen and Laws 1991). Typical plant species in the marsh habitat in the Litigation Area include all these except alkali and California bulrush (Harvey 1992a). Other species include peppergrass (*Lepidium latifolium*), Baltic rush (*Juncus balticus*), Olney bulrush (*Scirpus olneyi*), jaumea (*Jaumea carnosa*), ripgut grass (*Bromus diandrus*), perennial ryegrass (*Lolium perenne*), and sow thistle (*Sonchus oleraceus*) (Harvey 1992a). The shoreline marsh reference area used during the monitoring activities is west of the Litigation Area (Figure 2). Typical vegetation in the marsh reference area includes peppergrass, pickleweed, saltgrass, fat hen, marsh gum plant, common rush (*Juncus effusus var. pacificus*), cattail (*Typha latifolia*), and arrow grass (*Triglochin maritima*) (Harvey 1992a). A complete list of plants reported to occur at WPNSTA Concord is in Appendix A-1. Additional information on the tidal marsh habitats at the Litigation Area is found in O'Neil (1988).

The typical invertebrates in the sediments of the marsh areas include four oligochaetes, two amphipods, several species of clams, more than 50 families of insects, two groups of chilopods, one group of diplopods, and three groups of arachnids. Invertebrates reported to occur at WPNSTA Concord are listed in Appendix A-2.

The marsh provides habitat for more than 100 species of birds. Typical species include pied-billed grebe (*Polydimbus podiceps*), great blue heron (*Ardea herodias*), black-necked stilt (*Himantopus mexicanus*), long-billed dowitcher (*Limnodromus scolopaceus*), common snipe (*Gallinago gallinago*), bufflehead (*Bucephala albeola*), mallard (*Anas platyrhnchos*), white-tailed kite (*Elanus caerulens*), northern harrier (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), and American kestrel (*Falco sparverious*) (Audubon Society 1994). A complete list of birds expected to occur at WPNSTA Concord is provided in Appendix A-4.

Mammals common in the marshes of the Litigation Area include small herbivores such as the salt marsh harvest mouse (*Reithrodontomys raviventris*) and California vole (*Microtus californicus*), as

well as their predators, the native gray fox (*Urocyon cinereoargenteus*) and the introduced red fox (*Vulpes vulpes*). Mammals occurring at WPNSTA Concord are presented in Appendix A-5.

Many of the rare and endangered species near the WPNSTA Concord marsh are dependent on or found only in specific wetland habitats; these include the California black rail (*Laterallus jamaicensis coturniculus*), salt marsh harvest mouse, and Suisun song sparrow (*Melospiza melodia maxillaris*), found in pickleweed; Suisun ornate shrew (*Sorex ornatus*) and several species of rare plants, found in brackish marsh; salt marsh yellowthroat (*Geothlypis trichas sinuosa*), which nests in freshwater marsh and winters in salt marsh; and giant garter snake (*Thamnophis gigas*), an aquatic snake that breeds in riparian areas (Harvey 1991). At least seven rare plants, all candidates for federal endangered status, have been found in the brackish marsh of Suisun Bay: soft bird's beak (*Cordylanthus mollis ssp. mollis*), north coast and hispid bird's beak (*Cordylanthus mollis spp. hispidus*), Mason's lilaeopsis (*Lilaeopsis masonii*), Delta tule pea (*Lathyrus jepsonii var.*), Suisun thistle (*Circium hydrophilum var. hydrophilum*), and Suisun aster (*Aster lentus*) (Cohen and Laws1991).

3.1.2 Uplands

Wetlands gradually change to uplands within a transition zone. The well-drained uplands comprise the majority of the lands surrounding the San Francisco Bay. The upland habitats vary from the grasslands along the estuary's edge to the evergreen redwood forests on the wetter slopes. Uplands may influence the quality of adjacent wetlands by providing a buffer from human disturbance. Uplands within the estuary system include grassland, coastal scrub, mixed chaparral, oak woodland, broad-leaved evergreen forest, agricultural land, and urban land (Monroe and others 1992).

Two types of uplands occur in the Litigation Area: grassland and coastal shrub. Generally, grasslands occur on coastal terraces, foothills, ridges, south-facing slopes, and on the open lands around the delta. Grasslands are dominated by both annual and perennial grasses and forbs. Most of the grasses that occur in the estuary basin are exotic species from Europe and Australia (Monroe and others 1992). Coastal scrub, found on coastal terraces and slopes, is dominated by dense stands of low evergreen and deciduous shrubs. Scrub typically consists of coyote brush and a lower canopy of shrubs, herbs, and ferns, which are sometimes interspersed by patches of grasses.

Only a small portion of RASS 1 is upland habitat. The small upland area on RASS 1 is composed almost entirely of ripgut grass, perennial ryegrass, and Barnaby's star thistle (*Centaurea solsititalis*) (Harvey 1992a). More than half of RASS 2 and most of RASS 3 is upland; RASS 2 has a mixture of pickleweed, fat hen, alkali heath, beardless wildrye, meadow barley (*Hordeum brachyantherum*), salt grass, and perennial rye grass, while RASS 3 remains dominated by a mixture of upland grasses: oatgrass (*Avena fatua*), ripgut grass, rattail fescue (*Vulpia myuros*), and bindweed (*Conveolvulus arvensis*) (Harvey 1992a).

Most of RASS 4 is upland, including grassland and coastal shrub habitats (Harvey 1989). Prior to remediation, RASS 4 was characterized by ripgut grass and Barnaby's star thistle. After excavation of the active area of RASS 4, the uplands were replanted with coyote brush, California brome, purple stipa, California fescue, and wildrye (*Elymus glaucus*). Other upland plants at RASS 4 include oatgrass, perennial ryegrass, and rattail fescue (Harvey 1992a). Reference area 1, located along Nichols Creek, is entirely upland, dominated by perennial ryegrass and Mediterranean barley (*Hordeum marinum ssp. gussoneanum*) (Harvey 1991). Other important species in the upland reference area include soft chess (*Bromus mollis*), ripgut grass, oatgrass, and Barnaby's star thistle. Additional information on the upland habitats in the Litigation Area is in O'Neil (1988) and a complete list of plants reported to occur at WPNSTA Concord is in Appendix A-1.

Large soil invertebrates such as earthworms are probably uncommon in the uplands, because of the dry conditions that prevail during much of the year. Most insects and arachnids in the uplands occupy the vegetation and ground litter. Invertebrates reported to occur at WPNSTA Concord are listed in Appendix A-2.

Reptiles at WPNSTA Concord are most common in the uplands. Typical species include the western fence lizard (*Scelopurus occidentalis*), giant garter snake, and the Pacific gopher snake (*Pituophis melanoleucus catenifer*). Appendix A-3 lists reptiles and amphibians occurring at WPNSTA Concord. Common upland birds include the mourning dove (*Zenaida macroura*), Anna's hummingbird (*Calipte anna*), northern flicker (*Colaptes auratus*), black phoebe (*Sayornis nigricans*), loggerhead shrike (*Lanius ludovicianus*), yellow-rumped warbler (*Dendrioca coronata*), common yellowthroat (*Geothylpis trichas*), sparrows, and other passerines (Audubon Society 1994). Most of the raptors move between the marsh and upland habitats as they forage and nest. A complete list of birds

expected to occur at WPNSTA Concord is provided in Appendix A-4. The California vole, gray fox, and red fox are found in the upland as well as in the marsh habitat (Appendix A-5).

3.1.3 Non-tidal Wetland

The non-tidal wetlands at the Litigation Area consist of a riparian wetland surrounding Nichols Creek in RASS 3, the newly created pond in RASS 3, and a wetland in RASS 4. Although the pond in RASS 3 was observed to be influenced by tidal action during high tide in December, 1994, it is not expected to retain this connection during most of the year. Because this is a newly created habitat, its hydrology and ecology are not easily characterized by casual observation. The long-term monitoring plan for RASS 3 will address the role of the new pond in the ecology of the area.

The Nichols Creek area represents a thin riparian strip in RASS 3. Principal species in this riparian area are cattail, giant reed (*Arundo donax*), and willow (*Salix lasiandra*) (Harvey 1992a). The pond area in RASS 3 has not been actively revegetated and appears to be influenced by groundwater, input from Nichols Creek, and possibly tides. The new pond has a few small stands of cattails (PRC 1995b). Amphipods, stickleback (*Gasterosteus aculeatus*), and mosquito fish (*Gambusia affinis*) have been observed in this pond, and sandpipers and other shorebirds feed in the shallow margins.

The small emergent marsh at RASS 4 was revegetated with common cattails, common tule and saltgrass. Meadow barley, wildrye, and pickleweed also occur in the RASS 4 wetland (Harvey 1989, 1992a). These plants provide food and habitat for insects, small mammals, and birds such as red-wing blackbirds (*Agelaius pheoniceus*).

Since the RASS 3 and 4 non-tidal wetlands were created or modified in 1994, there has been little time for colonization; the abundance and nature of potential receptors is likely to change. The RASS 3 pond is used by waterfowl during the spring. On a recent site visit by PRC and H.T. Harvey on May 12, 1995, a mallard's nest containing 9 eggs was found in vegetation approximately two feet from the pond's edge. Small mammals live adjacent to these non-tidal wetlands and raptors and other higher level predators likely feed over and around these areas. Additional characterization of the physio-chemical parameters and ecology of these habitats is necessary to accurately identify the species using them.

3.2 SPECIAL STATUS SPECIES

Thirty-four species of special conservation concern, including listed and candidate species, are known or thought to occur at WPNSTA Concord (Table 1). Not all of these species have been confirmed in the Litigation Area. These species, including 7 plant species, two invertebrates, and 25 vertebrates, and their presence at WPNSTA Concord, are discussed below.

Two of the seven candidate plant species have been found at the WPNSTA Concord Litigation Area sites. The Delta tule pea, which occurs in brackish tidal marshes and swamps, was observed in the marsh reference area (Harvey 1992a). Soft bird's beak is found in coastal salt marshes and swamps in brackish Tidal Areas characterized by infrequent, brief inundation, and was reported in RASS 1 at five locations (Harvey 1992a). Mason's lilaeopsis grows on low, stable, wet banks of the bay and lower delta in brackish water with frequent tidal inundation, and was found at RASS 1 and the marsh reference area (Harvey 1992a). The Suisun marsh aster (*Aster chilensis* var. *lentus*), a California special plant, is native to brackish and freshwater marshes, growing along tidal streams among tules. However, Harvey (1992a) did not report its occurrence in the Litigation Area. Other plants of special concern that may occur in the Litigation Area but have not been sighted include the Contra Costa goldfields (*Lasthenia conjugens*), Suisun thistle, and Gairdner's yampah (*Perideridia gairdneri*).

Two invertebrates, the curve-footed diving beetle (*Hygrotus curvipes*) and the San Francisco fork-tailed damsel fly (*Ischnura gemina*), are reported to occur in the area around the installation (PRC 1993b, 1993c). Neither of these species has yet been observed in the Litigation Area.

Of the 25 special status vertebrates with potentially suitable habitats in the Litigation Area, not all have been recorded at the site. Suisun Bay is habitat to the federally threatened winter-run Chinook salmon (*Oncorhynchus tshawytscha*) and the federally threatened delta smelt (*Hypomesus transpacificus*). However, the QEA at the Litigation Areas at WPNSTA Concord does not extend to the offshore waters of Suisun Bay. The California silvery legless lizard (*Anniella pulchra pulchra*) has not been observed at WPNSTA Concord, but suitable habitat is available. The California tiger salamander (*Ambystoma californiense*) is widespread at the installation. The California red-legged frog (*Rana aurora*) has been introduced onto the installation but has not been observed in the Litigation Area.

Avian species include both yearlong residents and seasonal migrants. The federally endangered California clapper rail (*Rallus longirostris obsoletus*) was observed at WPNSTA Concord by O'Neil (1988). However, Harvey (1992c) did not report its occurrence a few years later. The habitat in the Litigation Area is not optimal for clapper rails due to reduced tidal action and scarce cordgrass habitat; however, clapper rails from adjacent habitats may use the site. California black rails (*Laterallus jamaicensis coturniculus*) are known to inhabit Tidal Areas in RASS 1 and the Hastings Slough area. Seventeen black rails were sighted in the marsh in 1991 (Harvey 1992c). The tricolored blackbird (*Agelaius triclor*) is a federal candidate species, and at least one breeding colony is present in the nearby Peyton Slough/Shell Marsh area (PRC 1993b, 1993c).

Rare avian visitors to the area include the federally endangered American peregrine falcon (*Falco peregrinus*), bald eagle (*Haliaetus leucocephalus*), and California brown pelican (*Pelecanus occidentalis californicus*). The short-eared owl (*Asio flammeus*) has been sighted occasionally in the salt marshes at WPNSTA Concord (Jones and Stokes 1982). The burrowing owl (*Athene cunicularia*) was also noted by Jones and Stokes (1982) as occurring in the grasslands.

The salt marsh harvest mouse has been found in the marsh habitat and the marsh reference area (Harvey 1992d). No other threatened and endangered mammals are reported to occur in the Litigation Area.

3.3 TROPHIC LINKAGES AMONG SPECIES

Food webs for both coastal marsh and upland habitats (Figures 3 and 4) were developed based on existing data on species occurrence and natural history. Both food webs consist of several trophic levels with decaying organic matter and primary producers at the base. The marsh food web contains both terrestrial and aquatic species. Marsh plants, like pickleweed and algae, and decaying organic matter are consumed by aquatic and terrestrial herbivorous invertebrates, including benthic clams, amphipods, and insects and oligochaetes. Marsh plants are also consumed by terrestrial herbivorous and omnivorous birds and mammals, such as the western meadowlark (*Sturnella neglecta*), Suisun song sparrow, salt marsh harvest mouse, and deer mouse (*Peromyscus maniculatus*). Shorebirds, waterfowl, and fish in the marsh consume benthic invertebrates. Other marsh invertebrates are eaten by passerines, other land birds, and some small rodents. Top predators of the food web include both

terrestrial and aquatic species. Raptors, like the American kestrel and northern harrier, and carnivorous mammals, like foxes, prey on small mammals in the marsh, such as the California vole and the salt marsh harvest mouse. The peregrine falcon preys principally on avian species such as shorebirds and passerines (Bell 1994). Wading birds (heron and egret) also are a major marsh-feeding guild (a group of species having similar foraging strategies) consuming benthic fish (sculpins and gobies) and small mammals.

Feeding guilds in the upland habitat parallel those in the marsh, and several species move between the two habitats. For example, many of the top carnivores, such as raptors and foxes, forage both in the marsh and upland habitats, feeding on small rodents and terrestrial birds, as well as amphibians and reptiles. The upland habitat also supports herbivorous mammals like the black-tailed jackrabbit and mule deer and a terrestrial invertebrate community that includes omnivorous insects, arachnids, and oligochaetes.

A food web for the non-tidal wetlands in RASSs 3 and 4 has not yet been generated due to limited information on the use of this habitat. Following reconnaissance activities, a food web will be developed and it will be determined if any additions to the basic sampling strategy are required to adequately characterize receptors and toxicity in the non-tidal wetland habitat. If the pond in RASS 3 becomes fresh during summer months, flying insects such as dragonflies, damselflies, and beetles are expected to breed in it, and terrestrial birds and mammals may use it for drinking water. If the pond retains a tidal connection and is brackish all year, the species composition will probably not differ substantially from that of the surrounding marsh/upland ecotone.

3.4 SEASONALITY IN USE OF HABITATS

Typically, yearlong residents of the coastal marshes of Suisun Bay include the great blue heron, northern harrier, red-shouldered hawk (*Buteo lineatus*), American kestrel, California black rail, salt marsh common yellowthroat, and Suisun song sparrow (Zeiner and others 1990). In winter a variety of migratory waterfowl, including Canada goose (*Branta canadensis*), diving and dabbling ducks such as teals, mallards, wigeons, shovelers, canvasbacks, scaup, and buffleheads, use the inundated portions of the marsh and non-tidal wetland habitats as well as the coastal embayments along Suisun Bay (USFWS 1994). The winter season also brings shorebirds and waterbirds such as sandpipers,

plovers, dowitchers, grebes, and loons to feed in the tidal mudflats and sloughs at the Litigation Area. Cogswell and Christman (1977) report Barrow's goldeneye (*Bucephala islandica*) to be fairly common from late October to March in central and northern California, but it is not common at the Litigation Area (USFWS 1994, Audubon Society 1994). Brown and others (1986) report that the peregrine falcon is a migrant and winter visitor near marshlands, grasslands, and inland cliffs. However, Zeiner and others (1990) report the peregrine to be uncommon as a migrant. Populations of the peregrine falcon residing in the bay area are expected to remain in the area year round (Bell and others 1994, PRC 1994d).

The salt marsh harvest mouse remains in the marsh all year. However, its movement from the marsh into the uplands is seasonal. The Suisun Bay population of the salt marsh harvest mouse is expected to use exclusively the marsh until early spring, when the cover in the grasslands is thick (Fisler 1965). Then, the salt marsh harvest mouse may range into the grasslands. During December and January, tides are highest during the day, and the salt marsh harvest mouse may be more exposed to predation by hawks, gulls, owls, and other predators than when high tides occur during the night (Fisler 1965).

3.5 LINKAGES AMONG HABITATS

The food webs for the marsh and upland habitats, Figures 3 and 4, respectively, depict linkages between these habitats formed by several common feeding guilds. Herbivorous/granivorous birds such as the western meadowlark are expected to feed in both habitats. Omnivorous mammals, such as the deer mouse, house mouse, and grey fox, are important in both habitats. Insectivorous mammals and birds move between habitats based on seasonal and tidal cycles. Predators forage in marsh, non-tidal wetland, and upland habitats. Peregrine falcons and red-shouldered hawks consume both shorebirds and land birds like doves and passerines (Bell 1994). Red-shouldered hawks also prey on small mammals. Similarly, the northern harrier may feed on salt marsh harvest mice in the marsh, in addition to preying on upland rodents, birds, and lizards. The movement of predators and prey within and between habitats as an agent of contaminant migration is discussed in Chapter 9.

CHAPTER 4
TOXICITY CHARACTERIZATION

4.1 CONTAMINANTS OF POTENTIAL CONCERN

The goal of the qualitative ecological risk assessment is to estimate the probability that plant and animal receptors will be adversely affected by contaminants. Until the risk assessment is complete, substances are designated COPCs. The majority of preliminary data available for the Litigation Areas are concentrations of heavy metals, specifically arsenic, cadmium, copper, lead, selenium, and zinc. Limited data on the potential for contamination of these sites by organic contaminants were collected during an earlier investigation (PRC 1994a, 1994b). Existing data for metals and organic compounds are summarized in the following sections. Section 4.1.1 reviews chemical data for surface soil, subsurface soil, sediment, groundwater, and surface water. The presence of other COPCs is discussed in Section 4.1.2. Data gaps are presented in Section 4.1.3.

4.1.1 Existing Data on Chemical Contamination

In 1991, PRC developed the site monitoring protocol (PRC 1991) to implement the monitoring plan for the Litigation Area (Lee and others 1989). This sampling program included the four RASSs and two reference areas. The initial sampling conducted under this program established baseline conditions for the passive and monitoring areas of RASSs 1, 2, 3, 4, and the upland and marsh reference areas. These areas were sampled based on a 100-foot grid system. Each 100-foot grid was further subdivided into 5-foot-square quadrants from which one quadrant was randomly selected. Triplicate samples were taken from within this quadrant. Samples of surface soils, subsurface soils, sediment, surface water, and groundwater were analyzed for six metals. The results are presented in the BCR (PRC 1994a) and outlined below.

Previous RI/FS sampling efforts at the Litigation Area focused on six metals (arsenic, cadmium, copper, lead, selenium, and zinc) because of the known releases of these metals onto Navy property. Virtually all existing chemical data from the Litigation Area is limited to these six metals. The existing data on the total concentrations of these metals, along with incidental data on other contaminants in surface and subsurface soils, sediment, groundwater, and surface water, are detailed

below. Proposed criteria used to compare total chemistry data for sediment and surface water during data analysis are presented in Table 2.

Surface Soils

Surficial soils in the passive and active areas contained levels of arsenic, cadmium, copper, lead, selenium, and zinc exceeding TTLC/STLC. The TTLC/STLC values are used by the State of California to classify solids destined for landfills, based on the total and leachable concentrations of contaminants. These criteria are not generally used to evaluate ecological risk; more appropriate criteria will be used in subsequent analyses. For the preliminary assessment of existing data, effects data are used as a basis of comparison to environmental concentrations. For this preliminary screening, National Oceanic Atmospheric Administration's (NOAA) effects range-low (ER-L) and effects range-median (ER-M) were used.

NOAA-established ER-Ls and ER-Ms are sediment concentrations reported in the NOAA Technical Memorandum entitled "An Evaluation of the Extent and Magnitude of Biological Effects Associated with Chemical Contaminants in San Francisco Bay, California" (Long and Markel 1992). The ER-L is the chemical concentration above which adverse biological effects may be expected at least 10 percent of the time. The ER-M is the chemical concentration above which adverse biological effects may be expected at least 50 percent of the time. Adverse biological effects include mortality or sublethal effects (for example, reduced growth or reproduction success).

The data on surface soil chemistry from the BCR (PRC 1994a) are summarized in Figure 5 (a-f). Mean concentrations (standard errors) and ranges of values for the six metals overlap between the passive and monitoring areas in many of RASS locations; this limits the usefulness of the passive and monitoring designations. Therefore, the designation of passive and monitoring areas will not be maintained in the ecological assessment. Rather, all areas outside of the actively remediated zones will be considered potentially contaminated and enough samples will be taken to adequately characterize the area in each RASS outside the active areas. Continued sampling of the active areas under the SMP will allow an assessment of risk associated with these sites.

Hydrocarbons were detected during the course of remedial activities at RASS 3, and the scope of work was revised to define the extent of hydrocarbon contamination. PRC performed a hydrocarbon investigation in soils at RASS 3 (PRC 1993a) and found up to 8,900 parts per million (ppm) total petroleum hydrocarbons (TPH) as motor oil; 4,200 ppm TPH as diesel; 2,800 ppm TPH as gasoline; and minor amounts of benzene, toluene, ethylbenzene, and total xylenes (up to 0.2, 0.2, 4.4, and 13.0 ppm, respectively). Volatile organic compounds (VOC) detected included acetone, methylene chloride, butanone, and several fuel additives. These hydrocarbons are thought to be the result of spills or leaks from oil lines or from the Getty oil pumping facility that previously operated in RASS 3.

Subsurface Soils

Sampling to determine the nature and vertical extent of contamination in the subsurface soil has occurred in active areas as part of the remediation actions, and in the monitoring areas as part of the monitoring activities. Before and during the remediation process, these areas were sampled to depths up to 5.5 feet. Data from the active remediation areas of RASSs 1, 2, and 3 are summarized in Table 3 (a-c) as mean, standard deviation, and ranges of concentrations found during the remediation process using both the waste extraction test (WET) and total chemistry. Data for RASS 4 have not yet been summarized. Not all metals were analyzed at all soil horizons. For those metals for which data are available, mean concentrations generally remain very high (compared to ER-L values) down to 3 feet below ground surface (bgs).

Sediment

Data on bulk chemistry in sediment from the BCR (PRC 1994a) collected in the sloughs and pans with standing water are limited. Mean concentrations of metals found at each RASS are summarized in Figure 6 (a-d); ranges of location means are listed in Table 4. The 95 percent upper confidence limit (95% UCL) of the data concentration means will be compared to appropriate criteria in consultation with regulatory agencies. Based on descriptive plots of mean sediment values from limited data for the RASS and reference sites, RASS 1 has high levels of zinc, copper, and cadmium compared to the ER-L values. RASS 2 has high levels of zinc and arsenic compared to ER-L values. RASS 3 has high levels of lead, zinc, and cadmium; and RASS 4 has high levels of lead and

selenium. Additional sampling in sloughs, ditches, and ponds is necessary to better characterize sediment chemical levels.

Groundwater

Limited samples of groundwater and surface water were collected in 1989; chromium, mercury, nickel, and silver, in addition to the six COPC metals, were detected in the groundwater at the Litigation Area (MMES 1993). Some VOC and semivolatile organic compounds (SVOC) were also detected in groundwater (MMES 1993). Organic compounds detected included 1,1,1-trichloroethane, 1,1-dichloroethane, methylene chloride, acetone, phenol, and bis(2-ethylhexyl)phthalate, di-n-octylphthalate, and bromoform. Because the analytical laboratory exceeded the holding times on numerous occasions, these data are considered unvalidated. They are presented here only for purposes of completeness. Additional groundwater data are available from the monitoring activities in the RASSs (PRC 1994e).

Surface Water

Surface water samples collected from RASS 1, 2, and 4 contained elevated concentrations of some metals (MMES 1993); again, these data are considered unvalidated because the holding times were exceeded on numerous occasions. Data on concentrations of the six metals in surface water were collected as a part of the baseline monitoring (PRC 1994a). Mean concentrations of the six metals in surface water are summarized in Figure 7 (a-d). Ranges are listed for each metal in Table 4. The 95% UCL of the data concentration means will be compared to appropriate criteria in consultation with regulatory agencies. Arsenic, copper, cadmium, zinc, and lead concentrations are high at most RASSs when compared to marine ambient water quality criteria (AWQC) (Figure 7a-d); however, sample sizes were limited. Selenium appears elevated at all RASSs compared to the AWQC values. Additional information is needed on metal and organic contamination in the newly created pond in RASS 3 and other areas with significant standing water such as the major sloughs.

4.1.2 Other COPCs

Whether other contaminants occur in the Litigation Area is not known due to limited sampling. The potential for organic contamination by mosquito abatement activities and operations of adjacent chemical companies was investigated and is described below.

Mosquito Abatement Activities

Since 1926, the Contra Costa Mosquito and Vector Control District (CCMVCD) has implemented a variety of mosquito control practices at WPNSTA Concord (PRC 1994c). The greatest emphasis at this site has been hydraulic manipulation of marsh areas by cutting ditches. Most of the ditches were dug between 1928 and the late 1940s. Maintenance of the ditches continued until 1978 (PRC 1994c).

CCMVCD sprayed dichlorodiphenyltrichloroethane (DDT) on the marsh from the mid 1940s until the chemical was banned in 1972. As resistance by mosquitoes to DDT and other organochlorine compounds increased, the district shifted to organophosphate and carbamate compounds; these were used in the 1970s and early 1980s. In the marsh areas of Contra Costa County, ditching, rather than chemicals, was the primary method of mosquito control, although chemicals were also used.

In the late 1980s, protein-based mosquito control compounds (altosid-methoprene, a synthetic juvenile hormone) and Bti (*Bacillus thuringiensis israelensis*) were sprayed. These narrow-spectrum products are applied either directly or as time-released capsules. The capsules can persist for 20 months or longer in stagnant areas (PRC 1994c). Currently, mosquito control products consist of a photoreactive light oil called "Golden Bear," applied about twice a month to marsh areas. The oil usually evaporates or photodegrades within several days, although it can persist if quickly buried, as in a storm event. These insecticides are currently in limited use in the Litigation Area (PRC 1994c).

Chemical Companies Bordering RASS 1 and 2

Additional sources of potential organic contaminants in the Litigation Area are the chemical companies bordering the property. The Rhone-Poulenc Basic Chemicals Company (formerly known as PolyPure) chemical plant at 501 Nichols Road, adjacent to the site boundaries, has been producing

water treatment chemicals for about 12 years. The company used to dispose of runoff containing cationic polyacrylamide solutions into an open lagoon about 100 feet from Suisun Bay. The unpolymerized form of the compound is a powerful neurotoxin in vapor form. Rhone-Poulenc (as PolyPure) shared the waste lagoons with the nearby General Chemical Company Bay Point Plant until 1992, when Rhone-Poulenc began recycling this waste water and ceased use of the lagoon altogether. Whether Rhone-Poulenc is regulated under the Resource Conservation and Recovery Act as a treatment, storage, or disposal facility has not yet been determined.

4.1.3 Data Gaps for Total Chemistry

Adequate chemical analyses to date have included only six metals. Additional information on the presence and distribution of other metals and organic compounds will be collected for the ecological assessment. Sampling for organic contamination will be focused on localities with a known or suspected potential source of organic contaminants based upon historical information. These potential contaminants include hydrocarbons (TPH as diesel, motor oil, and gasoline) in RASS 3, mosquito abatement compounds in marsh areas, and products of chemical companies bordering RASS 1 and 2.

Additionally, contaminant concentrations in some areas were not adequately measured in prior studies. Samples need to be taken in areas not previously covered in the marsh and upland habitats, as well as in the sloughs, ditches, and non-tidal wetlands. Subsurface soil concentrations are only available for the actively remediated areas, and only for metals. Samples taken to depths of 3 feet bgs indicate that contamination extends below the soil surface. The vertical extent of contamination has not yet been characterized outside the active areas. These issues are introduced in Chapter 7, and developed further in the FSP.

4.2 PRELIMINARY ASSESSMENT OF THE TOXIC EFFECTS OF CONTAMINANTS OF POTENTIAL CONCERN

This section provides an initial toxicity assessment of the six metals (inorganic compounds) found to date at the Litigation Area and the organic compounds potentially present based on a review of past use of the site. This section also describes toxicity data gaps. Appendix B (1-6) provides tables of toxicity data for these contaminants. Subsequent tasks will include further reviews of published

literature on the factors influencing toxicity in the field and analysis of site-specific conditions that may affect bioavailability and biomagnification of the contaminants. Toxicity of metals and organic compounds will be addressed as they are identified in future sampling efforts.

Contaminant fate and transport parameters, which include physical, chemical, and biological processes, influence the potential for exposure and environmental impact. Processes such as dispersion, volatilization, and sorption to soil and sediments (that is, physical processes) and biodegradation, biotransformation, and biomagnification (that is, biological processes) determine the mobility, availability, and toxicity of contaminants. These processes are briefly addressed here as justification that these contaminants are of potential concern, but are discussed more thoroughly in Chapter 5, where their habitat-specific effects are emphasized.

4.2.1 Inorganic Chemicals

Large areas of the Litigation Area have levels of arsenic, cadmium, copper, lead, selenium, and zinc in excess of ER-L and ER-M values. This section provides toxicological profiles for these metals. Subsequent tasks will include a review of published literature on the factors influencing toxicity in the field and analysis of site-specific conditions that may affect bioavailability of the metals. Other metals will be addressed as they are identified as COPCs. Toxicity effect levels of metals on a variety of receptors are provided in Appendix B (1-6).

4.2.1.1 Arsenic

Although arsenic occurs naturally in air, water, soil, and all living tissues and may be an essential nutrient, it is also a teratogen and a carcinogen that can traverse placental barriers and produce fetal death and malformations in many species of mammals (Eisler 1988a). Arsenic exists in four oxidation states in inorganic and organic forms, and changes its chemical form and state readily as a result of chemically and microbiologically mediated reactions. Its bioavailability and toxicity are modified by numerous biotic and abiotic factors that include the physical and chemical forms of arsenic, the route of exposure, the dose, and the species of receptor. In general, inorganic arsenic compounds are more toxic than organic arsenic compounds, and trivalent species are more toxic than

pentavalent species. Cells take up arsenic through an active transport system normally used in phosphate transport. Arsenic is bioconcentrated but not biomagnified by organisms (Eisler 1988a).

In water, arsenic occurs in both inorganic and organic forms and in dissolved and gaseous states (EPA 1980, as cited in Eisler 1988a) and may undergo complex transformations that include biotransformation (Callahan and others 1979, as cited in Agency for Toxic Substances and Disease Registry [ATSDR] 1993a). Arsenic in water primarily exists as a dissolved ionic species (Maher 1985a, as cited in Eisler 1988a). The formation of inorganic pentavalent arsenic, the most common species in water, is favored under conditions of high dissolved oxygen, basic pH, high Eh, and reduced content of organic material; the reverse conditions usually favor the formation of trivalent arsenics and arsenic sulfides (NRCC 1978, Pershagen and Vahter 1979, and EPA 1980; as cited in Eisler 1988a).

Pentavalent arsenics are readily sorbed by colloidal humic material and may also coprecipitate with or adsorb onto hydrous iron oxides and form insoluble precipitates with calcium, sulfur, aluminum, and barium compounds (EPA 1980, as cited in Eisler 1988a). In reducing environments, such as sediments, pentavalent arsenics become more strongly adsorbed to sediments than other forms of arsenic (EPA 1980, as cited in Eisler 1988a).

Arsenic in soil also can undergo many complex transformations. Pentavalent arsenics predominate in aerobic soils, and trivalent arsenics predominate in slightly reduced or temporarily flooded soils (EPA 1982a, as cited in ATSDR 1993a).

Arsenic Bioconcentration. Bioconcentration factors (BCF) experimentally determined for arsenic in aquatic organisms are, with the exception of algae, relatively low. While marine phytoplankton have the ability to accumulate high concentrations of inorganic arsenics and transform them to methylated arsenics that are later efficiently transferred in the food chain (Eisler 1988a), it does not appear to be biomagnified through the food chain (Eisler, 1988a; Callahan and others 1979, and EPA 1982a and 1983e, as cited in ATSDR 1993a).

Arsenic Effects on Aquatic Biota. The toxicity of arsenic in the water column to marine organisms depends on the form (oxidation state and counter ion) of the arsenic. Both carcinogenic and

mutagenic effects have been reported (Eisler 1988a). Acute toxicity, as well as sublethal effects, have been observed in fish and invertebrates (NOAA 1991), although acute toxicity can differ among even taxonomically similar species. Temperature, pH, speciation, and many other factors can also influence the toxicity; however, inorganic arsenics are generally more toxic than organic forms of arsenic (Eisler 1988a). Adverse effects to marine organisms have been observed at concentrations in water of 0.0019 milligrams per liter (mg/L) to 500 mg/L.

Arsenic Effects on Terrestrial Biota. Terrestrial plants may accumulate arsenic by root uptake from the soil or by absorption of airborne arsenic deposited on the leaves, and certain species may accumulate substantial levels (EPA 1982a, as cited in ATSDR 1993a). A significant depression in crop yields for many plants was evident at soil arsenic concentrations of 3 to 28 mg/L of water-soluble arsenic and 25 to 85 milligrams per kilogram (mg/kg) of total arsenic (NRCC 1978, as cited in Eisler 1988a). Soil microorganisms are capable of tolerating and metabolizing relatively high concentrations of arsenic (Wang and others 1984, as cited in Eisler 1988a). However, arsenic may result in reduced growth and metabolism of soil microbiota, diminished numbers of bacteria and protozoans, and the absence of earthworms (NRCC 1978, as cited in Eisler 1988a).

As with other organisms, the effects of arsenic on mammals varies with the species, the exposure route, and the physical and chemical form of the arsenic. Many mammals can rapidly excrete ingested inorganic arsenic (Eisler 1988a); however, arsenic does get distributed to most tissues including the placenta and fetus. Chronic exposure has resulted in reductions in litter size of mice.

4.2.1.2 Cadmium

Cadmium is more mobile in aquatic environments than most other heavy metals. In natural waters, most cadmium exists as the hydrated ion and as a complex with humic substances. Precipitation and sorption to mineral surfaces and organic materials are the most important removal processes for cadmium compounds. Sediment bacteria may also assist in the partitioning of cadmium from water to sediments (Burke and Pfister 1988, as cited in ATSDR 1993b). Cadmium may redissolve from sediments under varying ambient conditions of pH, salinity, and redox potential (Callahan and others 1979, Feijtel and others 1988, as cited in ATSDR 1993b).

Transformation processes for cadmium in soil are mediated by sorption from and desorption to water, processes influenced by the cation exchange capacity, pH, oxygen content, and the presence of clay minerals, carbonate minerals, oxides, and organic matter (McComish and Ong 1988, as cited in ATSDR 1993b). Cadmium in soils may leach into water, especially under acidic conditions (Callahan and others 1979 and Elinder 1985a, as cited in ATSDR 1993b). Cadmium-containing soil particles may also be entrained into the air or eroded into water (EPA 1985a, as cited in ATSDR 1993b).

Cadmium occurs in surface waters in the cadmium form as a constituent of inorganic halides, sulfides, and oxides and organic compounds. Cadmium transport to the sediments occurs mainly through sorption to organic matter and through coprecipitation with iron, aluminum, and manganese oxides (MacDonald 1993). Availability of cadmium to aquatic organisms is dependent on such factors as pH, redox potential, water hardness, and the presence of other complexing agents.

Cadmium has no essential biological function, and, in sufficient concentrations, is highly toxic to plants and animals. It is a known teratogen and carcinogen and a suspected mutagen, and has severe deleterious sublethal effects on wildlife (Eisler 1985a).

Cadmium Bioconcentration. Aquatic and terrestrial organisms at all trophic levels bioaccumulate cadmium, although the evidence suggests that only lower trophic levels exhibit biomagnification (Eisler 1985a). Bioconcentration in fish depends on the pH and the organic content of the water (John and others 1987, as cited in ATSDR 1993b). Although some data indicate increased cadmium absorption in animals at the top of the food chain, the data available on biomagnification are inconclusive (Beyer 1986, Gochfeld and Burger 1982, as cited in ATSDR 1993b).

Cadmium Effects on Aquatic Biota. Cadmium has been shown to be highly toxic in aquatic environments and has been implicated as the cause of severe deleterious effects on fish and wildlife including acute mortality, reduced growth, and inhibited reproduction (Eisler 1985a). Marine organisms are more resistant than freshwater biota to cadmium. Decapod crustaceans, the most sensitive of the marine organisms, have been shown to die at concentrations of cadmium in seawater ranging from 14.8 to 420 parts per billion (ppb). Sublethal effects to marine animals, which included decreased growth, respiratory disruptions, altered enzyme levels, and abnormal muscular contractions, have been recorded at cadmium concentrations of 0.5 to 10 ppb (Eisler 1985a).

Cadmium Effects on Terrestrial Biota. Cadmium is known to be toxic to plants at much lower soil concentrations than other heavy metals such as copper, lead, and zinc. Although birds appear to be relatively resistant to the toxic effects of cadmium, sublethal effects in birds include growth retardation, nephrotoxicity, anemia, damage to the testicles and absorptive epithelium of the duodenum, reduced egg production, and effects on calcium absorption (Scheuhammer 1987). In mammals, prenatal exposure to cadmium has fetotoxic effects, usually reduced fetal or pup weights (ATSDR 1993b).

4.2.1.3 Copper

In general, copper is very mobile under oxidizing and acidic conditions and immobile in organic-rich environments. Most copper deposited in soil is strongly adsorbed to organic matter and remains in the upper few centimeters of the soil. Adsorption increases with pH and also with higher organic matter content. However, copper can leach from soils, especially from sandy soils, under acidic conditions (ATSDR 1990).

In aquatic systems, copper binds primarily to organic matter and forms complexes with both organic and inorganic ligands (mainly with calcium carbonate) that settle out in sediments (Kirk-Othmer 1965). In reducing, acidic, or richly organic bed sediments, copper complexes can dissolve, resulting in remobilization of sorbed copper. Under normal pH and redox conditions, copper tends to be present in sediments in the form of organic complexes, and coprecipitates with iron and manganese oxides, and cupric carbonate complexes.

Copper Bioconcentration. Although copper is an essential nutrient, biomagnification is not a significant fate process for copper. Accumulated copper is stored in the liver, kidney, bone marrow, and hair (Hammond and Beliles 1980, as cited in Talmage and Walton 1991). Bioaccumulation has been demonstrated for fish, with BCFs for fish from the tens to the hundreds and BCFs for mollusks up to 30,000 (Perwack and others 1980; Chapman and others 1968; Raymont 1972). Bioaccumulation does not appear to occur in terrestrial ecosystems.

Copper Effects on Aquatic Biota. Copper is highly toxic in aquatic environments and is considered a pollutant of great concern (EPA 1992b). Saltwater organisms are acutely sensitive to copper in water concentrations ranging from 5.8 ppb to 600 ppb.

Copper Effects on Terrestrial Biota. Based on yield reductions of 14 to 28 percent in agronomic and grassland parts, 100 mg/kg total copper is considered to be a threshold concentration for toxicity to plants and soil invertebrates (EPA 1987 and Bengtsson and Tranvik 1989, as cited in International Copper Association [ICA] 1992). In a study measuring growth, no growth retardation was observed in chickens fed 40.5 mg/kg-day copper sulfate for 4 weeks (National Academy of Sciences [NAS] 1980). Increased fetal mortality and developmental abnormalities were observed in pregnant mice fed copper sulfate.

4.2.1.4 Lead

The fate of lead in soil is affected by the exchange adsorption at mineral interfaces, the precipitation of sparingly soluble solid forms of the compound, and the formation of relatively stable organic-metal complexed or chelates with soil organic matter. These processes depend on such factors as soil pH, organic content, ion-exchange characteristics, and the amount of lead in the soil (NSF 1977, as cited in ATSDR 1993c). Most lead is retained strongly in soil, and very little is transported into surface water or groundwater (EPA 1986a and NSF 1977, as cited in ATSDR 1993c). Lead is strongly sorbed to organic matter in soil, and although it is not subject to leaching, it may enter surface waters as a result of erosion of lead-containing soil particulates (Olson and Skogerboe 1975, as cited in ATSDR 1993c).

The movement of lead from soil to groundwater by leaching is very slow under most natural conditions except for acidic situations (NSF 1977, as cited in ATSDR 1993c). The conditions that induce leaching are the presence of lead in soil at concentrations that either approach or exceed the cation exchange capacity of the soil, the presence of materials in soil that are capable of forming soluble chelates with lead, and a decrease in the pH of the leaching solution (for example, acid rain) (NSF 1977, as cited in ATSDR 1993c).

The chemistry of lead in aqueous solution is highly complex because of its various chemical forms. Lead has a tendency to form compounds of low solubility with major anions found in natural waters. In most surface waters and groundwaters, the concentration of dissolved lead is low because the lead forms compounds with anions in the water such as hydroxides, carbonates, sulfates, and phosphates that have low water solubilities and will precipitate out of the water column (Mundell and others 1989, as cited ATSDR 1993c). A significant fraction of lead carried by river water is expected to be in an undissolved form, which can consist of colloidal particles or larger undissolved particles of lead carbonate, lead oxide, lead hydroxide, or other lead compounds incorporated in other components of surface particulate matters from runoff. Lead may occur either as sorbed ions or surface coatings on sediment mineral particles, or it may be carried as a part of living or nonliving organic matter in water (Getz and others 1977, as cited in ATSDR 1993c).

In sediments, lead is primarily found in association with iron and manganese hydroxides. It may also form associations with clays and organic matter. Under oxidizing conditions, lead may remain tightly bound to the sediments and be released under reducing conditions.

Lead has been known for centuries as a poison, and environmental pollution from lead is extensive and severe (Eisler 1988b). Lead is a mutagen and a teratogen, and when it is absorbed in excessive amounts, has carcinogenic or cocarcinogenic properties, impairs reproduction and liver and thyroid functions, and interferes with resistance to infectious disease (EPA 1979, as cited in Eisler 1988b). Several ecotoxicological properties of lead are agreed upon by investigators. First, lead is a ubiquitous characteristic trace constituent in rocks, soils, water, plants, animals, and air. Second, lead is neither essential nor beneficial to living organisms, and all data show that its metabolic effects are adverse. Third, lead is toxic in most of its chemical forms and can be incorporated into the body via inhalation, ingestion, dermal absorption, and placental transfer. Fourth, lead is an accumulative metabolic poison that affects behavior, as well as the hematopoietic, vascular, nervous, renal, and reproductive systems (Eisler 1988b).

Lead Bioconcentration. Plants and animals may bioconcentrate lead, but biomagnification has not been detected. Several studies have shown that invertebrates can accumulate lead in their tissues, although they show variability in tendencies to accumulate lead.

Organolead compounds, such as trialkyl and tetraalkyl lead compounds, are more toxic than inorganic forms and have been shown to bioconcentrate in aquatic organisms as do inorganic lead compounds. High accumulations of lead from ambient seawater by marine plants are well documented. Although lead is concentrated by biota from water, there is no convincing evidence that it is transferred through food chains (Wong and others 1978, Branica and Konrad 1980, and Settle and Patterson 1980; as cited in Eisler 1988b). Lead concentrations tend to decrease with increasing trophic level in both detritus-based and grazing aquatic, including marine, food chains (Wong and others 1978 and Stewart and Schulz-Baldes 1976, as cited in Eisler 1988b). Some BCFs for lead for marine organisms are provided in Appendix B-4.

Lead Effects on Aquatic Biota. Lead is toxic to all phyla of aquatic biota, though effects are modified significantly by various biotic (species and physiological state) and abiotic variables. Fish continuously exposed to toxic concentrations of waterborne lead show various signs of lead poisoning: spinal curvature; anemia; degeneration of the caudal fin; destruction of spinal neurons; reduced ability to swim against a current; destruction of the respiratory epithelium; muscular atrophy; paralysis; renal pathology; growth inhibition; retardation of sexual maturity; testicular and ovarian histopathology; and death (Eisler 1988b).

Lead Effects on Terrestrial Biota. Lead is not essential for plants, and excessive amounts can cause growth inhibition, as well as reduced photosynthesis, mitosis, and water absorption (Demayo and others 1982, as cited in Eisler 1988b). A concentration of 12,800 mg lead/kg is associated with reductions in natural populations of decomposers, such as fungi, earthworms, and arthropods. The poisoning of decomposers may disrupt nutrient cycling, reduce the number of invertebrates available to other wildlife for food, and contribute to food chain contamination (Beyer and Anderson 1985, as cited in Eisler 1988b). Absorbed lead produces a variety of effects in avian species leading to death, including damage to the nervous system, muscular paralysis, inhibition of heme synthesis, and damage to kidneys and liver (Mudge 1983, as cited in Eisler 1988b). Sublethal lead exposure may also have adverse effects of reproduction in some avian species by decreasing plasma calcium, inhibition of growth, and reduced hatchability of chicks.

Significant differences occur between mammalian species in response to lead exposure. Effects on mammals are more pronounced following exposure to organoleads than inorganic compounds.

Younger developmental stages are more sensitive to lead. Effects of lead include growth retardation, delays in maturation, and reduced body weight (Eisler, 1988b).

4.2.1.5 Selenium

Selenium is nutritionally important as an essential trace element, but harmful at slightly higher concentrations (Eisler 1985b). Results of laboratory studies and field investigations with fish, mammals, and birds have led to general agreement that elevated concentrations of selenium in diet or water were associated with reproductive abnormalities and growth retardation. Not as extensively documented are reports of selenium-induced chromosomal aberrations, intestinal lesions, shifts in species composition of freshwater algal communities, swimming impairment of protozoans, and behavioral modifications (Eisler 1985b).

In aerobic waters, selenium is present in the selenite (H_2SeO_3, $HSeO_3^{-1}$, SeO_3^{-2}) or selenate (H_2SeO_4, $HSeO_4^{-}$, SeO_4^{-2}) quadravalent or hexavalent oxidation states. These chemical species are very soluble, and most of the selenium discharged into the aquatic environment is probably transported in these forms to the oceans. Selenium has a sorptive affinity for hydrous metals oxides, clays, and organic materials. Sorption by bed sediments or suspended solids can result in enrichment of selenium concentrations in the bed sediments. Sorption or precipitation with hydrous iron oxides is probably the major control on mobility of selenium in aerobic waters.

Selenium can be methylated by a variety of organisms, including benthic microflora. In a reducing environment, hydrogen selenide may be formed. Both the methylated forms and hydrogen selenide are volatile and may escape to the atmosphere. Formation of volatile selenium compounds in the sediments can remobilize sorbed selenium.

Selenium Bioconcentration. Evidence suggests that the federal AWQC for selenium may not be protective of avian receptors exposed to selenium in aquatic environments because the criteria do not account for selenium bioaccumulation (Taylor and others 1992). The current understanding of selenium toxicology indicates that ecological effects are primarily caused by selenium in the food chain, rather than selenium dissolved in the water column (Philips 1988 and Luoma and others 1992, as cited in Taylor and others 1992). Once in the water column, selenium enters the food chain

through bioconcentration by phytoplankton, which are consumed in large quantities by crustaceans and bivalves. Crustaceans and bivalves are, in turn, eaten by fish and waterfowl. Bioconcentration and biomagnification of selenium can increase selenium levels more than 1,000 fold from water to fish and animals (Saiki and Lowe 1987, as cited in Taylor and others 1992). The greatest concentration step occurs between water and phytoplankton and other aquatic plants, with subsequent steps in the food chain typically increasing selenium concentrations by a factor of 2 to 6 (Lemly and Smith 1987, as cited in Taylor and other 1992). BCFs for various species of marine algae range from 16,000 to 337,000, depending on the species and the water column levels (Zhang and others 1990, as cited in Taylor 1992).

Selenium Effects on Aquatic Biota. Selenium is teratogenic, and its toxicity depends greatly on its chemical form (Eisler 1985b). It has been suggested that selenite is more toxic than selenate and is preferentially concentrated over selenate by mussels (EPA 1990, as cited in Eisler 1985b). A summary of lowest observed adverse effect levels (LOAEL) and no observed adverse effect level (NOAEL) for ingestion of selenium in food by various aquatic receptors is provided in Appendix B-5.

Selenium Effects on Terrestrial Biota. Selenium exposure in the diet or drinking water of avian species is associated with reproductive abnormalities, congenital malformations, selective bioaccumulation, and growth retardation (Eisler 1985b). Sublethal effects of selenium on mammals include reproductive abnormalities such as congenital malformations; reduced numbers of young in litters; high mortality of young; infertility among surviving young in rats, mice, swine, and cattle; and intestinal lesions (Harr 1978 and NRC 1983, as cited in Eisler 1985b). Selenium effects on various receptors are provided in Appendix B-5.

4.2.1.6 Zinc

Zinc is an essential trace element for all living organisms. Zinc deficiency can be a problem for both plants and animals, and manifestations of zinc poisoning in animals include growth retardation, testicular atrophy, skin changes, and poor appetite (Prasad 1979, as cited in Eisler 1993).

Most of the zinc introduced into aquatic environments is eventually partitioned into the sediments. Zinc released from sediment is enhanced under conditions of high dissolved oxygen, low salinity, and

low pH. Dissolved zinc usually consists of the toxic hydrated zinc ion and various organic and inorganic complexes. These hydrated ions and other toxic species greatly affect aquatic organisms under conditions of comparatively low pH, low alkalinity, low dissolved oxygen, and elevated temperatures. In reducing conditions, organically bound zinc generally forms insoluble sulfides (Mac Donald 1993).

Zinc Bioconcentration. BCF (accumulation from medium) varied widely between and within species of aquatic organisms (Eisler 1993). In marine environments the most effective zinc accumulators included red and brown algae, ostreid and crassotreid oysters, and scallops. Vegetation studies indicate little uptake of zinc from soil. Zinc accumulates in invertebrates and may be passed on to higher trophic level consumers. Studies show that bony structures can act as long-term repositories for zinc (Macapinlac and others 1966).

Zinc Effects on Aquatic Biota. Significant adverse effects of zinc on growth, survival, and reproduction occur in representative sensitive species of aquatic plants, protozoans, sponges, mollusks, crustaceans, echinoderms, fish, and amphibians at nominal water concentrations between 10 and 25 ppb (Eisler 1993). Biological effects have not been observed in association with zinc concentrations of about 50 ppm or less in sediments (NOAA 1991). In general, zinc was more toxic to embryos and juveniles than to adults, to starved animals, at elevated temperatures, in the presence of cadmium and mercury, in the absence of chelating agents, at reduced salinity, at decreased water hardness and alkalinity, and at low dissolved oxygen concentrations (Eisler 1993).

Zinc Effects on Terrestrial Biota. Although zinc is one of the essential nutrients for plant growth, plants require it only in small amounts. Zinc concentrations in acidic soils that produced toxicity to corn ranged from 450 to 1,400 mg/kg available zinc; toxicity to cowpeas ranged from 180 to 700 mg/kg available zinc (Gall and Barnette 1940, as cited in Adriano 1986).

Feeding studies indicate that decreased weight gain is first observed at zinc dietary concentrations of 270 mg/kg in Japanese quail, 800 mg/kg in chickens, and 4,000 mg/kg in turkeys (NAS 1980). Zinc is relatively nontoxic in mammals; however, excessive zinc intake adversely affects survival of all tested mammals and produces a wide variety of neurological, hematological, immunological, hepatic, renal, cardiovascular, developmental, and genotoxic effects (PHS 1989, as cited in Eisler 1993).

4.2.2 Organic Compounds

Toxicological profiles for each organic contaminant detected at elevated concentrations at the Litigation Area will be developed. Based on existing data and research on potential sources of organic contamination DDT and TPH (and organic constituents contained therein) may present risks to ecological receptors at WPNSTA Concord. The toxicological profiles for benzene (commonly found in hydrocarbon fuels), TPH as diesel, and DDT are presented below.

4.2.2.1 Benzene

The high volatility and water solubility of benzene are the physical properties with the greatest influence on environmental transport and partitioning (Mackay and Leinonen 1975, as cited in ATSDR 1993d). Benzene released to the soil partitions to the atmosphere through rapid volatilization, to surface water in runoff, and to groundwater as a result of leaching. Estimates of the organic carbon partitioning coefficient (Koc) range from 60 to 83 (Karickhoff 1981 and Kenaga 1980, as cited in ATSDR 1993d) and 31.7 to 143 (Hansch 1985, as cited in Hazardous Substances Data Bank [HSDB] 1994), classifying benzene as highly mobile.

A model developed to predict the environmental fate of benzene following leakage from an underground storage tank indicated that most (67 percent) of the benzene would volatilize from the shallow, sandy soil within 17 months. Of the remaining benzene, 29 percent would leach to groundwater, 3 percent would remain in the soil, and 1 percent would be degraded (Tucker and others 1986, as cited in ATSDR 1993d). Benzene also volatilizes rapidly from water and is not expected to significantly adsorb to sediment or hydrolyze. A half-life of 3.1 days (summer) to 23 days (spring) was reported for benzene in seawater in a mesocosm simulating Narragansett Bay, Rhode Island, containing the associated planktonic and microbial communities (Wakeham and others 1983, as cited in HSDB 1994).

Benzene biodegrades in both surface water and groundwater. Benzene biodegradation is much slower under anaerobic conditions than under aerobic conditions, making biodegradation in any groundwater other than shallow aerobic groundwater unlikely. After 40 weeks, benzene concentrations had been reduced by 72 percent under laboratory anaerobic conditions, and after 120 weeks, 99 percent

degradation had taken place (Wilson and others 1972, as cited in ATSDR 1993d). Benzene is biodegraded in soil under aerobic conditions. However, one study concluded that only small numbers of the specific organisms that degrade benzene were present in the soil.

Benzene Bioconcentration. The octanol-water partitioning coefficient (Kow) for a given compound is a measure of that compound's propensity to be associated with water or with octanol. Because the Kow is an indicator of a compound's fat-solubility, it is also a strong predictor of the compound's tendency to bioaccumulate. Some calculations of the Kow for benzene range from 2.13 to 2.15 (HSDB 1990 and Gossett and others 1983, as cited in ATSDR 1993d). Studies suggest that bioaccumulation in aquatic food chains is not significant (ATSDR 1993d).

Benzene Effects on Aquatic Biota. No data were found on the effects of benzene on aquatic invertebrates and fish.

Benzene Effects on Terrestrial Biota. Because benzene exists primarily in the vapor phase, root uptake is not expected to be a major source of vegetative contamination, making air to leaf transfer the major pathway of vegetative contamination (Hattemer-Frey and others 1990, as cited in ATSDR 1993d). No data on the effects of benzene exposure on birds or mammals were found.

4.2.2.2 Total Petroleum Hydrocarbons as Diesel (Fuel Oil Number Two)

The transport and dispersion of fuel oils are dependent upon the water solubility of the aliphatic and aromatic hydrocarbon fractions. Larger aliphatic hydrocarbons (greater than C_9 chain length), such as fuel oil number two, may be sorbed to organic particles in water or soil. Koc measures a compound's propensity to be associated with organic carbon and describes the equilibrium between water and organic carbon. Logarithmic transformations of Koc values (log Koc) calculated for fuel oil number two range from 3.0 to 6.7 (Air Force 1989, as cited in ATSDR 1993e). Aromatic hydrocarbons will be dissolved in the aqueous phase in both soil and water and may undergo some volatilization. Kow values calculated for fuel oil number two range from 3.3 to 7.06 (Air Force 1989, as cited in ATSDR 1993e).

In aquatic systems evidence shows that the aliphatic fractions of fuel oil can be transported to the microlayer at the air-water interface or to the sediment on suspended particulate matter. The surface microlayer interface may be composed of different fuel oil hydrocarbons than the subsurface waters. When fuel oil number two was added below the surface of a marine ecosystem, the microlayer was more enriched than the subsurface water for both saturated and unsaturated hydrocarbons. There was a significantly greater proportion of total saturates compared with aromatics. The hydrocarbons in the microlayer were predominantly higher molecular weight hydrocarbons greater than C_{18}. This indicates that all of the hydrocarbons are transported from the water column to the microlayer and weathered by evaporation once they are in the microlayer (Gearing and Gearing 1982b, as cited in ATSDR 1993e).

A spill of fuel oil number two to waters off Massachusetts showed that the oil was detected at distant monitoring locations 46 months after the spill, although the greatest concentration in the sediments remained in the vicinity of the original spill. Oil continued to move in pulses from the more polluted areas to less polluted areas for several years after the spill, with much of the oil being exhumed from sediments in the shallower waters as a result of storm action (EPA 1981, as cited in ATSDR 1993e). Movement of the oil to adjacent salt marshes indicated that the oil was sorbed to the anoxic sediment where it persisted (Burns and Teal, 1979, as cited in ATSDR 1993e). Biodegradation and dissipation resulted in the decrease of n- and branched alkanes from the surface sediment within 4 years. Even 8 years after the spill, some sediments contained over 1,200 ppm petroleum hydrocarbons with naphthalene and heavier aromatics expected to persist for many more years (Burns and Teal 1979, as cited in ATSDR 1993e).

Fuel oils can undergo a variety of degradation processes. The photo-oxidation of fuel oil number two in water is quite rapid in sunlight. Biodegradation of fuel oils is dependent on the degradation of the various hydrocarbon fractions present in the oils. The relative order for biodegradation of the hydrocarbon fractions from the most readily degraded to the least is as follows: n-alkanes, iso-alkanes, olefins, low molecular weight aromatics (at nontoxic concentrations), polycyclic aromatic hydrocarbons (PAH), and cycloalkanes (Bartha and Atlas 1977 and Edgerton and others 1987, as cited in ATSDR 1993e). A mixed culture of estuarine bacteria was observed to degrade fuel oil number two by 55 percent in 28 days (Walker and others 1976, as cited in ATSDR 1993e).

Biodegradation of fuel oils in sediments is inhibited under anaerobic conditions (Bartha and Atlas 1977, as cited in ATSDR 1993e).

Microbial degradation in soils is greatest for the aromatic fractions of fuel oils, and the biodegradation of the aliphatic hydrocarbons decreases with increasing carbon chain length. Evaporation is the primary fate process for these aliphatics (Air Force 1989, as cited in ATSDR 1993e). Application of diesel oil to soil at 1 percent or 10 percent showed that based on carbon dioxide evolution, degradation did occur. After 12 weeks, the application of 1 percent diesel oil was degraded by 45 percent, whereas the 10 percent application showed that only 10 percent of each oil was degraded in this time.

TPH-Diesel Bioconcentration. Aquatic organisms are known to bioconcentrate hydrocarbons. Adding fuel oil number two containing 38 percent aromatics to a commercial shrimp pond indicated that the concentrations in marine organisms are more closely correlated with water concentrations than with sediment concentrations of aromatic hydrocarbons (Cox and others 1975, as cited in ATSDR 1993e).

Organism-specific differences show that organisms in close contact with the sediment had relatively higher concentrations of lower molecular weight napthalenes, as these compounds are more readily retained in the sediment than in the water column. Similarly, organisms that lived in the water column had fewer napthalenes. These results indicate that fuel oil number two degradation products are taken up by benthic organisms, that they may be selectively retained in both sediments and aquatic organisms, and may thus enter the food chain (Farrington and others 1982b, as cited in ATSDR 1993e).

TPH-Diesel Effects on Aquatic Biota. The State of Alaska has determined a criterion for total hydrocarbons of 15 micrograms per liter (μg/L) for the protection of aquatic life in marine ecosystems (State of Alaska 1989, as cited in ATSDR 1993e).

TPH-Diesel Effects on Terrestrial Biota. No data were found on the effects of fuel oil number two on terrestrial invertebrates, plans, and mammals. Behavioral changes in mallard ducklings were

evident when they were exposed to larvicide and fuel oil during incubation (Albers and Heinz 1983, as cited in Peterle 1991).

4.2.2.3 Dichlorodiphenyltrichloroethane and its Congeners

DDT is a broad-spectrum organochlorine pesticide used widely between 1944 and 1972; general use in the United States was banned in 1972. DDT has many environmental congeners, two of the most important of which are dichlorodiphenyldichloroethylene (DDE, also used as a pesticide itself) and dichlorodiphenyldichloroethane (DDD, an impurity of DDT). DDT, DDE, and DDD have similar fate and transport properties. DDT, like many organochlorine contaminants, remains an ecological threat because of its persistence in the environment, potential for volatilization and transport to untreated areas, lipophilic nature, toxicity of metabolites primarily DDE, and the variability of species responses to chronic exposure to DDT and DDT metabolites (Peterle 1991). DDT, DDE, and DDD are only slightly soluble in water, and adhere to soil and sediment particles, as predicted by their high Kocs ranging in the order of 10^5 to 10^6 (ATSDR 1992). DDT and its derivatives are fairly resistant to biodegradation and hydrolysis in soil and in aquatic ecosystems (Alexander 1965, as cited in Forsyth and others 1983). Consequently, these compounds are highly persistent in soil, with half-life estimates of greater than 15 years (Lichtenstein and others 1959 and Stewart and others 1971, as cited in ATSDR 1992). Volatilization of DDT residues is believed to be an important fate process in soils and in aquatic ecosystems (Callahan and others 1979). Volatilization accounts for the majority of initial decreases of DDT residues in soils (Willis and others 1971, as cited in Forsyth and others 1983).

DDT and its Congeners Bioconcentration. DDT and its metabolites are highly lipid soluble, which, combined with their relatively long half-life, results in very high bioconcentration factors. The Kow for DDD is 3.63×10^5, and the log Kow for DDT is 1.58×10^6. Biomagnification has been demonstrated for DDT and its metabolites in aquatic ecosystems, with organism residues increasing with increasing trophic levels (Bevenue 1976, as cited in Forsyth and others 1983). DDT is most widely known for its reproductive effects on birds, primarily predatory species, and for its toxicity to aquatic fish and invertebrates. Reported BCFs for DDT in a variety of taxa are provided in Appendix B-6.

DDT and its Congeners Effects on Terrestrial Biota. Persistence of DDT in soil of agricultural plots, orchards, and forests, and its accumulation by plants and invertebrates has been demonstrated in several studies (Forsyth and others 1983). Reproductive effects of DDT and its metabolites on birds has been extreme. To date, organochlorines, including DDT, have been implicated in the thinning of eggshells of at least 54 species of 10 orders of birds (Stickel 1975, as cited in Peterle 1991). Reproductive effects of DDT and its metabolites extend beyond eggshell thinning. Mallards treated with DDE showed delayed egg laying, reduced hatchability, and alteration of egg size, weight, and content (Vangilder and Peterle 1980, 1981, and 1983, as cited in Peterle 1991). Subacute effects of DDT on mammals range from transient effects on respiration to reproductive and behavioral effects in various species.

4.2.3 Toxicity Data Gaps

More detailed toxicological data will be compiled for all COPCs and for derivation of toxicity reference values to be used in the exposure and ecological effects assessment, as described in Chapter 9. Few data on toxicity of sediments and soil at the Litigation Area are available, except for some observed mortality in the clam and earthworm bioassays (PRC 1994a). Site-specific toxicity of COPCs will be evaluated in the QEA, as described in Chapters 7 and 9.

4.3 PRELIMINARY ASSESSMENT OF BIOAVAILABILITY, BIOACCUMULATION AND BIOMAGNIFICATION POTENTIAL

The speciation of a chemical, especially a metal, defines the form in which it exists in nature, which ultimately affects its bioavailability. The total measured concentration of a contaminant in the environment may not be available for uptake by living organisms due to the chemical's interactions with the medium. Different forms of metal may vary in bioavailability to an organism. Ionic metal species, for example, adsorb more readily to the surface of soil particles and thus become less mobile. The mobility of non-ionic organic chemicals in soils and sediments depends in part on Kow, the pH, and the amount of organic carbon in the medium. If the chemical does not occur in a bioavailable form, then its concentration at the exposure point is reduced, and toxic effects may be minimal. Once bioavailable, a toxicant may be accumulated by an organism. Bioaccumulation is the net accumulation of a chemical by an organism as a result of uptake from all routes of exposure including

bioconcentration and biomagnification. The following sections describe the influence of bioavailability and bioaccumulation on exposure and risk at the Litigation Area and discuss how existing data on tissue concentrations will be used.

4.3.1 Bioavailability

Total inorganic chemical results do not generally correlate well with biological effects data. This may be due in part to a lack of data concerning the fraction of inorganic contaminants available to biotic receptors (bioavailable fraction). The bioavailability of sediment-associated contaminants can be defined as the fraction of the total contaminant in interstitial water and on sediment particles that is available for uptake by organisms. This QEA assumes that the more soluble constituents of a soil and sediment, including the labile (weakly bound) fraction, are more bioavailable and likely to be more toxic to biological receptors (PRC 1994f).

The current test method approved by EPA for measuring concentrations of inorganic elements in media involves quantifying the total concentration. However, the toxicity and potential for bioaccumulation of elements depend on the bioavailability of the element in the medium (Adriano 1986). For instance, in soil, elements dissolved in moist soil or held onto chemical exchange sites are mobile and available for uptake by plants or other organisms. Elements that are incorporated into mineral matrices, coprecipitated with other chemicals in the soil or sediment, or incorporated into biological material are generally immobile, although they may become mobile and available with time.

The complex factors governing the equilibrium of trace elements between solution and solid phases include pH, water content, percent of organic matter, cation exchange capacity, and the amount of clay in relation to the amount of silt and sand (Adriano 1986). Generally, an increase in pH and percent organic matter decreases the bioavailability of trace elements in the soil; elements are more available in sandy soils than in soils with a high clay content. Studies on the uptake of metals from soil by earthworms have shown that pH significantly influences the rate of uptake of cadmium, lead, and zinc, but not that of copper (Ma 1982; Ma and others 1983). In Ma (1982), lead was the only metal significantly influenced by percent organic matter. The influence of these factors on bioavailability of trace elements may depend on properties of the element or the oxidation state of the

element in the soil. In addition, interactions with other trace elements can affect bioavailability and uptake.

The availability of an element for gastrointestinal absorption is also dependent upon the chemical form. Elements in food and water are most often found in the ionic form, usually as free ions in water and as complex forms in food. Thus, elements incorporated into food items, soil, or sediment may be less available for gastrointestinal absorption than elements in water, although this varies by element. Experimental studies of the toxicology of metals generally use soluble salts for dietary and drinking water exposures, and may overestimate the toxicity of elements that may be bound onto food items, soil, or sediment in the environment. Toxicity of inorganic contaminants also varies with a variety of biotic factors, including the type of receptor, life stage, feeding behavior, prey type, and others.

Total organic carbon (TOC) is a measure of the amount of organic matter in the sediments. Sediments with high TOC content (> 15 percent) tend to bind higher concentrations of toxic substances than those with low TOC content from the same area due to the propensity of many low-solubility organic compounds and some metals to bind organic carbon. Organic matter in the sediment is food for many benthic organisms, but highly organic sediments may be inhospitable to larger organisms because of microbes that reduce the available oxygen, often producing natural toxins such as ammonia and sulfides as waste products (MacDonald and others 1992).

Grain size is an important physical characteristic of sediments. Because grain size influences both chemical and biological variables, it can be used to normalize chemical concentrations according to sediment characteristics and to account for some of the variability found in biological assemblages (Tetra Tech, Inc. 1986).

Different sediment textures support characteristic communities of benthic organisms. In addition, adsorption of chemicals to particulate matter in the water column is a function of increasing surface area, so that finer particles, which have larger surface area per volume have a greater potential of accumulating chemicals per unit volume than do coarser particles. Thus, variability in grain size can account for some of the differences in contaminant accumulation in sediments (MacDonald and others 1992).

To date, there is little site-specific information on the bioavailability of contaminants at the Litigation Area. Chemical sampling in the active areas of each RASS conducted during remediation included WET analysis on a portion of the samples. These data are presented in Tables 3(a - c). The potential use of these data is discussed in Section 9.1).

4.3.2 Existing Data on Bioaccumulation and Tissue Concentration Analysis

The effects of a chemical on a specific individual, population, and community are influenced by the processes of bioconcentration and biomagnification. Bioconcentration is the net uptake of chemicals by an individual organism from aqueous solution. Bioaccumulation represents the net uptake of chemicals by an individual organism from all exposure routes. Biomagnification is the process through which an organism accumulates chemicals through trophic transfer; the potential for biomagnification is greater at higher levels of the food web (Suter 1993).

The COPCs at the Litigation Area may affect many levels of the food web through bioaccumulative processes. The following sections describe the existing data on tissue concentration studies conducted as part of the remedial action monitoring at the Litigation Area. As part of the baseline monitoring (PRC 1991), several studies of bioaccumulation of metals in the laboratory and field and several measures of tissue concentration of field collected clams, earthworms, small mammals, and plants were made. A study of bioaccumulation in the asiatic clam (*Corbicula fluminea*) used replicated groups of clams caged *in situ* in areas sampled for bulk chemistry in the four RASSs, control sediments, and in the upland and shoreline reference areas. These data are plotted as mean values of bioaccumulation over 28 days and compared to control clams that were kept in clean reference sediment in the laboratory (Figure 8a-f). These descriptive plots indicate that cadmium levels in clam tissue were elevated in a few locations in RASS 4; zinc levels were variable, though elevated in some areas of each RASS; lead levels in RASSs 1 and 4 were elevated; copper levels were elevated in RASSs 1 and 4.

Earthworm bioaccumulation tests were performed in the laboratory under the same monitoring plan, using sediment samples from multiparameter sampling locations. Figure 9a-b shows that earthworm tissue contained high levels of arsenic and copper at RASS 1; cadmium at RASSs 2, 3, and 4; lead at RASSs 2, 3, and 4; and selenium at RASSs 1, 2, and 4, compared to the controls.

A study of tissue concentration in small mammals was also conducted under the baseline monitoring (PRC 1991). Small mammals (*Mus musculus*, *Microtus californicus*, and *Peromyscus maniculatus*) were trapped in each RASS and reference area. The concentrations of the six metals were measured in the femur, kidneys, and liver of each specimen. Data are plotted in Figure 10a-f as mean concentration of metals by species collected in each RASS. Background concentrations for these metals in these species can be approximated using reference sites and literature values to determine what constitutes elevated tissue concentrations. These data will be used to estimate body burdens for each species and in exposure models to estimate ingestion by carnivorous predators. Data for each species and tissue type will be compared to appropriate reference sites and literature values in consultation with regulatory agencies.

Concentration of the six metals was also measured in a variety of plant species under the baseline monitoring (PRC 1991). A complete analysis of the data has not been performed yet; however, the tissue concentration of metals in pickleweed was estimated for each RASS as a grand mean of sample location means. Means were plotted for those sample locations with surface soil chemistry less than ER-L values and greater than ER-L values (Figure 11a-b). In addition, a regression of mean soil metal concentration on mean pickleweed tissue concentration at each sample location is shown in Figure 12a-f. No strong relationships between soil chemistry and tissue concentration for pickleweed are evident in the plots of 25 sampling locations.

4.3.3 Data Gaps

Measurements of bioavailability and tissue concentrations will be conducted in the QEA to fill data gaps that currently limit characterization of ecological risk. Future sampling for contamination will include measurement of physio-chemical parameters such as grain size, TOC, pH, and surface extractions, all of which will help predict or estimate contaminant bioavailability. Furthermore, not all of the tissue concentration data collected under the baseline monitoring (PRC 1991) will be useful in the ecological assessment due to the design of the monitoring study. Tissue concentration data that are needed on other taxa in order to evaluate food chain transfer are discussed in Chapter 7.

CHAPTER 5
CONCEPTUAL SITE MODELS

Ecological risk assessment methodology is based on establishing a conceptual site model that (1) identifies the site setting in an ecological context; (2) describes potential pathways of contaminant transport; and (3) identifies ecological exposure pathways (EPA 1992a). Separate conceptual site models have been developed for each habitat type. The following sections review the relevant site setting, important chemical stressors, and exposure pathways for each habitat type. A map describing vegetation characterization was generated for each site and used to identify the portions of each RASS that are marsh, upland, or non-tidal wetland habitat. The map will be included in the final QEA report.

5.1 TIDAL MARSH HABITAT

Tidal marsh habitat is present throughout RASS 1 and through most of RASS 2, except for a narrow transitional zone on the upper portion of RASS 2 that abuts the Southern Pacific Transportation Company railroad tracks. This habitat is described in Chapter 3.

5.1.1 Chemical Stressors

Data indicate chemical stressors in the marsh of RASSs 1 and 2 include all six metals identified as COPC. Table 2 presents the proposed preliminary comparison criteria for the protection of sediment and surface water.

In RASS 1, 39 percent of surface soil sampling locations had concentrations of arsenic above ER-M values and 89 percent above ER-L values; the maximum concentration measured was 2,336.7 mg/kg (Table 5). Selenium was also detected at high levels, with 90 percent of sampling locations above the marine amphipod apparent effects threshold (AET); the maximum concentration was 20.1 mg/kg. Forty-three percent of locations exceeded ER-M values for zinc, and 34 percent for copper.

In surface soil of RASS 2, zinc was measured in the highest relative concentration, with 100 percent of locations above ER-L and 84 percent above ER-M; the maximum concentration was 7,128.3

mg/kg. More than one-third of the sampling locations exceeded ER-M values for cadmium, copper, and lead. The maximum concentration of selenium in RASS 2 was 51.0 mg/kg, with 96 percent of locations exceeding marine amphipod AET (Table 5).

The marsh reference area (Reference 2) was sampled in six locations; concentrations of all six metals exceeded ER-L (or AET for selenium) values at some locations. None of the metals were found in concentrations exceeding ER-M values. For arsenic, copper, and selenium, all six locations exceeded ER-L values. These data indicate that this area is not an appropriate reference site for comparison to the tidal marsh habitat at RASS 1 and 2.

Other contaminants not yet analyzed for may also be present. The presence of organic contaminants in the tidal marsh will be investigated in the field sampling program. DDT, DDE, and DDD may be present in the mosquito ditches or other areas of the marsh. In addition, other unknown organic compounds may be present near the border of the property with Allied Chemical. Hydrocarbons found in the upland habitat of RASS 3 (PRC 1993a) may have migrated to the tidal marsh areas through the drainages under the Southern Pacific Transportation Company railroad tracks or through groundwater movement.

5.1.2 Exposure Pathways

Based on typical species and COPCs, and conversations with regulatory agencies and natural resource trustees, dominant exposure pathways were identified (Figures 13 and 14). Ingestion of contaminated prey and media is thought to be the predominant exposure pathway in the marsh. Ingestion of sediment may be an important exposure pathway for many species that ingest sediment particles and detritus directly while feeding (oligochaetes and filter feeders) or indirectly while preying on sediment-covered taxa (demersal fishes, herons, egrets, shorebirds, and waterfowl). High trophic level predators may obtain contaminants from the tissues of their prey; this is especially important for contaminants that biomagnify, such as organochlorine pesticides. Raptors feeding on ground-dwelling mammals are likely to ingest soil and sediment on the coats of their prey. Direct dermal contact with surface soils might be an important exposure pathway for benthic invertebrates, burrowing mammals, and benthic feeding fish and birds. Plants may take up contaminants directly from the soil or surface

water and transfer them to herbivores. Potential herbivores include insects, rodents, and granivorous birds.

5.2 UPLANDS

A small portion of upland habitat is found in RASSs 1 and 2; the majority of land in RASSs 3 and 4 is upland. The upland habitat was described in Chapter 2.

5.2.1 Chemical Stressors

PRC used the NOAA ER-L, ER-M, and AET values for sediment in a preliminary ranking of chemical stressors in the upland habitats (Table 2). Because approved screening criteria for soil do not currently exist, ER-L values were chosen to represent conservative screening levels; using the same criteria in the upland and wetland habitats provides consistency to the screening approach. Site-specific toxicity reference values (TRV) for assessment endpoints will be developed for the risk assessment in this habitat (see section 9.2).

In surface soil samples, all six metals were measured in concentrations exceeding ER-L values in RASSs 3 and 4. In RASS 3, 34 percent of sampling locations had zinc concentrations exceeding ER-M values, and 13 percent had lead values greater than ER-M. In RASS 3, 97 percent of locations had selenium values exceeding the amphipod AET values; however the highest concentration recorded was only 1.1 mg/kg (Table 5).

In RASS 4, 23 percent of locations had lead concentrations greater than ER-M values; the maximum concentration was 2,253.7 mg/kg. For zinc and cadmium, 14 percent of sampling locations had values higher than ER-M. All sampling locations had selenium concentrations higher than the amphipod AET.

The upland reference area (Reference 1) was sampled in four locations, none of which had concentrations exceeding the ER-L for arsenic, cadmium, copper, lead, and zinc. All four sampling locations exceeded amphipod AET values for selenium; however, all four locations were measured at 0.4 mg/kg, the lowest of all RASS and reference locations. Based on the limited sampling conducted

thus far, this area seems to be a reasonable reference area for comparison to the upland habitat in the RASSs.

Other chemical stressors may be present in the upland habitat and may be analyzed for in the additional sampling program. To date, the area of greatest concern for possible organic contamination is the site of the old Getty pump station in RASS 3, where motor oil and other hydrocarbons were discovered during remediation (PRC 1993a).

5.2.2 Exposure Pathways

Based on species composition and COPCs, and conversations with regulatory agencies and natural resource trustees, dominant exposure pathways for the upland habitats were identified (Figures 13 and 14). Ingestion of contaminated prey and media is thought to be the predominant exposure pathway in the uplands. Many species ingest soil as a result of feeding, grooming, burrowing, and other activities. Detritivores ingest contaminated soil and detritus in the process of feeding. Many raptors ingest soil on the coats and in the guts of their prey. Bioaccumulation may result in exposure of high trophic level receptors to unacceptably high levels of contaminants even when concentrations in soil or sediment are not considered toxic to species at lower trophic levels.

Plant uptake and dermal contact may also be major pathways of exposure for ecological receptors in the uplands. Contamination in the soil may be transferred to plants through roots or leaves, which could then become available to herbivores. Burrowing animals can be exposed to contaminants through dermal contact in addition to direct ingestion of soil.

5.3 NON-TIDAL WETLANDS

The non-tidal wetlands are described in Chapter 2. This habitat in the Litigation Area is limited to the drainage basin of Nichols Creek, the new pond in RASS 3, and the small marsh in RASS 4.

5.3.1 Chemical Stressors

Data on concentrations of COPCs in the non-tidal wetlands are inadequate to allow characterization of chemical stressors in this habitat. This habitat will be characterized during the field sampling in 1995. It is reasonable to expect the same suite of contaminants in this habitat as in the rest of the Litigation Area.

5.3.2 Exposure Pathways

Ingestion of contaminated prey and media and dermal contact are expected to be the main exposure pathways of concern in the non-tidal wetlands. Due to the periodic inundation of these habitats, receptors could be exposed to contamination in surface water, soil, and sediment. Also, because these wetlands may be supplied in part from groundwater, chemicals in groundwater could add to the total exposure of receptors in the area.

5.4 FATE AND TRANSPORT OF CONTAMINANTS

This section describes possible pathways of contaminant migration at the Litigation Area. The major pathways involve hydrologic and climatic movement, food chain transfer, and biotic movement.

5.4.1 Hydrologic/Climatic Influences

Contaminants of concern may migrate within the site and off site via sediment/soil, surface water, groundwater, or as particles on the wind. The importance of these pathways will be discussed in the context of habitat type.

Marsh Habitat

The marsh habitat is subject to tidal action and seasonal inundation in the winter rainy season. Diurnal and seasonal tidal action may carry contaminated surface water, sediment, and organic matter further into the marsh and/or out to Suisun Bay. Tidal marshes in Suisun Bay are

typically aggrading rather than eroding, and the marsh of RASSs 1 and 2 is no exception (PRC 1994g). Due to the wetness of the marsh habitat, the potential movement of COPCs as particles on the wind not considered to be a significant exposure source.

Metals in sediments may be present as both dissolved fractions in the interstitial water and as solid-phase adsorptions to surfaces or organic material (Campbell1988). Preliminary study of the surface water hydrology indicates that the marsh in RASS 1 and RASS 2 is low energy, meaning that sediments are not being deposited or eroded very quickly (PRC 1994g). Further evidence of the marsh's low energy is found in the clarity of the water receding at low tide; sediments are suspended during inundation, then dropped out as the water recedes. This scenario suggests that sediment migration through the marsh downgradient from the active areas is slow, and that contaminants adsorbed to sediments remain on the site for some time. Sediments several inches below ground surface are not likely to come to the surface, unless the surface is out by a channel (PRC 1994g). Prior to the remediation in RASS 1 and RASS 2, the sloughs, too, were aggrading. Possibly changes in the tidal prism, and thus the rate of erosion, will be monitored subsequent to remedial action.

Surface water drains out of Nichols Creek in the area of RASS 3, near the new pond, and exits through the sloughs and mosquito ditches of the lower marsh. In addition, tidally forced surface water travels through the sloughs in the marsh. Mosquito ditches also have standing surface water; this water is fairly stagnant and may not connect with other drainages directly. The sediments of the marsh are at least part of the time saturated with water, and subsurface movement of contaminants could be occurring.

Groundwater flow in the marsh habitat is not well characterized as few wells are located in this habitat. Groundwater is generally flowing downslope toward Suisun Bay and is a potential source of contaminant migration (PRC 1994g). There is an as yet undetermined point where the tidal wedge of saline water likely encounters the outflowing groundwater wedge. The importance of this contact in terms of transport of contamination to Suisun Bay is not known at this time.

Upland Habitat

The predominant climatic influence on contaminant migration in the upland habitat is wind. Contaminants adsorbed to soil particles could migrate on the wind, which blows primarily from the west-northwest through the Carquinez Strait. This could result in airborne particles being deposited to the east-southeast. This would primarily be a problem in the dry period of late summer and early fall months; revegetation of the active areas is expected to reduce the probability of soil migrating off site in this way.

Groundwater at RASS 3 has been shown to be contaminated above maximum contaminant level (MCL) criteria (California Code of Regulations, Title 22) for some of the six metals (PRC 1994b); however, because groundwater at the Litigation Area is not potable due to high salinity, MCLs are not appropriate screening criteria. Groundwater movement has not been characterized adequately for RASS 4.

Non-Tidal Wetland Habitat

In the non-tidal wetland habitat, the physical forces potentially responsible for contaminant migration are surface water movement and groundwater upwelling into these low elevation zones. The new pond at RASS 3 may be receiving water from the groundwater, Nichols Creek, and from tidal action. This water may run out of the lake into a culvert under the railroad and join with the slough and ditch system in the tidal marsh habitat in RASS 2. The small marsh in RASS 4 does not appear to be connected to a larger drainage system, so transport off site is unlikely through this pathway.

5.4.2 Food Chain Transfer

Bioavailable contaminants accumulated in prey (living and nonliving material) can be transferred to higher trophic levels through food chain transfer. Concentrations of contaminants may be higher in top-level predators if contaminants biomagnify. Selenium and arsenic, detected at the Litigation Area, have been shown to biomagnify in some cases (Eisler 1988a; Saiki and Lowe 1987, as cited in Taylor and others 1992). If organic contamination is demonstrated to occur in the upland or marsh habitat, significant transfer to top-level predators may occur.

5.4.3 Biotic Movement

Contaminants may also migrate within and off site as constituents of plant and animal bodies. Contaminants in or on the bodies of mobile receptors such as fish, migrating birds, and other far-ranging predators may be carried off site and deposited in other locations in the form of feces or corpses. In addition, in estuarine environments such as the marsh, contaminant distribution or partitioning in sediment, pore water, and surface water may be affected by the activities of burrowing animals such as amphipods (Green and Chandler 1994). Large organisms responsible for significant bioturbation of the mud may mobilize subsurface contaminants. Examples include herons walking in shallow water, fishes feeding in sediments, and amphipods burrowing.

CHAPTER 6

OVERVIEW OF ECOLOGICAL ASSESSMENT FIELD INVESTIGATION

This chapter presents the objectives of the ecological assessment. To accurately characterize risk to ecological receptors at the Litigation Area, additional information is needed on the nature and extent of contamination by metals and organic compounds at the site. This information will be used to assess the ecological risk of site-specific contamination and to determine the potential for contaminant migration and transfer through the food chain.

The four main goals of the field investigation in support of the QEA are listed below:

1. To determine nature and areal extent of contamination
2. To characterize exposure of receptors to contaminants
3. To characterize toxicity and potential for bioaccumulation
4. To use these data in qualitative assessment of ecological risk to site-specific ecological receptors

Consistent with a phase 1 risk assessment under the 1992 EPA guidance, this ecological risk assessment will be qualitative, not quantitative, although quantitative data will be used during the assessment. The Navy intends to use the chemical and biological data collected under the SMP described in Chapters 4 and 7 in support of the ecological assessment. Use of these existing data will allow the QEA to be more quantitative than is usual, but will not override the goal of performing a qualitative assessment to validate remedial action decisions at the Litigation Area.

The field investigation in support of the QEA at the Litigation Area will begin in summer 1995. Chapters 7, 8, 9, and 10 outline the overall strategy of sampling and analysis to be used at these sites based on the goals of documenting the nature and areal extent of contamination and the potential for adverse effects of contaminants on biota. Chapter 7 presents the methodology for measuring the nature and extent of contamination. Chapters 8 and 9 describe how potential exposure and resulting toxic effects to receptors will be characterized, including a discussion on the potential for bioaccumulation. Chapter 10 presents the methodology for the risk characterization. The draft final FSP includes details such as the number and location of sampling locations, selection of locations for

bioassays and tissue concentration studies, field methods, and data analysis and interpretation. The quality assurance project plan (QAPjP) describes standard operating procedures, laboratory analyses, data quality objectives, and QA/QC. Figures 15 and 16 provide an overview of details to be found in the FSP.

CHAPTER 7
NATURE AND AREAL EXTENT OF CONTAMINATION

The objective of this sampling plan is to better characterize the nature and areal extent of contamination in the Litigation Area by randomly selecting sampling locations within spatial areas of the Litigation Area not previously sampled and analyzing for contaminants not previously investigated. The spatial distribution of contaminants will be determined by collecting soil, sediment, sediment pore water and surface water samples from areas not sufficiently sampled during baseline monitoring. It is important to determine the concentrations of organic contaminants and other metals not analyzed for in the past to adequately estimate risk to ecological receptors. In addition, other parameters will be measured to assess the bioavailability of contaminants at these sites. Specific areas to be sampled are listed in Section 7.6.

7.1 USE OF EXISTING DATA

To date, data on dry weight and wet weight concentrations of six metals (arsenic, cadmium, copper, lead, selenium, and zinc) have been collected from surface soils, with minimal data on subsurface soils, sediment, surface water, and groundwater. Some of the sampling locations were chosen randomly; however, most were biased toward the borders between active and passive remediation areas. Non-random samples in the middle of the passive and monitoring areas are not adequate for assessing ecological risk. Few samples were taken in the sloughs and ditches. Metals other than the six listed and organic compounds have not been included in the sampling program as yet. In addition, no extraction or measure of bioavailability was performed, except in the active areas. The biased sample design and restricted list of analytes limits the applicability of these data to the QEA.

Spatial gaps in existing data will be filled with additional sample locations. The final QEA report will include a spatial analysis of contamination contours based on the data from the BCR (PRC 1994a) and the additional data collected during the upcoming field sampling.

Bulk chemistry data collected during baseline monitoring (PRC 1994a) have been incorporated into site maps based on the relationship of observed concentrations to effects range - low (ER-L) and effects range - median (ER-M) values. These maps will be included in the final QEA report.

Table 5 indicates the number of sampling locations in each RASS that exceed the ER-L and ER-M values for arsenic, cadmium, copper, lead, and zinc and the amphipod apparent effects threshold (AET) values for selenium. The metals were ranked in each column to indicate their relative concentrations at each RASS based on the criteria used. The bulk chemistry data from the baseline monitoring will be used to focus additional chemical sampling that will include a broader array of contaminants and measures of bioavailability. In addition, hazard quotients and hazard indices (see Section 7.3) based on the concentrations found during the baseline monitoring, will be used to supplement similar calculations based on the newly obtained data. These calculations will be used to determine locations requiring additional study.

In preparation for the baseline monitoring study, 22 wells were installed in the Litigation Area: six at RASS 1, six at RASS 2, seven at RASS 3, and three at RASS 4 (PRC 1994e). A report on the elevation and chemical composition of groundwater collected from these wells for the past 3 years (PRC 1994e) is now under review by the regulatory agencies. The Navy understands that the San Francisco Regional Quality Control Board (RWQCB), California Department of Toxic Substances Control (DTSC), and EPA have some concerns about the appropriate use of those data, due to the location, depth, and screening of the wells. The Navy is currently in discussions with the regulatory agencies to reach consensus on the best way to monitor groundwater at the RASSs. Outstanding issues include the appropriate use of a reference well, the depth and screening of wells, and the tidal influence on existing wells. Groundwater is not considered a primary exposure pathway to ecological receptors in the Litigation Area at this time, although this perspective may change as more data are collected.

The Navy anticipates that the long-term monitoring study will be revised to make best use of baseline data collected so far. Relocation of wells is to be considered in the revision. However, for the immediate purposes of the QEA, thorough characterization of surface water hydrology may be a greater priority than characterization of groundwater at the site. Metals commonly bind to sediments at the surface and may be transported with the sediments by wind, water, and animals. To predict the potential for migration of contaminants, both surface water and groundwater models must be developed.

7.2 ADDITIONAL CHEMICAL SAMPLING

Additional sampling for soil, sediment, sediment pore water, and surface water locations will be selected randomly in areas that need further characterization and in areas that are suspected of being contaminated by organic compounds. All new sample locations will be analyzed for metals, SVOCs, PAHs, organochlorine pesticides, and PCBs. Samples will also be analyzed for VOCs, TPH-diesel, TPH-gasoline, and organotins at locations where historical releases or activities warrant such analyses. Contaminant bioavailability will be evaluated using surface extractions of soil and sediment. The surface extractions and their relationship to bioavailability are discussed in detail in Section 9.1. Samples will be taken from the soil/sediment surface (0 to 0.5 foot) and below the surface (1 to 1.5 feet), as described below. The number of sampling locations and exact locations are discussed in the FSP.

The data in Table 3 indicate that levels of metal concentrations in subsurface soil samples exceed ER-L values to a vertical extent of at least 3 feet bgs. While these data are limited to the areas that have been excavated, characterization of subsurface contamination increases the accuracy of exposure pathway models and improves the quality of the QEA. Based on PRC field observations at RASSs 1 and 2, the direct exposure of receptors such as plant roots, burrowing mammals, or burrowing clams is probably limited to the upper 18 inches of soil or sediment (PRC 1994h, PRC 1995c, 1995d). Although contamination at depths greater than 18 inches may pose a long-term risk if the contamination were brought to the surface layer, hydrologic study of the area suggests that sediment at that depth is unlikely to reach the surface unless purposely disturbed (PRC 1994g).

All new sampling locations in the sloughs and ditches of RASSs 1 and 2 and the wetlands of RASS 3 and 4 will include measures of chemical concentrations and physical parameters (TOC, grain size, pH) at the surface and at 12 to 18 inches bgs. For the marsh and upland habitats, 20 percent of new sampling locations will include measurements of chemical and physical parameters at 18 inches bgs. This 20 percent subsample of the new locations will be selected randomly. Exact locations of subsurface samples are mapped in Figures 2a and 2b in the FSP. Physical parameters to be sampled at the additional sampling locations, where appropriate, are salinity, dissolved oxygen (DO), conductivity, temperature, biological oxygen demand, sediment oxygen demand, TOC, pH, oxidation/reduction potential (Eh), and sediment grain size. All of these measurements are useful in

estimating the bioavailability of contaminants found. Specific measurement parameters and sampling locations are detailed in Tables 1, 2, and 3 in the FSP.

Additional sampling locations were chosen in the center of the passive area and in parts of the monitoring areas of RASS 1. In addition, randomly selected locations in representative areas of the mosquito ditches and sloughs will be sampled for metals and selected organic compounds. In RASS 2, samples will be taken in the center of the passive areas and in the sloughs that connect the marsh to the upland habitat. Selection of sampling locations is discussed in Section 7.6 of this work plan and shown in Figure 2 of the FSP.

In RASS 3, locations will be randomly selected in the area described as a possible plume from the Getty refinery site described in Chapter 4. In addition, surface water and sediment from the new pond will be sampled. Finally, sample locations will be added to the passive and monitoring areas to fill in spatial gaps in the current monitoring plan. In RASS 4, sediment and water samples will be taken from the non-tidal wetland. Additional samples will be located in the central areas of the passive and monitoring plots.

7.3 CALCULATION OF HAZARD QUOTIENTS AND HAZARD INDICES

The bulk chemistry data will be used to calculate hazard quotients (HQ) for each metal and organic contaminant. The following equation used to calculate HQs is based on guidance by DTSC (DTSC 1994):

$$HQ = \text{Concentration in field samples} / \text{criterion value}$$

The criterion value used will be either the ER-L or the mean contaminant concentrations for metals in the San Francisco Bay sediments (RWQCB 1994). For metals, the higher of the two criteria will be used in the calculation of the HQ. Because ER-Ls are based on data collected from across the nation, they cannot be expected to accurately represent site-specific conditions in San Francisco Bay. In fact, for some metals, San Francisco Bay mean concentrations may exceed ER-L values. Whether the higher levels in San Francisco Bay stem from natural geochemical processes or from anthropogenic activities, an ER-L lower than the local mean concentration could not be considered a valid screening

criterion for a QEA. For example, a study is underway at the Tidal Area at WPNSTA Concord to explain the origin of seemingly elevated levels of mercury in environmental samples. Some evidence points to the rock formations in the nearby hills as the source of some of the mercury detected in soils at the installation. A further complication is that even when local mean concentrations of metals are above a hypothetically toxic level, natural geochemical factors may reduce the mobility of the metals to such an extent as to make the metal unavailable to organisms. Because ER-L values are derived from toxicity studies (bioassays), site-specific differences in bioavailability of the metals can weaken the power of the ER-Ls as screening criteria at a given site.

The most appropriate use of ER-L and San Francisco Bay mean concentrations will be determined through conversations among the Navy, the regulatory agencies, and the natural resource trustees. For those contaminants for which no ER-L value has been estimated, such as many of the organic compounds, criteria based on available toxicity literature on chronic and sublethal effects will be used. Because there is no ER-L value for selenium, the most appropriate surrogate now is the marine amphipod AET value (PTI 1989) (Table 2).

Hazard indices (HI) for metals were calculated for each RASS by summing the HQs. As an example, the HQ values were summed for arsenic, cadmium, copper, lead, and zinc using the existing site data to create an HI for each sampling location. Because of the low value of the amphipod AET compared to San Francisco Bay median values, the assessment of risk to ecological receptors from selenium will be kept separate from the other five metals to prevent its domination of the HI. A histogram of ranked HIs for each RASS (Figure 17) based on five metals shows that all but one of the locations exceeds 1.0; an HI greater than 1.0 is generally considered an indication of toxicity (EPA 1992a; DTSC draft 1994). The HIs for five metals for each sampling location at the RASSs are shown in Figure 18. The HQ used to calculate the HI are listed in Appendix C-1.

Selenium will be considered separately from the other metals in the risk assessment due to the lack of ER-L values and because selenium's bioaccumulation in the aquatic environment differs from other metals (Taylor and others 1992). A map indicating spatial distribution of HQs for selenium is shown in Figure 19. Generally, selenium levels increase toward the bay in the Litigation Area. Appendix C-2 provides the HQs for selenium at RASS and reference locations.

7.4 ANALYSIS OF CHEMICAL DATA

The HIs were used as a way to rank the previously sampled locations and to make sense of the spatial patterns of measured chemical concentrations. In and of themselves, HQs and HIs have not always been reliable indicators of toxicity or risk to ecological receptors. In conjunction with estimates of bioavailability, however, HIs may be used to assign relative risk to a variety of sites during the scoping phase of a QEA. The relevance of using HIs in this way at the Litigation Area will be tested using correlational analysis between HI value and toxicity as measured by amphipod mortality and reburial. A positive correlation greater than 0.50 between HIs and toxicity will be interpreted as a suggestion for the use of HIs as a preliminary indicator of ecological effect at the Litigation Area. If, for example, percent survival of *Eohaustorius* decreases as HI increases, then HI can be said to be a useful indicator, although not a causal agent of, amphipod mortality. Poor or negative correlations will be interpreted as evidence that HIs should not be used as indicators of ecological effect; in this case, bioassay results will be used as a primary risk component. Correlations of all combinations will be arrayed in a matrix, and a weight-of-evidence approach will be used to interpret overall significance of observed effects. Because the high cost of bioassays limits the proportion of sediment and soil samples that can be tested in this way, estimates of the correlation between a randomly selected set of HIs and bioassay results can enhance the accuracy of exposure and toxicity models used in the QEA.

7.5 CHEMICAL AND PHYSICAL CRITERIA FOR SELECTION OF REFERENCE SITES

The marsh reference site used in the preliminary data collected for the BCR (PRC 1994a) exhibited high levels of metal contamination and high HIs. The problems with finding adequate reference sites include widespread but unquantified contamination, differences in physical and biological characteristics, such as sediment grain size and soil type, and variability in community structure, all of which greatly affect interpretation of data. The northwest corner of RASS 1 may represent an alternative reference site for the marsh habitat. Low levels of metal contamination were detected at the single sampling station in this location (1M57), and low HIs were calculated based on the preliminary data. The Navy is proposing to collect replicate soil samples (five at the surface and five at depth) in the vicinity of sampling station 1M57 to evaluate the area as an alternative marsh

reference site. In addition, bioassays and tissue residue analysis are proposed for this location. If these samples continue to show low concentrations when analyzed for the full suite of metals and organic compounds, and toxicity to test organisms is low, it could provide the best control plot for this study. In cooperation with regulatory agencies and natural resource trustees, an appropriate marsh reference station will be selected.

The upland reference site will continue to be used as a reference area for the upland habitats, as preliminary data indicate low values of metal contamination and overall low HIs. The four randomly located sample locations selected during the baseline monitoring will be used, and one additional location randomly selected, for a total of five random sampling locations that will be collected to better characterize chemical contaminants and the bioavailability of metals at the reference site.

7.6 SELECTION OF SAMPLING LOCATIONS

Specific sampling locations were chosen using a stratified random sampling design based on the sampling objectives and utilizing the sampling grid system created for the baseline monitoring (PRC 1991). Each RASS and reference area is overlain with a grid system that divides the area up into 100- by 100- foot units. For analysis of surface and subsurface soil bulk chemistry, surface extraction, and additional physio-chemical parameters, randomly selected grids were chosen from within areas identified as needing additional chemical characterization. The characterization of physio-chemical parameters in sloughs, ditches, and ponds will be carried out using a stratified random sampling design. Ditches and sloughs were addressed separately by subdividing each into smaller units and choosing sampling locations randomly within those subunits. Detailed maps of sample locations are provided in the FSP.

Sampling locations for bioassays were selected using a stratified random sampling design. All bioassay samples will use surface sediments collected from slough and ditch locations that are also being sampled for chemical and physio-chemical parameters. Amphipod whole sediment and sea urchin pore water bioassays are restricted to sloughs and ponds because these areas are expected to provide the greatest exposure pathway to the rest of the marsh community, and are thus of the greatest interest to the QEA. In addition, surface soils at the proposed marsh reference location will be tested using both types of bioassays.

Locations for collecting field organisms for analysis of tissue residue were chosen randomly based on a stratified sampling design. Slough and ditch locations were selected for amphipods because PRC observed large numbers of amphipods in these areas during a previous field visit. Locations for collecting fishes were restricted to the larger sloughs to ensure adequate mass for analysis. Pickleweed will be collected from the proposed marsh reference area for comparison to specimens that will be collected from elsewhere in the Litigation Area.

CHAPTER 8

PRELIMINARY ASSESSMENT AND MEASUREMENT ENDPOINTS

In accordance with EPA guidance (1992a), preliminary assessment and measurement endpoints were selected for the Litigation Area at WPNSTA Concord. These endpoints may be subject to modification based on additional data collected during reconnaissance activities and a thorough review of the literature to determine their suitability as representatives of feeding guilds. Tables 6, 7, and 8 presents a list of assessment endpoints, the rationale for their selection, appropriate measurement endpoints, and the linkage between assessment and measurement endpoints. At a pre-work plan meeting, the Navy, PRC, and the regulatory agencies agreed to the preliminary selection of these species as endpoints. Subsequent review of species lists indicated that Barrow's goldeneye is not a frequent visitor to the site; therefore, the Navy proposes to substitute another diving duck that is present in the marsh and maximally exposed.

8.1 RATIONALE FOR SELECTION OF ASSESSMENT AND MEASUREMENT RECEPTORS

Taxa reported to use the habitats at the Litigation Area were considered as possible assessment endpoints. Protection of the population was used as the endpoint for all species except those for which the individual is the unit of protection due to federal or state threatened or endangered status. By definition, assessment endpoints have ecological, toxicological, and societal importance (EPA 1992a). Several site-specific factors influenced the selection of endpoints, including the occurrence, ecological significance, conservation status, life and natural history characteristics, and toxicological susceptibility of receptors; the known and potential contaminants present and their mechanisms of toxicity; and the spatial and temporal exposure patterns and pathways. Species that occur all or part of the year at WPNSTA Concord were selected for their potential exposure to contaminants within a feeding guild; it is reasonable to assume that if resident species are shown not to be at risk, then migrants are safe from contaminants at the site, as well. An exception to this is the state and federally endangered peregrine falcon. Although the falcon does not reside at the site, nearby nesting pairs on Mt. Diablo or the Carquinez Bridge may be taking prey that feed at the Litigation Area. Moreover, the endpoints have important and diverse ecological roles as species native to the site and were chosen to provide protection of major ecological niches in the Litigation Area habitats. For

example, pickleweed is not only an important primary producer, but also functions as a structural element for the wetland habitats. On the other hand, top predators, like raptors, great blue heron, and gray fox, are essential stabilizing members of the community that help maintain diversity and prevent overpopulation by lower trophic level organisms. The taxa are valued by society, as evidenced by their conservation status. The salt marsh harvest mouse and the peregrine falcon are federal and state endangered species; the northern harrier and the Suisun song sparrow are California special animals; and the black rail is a state threatened species. Waterfowl are prey of the peregrine falcon, as well as being harvested and consumed by humans. These taxa also have recreational value for birdwatchers and naturalists across the state and country.

Taxa selected as assessment endpoints were chosen to represent ecologically important and toxicologically sensitive groups of receptors. For example, the potential for risk to the great blue heron can indicate potential risks for other piscivorous birds having similar exposure routes and physiology. Also, the risk characterizations for the northern harrier and the American kestrel can be used to evaluate potential risks to birds of prey.

Toxicological concerns also guided the selection of endpoints. Factors considered included the sensitivity of receptors to contaminant effects, such as the effects of organochlorine pesticides on reproduction of avian species, the fate and transport characteristics of contaminants, such as selenium bioaccumulation in aquatic systems, and dominant exposure routes, such as ingestion of contaminated prey. Endpoints were chosen to represent risk posed through all major exposure pathways considered important at this site (Chapter 5), emphasizing pathways to particularly sensitive receptors.

8.2 NATURAL HISTORY RELEVANT TO ENDPOINT SELECTION

Receptor-specific natural and life history characteristics influencing potential risk, such as diet, trophic relationships, residency, foraging range, and possible exposure pathways, were evaluated during the selection of assessment endpoints. These features are presented for each receptor in Table 8. A complete literature review examining diet composition, foraging range, trophic relationships, behavior, and other factors influencing risk is being conducted for each species to evaluate the overall appropriateness of each assessment endpoint as representative of an ecological niche at the Litigation Area.

8.3 RELATIONSHIPS BETWEEN ASSESSMENT AND MEASUREMENTT ENDPOINTS AND RISK CHARACTERIZATION METHODS

Assessment and measurement endpoints were designed to function together in models for characterization of risk at the Litigation Area. Risk to some assessment endpoints (such as pickleweed and the benthic invertebrate community) will be measured directly; however, many assessment endpoints must be measured indirectly due to conservation concerns. For assessment endpoints that cannot be measured directly, measurement endpoints were selected based on dominant exposure pathways for each assessment endpoint as defined in the conceptual site model. The relationships between assessment and measurement endpoints are described in Table 7.

The methodologies for characterization of risk to assessment endpoint taxa and measurement endpoints proposed consist of three general types: (1) risk characterization through direct toxicity testing, (2) risk characterization through exposure and effects modeling, and (3) risk characterization through bioaccumulation and tissue residue analysis. Each of these methodologies is introduced below.

For some assessment endpoints, such as the benthic invertebrate community, risks will be evaluated based on direct toxicity testing of assessment endpoint taxa. The specific bioassays to be performed are detailed in the FSP. The effects assessment and risk characterization methodologies associated with direct toxicity testing are detailed in Sections 9.1, 10.1, and 11.1.

For assessment endpoints that cannot be measured directly, risk will be evaluated based on HQs calculated from contaminant exposure and effects modeling. For these taxa, exposure models will estimate a daily chemical dose for each assessment endpoint and COPC based on field measurement of tissue contaminant concentrations for prey species important to assessment endpoint taxa. This methodology for exposure and effects modeling and the associated risk assessment methodology is detailed in Sections 9.2, 10.2, and 11.1.

For other assessment endpoints, such as pickleweed and the salt marsh harvest mouse, risks will be evaluated by comparing contaminant tissue residues from surrogate species collected on site with

tissue concentrations considered to indicate exposure to contamination. For example, organ and bone tissue residue data on the California vole gathered under the monitoring plan will be used to evaluate potential risks to the salt marsh harvest mouse through comparison of the vole's tissue residues with small mammal residues believed to be above background. This risk assessment methodology is purely qualitative and is detailed in sections 9.2, 10.2, and 11.1. The proposed prey species to undergo tissue concentration analysis and the brief methodologies for these analyses are presented in Chapter 7.

Table 7 shows the primary risk characterization methodology to be used for each assessment endpoint, as well as the data to be used in making this risk characterization.

For most assessment endpoints, a quantitative analysis of exposure and effects will be performed for qualitative risk characterization. However, because of limited or undetermined use of the site by some taxa, such as the peregrine falcon, or because of uncertainties involved in the proposed effects assessment methodologies, a quantitative analysis of exposure and effects may not be possible for every assessment endpoint. However, factors such as these do not merit elimination of such taxa from some consideration of potential risk, especially when the species is of special conservation concern or when the species might experience high levels of exposure.

If, in the process of gathering data needed for the quantitative exposure and effects analysis, it becomes apparent that the required data are not available for some assessment endpoint taxa or that the methodology will not permit a quantitative exposure and effects assessment, a qualitative analysis of exposure and effects will be conducted for these taxa. This qualitative analysis will be based on the available data on the species, as well as the quantitative exposure and effects assessment conducted on assessment endpoint receptors that are in related guilds or that are possible prey items. For example, a qualitative exposure and effects assessment for the peregrine falcon may be based partly on the quantitative analyses for the American kestrel and the northern harrier, by virtue of similarity in guild, and for diving ducks and the Suisun song sparrow, by virtue of their possible use as prey.

Example descriptions of the rationales for use of measurement endpoints in risk characterization is provided below for pickleweed and benthic invertebrates. In the marsh habitat, pickleweed is a major food source and structural component required by the salt marsh harvest mouse, which in turn

is eaten by several raptors and the gray fox. Toxicity and tissue concentration of pickleweed will be measured directly. These data will provide information for the characterization of risk to several assessment endpoints. First, ingestion of contamination through food by the salt marsh harvest mouse and other herbivorous rodents will be estimated, which will yield toxicity information directly applicable to these species. These data will also provide information on the potential biomagnification of contaminants through food chain exposure from pickleweed to predators feeding on herbivorous rodents, such as the raptors and gray fox.

Filter-feeding benthic invertebrates inhabiting the sloughs and marsh are fed on by shorebirds, such as the black rail, diving ducks, and benthic-feeding fish. Large invertebrates, fish, and other small vertebrates are prey for the great blue heron. Toxicity and/or tissue concentration studies of amphipods and fish (species and size class to be determined) will be used to assess health of the prey base and dietary exposure of the black rail, diving ducks, and great blue heron. In the uplands and marsh habitat, several passerines, including the red-wing blackbird, salt marsh yellowthroat, and the Suisun song sparrow, also feed on marsh invertebrates and seeds. Bioassay and tissue concentration data from the benthic invertebrates will be supplemented with ryegrass bioassays to evaluate the effect of contaminants on the plant and animal foods of the passerines.

8.4 RECONNAISSANCE ACTIVITIES

Additional ecological information needed to finalize selection of assessment and measurement endpoints will be gathered before the beginning of the primary sampling period in summer of 1995. Additional information needed includes the range of salinity of standing water, the use of the ditch and slough habitats by benthic invertebrates and fish, and the seasonal use of habitats by birds.

8.4.1 Salinity Measures

Salinity was measured in standing water in sloughs and ditches in the marsh habitat and in the new pond in RASS 3 to help focus choices of bioassays (specifically amphipod bioassays) on species tolerant of site-specific conditions and to better characterize physical parameters affecting biotic community composition. Salinity values ranged from 2.0 to 4.0 parts per thousand (ppt) in sloughs, ditches, and the pond in RASS 1 and RASS 2 (PRC 1995b).

8.4.2 Benthic Invertebrate and Fish Fauna in Sloughs, Ditches, and Non-tidal Wetlands

Benthic invertebrate abundance and diversity will be qualitatively sampled in the sloughs and ditches in the marsh habitat and in the new pond. The goal of this approach is to qualitatively characterize the benthic fauna as a prey base for assessment endpoints and as a check on the appropriateness of taxa to be used in bioassay and bioaccumulation studies. These surveys will be conducted in summer 1995 and will include appropriately replicated sediment cores and dip net sweeps taken from mosquito ditches and sloughs that bisect the marsh habitat. Dip nets and sediment cores will also be used in the pond in RASS 3. Cores will be sieved and contents examined for diversity and a measure of abundance of major taxa, as described in Section 3.1 of the FSP. In a similar fashion, replicated samples of fish fauna in sloughs, ditches, and the pond will be sampled with minnow traps, dip nets, and seines, as described in Section 3.2 of the FSP. This qualitative description of diversity and abundance of fish taxa will be used to assess the nature of the fish prey base for piscivorous receptors and to select a species suitable for use in bioaccumulation studies.

8.4.3 Seasonal Use of Habitats by Birds

Seasonal use of marsh and upland habitats by birds will be assessed with surveys in summer 1995 and early winter 1995-1996 to document the presence of birds and to verify existing species lists for these areas. The waterfowl database compiled by the National Biological Survey (USFWS) and the Audubon Society Christmas bird counts have been queried for occurrence of avian species at and near WPNSTA Concord. These data were used in the selection of assessment and measurement endpoints. Further data on seasonal use of habitats by birds will be obtained from other sources, such as the Golden Gate Raptor Observatory and the Point Reyes Bird Observatory, to increase the accuracy of the species lists and the appropriateness of assessment and measurement endpoints. Survey data will be used to identify an appropriate waterfowl species to serve as an assessment endpoint.

CHAPTER 9
CHARACTERIZATION OF EXPOSURE TO RECEPTORS

Exposure characterization is a description of the interaction between receptors and COPCs at a site. Estimates of actual exposure are based on characteristics of chemical, biological, and physical components of the site. For example, the maximum risk posed by a contaminant depends in part on its fate and transport in the medium of concern, its spatial and temporal variability in concentration, its potential to reach receptors, its mode of action, and the nature of other chemical and physical stressors at the site. The sensitivity of a receptor to a contaminant depends in part on the timing and duration of exposure, the life history stage exposed, the overall condition of the receptor apart from any effects due to contaminants, species-specific sensitivity, the presence of other contaminants, and other factors. Furthermore, the physical characteristics of a site, such as pH, salinity, soil and sediment qualities, and presence of sulfides, can affect the toxicity of contaminants by affecting their bioavailability. These chemical, biological, and physical factors together affect the exposure and thus the realized toxicity of a contaminant to ecological receptors at a given site.

Evaluation of these chemical, biological, and physical factors to develop potential exposure pathway models for each assessment endpoint is one of the first steps in characterizing risk. Measurement of the results of potential exposure, such as toxicity testing and tissue analysis, are methods of identifying ecological effects. However, for many of the wildlife species at WPNSTA Concord, direct toxicity testing and tissue analysis are not practical. All of the assessment endpoints at the site are species native to California; some are species of special conservation concern, making direct tissue sampling undesirable. For example, no toxicity testing or tissue sampling of shorebirds and raptors is suggested because of their conservation status. However, direct toxicity testing and tissue sampling of benthic invertebrates is practical since these species are commonly harvested.

For evaluation of potential risks to assessment endpoints using direct toxicity testing, a separate exposure assessment is not necessary, since toxicity testing measures both exposure and effects. However, exposure of and risks to these assessment endpoints will also be evaluated based on the data on the bioavailability of contaminants, as described in Section 9.1.

For receptors not available for direct toxicity testing or tissue measurement, the route, magnitude, duration, and frequency of exposure will be analyzed through receptor-specific exposure models, as described in Section 9.2. Based on the conceptual site models and the assessment endpoints, exposure scenarios will be developed to describe the pathways COPCs take through various environmental compartments to reach the receptor. Models will estimate exposure of receptors based on complete pathways, distributions of contaminants in the media to which they are exposed, and the life history traits affecting the receptor's probability of contact with contaminated media. The model will produce a dose estimate to be used in characterizing risk by comparison with TRVs.

9.1 BIOAVAILABILITY

Use of direct toxicity testing and tissue residue analysis to evaluate risk to organisms precludes conducting a separate exposure assessment. However, because the toxicity and bioaccumulation of certain elements depend on the bioavailability of the element in the medium (Adriano 1986), estimates of the bioavailability of contaminants to receptors is of value to ecological assessments, as discussed in Section 4.3.1.

No comprehensive study of the bioavailability of contaminants at WPNSTA Concord has been conducted. The only available measure of the labile fraction of metals at the site is a limited set of data based on WET analysis of soil. WET analysis uses either a weak organic acid (0.2 molar sodium citrate) or deionized water to measure the mobility of metals and metalloids, which is strongly correlated with their bioavailability (Luoma and Bryan 1981).

The available WET data were collected as a way of determining the disposal options for soil to be excavated from the active areas. Soil samples from the active areas were screened against the TTLC and STLC, criteria set forth by the state of California to screen hazardous waste for disposal. Any sample concentrations greater than the TTLC and less than 10 times the STLC were analyzed by the WET method. Descriptive statistics of the WET results and the bulk dry chemistry results are presented in Tables 2a through 2c. These WET data will be statistically compared to data from toxicity testing to be conducted (Section 10.1) to examine their use as descriptors of bioavailability and toxicity. These comparisons will be detailed in the FSP, as will other methods of estimating bioavailability.

This QEA assumes that the more soluble constituents of a soil and sediment, including the labile (weakly bound) fraction, are more bioavailable and more likely to be toxic to biological receptors (RWQCB 1992, RWQCB 1994). The labile metal fraction has been correlated to metal uptake by freshwater aquatic plants (Auleo 1980) and estuarine aquatic plants (Folsom and Lee 1983; Millward 1980), and to bioaccumulation of metals by filter-feeding benthic invertebrates (Loganathan and Burau 1975). The bioavailable fraction of metals and metalloids can be estimated using surface extraction methods that extract the labile fraction. Two leachability tests, one following the WET protocol (California Code of Regulations, Title 22) using deionized (DI) water and the other using 0.5 normal hydrochloric acid, will be conducted on sediments at the Litigation Area. The extraction with DI water is thought to estimate bioavailability of contaminants in the short term, while the extraction with the hydrochloric acid is a stronger extraction thought to estimate longer term bioavailability. The methods are described in Section 8.8 of the QAPjP. The following factors influencing bioavailability in sediments and soil will also be measured in sediment, soil, and water, where appropriate: salinity, dissolved oxygen, pH, conductivity, temperature, total organic carbon, biological oxygen demand, sediment oxygen demand, and grain size. The use of these data to estimate and describe bioavailability is discussed in the FSP.

9.2 EXPOSURE MODELING

Exposure models will be used to estimate the mass of a chemical internalized daily by an assessment endpoint receptor per kilogram of body weight (daily chemical dosage). For each COPC and each assessment endpoint, the estimated daily chemical dosage will be compared to a toxicity reference value using the HQ method to determine the potential adverse biological effects to the receptor. Based on the HQ, risks for the assessment endpoint will be qualitatively evaluated.

The principal routes of exposure are ingestion, inhalation, and dermal contact. For this phase of the QEA at the Litigation Area, exposure through ingestion will be evaluated quantitatively for certain assessment endpoints as described in Section 8.4. Exposure through inhalation or dermal contact will be evaluated qualitatively.

An example exposure model follows. This generic equation will be customized for each assessment endpoint.

$$Dose_{total} = \frac{[(IR_{prey} \times C_{prey}) + (IR_{soil} \times C_{soil})] \times ED \times SUF}{BW}$$

where:

$Dose_{total}$	=	Estimated dose from ingestion (milligrams per kilogram [mg/kg] body weight-day)
IR_{prey}	=	Amount of prey ingested (mg/day)
C_{prey}	=	Concentration of contaminant in prey (mg/kg)
IR_{soil}	=	Amount of soil ingested (mg/day)
C_{soil}	=	Concentration of contaminant in soil (mg/kg)
ED	=	Exposure duration (fraction of year spent at WPNSTA Concord) (unitless)
SUF	=	Site use factor (unitless)
BW	=	Body weight (kg)

The total exposure from ingestion for each receptor of concern will be calculated as the sum of the dietary and soil (or sediment) exposure estimates. Potential exposure through ingestion of contaminated water will not be included in the exposure model, since the pathway does not exist at the Litigation Area due to the lack of on-site sources of fresh surface water.

The basic components of the exposure models are (1) temporal and spatial characterization of receptors and contaminants, (2) ingestion rates and diet composition, and (3) food chain exposure calculations. The specific parameters associated with these components are addressed in the following subsections.

9.2.1 Temporal and Spatial Characteristics

Seasonal activities, habitat preference, and the feeding behavior of a receptor, as well as spatial variation in contaminant distribution, can influence the degree to which a receptor is exposed to a contaminant. To account for the seasonal use of habitat at the Litigation Area, an exposure duration (ED) factor will be calculated. An ED value of 1 will be used for species that are year-round residents of the assessment area, and a value between 0 and 1 will be used for migratory species based on the fraction of the year spent in the region. This information will be developed first from

site-specific or regional information and secondarily from literature; the data providing the most conservative estimation of risk will be used.

In addition to seasonal factors, a receptor's exposure is influenced by the likelihood of its using the habitat in which contamination is found. One measure of habitat use is the receptor's home range. That is, species with comparatively large home ranges relative to the area of contamination may be exposed less than those with small home ranges. However, standard estimates of home ranges in the published literature may need to be modified for exposure assessment. Home range generally includes the total area in which an animal spends some amount of time during a certain season, including breeding, foraging, roosting, and travel routes (Lincoln and others 1982). A further complication is that home ranges can vary by gender, reproductive condition, and size of the animal, as well as by season and other dynamic factors. A more appropriate comparison may be the size of the animal's foraging area with the area of contamination, if the primary exposure pathway is ingestion. Estimates for different age and sex classes may need to be made, depending on the species. If the primary exposure pathway is direct contact with contaminated soil or sediment during burrowing, then the extent of burrow area should be compared with the area of contamination. A site use factor (SUF) will be developed for each receptor based on the following ratio:

SUF = Area of contamination (acres)/Area of potential exposure (acres)

where	Area of contamination (AC)	=	areal extent of contamination by a single contaminant
and	Area of potential exposure (APE)	=	area used by the receptor in a way that represents exposure, such as foraging, digging, or other use

SUF will be reported as a proportion, with any values greater than unity being converted to 1.0; values less than 1.0 will be reported directly. The SUF will be used in the daily dose estimate equation presented in Section 9.2. The AC will be measured by drawing contaminant contours on the site maps for each COPC. For the exposure estimate, two contours will be drawn: (1) "Low" - concentrations between ER-L and ER-M and (2) "High" - concentrations exceeding ER-M. The area within each contour will be digitized and quantified as a proportion of the total habitat at the Litigation Area.

To arrive at a more accurate estimation of site use, two estimates of the SUF will be calculated, one using the "Low" AC and one using the "High" AC. These two estimates will result in different daily dose estimates. Estimates of exposure to the receptor will be based on the proportion of the habitat that falls into the "Low" and "High" concentration areas compared to the area used by the receptor. For example, if a kestrel's foraging range extends across the marsh habitat, and the "Low" AC represents 40 percent of the habitat, then the daily dose estimate for the kestrel would be the sum of 40 percent of the "Low" dose and 60 percent of the "High" dose. Existing data gathered during monitoring on the use of habitats at the Litigation Area by taxa of concern is detailed enough to allow this more site-specific determination of an appropriate SUF.

Almost all of the chemical sampling conducted at the site has focused on bulk chemical analysis of six metals (arsenic, copper, cadmium, lead, selenium, zinc). At this point, all six of these metals are considered COPCs. Subsequent sampling will determine whether other metals, PAHs, petroleum hydrocarbons, and organic pesticides are elevated at the site. This discussion of potential exposure assumes that in addition to the six metals, one or more organic compounds with the potential to be biomagnified will be identified as a COPC at the Litigation Area. If no organic compounds are found in elevated concentrations at the site, those portions of the exposure model will be revised. Based on the results of the HI calculations and bioassay, bioaccumulation, and tissue residue measurements (as described in Chapter 7), contaminant hot spots will be defined at the Litigation Area. Use of these hot spots by receptors will be analyzed to identify the potential coincidence of high contaminant concentrations and receptor feeding sites.

9.2.2 Ingestion Rate and Diet

Ingestion is a route of exposure that may involve many different media, most commonly food, water, soil, and sediment. While the diet content and ingestion rate may vary seasonally, in general, a receptor's ingestion rate can be defined as a function of its metabolic rate and body size. When available, regional information will be used to estimate the body weight and amount of food a receptor ingests. Literature values or allometric regression models (EPA 1993a, 1993b) will be used to estimate ingestion rates if regional information is lacking.

Diet composition may be affected by changes in season, availability of prey or forage, reproductive condition, individual variation, and many other factors. Since all of this variability is not easy to incorporate into an exposure model, average estimates will be used as much as possible. For year-round resident species for which seasonal data are available, diet composition will be averaged over seasons. For migratory species, diet appropriate to the season of the year they are present in the region will be used. In some cases, it will be necessary to make conservative assumptions because of the availability of information and model constraints. These conservative assumptions would result in overestimates of exposure.

Many wildlife species ingest soil or sediment while feeding or grooming (Beyer and others 1994; Arthur and Gates 1988). For some receptors, ingestion of contaminated soil or sediment may constitute a significant portion of the total dietary exposure to contaminants. In a study of soil ingestion by wildlife through analysis of the acid-insoluble ash content of scat, Beyer and others (1994) demonstrated that sandpipers had the greatest estimated percentage of soil/sediment in their diets (7.3 to 30 percent). Mammals like the white-footed mouse, the meadow vole, and the red fox were estimated to have less soil/sediment in their diets (less than 2 percent, 2.4 percent, and 2.8 percent, respectively). Estimates of incidental ingestion of soil or sediment will be gathered from the scientific literature for each assessment endpoint, and appropriate values will be used in the exposure model. Because estimated soil/sediment ingestion rates are known for few species, rates may be approximated or extrapolated from another species.

9.2.3 Food Chain Exposure Calculations

Detailed conceptual models based on food webs featuring assessment and measurement endpoints will be developed based on diet composition, prey preferences, and the behavior of assessment endpoint species. Using these food web conceptual models, prey species will be identified that are likely to be significant exposure routes for receptors of concern. Based on their abundance at the Litigation Area, their importance in the receptor's diet, and the potential for uptake and bioaccumulation of site contaminants, certain prey types were chosen as measurement endpoints, and will be collected for tissue residue analysis (Section 10.3). Direct measures of contaminant concentration in prey will reduce the amount of uncertainty associated with the use of bioaccumulation factors extrapolated from the literature. Currently, the FSP calls for tissue residue measurement on amphipods, fish, and

pickleweed. Other measurement endpoints are discussed in detail in Section 8.1. Also, as discussed in Section 4.3.2, tissue residue data for plants, rodents, and clams have been collected under baseline monitoring. These data will be used as appropriate in the exposure models.

9.2.4 Life History and Behavioral Information for Exposure and Risk Analysis

As discussed above, several life and natural history characteristics of receptors influence exposure to contamination and must be incorporated into the exposure model for an assessment endpoint. These characteristics include diet composition, ingestion and metabolic rates, body weight, foraging range, seasonal presence at the site, feeding behavior, reproductive behavior, and others. For each assessment endpoint, detailed data on relevant life and natural history characteristics influencing exposure and risk will be collected and used in the risk characterization. This information will be detailed in a table, a prototype of which is shown in Table 8. Data will be obtained through literature review and consultation with local organizations and resources, including the following.

- Golden Gate Raptor Observatory
- Point Reyes Bird Observatory
- California Academy of Sciences
- U.S. Fish and Wildlife Service
- California Department of Fish and Game
- University of California Libraries
- Wildlife Habitat Relational System
- EPA's Wildlife Exposure Factors Handbook (EPA 1993a, 1993b)
- National Biological Survey's Raptor Management Information System

Data from the San Francisco Bay region and California will be preferred over data from other locations. Data will be specific to the assessment endpoint receptors and will be from studies conducted in habitats similar to those found in the Litigation Area.

To clearly present data that will be used to estimate exposure model parameters, another table will be developed for each assessment endpoint receptor that presents the best data available from the scientific literature for each exposure model parameter. From these data, specific values for each parameter will be selected for use in calculating the receptor's dose. The reasons for selecting the specific values for each exposure model parameter from the range of those possible. A blank version of this table to be developed for each assessment endpoint receptor is presented below.

Body Weight	Home Range/ Area of Potential Exposure	Exposure Duration	Incidental Ingestion of Soil or Sediment	Dietary Proportion of Prey of Interest

9.2.5 Dose Estimates Resulting from Exposure Model Calculations

Limited availability of natural history data applicable to the conditions at the Litigation Area may result in uncertainty in dose estimates. Other sources of uncertainty result from the potential inappropriateness of the exposure model assumptions to the site-specific conditions influencing exposure and toxicity at the Litigation Area, such as bioavailability, diet proportions of receptors, food chain transfer, and other biological and physical factors and processes.

Every effort was made both to tailor assumptions exactly to conditions at the Litigation Area and to reduce uncertainty. Nevertheless, sources of uncertainty, both known and unknown, are unavoidable in ecological modeling. For these reasons, two estimates of low and high dose will be calculated to identify a range of possible doses. These estimates will use reasonably conservative values from appropriate literature sources based on habitat, taxa, exposure route, and other relevant ecological factors. Prey tissue residues to be included will be from prey expected to have the highest potential exposure to contaminants. The following assumptions will be used in applying values to exposure model parameters to arrive at low and high estimates of dose.

High dose estimates will follow these principles:

- Use the *lowest* body weight found in the literature
- Use the *lowest* estimate of home range found in the literature
- Assume *100 percent* of the diet is composed of the prey species on which we have tissue residue data (an uncertainty factor may be used if necessary)
- Assume exposure duration is *all year* or a lifetime
- Designate incidental ingestion of soil or sediment as *one and one half times* the mean of the percentage of soil or sediment reported in the literature
- Use the *lower* of either the 95 percent upper confidence interval of the mean or the maximum concentration as the concentration of the COPC in soil or sediment

Low dose estimates will follow these principles:

- Use the *highest* body weight found in literature
- Use the *highest* estimate of home range in the literature
- Assume *50 percent* of the diet is composed of the prey species on which we have tissue residue data
- Assume exposure duration of exposure is the *minimum reported*
- Designate incidental ingestion of soil or sediment as *half* of the mean of the percentage of soil or sediment reported in the literature
- Use the *mean* concentration as the concentration of the COPC in soil or sediment

These estimates of dose will be used in the effects assessment and risk characterization as described in Sections 10.2 and 11.1.

CHAPTER 10
CHARACTERIZATION OF ECOLOGICAL EFFECTS AND BIOACCUMULATION POTENTIAL

The purpose of the effects assessment is to characterize the possible ecological effects on assessment endpoints resulting from exposure to COPCs. Characterization of effects must include examination of the potential for adverse biological effects of contaminant stressors not only at the individual level, but also at the population and community level, and must consider the potential for bioaccumulation. Some effects of exposure to contaminants may be limited to the individual level. However, certain effects occurring at the individual level also result in changes in the population and community. For example, a decrease in individual reproductive success may result in decreased recruitment for that species, a situation that, if sustained, may cause a reduction in population size. Furthermore, the ecological community may experience adverse effects of contamination when changes in the interactions among species affect community structure and function. Although ecological risk assessment must consider community level responses, detecting changes in community structure and function is difficult without data on the spatial and temporal abundances of species gathered before the stressor's introduction.

This chapter presents the methodology for the ecological effects assessment, including a discussion of bioaccumulation. As discussed in Section 8.3, risks to assessment endpoints will be characterized using three types of effects assessment methodologies: (1) direct toxicity testing (Section 10.1), (2) comparisons of estimates of contaminant intake to toxicity reference values (Section 10.2), and (3) comparisons of contaminant tissue concentrations to tissue concentrations considered to indicate exposure to contamination. Section 10.3 addresses bioaccumulation.

10.1 EFFECTS ASSESSMENT: TOXICITY TESTS

Toxicity tests involve the exposure of organisms to environmental samples under controlled conditions to determine whether adverse effects occur. Media collected from the site, usually containing mixtures of contaminants, are tested. This section describes the toxicity tests that will be conducted at the Litigation Area.

10.1.1 Use of Existing Toxicity Data

No laboratory bioassays of soils, sediments, or groundwater have been performed at the Litigation Area.

10.1.2 Plant Bioassays

Ryegrass seedling survival and growth bioassays will measure phytotoxicity of the saline soils in the upland habitat (Table 9). Ryegrass is a dominant plant in this habitat (PRC 1994a), and its seeds are a component of the food base of the salt marsh yellowthroat and the Suisun song sparrow. Plant seedling survival and growth is considered a more sensitive test endpoint than root elongation (EPA 1992c).

10.1.3 Amphipod Bioassay

Solid phase bioassays will be conducted to measure the toxicity to biota of sediment from the Litigation Area; these bioassays are summarized in Table 10. Bioassays will be conducted using sediment collected from sediment sampling stations illustrated in Figures 2a and 2b of the FSP.

Amphipods are an important and abundant ecological component of soft-bottom estuarine and marine habitats. Amphipods are more sensitive to contaminated sediments than are other major taxa and are the first to disappear from benthic communities impacted by pollution (Flegal and others 1994). The EPA has recently developed draft methods for measuring the toxicity of sediment-associated contaminants with freshwater invertebrates using the freshwater amphipod *Hyalella azteca*. Protocols for growth tests with *H. azteca* are available. In addition, the American Society for Testing and Materials (ASTM 1991) has developed and approved the acute 10-day static sediment protocols for five different estuarine and marine amphipods: *Rhepoxynius abronius*, *Eohaustorius estuarius*, *Ampelisca abdita*, *Grandidierella japonica*, and *Leptocheirus plumulosus*.

Table 10 compares the habitat, salinity tolerance, sediment tolerance, and sensitivity to contaminants of five species of freshwater, estuarine, and marine amphipods. *Rhepoxynius abronius*, a burrowing species, can tolerate salinities greater than 25 ppt but is very sensitive to grain size (Long and

Buchman 1989; MacDonald and others 1992). *Eohaustorius estuarius*, another burrowing species, can tolerate salinities ranging from 2 to 28 ppt and is not as sensitive to grain size as *R. abronius* (MacDonald and others 1992). *Estuarius* does not normally live in salinities less than 10 ppt (RWQCB 1994). *Ampelisca abdita* lives in burrows and is tolerant of salinities from 10 to 35 ppt and is not as sensitive to sediment grain size (MacDonald and others 1992). *Grandidierella japonica* also forms burrows, can tolerate salinities from 30 to 35 ppt, and lives in a variety of sediment types (MacDonald and others 1992). *Hyalella azteca* can reproduce in salinities up to 12.5 ppt (Nebeker and Miller 1988) and is tolerant of a wide range in sediment particle sizes. The EPA (1994) reports that *H. azteca* can be used to test sediments at salinities up to 15 ppt. Tests with *H. azteca* have been conducted using marine and estuarine sediments, but the test solution was freshwater (Nebeker and Miller 1988).

Amphipods used in bioassays have been shown to differ in their level of sensitivity to contaminated sediments. Burton (1991) reports *H. azteca* to be highly sensitive to sediment contamination. However, the RWQCB (1994) experienced problems in their tests with *H. azteca* because of salinity tolerances. Karen Taberski (PRC 1994i) reported that *H. azteca* performed better at salinities below 5 ppt and *E. estuarius* performed better at salinities above 5 ppt. Long and Buchman (1989) found the test with *A. abdita* to be less sensitive than some of the other amphipods, including *R. abronius*. *Rhepoxynius abronius* is more sensitive to contaminants than *E. estuarius*, which is more sensitive than *A. abdita* (Pastorok and Becker 1989; Flegal and others 1994). *Grandidierella japonica* is less sensitive than *R. abronius*. Based on a variety of studies, the relative level of sensitivity to various contaminants can be expressed as *R. abronius* > *E. estuarius* > *A. abdita* = *G. japonica*. *H. azteca* appears to be less sensitive than *E. estuarius* (RWQCB 1994).

With the support of the regulatory community, the Navy has decided that *E. estuarius* will be used to test the toxicity of whole sediment. *E. estuarius* will be used because it burrows directly into the sediment and is tolerant of various sediment grain sizes. In addition, *E. estuarius* is found naturally in the San Francisco Bay estuary, has a wide salinity tolerance, and is highly sensitive to contaminants. Other contaminant studies in San Francisco Bay using *E. estuarius* can be used for evaluation of the results at the Litigation Area. The SOP for the amphipod bioassay is included in the FSP.

10.1.4 Pore Water Bioassays

A pore water bioassay on sea urchin larval development (*Strongylocentrotus purpuratus*) was also selected to evaluate the toxicity of bioavailable contaminants in sediment pore water. Pore water is thought to be the most likely route of exposure of aquatic organisms to contaminants in sediments. The selection of an appropriate species for a pore water chronic bioassay is complicated by the range of salinities encountered in the Litigation Area marsh. Salinities range from 2 to 4 ppt at high tide in the winter (PRC 1995b) to approximately 12 to 14 ppt near the bay in the summer (PRC 1994j). Some species for which a pore water chronic bioassay protocol has been developed, such as *Ceriodaphnia* sp., cannot tolerate salinities elevated above 1 or 2 ppt (PRC 1995e). However, marine invertebrates require more saline water than that found in the Litigation Areas. Therefore, the sea urchin development test was selected for the pore water bioassay, and appropriate salts will be added to the samples collected in the study area to meet the requirements of the animal.

Interstitial water will be extracted from whole sediment and used to test the echinoderm *Strongylocentrotus purpuratus*. The 48- to 96-hour purple sea urchin (*S. purpuratus*) fertilization test is a sensitive bioassay for measuring the toxicity of liquid phase samples. This test will provide information on the toxicity of pore water and will act as a check on the acute effects from tests using whole sediment. This bioassay is further described in the FSP.

10.1.5 Analysis and Interpretation of Bioassay Results

Interpretation of toxicity tests may be confounded by a number of variables, most of which can be measured for or controlled to a degree acceptable for statistical treatment and interpretation. For example, natural factors such as grain size, ammonia, or sulfides can elicit a toxic response in some organisms. Measuring these parameters allows an estimation of their influence on an organism's responses. Comparison with control organisms from a reference site provides another means of discriminating a toxic response from a site characteristic response. These confounding variables will be measured in all test, reference, and laboratory control samples so that they can be treated as covariates when appropriate.

10.1.5.1 Hypotheses and Statistical Tests

The endpoint of a toxicity test is the response of the organism to the treatment. This response is used as a measure of toxicity (MacDonald and others 1992). Endpoints may be classified as either lethal or sublethal. The most common endpoint in toxicity testing is mortality, which is a dichotomous or categorical attribute. The lethal endpoint may be reported as either percent survival or percent mortality. Endpoints often reported in sublethal tests are growth, developmental abnormalities, behavioral changes, and reproductive function. These sublethal endpoints are representative of continuous data.

The purpose of a toxicity test is to determine if the biological response to a treatment sample differs from the response to a control sample. The null hypothesis is that no difference exists between the mean control and the mean treatment response. The alternative hypothesis is that the sample treatment is toxic relative to the control or reference sample. Test protocols and the EPA guidance (Weber and others, 1991; EPA 1994) provide standard procedures for hypothesis testing.

10.1.5.2 Criteria for Acceptance

Each test protocol specifies the requirements for test acceptability. Typically, each test requires a minimum mean control survival of 80 percent; often the minimum is 90 percent. In addition, performance-based criteria specifications, such as age of test organisms, physical-chemical requirements of the test solutions, and others, are specified by the protocol. Protocols are included in the FSP and QAPjP.

10.1.5.3 Determination of Toxicity

The results of toxicity tests on environmental samples are rarely reported as effects concentration $_{50}$ (EC_{50}) or lethal concentration$_{50}$ (LC_{50}) values because the samples usually consist of a mixture of chemicals, and the toxicity cannot be associated with any one specific chemical. The ASTM (1991) amphipod bioassay protocol states that an individual test sample should be considered toxic if the single sample value lies outside the 95 percent tolerance limits of the survival of the controls. If toxicity tests are run on a series of dilutions of the test sample, then the results can be reported as

either an EC_{50} or an LC_{50} with regard to the sample dilution, but not to the chemical concentrations in the sample.

Whenever possible, sublethal rather than lethal bioassays will be used to estimate toxicity. The interpretation of sublethal bioassay data is based on assumptions about the population-level effects of the chemical exposure. These assumptions will be made explicit, and tested whenever practicable. Whether sublethal or lethal bioassays are used, the decision criteria for identifying a result indicating sample toxicity will be explicitly stated.

10.2 EFFECTS ASSESSMENT: TOXICITY REFERENCE VALUES

As discussed in Section 8.3, toxic effects on legally protected assessment endpoints cannot be measured through direct testing. For these taxa, contaminant intake (daily dosage) will be estimated using the exposure models described in Section 9.2. The purpose of the ecological effects assessment is to characterize the possible ecological effects on assessment endpoints resulting from exposure to COPCs. For each assessment endpoint and COPC, HQs will be calculated by comparing the doses estimated from the quantitative exposure model for that endpoint with appropriate TRVs. The TRV represents a critical exposure level from the best available toxicological studies. The methodology for TRV development is discussed in the following sections. The EPA and the Navy have agreed to work together to develop an appropriate set of TRVs for use at the Litigation Area; if these methods prove useful, they will be recommended at other Navy installations.

10.2.1 Toxicological Data for TRV Development

In Section 4.2, a brief toxicological profile, including toxic effect and fate and transport data, was presented for each existing COPC and some anticipated ones. Data consisted of a variety of no-effect level (NOEL), lowest-effect level (LOEL), LOAEL, and NOAEL concentrations, lethal concentration and lethal dosage values (LC_{50} and LD_{50}), and other sublethal, chronic, and acute-effect level concentrations. Such data will be used to develop TRVs. In addition, a comprehensive literature search focused on COPCs and assessment endpoints at the Litigation Area will be conducted to form a core toxicological data set from which TRVs will be derived. The following criteria will be used in selecting data for TRV derivation:

- Experimental taxa should be as similar as possible to receptor species at the Litigation Area with respect to taxonomy, body size, and feeding habits and behavior.
- Test exposure routes and media should be similar to those expected in the field.
- Endpoints related to reproduction, growth, and mortality are preferred since they best reflect population impacts.
- Chronic exposures and responses and no-effect or lowest observed levels data will be preferred.
- The study design must be of high quality, with adequate sample size, explicit analysis of experimental uncertainty, and well-justified conclusions.

Mortality is not an appropriate endpoint in toxicological studies for use in ecological risk assessment, since detrimental effects on populations and ecosystems can occur at chemical concentrations much lower than those causing mortality. Also, the high degree of uncertainty involved in estimating a no effect level from a lethal dose or concentration reduces the useability and certainty of the converted data. Therefore, toxicological data having mortality as an endpoint will be used only if no other data are available or if the data are on an assessment endpoint receptor.

Sources of data on ecological effects include:

- Primary literature (scientific publications)
- Agency for Toxic Substances and Disease Registry
- U.S. Fish and Wildlife Service Contaminant Hazard Reviews
- Hazardous Substance Databank
- Integrated Risk Information System
- AQUIRE
- ECOTOX (when available)

The following sections discuss the methodology for deriving TRVs from these data.

10.2.2 Derivation Of TRVs

The toxicological literature search will produce a core set of data most applicable to the development of a TRV for each assessment endpoint receptor and COPC at the Litigation Area. Due to the limited availability of toxicological data on COPCs and receptors of concern at the Litigation Area, the core data set may contain studies on a variety of test species of various ages and sexes, examining a variety of endpoints, effects, and exposure durations. Consequently, individual, primary values may need to undergo conversion to chronic, no-effect level equivalents for the receptor and COPC being addressed. Such conversions generally result in chronic, no effect level equivalents for receptors of concern and add uncertainty to the accuracy of the TRV.

Several studies were reviewed to investigate possible methodologies for deriving TRVs (Calabrese and Baldwin 1993, Opresko and others 1993, EPA 1993c). Figure 20 is a flowchart describing some possible conversions that an individual toxicity value may undergo in becoming a TRV. Conversions depicted in Figure 20 involve the application of uncertainty factors to extrapolate from low effect level or mortality to no effect level and from acute to chronic exposures and the use of allometric conversion to extrapolate effects between different species.

Published methods for conducting ecological assessments differ on the magnitude and type of uncertainty factors recommended in such conversions (Opresko and others 1993; Suter 1993; Calabrese and Baldwin 1993). Figure 20 shows uncertainty factors used or advised by different authors. Similarly, researchers differ on the use of allometry to extrapolate between effects on different species. Allometric conversions may be inappropriate for extrapolation between species having large phylogenetic differences or even between closely related species, if they have different feeding behaviors, habits, or physiology.

Because of these confounding factors and because the availability and type of toxicological data on COPCs and receptors of concern is not known currently, the exact numbers used as uncertainty factors, the conditions for their use, and the conditions for use of allometry will not be detailed at this time. Rather, these conversion factors will be defined after the core toxicological data set used to derive TRVs is identified, presented, and discussed with the regulatory agencies. In this way, exactly which conversions are needed will be defined based on the actual data to be used. When appropriate

uncertainty factors and allometric conversions are identified, they will be presented in a flow chart similar to that in Figure 20.

Also due to the uncertainties discussed above in arriving at TRVs, a low and high TRV will be derived for each assessment endpoint and COPC. A TRV will be derived from each toxicity value in the core data set, applying uncertainty factors and allometric conversions as necessary. The resulting TRVs will be ordered numerically. Low and high TRVs will be selected from the range of calculated TRVs based on quality of the original data, endpoints measured, test species, exposure duration, uncertainty factors and allometric conversions applied, and the size of the numerical range of TRVs. The low TRV is a conservative value thought to be the closest to a chronic no effect level; the high TRV is a less conservative effect level that is still thought to be relatively protective of the receptor of concern. When possible, the highest NOAEL and the lowest LOAEL on a single effect and organism derived in one study will be used as the low and high TRVs.

A TRV data table will be presented for each COPC and assessment endpoint, as illustrated below, to demonstrate how each toxicity value was converted into a TRV. The reasons for the selection of the low and high TRVs will be clearly documented.

Raw Toxicological Data					UFs Applied	Allometric Conversions Applied	Final TRV
Test organism	Dose (mg/kg bw-day)	Exposure Duration	Endpoint	Effect			
Mouse[1]	10		LOAEL	reproductive impairment	LOAEL→ NOAEL (#)	(equations)	X

[1]Reference cited

10.3 BIOACCUMULATION AND TISSUE RESIDUE ANALYSIS

Bioconcentration of contaminants from media to organisms provides a means by which contaminants may be introduced into the food web. Once in an organism, contaminants may be transferred from prey to predator, which may result in elevated exposures for high trophic level predators that consume prey carrying heavy contaminant loads. In some cases, lower trophic level organisms are exposed to and bioaccumulate the contaminant, but may be unaffected by it. However, high trophic level organisms may be more susceptible to the contaminant's effects, and, due to biomagnification, these species may be exposed to increased concentrations.

Chronic effects on higher trophic level organisms resulting from ingestion of contaminated prey may be manifested at the individual level by way of a contaminant's specific mode of action. However, the effects of biomagnification may also be evident at the population and community levels (also refer to Section 11.4). For example, because many toxic substances affect behavior, chronic exposure may alter the ability of the predator to seek, locate, and catch prey. Consequently, predators may have less energy available for survival and reproduction (Peterle 1991). Also, mortality or alteration of behavior among prey may alter the ability of a predator to survive. Reduced populations of prey may cause predators to concentrate in certain areas and increase the potential for competition and the adverse effects of crowding. The behavior of prey might be altered to make them more susceptible to predation, causing predators to select prey with high tissue residues, and thereby increasing exposure (Peterle 1991).

Some bioaccumulative metals have been identified at the Litigation Area, and future sampling for organic chemicals may reveal other bioaccumulative contaminants. Based on available data from the soil, selenium, and DDT (if found) may be of significant concern to aquatic and avian receptors because of their capacity to bioconcentrate and to biomagnify. Because of this, selenium will be assessed separately from other metals.

The potential for contaminants to undergo trophic transfer at the Litigation Area and to reach higher trophic levels will be assessed through modeling of tissue residue data from measurement endpoint receptors and tissue residue analysis from the BCR (PRC 1994a). Bioaccumulation or tissue residue data can be used to confirm a suspected food chain transfer pathway, and to build a quantitative

model of the effects of contaminated food on receptors of concern. Such modeling requires site-specific natural history information on the receptors in question. Resident organisms (amphipods, fish, and pickleweed) will be collected from locations at the Litigation Area and analyzed for the presence of contaminants in tissues.

10.3.1 Use of Existing Data

The existing bioaccumulation and tissue residue data on clams, plants, earthworms, and rodents summarized in Section 4.3.2 will be used in the QEA. These data will be used to the fullest extent possible to characterize body burdens and possible toxicity to receptors and to estimate exposure of predators that feed on these species. Because existing data are limited to the six metals, no information on bioaccumulation of organic compounds is available. Tissue residues from organisms collected at the Litigation Area will be compared to reference contaminant tissue concentrations considered to indicate exposure, resulting in a qualitative assessment of potential biological effects on these species. These reference tissue concentrations will be obtained from the scientific literature, and the criteria used to select these data will be based on principles similar to those described in Section 10.2.1. The existing tissue residue data will also be used as appropriate in the exposure modeling detailed in Section 9.2.

10.3.2 Sampling of Tissue Residues

To model movement of contaminants through the food web, some knowledge of tissue residues in lower trophic levels is essential. In the marsh habitat, tissue residues of amphipods, fish, and pickleweed will be measured. Locally dominant amphipods, such as *Anisogammarus confervicolus*, will be collected, including species of various size classes, if biomass sufficient for analysis can be collected. If amphipods are not plentiful enough for analytical purposes, a resident oligochaete, such as *Quistarillus multisetasus*, *Enchytraeus* c.f. *albidus*, *Telematedrilus vejdorskyi*, or *Paranais litoralis*, will be used. Amphipods and oligochaetes are critical components of the prey base for many fish and bird species. In addition, small clams (*Macoma*) may be present in sufficient density in the slough to warrant their inclusion in the investigation of tissue residue. Benthic, resident fish will also be selected for tissue analysis. Probable fishes in the sloughs are gobies, stickleback, and sculpins.

Final determination of which species to include will be made after a field reconnaissance visit in spring 1995.

Pickleweed is a dominant plant in the marsh habitat, occurring throughout the marsh in the Litigation Area. Halophytes such as pickleweed are known to accumulate contaminants (EPA 1992c). Pickleweed is the primary food item of the federally endangered salt marsh harvest mouse; protection of individuals of a listed species is a requirement of the federal Endangered Species Act (50 CFR Section 17). Tissue residue analysis will be performed on pickleweed lateral and upright shoots. The shoot categories will be analyzed separately to address different exposure pathways scenarios.

Quantification of tissue concentrations allows not only comparison with concentration of contaminant at the exposure point, but also aids in the modeling of exposure to higher trophic levels. As stated above, tissue residues from organisms collected at Litigation Area will be compared to reference contaminant tissue concentrations considered to be indicative of exposure to contamination, resulting in a qualitative assessment of potential biological effects on these taxa. These reference tissue concentrations will be obtained from the scientific literature, and the criteria used to select these data will be based on principles similar to those described in Section 10.2.1. Tissue residue data will also be used as appropriate in the exposure modeling detailed in Section 9.2.

CHAPTER 11
RISK ASSESSMENT

This chapter describes the risk characterization for receptors at the Litigation Area, including discussions of the effects of multiple stressors and uncertainty on the risk assessment.

11.1 RISK CHARACTERIZATION: WEIGHT-OF-EVIDENCE APPROACH

Risk to assessment endpoints will be characterized using a qualitative, weight-of-evidence approach based on the quantitative results from the effects assessments (Sections 10.1, 10.2, and 10.3), the site conceptual model, the results of the chemical analyses and bioavailability testing (Section 9.1), and other ecological factors. For each COPC and assessment endpoint receptor that may be at risk due to contamination at the Litigation Area, site conceptual models will be reviewed to identify the pathways that contribute most to exposure. These pathways will then be further analyzed to identify source areas and critical chemical levels at the Litigation Area. The following sections discuss the data analysis and interpretation methods used in the weight-of-evidence approach to risk characterization for assessment endpoints using direct toxicity testing (Section 11.1), exposure and effects modeling (Section 11.2), and bioaccumulation and tissue residue analysis (Section 11.3). Multiple stressors, population and community level responses, and uncertainty analysis are also discussed in the following sections.

11.1.1 Toxicity Testing

For assessment endpoints that are evaluated using direct toxicity testing (Section 10.1), decision criteria will be developed to identify measurement endpoint results that are indicative of toxicity. These criteria are presented in Sections 6.6 and 7.6 of the FSP. Each bioassay station will be identified as toxic or non-toxic based on these criteria. These results will be mapped to identify areas of toxicity.

In addition to identifying areas of toxicity, important correlations between chemical concentrations, surface extractions, and toxicity test data will be developed. The analysis will generally be concerned with the following questions:

1. Are the various chemical measures of contaminant concentrations, especially measures of the labile fraction (from the extraction tests), and the biological toxicity tests correlated?

2. How strong is the correlation?

3. Can a simple rule be formulated for predicting biological effects from chemical measures of bioavailability, and, if so, how good is this rule?

A positive correlation between chemical analysis and biological test results will be used in a weight-of-evidence approach to determine risk. The usefulness of the chemical analyses will be determined by their ability to explain the bioassay results. Pearson correlation coefficients greater than 0.5 will be considered suggestive of a relationship between chemical contaminants and bioassay effects concentrations. The correlations described in the following matrix will be examined:

	E. estuarius whole sediment bioassay	*S. purpuratus* sediment pore water bioassay	*L. perenne* soil bioassay
Sediment bulk chemistry	X	X	
Pore water bulk chemistry		X	
Soil bulk chemistry			X
WET: deionized water	X	X	X
WET: 0.5 N HCl	X	X	X
Hazard index	X		X

11.1.2 Exposure and Effects Modeling

For assessment endpoints that were evaluated using the exposure model/TRV method (Sections 9.2 and 10.2), risk will be characterized by calculating a HQ. HQs will be calculated by dividing each dose estimate by each TRV, resulting in four HQs for each COPC and receptor. Calculating a range of HQs will allow a greater amplitude of possible risks to be identified than if only one HQ was calculated, since the extremes are defined.

As explained in regulatory guidance (EPA 1989, 1992a), receptors may experience risk from exposure to a COPC if the HQ exceeds one. The eight possible results of the HQ calculations are presented in the matrix below. Analysis of risk through exposure of assessment endpoint receptors to each COPC will be based upon this matrix.

	Low TRV	High TRV
Low Dose	HQ ≤ 1 ⇒ Risk? HQ > 1 ⇒ Risk?	HQ ≤ 1 ⇒ Risk? HQ > 1 ⇒ Risk
High Dose	HQ ≤ 1 ⇒ No Risk HQ > 1 ⇒ Risk?	HQ ≤ 1 ⇒ Risk? HQ > 1 ⇒ Risk?

The best case scenario, represented by the situation in which the HQ calculated using the higher dose and the lower TRV is less than one, would indicate no risk for exposure of the receptor to that COPC. These cases would be recommended for "no further investigation" based on that COPC and that receptor. If all COPCs and assessment endpoints for a site fall into this category, the whole site would be recommended for no further investigation. The worst case scenario, represented by the situation in which the HQ calculated using the lower dose and the higher TRV is greater than one, would indicate a high likelihood of risk to that receptor resulting from exposure to that COPC. These are the two most clear-cut risk decision criteria, with the least uncertainty.

Calculated HQs falling in the other six categories are not amenable to simple distinctions of risk. For these situations, to identify the potential for risk due to exposure of a receptor to a COPC, the following will be evaluated using a weight-of-evidence approach: the HQ values, the assumptions used in the exposure model, and the quality of the data used in the exposure model and to derive the TRVs.

11.1.3 Bioaccumulation and Tissue Residue Analysis

For assessment endpoints evaluated using the bioaccumulation and tissue residue analysis, risks will be qualitatively evaluated using the results of the qualitative ecological effects assessment (Section 10.3).

As described in Sections 10.3, tissue residues of organisms collected on site will be compared to tissue residue concentrations considered to be indicative of exposure to contaminants in these organisms (tissue reference concentration). The on-site tissue residues will be directly compared to the tissue reference concentration. Residues for COPCs and receptors exceeding the tissue reference concentration will be identified as experiencing exposure and as bioaccumulating contaminants. The results of this comparison will be incorporated into the weight-of-evidence approach to characterization of risk to assessment endpoints.

For each COPC and assessment endpoint receptor that may be at risk due to contamination at Litigation Area, the site conceptual models will be reviewed to identify the pathways (that is, the major prey base) that contribute most to exposure. These pathways will then be further analyzed to identify source areas and critical soil chemical levels at the Litigation Area.

11.2 RISKS TO THREATENED AND ENDANGERED SPECIES

The risk of these chemicals to threatened and endangered species using the site is not fundamentally different than the risk to nonlisted species using the area, but the level of protection afforded threatened and endangered species is greater. Furthermore, an already stressed species or population, such as threatened and endangered species, may be particularly sensitive to any added stresses (EPA 1992a). For threatened and endangered species, the individual, rather than the population, is the unit of concern in the risk assessment. The federally or state threatened and endangered (or candidate) species that may be exposed to contamination at the Litigation Area are listed in Table 1.

Because specific toxicity data on threatened and endangered species is generally rare or nonexistent, extrapolations from data on similar taxa may be necessary to estimate risk to these protected species. Also, characterization of risk to these species may be difficult for a variety of reasons. For some species, such as the peregrine falcon, it may not be feasible to measure tissue residues in the prey species having the most significant exposure, such as shorebirds, because they, too, are protected. Furthermore, appropriate prey species for which tissue residue can be measured may be exposed to contaminants from other bay area locations because of the prey's mobility. Mobile prey would not provide an indication of the contaminant burdens obtained only from the site.

In this QEA, risks to threatened and endangered species, like risks to other species, will be evaluated qualitatively. However, due to factors described above, uncertainty in characterization of risk to threatened and endangered species may be greater than that for other receptors.

11.3 MULTIPLE STRESSORS

Most wildlife species in natural systems are exposed to more than one contaminant at any given time, so consideration of the cumulative effects of exposure to several contaminants (that is, synergy, additivity, antagonism) must be considered important. Aside from a few laboratory studies where multiple exposures have been tested, little is known of how multi-contaminant exposure influences the responses of wildlife to toxic substances. In addition, other physical, social, behavioral, nutritional and human-induced disturbances impact the individuals and populations at the Litigation Area.

For example, many compounds, such as organochlorines, can enhance microsomal action in the liver and alter the susceptibility of an organism to subsequent intake of a toxic substance. Responses are not general, but are specific to the compounds and organisms involved. Also, combinations of heavy metals are associated with both uptake and retention in toxicity. In mussels, saturation of binding sites with zinc will permit rapid excretion or binding of cadmium and thereby reduce cadmium toxicity (Peterle 1991). Little is known of the potential combined effects of toxic substances to which wildlife species are simultaneously exposed, particularly at chronic levels related to physiological function and reproduction (Peterle 1991).

Risks possibly from multiple contaminant stressors will be characterized using the HI approach for those assessments evaluated through exposure and effects modeling. Contaminants having similar chemistry and toxicological modes of action will be grouped and their HQs summed to calculate a HI for each contaminant group. These HIs will provide a qualitative evaluative tool for identifying risks due to exposure to multiple contaminant stressors.

11.4 POPULATION AND COMMUNITY LEVEL RESPONSES

Ecological effects acting on individuals may impact both the population and the community in which the individual lives. Population characteristics are collective expressions of the state and fate of

individual organisms (Suter 1993). Chronic effects on populations are difficult to assess or predict. In the simplest case, direct survivorship of individuals may be so impacted as a result of the exposure to contaminants that the lethal effects on individuals may be manifest in the population at large. More subtle non-lethal effects on populations might relate to disruption of breeding systems; delayed growth and sexual maturity; changes in behavior, migration, emigration, or dispersal; and changes in recruitment (Peterle 1991). Community level responses are based on the interaction of populations of organisms and the structure and function of the ecosystem (Suter 1993). Any effect on a population that also influences the relationship of that population with others in the community, for example, in predator-prey or symbiotic relationships, may affect the structure and function of the community at large.

Population and community level responses are difficult to demonstrate without data on the natural patterns of spatial and temporal variability before the chemical stressor was introduced into the system (Stewart-Oaten and others 1986). Furthermore, the inability to assess chronic ecosystem effects is partially due to the state of ecological understanding of what characteristics to measure, and how to assess them in ever-changing environments (Peterle 1991). However, ecological risk must be assessed in the context of these higher level effects. Based on what is known about subtle, chronic effects of toxic substances on individuals, the probability of these cumulative negative effects resulting in chronic ecosystem impacts must also be considered.

A change in the density, sex ratio, or age-class structure of a population can change the structure of the community. For example, the effects of heavy metal sediment contamination may cause populations of gem clams (*Gemma gemma*) to decrease, while allowing populations of a less susceptible benthic invertebrate to increase. This alteration in benthic invertebrate species distribution and abundance exemplifies a community-level change in the benthos. However, a cascade of effects on the community may result from the decrease in the gem clam population. For instance, because gem clams are a common prey item for some shorebirds, shorebirds may also be affected in a number of ways. Shorebirds may need to forage in a different location, if no other prey are available, thereby altering their presence and function in the community. If shorebirds rely on the decreasing population of clams as a main food source, shorebird health may decline, which may decrease the viability of local populations. Furthermore, if the shorebirds are nesting in the area where the clam population is in decline, the lowered food availability may cause malnourishment of shorebird chicks,

decreasing survival and recruitment in shorebirds, and possibly causing a population decline. Similarly, a decrease in the populations of shorebirds may have effects on the populations of predators feeding on shorebirds, such as raptors. These predators may seek new foraging grounds, or, if none are available, survivability of raptors may be lowered.

The QEA at the Litigation Area will qualitatively evaluate effects at the population and community levels by developing exposure pathway and effects scenarios predictive of these higher level effects. This evaluation of population and community level effects may involve an event tree that uses the probable risks identified through the analysis of acute and chronic effects and bioaccumulation to describe the possible population and community level responses that may result.

11.5 UNCERTAINTY ANALYSIS

The predictive nature of risk assessment requires that decisions be made with incomplete data and untested assumptions about the ways in which chemicals and receptors interact. Through analysis of uncertainty, especially uncertainty about the accuracy of predicted values, risk assessors try to narrow the margin of error resulting from inadequate analytical results. Suter (1993) discusses types of uncertainty, including stochasticity, parameter error, and model error, and provides limited guidance on methods of analyzing and quantifying uncertainty. Unfortunately, the analysis of uncertainty by statistical methods is in itself compromised by uncertainties, and does not typically result in unambiguous description of the type and degree of uncertainty. Because of the confounding effects of uncertainty at every level of analyses, particularly in selecting a risk model, Suter (1993) recommends using a weight-of-evidence approach for assessing risk; that is, one should use several alternative models and compare the results. If the results or trends lead to similar conclusions, then uncertainty can be assumed to have been reduced (Suter 1993).

Attempts to quantify and correct for uncertainty resulting from the use of surrogate species in ecological risk assessments is common but controversial. The route, duration, timing, and sequence of exposures influence the types and magnitudes of risks experienced by a receptor (Peterle 1991); such natural variation is seldom reflected in the toxicity literature used to develop TRVs. Calabrese and Baldwin (1993) discuss the use of uncertainty factors to adjust for extrapolations among taxa, between laboratory and field responses, and between acute and chronic responses. These multipliers

are expected to adjust for differences in responses among taxa resulting from differences in physiology and metabolism. When extrapolating from laboratory to field settings, important considerations include differences in physical environment, the behavior of organisms, and interactions with other ecological components. Extrapolation between responses will be necessary in some cases when data on relevant endpoints are not available (most commonly when extrapolating from LOAELs to NOAELs). The net effect of uncertainty factors on the accuracy of the risk assessment depends on the accuracy of the assumptions that underlie the factors themselves. Because of the confounding of uncertainty with uncertainty factors, a weight-of-evidence approach will be used to assess risk.

Other sources of uncertainty, and an explanation of the ways in which they will be managed in the QEA, were discussed earlier in this document. Uncertainty in estimating dose estimates is discussed in Section 9.2.5. Sources of variation in a contaminant eliciting an effect, and of error in measuring an elicited effect, are presented in Section 10.2.1. The uncertainty inherent in deriving site- and species-specific TRVs from toxicity literature, and the assumptions embedded in the allometric conversion procedures, are explained in Section 10.2.2.

A qualitative ecological risk assessment, such as the Navy is conducting at the Litigation Area at WPNSTA Concord, should include a qualitative analysis of uncertainty. At this stage, uncertainty can be reduced by using a weight-of-evidence approach to developing models of exposure and contaminant migration. In cases where the actual measurement of a parameter is too costly or intrusive to justify, conservative assumptions will be substituted for measured values. This will not reduce the overall uncertainty of the risk assessment, but will tend to make it unidirectional, erring on the side of overestimating rather than underestimating risk.

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TABLE 1

SPECIAL STATUS SPECIES REPORTED TO OCCUR AT WPNSTA CONCORD

Common Name	Scientific Name	Status	Comment
Delta Tule-Pea	*Lathyrus jepsonii ssp jepsonii*	2	
Soft Bird's-Beak	*Cordylanthus mollis ssp mollis*	1, Rare	
Contra Costa Goldfields	*Lasthenia conjugens*	1	
Suisun Marsh Aster	*Aster chilensis var. lentus*	FC2	
Suisun Thistle	*Cirsium hydrophilum var. hydrophilum*	FC1	
Gairdner's Yampah	*Perideridia gairdneri ssp. gairdneri*	FC2	Wet meadows
Mason's Lilaeopsis	*Lilaeopsis masonii*	SR,FC 2	Tidal brackish marshes and pilings
Curve-footed Diving Beetle	*Hygrotus curvipes*	FCS	Known from small, drying, mineralized pools near Oakley, Contra Costa County
San Francisco Fork-tailed Damsel Fly	*Ischnura gemina*	FC2	Populations recently identified in Suisun Bay region. Suitable habitat present in other sloughs and channels.
Chinook Salmon-Winter Run	*Oncorhynchus tshawytscha*	FT,SE	Open water
Delta Smelt	*Hypomesus transpacificus*	FT,ST	Dead-end sloughs
Sacramento Splittail	*Pogonichthys macrolepidotus*	2	Dead-end sloughs, tidal brackish marshes
California Tiger Salamander	*Ambystoma californiense*	2,SSC, FC	Widespread in moist or rocky habitats
California Red-Legged Frog	*Rana aurora*	FC,SSC	Introduced population of marginal viability

TABLE 1

SPECIAL STATUS SPECIES REPORTED TO OCCUR AT WPNSTA CONCORD (Continued)

Common Name	Scientific Name	Status	Comment
California Silvery Legless Lizard	*Anniella pulchra pulchra*	SSC	Not observed, but suitable habitat is available
Western Pond Turtle	*Clemmys marmorata marmorata*	FC2 CSC	Previous studies documented as occuring in Middle Point and Seal Creek wetlands.
San Francisco Garter Snake	*Thamnophis sirtalis tetrataenia*	FE	
American Peregrine Falcon	*Falco peregrinus anatum*	FE,SE	Foraging over all wetland types except riparian. Only one sighting.
Golden Eagle	*Aquila chrysaetos*	SSC	Uncommon in this habitat, but resident
Bald Eagle	*Haliaeetus leucocephalus*	FE,SE	Rare, occasional visitation by migrants
Aleutian Canada Goose	*Branta canadensis leucopareia*	FE,SE	Seasonal and permanent marshes, palustrine farmed wetlands, reservoirs
Burrowing Owl	*Athene cunicularia*	SSC	Not sighted, although suitable habitat is available
Short-Eared Owl	*Asio flammeus*	CSC	Incidental sightings in salt marsh within WPNSTA Concord
California Least Tern	*Sterna antilarum browni*	FE,SE	Salt ponds, tidal lagoons, open bay
California Black Rail	*Laterallus jamaicensis coturniculus*	FC.ST2	Tidal salt marshes
California Clapper Rail	*Rallus longirostris obsoletus*	FE,SE	
Tricolored Blackbird	*Agelaius tricolor*	FC2 CSC	At least one breeding colony present in nearby Peyton Slough/Shell Marsh

TABLE 1

SPECIAL STATUS SPECIES REPORTED TO OCCUR AT WPNSTA CONCORD (Continued)

Common Name	Scientific Name	Status	Comment
Grasshopper Sparrow	*Ammodramus savannarum*	NA	Occurs in Contra Costa County. Not sighted at WPNSTA Concord, but suitable habitat is available
Suisun Song Sparrow	*Melospiza melodia maxillaris*	2,SC	Brackish marshes
Saltmarsh Common Yellowthroat	*Geothlpyis trichas sinuosa*	2	Tidal and diked salt and brackish marshes, freshwater marshes, riparian woodland
Long-billed Curlew	*Numenius americanus*	2	Palustrine farmed, freshwater marshes
California Brown Pelican	*Pelecanus occidentalis californicus*	FE	
Salt Marsh Harvest Mouse	*Reithrodontomys raviventris*	FE, SE	Tidal salt marshes, diked seasonal salt marshes, and transitional habitat
Suisun Ornate Shrew	*Sorex ornatus sinuosus*	1	Tidal salt and brackish marshes

Source: O'Neil (1988).

Status

FC	Federal candidate species for listing
FE	Federally endangered
FT	Federally threatened
SC	State candidate species for listing
SE	State endangered
SR	State rare
ST	State threatened
1	Category 1: Taxa for which the U.S. Fish and Wildlife Service has sufficient biological information to support a proposal to list as endangered or threatened.
2	Category 2: Taxa for which existing information indicated may warrant listing, but for which substantial biological information to support a proposed rule is lacking.
FC 2	Federal Category 2: Taxa for which existing information indicated may warrant listing, but for which substantial biological information to support a proposed rule is lacking.
SSC	Species of special concern - California Department of Fish and Game

TABLE 2

PROPOSED CRITERIA FOR PROTECTION OF SEDIMENT AND SURFACE WATER

	Sediment					Surface Water	
Constituent	SF Bay Basin Mean[a] (No. of samples) (Concentration Range)	NOAA[b] ER-L/ER-M	Bivalve AET[c]	Amphipod AET[c]	Benthic AET[c]	Ambient Water Quality Criteria[d]	SFBBP[e]
Metals (ppm)							
Arsenic	--	8.2 / 70.0*	70.0	> 72.0	70.0	0.036	0.036
Cadmium	0.94 (256) (0.02-17.3)	1.2 / 9.6*	0.57	1.7	0.48	0.0093	0.0093
Copper	36 (376) (3 - 145)	34.0 / 270.0*	66.0	98.0	66.0	--	0.0029
Lead	32 (461) (1 - 421)	46.7 / 223.0*	71.0	120	41.0	0.0085	0.0056
Selenium	--	--	--	0.2	--	0.071	0.005
Zinc	--	150 / 410*	150.0	230	150.0	0.086	0.086
Pesticides (ppb)							
Total DDT	9.0 (75) (0.25 - 9100)	3.0 / 350	27.0	27.0	24.0	0.001	0.001
DDT	--	1.0 / 7.0	9.6	9.6	4.7	0.001	--
DDE	--	2.0 / 15.1	2.6	2.9	>2.6	--	--
DDD	--	2.0 / 20.0	3.1	2.4	1.4	--	--

TABLE 2

PROPOSED CRITERIA FOR PROTECTION OF SEDIMENT AND SURFACE WATER (Continued)

	Sediment					Surface Water	
Constituent	SF Bay Basin Mean[a] (No. of samples) (Concentration Range)	NOAA[b] ER-L/ER-M	Bivalve AET[c]	Amphipod AET[c]	Benthic AET[c]	Ambient Water Quality Criteria[d]	SFBBP[e]
PAH (ppb)							
Total PAH	4100 (101) (2.0-80900)	4022.0 / 44790.0	--	--	--	--	--

a NOAA 1988
b NOAA 1991; *MacDonald 1993
c PTI 1989
d EPA 1992
e RWQCB 1992

NOAA National Oceanic and Atmospheric Administration
ER-L effects range-low
ER-M effects range-median
Bivalve bivalve larvae abnormality bioassay
AET apparent effects threshold
SFBBP San Francisco Bay Basin Plan
DDT dichlorodiphenyltrichloroethane
DDE dichlorodiphenyldichloroethylene
DDD dichlorodiphenyldichloroethane

PAH polynuclear aromatic hydrocarbons

TABLE 3a

SUBSURFACE SOIL CONCENTRATIONS OF SELECTED METALS IN RASS 1 ACTIVELY REMEDIATED AREAS

Soil Strata (Feet)	Statistic	Arsenic		Copper		Lead		Cadmium		Selenium		Zinc	
	Analysis	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)
0 - 0.5	Max	137000.00	16900.00	85500.00	6620.00	2480.00	1530.00	ND	ND	ND	ND	ND	ND
	Min	175.00	16.40	12.90	21.10	20.30	13.50	ND	ND	ND	ND	ND	ND
	X	8610.06	1163.03	6981.62	521.92	308.18	133.89	ND	ND	ND	ND	ND	ND
	SD	10843.40	1775.08	11438.87	560.87	287.55	151.30	ND	ND	ND	ND	ND	ND
	N	569.00	965.00	556.00	1000.00	569.00	1000.00	ND	ND	ND	ND	ND	ND
0.5 - 1.0	Max	197000.00	13500.00	121000.00	3480.00	3110.00	1760.00	ND	ND	ND	ND	ND	ND
	Min	80.80	15.40	10.00	19.90	20.30	13.70	ND	ND	ND	ND	ND	ND
	X	6943.39	1104.27	4548.46	400.51	271.13	119.47	ND	ND	ND	ND	ND	ND
	SD	10644.26	1620.94	9570.29	376.57	290.18	139.35	ND	ND	ND	ND	ND	ND
	N	596.00	954.00	581.00	998.00	596.00	999.00	ND	ND	ND	ND	ND	ND
1.0 - 1.5	Max	61000.00	17500.00	153000.00	3580.00	22600.00	1180.00	ND	ND	ND	ND	ND	ND
	Min	42.50	17.90	10.00	13.70	20.30	13.80	ND	ND	ND	ND	ND	ND
	X	4926.40	914.79	4032.92	385.09	250.61	100.43	ND	ND	ND	ND	ND	ND
	SD	6106.76	1535.39	10768.96	409.71	988.56	116.73	ND	ND	ND	ND	ND	ND
	N	559.00	950.00	521.00	999.00	562.00	1000.00	ND	ND	ND	ND	ND	ND
1.5 - 2.0	Max	4490.00	8330.00	9080.00	6740.00	261.00	820.00	ND	117.00	ND	207.00	ND	8610.00
	Min	4490.00	0.93	9080.00	2.50	261.00	1.45	ND	0.04	ND	0.31	ND	10.60
	X	4490.00	201.57	9080.00	208.43	261.00	28.83	ND	5.93	ND	3.16	ND	689.59
	SD	ND	504.52	ND	371.09	ND	49.89	ND	11.12	ND	9.93	ND	916.13
	N	1.00	995.00	1.00	995.00	1.00	995.00	ND	995.00	ND	995.00	ND	995.00
2.0 - 2.5	Max	ND	10100.00	ND	2300.00	ND	543.00	ND	394.00	ND	149.00	ND	32300.00
	Min	ND	0.49	ND	3.72	ND	2.01	ND	0.02	ND	0.32	ND	7.99
	X	ND	169.01	ND	167.74	ND	27.12	ND	5.72	ND	2.84	ND	683.34
	SD	ND	440.64	ND	268.47	ND	46.74	ND	16.43	ND	7.45	ND	1437.58
	N	ND	999.00	ND	999.00	ND	999.00	ND	999.00	ND	999.00	ND	999.00
2.5 - 3.0	Max	ND	6040.00	ND	17700.00	ND	697.00	ND	74.52	ND	168.26	ND	11900.00
	Min	ND	0.42	ND	1.73	ND	1.29	ND	0.05	ND	0.18	ND	4.24
	X	ND	162.16	ND	159.73	ND	24.08	ND	4.07	ND	2.82	ND	544.91
	SD	ND	408.11	ND	631.31	ND	45.12	ND	6.88	ND	7.04	ND	811.36
	N	ND	998.00	ND	998.00	ND	998.00	ND	998.00	ND	998.00	ND	998.00

TABLE 3a

SUBSURFACE SOIL CONCENTRATIONS OF SELECTED METALS IN RASS 1 ACTIVELY REMEDIATED AREAS (Continued)

Table Notes:

WET	Waste Extraction Test, protocol as designated by the state of California
Total	Total bulk chemistry, normalized to the dry weight of the sample
Max	Maximum value
Min	Minimum value
X	Arithmetic mean
SD	Standard deviation
N	Number of samples
ND	No Data

TABLE 3b

SUBSURFACE SOIL CONCENTRATIONS OF SELECTED METALS IN RASS 2 ACTIVELY REMEDIATED AREAS

Soil Strata (Feet)	Statistic	Arsenic		Copper		Lead		Cadmium		Selenium		Zinc	
	Analysis	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)
0 - 0.5	Max	32600.00	92600.00	123000.00	5450.00	253000.00	73900.00	10200.00	460.00	ND	59.10	7550000.00	482000.00
	Min	226.00	5.20	278.00	12.70	70.80	5.00	39.00	0.66	ND	1.10	2340.00	23.00
	X	2774.48	429.37	10096.59	639.81	23448.44	3942.09	909.29	43.23	ND	10.97	343978.92	22668.54
	SD	4315.50	5530.38	15471.80	889.56	38463.63	11065.91	1262.59	77.80	ND	9.71	844772.85	65109.88
	N	120.00	279.00	120.00	283.00	120.00	281.00	120.00	267.00	ND	466.00	120.00	283.00
0.5 - 1.0	Max	32600.00	891.00	112000.00	2170.00	296000.00	46400.00	6680.00	318.00	ND	29.90	8280000.00	264000.00
	Min	68.50	2.90	166.00	9.20	59.20	4.60	6.80	0.73	ND	1.10	529.00	19.70
	X	2022.16	47.10	7222.28	159.06	10420.05	479.71	849.23	16.48	ND	10.22	314062.03	4179.70
	SD	4469.83	83.96	14574.40	282.44	31912.15	3080.56	1091.78	26.47	ND	5.32	868527.99	16522.88
	N	152.00	273.00	152.00	284.00	152.00	277.00	152.00	246.00	ND	90.00	152.00	284.00
1.0 - 1.5	Max	22800.00	27200.00	109000.00	3240.00	179000.00	179000.00	5240.00	140.00	ND	22.60	6170000.00	90700.00
	Min	46.90	2.30	80.40	6.50	54.40	54.40	3.30	0.76	ND	1.20	349.00	8.70
	X	1058.88	137.79	6818.57	127.22	8661.48	261.51	876.37	15.21	ND	10.27	267797.69	3292.23
	SD	2288.54	1652.50	13865.89	264.91	24762.01	1348.15	969.45	17.29	ND	4.72	619205.24	7418.05
	N	156.00	270.00	156.00	284.00	156.00	277.00	155.00	242.00	ND	101.00	156.00	284.00
1.5 - 2.0	Max	15700.00	1800.00	61000.00	3140.00	203000.00	41800.00	4790.00	299.00	ND	41.70	9490000.00	382000.00
	Min	42.60	2.10	81.40	9.70	27.20	3.00	4.20	0.80	ND	1.20	252.00	24.60
	X	698.66	32.07	3972.47	103.20	6110.25	424.53	725.86	18.84	ND	11.71	236257.87	4772.72
	SD	1460.03	111.90	8704.65	258.01	20321.32	3312.28	782.46	31.98	ND	7.22	796987.82	25949.18
	N	138.00	270.00	141.00	284.00	141.00	275	141	221	ND	102	141	284
2.0 - 2.5	Max	7360.00	418.00	41300.00	2570.00	180000.00	37700.00	3340.00	392.00	ND	33.20	1320000.00	244000.00
	Min	41.80	2.90	33.70	11.60	24.50	.00	4.20	0.86	ND	1.20	73.70	17.30
	X	575.92	29.53	3344.35	101.70	5325.04	5.40	557.02	20.67	ND	11.51	149551.52	5341.94
	SD	970.25	48.85	7633.11	229.50	17916.80	634.01	643.88	40.03	ND	6.41	165186.64	22252.31
	N	126	261	129	284	128	3661.73	127.00	205.00	ND	103.00	129.00	284.00
							274						
2.5 - 3.0	Max	2090.00	171.00	21200.00	2710.00	106000.00	51100.00	3910.00	545.00	ND	34.60	1280000.00	311000.00
	Min	45.40	39.60	39.60	9.20	25.60	2.70	3.20	0.73	ND	1.20	85.00	24.20
	X	355.20	21.72	1768.23	95.76	6034.06	508.44	566.81	27.22	ND	9.92	184792.50	4727.10
	SD	327.26	23.64	3478.13	249.19	16378.42	3739.48	605.13	58.10	ND	6.15	195218.27	21868.79
	N	105.00	264.00	107.00	284.00	109.00	273.00	108.00	185.00	ND	102.00	109.00	284.00

TABLE 3b

SUBSURFACE SOIL CONCENTRATIONS OF SELECTED METALS IN RASS 2 ACTIVELY REMEDIATED AREAS (Continued)

Table Notes:

WET	Waste Extraction test, protocol as designated by the State of California
Total	Total bulk chemistry, normalized to the dry weight of the sample
Max	Maximum value
Min	Minimum value
X	Arithmetic mean
SD	Standard deviation
N	Number of samples
ND	No data

TABLE 3c

SUBSURFACE SOIL CONCENTRATIONS OF SELECTED METALS IN RASS 3 ACTIVELY REMEDIATED AREAS

Soil Strata (Feet)	Statistic	Arsenic		Copper		Lead		Cadmium		Selenium		Zinc	
	Analysis	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)	Wet (mg/L)	Total (mg/kg)
0 - 0.5	Max	6090.00	368.00	230000.00	37000.00	472000.00	32900.00	2120.00	269.00	390.00	82.40	6480000.00	359000.00
	Min	89.00	9.80	20.00	10.50	96.00	12.60	5.00	0.91	50.00	9.50	811.00	43.40
	X	504.30	32.57	7636.26	545.92	17678.21	1481.79	575.21	24.03	68.41	28.46	324151.24	13811.21
	SD	468.67	21484.58	21484.58	1824.01	42631.31	2687.71	442.79	18.19	37.06	14.72	516574.39	24351.19
	N	332.00	332.00	574.00	778.00	332.00	761.00	332.00	770.00	331.00	444.00	332.00	778.00
0.5 - 1.0	Max	2920.00	297.00	97200.00	14600.00	190000.00	30500.00	2380.00	179.00	330.00	73.90	2780000.00	2380000.00
	Min	94.20	9.50	20.00	7.40	60.00	11.70	5.00	1.00	50.00	9.30	320.00	28.00
	X	371.38	27.48	2972.42	194.17	6778.62	474.10	461.91	16.38	59.51	23.13	205388.43	5942.67
	SD	262.09	22.89	7919.94	726	29949.67	1785.28	378.94	14.99	26.54	11.83	225255.07	13331.84
	N	514.00	392.00	514.00	775.00	514.00	737.00	514.00	761.00	508.00	363.00	514.00	775.00
1.0 - 1.5	Max	1390.00	161.00	129000.00	6720.00	504000.00	25400.00	1900.00	112.00	230.00	122.00	7440000.00	193000.00
	Min	79.60	9.20	20.00	4.50	61.90	8.90	5.00	0.91	30.00	9.80	208.00	36.80
	X	266.26	28.94	1907.44	181.67	5641.63	640.79	268.92	12.99	53.85	26.34	172969.16	5987.40
	SD	169.42	20.94	7552.51	551.78	33726.84	2129.19	287.82	12.96	14.78	15.78	435442.62	14966.51
	N	458.00	322.00	458.00	772.00	458.00	657.00	458.00	737.00	455.00	375.00	458.00	772.00
1.5 - 2.0	Max	987.00	162.00	85800.00	8460.00	260000.00	17600.00	1400.00	71.40	250.00	156.00	990000.00	138000.00
	Min	14.80	10.10	24.90	5.80	60.00	8.10	5.00	0.84	14.40	10.10	210.00	15.80
	X	229.80	24.08	1362.06	100.42	3932.71	321.69	185.45	8.78	53.04	26.59	115439.65	3383.67
	SD	142.00	15.69	4734.19	439.72	16672.12	1283.03	241.01	9.24	14.40	16.19	148508.52	9516.38
	N	418.00	240.00	418.00	777.00	418.00	577.00	418.00	698.00	414.00	351.00	418.00	778.00
2.0 - 2.5	Max	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	X	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	SD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	N	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2.5 - 3.0	Max	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	X	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	SD	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	N	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 3c

SUBSURFACE SOIL CONCENTRATIONS OF SELECTED METALS IN RASS 3 ACTIVELY REMEDIATED AREAS (Continued)

Table Notes:

WET	Waste extraction test, protocol as designated by the State of California
Total	Total bulk chemistry, normalized to the dry weight of the sample
Max	Maximum value
Min	Minimum value
X	Arithmetic mean
SD	Standard deviation
N	Number of samples
ND	No data

TABLE 4

RANGES OF METAL CONCENTRATIONS IN SEDIMENT AND SURFACE WATER AT WPNSTA CONCORD LITIGATION AREA

(Values represent location means)

	RASS 1	RASS 2	RASS 3	RASS 4	REF 1 (UPLANDS)	REF 2 (MARSH)
SEDIMENT (mg/kg)	--	--	--	--	--	--
As	14.97 - 830.33	10.57 - 109.47	4.37 - 28.58	2.67 - 33.5	1.9 - 2.48	13.55 - 34.37
Cd	0.92 - 127.67	1.05 - 8.03	0.79 - 17.62	0.83 - 2.8	0.57 - 0.59	1.03 - 1.17
Cu	35.17 - 616	34.88 - 133	27.08 - 100.57	25.55 - 68.9	8.37 - 9.32	64.6 - 83.87
Pb	22.07 - 118.10	11.52 - 79.27	38.58 - 1010.33	59.9 - 177.67	6.2 - 7.05	57 - 97.23
Se	0.75 - 4.27	1.13 - 1.4	0.78 - 1.53	0.7 - 24.73	0.62 - 0.68	.99
Zn	116.35 - 11480	113.8 - 1663.33	263.17 - 5406.67	156.17 - 58	35.43 - 42.53	143.5 - 175.67
SURFACE WATER (ug/l)	--	--	--	--	--	--
As	3.3 - 2510.3	4.32 - 5.33	5.75	5.8 - 188.23	3.98 - 6.2	2.82 - 3.68
Cd	2 - 41.33	2 - 2.06	3.58	2 - 27.5	2	2
Cu	7.77 - 904.33	10.75 - 14.53	19.59	8.23 - 425.47	9.27 - 17.7	13.07 - 17.82
Pb	6.47 - 331.17	5.32 - 6.27	19.28	11.3 - 959.47	5.3 - 11.93	10 - 10.93
Se	2.2 - 2.5	3.22 - 4.17	3.1	2.8 - 157.53	4.83 - 7.15	4.07 - 6
Zn	16.3 - 5026	224 - 229	580	41 - 3915	33.8 - 65.7	35.5 - 47

TABLE 5

SUMMARY OF SURFACE SOIL CHEMICAL DATA FROM EACH RASS AND REFERENCE SITE AT WPNSTA CONCORD LITIGATION AREA

	Range (mg/kg) min-max of location means	Proportion and percent of sampling locations above ER-L (amphipod AET for selenium)	Proportion and percent of sampling locations between ER-L and ER-M	Proportion and percent of sampling locations percent above ER-M
Rass 1				
Arsenic	1.4 - 2336.7	74/83 = 89%	42/83 = 51%	32/83 = 39%
Cadmium	0.1 - 12.8	61/83 = 73%	60/83 = 72%	1/83 = 1%
Copper	7.9 - 1563.3	72/83 = 87%	44/83 = 53%	28/83 = 34%
Lead	5.5 - 1192.7	59/83 = 71%	49/83 = 59%	10/83 = 12%
Selenium	0.1 - 20.1	74/82 = 90%		
Zinc	24.4 - 2886.7	61/83 = 73%	26/83 = 31%	35/83 = 43%
		Se > As > Cu > Cd = Zn > Pb		**Zn > As > Cu > Pb > Cd**
Rass 2				
Arsenic	12.9 - 93.1	25/26 = 96%	22/26 = 85%	3/26 = 11%
Cadmium	0.8 - 33.1	23/26 = 88%	13/26 = 50%	10/26 = 38%
Copper	32.4 - 720.3	24/26 = 92%	13/26 = 50%	11/26 = 42%
Lead	53.5 - 1017.3	24/26 = 92%	15/26 = 58%	9/26 = 35%
Selenium	0.5 - 51.0	25/26 = 96%		
Zinc	227.0 - 7128.3	26/26 = 100%	4/26 = 15%	22/26 = 84%
		Zn > Se = As > Cu = Pb > Cd		**Zn > Cu > Cd > Pb > As**
Rass 3				
Arsenic	2.8 - 160.7	16/38 = 42%	15/38 = 39%	1/38 = 3%
Cadmium	0.4 - 12.7	10/38 = 26%	9/38 = 24%	1/38 = 3%
Copper	16.2 - 315.6	13/38 = 34%	12/38 = 32%	1/38 = 3%
Lead	9.4 - 8602.0	29/38 = 76%	24/38 = 63%	5/38 = 13%
Selenium	0.2 - 1.1	37/38 = 97%		
Zinc	76.3 - 18233.3	28/38 = 74%	15/38 = 39%	13/38 = 34%
		Se > Pb > Zn > As > Cu > Cd		**Zn > Pb > As = Cd = Cu**
Rass 4				
Arsenic	8.0 - 82.3	21/22 = 95%	20/22 = 91%	1/22 = 5%
Cadmium	0.6 - 11.2	20/22 = 91%	17/22 = 77%	3/22 = 14%
Copper	11.0 - 105.5	13/22 = 59%	13/22 = 59%	0/22 = 0%
Lead	11.0 - 2253.7	15/22 = 68%	10/22 = 45%	5/22 = 23%
Selenium	0.3 - 160.7	22/22 = 100%		
Zinc	65.4 - 529.3	13/22 = 59%	10/22 = 45%	3/22 = 14%
		Se > As > Cd > Pb > Cu = Zn		**Pb > Cd = Zn > As > Cu**

TABLE 5

SUMMARY OF SURFACE SOIL CHEMICAL DATA FROM EACH RASS AND REFERENCE SITE AT WPNSTA CONCORD LITIGATION AREA (Continued)

	Range (mg/kg) min-max of location means	Proportion and percent of sampling locations above ER-L (amphipod AET for selenium)	Proportion and percent of sampling locations between ER-L and ER-M	Proportion and percent of sampling locations percent above ER-M
Reference 1				
Arsenic	4.4 - 5.2	0/4 = 0%	0/4 = 0%	0/4 = 0%
Cadmium	0.4 - 0.7	0/4 = 0%	0/4 = 0%	0/4 = 0%
Copper	20.6 - 22.4	0/4 = 0%	0/4 = 0%	0/4 = 0%
Lead	31.2 - 45.4	0/4 = 0%	0/4 = 0%	0/4 = 0%
Selenium	0.4 - 0.4	4/4 = 100%	-	-
Zinc	102.4 - 127.3	0/4 = 0%	0/4 = 0%	0/4 = 0%
Reference 2				
Arsenic	13.0 - 31.8	6/6 = 100%	6/6 = 100%	0/6 = 0%
Cadmium	1.0 - 2.1	2/6 = 33%	2/6 = 33%	0/6 = 0%
Copper	77.9 - 212.7	6/6 = 100%	6/6 = 100%	0/6 = 0%
Lead	36.9 - 162.7	4/6 = 67%	4/6 = 67%	0/6 = 0%
Selenium	1.1 - 15.9	6/6 = 100%		-
Zinc	119.0 - 257.3	5/6 = 83%	5/6 = 83%	0/6 = 0%

Notes:

1. Values listed are means from each 5'x 5'sampling location. Passive, uncharacterized, and monitoring areas were pooled.

TABLE 6

RATIONALE FOR SELECTION OF ASSESSMENT ENDPOINTS FOR WPNSTA CONCORD LITIGATION AREA

Assessment Endpoints	Rationale [1]
Protection of populations of ryegrass and upland plants	- Dominant plant in the upland habitat - Assessment of soil toxicity - Potential food chain transfer to terrestrial herbivores - Exposure via soil and surface water
Protection of populations of pickleweed	- Provides habitat structure and cover; protection would help protect marsh community - Food and habitat for salt marsh harvest mouse - Exposure via sediment and surface water
Protection of the benthic invertebrate community	- Prey for shorebirds - Sensitive to contaminated sediments - Exposure via sediment and surface water
Protection of populations of the great blue heron	- Top predator on fish and invertebrates - High societal value - Exposure via prey, sediment, and surface water
Protection of populations of diving ducks [2]	- Diving duck that feeds on invertebrates - Special-status species - Migratory; protected under Migratory Bird Treaty Act (MBTA) - Potential food of peregrine falcon - Exposure via prey, surface water, and sediment
Protection of populations of American kestrel northern harrier red-shouldered hawk white-tailed kite	- Top predators on rodents in marsh - Kestrel, kite, and harrier are common at the site - Red-shouldered hawk is a special-status species - Exposure via prey and soil
Protection of individual peregrine falcons	- Top predator of shorebirds and passerines in marsh - Endangered species status - Exposure via prey
Protection of populations of the black rail	- Preys on benthic invertebrates in marsh - Special-status species - Year-round resident; probably nests on site - Exposure via prey, sediment, and surface water
Protection of populations of the Suisun song sparrow	- Special-status species - Feeds on marsh invertebrates and plants - Represents avian prey of raptors - Exposure via plants, prey, soil, and surface water

TABLE 6

RATIONALE FOR SELECTION OF ASSESSMENT ENDPOINTS FOR WPNSTA CONCORD LITIGATION AREA (Continued)

Assessment Endpoints	Rationale [1]
Protection of individual salt marsh harvest mouse	- Special-status species - Prey for top predators - Exposure via plants, prey, soil, and surface water
Protection of populations of river otter	- Top mammalian predator in marsh - Exposure via prey, surface water, and sediment
Protection of populations of gray fox	- Top mammalian predator of marsh rodents - Exposure via prey, surface water, and soil

Table Notes:

[1] Diving duck species to be determined after bird surveys are conducted.
[2] References are cited in the natural history tables in Appendix A.

TABLE 7

PRIMARY RISK CHARACTERIZATION METHODOLOGY FOR WPNSTA CONCORD LITIGATION AREA

Assessment Endpoint	Primary Method for Risk Characterization	Sources of Data for Primary Method	Other Data used in Weight-of-Evidence Approach to Risk Assessment	Linkage to Assessment Endpoint
Ryegrass/upland plants (protection of populations)	Direct toxicity testing	- Ryegrass bioassays (seedling survival and growth)	- Bioavailability data (leachability tests, physical parameters) - Plant tissue residue data in Baseline Conditions Report (BCR)	- Direct measure of effects of contaminants on ryegrass
Pickleweed (protection of populations)	Tissue residue analysis	- Pickleweed tissue residue analysis	- Bioavailability data (leachability tests, physical parameters)	- Comparison of pickleweed residues to reference tissue concentrations from literature and reference area
Protection of the Benthic Invertebrate Community	Direct toxicity testing	Amphipod bioassay Sea urchin pore water bioassay	- Tissue residue studies on amphipods - Bioavailability data (leachability tests, physical parameters)	- Direct measure of effects of contaminants on amphipods and sea urchin larvae
Great blue heron (protection of populations)	Contaminant exposure and effects modeling	- Amphipod bioassay - Ryegrass bioassay - Sea urchin pore water bioassay - Bioaccumulation data on clams (BCR data) - Fish tissue residue analysis - Amphipod tissue residue analysis	- Bioavailability data (leachability tests, physical parameters)	- Measures effects of contaminants on invertebrate prey base of fish eaten by herons - Evaluate potential food chain transfer from invertebrates to fish prey

TABLE 7

PRIMARY RISK CHARACTERIZATION METHODOLOGY FOR WPNSTA CONCORD LITIGATION AREA (Continued)

Assessment Endpoint	Primary Method for Risk Characterization	Sources of Data for Primary Method	Other Data used in Weight-of-Evidence Approach to Risk Assessment	Linkage to Assessment Endpoint
Diving ducks[1] (protection of populations)	Contaminant exposure and effects modeling	- Amphipod bioassay - Ryegrass bioassay - Sea urchin pore water bioassay - Bioaccumulation data on clams (BCR data) - Amphipod tissue residue analysis	- Bioavailability data (leachability tests, physical parameters)	- Measures effects of contaminants on prey base - Evaluate potential for food chain transfer from invertebrate prey to ducks
American kestrel, northern harrier, white-tailed kite, and red-shouldered hawk (protection of populations)	Contaminant exposure and effects modeling	Rodent and earthworm tissue residue data in BCR	- Bioavailability data (leachability tests, physical parameters) - Ryegrass bioassay - Plant tissue residue data in BCR - Pickleweed tissue residue data	- Evaluate potential for food chain transfer to raptors
Peregrine falcon (protection of individuals)	Contaminant exposure and effects modeling	- Amphipod bioassay - Sea urchin pore water bioassay - Bioaccumulation data on clams (BCR data) - Amphipod tissue residue analysis - Fish tissue residue analysis	- Bioavailability data (leachability tests, physical parameters)	- Food chain transfer from invertebrate prey through shorebirds and passerines to peregrine falcon - Evaluate potential for food chain transfer from birds to peregrine falcon

TABLE 7

PRIMARY RISK CHARACTERIZATION METHODOLOGY FOR WPNSTA CONCORD LITIGATION AREA
(Continued)

Assessment Endpoint	Primary Method for Risk Characterization	Sources of Data for Primary Method	Other Data used in Weight-of-Evidence Approach to Risk Assessment	Linkage to Assessment Endpoint
California black rail (protection of populations)	Contaminant exposure and effects modeling	- Amphipod bioassay - Sea urchin pore water bioassay - Bioaccumulation data on clams (BCR data) - Amphipod tissue residue analysis - Fish tissue residue analysis	- Bioavailability data (leachability tests, physical parameters)	- Measures effects of contaminants on prey base - Evaluate potential for food chain transfer from invertebrate prey to black rail
Suisun song sparrow (protection of populations)	Contaminant exposure and effects modeling	- Amphipod bioassay - Ryegrass bioassay - Sea urchin pore water bioassay - Bioaccumulation data on clams (BCR) - Amphipod tissue residue analysis	- Bioavailability data (leachability tests, physical parameters)	- Measures effects of contaminants on seed and invertebrate prey base - Evaluate potential for food chain transfer from plants and invertebrates to song sparrows
Salt marsh harvest mouse (protection of individuals)	Contaminant exposure and effects modeling	- Pickleweed tissue residue data	- Bioavailability data (leachability tests, physical parameters) - Tissue residue data on other rodents (BCP)	- Measures effects of contaminants on population of pickleweed food base - Evaluate potential for food chain transfer from plants to mice

TABLE 7

PRIMARY RISK CHARACTERIZATION METHODOLOGY FOR WPNSTA CONCORD LITIGATION AREA
(Continued)

Assessment Endpoint	Primary Method for Risk Characterization	Sources of Data for Primary Method	Other Data used in Weight-of-Evidence Approach to Risk Assessment	Linkage to Assessment Endpoint
River otter (protection of populations)	Contaminant exposure and effects modeling	- Bioaccumulation data on clams (BCR data) - Amphipod tissue residue analysis - Fish tissue residue analysis	- Amphipod bioassay - Sea urchin pore water bioassay	- Measures effects of contaminants on prey base - Evaluate potential for food chain transfer to mammalian predator through measurement of concentration in prey
Gray fox (protection of populations)	Contaminant exposure and effects modeling	Rodent tissue data (BCR)	- Bioavailability data (leachability tests, physical parameters) - Ryegrass bioassay - Plant tissue residue data (in BCR) - Pickleweed tissue residue analysis	- Evaluate potential for food chain transfer to mammalian predator through measurement of concentration in prey

Table Notes:

[1] Diving duck species to be determined.

TABLE 8

NATURAL HISTORY OF PROPOSED ASSESSMENT ENDPOINTS FOR WPNSTA CONCORD LITIGATION AREA

Species	Status	CA Native	Suisun Bay Residency	Home Range	Exposure Route	Concord Habitat	Feeding Guild
Pickleweed *Salicornia virginica*	None	Yes	All year	N/A	Soil, Sed, SW, GW	M	Primary Producer
Ryegrass (and upland plants) *Lolium perenne*	None	No	All year	N/A	Soil, Sed, SW, GW	U	Primary Producer
Benthic Invertebrate Community	None	Yes	All year	Soft bottom estuarine and marine habitats	Sed, SW, GW	M	Benthic Invertebrates
Great Blue Heron *Ardea herodias*	None	Yes	All year	Breeders flew up to 16 km from nest in British Columbia	Air, Soil, Sed, SW	M	Carnivore Mainly fish, also small rodents, amphibians, snakes, lizards, insects, crustaceans, some small birds
Diving Duck (Natural history data to be compiled when a species is identified as an assessment endpoint.)							

TABLE 8

NATURAL HISTORY OF PROPOSED ASSESSMENT ENDPOINTS FOR WPNSTA CONCORD LITIGATION AREA
(Continued)

Species	Status	CA Native	Suisun Bay Residency	Home Range	Exposure Route	Concord Habitat	Feeding Guild
Northern Harrier *Circus cyaneus*	SSC, AB	Yes	All year	Breeding range: avg. 405-429 hectacre (ha)	Air, Soil, SW	M, U	Carnivore Voles, small mammals, birds, frogs, small reptiles, crustaceans, insects, rarely fish
Red-shouldered Hawk *Buteo lineatus*	AB	Yes	All year	Winter range: 127-503 ha	Air, SW Has been reported bathing	U	Carnivore Highly varied diet. Small mammals, snakes, lizards, amphibs, small or young birds, large insects
American Kestrel *Falco sparverius*	None	Yes	All year	Winter range: 154-452 ha	Air, Soil, SW	M, U	Carnivore Small mammals, birds, insects, earthworms, reptiles, amphibs
Peregrine Falcon *Falco peregrinus*	SE, FE	Yes	All year	Approx. 320 sq. km; size fluctuates with prey availability	Air, Soil, SW Bathes frequently, hunts over water	M, U	Carnivore Variety of birds up to ducks in size, some mammals, insects, fish

TABLE 8

NATURAL HISTORY OF PROPOSED ASSESSMENT ENDPOINTS FOR WPNSTA CONCORD LITIGATION AREA (Continued)

Species	Status	CA Native	Suisun Bay Residency	Home Range	Exposure Route	Concord Habitat	Feeding Guild
California Black Rail *Laterallus jamaicensis coturniculus*	ST	Yes	All year	No data; densities of 1.1-1.6/ha in spring, 0.7/ha in winter	Air, Soil/Sed, SW Gleans food from mud, vegetation	M	Carnivore Isopods, insects, other arthropods from mud and vegetation
Suisun Song Sparrow *Melospiza melodia maxillaris*	SSC, SC	Yes	All year	Winter range: 0.6-3.6 ha	Air, SW Prefers moist areas	M	Omnivore 50% seeds, 50% insects, spiders, small inverts in breeding season. Mollusks and crustaceans abundant in diet of marsh race.
Salt Marsh Harvest Mouse *Reithrodontomys raviventris*	FE, CE	Yes	All year	No data	Air, Soil, SW Drinks fresh or salt water	M	Herbivore Leaves, stems, seeds
River Otter *Lutra canadensis*	None	Yes	All year	Avg. 24 km	Air, Soil/Sed, SW Digs on bottom of watercourses; may live in burrows	M, U	Carnivore Fish, mollusks, crustaceans, other aquatic invertebrates, amphibians, carrion

TABLE 8

NATURAL HISTORY OF PROPOSED ASSESSMENT ENDPOINTS FOR WPNSTA CONCORD LITIGATION AREA (Continued)

Species	Status	CA Native	Suisun Bay Residency	Home Range	Exposure Route	Concord Habitat	Feeding Guild
Gray Fox *Urocyon cinereoargenteus*	None	Yes	All year	Avg. 1.2 sq. km	Air, Soil, SW May live in abandoned dens or burrows, drink water	M, U	Omnivore Rabbits, mice, gophers, woodrats, squirrels; also fruits, nuts, grains, insects, carrion, little herbage

Table Notes:

References for natural history data are provided in the natural history tables in Appendix A.

Status

Species of special conservation status, as registered in the California Department of Fish and Game's Natural Diversity Data Base, are indicated by the following codes.

SSC California Department of Fish and Game (CDFG) Species of Special Concern
SE State Endangered Species
ST State Threatened Species
SC Candidate for listing as Endangered Species by state
FE Federal Endangered Species
AB Species listed on the Audubon Blue List of birds designated by the National Audubon Society as experiencing a population decline.
None Species has no special status

Native

Yes Species is native to California.
No Species is not native to California.

TABLE 8

NATURAL HISTORY OF PROPOSED ASSESSMENT ENDPOINTS FOR WPNSTA CONCORD LITIGATION AREA (Continued)

Exposure Route

The exposure route column reflects the primary routes of exposure to contaminants for the species, excluding exposure due to contaminant concentration in prey tissue.

Air	Air at Concord
Soil	Soil at Concord
Sed	Sediments of Concord, Suisun Bay
SW	Surface Water of Concord (including Suisun Bay water)
GW	Groundwater at Concord

Concord Habitat

M	Marsh (includes freshwater, saltwater, and slough habitats)
U	Upland

Feeding Guild

Carnivore	Eats primarily animals.
Herbivore	Eats primarily plants.
Omnivore	Eats a combination of animals and plants.
Primary Producer	Photosynthesizes.

TABLE 9

PLANT BIOASSAY RECOMMENDED FOR WPNSTA CONCORD LITIGATION AREA

Bioassay	RASS	Protocol Reference	Rationale
Ryegrass seedling survival and growth test	3, 4	Linder and others, 1990 (ASTM Standard Temperature and Pressure 1091)	Ryegrass is a salt tolerant plant that occurs in the Litigation Area

Source: EPA 1992c.

TABLE 10

COMPARISON OF AMPHIPOD SOLID PHASE BIOASSAY TESTS

Organism	Habitat	Salinity Tolerance	Sediment Tolerance	Sensitivity to Contaminants	General Comments
Rhepoxinius abronius	Free burrowing	>25ppt[6]	Less tolerant of fine sediments.[1]	Highly sensitive[4,5]	Sensitive to high Total Organic Content[2] and grain size.
Ampelisca abdita	Tube dweller	10 - 35ppt[6]	Sediments from fine sand to mud and silt without shell.[3] May be sensitive to coarse grained sediments.	Less sensitive[4] than *E. estuarius*	Abundant in sediments of high organic content. Introduced species.
Eohaustorius estuarius	Free burrowing	2 - 28ppt[6]	Tolerant of fine sediments.[1] Lives in sandy sediments.	Less sensitive[4] than *R. abronius*	Less sensitive to grain size.
Grandiderella japonica	Infaunal tube dweller	30 - 35ppt[6]	Lives in a variety of sediment types[3].	Less sensitive than *R. abronius*	Introduced species.[3]
Hyalella azteca	Free burrowing	0 - 12.4 ppt[72]	Tolerates wide range of particle sizes[6].	Less sensitive than *E. estuarius*[9]	Some problems in studies in San Francisco Estuary[9]

TABLE 10

COMPARISON OF AMPHIPOD SOLID PHASE BIOASSAY TESTS
(Continued)

Table Notes:

1 Dewitt, Swartz, and Lamberson, 1989.
2 Long and others, 1990.
3 American Society for Testing Materials, 1991.
4 PRC, 1994f.
5 Long and Buchman, 1989.
6 MacDonald and others, 1992.
7 Nebeker and Miller, 1988.
8 Burton, 1991.
9 RWQCB, 1994.

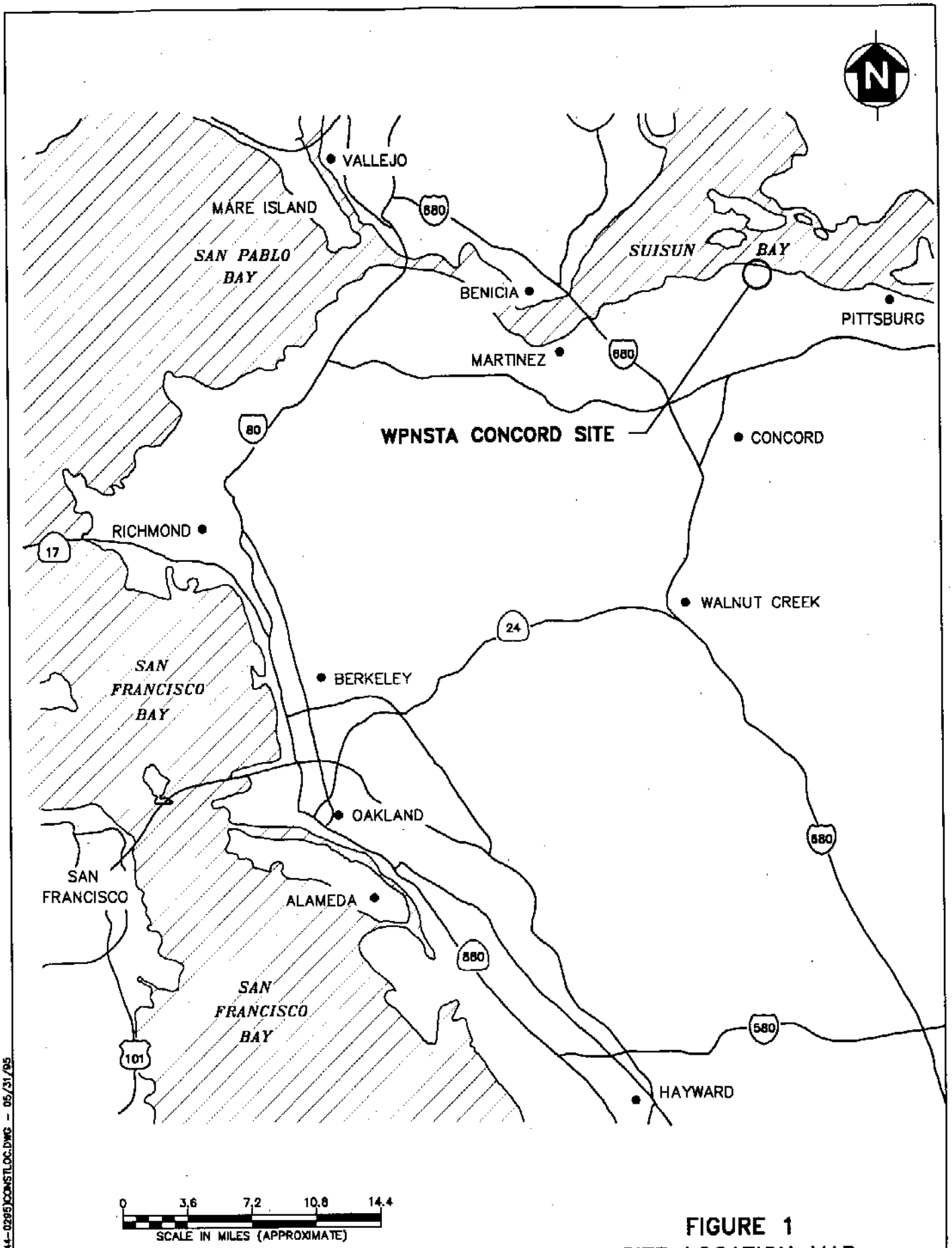
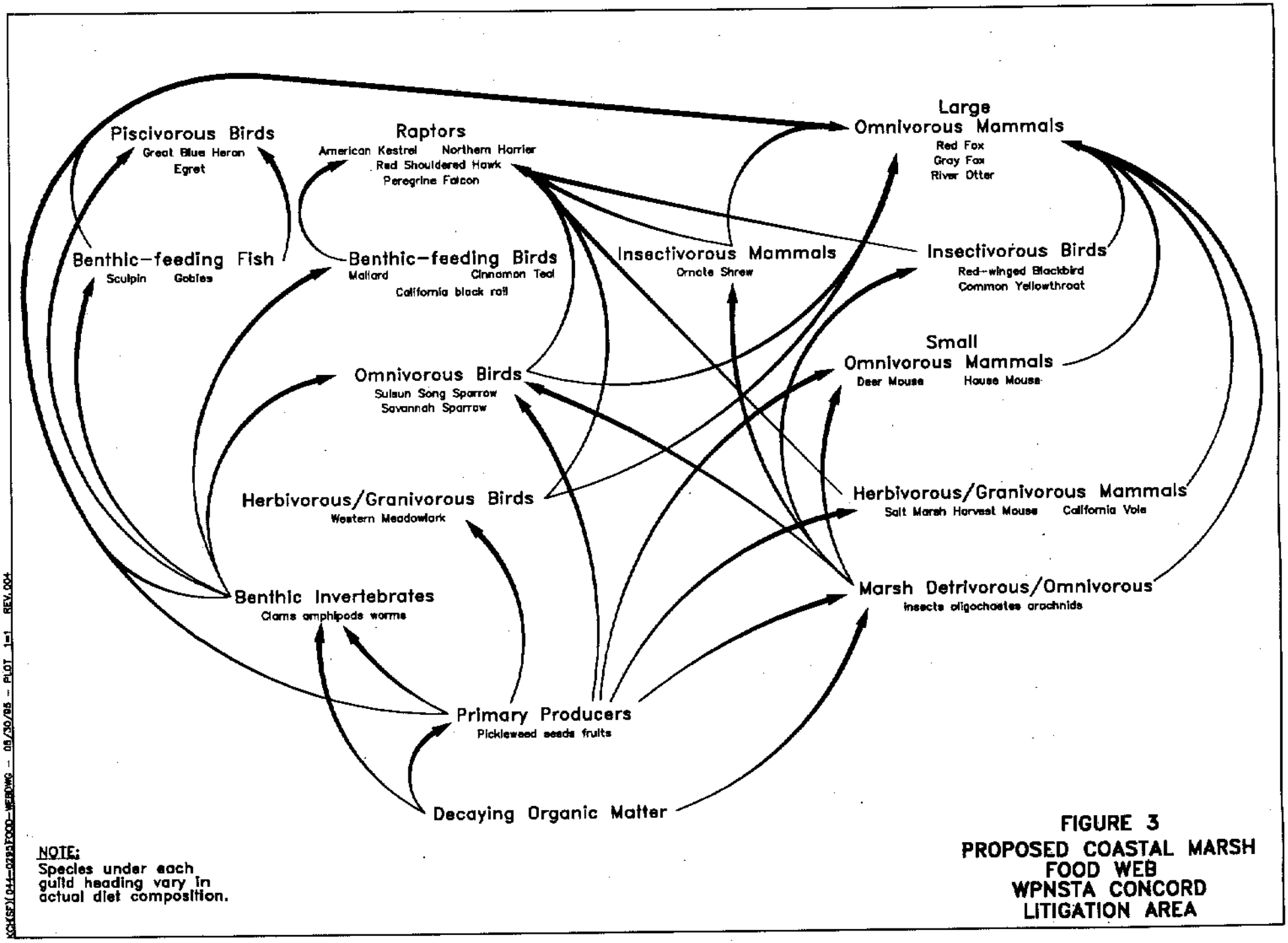


FIGURE 1
SITE LOCATION MAP
WPNSTA CONCORD, CALIFORNIA

KCH SF (044-0295)CONSTLOC.DWG - 05/31/95

Figure 2

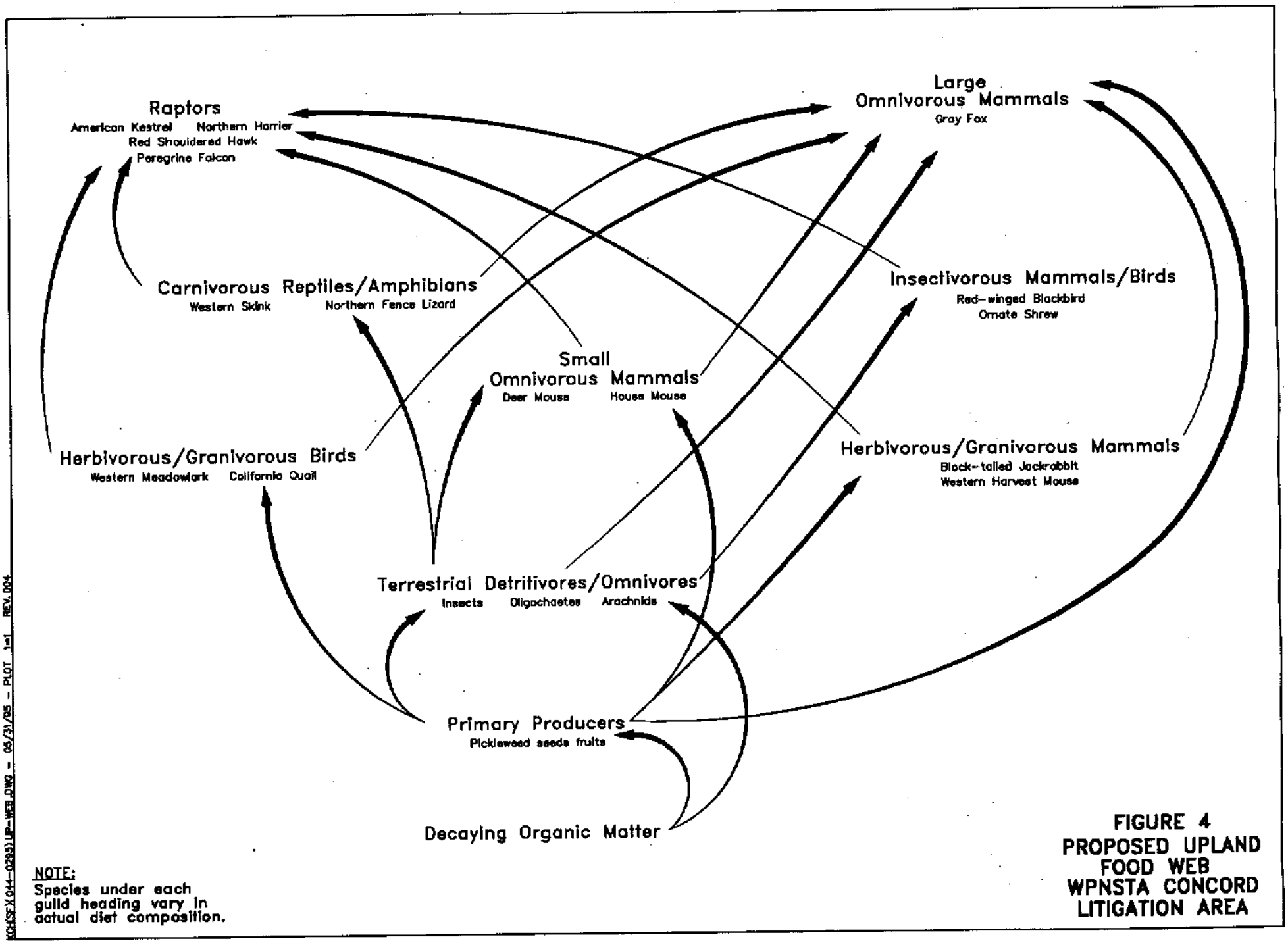
This detailed station map has been deleted from the Internet-accessible version of this document as per Department of the Navy Internet security regulations.



NOTE:
Species under each guild heading vary in actual diet composition.

FIGURE 3
PROPOSED COASTAL MARSH FOOD WEB
WPNSTA CONCORD
LITIGATION AREA

KCK(SED)044-0299\FOOD-WEB.DWG -- 08/30/95 -- PLOT 1=1 REV.004



NOTE:
Species under each guild heading vary in actual diet composition.

FIGURE 4
PROPOSED UPLAND FOOD WEB
WPNSTA CONCORD
LITIGATION AREA

KCHSF\X044-0289\LIP-WEB.DWG - 05/31/05 - PLOT 1st REV.004

FIGURE 5

MEAN METALS CONCENTRATIONS IN SURFACE SOIL

Figure 5a: Arsenic

Figure 5b: Cadmium

Figure 5c: Copper

Figure 5d: Lead

Figure 5e: Selenium

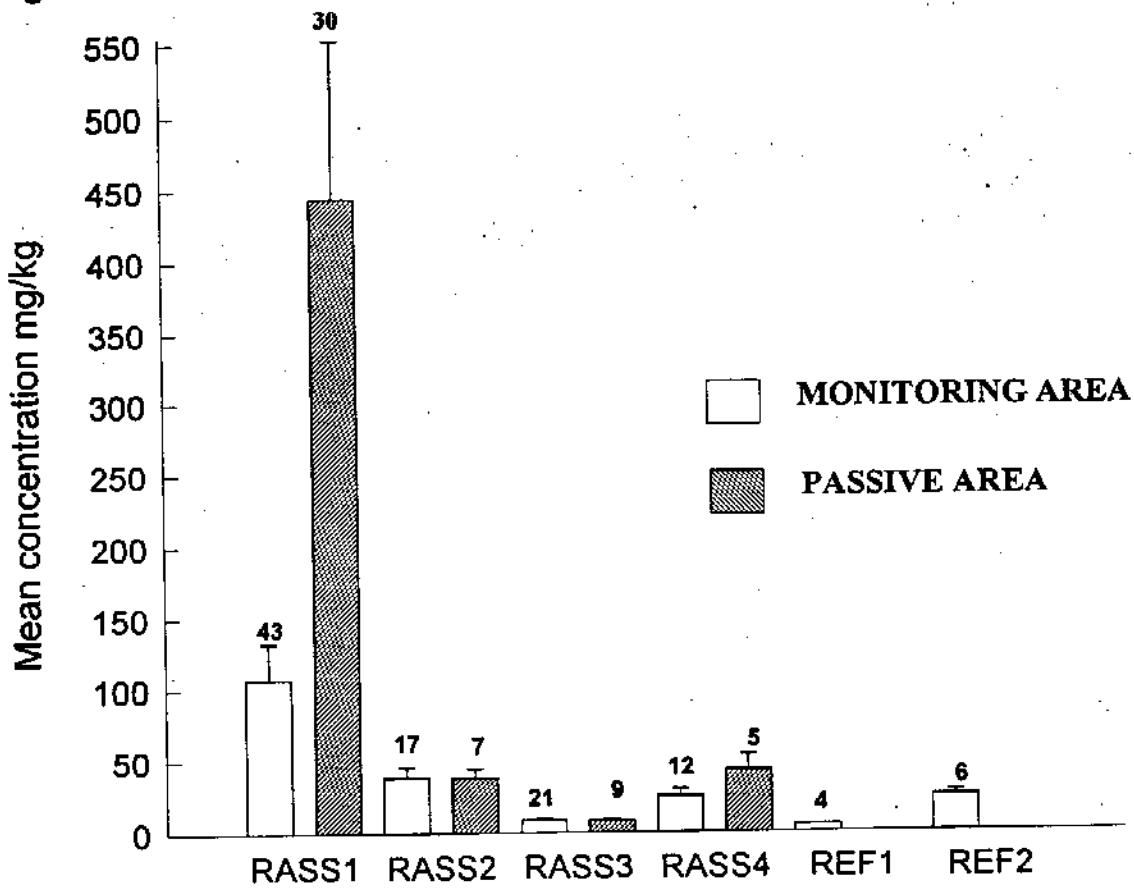
Figure 5f: Zinc

Note: Grand mean (and standard error) metal concentration in surface soil from sampling locations in the monitoring and passive areas of each RASS and the reference areas. Ranges of location means are presented in tabular form. Reference 1 is the upland site. Reference 2 is the marsh site. Sample sizes are indicated above error bars.

Mean Arsenic Concentration in Surface Soils

(standard error and sample sizes noted)

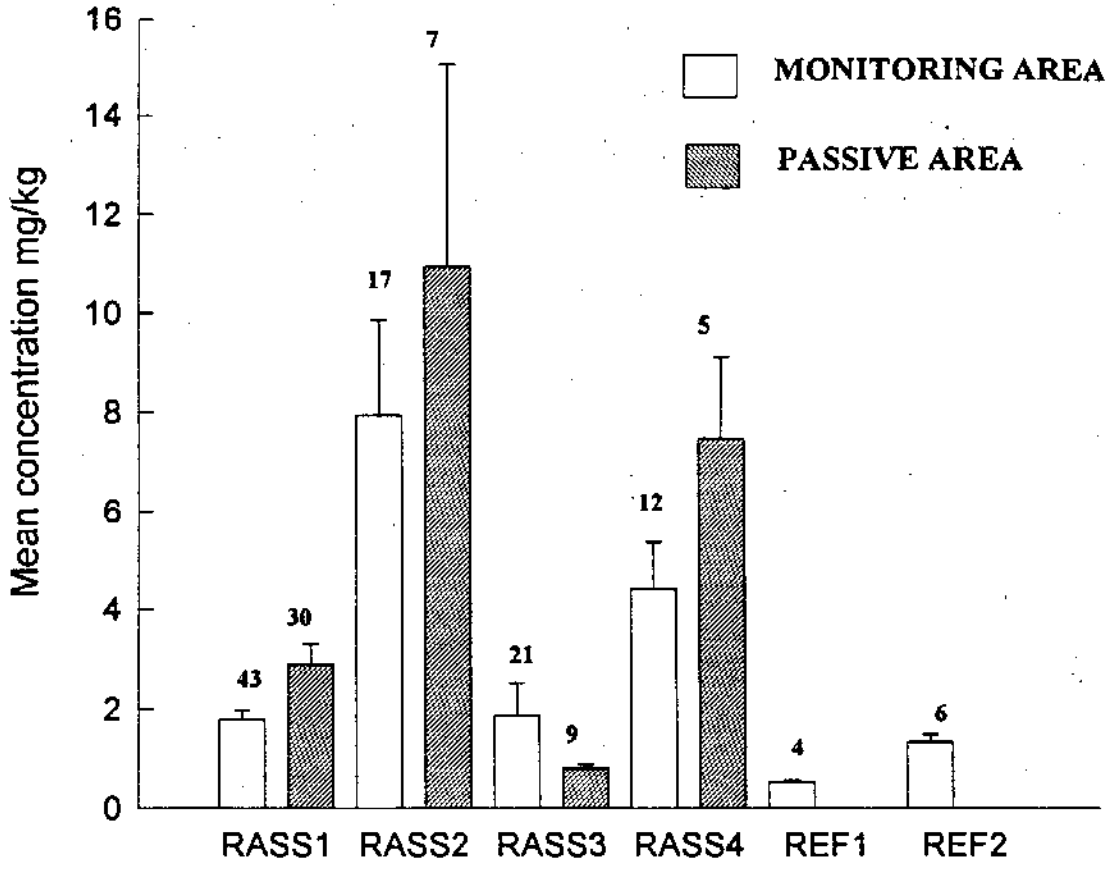
Fig 5a



ARSENIC	RANGES of Location Means (minimum - maximum in mg/kg)	
	Monitoring Area	Passive Area
RASS 1	6.08 - 894.67	11.70 - 2336.67
RASS 2	12.90 - 93.13	23.07 - 69.87
RASS 3	2.83 - 14.90	4.47 - 14.60
RASS 4	8.00 - 61.47	11.37 - 82.30
REF 1	4.40 - 5.22	
REF 2	12.97 - 31.80	

Mean Cadmium Concentration in Surface Soils
(standard error and sample size noted)

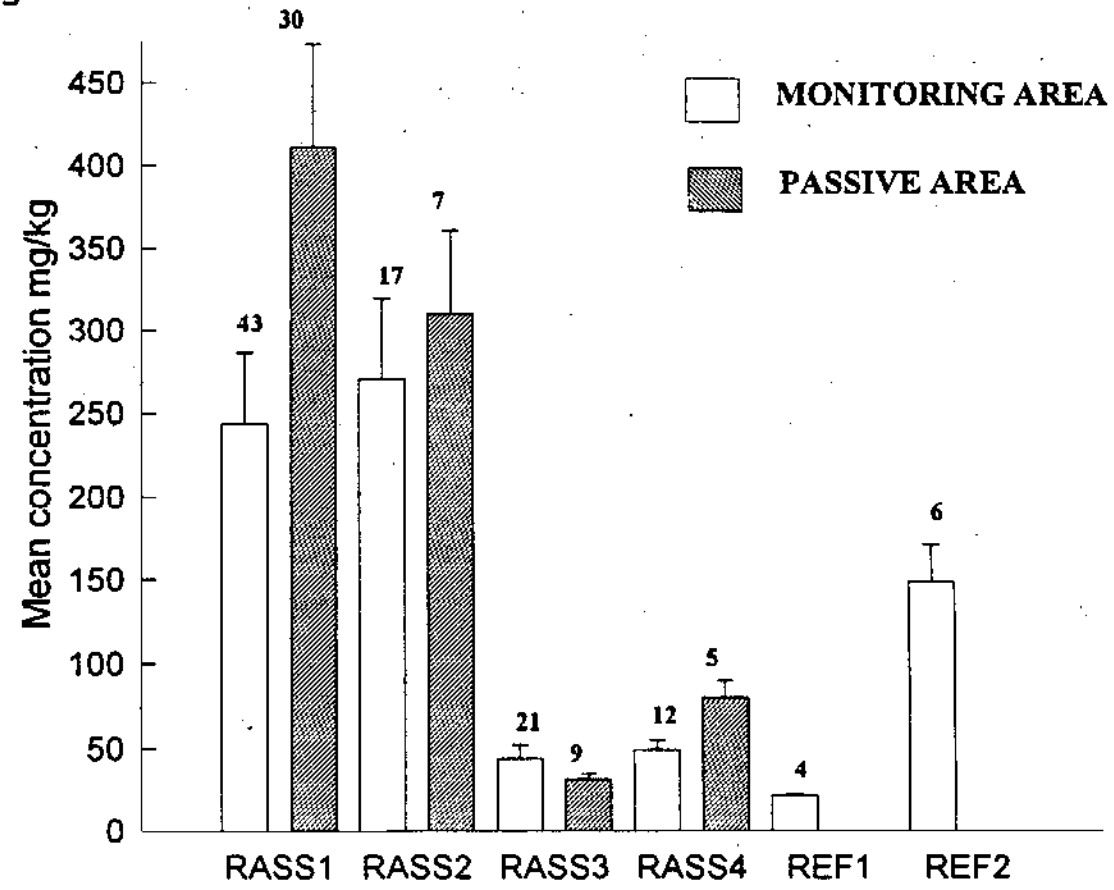
Fig 5b



CADMIUM	RANGES of Location Means (minimum - maximum in mg/kg)	
	Monitoring Area	Passive Area
RASS 1	0.42 - 7.80	0.83 - 12.83
RASS 2	0.76 - 23.90	1.87 - 33.10
RASS 3	0.47 - 12.73	0.49 - 1.23
RASS 4	0.60 - 9.97	1.66 - 11.17
REF 1	0.42 - 0.66	
REF 2	1.01 - 2.07	

Mean Copper Concentration in Surface Soils
(standard error and sample sizes noted)

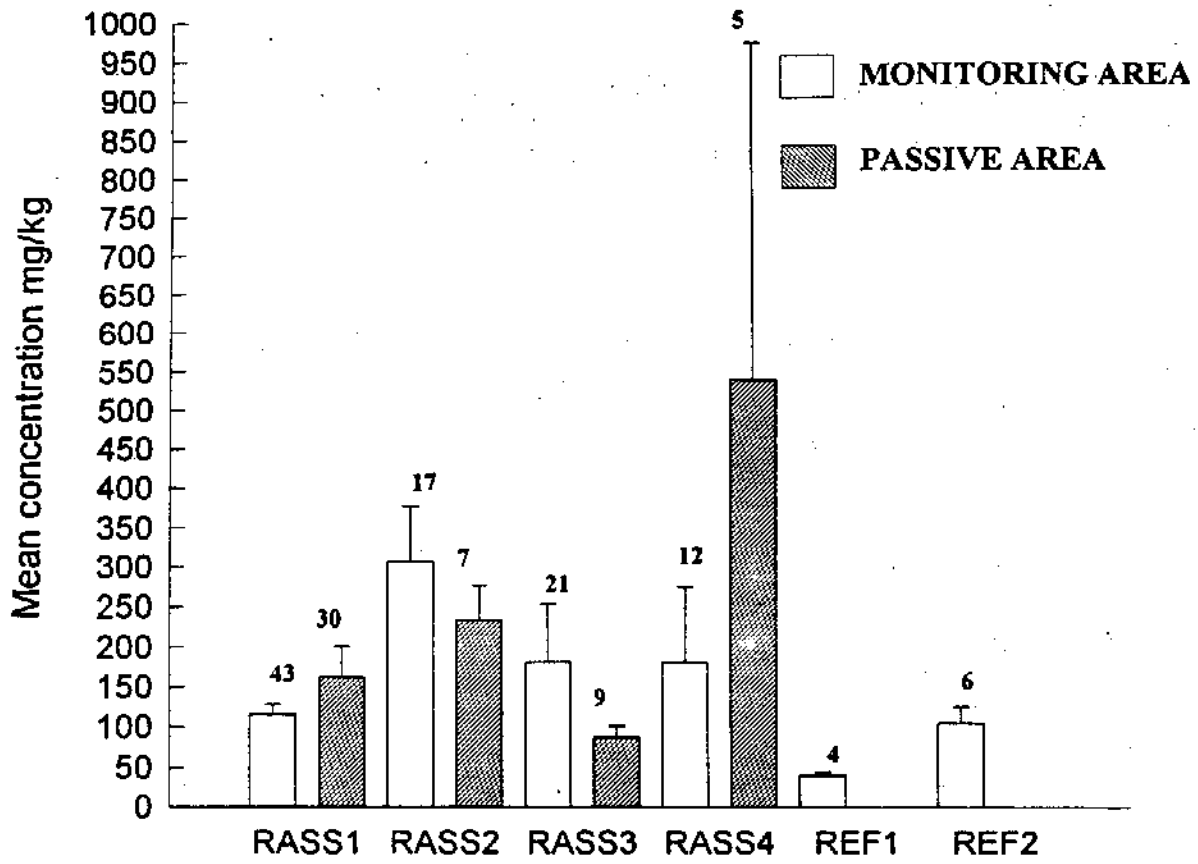
Fig 5c



COPPER	RANGES of Location Means (minimum - maximum in mg/kg)	
	Monitoring Area	Passive Area
RASS 1	9.78 - 1048.67	64.63 - 1563.33
RASS 2	32.37 - 720.33	151.57 - 511.17
RASS 3	19.93 - 150.37	18.63 - 49.70
RASS 4	21.37 - 87.90	53.33 - 105.54
REF 1	20.62 - 22.40	
REF 2	77.93 - 212.67	

Mean Lead Concentration in Surface Soils
(standard error and sample size noted)

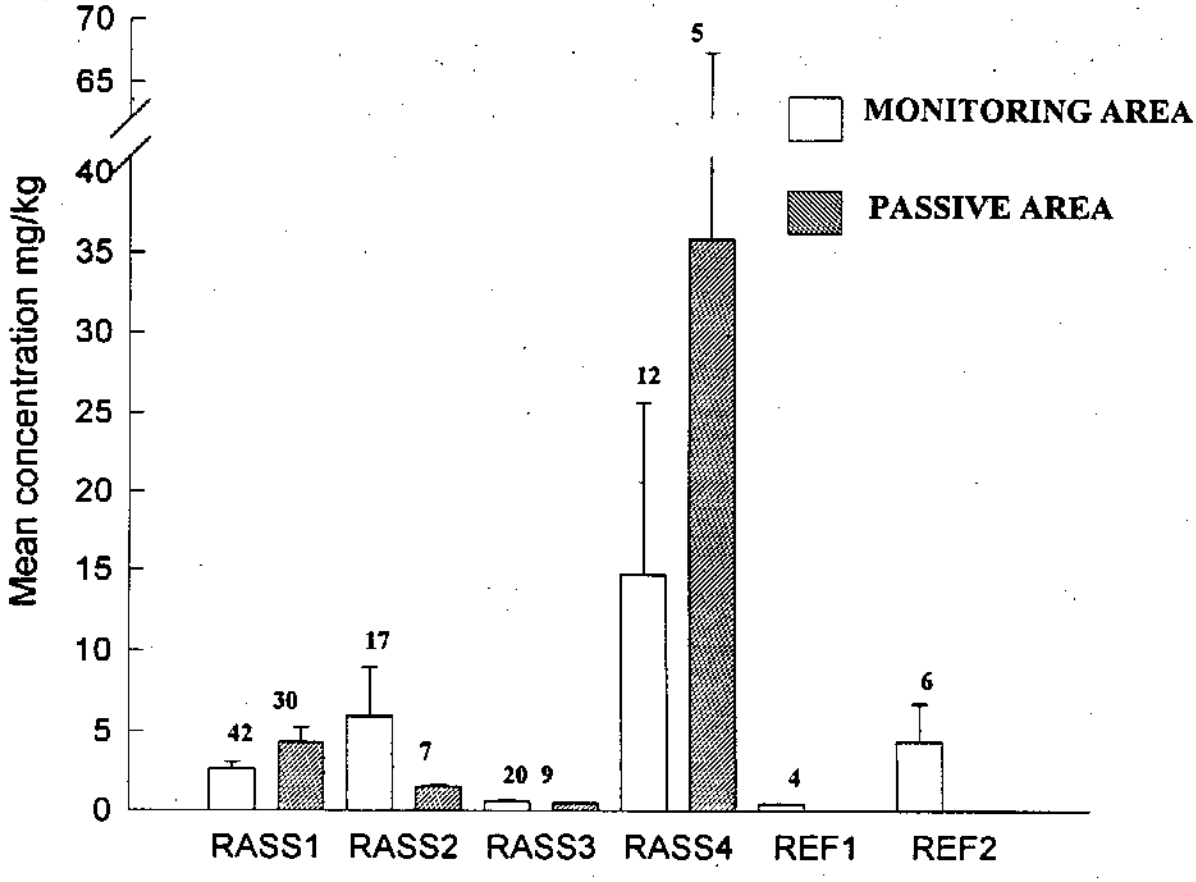
Fig 5d



LEAD	RANGES of Location Means (minimum - maximum in mg/kg)	
	Monitoring Area	Passive Area
RASS 1	12.15 - 395.83	25.17 - 1192.67
RASS 2	53.50 - 1017.33	126.67 - 466.67
RASS 3	24.83 - 1418.33	23.83 - 148.67
RASS 4	40.38 - 1185.67	48.13 - 2253.67
REF 1	31.17 - 45.43	
REF 2	36.87 - 162.67	

Mean Selenium Concentration in Surface Soils
(standard error and sample size noted)

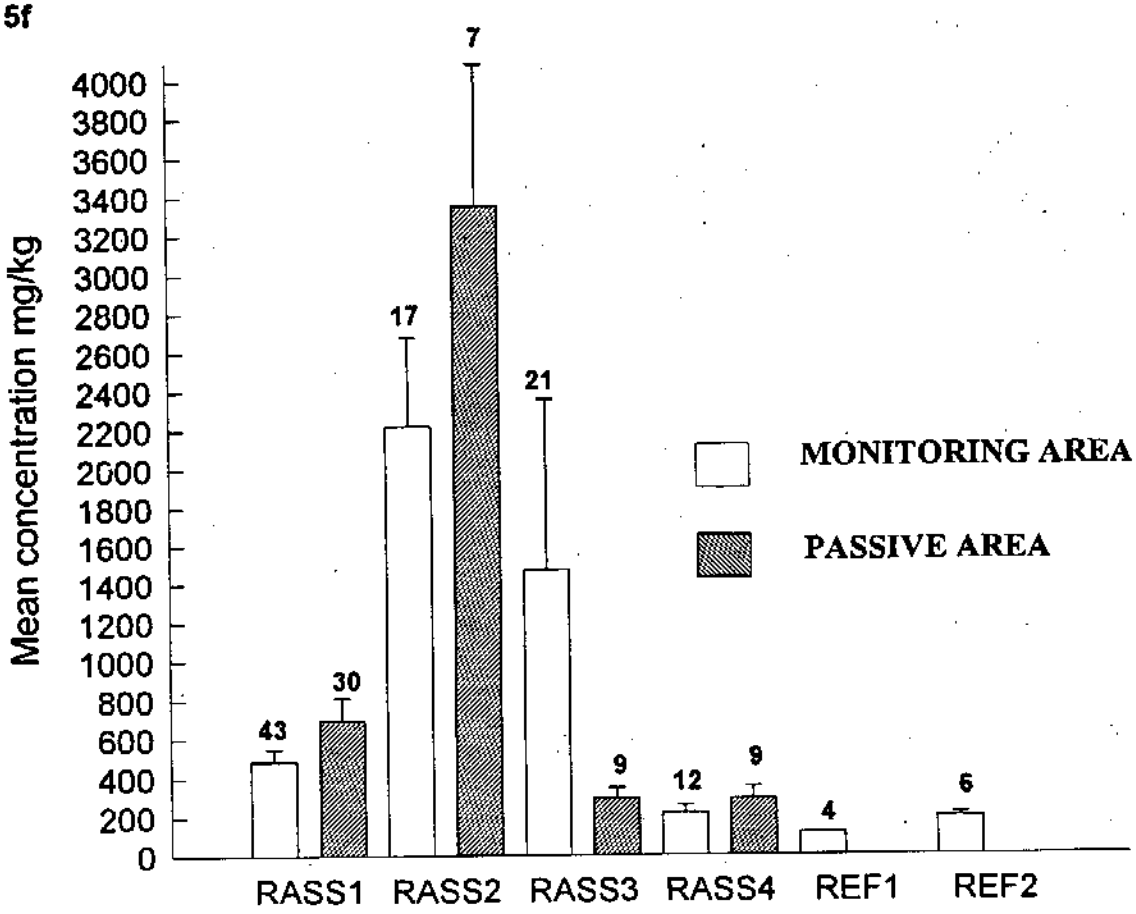
Fig 5e



SELENIUM	RANGES of Location Means (minimum - maximum in mg/kg)	
	Monitoring Area	Passive Area
RASS 1	0.45 - 12.73	0.51 - 20.07
RASS 2	0.50 - 51.00	0.89 - 2.00
RASS 3	0.40 - 1.11	0.43 - 0.78
RASS 4	0.49 - 133.37	0.47 - 160.67
REF 1	0.40 - 0.42	
REF 2	1.13 - 15.87	

Mean Zinc Concentration in Surface Soils
(standard error and sample size noted)

Fig 5f



ZINC	RANGES of Location Means (minimum - maximum in mg/kg)	
	Monitoring Area	Passive Area
RASS 1	58.33 - 1831.67	139.00 - 2886.67
RASS 2	227.00 - 6810.00	1143.33 - 7128.30
RASS 3	80.40 - 18233.33	101.03 - 584.33
RASS 4	69.50 - 524.33	173.33 - 529.33
REF 1	102.43 - 123.30	
REF 2	119.03 - 257.33	

FIGURE 6

MEAN METALS CONCENTRATIONS IN SEDIMENTS

Figure 6a: Lead

Figure 6b: Zinc

Figure 6c: Copper, Arsenic

Figure 6d: Cadmium, Selenium

Note: Grand mean (and standard error) concentration of six metals in surface sediment at each RASS and reference area. Sample sizes are noted at the bottom of each page. Reference 1 is the upland site. Reference 2 is the marsh site. Effects Range-Low or Apparent Effects Threshold (for amphipod) are indicated for each metal.

Mean Sediment Concentrations

Fig 6a

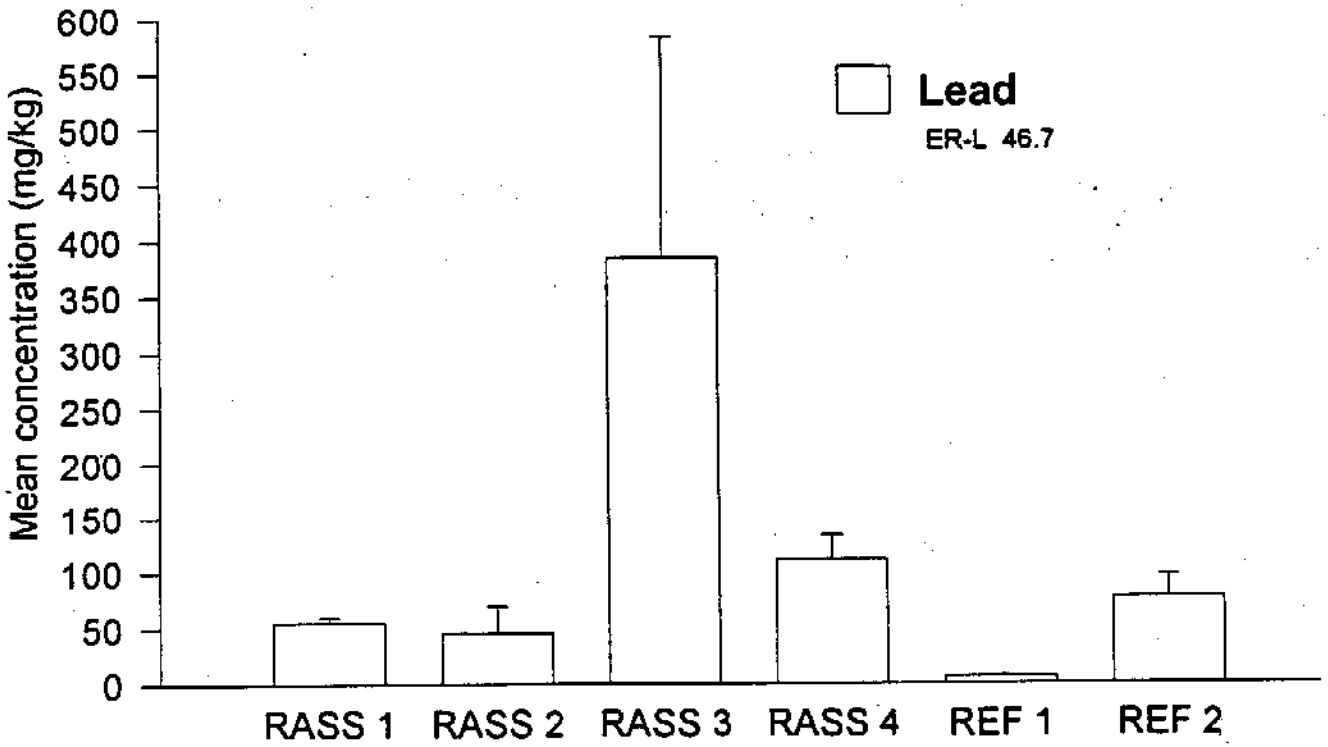
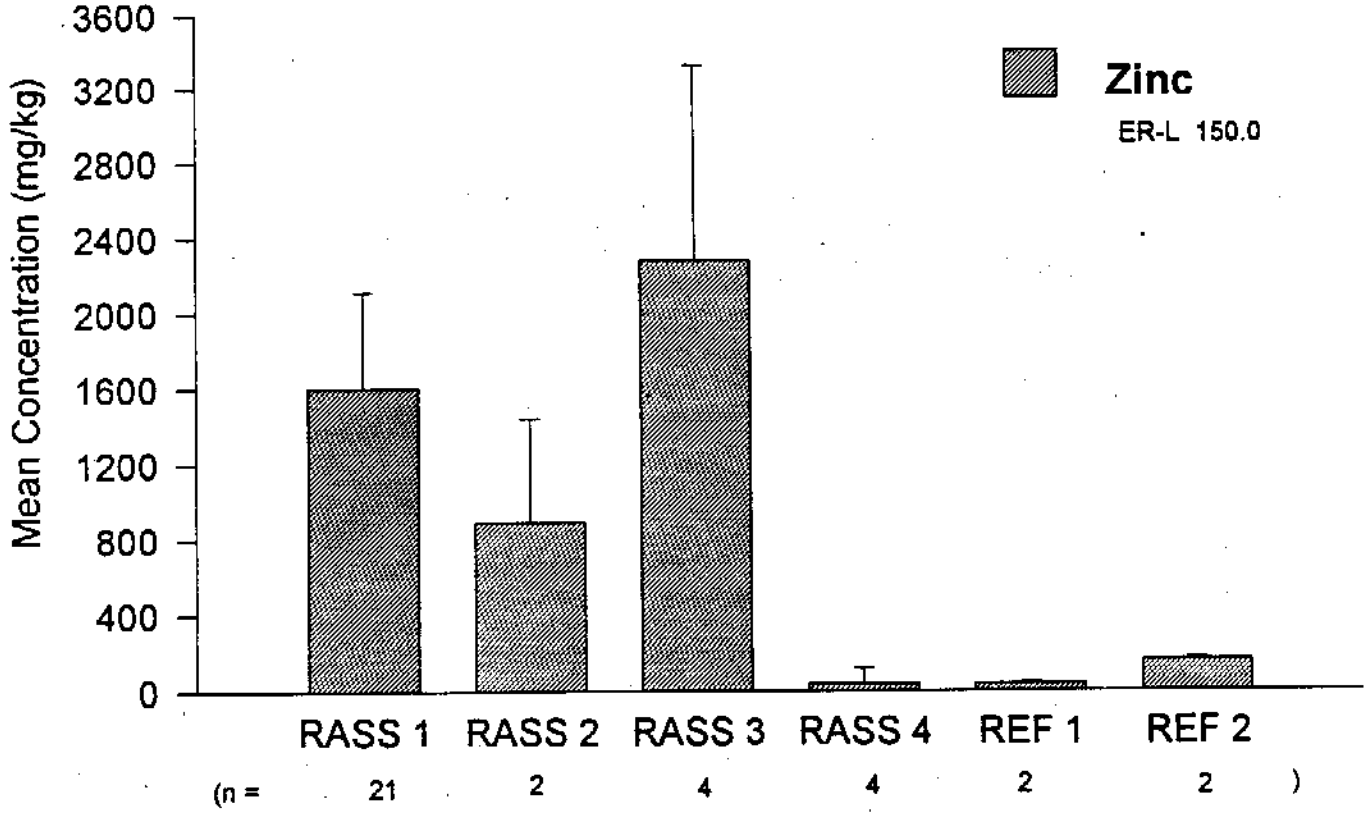


Fig 6b



Mean Sediment Concentrations

Fig 6c

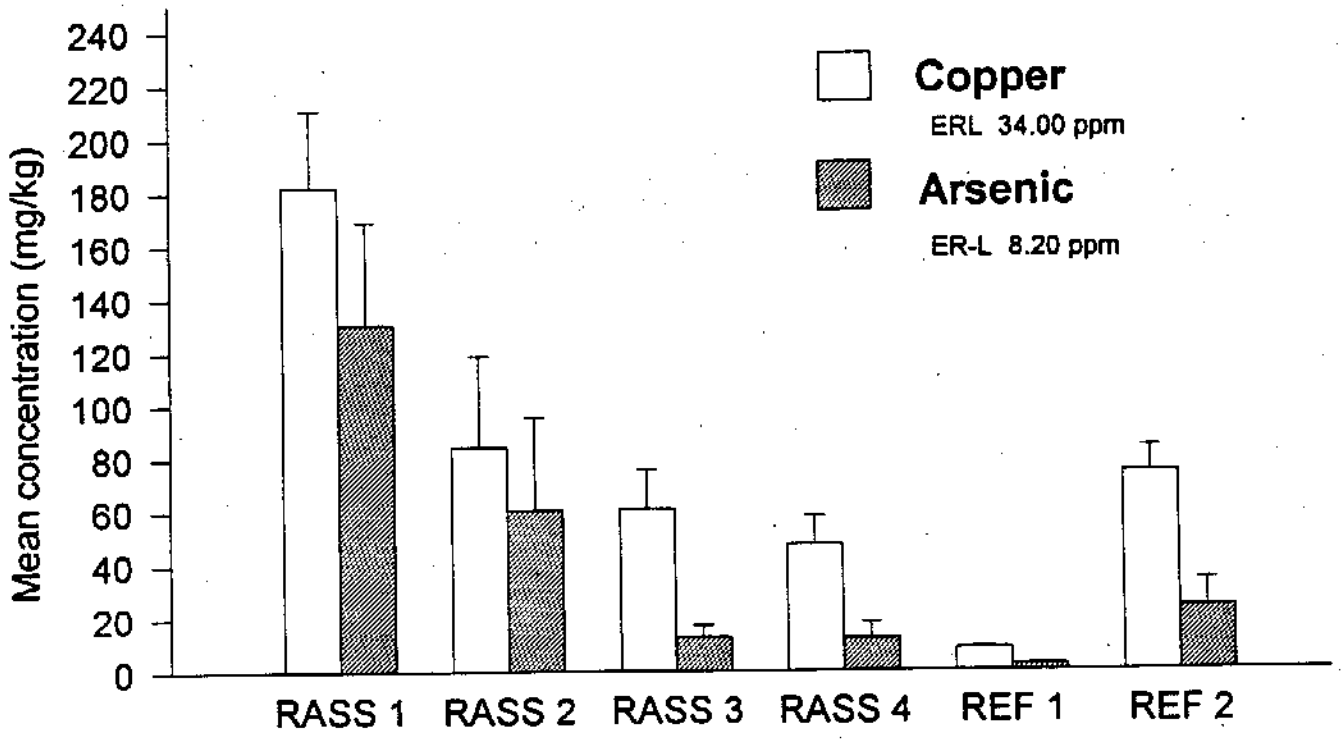


Fig 6d

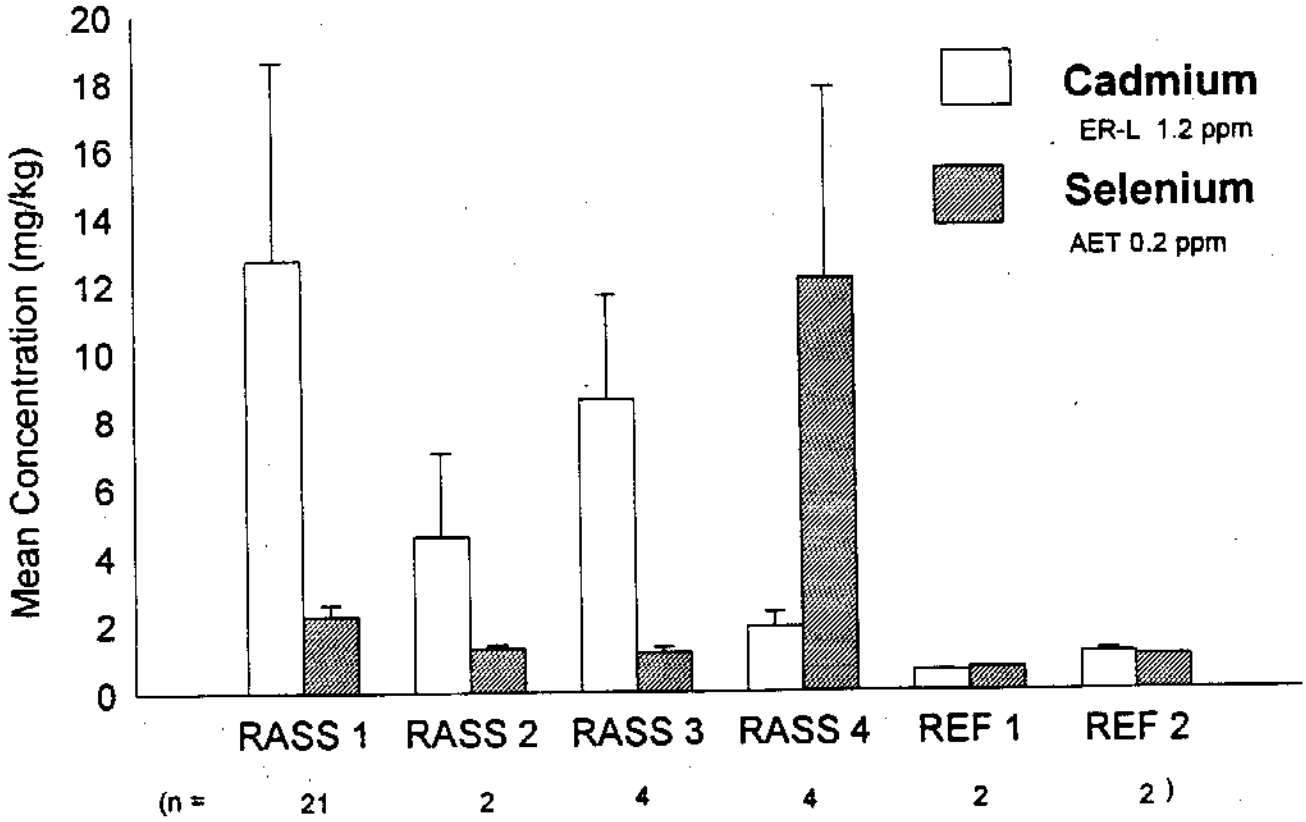


FIGURE 7

MEAN METALS CONCENTRATIONS IN SURFACE WATER

Figure 7a: Arsenic, Copper

Figure 7b: Cadmium, Lead

Figure 7c: Selenium

Figure 7d: Zinc

Note: Grand mean (and standard error) concentration of six metals in surface water samples from RASS and reference sites. Sample sizes are indicated on the lower graph. Reference site 1 is the upland site. Reference site 2 is the marsh site. Ambient Water Quality Criteria or San Francisco Bay Basin Plan criteria are indicated for each metal.

Mean surface water concentrations

Fig 7a

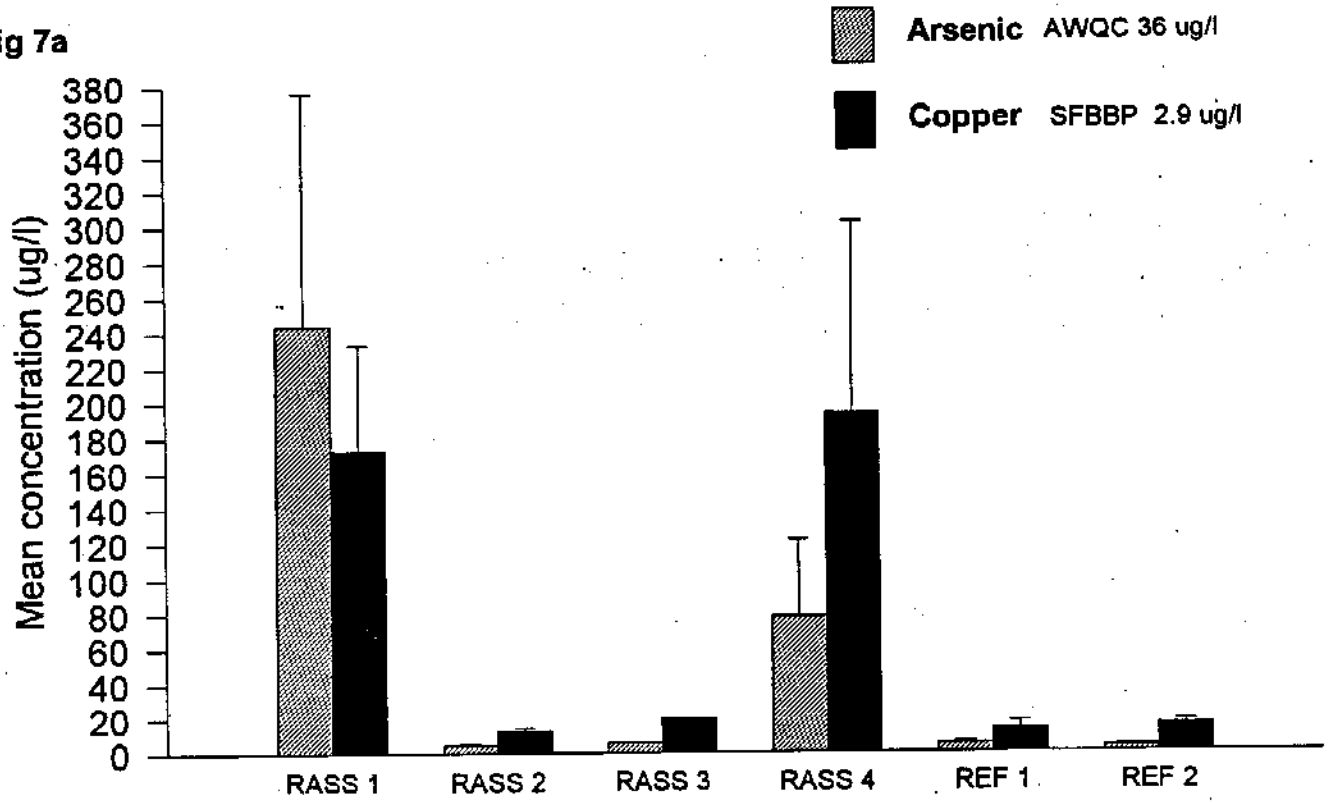
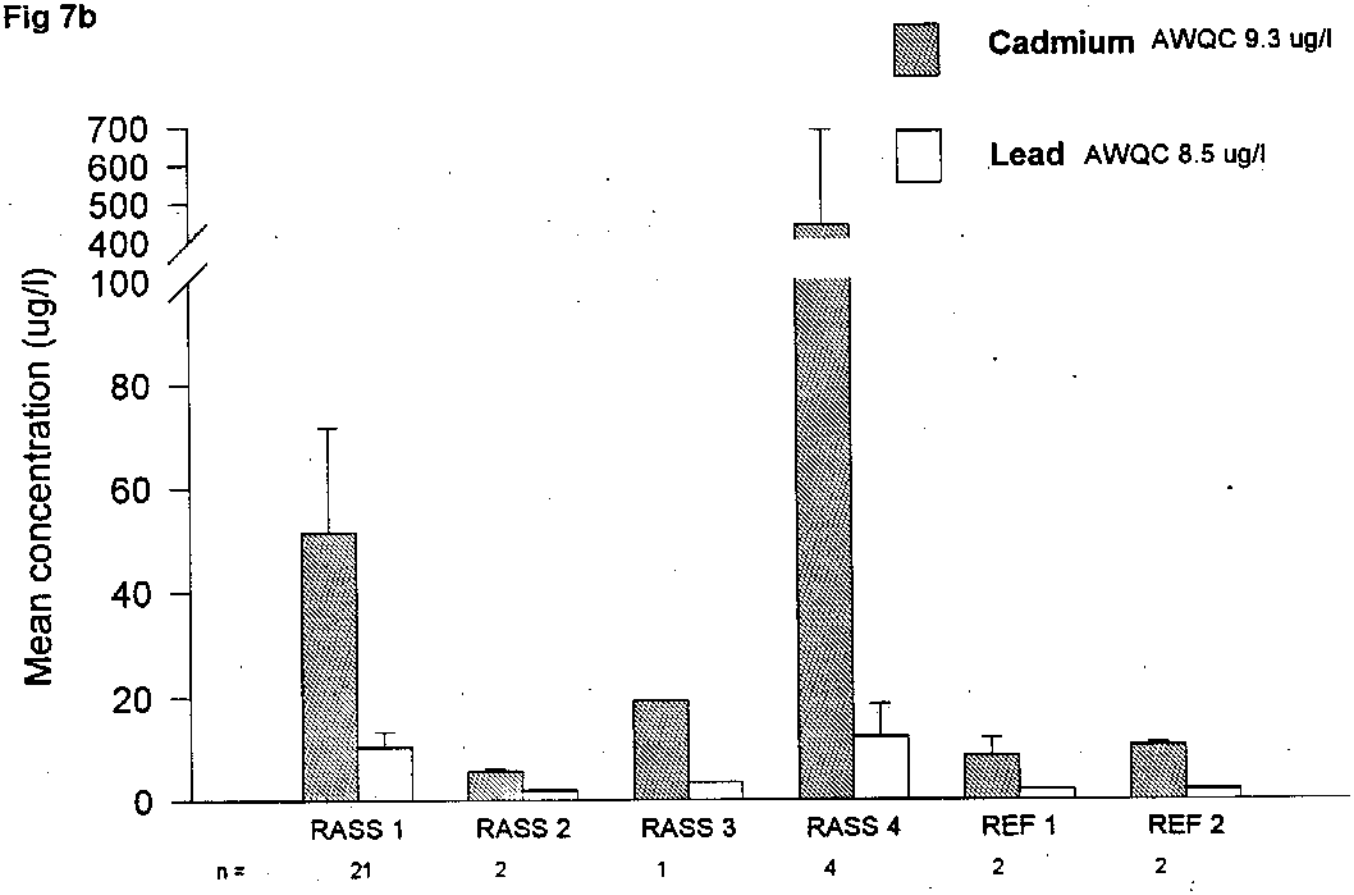


Fig 7b



Mean surface water concentrations

Fig 7c

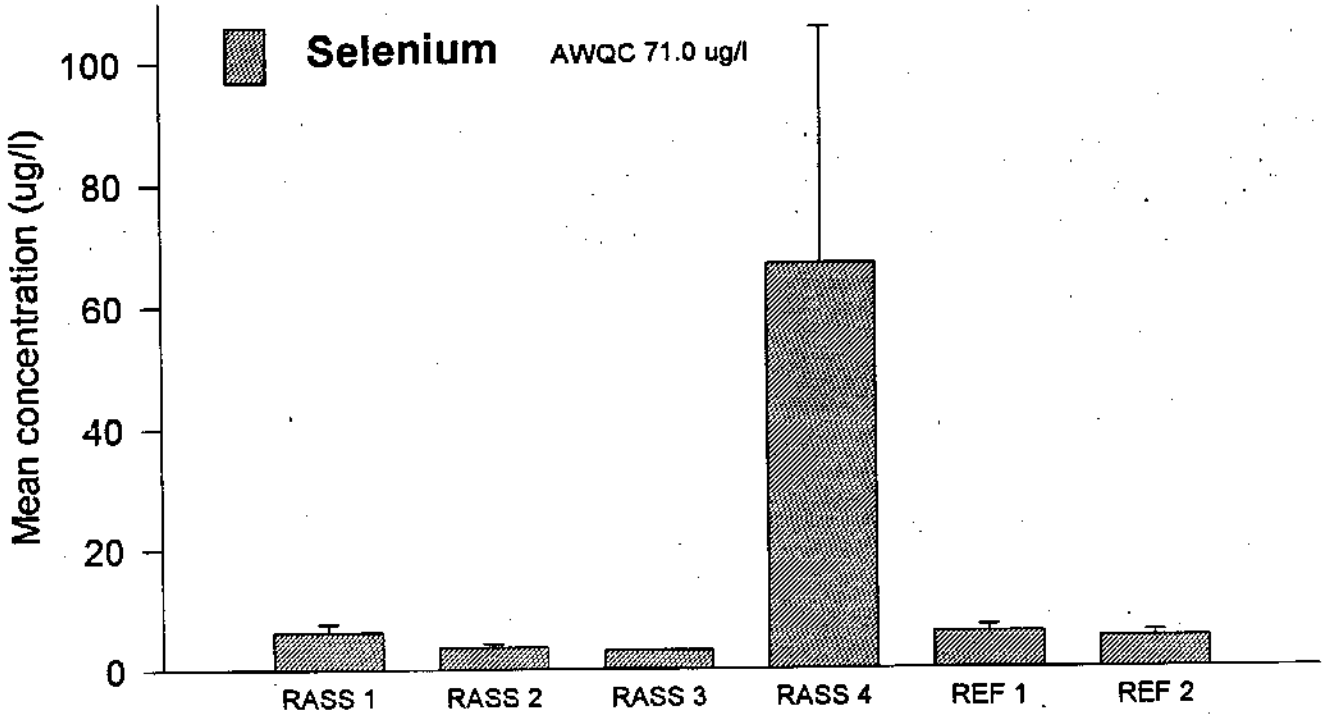


Fig 7d

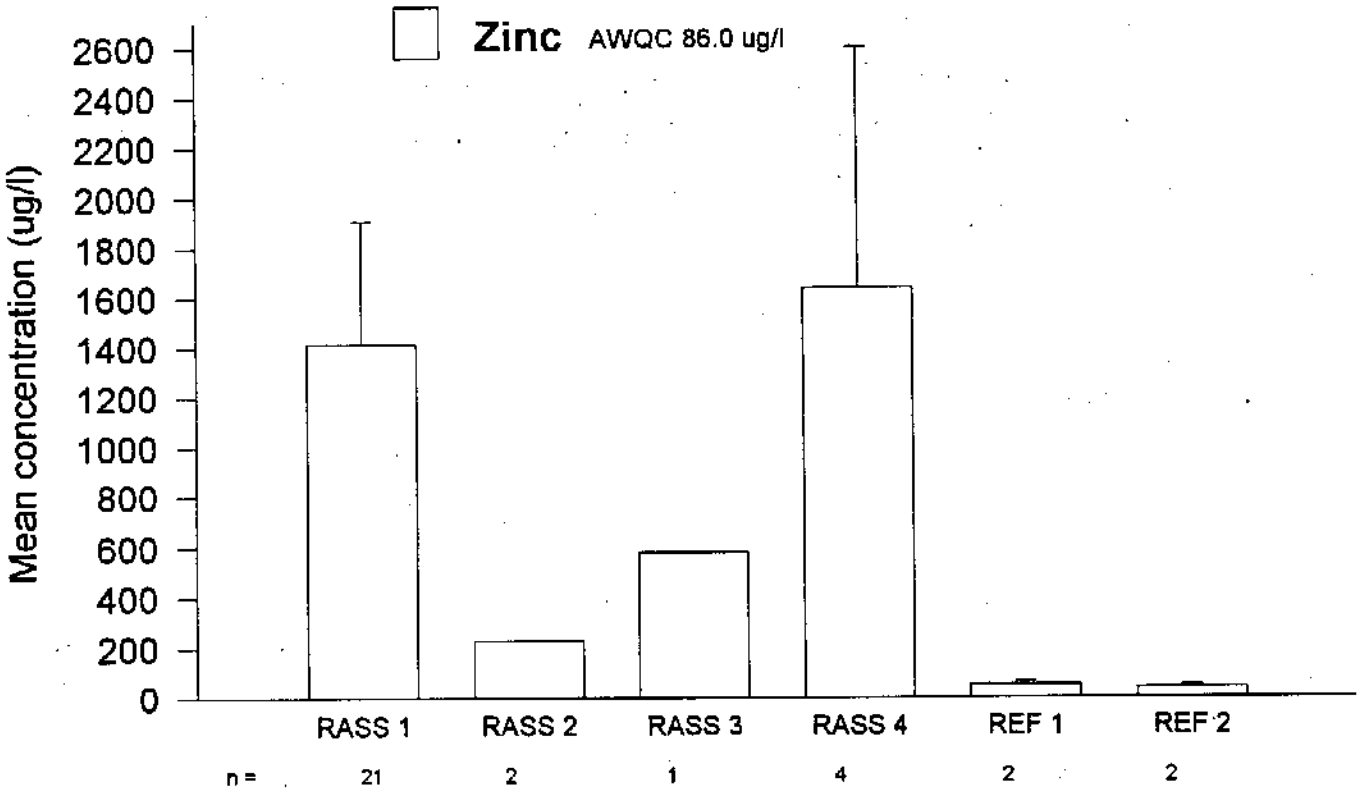


FIGURE 8

TISSUE CONCENTRATIONS OF METALS

IN ASIATIC CLAMS *(CORBICULA FLUMINEA)*

Figure 8a: Arsenic

Figure 8b: Cadmium

Figure 8c: Copper

Figure 8d: Lead

Figure 8e: Selenium

Figure 8f: Zinc

Note: Data represent mean (and standard error) concentrations of six metals at each sampling location in RASSs where clams were caged *in situ* and laboratory-held controls (location 1). Sample sizes ranged from 1 to 3 cages of 20-30 clams at each location.

Fig 8a

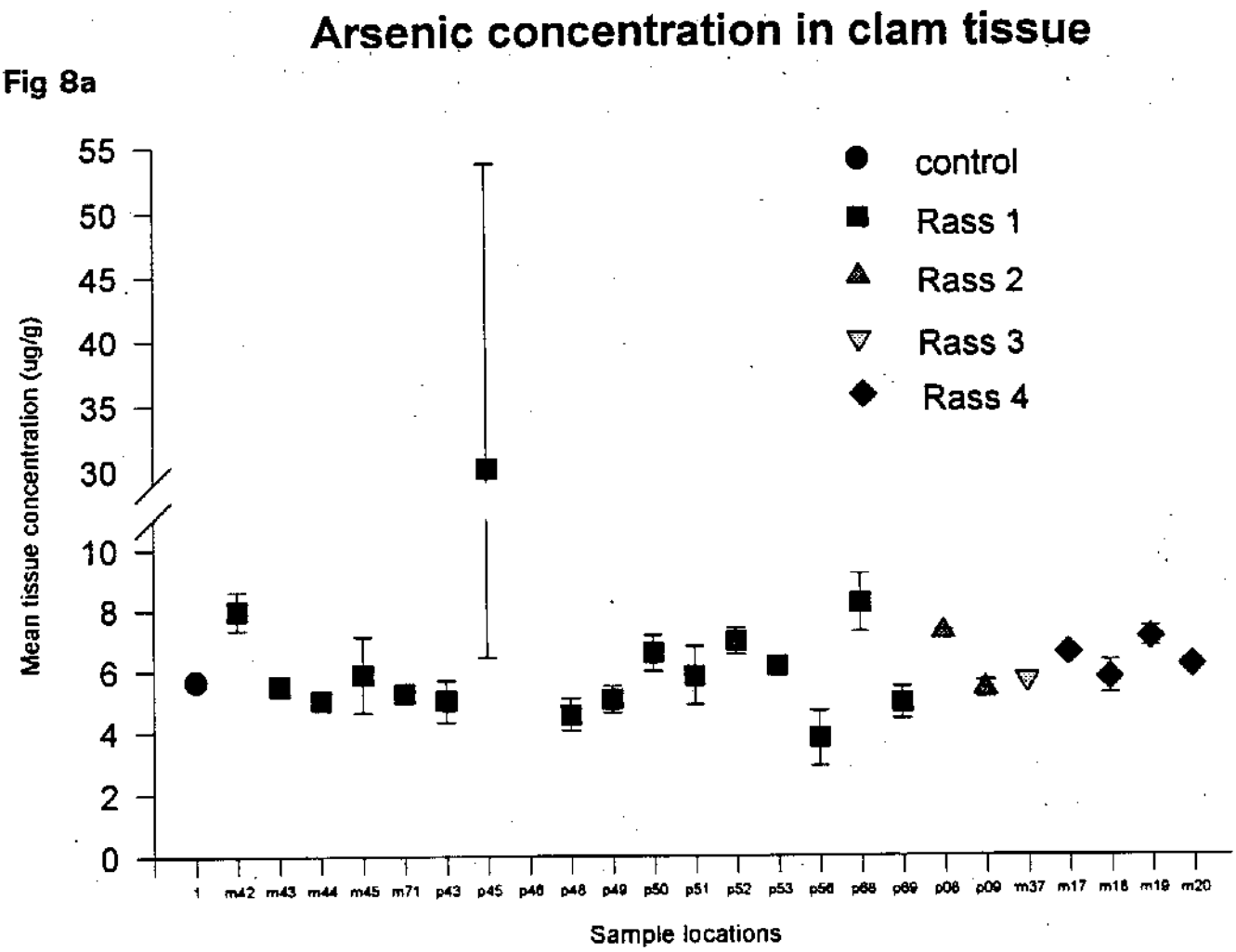

Arsenic concentration in clam tissue
control
Rass 1
Rass 2
Rass 3
Rass 4
Mean tissue concentration (ug/g)
55
50
45
40
35
30
10
8
6
4
2
0
1
m42
m43
m44
m45
m71
p43
p45
p46
p48
p49
p50
p51
p52
p53
p56
p68
p69
p08
p09
m37
m17
m18
m19
m20
Sample locations

Fig 8b

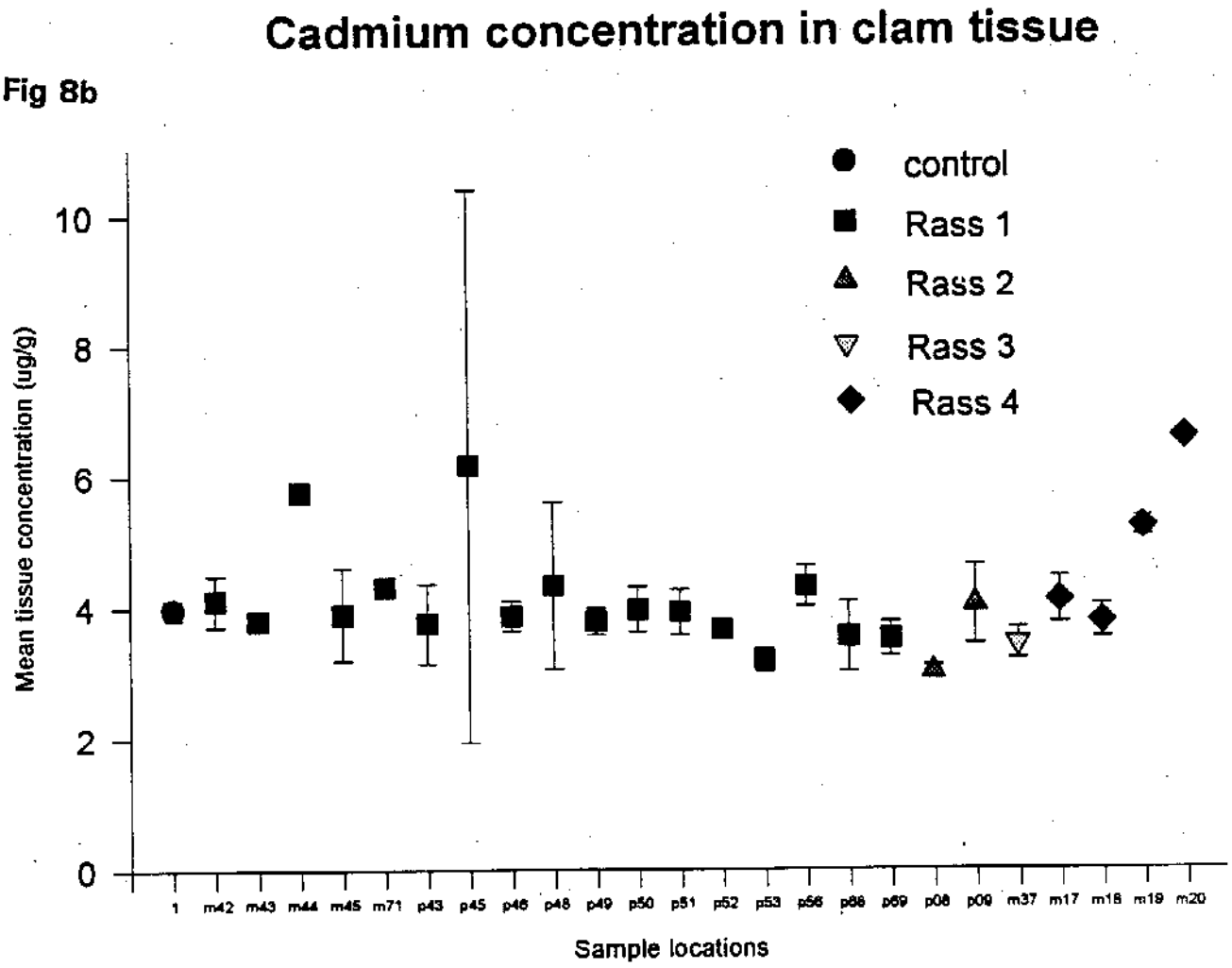

Cadmium concentration in clam tissue
control
Rass 1
Rass 2
Rass 3
Rass 4
Mean tissue concentration (ug/g)
0
2
4
6
8
10
1
m42
m43
m44
m45
m71
p43
p45
p46
p48
p49
p50
p51
p52
p53
p56
p68
p69
p08
p09
m37
m17
m18
m19
m20
Sample locations

Fig 8c

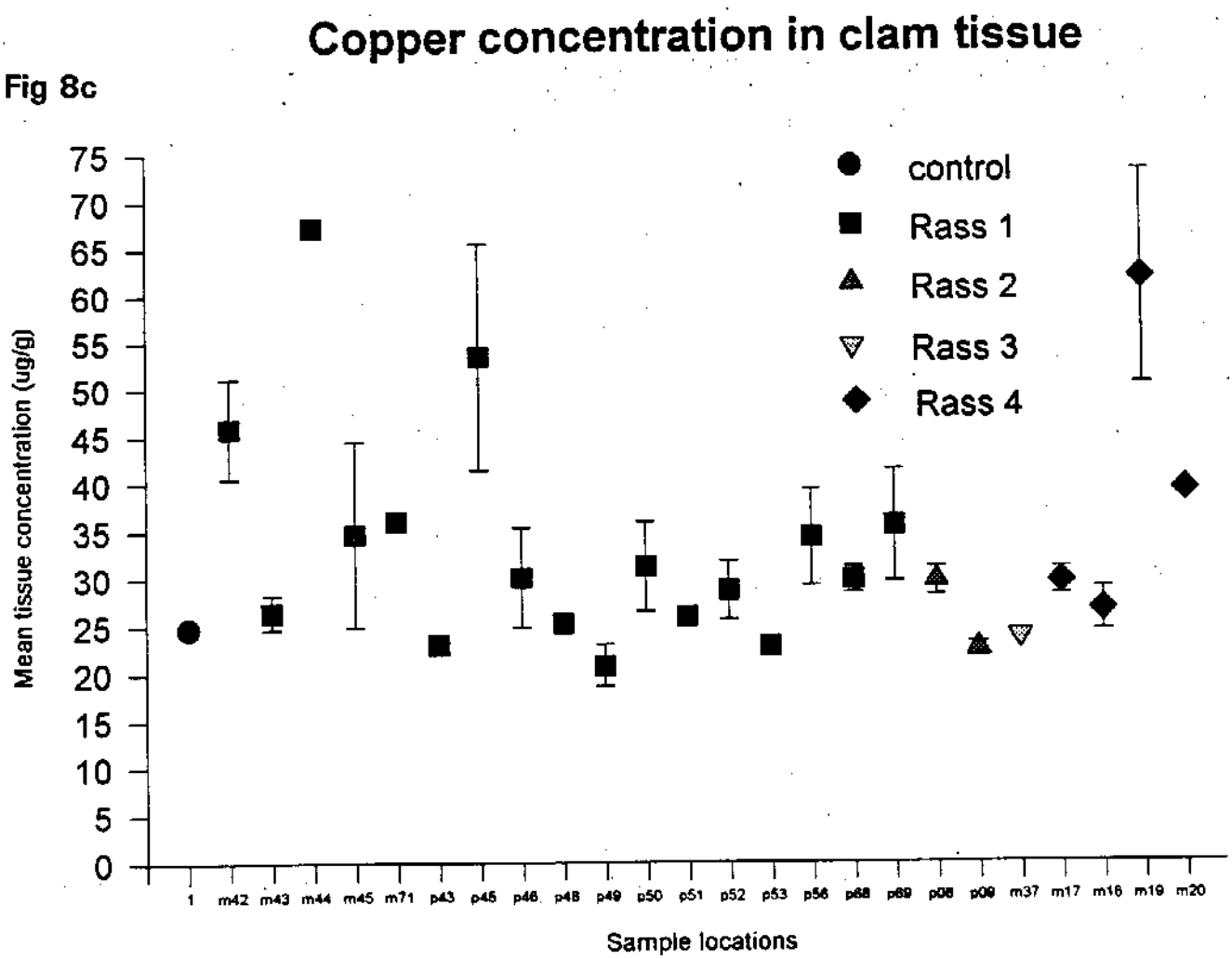

Copper concentration in clam tissue
control
Rass 1
Rass 2
Rass 3
Rass 4
Mean tissue concentration (ug/g)
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1
m42
m43
m44
m45
m71
p43
p45
p46
p48
p49
p50
p51
p52
p53
p56
p68
p69
p08
p09
m37
m17
m16
m19
m20
Sample locations

Fig 8d

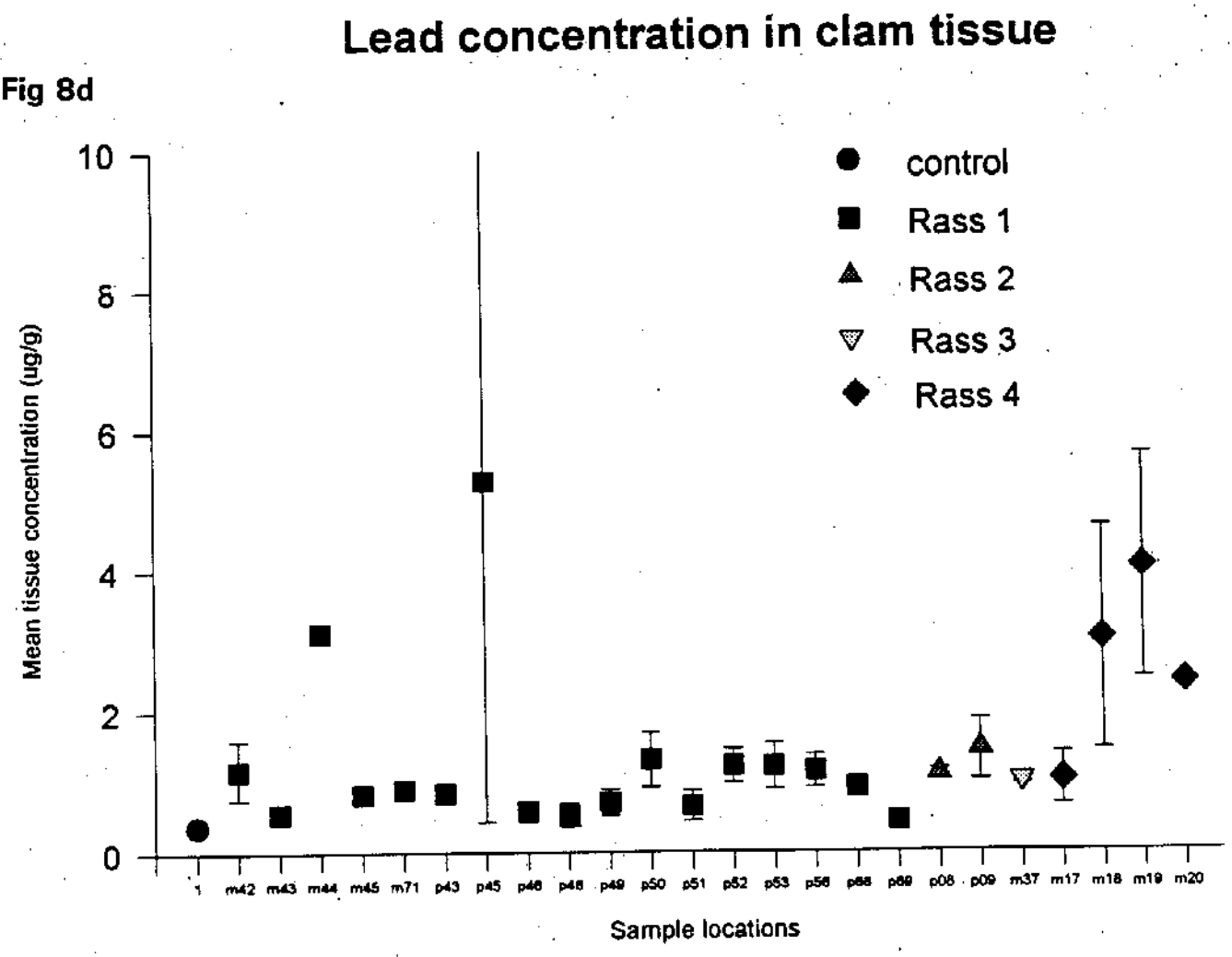
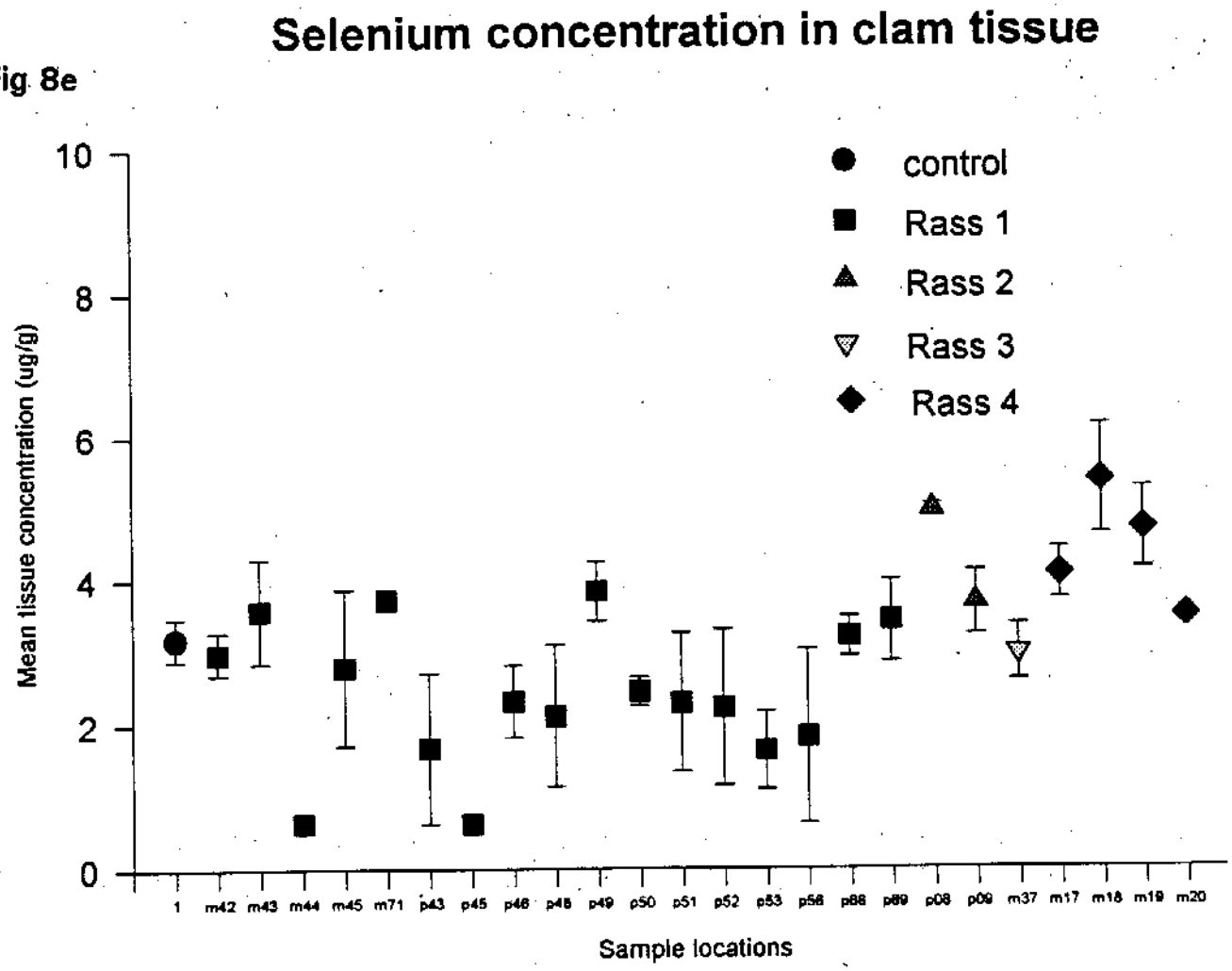

Lead concentration in clam tissue
control
Rass 1
Rass 2
Rass 3
Rass 4
Mean tissue concentration (ug/g)
10
8
6
4
2
0
1
m42
m43
m44
m45
m71
p43
p45
p46
p48
p49
p50
p51
p52
p53
p56
p68
p69
p08
p09
m37
m17
m18
m19
m20
Sample locations

Fig 8e


Selenium concentration in clam tissue
control
Rass 1
Rass 2
Rass 3
Rass 4
Mean tissue concentration (ug/g)
10
8
6
4
2
0
1
m42
m43
m44
m45
m71
p43
p45
p46
p48
p49
p50
p51
p52
p53
p56
p88
p89
p08
p09
m37
m17
m18
m19
m20
Sample locations

Zinc concentration in clam tissue

Fig 8f

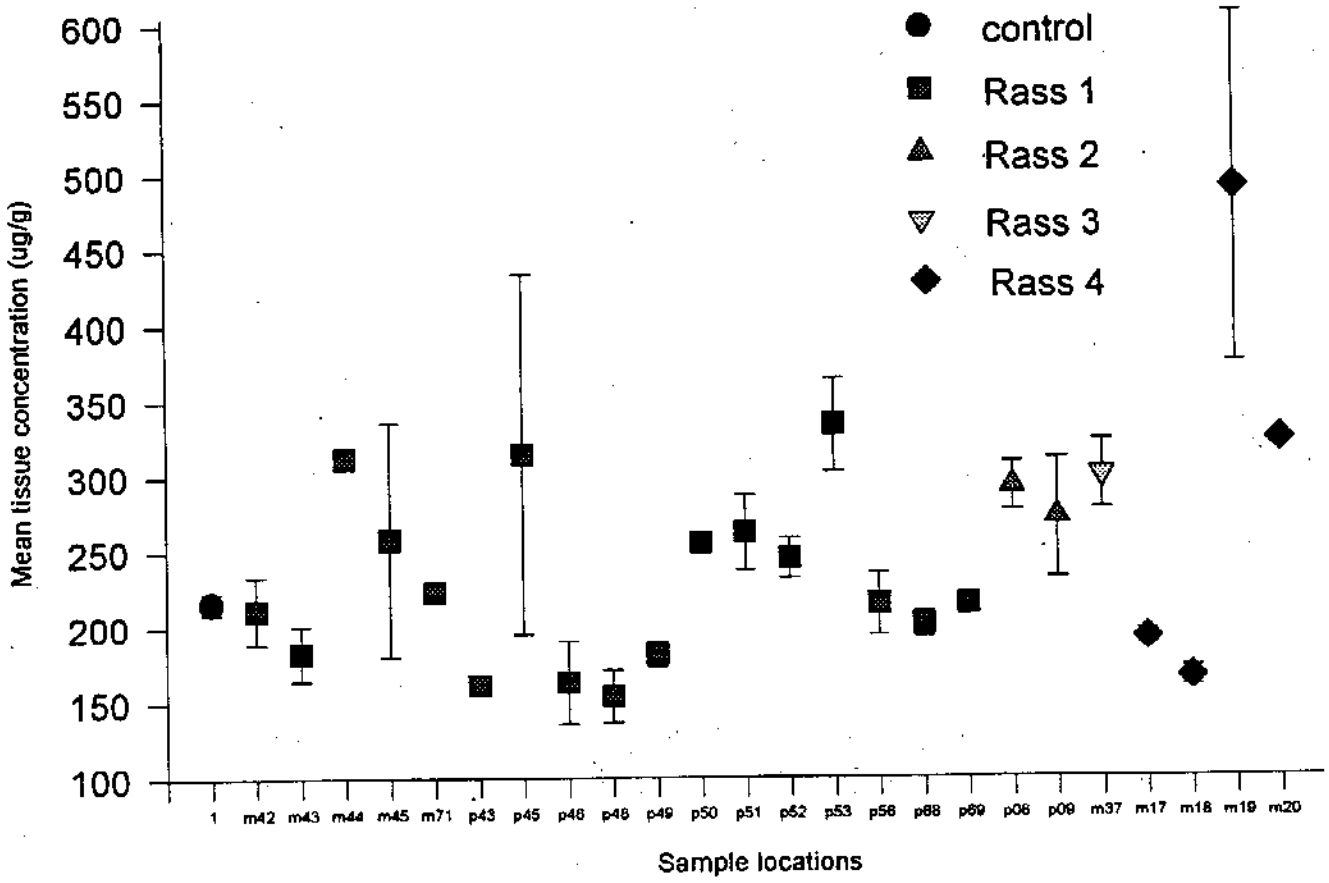


FIGURE 9

TISSUE CONCENTRATIONS OF METALS IN EARTHWORMS

Figure 9a: Arsenic, Copper, Zinc

Figure 9b: Cadmium, Lead, Selenium

Note: Data represent mean (and standard error) concentrations of six metals at each RASS and reference site. Grand means were generated from sampling location means of 3 replicate measures; sample sizes at the bottom of the page indicate the number of sampling locations used to generate the grand means. Reference area 1 is the upland site. Reference area 2 is the marsh site.

Tissue concentration in earthworms

Fig 9a

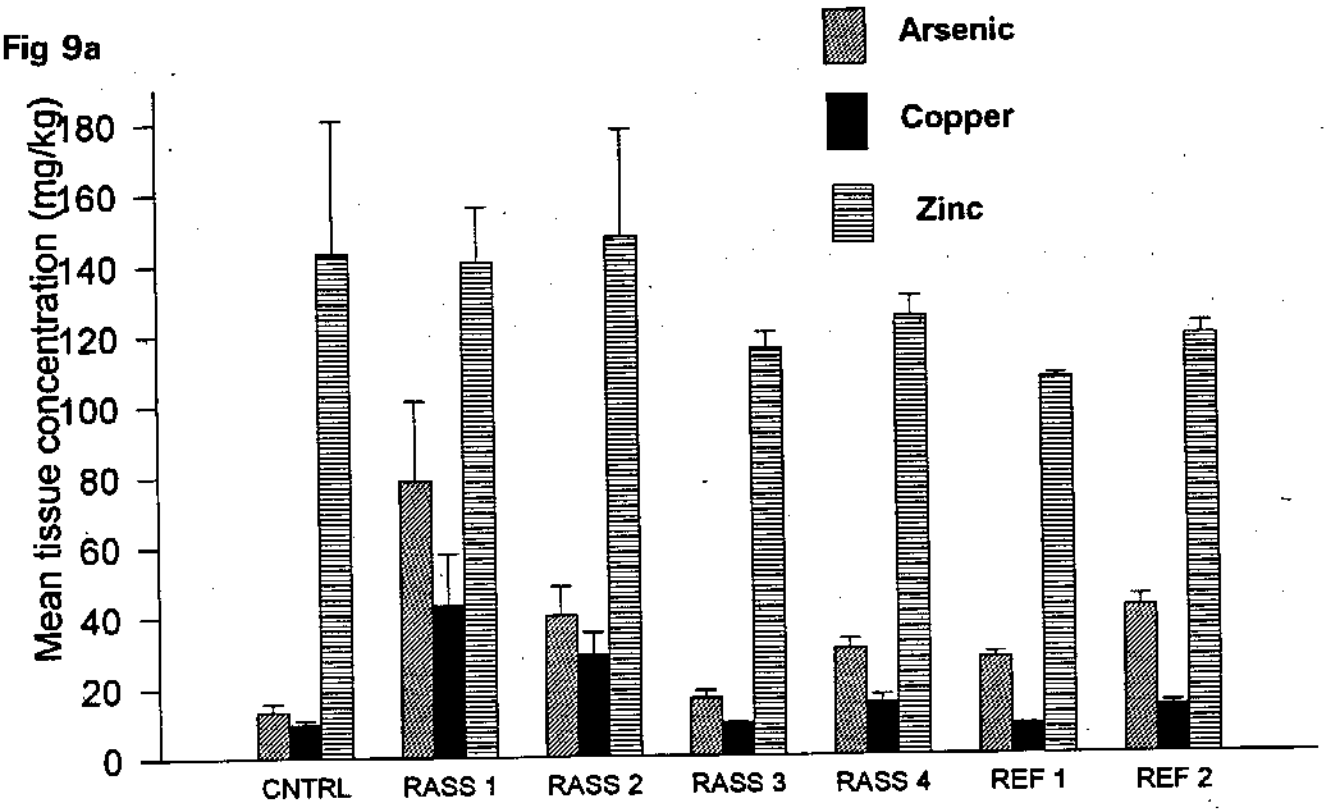


Fig 9b

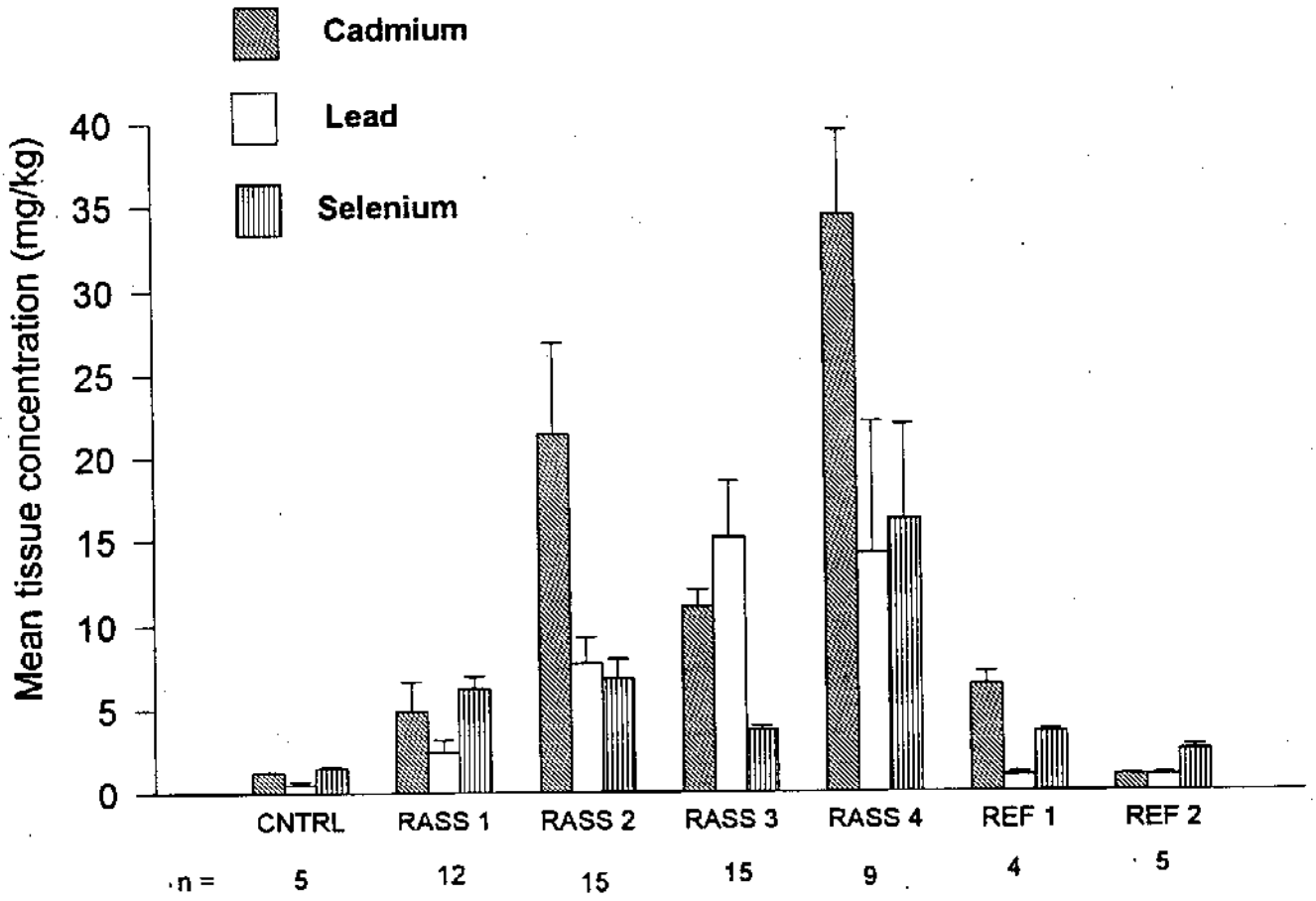


FIGURE 10

TISSUE CONCENTRATIONS OF METALS IN SMALL MAMMALS

Figure 10a: Arsenic

Figure 10b: Cadmium

Figure 10c: Copper

Figure 10d: Lead

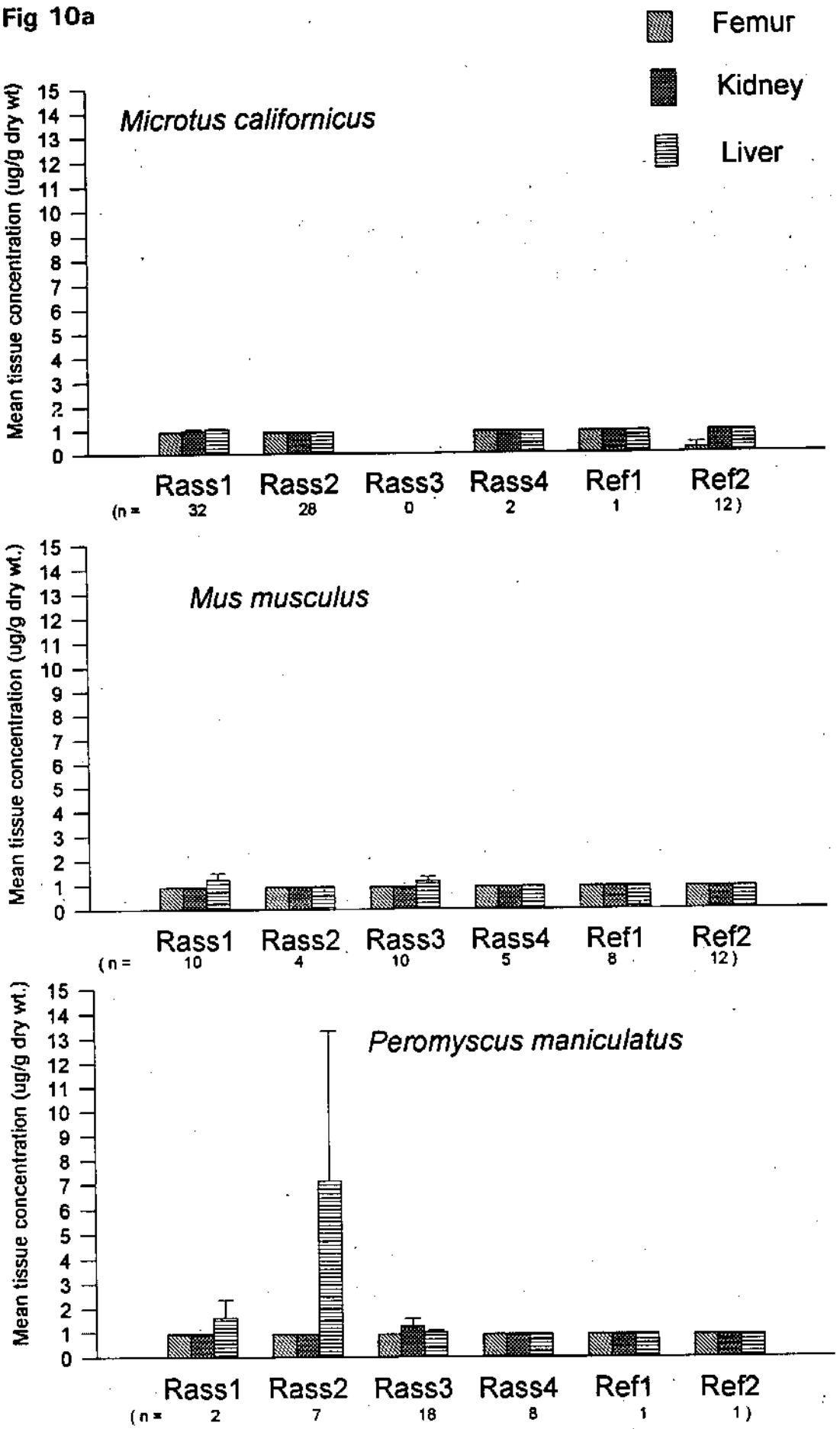
Figure 10e: Selenium

Figure 10f: Zinc

Note: Data represent mean (and standard error) concentrations of six metals at each RASS and the reference area for femur, liver and kidney tissue in three species collected on site. Reference site 1 is the upland site; reference site 2 is the marsh site. Sample sizes are indicated below each graph.

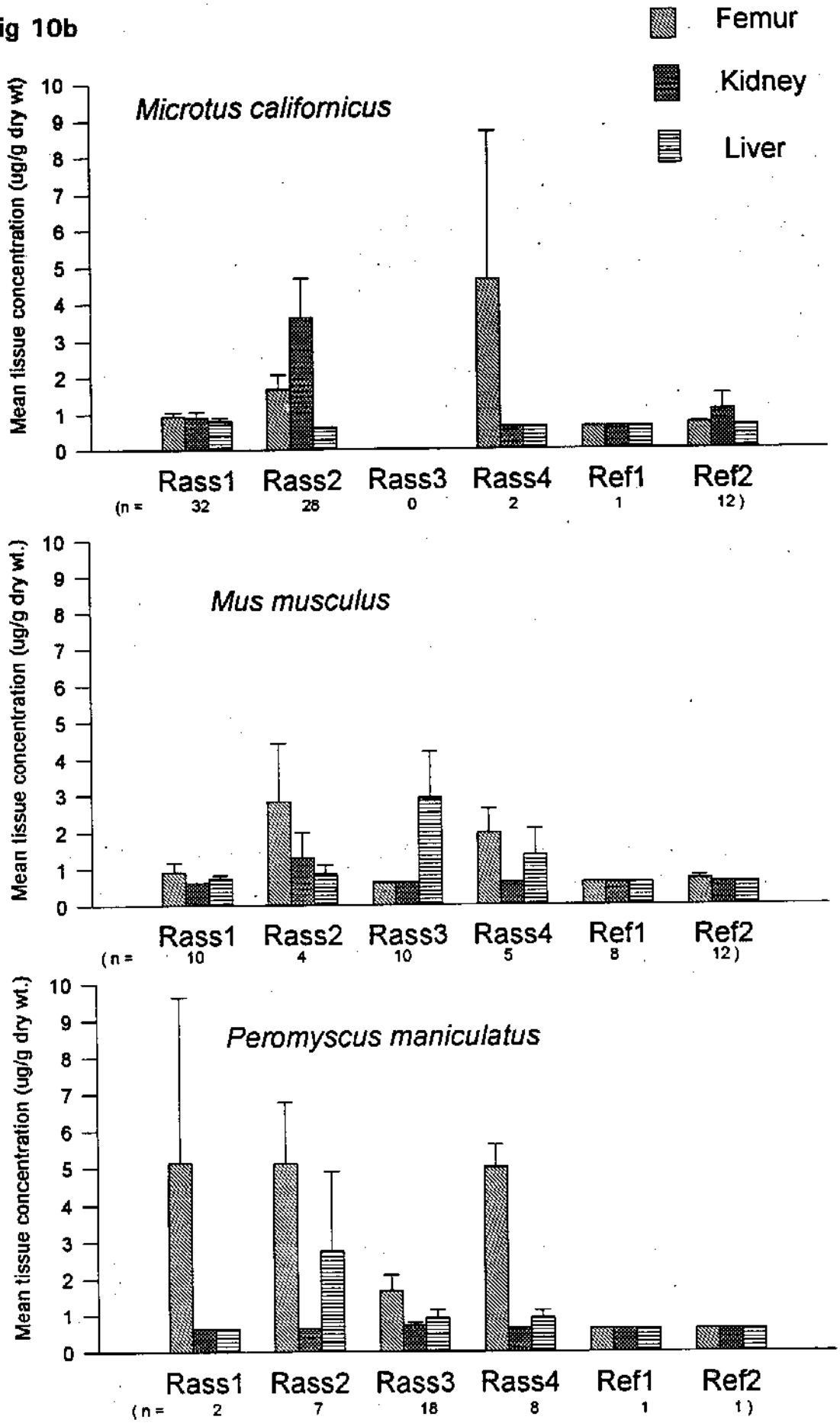
Tissue Concentration of Arsenic in Mammals

Fig 10a



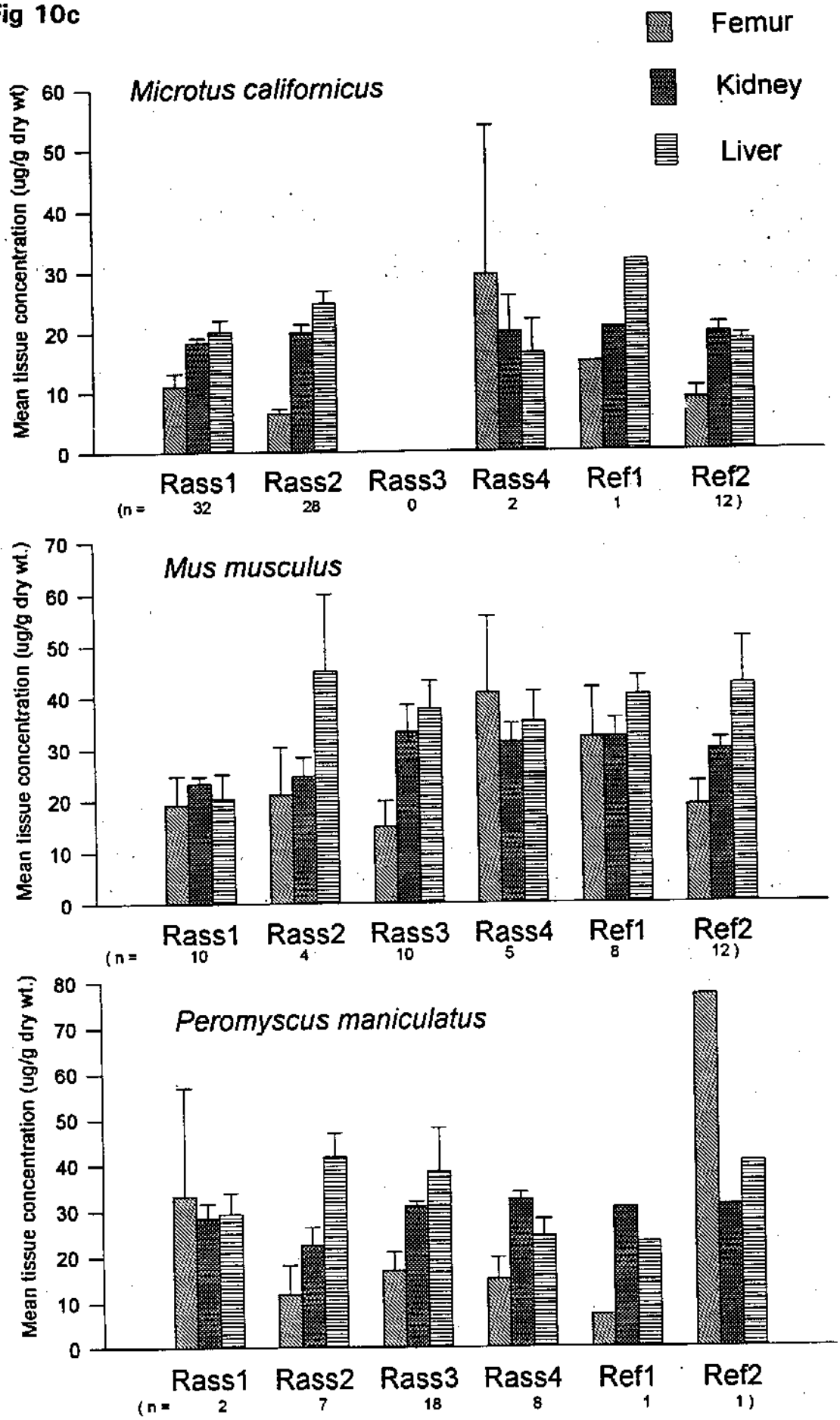
Tissue Concentration of Cadmium in Mammals

Fig 10b



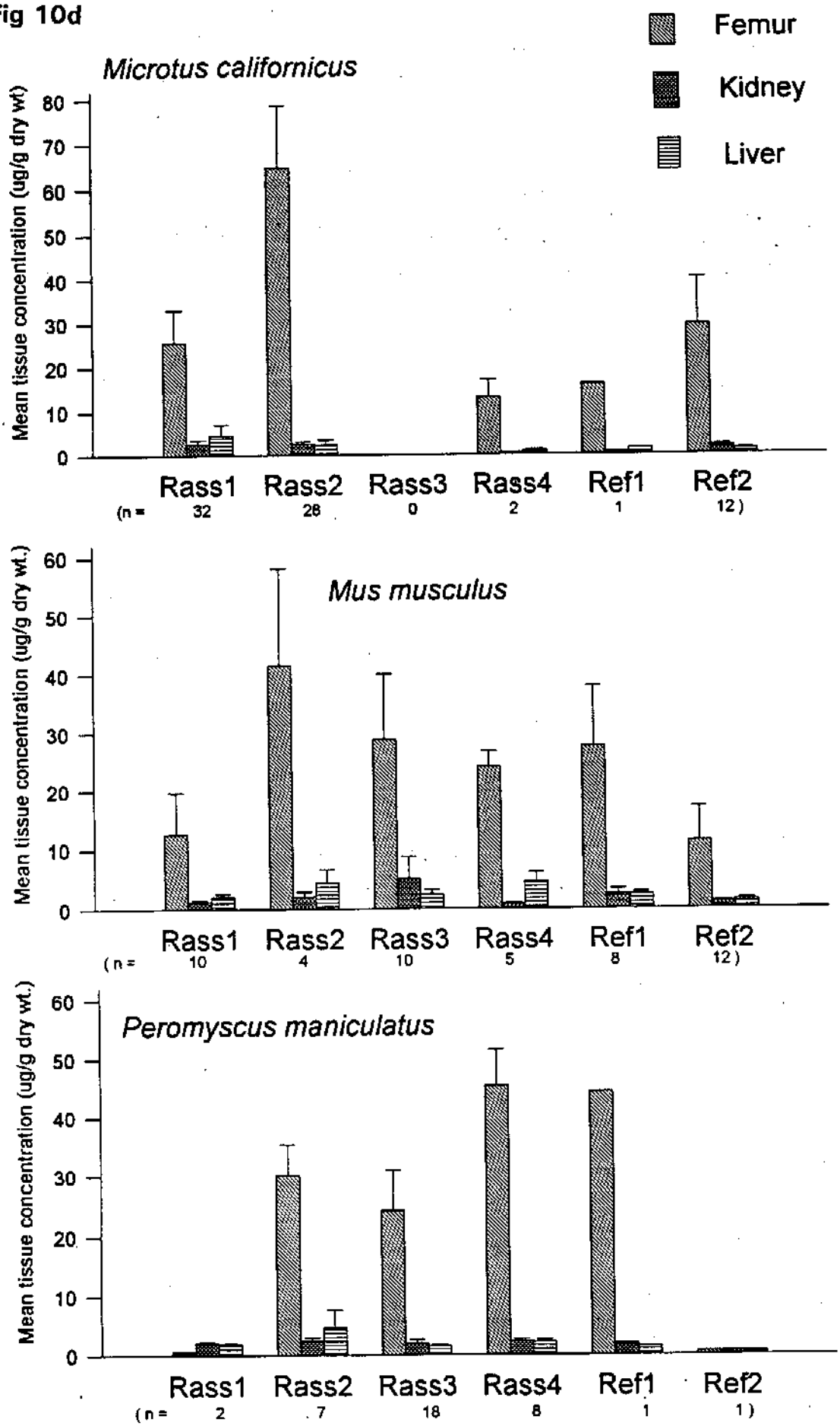
Tissue Concentration of Copper in Mammals

Fig 10c



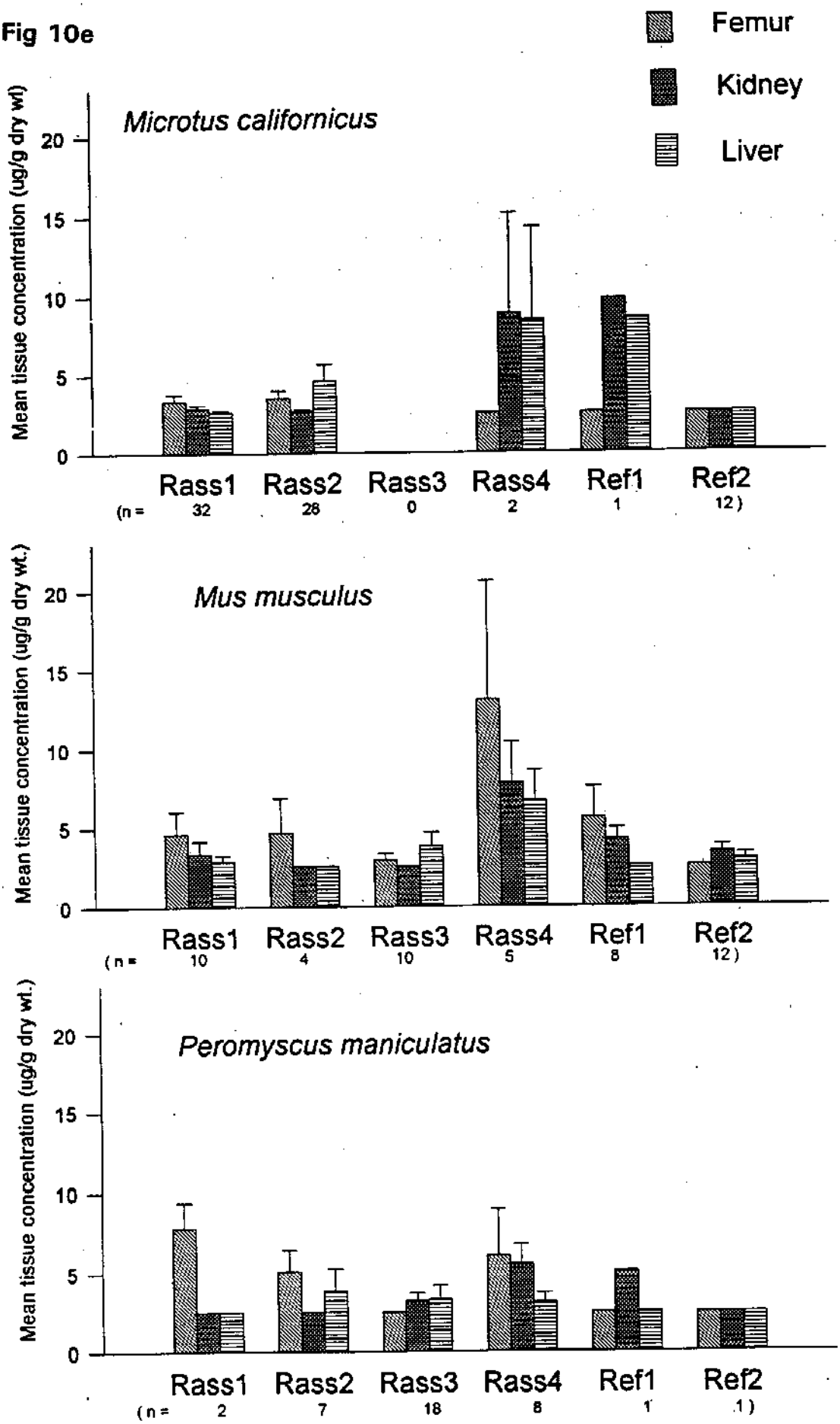
Tissue Concentration of Lead in Mammals

Fig 10d



Tissue Concentration of Selenium in Mammals

Fig 10e



Tissue Concentration of Zinc in Mammals

Fig 10f

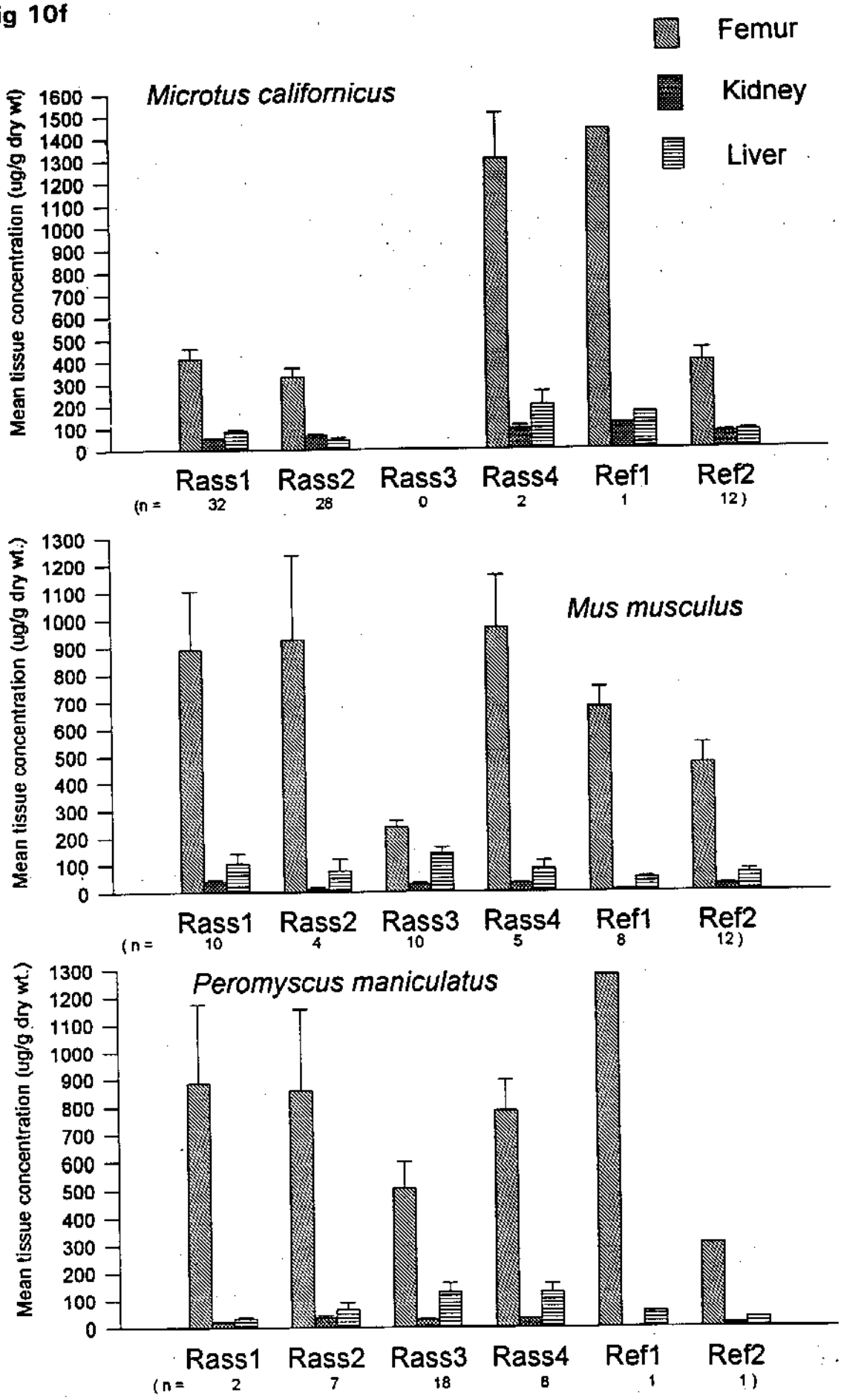


FIGURE 11

TISSUE CONCENTRATIONS OF METALS IN PICKLEWEED *(SALICORNIA VIRGINICA)*

Figure 11a: Copper, Zinc, Cadmiun, Lead, Arsenic

Figure 11b: Selenium

Note: Mean (and standard error) concentration of metals in pickleweed tissue from sample locations with bulk surface soil chemistry less than ER-L, between ER-L and ER-M, and greater than ER-M for each metal. All RASS locations were combined. Sample sizes for the three categories of soil locations (< ER-L, ER-L to ER-M, and > ER-M, respectively) for each metal were: arsenic (n=1,10,14), cadmium (n=3,21,1), copper (n=2,13,10), lead (n=2,17,6), and zinc (n=4,7,14). For selenium, for which all locations were combined, n = 25.

Mean Tissue Concentration in Pickleweed

Fig 11a

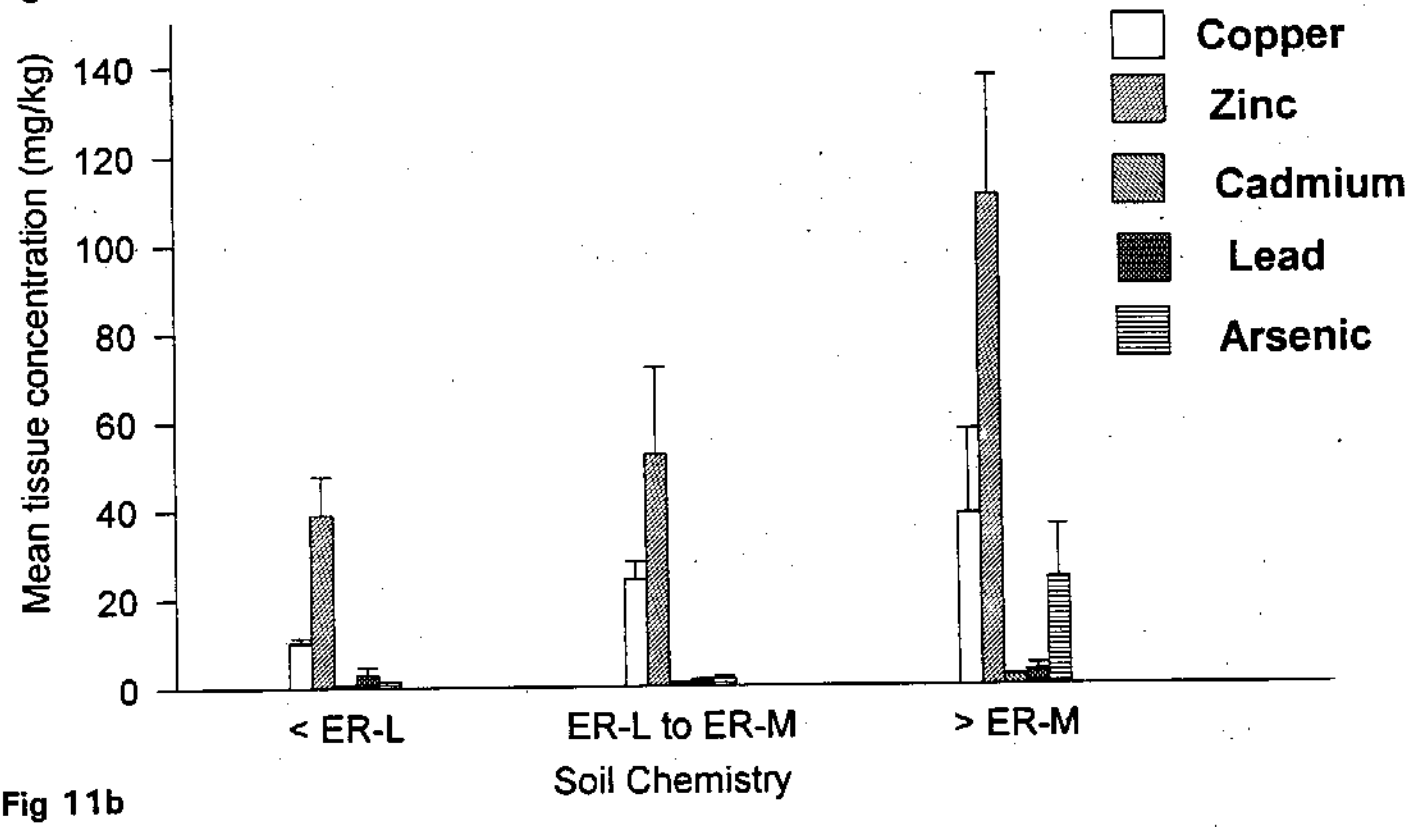


Fig 11b

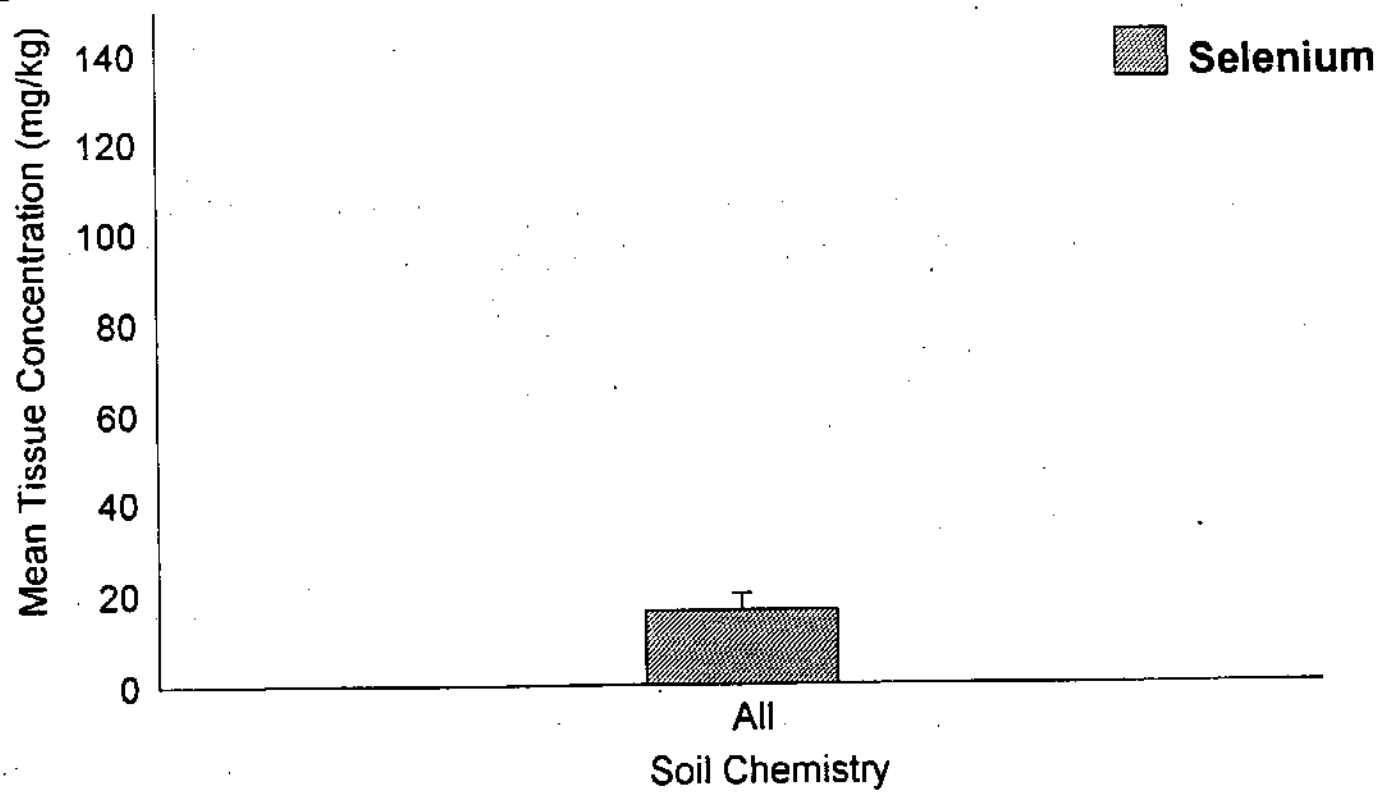


FIGURE 12

CORRELATION OF SOIL CHEMISTRY AND PICKLEWEED TISSUE CONCENTRATION

Figure 12a: Arsenic

Figure 12b: Lead

Figure 12c: Copper

Figure 12d: Cadmium

Figure 12e: Zinc

Figure 12f: Selenium

Note: Data from 25 sampling locations were plotted on a log scale to illustrate the correlation between surface soil chemistry and plant tissue concentration for pickleweed for the six metals.

Fig 12a **Pickleweed Tissue Concentration at RASS 1- 4**

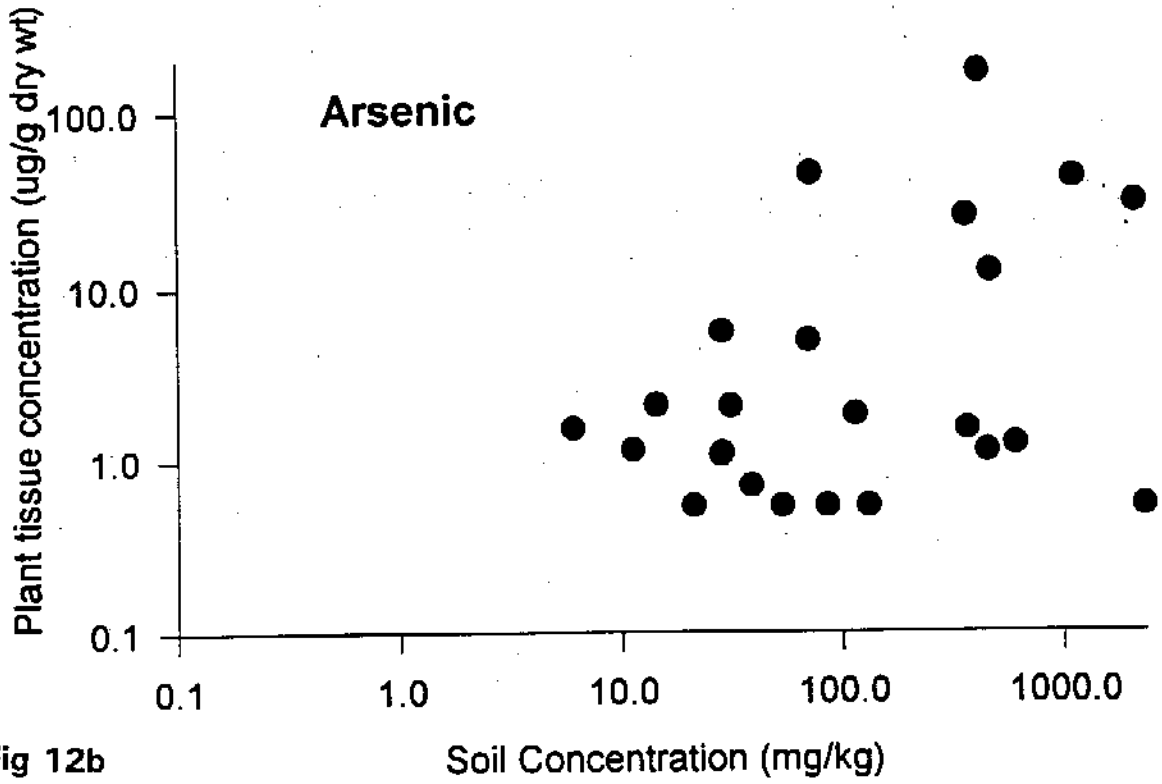


Fig 12b

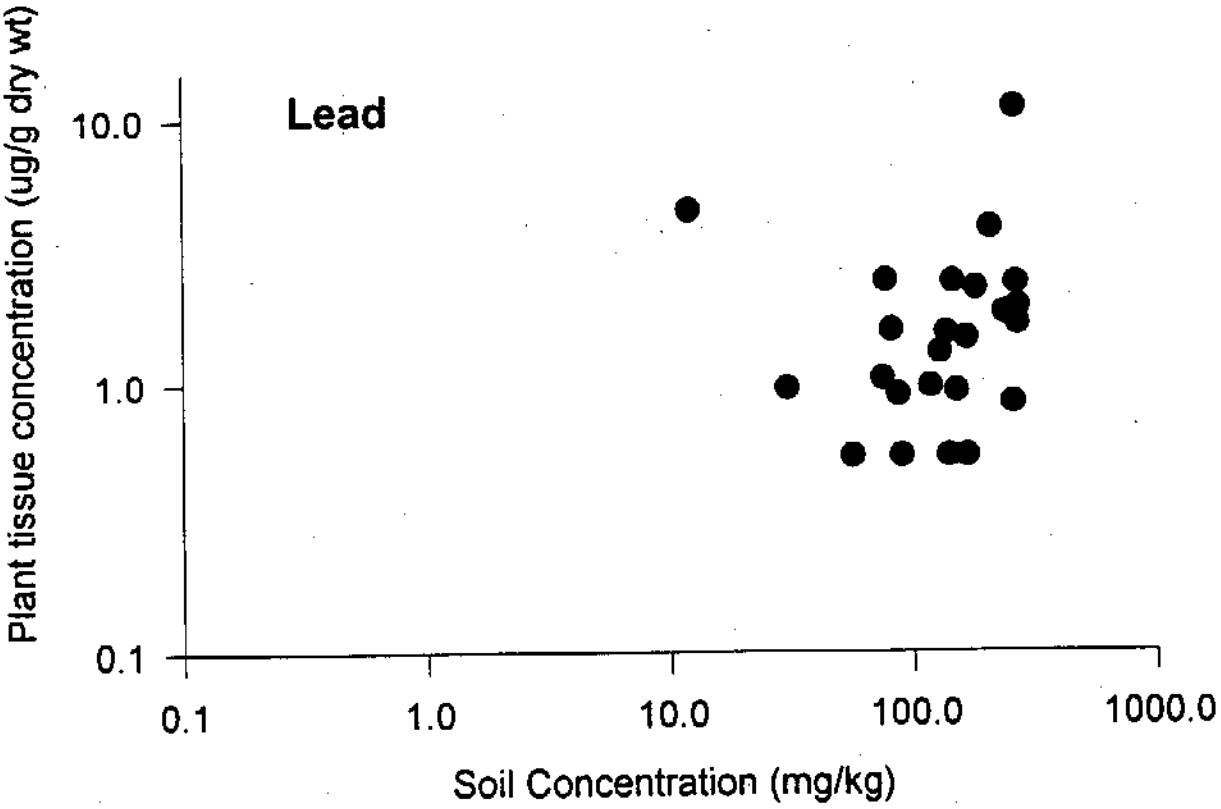


Fig 12c

Pickleweed Tissue Concentration at RASS 1- 4

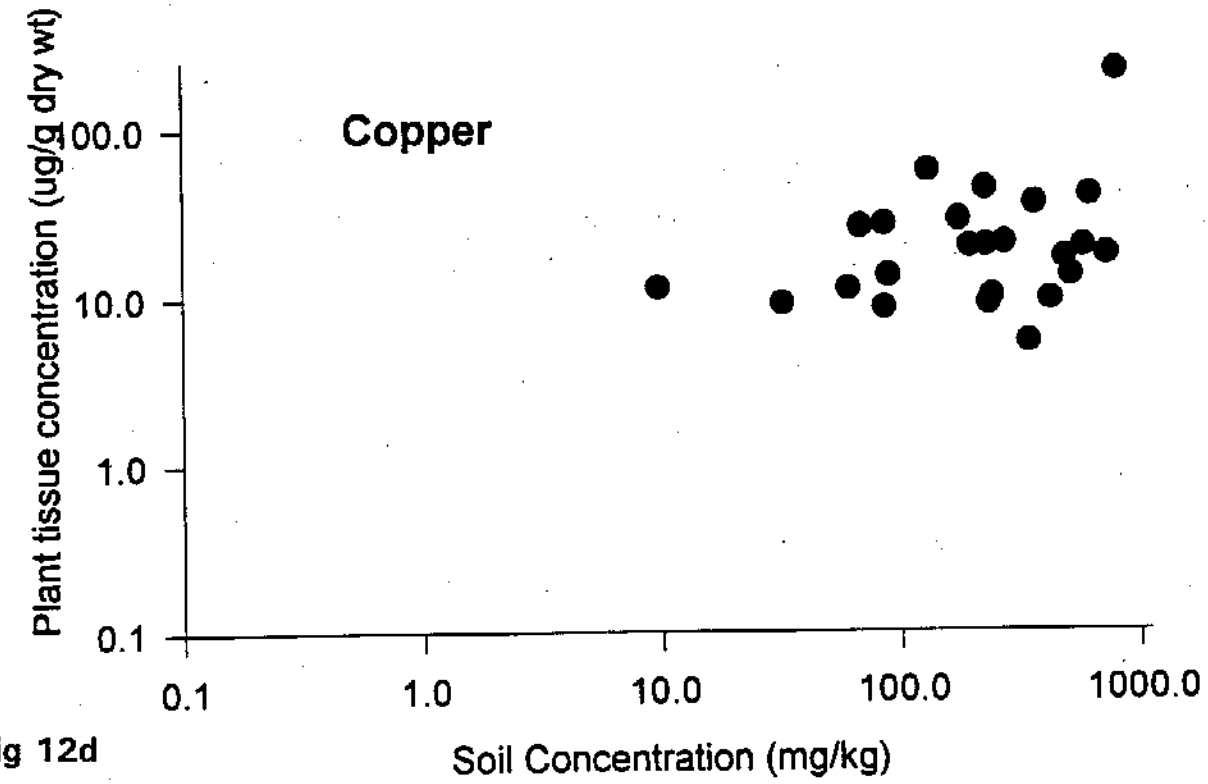
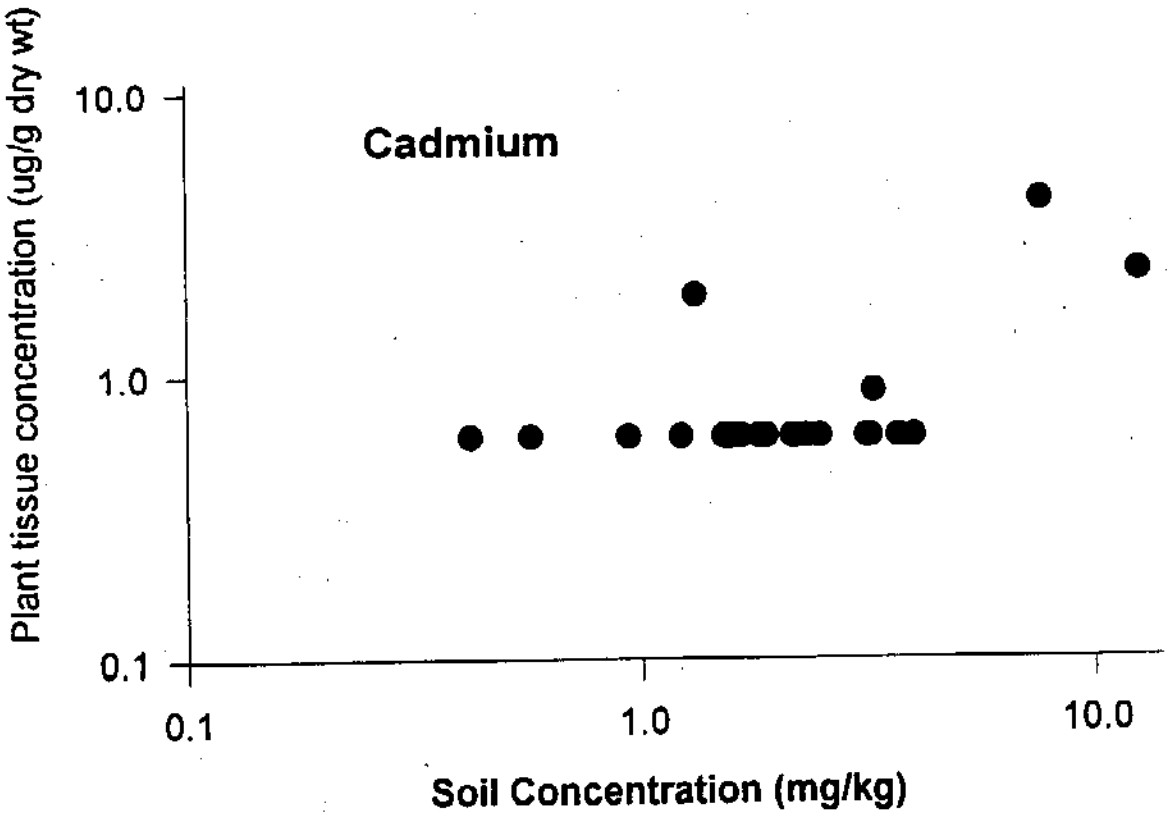


Fig 12d



Pickleweed Tissue Concentration at RASS 1- 4

Fig 12e

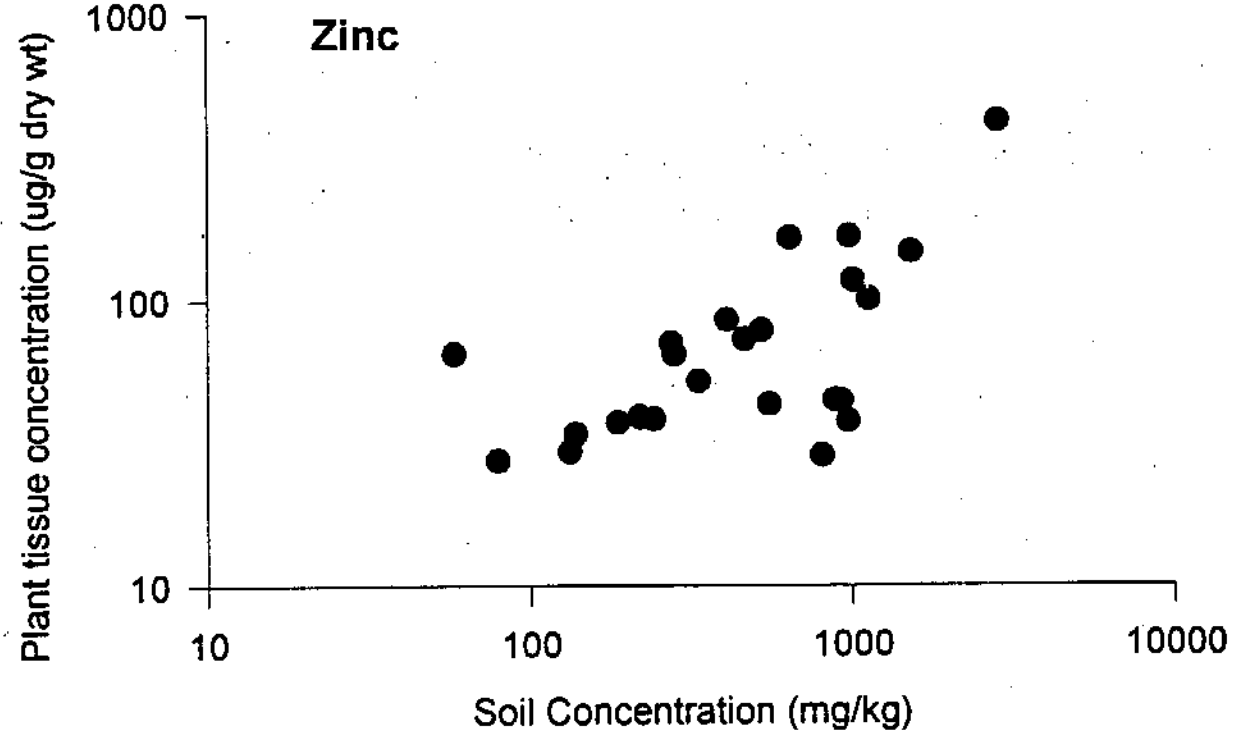
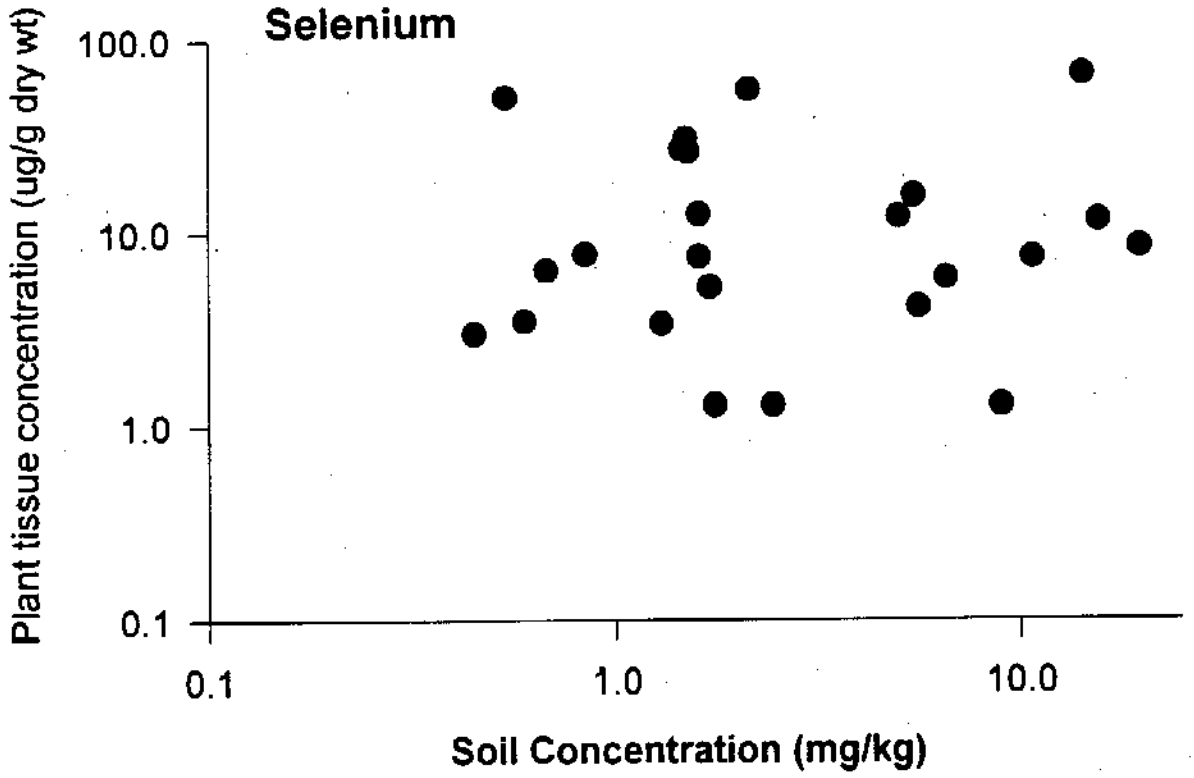


Fig 12f



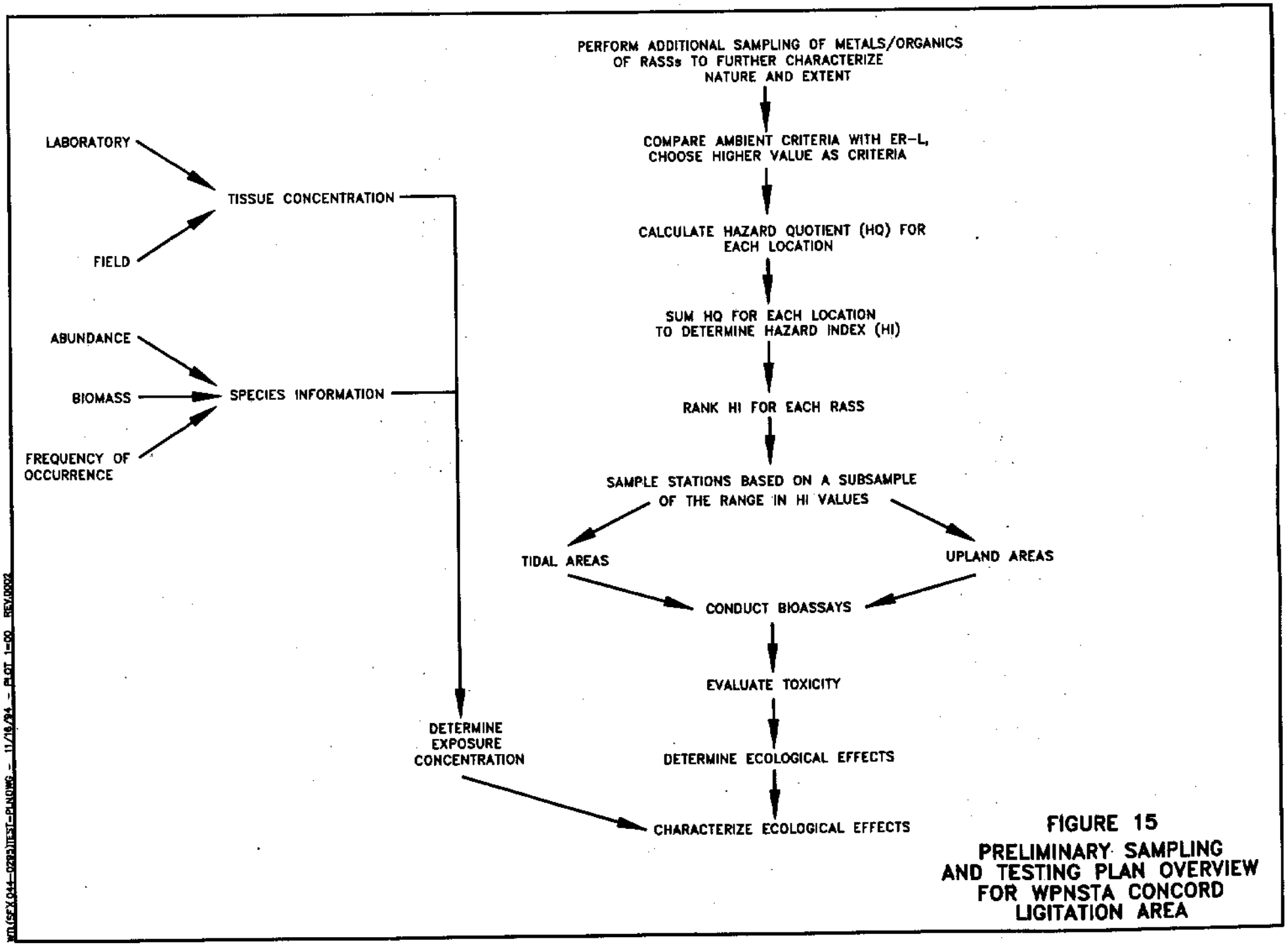
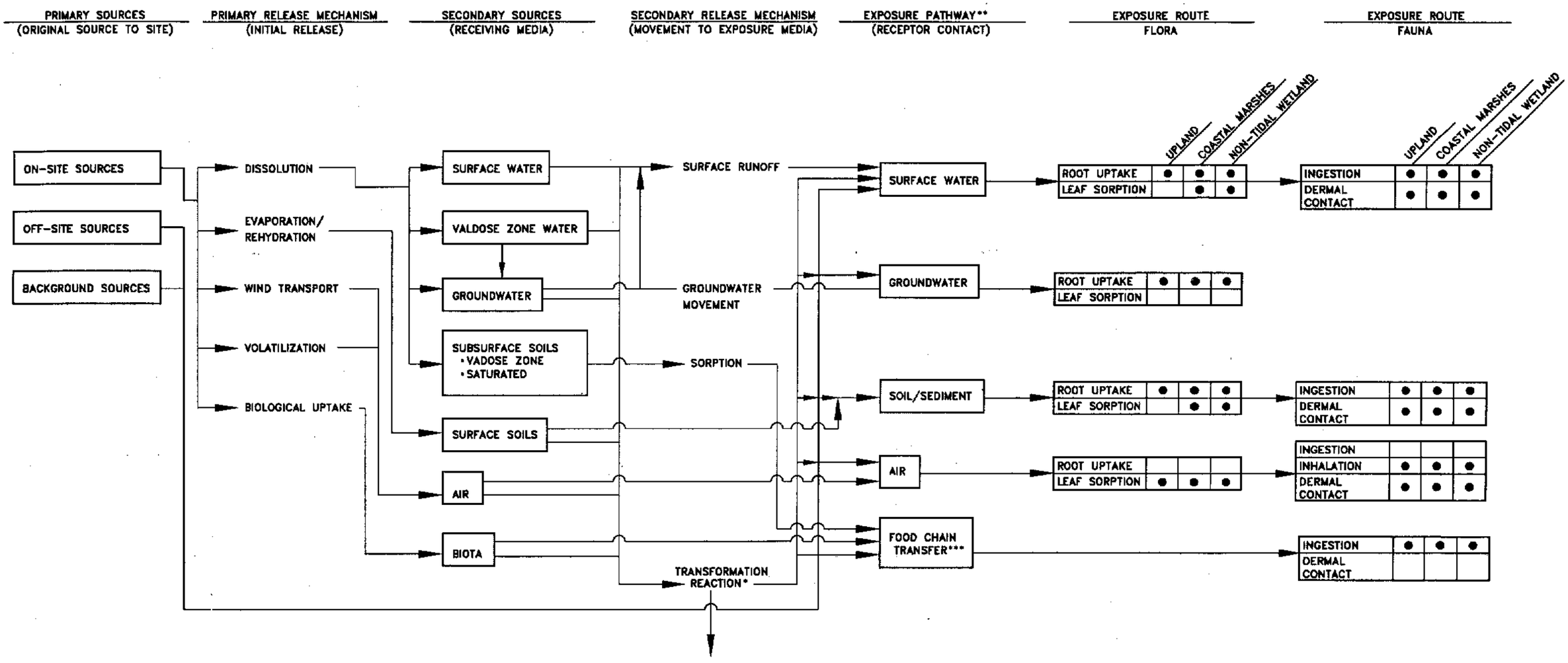


FIGURE 15
PRELIMINARY SAMPLING AND TESTING PLAN OVERVIEW FOR WPNSTA CONCORD LIGITATION AREA

WTL(SEX)044-0295)TEST-PLN.DWG - 11/16/94 - PLOT 1=00 REV.0002



LEGEND

* TRANSFORMATION REACTIONS MAY ALSO OCCUR AS A PRIMARY RELEASE MECHANISM

** ADDITIONAL INTERACTION MAY OCCUR BETWEEN EACH OF THESE PATHWAYS THAT MAY NOT BE SHOWN

*** INCLUDES DETRITIVORES, PRIMARY AND SECONDARY CONSUMERS

FIGURE 13
POTENTIAL EXPOSURE ROUTES AND RECEPTORS FOR WPNSTA CONCORD LIGITATION AREA

KCHSF(044-0295) POTENT.DWG - 05/31/95 - PLOT 1=1 REV.003

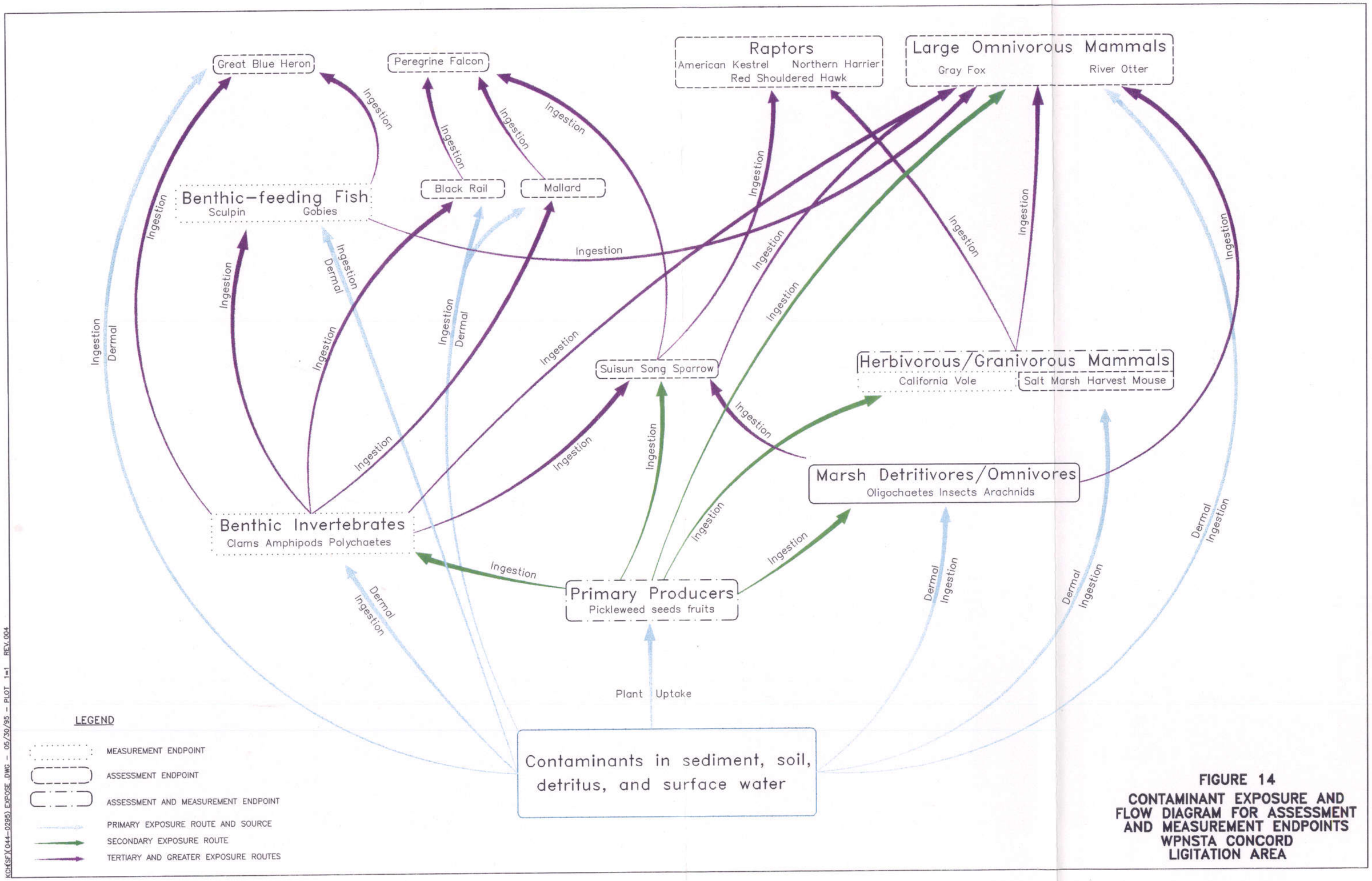


FIGURE 14
CONTAMINANT EXPOSURE AND FLOW DIAGRAM FOR ASSESSMENT AND MEASUREMENT ENDPOINTS WPNSTA CONCORD LIGITATION AREA

KCH(SF)(044-0295) EXPOSE.DWG - 05/30/95 - PLOT 1=1 REV.004

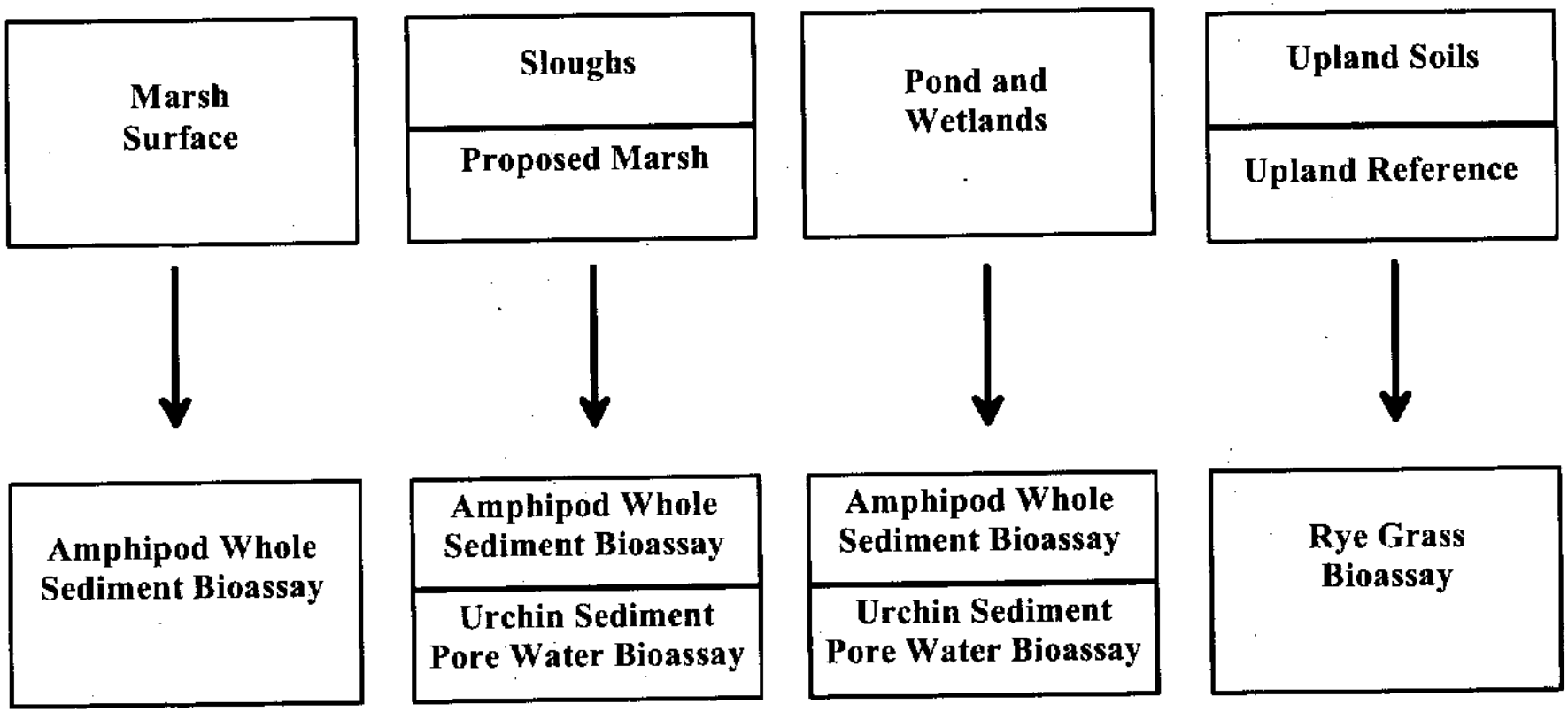
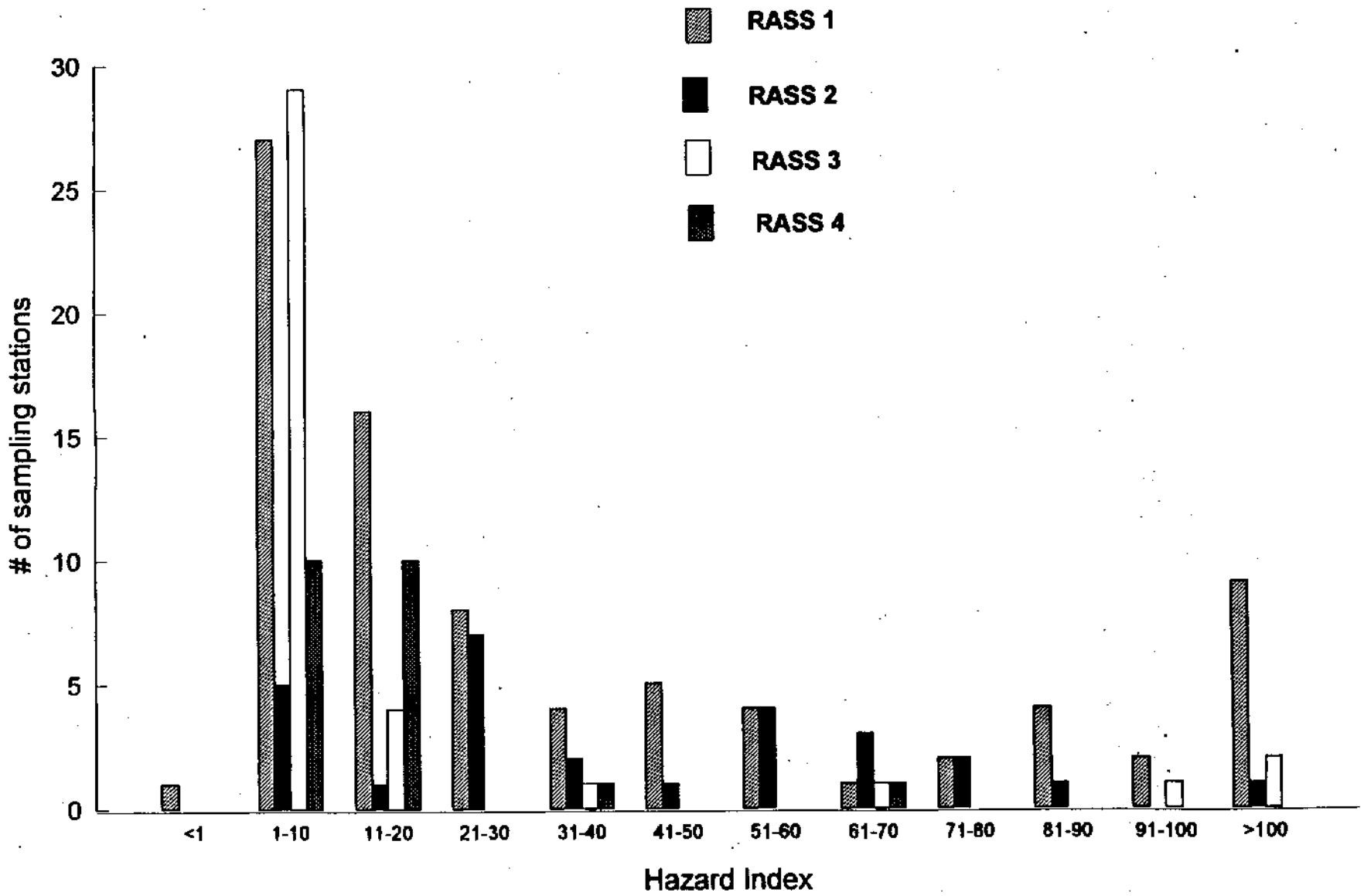


FIGURE 16
DIRECT MEASUREMENTS OF TOXICITY IN EACH HABITAT
WPNSTA CONCORD
LITIGATION AREA

Figure 17

SUMMARY OF HAZARD INDICES FOR METALS (EXCEPT SELENIUM)



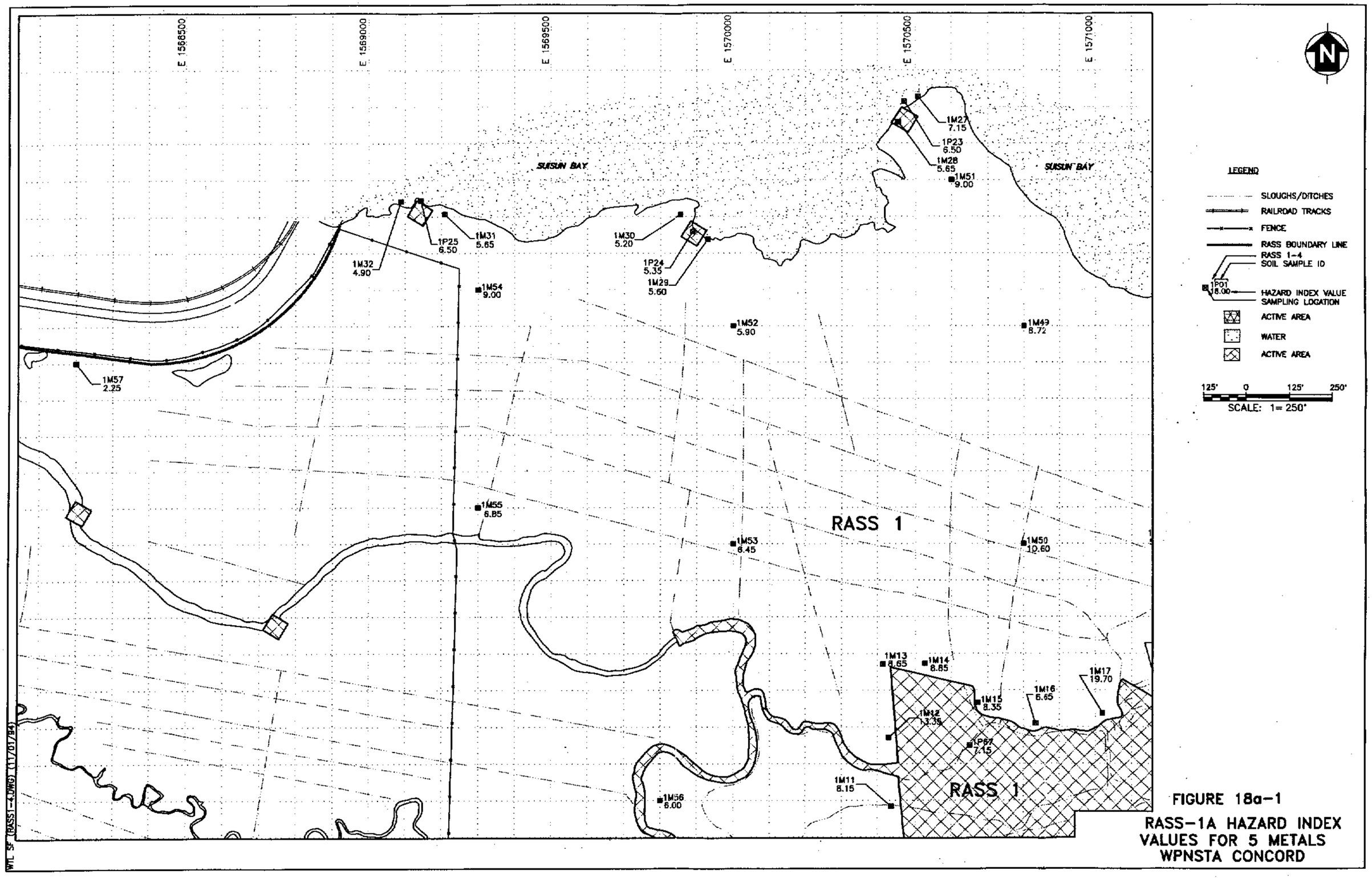


FIGURE 18a-1

RASS-1A HAZARD INDEX VALUES FOR 5 METALS WPNSTA CONCORD

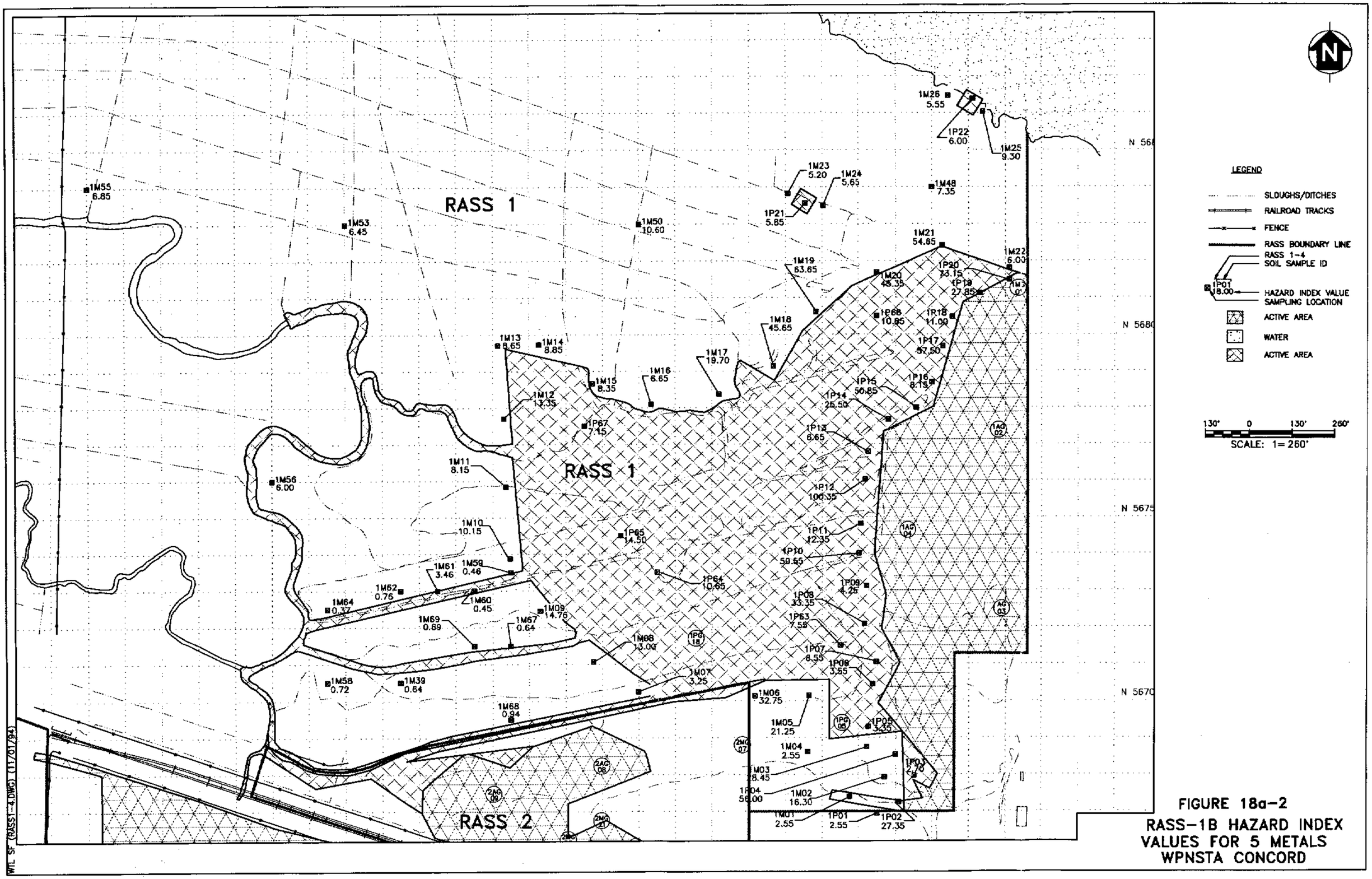


FIGURE 18a-2
RASS-1B HAZARD INDEX VALUES FOR 5 METALS
WPNSTA CONCORD

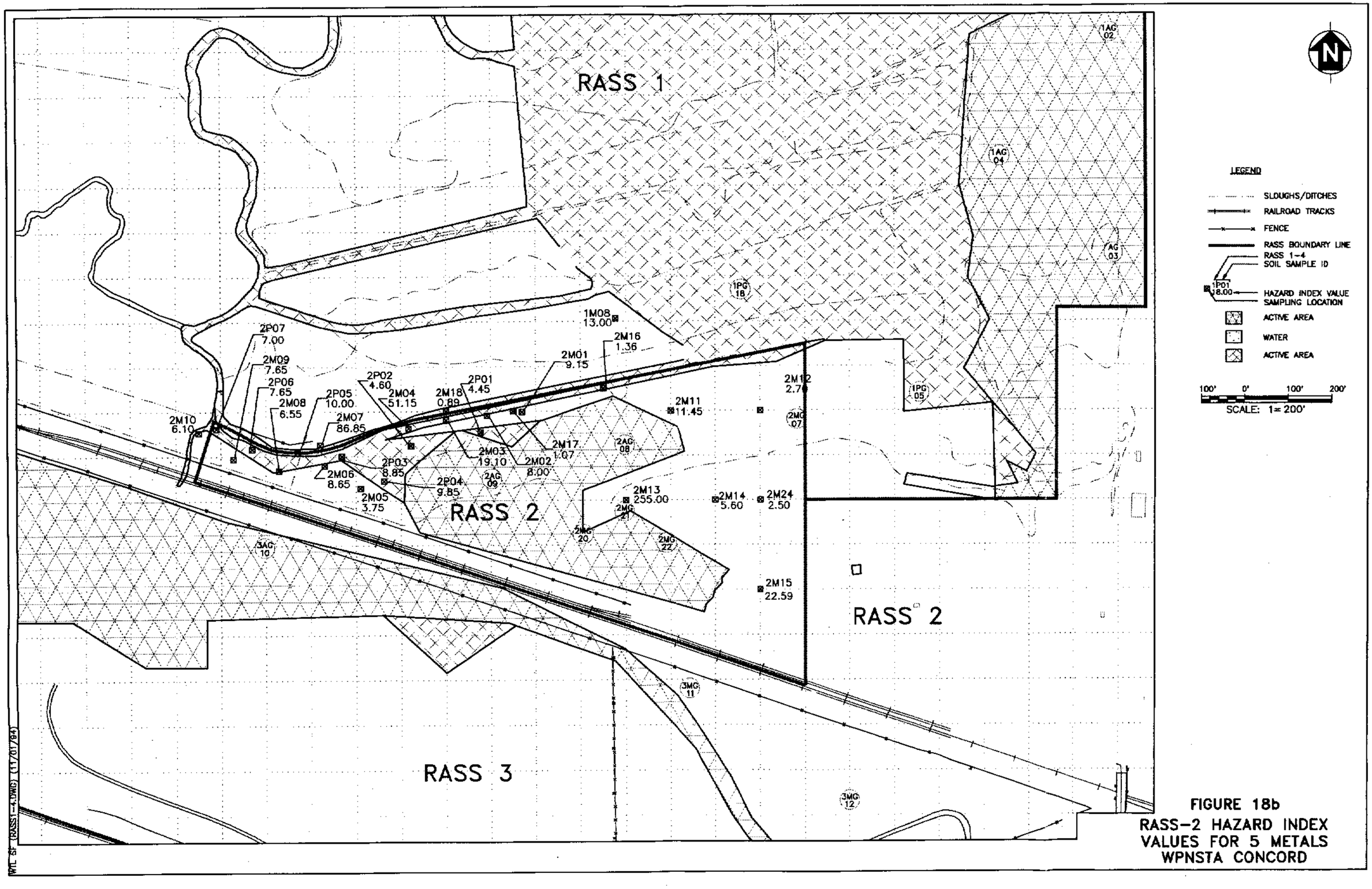


FIGURE 18b
RASS-2 HAZARD INDEX VALUES FOR 5 METALS
WPNSTA CONCORD

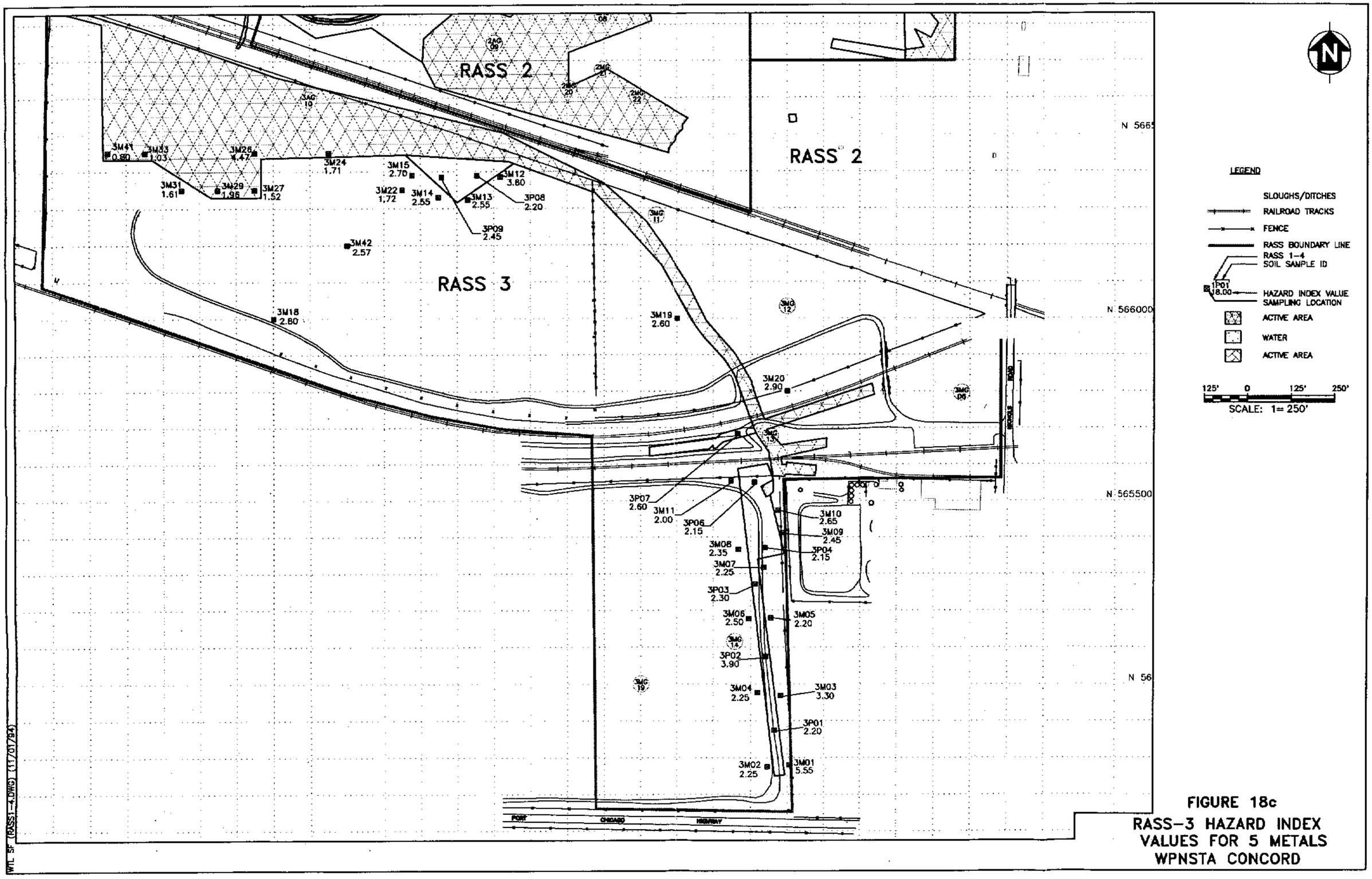


FIGURE 18c
RASS-3 HAZARD INDEX VALUES FOR 5 METALS
WPNSTA CONCORD

WIL SF (RASS1-4.DWG) (11/01/94)

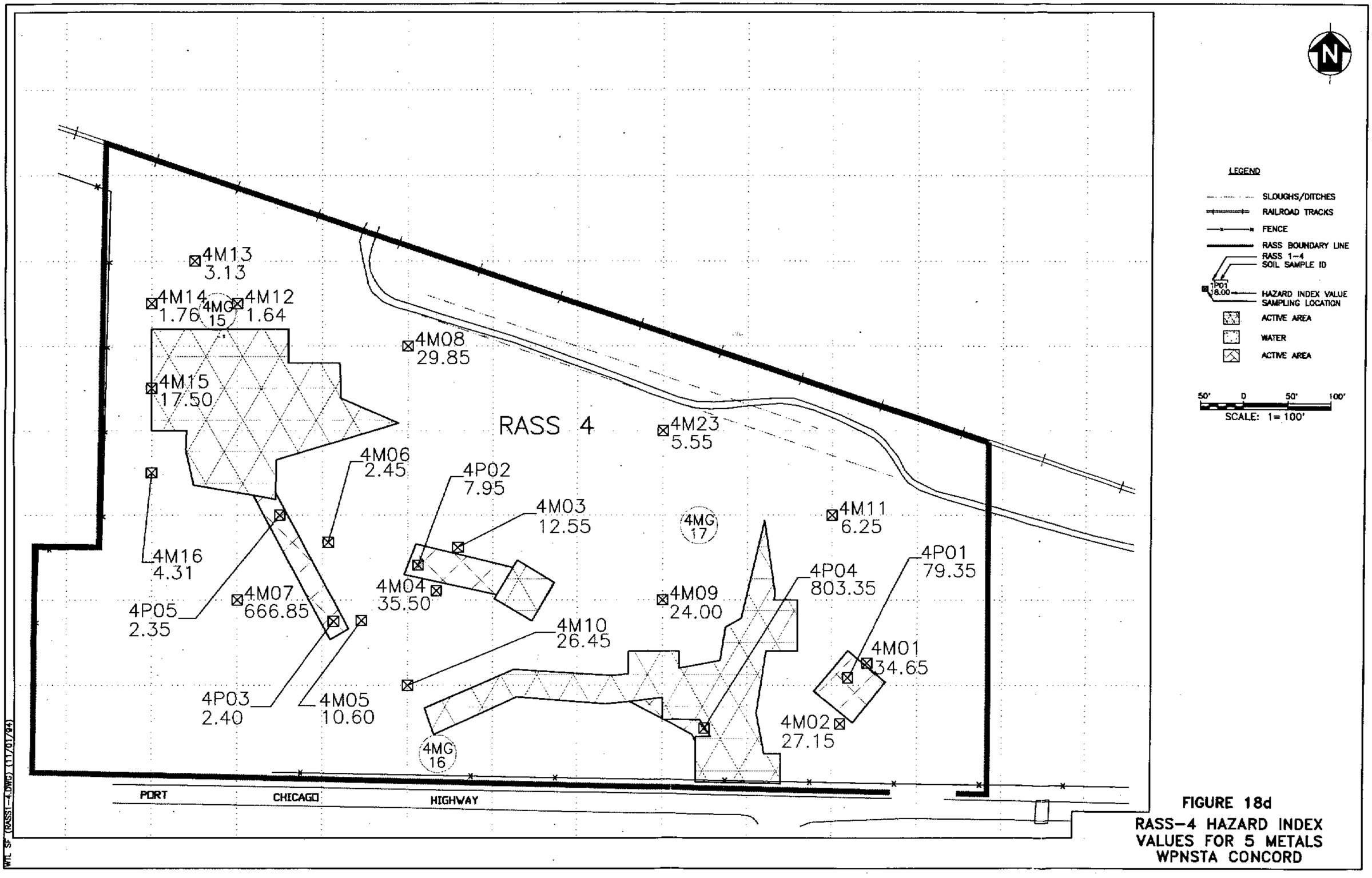


FIGURE 18d
RASS-4 HAZARD INDEX VALUES FOR 5 METALS
WPNSTA CONCORD

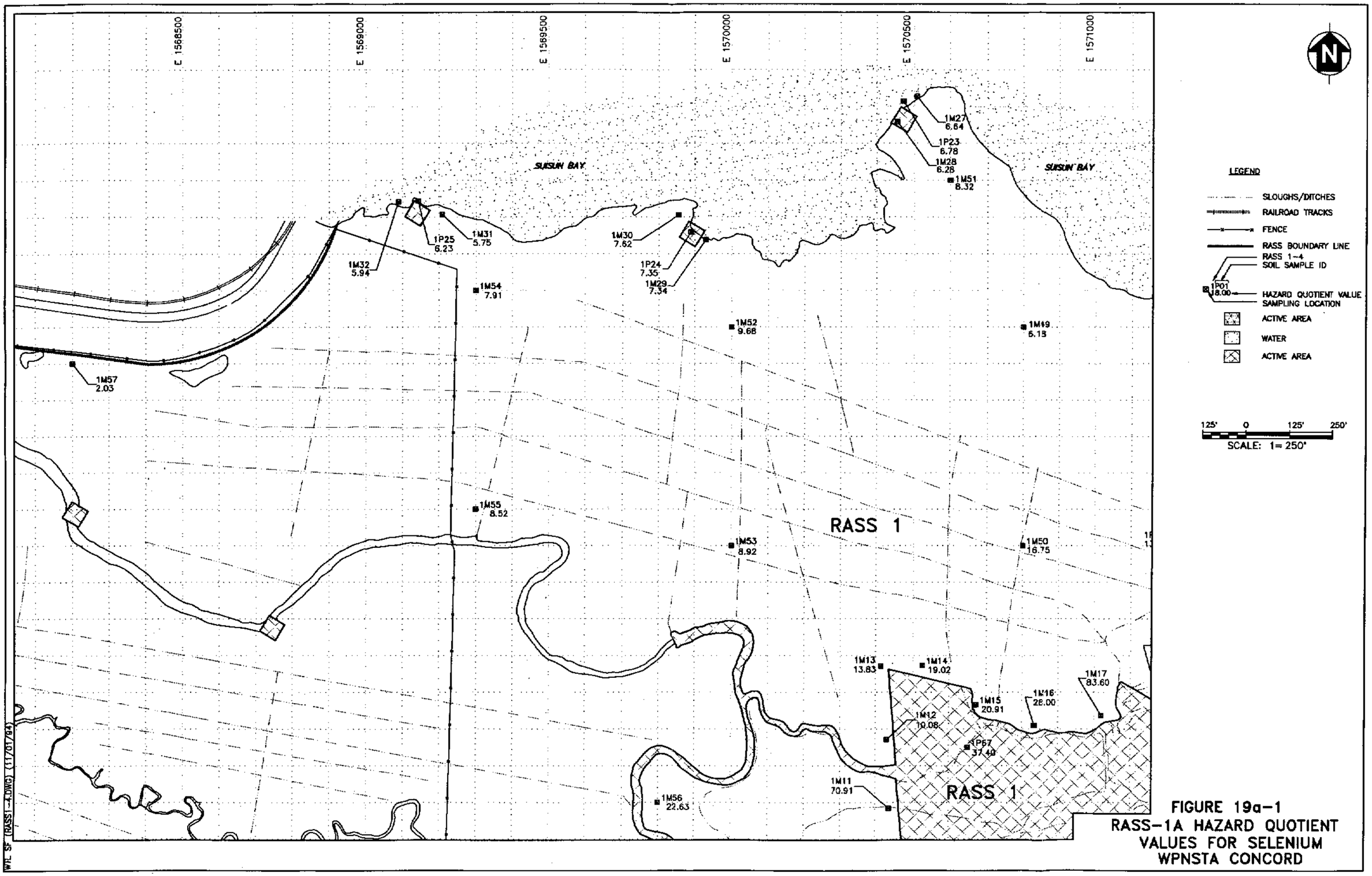


FIGURE 19a-1
RASS-1A HAZARD QUOTIENT VALUES FOR SELENIUM
WPNSTA CONCORD

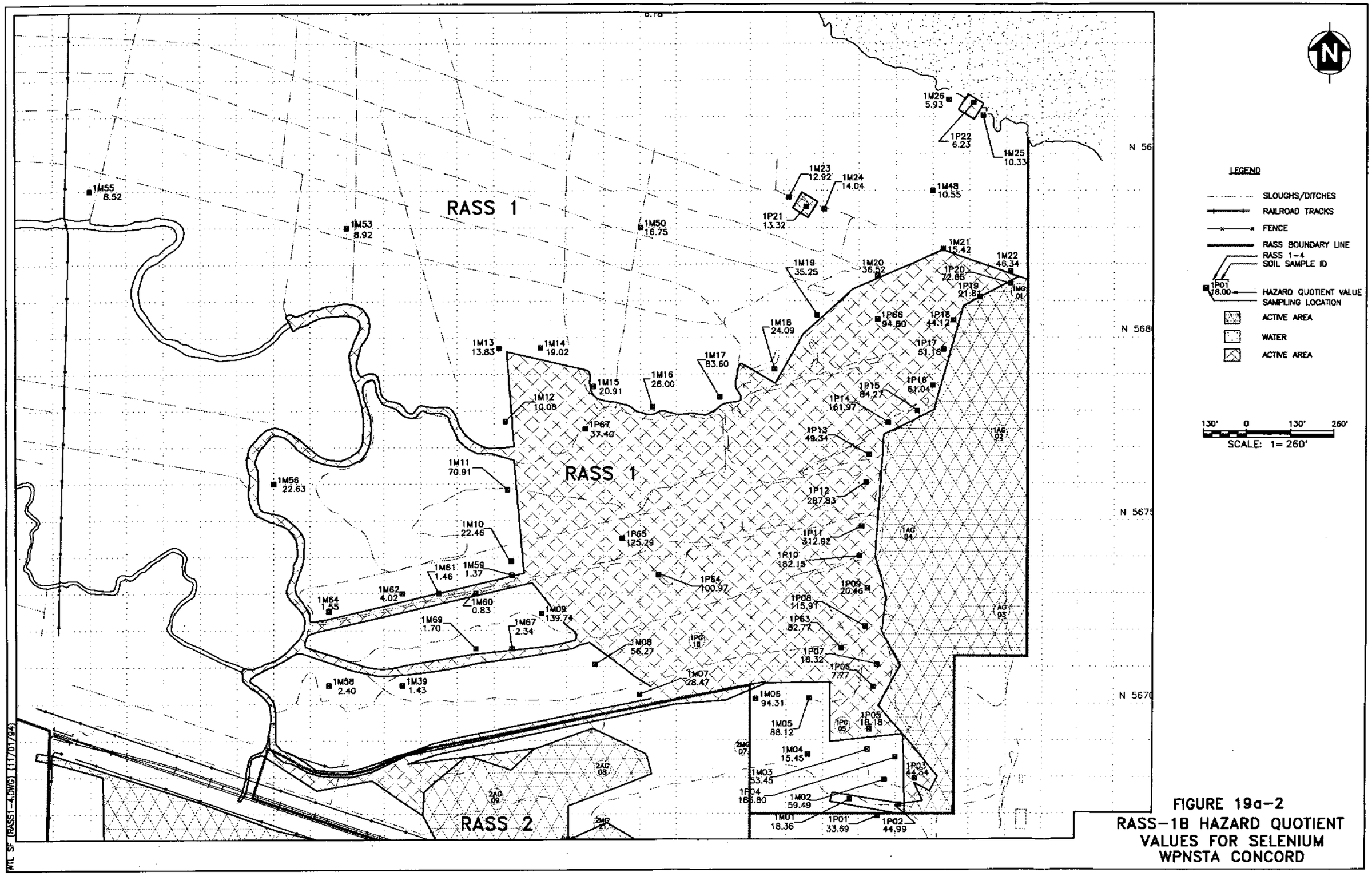


FIGURE 19a-2
RASS-1B HAZARD QUOTIENT VALUES FOR SELENIUM
WPNSTA CONCORD

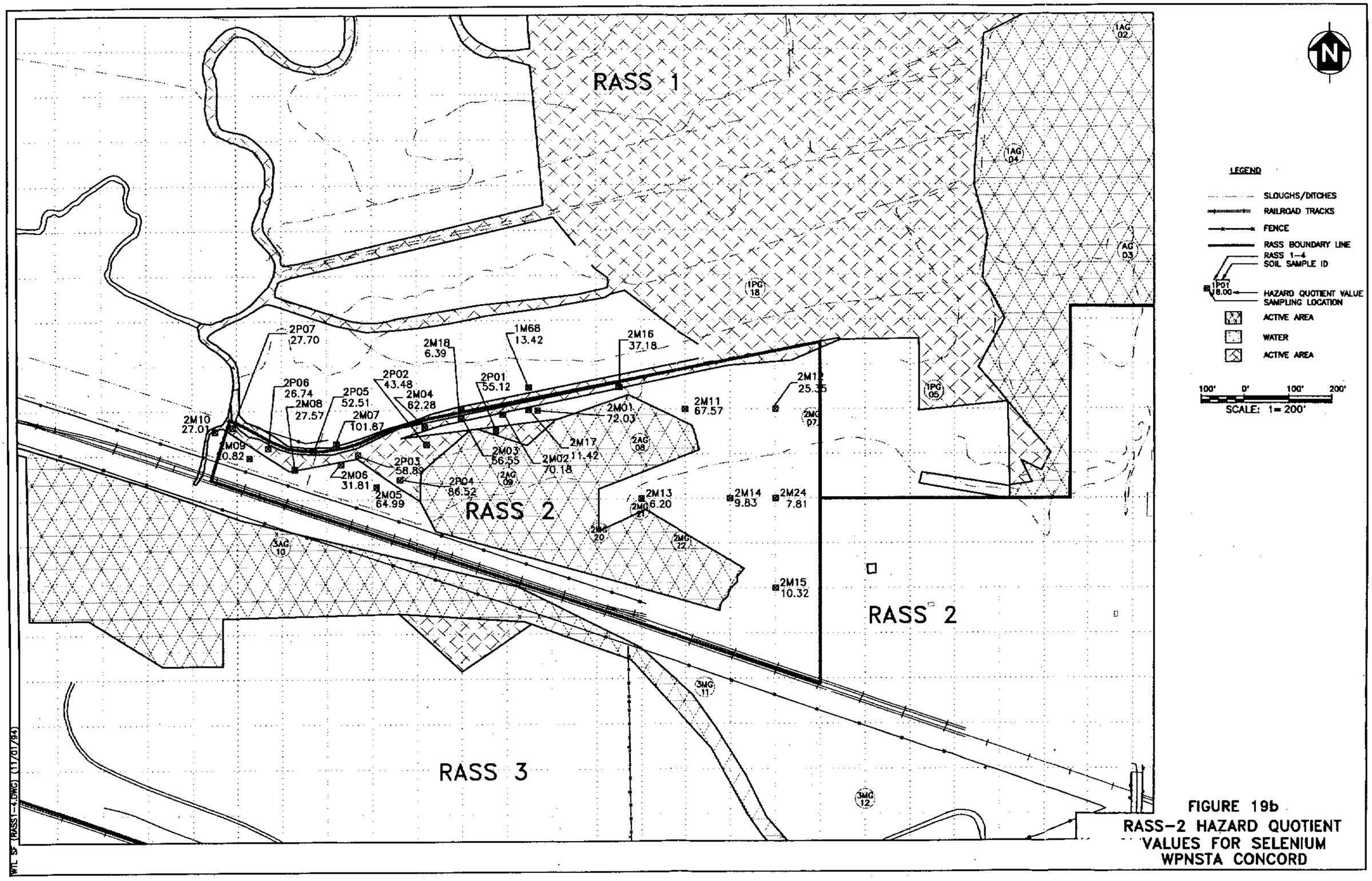


FIGURE 19b
RASS-2 HAZARD QUOTIENT VALUES FOR SELENIUM
WPNSTA CONCORD

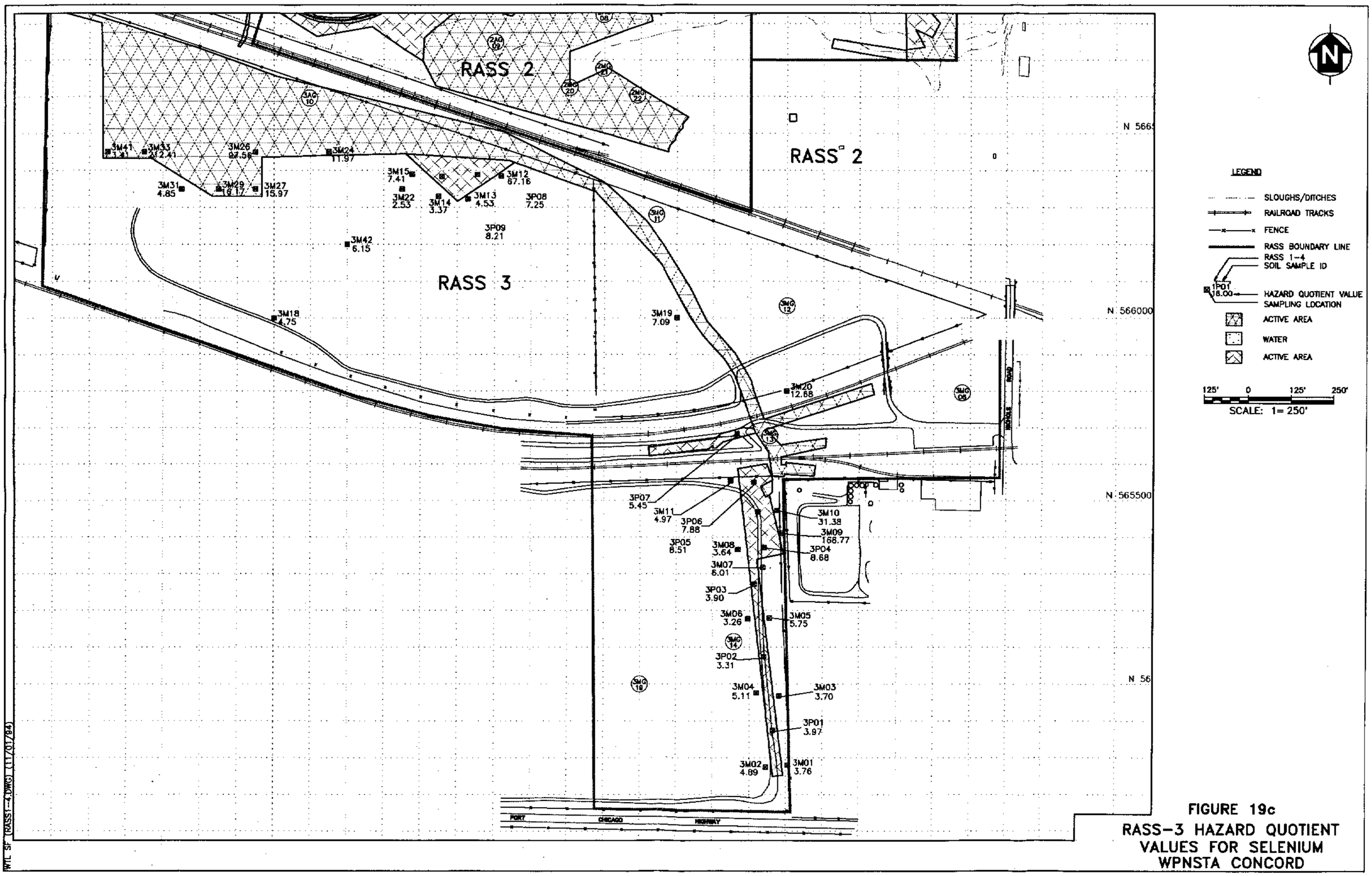


FIGURE 19c
RASS-3 HAZARD QUOTIENT VALUES FOR SELENIUM
WPNSTA CONCORD

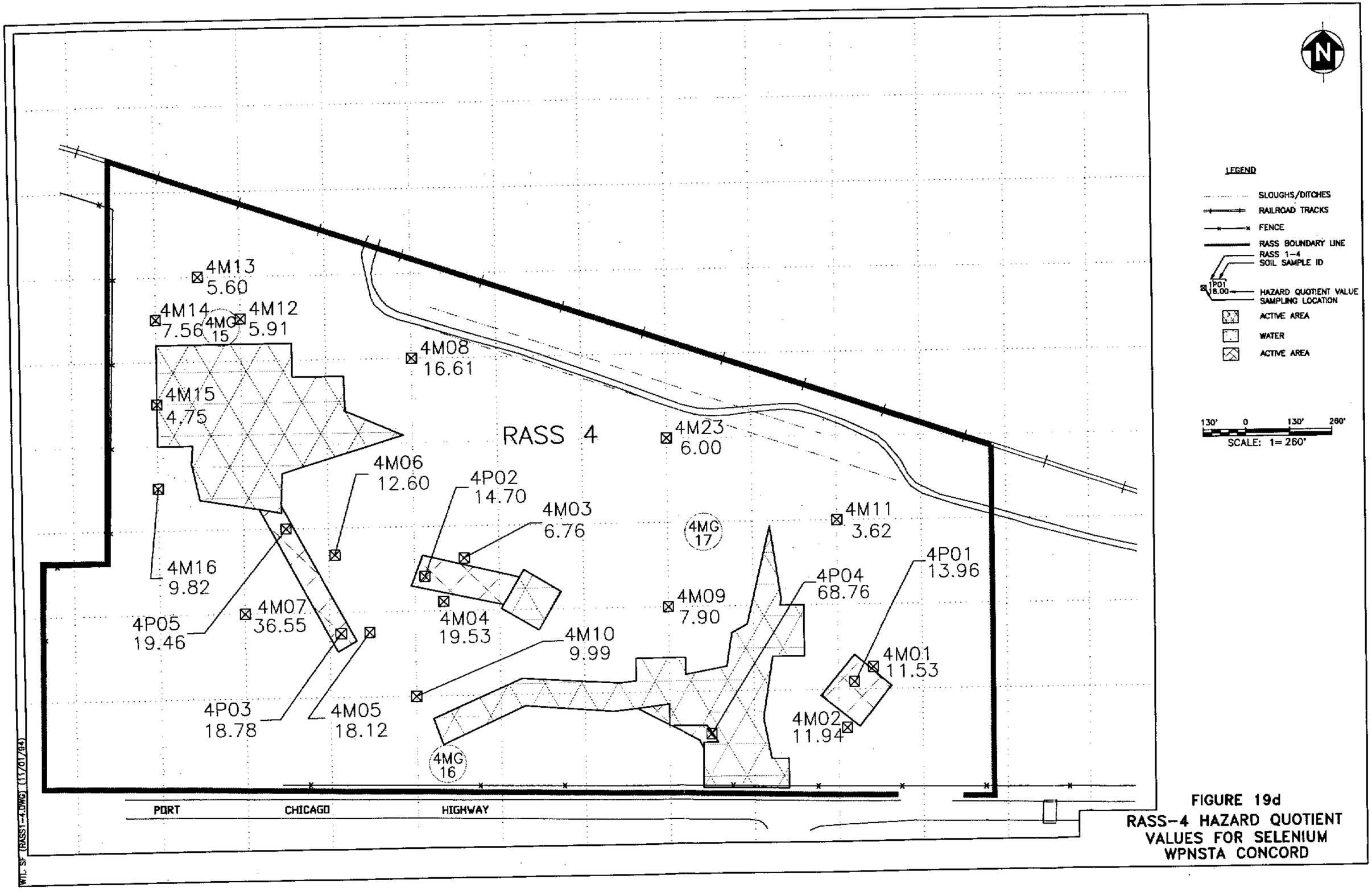
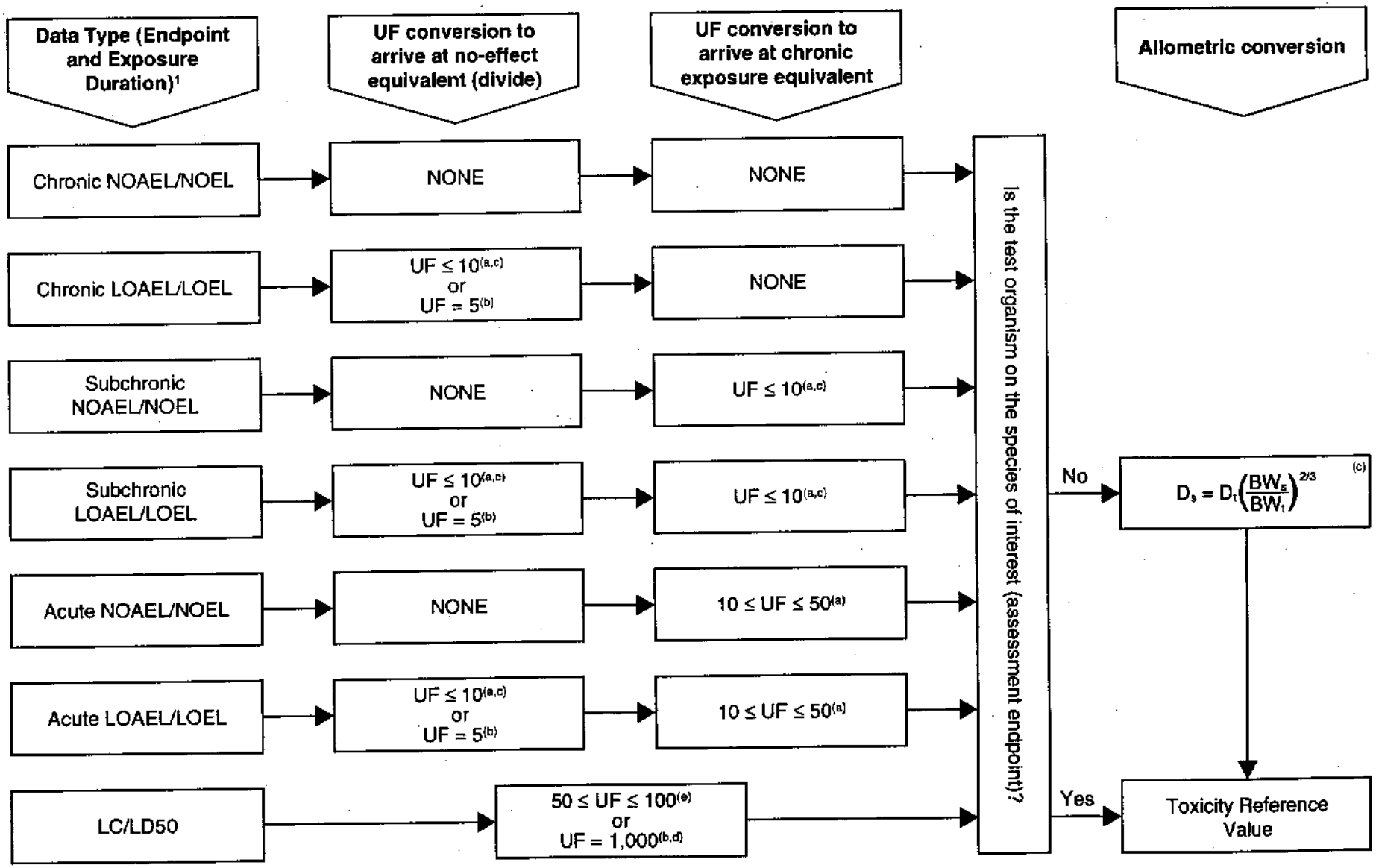


FIGURE 19d
RASS-4 HAZARD QUOTIENT VALUES FOR SELENIUM
WPNSTA CONCORD

Figure 20
Flowchart for Derivation of Toxicity Reference Values



Notes:

1 = All data must be in dose units = mg/kgbw-day. Convert if necessary.

a = Calabrese and Baldwin (1993), page 89; **b** = EPA (1993), Rocky Mountain Arsenal Case Study page 8-A7; **c** = Opresko, and others (1993) page 6;

d = Calabrese and Baldwin (1993), page 52; **e** = Calabrese and Baldwin (1993), page 51-60

UF = Uncertainty Factor, $\mathbf{D_s}$ = Unknown Dose for species of interest, $\mathbf{D_t}$ = Known Dose for test organism, $\mathbf{BW_s}$ = Body weight for species of interest, $\mathbf{BW_t}$ = Body weight for test organism

Note: Rocky Mountain Arsenal case study treats acute LOAEL/LOEL the same as LC/LD50 in terms of UF application, where UF = 1,000

APPENDICES

APPENDIX A

A-1 PLANT SPECIES REPORTED TO OCCUR AT WPNSTA CONCORD

A-2 INVERTEBRATE TAXA REPORTED TO OCCUR AT WPNSTA CONCORD

A-3 NATURAL HISTORY OF AMPHIBIANS AND REPTILES OF WPNSTA CONCORD

A-4 NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD

A-5 NATURAL HISTORY OF MAMMALS OF WPNSTA CONCORD

APPENDIX A-1

PLANT SPECIES REPORTED TO OCCUR AT WPNSTA CONCORD

Common Name	Scientific Name
Garlic	*Allium sativum*
Harvest brodiaea	*Brodiaea elegans*
Pepper tree	*Schinus molle*
Narrow leaf milkweed	*Asclepias fascicularis*
Salt heliotrope	*Heliotropium curassavicum*
Water starwort	*Callitriche marginata*
Sand spurrey	*Spergularia marina*
Fat hen	*Atriplex patula hastata*
Common pickleweed	*Salicornia virginica*
Tamarisk	*Tamarix pentandra*
Common yarrow	*Achillea millefolium*
Douglas mugwort	*Artermisia douglasiana*
Suisun marsh aster	*Aster lentus*
Common California aster	*Aster chilensis var. lentus*
Coyote bush	*Baccharis pilularis*
Italian thistle	*Carduus pycnocephalus*
Purple star thistle	*Centaurea calcitrapa*
Iberian star thistle	*Centaurea iberica*
Barnaby's thistle	*Centaurea solstitialis*
Canada thistle	*Cirsium arvense*
Bull thistle	*Cirsium vulgare*
Horseweed	*Conyza canadensis*
Brass-buttons	*Cotula coronopifolia*
Cardoon	*Cynara cardunculus*
Marsh gum-plant	*Grindelia humilis*
Kellogg's tarweed	*Hemizonia kelloggii*
Telegraph weed	*Heterotheca grandiflora*
Jaumea	*Jaumea carnosa*
Prickly lettuce	*Lactuca serriola*
Bristly ox tongue	*Picris echioides*
Marsh-fleabane	*Pluchea purpurascens*
Milk thistle	*Silybum marianum*
Suisun thistle	*Cirsium hydrophylum* var. *hydrophylum*
Spiny sow-thistle	*Sonchus asper*
Common sow-thistle	*Sonchus oleraceus*
Common dandelion	*Taraxacum officinale*
Salsify	*Tragopogon porrifolius*
Narrow leaf mule's ear	*Wyethia angustifolia*
Spiny clotbur	*Xanthium spinosum*
Bindweed	*Convolvulus arvensis*

APPENDIX A-1

PLANT SPECIES REPORTED TO OCCUR WPNSTA CONCORD (Continued)

Common Name	Scientific Name
Alkali weed	*Cressa truxillensis var.*
Field mustard	*Brassica campestris*
Short pod mustard	*Brassica geniculata*
Perenial peppergrass	*Lepidiun latifolium*
Watercress	*Nasturtium officinale*
Wild radish	*Raphanus sativus*
Salt marsh dodder	*Cuscuta salina*
Tall umbrella-sedge	*Cyperus eragrostis*
Blunt spike-rush	*Eleocharis obtusa*
Common tule	*Scirpus acutus*
California bulrush	*Scirpus californicus*
Olney bulrush	*Scirpus olneyi*
Alkali bulrush	*Scirpus robustus*
Turkey-mullein	*Eremocarpus setigerus*
Alkali heath	*Frankenia grandifolia*
Redstem filaree	*Erodium cicutarium*
Cut-leaved geranium	*Geranium dissectum*
Silvery hairgrass	*Aira caryophyllea*
Giant reed	*Arundo donax*
Oat	*Avena fatua*
California brome	*Bromus carinatus*
Ripgut grass	*Bromus diandrus*
Soft chess	*Bromus mollis*
Foxtail chess	*Bromus rubens*
Prickle grass	*Crypsis niliaca*
Bermuda grass	*Cynodon dactylon*
Pacific hairgrass	*Deschampsia holciformis*
Salt grass	*Distichlis spicata var.*
Alkali rye grass/ Beardless wildrye	*Elymus triticoides*
Meadow barley	*Hordeum brachyantherum*
Mediterranean barley	*Hordeum geniculatum*
Foxtail barley	*Hordeum jubatum*
Barnyard foxtail	*Hordeum leporinum*
Perennial ryegrass	*Lolium perenne*
Smilo	*Oryzopsis miliacea*
Dallis grass	*Paspalum dilatatum*
Canary grass	*Phalaris minor*
Common reed	*Phragmites communis var.*
Rabbit's foot grass	*Polypogon monspeliensis*

APPENDIX A-1

PLANT SPECIES REPORTED TO OCCUR WPNSTA CONCORD (Continued)

Common Name	Scientific Name
Bristlegrass	*Setaria geniculata*
Purple stipe	*Stipa pulchra*
Rattail fescue	*Vulpia myuros*
California fescue	*Festuca californica*
Yellow iris	*Iris pseudacorus*
Walnut	*Juglans hindsii*
Arrow-grass	*Triglochin maritima*
Baltic rush	*Juncus balticus*
Toad rush	*Juncus bufonius*
Common rush	*Juncus effusus var. pacificus*
Spearmint	*Mentha spicata*
Delta tule pea	*Lathyrus jepsonii var.*
Bird's foot trefoil	*Lotus coriculatus*
Miniature lotus	*Lotus micranthus*
Summer lupine	*Lupinus formosus var. robustus*
Alfalfa	*Medicago sativa*
Yellow sweet-clover	*Melilotus indicus*
Red clover	*Trifolium pratense*
Vetch	*Vicia americana*
Spring vetch	*Vicia sativa*
Garden asparagus	*Asparagus officinalis*
California loosestrife	*Lythrum californicum*
Hyssop loosestrife	*Lythrum hyssopifolia*
Tree mallow	*Lavatera arborea*
Cheeseweed	*Malva parviflora*
Alkai mallow	*Sida hederacea*
Blue gum	*Eucalyptus globulus*
Northern willow-herb	*Epilobium adenocaulon var.*
Panickled fireweed	*Epilobium paniculatum*
Yellow water weed	*Jussiaea repens var.*
Date palm	*Phoenix dactylifera*
California poppy	*Eschscholzia californica*
Mexican plantain	*Plantago hirtella var.*
Ribgrass	*Plantago lanceolata*
Common knotweed	*Polygonum aviculare*
Water smartweed	*Polygonum punctatum*
Sheep sorrell	*Rumex acetosella*
Curly dock	*Rumex crispus*
Pimpernel	*Anagallis arvensis*
Sea milkwort	*Glaux maritima*

APPENDIX A-1

PLANT SPECIES REPORTED TO OCCUR WPNSTA CONCORD (Continued)

Common Name	Scientific Name
Silverweed	*Potentilla egedii var.*
Almond	*Prunus amygdalus*
California wild rose	*Rosa californica*
Bedstraw	*Galium aparine*
Ditch-grass	*Ruppia maritima*
Fremont's cottonwood	*Populus fremontii*
Yellow willow	*Salix lasiandra*
Yerba mansa	*Anemopsis californica*
Bellardia	*Bellardia trixago*
Softbird's beak	*Cordylanthus mollis*
Yellow monkey-flower	*Mimulus guttatus*
Owl's-clover	*Orthocarpus purpurascens*
Nightshade	*Solanum xantii*
Narrow-leaved cattail	*Typha augustifolia*
Common cattail	*Typha latifolia*
Sweet fennel	*Foeniculum vulgare*
Mason's lilaeopsis	*Lilaeopsis masonii*
Gairdner's yampah	*Perideridia gairdneri girdneri*
Water Parsley	*Oenanthe sarmentosa*
Dogwood	*Cornus stolonifera*
Buttonbush	*Cephalanthus occidentalis*
Gum plant	*Grindelia humilis*
Contra Costa goldfields	*Lasthenia conjugens*

Source: O'Neil (1988).

APPENDIX A-2A

INVERTEBRATES KNOWN TO OCCUR IN SUISUN BAY ADJACENT TO WPNSTA CONCORD

Annelida	
	Neanthes succinea
	Streblospio benedicti
	Polydora uncata
Arthropoda	
	Corophium spinicorne
	Photis californica
	Pontharphinia obtusidens
	Corophium acherusicum
	Synidotea laticauda
	Corophium insidiosum
	Acartia clausi
	Eurytemora affinis
	Neomysis awatschensis
Mollusca	
	Corbicula fluminea
	Potamocarbula amurensis[1]
	Macoma inconspicua
	Mya arenaria
	Petricola pholadiformis

Source: Ecology and Environment (1983).

[1] Reported to occur by Monroe, Kelly, and Lisowski 1992.

APPENDIX A-2B

INVERTEBRATES REPORTED TO OCCUR IN WPNSTA CONCORD LITIGATION AREA

Rhizopoda	Foraminifera
Gastropoda	*Assiminea californicia*
Oligochaeta	*Quistadrilus multisetasus*[1] *Telematedrilus vejdorskyi*[1] *Enchytraeus c.f. albidus*[1] *Paranais litoralis*[1]
Crustacea	*Porcellio* species
Amphipoda	*Orchestia c.f. traskiana*[1]
Ostracoda	Unknown
Copepoda	Unknown
Diplopoda	Spirobolida
Chilopoda	Lithobiomorpha Geophilomorpha
Symphyla	Unknown
Insecta	Protura Diplura Machilidae or Lepismatidae Japygidae

APPENDIX A-2
(Continued)

INVERTEBRATES REPORTED TO OCCUR IN WPNSTA CONCORD LITIGATION AREA

Insecta (Cont.)

Sminthuridae
Onychiuridae
Poduridae
Entomobryidae
Isotomidae
Acrididae
Gryllacrididae
Forficulidae
Embiidina
Psocoptera
Phloeothripidae
Aeolothripidae
Thripidae
Terebrantia
Nabidae
Lygaeidae
Rhopalidae (Corizidae)
Miridae
Pentatomidae
Cicadellidae
Fulgoridae
Psyllidae
Aphididae
Coccidae
Neuroptera
Carabidae
Hydrophilidae
Staphylinidae
Malachiidae (Melyridae)
Dermestidae
Cleridae
Elateridae
Lathrididae
Coccinellidae
Anthicidae
Salpingidae
Melyridae
Tenebrionidae

APPENDIX A-2
(Continued)

INVERTEBRATES REPORTED TO OCCUR IN WPNSTA CONCORD LITIGATION AREA

Insecta (Cont.)	
	Chrysomelidae
	Curculionidae
	Noctuidae
	Tipulidae
	Psychodidae
	Culicidae
	Ceratopogonidae
	Mycetophilidae
	Scatopsidae
	Cecidomyiidae
	Psychodidae
	Nematocera
	Anthomyiidae
	Calypteratea
	Chalcidae
	Dolichopodidae
	Platypezidae
	Syrphidae
	Ephydridae
	Drosophilidae
	Anthomyzidae
	Muscidae
	Stratiomyidae
	Diprionidae
	Eulophidae
	Formicidae
Arachnida	
	Araneidae
	Acarina
	Pseudoscorpionida

Source: Harvey (1992b)

[1] Reported to occur by Harvey 1991.

APPENDIX A-2C

INVERTEBRATES KNOWN TO OCCUR IN TIDAL AREAS, WPNSTA CONCORD

Annelida

Neanthes limnicola?

Arthropoda
- Crustacea
  - Amphipoda
    - *Anisogammarus confervicolus*
    - *Orchestia sp.*
  - Isopoda
    - *Gnorimosphaeroma oregonense?*

Mollusca
- *Macoma balthica*
- Gastropoda

Insecta
- Chironomidae
  - Diptera
    - *Chironomus stigmaterus*
    - *Tropisternus sp.*
- Coeloptera
  - Hydrobiidae
  - Hemiptera
    - *Trichocorixa reticulata*

Source: WESCO 1994. Summer aquatic sampling data WPNSTA Concord.

APPENDIX A-3

NATURAL HISTORY OF AMPHIBIANS AND REPTILES OF WPNSTA CONCORD

Species (and reference)	Status	Behavior	Habitat/Primary Exposure	Concord Habitat	Feeding Guild
California Tiger Salamander *Ambystoma tigrinum*	None	Use ponds for reproduction, live in burrows	Air, Soil, Sed, SW	U	Carnivore Adults:earthworms, snails, insects, fish, small mammals larvae: zooplankton, arthropods, amphipods, mollusks, insect larvae
Western Spadefoot *Scaphiopus hammondi*	None	Construct underground burrows	Air, Soil, Sed, SW	U	Carnivore Adults:insects, worms, invertebrates (butterfly, moth larvae, ants, termites, beetles) tadpoles:omnivore plankton, algae, dead aquatic larvae
California Toad *Bufo boreas halophilus*	None	Use rodent burrows, hide under objects, bury themselves in loose soil	Air, Soil, Sed, SW	M, U	Carnivore Adults: terrestrial insects, small arthropods, some earthworms, snails and slugs. tadpoles: filter plankton or eat bottom detritus
Western Pond Turtle ***Clemmys marmorata***	None	Bask on edge of water, retreat underwater	Air, Soil, Sed, SW	M	Omnivore Aquatic plants (pond lilies), beetles, aquatic inverts, fishes, frogs, carrion

APPENDIX A-3

NATURAL HISTORY OF AMPHIBIANS AND REPTILES OF WPNSTA CONCORD (Continued)

Species (and reference)	Status	Behavior	Habitat/Primary Exposure	Concord Habitat	Feeding Guild
Northwestern Fence Lizard ***Sceloporus occidentalis occidentalis***	None	Bask on vertical objects, may go in burrows and crevices	Air, Soil	U	Carnivore Mainly terrestrial insects, some other terr. inverts
California Side-blotched Lizard *Uta stansburiana hesperis*	None	Ground dwelling	Air, Soil	U	Carnivore Insects, arthropods, some scorpions, spiders, mites, ticks, and sowbugs. Some vegetable matter
Coast Horned Lizard *Phrynosoma coronatum*	None	Bask, burrow into loose soil	Air, Soil	U	Carnivore Ants, small beetles, wasps, grasshoppers, flies, caterpillars
Western Skink *Eumeces skiltonianus*	None	Burrow, prefer moist habitats	Air, Soil, Sed, SW	M, U	Carnivore Insect eggs, adult and larval beetles, caterpillars, moths, grasshoppers, crickets, insect larvae, ants, spiders, centipedes, sow bugs
Western Whiptail *Cnemidophorus tigris*	None	Forage in cracks, crevices and loose soil	Air, Soil	U	Carnivore Ground dweeling inverts grasshoppers, beetles, ants, termites, insect larvae, spiders

APPENDIX A-3

NATURAL HISTORY OF AMPHIBIANS AND REPTILES OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	Behavior	Habitat/Primary Exposure	Concord Habitat	Feeding Guild
Sharp-tailed Snake *Contia tenuis*	None	Stay under surface objects, prefer moist microhabitats	Air, Soil, Sed	M, U	Carnivore Slugs, maybe small salamanders
Western Yellow-bellied Racer *Coluber constrictor mormon*	None	Seek cover under surface objects	Air, Soil	M, U	Carnivore Small mammals, birds, snakes, lizards, frogs, insects
San Joaquin Coachwhip *Masticophis flagellum*	None	Seek cover in rodent burrows, bushes, trees, rock piles	Air, Soil, SW	U	Carnivore Rodents, lizards, eggs, snakes, birds and eggs, young turtles, insects, carrion
Pacific Gopher Snake ***Pituophis melanoleucus catenifer***	None	Seek cover in rodent burrows and under objects	Air, Soil	M, U	Carnivore Adults:mainly mammals, birds-mice, kangaroo rats, gophers, ground squirrels, rabbits, quail, ducks and eggs juveniles:young mice, small lizards
California Kingsnake *Lampropeltis getulus californiae*	None	Seek cover in rodent burrows and under objects	Air, Soil	M, U	Carnivore Lizards, snakes, small rodents, birds and eggs

APPENDIX A-3

NATURAL HISTORY OF AMPHIBIANS AND REPTILES OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	Behavior	Habitat/Primary Exposure	Concord Habitat	Feeding Guild
Valley Garter Snake *Thamnophis sirtalis fitchi*	None	Diurnal, retreat to holes at night	Air, Soil, Sed, SW	M, U	Carnivore Treefrogs, fish mice, leeches,earthworms, toads, also small mammals, birds, lizards, amphibians, slugs
Coast Garter Snake *Thamnophis elegans terrestris*	None	Basks in open. Prefers holes, burrows and hiding under surface objects	Air, Soil, Sed	M, U	Carnivore More terr. prey than other garter snakes small mammals, birds, fishes, frogs, salamanders, insects, crabs, marine polychaete worms, leeches, earthworms, snails, slugs, refuse
Giant Garter Snake *Thamnophis couchi gigas*	CT CP	Diurnal. Forage along streams, retreat to holes at night	Air, Soil, Sed, SW	M	Carnivore Mainly aquatic, fishes (trouts and sculpins), amphibians and amphib. larvae, small mammals, leeches, earthworms

APPENDIX A-3

NATURAL HISTORY OF AMPHIBIANS AND REPTILES OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	Behavior	Habitat/Primary Exposure	Concord Habitat	Feeding Guild
Northern Pacific Rattlesnake *Crotalus viridis oreganus*	None	Seek cover in crevices, under surface objects, under dense vegetation and in mammal burrows	Air, Soil	M, U	Carnivore Mostly rodents, esp. ground squirrels. Also rabbits, birds, carrion. Juveniles:mostly lizards, esp. western fence and side-blotched lizards. Also young rodents.

APPENDIX A-3

NATURAL HISTORY OF AMPHIBIANS AND REPTILES OF WPNSTA CONCORD (Continued)

Notes:

- Common and scientific names of species that are shaded and in bold typeface reflect taxa that have been observed at WPNSTA Concord (Concord). Taxa in regular typeface reflect may occur at Concord.
- All of the species listed above are native to California.
- Due to the small ranges of the species listed above, all species observed at Concord are expected to be year-round residents and to reproduce at Concord.
- Blank cells indicate that no information was available.

Table Explanation

Status

CT State of California Threatened Species
CP State of California Protected Species
None Does not have special status

Behavior

The behavior that influences the species exposure to contaminants is noted.

APPENDIX A-3

NATURAL HISTORY OF AMPHIBIANS AND REPTILES OF WPNSTA CONCORD (Continued)

Habitat

The species' habitat preferences are noted.

Primary Exposure

The following descriptors indicate the primary routes of exposure to contaminants for the species, excluding exposure through ingestion of contaminated prey.

Air	Air at Concord
Soil	Soil at Concord
Sed	Sediments at Concord, Suisun Bay
SW	Surface water at Concord (including Suisun Bay water)

Concord Habitat Types

M	Marsh
U	Upland

Sources

Zeiner and others. 1990.

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Pied-billed Grebe *Podilymbus podiceps*	None	Yes	All year	Air, Sed, SW Food taken in aquatic or wetland habitat. Dives.	M	Carnivore/Omnivore Mostly insects, crustaceans, fish. Also amphibs, mollusks, leeches and aquatic plants. Young: insects
Eared Grebe *Podiceps nigricollis*	None	Yes	Migrant - winter resident	Air, Sed, SW Dives to bottom to catch prey. Does not come ashore.	M	Carnivore Aquatic and land insects & larvae, crustaceans, mollusks, inverts, small fishes, amphibs. Takes land insects from water surface, dives.
Western Grebe *Aechmophorus occidentalis*	None	Yes	Migrant - winter resident	Air, SW Dives to catch prey, nest at edge of or in open water	M	Carnivore Mostly fish, also insects, inverts, rarely amphibs and plants
American White Pelican *Pelecanus erythrorhynchos*	SSC	Yes	Transient	Air, Soil, Sed, SW		Carnivore Mainly fish, occasionally amphibians and crustaceans
California Brown Pelican *Pelecanus occidentalis californicus*	FE CE CFP	Yes	Transient	Air, Soil, Sed, SW		Carnivore Mainly fish, occasionally crustaceans, carrion, and young of its own species
Double-crested Cormorant *Phalacrocorax auritis*	SSC	Yes	All year	Air, SW Dives to catch prey. Roosts on shore.	M	Carnivore Mainly fish, also crustaceans and amphibians

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
American Bittern *Botaurus lentiginosus*	None	Yes	All year	Air, Soil, Sed, SW feeds in water, wetlands, along shore	M	Carnivore Mainly insects, amphibs, fish, crayfish, small mammals; also snakes, misc, inverts and birds
Great Blue Heron *Ardea herodias*	None	Yes	All year	Air, Soil, Sed, SW	M	Carnivore Mainly fish, also small rodents, amphibs, snakes, lizards, insects, crustaceans, occasionally small birds
Great Egret *Casmerodius albus*	None	Yes	All year	Air, Soil, Sed, SW	M	Carnivore Mainly fishes, amphibs, snakes, snails, crustaceans, insects, small mammals
Snowy Egret *Egretta thula*	None	Yes	All year	Air, Sed, SW	M	Carnivore Prefers small fish, crustaceans and large insects; also eats amphibs, reptiles, worms, snails, small mammals
Black-crowned Night-Heron *Nycticorax nycticorax*	None	Yes	All year	Air, Soil, Sed, SW	M	Carnivore Fishes, crustaceans, aquatic insects & inverts, amphibs, reptiles, small mammals, rarely young birds
Tundra Swan *Cygnus columbianus*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW grubs in mud for food	M	Herbivore Leaves, stems seeds and tubers of aquatic and marsh plants, cultivated grains. Young eat insects and other inverts at first.

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Greater White-fronted Goose *Anser albifrons*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW drinks water	M	Herbivore Seeds and sprouts of cultivated grains and wild grasses, occasionally feeds in open waters, tipping for aquatic plants.
Canada Goose *Branta canadensis*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Herbivore Mainly green shoots and seeds of cultivated grains and wild grasses and forbs, also aquatic plants
Green-winged Teal *Anas crecca*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Omnivore Seeds of aq. plants, terr. grasses, forbs and grains, also leaves and stems. Mostly aquatic inverts in the summer
Mallard *Anas platyrhynchos*	HS	Yes	All year	Air, Soil, Sed, SW feeds in water, wetlands, fields, shore	M	Herbivore/Omnivore 90% grains, seeds, leaves of aquatic plants, grasses, other green veg. 10% mostly aquatic insects, also snails, earthworms, tadpoles, crustaceans, small fish
Northern Pintail *Anas acuta*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Omnivore Aquatic plant seeds, wild grasses, forbs, grains, insects, crustaceans, mollusks, worms, stems and leaves.
Blue-winged Teal *Anas discors*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Omnivore Seeds and vegetative parts of aquatic plants, also mollusks, insects, few crustaceans

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Cinnamon Teal *Anas cyanoptera*	HS	Yes	All year	Air, Soil, Sed, SW	M	Omnivore 80% plant matter, mostly seeds & veg.parts of sedges, pondweeds, grasses. Also mollusks and insects
Northern Shoveler *Anas clypeata*	HS	Yes	Migrant - winter resident	Air, Sed, SW	M	Omnivore Mostly phyto- and zooplankton, also seeds and aquatic plant parts, mollusks, aquatic insects, macroinverts and small fish
Gadwall *Anas strepera*	HS	Yes	All year	Air, Sed, SW	M	Mainly Herbivore Leaves and stems of aquatic plants, also seeds and cultivated grains. Insects, mollusks, and crustaceans make up 2-4% of diet, important to breeding adults and ducklings.
Eurasian Wigeon *Anas penelope*	HS	Yes	Migrant - winter visitor	Air, Soil, Sed, SW	M	Omnivore Algae, herbage, upland grasses and clover, insects, gravel. Rarely mollusks, crustaceans, worms, frogs, small fish.
American Wigeon *Anas americana*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Omnivore Mainly leaves, stems of aq. plants and terr. grasses and forbs. Also crops- lettuce, alfalfa, clover, some seeds, waste grain. Mainly aq. insects in summer. Young eat mainly insects, inverts

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Canvasback *Aythya valisineria*	HS	Yes	Migrant - winter resident	Air, Sed, SW	M	Omnivore Seeds, tubers, leaves, stems of aq. plants, aq. mollusks, crustaceans, worms, insects, fish. inverts=main food in winter and adult females & young in summer
Greater Scaup *Aythya marila*	HS	Yes	Migrant - winter resident	Air, Sed, SW	M	Omnivore Winter: mostly mollusks, crustaceans, insects. Summer: more vegetation
Lesser Scaup *Aythya affinis*	HS	Yes	Migrant - winter resident	Air, Sed, SW	M	Omnivore Primarily aquatic inverts, also leaves, stems, seeds and tubers of aquatic plants
Surf Scoter *Melanitta perspicillata*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Mainly Carnivore Mostly mollusks, also crustaceans, inverts, few fish, small amounts of aquatic plants
White-winged Scoter *Melanitta fusca*	HS	Yes	Migrant - absent June to August	Air, Sed, SW	M	Mainly Carnivore Mostly mollusks, some crustaceans, lesser amounts of inverts and fishes, small amounts of aquatic plants
Common Goldeneye *Bucephala clangula*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW Seldom ashore except to visit nest	M	Omnivore Mainly crustaceans, mollusks, small fish, insects. 25% seeds, tubers, leaves, stems of aquatic plants.

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Barrow's Goldeneye *Bucephala islandica*	SSC HS	Yes	Migrant - winter resident	Air, Sed, SW	M	Omnivore Principally mollusks and crustaceans in saltwater, aquatic insects and crustaceans in freshwater; also algae and aquatic plant parts. Young eat almost entirely aquatic insects.
Bufflehead *Bucephala albeola*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW Seldom ashore except to nest	M	Omnivore Mainly small inverts, crustaceans & mollusks in saltwaster, aquatic insects & gastropods in freshwater. Eats some fish, seeds, parts of aq. plants. Young eat almost entirely aquatic insects.
Hooded Merganser *Lophodytes cucullatus*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Mainly Carnivore Small fish, crustaceans, frogs, aquatic insects, rarely seeds, buds and stems of aquatic plants
Ruddy Duck *Oxyura jamaicenses*	HS	Yes	All year	Air, Sed, SW	M	Omnivore Submerged aquatic plants, algae, bulrush seeds; aquatic insects in freshwater; mollusks, crustaceans, worms in saltwater.
Turkey Vulture *Cathartes aura*	None	Yes	All year	Air, Soil, SW	M, U	Carnivore Mainly carrion, rarely rotting fruit, live birds, eggs, live mammals

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
White-tailed Kite *Elanus caerulens*	CFP	Yes	All year	Air, Soil, Sed, SW Forages in wetlands	M, U	Carnivore Mostly voles and small diurnal mammals, occ. birds, insects, reptiles, amphibs
Bald Eagle *Haliaeetus leucocephalus*	FE CE CFP	Yes	Transient	Air, SW		Carnivore Fish, water birds, voles, small mammals, scavenges
Northern Harrier *Circus cyaneus*	SSC AB	Yes	All year	Air	M, U	Carnivore Voles, small mammals, birds, frogs, small reptiles, crustaceans, insects, rarely fish
Sharp-shinned Hawk *Accipiter striatus*	SSC	Yes	Migrant - winter resident	Air, Soil, SW	U	Carnivore Mostly small birds, also small mammals, insects, reptiles, and amphibians
Red-shouldered Hawk *Buteo lineatus*	AB	Yes	All year	Air, SW has been reported bathing	U	Carnivore Highly varied diet. Small mammals, snakes, lizards, amphibs, small or young birds, large insects
Red-tailed Hawk *Buteo jamaicensis*	None	Yes	All year	Air	M, U	Carnivore Small mammals up to hares, small birds, reptiles, amphibs, some carrion
Ferruginous Hawk *Buteo regalis*	SSC	Yes	Migrant - winter resident	Air	U	Carnivore Mostly lagomorphs, ground squirrels and mice; also birds, reptiles and amphibians

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Golden Eagle *Aquila chrysaetos*	CFP SSC	Yes	Transient	Air, Soil		Carnivore Mostly lagomorphs & rodents, also other mammals, birds, reptiles & carrion
American Kestrel *Falco sparverius*	None	Yes	All year	Air	M, U	Carnivore Small mammals, birds, insects, earthworms, reptiles, amphibs
Prairie Falcon *Falco mexicanus*	SSC	Yes	All year, some only winter residents	Air	U	Carnivore Mostly small mammals, some small birds, reptiles
Peregrine Falcon *Falco peregrinus anatus*	FE SE	Yes	Resident or Transient	Air	M, U	Carnivore Mostly birds, such as ducks, shorebirds, and pigeons
Ring-necked Pheasant *Phasianus colchicus*	HS	Yes	All year	Air, Soil, SW	M	
California Quail *Callipepla californica*	HS	Yes	All year	Air, Soil, SW	U	Herbivore Primarily legume & other seeds, also green veg, arthropods, grains, fruits Chicks: lots of arthropods
California Black Rail *Laterallus jamaicensis cotuniculus*	CT CFP	Yes	All year	Air, Soil, Sed, SW Gleans food from mud and vegetation	M	Carnivore Isopods, insects, other arthropods from mud & veg.

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
California Clapper Rail *Rallus longirostris obsoletus*	FE CE CFP	Yes	All year	Air, Soil, Sed, SW	M	Carnivore Crabs, mussels, clams, snails, insects, spiders, worms. Also mice at high tide, may scavenge dead fish
Virginia Rail *Rallus limicola*	None	Yes	All year	Air, Soil, Sed, SW Forages, probes mud, wades	M	
Sora *Porzana carolina*	None	Yes	All year	Air, Soil, Sed, SW	M	Omnivore 73% seeds, also small mollusks & aq. insects during Spring & Summer
American Coot *Fulica americana*	HS	Yes	All year	Air, Soil, Sed, SW	M	Omnivore Submerged aq. plants, seeds, insects, small fish
Semipalmated Plover *Charadrius semipalmatus*	None	Yes	Migrant - winter resident	Air, Sed, SW	M	Carnivore Worms, small mollusks, amphipods, fly larvae, locusts, other aquatic and terrestrial insects
Killdeer *Charadrius vociferus*	None	Yes	All year	Air, Soil, Sed, SW forages on ground, shore, probably drinks water	M	Carnivore Inverts, esp. insects, beetles, grasshoppers, flies, mosquitoes, weevils, crustaceans, worms, mollusks, seeds
Black-necked Stilt *Himantopus mexicanus*	None	Yes	All year	Air, Sed, SW	M	Carnivore Insects, crustaceans, mollusks, other aq. inverts, some small fish

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
American Avocet *Recurvirostra americana*	None	Yes	All year	Air, Soil, Sed, SW Soil only when nesting in scrape	M	Omnivore Aquatic insects, crustaceans, snails, worms, occ. aq. plant seeds
Greater Yellowlegs *Tringa melanoleuca*	None	Yes	Migrant - winter resident	Air, Sed, SW	M	Carnivore Aquatic insects, small fish, crustaceans, worms, terr. insects, gobies
Lesser Yellowlegs *Tringa flavipes*	None	Yes	Migrant - winter resident	Air, Sed, SW	M	Carnivore Adult and larval aquatic insects, grasshoppers, small fish, crustaceans and worms
Willet *Catoptrophorus semipalmatus*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Carnivore Invertebrates, mainly small crustaceans & mollusks, also fish, polychaete worms,larval & pupal dipteran insects, fish eggs. inland: mud burrowing insects and crustaceans
Long-Billed Curlew *Numenius americanus*	SSC	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Carnivore Invertebrates, mainly small crustaceans & mollusks, insects & pupae
Spotted Sandpiper *Actitis macularia*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Carnivore Flying and benthic insects, beetles, crickets, flies, grasshoppers, worms, ants.Other aq. inverts, small fish

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Whimbrel *Numenius phaeopus*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Omnivore Berries, insects while breeding. crabs, crayfish, marine worms, grasshoppers, spidrs, berries when not breeding in estuarine, grashoppers, spiders, beetles when inland
Western Sandpiper ***Calidris mauri***	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Carnivore Insects, mollusks, crustaceans, worms Young eat adult & larval flies & beetles
Least Sandpiper ***Calidris minutilla***	None	Yes	Migrant - winter visitor	Air, Soil, Sed, SW Bathes, may drink	M	Carnivore Crustaceans, worms, adult insects and insect larvae. May take some seeds and plant material.
Dunlin ***Calidris alpina***	None	Yes	Migrant - winter visitor	Air, Soil, Sed, SW	M	Carnivore Larval and adult crane flies and midges when breeding. In estuarine habitats, polychaete worms, small crustaceans and small mollusks
Long-billed Dowitcher ***Limnodromus scolopaceus***	None	Yes	Migrant - winter resident	Air, Sed, SW	M	Omnivore Winter: FW midge & other fly larvae, small burrowing crustaceans. Summer: crane fly and midge larvae, other insect larvae, small snails, some seeds & plant fiber

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Common Snipe *Gallinago gallinago*	HS	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M	Omnivore Insects (esp. beetle & fly larvae), earthworms, FW crustaceans & mollusks, occ. fish Also grass & sedge seeds, grit
Bonaparte's Gull *Larus philadelphia*	None	Yes	Transient, winter visitor	Air, Soil, Sed, SW	M, U	Carnivore/Scavenger Insects, fish, crustaceans, marine worms
Mew Gull *Larus canus*	None	Yes	Migrant - winter visitor	Air, Soil, Sed, SW	M, U	Carnivore/Scavenger Mollusks, crustaceans, echinoderms at coast; worms and insect larvae inland.
Ring-billed Gull *Larus delawarensis*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW Drinks and bathes in freshwater	M, U	Omnivore/Scavenger Forages in dumps, etc. Also eats fish, insects, earthworms, crustaceans, garbage, grain, rodents, amphibs & reptiles, carrion, large amt of plant material early in breeding season
California Gull *Larus californicus*	SSC	Yes	All year	Air, Soil, Sed, SW	M, U	Omnivore Garbage, carrion, adult insects and larvae. Young fed larval insects, brine shrimp, young birds, garbage, earthworma and insects
Herring Gull *Larus argentatus*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M, U	Omnivore/Scavenger Scavenges. Also eats small fishes, inverts. Inland: worms, insect larvae, rats, mice, moles, small rabbits

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Western Gull *Larus occidentalis*	None	Yes	All year	Air, Soil, Sed, SW	M, U	Carnivore Fish, intertidal inverts, small birds & eggs, scavenges
Glaucous-winged Gull *Larus glaucescens*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW Drinks and bathes in freshwater	M, U	Omnivore Scavenges at dumps, docks, shoreline, eats barnacles, mollusks, sea urchins, carrion, fish
Caspian Tern *Sterna caspia*	None	Yes	Migrant - summer resident	Air, Soil, Sed, SW		Piscivore Small fish (up to 15cm)
Forster's Tern *Sterna forsteri*	None	Yes	All year	Air, Soil, Sed, SW		Carnivore Small fish, aquatic insects, crustaceans, small amphibians
Least Tern *Sterna antillarum browni*	None	Yes	Migrant - summer resident	Air, Soil, Sed, SW		Piscivore Small fish, anchovy, silversides, shiner surfperch
Rock Dove *Columba livia*	HS	Yes	All year	Air, Soil, SW Drinks regularly	U	Herbivore Waste grains, seeds, grasses, forbs, bread, other human food scraps
Mourning Dove *Zenaida macroura*	HS	Yes	All year	Air, Soil, SW Drinks water	U	Herbivore Almost entirely seeds of cereal grains, forbs, grasses. occ. snails, less on insects
Barn Owl *Tyto alba*	None	Yes	All year	Air, Soil	M, U	Carnivore Small mammals, invertebrates, reptiles, small birds.

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Western Screech Owl *Otus kennicottii*	None	Yes	All year	Air, Soil, SW	U	Carnivore Mice and other small mammals, birds, fish, reptiles, amphibians, arthropods. Insects important in summer and fall.
Great Horned Owl ***Bubo virginianus***	None	Yes	All year	Air, Soil, Sed	U	Carnivore Rabbits, rodents, small to med. mammals = 90%, some birds, amphibs, reptiles, fish, arthropods
Burrowing Owl ***Athene cunicularia***	SSC	Yes	All year	Air, Soil, SW Burrows, observed drinking water	U	Carnivore Mostly insects, also small mammals, reptiles, birds, carrion
Short-eared Owl ***Asio flammeus***	SSC	Yes	Migrant - summer resident	Air, Soil, SW Nests on ground, observed drinking water	U	Carnivore Voles and other small mammals, also reptiles, amphibs, arthropods
Anna's Hummingbird ***Clypte anna***	None	Yes	All year	Air, SW Bathes	M, U	Omnivore Nectar, small insects & spiders, pollen, plant sap
Allen's Hummingbird ***Selasphorus sasin***	None	Yes	Migrant - summer resident	Air, SW Bathes	M, U	Omnivore Nectar, insects, spiders
Belted Kingfisher ***Ceryle alcyon***	None	Yes	All year	Air, Soil, Sed, SW Excavates nest burrows	M, U	Carnivore Mostly fish, also amphibs, crayfish & insects

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Red-breasted Sapsucker *Sphyrapicus ruber*	None	Yes	Migrant - winter resident	Air	U	Omnivore Insects, especially ants, sap, cambium, other soft tree tissues, berries, fruits
Nuttall's Woodpecker *Picoides nuttallii*	None	Yes	All year	Air, Soil	U	Omnivore 80% adult and larval insects (mainly beetles), also berries, poison oak seeds, nuts, other fruits and sap
Northern Flicker *Colaptes auratus*	None	Yes	All year	Air, Soil May burrow in bank	M	Omnivore 55% insects, esp. ants, also beetles, grasshoppers, moths, larvae. Fall: acorns, seeds. Winter: berries, fruits
Black Phoebe *Sayornis nigricans*	None	Yes	All year	Air, Soil, Sed, SW Nest built of mud, drinks & bathes regularly	M	Carnivore Mostly insects, occ. small fish
Say's Phoebe *Sayornis saya*	None	Yes	Migrant - winter resident	Air, Soil May nest in undercut bank, erosion hole	U	Insectivore
Western Kingbird *Tyrannus verticalis*	None	Yes	Migrant - summer resident	Air	U	Omnivore Almost only flying insects, occ. seeds, berries
Tree Swallow *Tachycineta bicolor*	None	Yes	Migrant - summer resident	Air	U	Omnivore Mostly insects, 20% small seeds and berries

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Violet-green Swallow *Tachycineta thalassina*	None	Yes	Migrant - summer resident		U	Insectivore
Northern Rough-winged Swallow *Stelgidopteryx serripennis*	None	Yes	Migrant - summer resident	Air	U	Insectivore
Cliff Swallow ***Hirundo pyrrhonota***	None	Yes	Migrant - summer resident	Air, Soil, Sed, SW Makes nest of mud pellets, drinks water	M, U	Omnivore Mostly insects, occ. berries
Barn Swallow ***Hirundo rustica***	None	Yes	Migrant - summer resident	Air, Soil, Sed, SW Makes nest of mud pellets, drinks, bathes	M	Omnivore Mostly insects, occ. berries and seeds
Scrub Jay ***Aphelocoma coerulescens***	None	Yes	All year	Air, Soil, SW Drinks water	U	Omnivore Mostly acorns, nuts, seeds, fruits, insects, other inverts. also small vertebrates, bird eggs and young
American Crow ***Corvus brachyrhychos***	HS	Yes	All year	Air, Soil, SW Drinks water	U	Omnivore Nuts, seeds, grains, fruits, insets, bird eggs & nestlings, carrion, small vertebrates, garbage
Common Raven *Corvus corax*	None	Yes	All year	Air, Soil	U	Omnivore Carrion, small vertebrates (incl. mice & rabbits), bird eggs & young, insects, seeds and grains, nuts, berries & other fruit

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Bushtit *Psaltriparus minimus*	None	Yes	All year	Air, Soil, SW Bathes occasionally	U	Omnivore Mostly insects and spiders, also berries, rarely seeds and nectar
Marsh Wren *Cistothorus palustris*	None	Yes	All year	Air, Soil, Sed Nests in emergent wetland, gleans food from surface of water, ground, etc	M	Omnivore Insects, spiders, other small inverts, rarely seeds and grains
Ruby-crowned Kinglet *Regulus calendula*	None	Yes	All year	Air, SW Bathes	M	Omnivore Insects, spiders, other small arthropods, some fruits, occ. seeds
Western Bluebird *Sialia mexicana*	None	Yes	All year	Air, SW Drinks regularly	U	Carnivore Primarily insects, incl. grasshoppers, caterpillars, beetles, ants, also earthworms, snails, other small arthropods.Berries in non-breeding season
Hermit Thrush *Cathatrus guttatus*	None	Yes	Migrant - winter resident	Air, Soil, SW	U	Omnivore Insects, spiders, worms, other small inverts; also large amounts of berries, other fruits and seeds
American Robin *Turdus migratorius*	None	Yes	All year	Air, Soil, Sed, SW Bathes and drinks regularly, builds nest from mud	U	Omnivore When breeding: earthworms, caterpillars, beetles, arthropods, snails. Nonbreeding: more berries and other fruits, seeds, seedlings and sprouts

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Northern Mockingbird *Mimus polyglottus*	None	Yes	All year	Air, Soil, SW	U	Omnivore Mostly insects, earthworms, snails in breeding season; more berries and small fruits in non-breeding season.
American Pipit *Anthus rubescens*	None	Yes	Migrant - winter resident	Air, Soil, Sed, SW	M, U	Omnivore Almost entirely insects while breeding, also mollusks, crustaceans, arthropods, seeds in fall & winter
Loggerhead Shrike *Lanius ludovicianus*	None	Yes	All year	Air, SW May drink water, may catch fish	M, U	Carnivore Mostly large insects, also small birds, mammals, reptiles, fish, carrion & various invertebrates
European Starling *Sturnus vulgaris*	None	No	All year	Air, SW Probably requires drinking water	U	Omnivore Insects, other inverts, grains, seeds, nuts, fruits, garbage
Yellow-rumped Warbler *Dendroica coronata*	None	Yes	Migrant - winter resident	Air, SW Bathes	M, U	Omnivore Mostly insects and spiders, also small fruits, seeds, occ. nectar, sap
Saltmarsh Common Yellowthroat *Geothlypis trichas sinuosa*	SSC	Yes	All year	Air May drink water, inhabits wetlands	M	Omnivore Insects, esp. caterpillars & other larvae, also spiders and a few seeds
California Towhee *Pipilo crissalis*	None	Yes	All year	Air, Soil, SW	U	Omnivore Seeds, insects, some fruits

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Vesper Sparrow ***Pooecetes gramineus***	None	Yes	Migrant - winter resident	Air	U	Omnivore 50% insects & spiders, 50% grass & forb seeds
Lark Sparrow *Chondestes grammacus*	None	Yes	All year	Air, Soil, SW Drinks and bathes	U	Omnivore Seeds, grains & insects, esp. grasshoppers
Suisun Song Sparrow ***Melospiza melodia maxillaris***	CCE SSC	Yes	All year	Air, Soil, Sed, SW Prefers moist areas	M	Omnivore 50% seeds, 50% insects, spiders, small inverts in breeding season. Berries, small fruits are minor. Also mollusks, crustaceans along coast
Savannah Sparrow ***Passerculus sandwichensis***	None	Yes	All year	Air, Soil, SW Scratches ground, seen bathing and drinking	M, U	Omnivore Grass & other seeds, insects, snails & spiders
Lincoln's Sparrow ***Melospiza lincolnii***	None	Yes	Winter	Air, Soil, Sed, SW Probably drinks	U	Omnivore Seeds, millipedes, other small inverts
Golden-crowned Sparrow ***Zonotrichia atricapilla***	None	Yes	Migrant - winter resident	Air, Soil	M	Omnivore Almost 100% plant foods (buds, seedlings, flowers, seeds), some insects and fruits when breeding
White-crowned Sparrow ***Zonotrichia leucophrys***	None	Yes	All year	Air, SW Probably require drinking water	M	Omnivore Primarily seeds of grasses & forbs, also green shoots, insects, spiders, flowers & berries

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Dark-eyed Junco *Junco hyemalis*	None	Yes	Migrant - winter visitor	Air, Soil, SW Drinks and bathes	U	Omnivore Insects, spiders, other small arthropods, seeds, fruits
Red-winged Blackbird *Agelaius pheoniceus*	None	Yes	All year	Air, SW Drinks, bathes	M, U	Omnivore Seeds, cultivated grains (90% in winter), insects & spiders
Tricolored Blackbird *Agelaius tricolor*	SSC	Yes	Winter	Air, Soil, Sed, SW Probably drinks	M	Omnivore Insects, spiders, seeds, cultivated grains.
Western Meadowlark *Sturnella neglecta*	None	Yes	All year	Air, Soil, SW Probes in earth, drinks & bathes	M, U	Omnivore 63% insects, spiders, sowbugs, snails, 37% grass and forb seeds and grains. Occ. carrion, bird eggs
Brewer's Blackbird *Euphagus cyanocephalus*	None	Yes	All year	Air, Soil, SW	M, U	Omnivore Mostly insects, also spiders, crustaceans, snails in sp & sum, seeds & cultivated grains are most of fall & winter diet
Brown-headed Cowbird *Molothrus ater*	None	Yes	All year	Air, Soil, Sed, SW	M, U	Omnivore Fall & win:mostly seeds & grains, Sp&Su: insects, spiders, snails often >50% diet
Northern Oriole *Icterus galbula*	None	Yes	Migrant - winter resident	Air	U	Omnivore 80+% insects & spiders, rest berries, fruits, buds & nectar

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Suisun Bay Residency	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Purple Finch *Carpodacus purpureus*	None	Yes	All year	Air, SW Requires either water or moist food	U	Omnivore Flowers, seeds, berries, buds, some insects. fewer insects in winter
House Finch ***Carpodacus mexicanus***	None	Yes	All year	Air, SW May nest in earthen bank. Needs water daily	M, U	Omnivore Mainly seeds of grasses and forbs, also buds, berries, small fruits, only small amt of insects
Lesser Goldfinch ***Carduelis psaltria***	None	Yes	All year	Air, SW Drinks water daily	U	Omnivore Mostly seeds, some buds, fruits, leaves, a few insects
American Goldfinch ***Carduelis tristis***	None	Yes	All year	Air, Soil, SW Drinks and bathes	U	Omnivore Mainly seeds, in spring, 50% insects, mostly aphids & caterpillars. Tree buds important in late winter, spring
House Sparrow ***Passer domesticus***	None	Yes	All year	Air, Soil, SW Probably drinks	U	Omnivore Primarily seeds, also fruits, other plant materials, some insects, scavenges human food scraps

APPENDIX A-4

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Notes:

- Common and scientific names of species that are shaded and in bold typeface reflect taxa that have been observed at WPNSTA Concord (Concord). Taxa appearing in regular typeface may occur at Concord.

- Blank cells indicate that information was unavailable, except for status.

Table Explanation

Status

Species of special conservation status, as registered in the California Department of Fish and Game's Natural Diversity Data Base, are indicated by the following codes.

SSC	California Department of Fish and Game (CDFG) Species of Special Concern
CE	State of California Endangered Species
CCE	State of California Candidate for Endangered Species
CT	State of California Threatened Species
CFP	State of California Fully Protected Species
FE	Federal Endangered Species
HS	Species designated for harvest under California State Fish and Game Code and USFWS regulations.
AB	Species listed on the Audubon Blue List of birds designated by the National Audubon Society as experiencing a population decline.
None	Species has no special status

Native

Yes	Species is native to California.
No	Species is not native to California.

NATURAL HISTORY OF BIRDS OF WPNSTA CONCORD
(Continued)

Primary Exposure

The primary exposure description reflects the primary routes of exposure to contaminants for the species, excluding exposure through ingestion of contaminated prey.

Air	Air at Concord
Soil	Soil at Concord
Sed	Sediments of Concord, Suisun Bay
SW	Surface Water of Concord (including Suisun Bay water)

Concord Habitat

M	Marsh
U	Upland

Feeding Guild

Carnivore	Eats primarily animal matter.
Herbivore	Eats primarily plant matter.
Omnivore	Eats a combination of animal and plant matter.

Sources

Zeiner and others. 1990.
USFWS. 1992.
Ehrlich and others 1988.
Bent. 1962.
Bent. 1963
Cogswell. 1977.

APPENDIX A-5

NATURAL HISTORY OF MAMMALS OF WPNSTA CONCORD

Species (and reference)	Status	CA Native	Residency	Breed	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Virginia Opossum ***Didelphis virginiana***	None	No	All year	Yes	Air, Soil, SW May nest in burrow, drinks water	M, U	Omnivore Carrion, insects, fruits, berries, veg, earthworms, fungi
Ornate Shrew ***Sorex ornatus***	SSC	Yes	All year	Yes	Air, Soil Nest in burrows	M	Carnivore Insects, inverts
Black-tailed Jackrabbit ***Lepus californicus***	None	Yes	All year	Yes	Air, Soil, SW Drink SW when avail.	U	Herbivore
California Ground Squirrel *Spermophilus beecheyi*	None	Yes	All year	Yes	Air, Soil, SW Excavate burrows, require very little water	U	Omnivore Seeds, nuts, fruits, grasses, forbs, insects, eggs, carrion
Beaver *Castor canadensis*	None	Yes	All year	Yes	Air, Soil, SW, Sed Burrow in banks, construct dams	M	Herbivore Grasses. leaves, aq. veg, trees, bark
Western Harvest Mouse ***Reithrodontomys megalotis***	None	Yes	All year	Yes	Air, Soil, SW drinks water	M, U	Omnivore Seeds, insects, fruit, shoots

APPENDIX A-5

NATURAL HISTORY OF MAMMALS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Residency	Breed	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Salt Marsh Harvest Mouse *Reithrodontomys raviventris*	FE CE	Yes	All year	Yes	Air, Soil, SW	M	Herbivore Leaves, seeds, stems
Deer Mouse *Peromyscus maniculatus*	None	Yes	All year	Yes	Air, Soil, SW	M, U	Omnivore Seeds, fruits, leaves, fungi, insects, animal material
California Vole *Microtus californicus*	None	Yes	All year	Yes	Air, Soil Burrow in soft soil	M, U	Herbivore Grasses, sedges, herbs
Muskrat *Ondatra zibethicus*	None	Yes	All year	Yes	Air, Soil, SW, Sed Burrow in banks or build houses above water level	M	Herbivore Aquatic plants, occasionally inverts and vertebrates (turtles, fish) taken opportunistically
House Mouse *Mus musculus*	None	No	All year	Yes	Air, Soil, SW	M	Omnivore Grains, fruits, meat, arthropods, etc.

APPENDIX A-5

NATURAL HISTORY OF MAMMALS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Residency	Breed	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Coyote ***Canis latrans***	None	Yes	All year	Yes	Air, Soil, Sed, SW Excavate dens, drink water	M	Omnivore Mice, rats, squirrels, gophers, lagomorphs, carrion, some insects, reptiles, amphibs, frutis, occ. birds, eggs, deer fawns
Red Fox ***Vulpes vulpes***	None	Yes	All year	Yes	Air, Soil Burrow in deep, loose soil	U	Carnivore Mainly small & med. mammals, squirrels, gophers, mice, marmots, rabbits, birds, eggs, occ. insects, carrion, fruit, earthworms

APPENDIX A-5

NATURAL HISTORY OF MAMMALS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Residency	Breed	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
Gray Fox *Urocyon cinereoargenteus*	None	Yes	All year	Yes	Air, Soil, SW May live in abandoned dens or burrows, drink water	M, U	Omnivore Rabbits, mice, gophers, woodrats, squirrels; also fruits, nuts, grains, insects, carrion, little herbage
Raccoon *Procyon lotor*	None	Yes	All year	Yes	Air, Soil, SW, Sed Forage in shallow water and on the ground, drink water	M	Omnivore Crayfish, fish, arthropods, amphibs, small mammals, birds, eggs, grains, acorns, nuts, fruits
Striped Skunk *Mephitis mephitis*	None	Yes	All year	Yes	Air, Soil, SW Excavate burrows, dig for food, drink water	M, U	Omnivore Insects, sm. mammals, sm. verts, eggs, crustaceans, fruits, seeds, some carrion

APPENDIX A-5

NATURAL HISTORY OF MAMMALS OF WPNSTA CONCORD
(Continued)

Species (and reference)	Status	CA Native	Residency	Breed	Habitat/ Primary Exposure	Concord Habitat	Feeding Guild
River Otter *Lutra canadensis*	None	Yes	All year	Yes	Air, Soil, Sed, SW nest in burrows & cavities, swim, dig on bottom of watercourses, drinks water	M, U	Carnivore Fish, crayfish, crustaceans, aquatic inverts, carrion, mammals, occasionally fruits
Tule Elk *Cervus elaphus nannodes*	None	Yes		U	Air, SW		Herbivore Grasses, forbs, twigs & leaves of shrubs & trees, fungi, mast, aq. veg.
Mule Deer ***Odocoileus hemionus***	None	Yes		U	Air, SW		Herbivore Shrubs, forbs, grasses, trees, also mushrooms, acorns

APPENDIX A-5

NATURAL HISTORY OF MAMMALS OF WPNSTA CONCORD
(Continued)

Notes:

- Common and scientific names of species that are shaded and in bold typeface reflect taxa that have been observed at WPNSTA Concord (Concord). Taxa in regular typeface may occur at Concord.

- Blank cells indicate that no information was available.

Table Explanation

Status

CE State of California Endangered Species
FE Federal Endangered Species
SSC State of California Species of Special Concern

California Native

Yes Species is native to California.
No Species is not native to California.

Residency

The seasons of expected residencies at Concord are indicated.

Breed

Yes Species is expected to breed and rear young at Concord
No Species is not expected to breed and rear young at Concord

APPENDIX A-5

NATURAL HISTORY OF MAMMALS OF WPNSTA CONCORD
(Continued)

Primary Exposure

The following desciptors indicate the primary routes of exposure to contaminants for the species, excluding exposure through ingestion of contaminated prey.

Air	Air at Concord
Soil	Soil at Concord
Sed	Sediments of Concord, Suisun Bay
SW	Surface water at Concord (including Suisun Bay water)

Concord Habitat

The following descriptors indicate expected occurrences of species in Concord habitat types.

M	Marsh
U	Upland

Feeding Guild

Carnivore	Species eats primarily animal matter.
Herbivore	Species eats primarily plant matter.
Omnivore	Species eats a combination of both plant and animal matter.

Sources

Zeiner and others. 1990.
Jameson and Peeters. 1988.
Ingels. 1965.

APPENDIX B

B-1 AVAIAN AND MAMMALIAN TOXICITY DATA FOR COPCs

B-2 EFFECTS OF INORGANICS ON TERRESTRIAL PLANTS

B-3 TOXIC EFFECTS OF INORGANICS ON SOIL FAUNA

B-4 LEAD BCFs FOR MARINE ORGANISMS

B-5 REPORTED BCFs FOR DDT RESIDUES IN AQUATIC AND TERRESTRIAL ORGANISMS

B-6 SELENIUM LOAELs AND NOAELs FOR AQUATIC AND TERRESTRIAL RECEPTORS

APPENDIX B-1

AVIAN AND MAMMALIAN TOXICITY DATA FOR COPCs

Element[a]	Organism	Exposure Route[b]	Effects	Reported Results			Reference
				Endpoint[c]	Value	Units[d]	
ARSENIC							
	Mallard	Feed	Lethality	LD50	2.5	mg/kg/day	NAS 1980
	Mouse	Feed	Reduced litter size	LOAEL	5	mg/kg diet	Eisler 1988a
	Hamster	Oral-gest	Maternal death	LOAEL	5	mg/kg/day	Eisler 1988a
	Mouse	Water	Reduced litter size after three generations, no other toxicity	LOAEL	1	mg/kg/day	ATSDR 1993b
CADMIUM							
	Mallard	Feed	Reduced egg production	LOAEL	200	mg/kg diet	Scheuhammer 1987
	Chicken	Feed	Reduced egg production	LOAEL	48	mg/kg diet	Scheuhammer 1987
	Mallard	Feed	Testicular atrophy	LOAEL	200	mg/kg diet	Scheuhammer 1987
	Japanese quail	Feed	Delayed testes maturation	LOAEL	75	mg/kg diet	Scheuhammer 1987
	Rat	Oral	Neurobehavior development	LOAEL	1	mg/kg/day	ATSDR 1993e
	Rat	Water	Decreased fetal wt	LOAEL	5.5	mg/kg/day	ATSDR 1993e
	Rat	Water	Decreased fetal wt	LOAEL	8.4	mg/kg/day	ATSDR 1993e
	Rat	Feed	Reduced birth wt	LOAEL	19.7	mg/kg/day	ATSDR 1993e
	Mouse	Water	Congenital abnormalities; reproductive failure	LOAEL	1.9	mg/kg/day	ATSDR 1993e
	Rat	Water	Testicular necrosis	LOAEL	14	mg/kg/day	ATSDR 1993e
	Rat	Feed	Developmental effects	NOAEL	12.5	mg/kg/day	ATSDR 1993e
COPPER							
	Chicken	Feed	No growth retardation	NOAEL	40.5	mg/kg/day	NAS 1980
	Rat	Feed	Decrease body wt	LOAEL	150	mg/kg/day	ATSDR 1990
	Rat	Feed	Decreased growth, testes wt	LOAEL	130	mg/kg/day	ATSDR 1990

APPENDIX B-1

AVIAN AND MAMMALIAN TOXICITY DATA FOR COPCs
(Continued)

Element[a]	Organism	Exposure Route[b]	Effects	Reported Results			Reference
				Endpoint[c]	Value	Units[d]	
	Rat	Feed	No decreased wt gain	NOAEL	89	mg/kg/day	ATSDR 1990
COPPER (CONTINUED)							
	Rat	Feed	Decreased wt gain	LOAEL	144	mg/kg/day	ATSDR 1990
	Pig	Feed	Decreased wt gain	LOAEL	14.6	mg/kg/day	ATSDR 1990
	Mouse	Feed-gest	No fetal mortality	NOAEL	78	mg/kg/day	ATSDR 1990
	Mouse	Feed-gest	Fetal mortality	LOAEL	104	mg/kg/day	ATSDR 1990
	Mouse	Water	Survival	LOAEL	42.5	mg/kg/day	ATSDR 1990
	Mink	Feed	Reproductive success normal	NOAEL	12.9	mg/kg/day	ATSDR 1990
LEAD							
	Japanese quail	Feed	Reduced egg production	LOAEL	1.25	mg/kg/day	Edens and Gerlich 1983
	Am. kestrel	Feed	Normal BW and histopath; reduced blood ALAD	LOAEL	50	mg/kg diet	Franson and others 1983
	Kestrel chicks	Feed	Reduced growth	LOAEL	125	mg/kg diet	Hoffman and others 1985
	Quail	Feed	Reduced egg production	LOAEL	1	mg/kg diet	Pattee 1984
	Quail	Feed	Reduced hatching, growth	LOAEL	1,000	mg/kg diet	Pattee 1984
	Rat	Water	Growth retardation	LOAEL	50	mg/kg/day	Kimmel and others 1980
	Rat	Water	Testicular atrophy	LOAEL	90	mg/kg/day	Chowdhury and others 1984
	Mouse	Feed	Decrease live births	LOAEL	3.2	mg/kg/day	Al-Hakkak and others 1988
	Mouse	Feed	Decreased fertility	LAOEL	830	mg/kg/day	Maisin and others 1978
SELENIUM							
Selenite	Quail	Feed	Reduced egg hatching	LOAEL	1	mg/kg/day	El-Bergearmi and others 1977

APPENDIX B-1

AVIAN AND MAMMALIAN TOXICITY DATA FOR COPCs
(Continued)

Element[a]	Organism	Exposure Route[b]	Effects	Reported Results			Reference
				Endpoint[c]	Value	Units[d]	
SELENIUM (CONTINUED)							
Selenite	Mouse	Water	No effects on reproduction, skeleton, gross anatomy	NOAEL	0.78	mg/kg/day	Patrias 1969
Selenite	Mouse	Water	Fetal body wt	LOAEL	0.78	mg/kg/day	Patrais 1969
+4	Mouse	Water	Decreased fetal growth	NOAEL	0.17	mg/kg/day	ATSDR 1988
+4	Mouse	Water	Decreased fetal growth	LOAEL	0.34	mg/kg/day	ATSDR 1988
+4	Hamster	Feed	Decreased body wt	LOAEL	0.42	mg/kg/day	ATSDR 1988
+6	Mouse	Water	Decreased breeding success	LOAEL	0.42	mg/kg/day	ATSDR 1988
ZINC							
	Japanese quail	Feed	Decreased wt gain	LOAEL	270	mg/kg diet	NAS 1980
	Chicken	Feed	Decreased wt gain	LOAEL	800	mg/kg diet	NAS 1980
	Turkey	Feed	Decreased wt gain	LOAEL	4,000	mg/kg diet	NAS 1980
	Chicken-chicks	Feed	Decreased growth	LOAEL	1,500	mg/kg diet	NAS 1980
	Ducks	Feed	Reduced survival	LOAEL	2,500	mg/kg diet	Eisler 1993
	Chicken-chicks	Feed	Immunosuppression	LOAEl	178	mg/kg diet	Eisler 1993
	Rat	Feed	Fetal resorption	LOAEL	200	mg/kg/day	ATSDR 1989
	Rat	Feed	Reproductive dysfunction	LOAEL	500	mg/kg/day	ATSDR 1989
DDT							
	Rat	Feed	Decreased growth	NOAEL	1	mg/kg/day	ATSDR 1992
	Rat	Feed	Decreased growth	LOAEL	10	mg/kg/day	ATSDR 1992
	Rat	Feed	Decreased fertility	LOAEL	0.35	mg/kg/day	ATSDR 1992
	Mouse	Feed	Small litter size	LOAEL	0.91	mg/kg/day	ATSDR 1992

APPENDIX B-1

AVIAN AND MAMMALIAN TOXICITY DATA FOR COPCs
(Continued)

Element[a]	Organism	Exposure Route[b]	Effects	Reported Results			Reference
				Endpoint[c]	Value	Units[d]	
DDT (CONTINUED)							
	Mouse	Feed	Increase estrus	LOAEL	1.67	mg/kg/day	ATSDR 1992

aElement: Form of element indicated when reported
bExposure route: Gavage = introduced into stomach by tube; -gest = dose administered to female during gestation; Oral = means of administration not known
cEndpoint: LD50, LD100 = dose lethal to 50 or 100%, respectively; LOAEL = Lowest observable adverse effect level; NOAEL = no observable adverse effect level.
dUnits: mg/kg/day = daily dose per kilogram body weight; mg/kg diet = concentration in diet; NOTE - doses and dietary concentrations cannot be directly compared

APPENDIX B-2

EFFECTS OF INORGANICS ON TERRESTRIAL PLANTS

Element[a]	Organism[b]	Effect	Value (mg/kg)	pH	Reference[c]
ARSENIC					
soluble	Alfalfa, barley	"Marked change" in crops	2		1
soluble	Alfalfa, barley	"Poor condition" of young in fields	3.4-9.5		1
total (soluble)	Crops	Reduction in yield	25-85 (3-28)		2
CADMIUM					
	Pine, choke cherry	Reduction in growth	100		4
	Spinach	25% reduction in yield	4		4
	Rice	25% reduction in yield	640		4
	Agronomic & grassland spp	Threshold based on yield	100		5
COPPER					
	n.s.	Suggested toxicity threshold	150		3
	Oats	<15% reduction in yield	100	5.7	3
	Mustard	>70% reduction in yield	200	5.7	3
	Oats, mustard	No effect on yield	200	6.4	3
	Oats	>60% reduction in yield	500	5.7	3
	Mustard	>90% reduction in yield		5.7	3
	Oats	<20% reduction in yield	500	6.4	3
	Mustard	>70% reduction in yield	500	6.4	3

APPENDIX B-2

EFFECTS OF INORGANICS ON TERRESTRIAL PLANTS
(Continued)

Element[a]	Organism[b]	Effect	Value (mg/kg)	pH	Reference[c]
COPPER (CONTINUED)					
	Maize	"Slight toxic symptoms"	360		3
	All crops	"Severe toxicity"	800		3
	Barley	Slight stunting	200	5.2	3
	Barley	Root knotting	200	6.8	3
	Barley	Failure to form ears	600	5.2	3
	Barley	Slight stunting	600	6.8	3
	Barley	No adverse effects	1200	8.3	3
	Citrus seedlings	"Appreciable" chlorosis	150	<5.0	1
	Citrus seedlings	Reduction in yield, twig dieback	150-200		1
extractable Cu	Spinach, gladiolus	"Toxicity symptoms"	98-130	4.5-4.7	1
	Agronomic & grassland spp	Threshold based on yield	100		5
LEAD					
	Roadside weed	Reduced pollen, seed germination	500		4
	Roadside weed	Normal pollen, seed germination	46		4
SELENIUM					
sodium selenate	Wheat	Chlorosis, extreme stunting	30		1
sodium selenite	Wheat	Decreased growth rate	1-4		1
sodium selenite	Wheat	Extreme chlorosis, death	8-64		1

APPENDIX B-2

EFFECTS OF INORGANICS ON TERRESTRIAL PLANTS (Continued)

Element[a]	Organism[b]	Effect	Value (mg/kg)	pH	Reference[c]
ZINC					
	Wheat	No adverse effects	3,000	7.5	3
	Wheat	Slight chlorosis	4,000	7.5	3
extractable	Corn	"Toxicity"	450	acidic	4
extractable	Cowpea	"Toxicity"	180	acidic	4
extractable	Raspberry, maize, pea, tomato	Diminished yields	100-150 (1,000 total)	7.5	3
extractable	Chrysanthemum	"Poor growth"	93		3
extractable	Wall flower	"Poor growth"	154		3
extractable	Sugar beet	"Poor growth"	96		3
extractable	Bedding plants	"Poor growth"	150		3

a Element: form of element indicated when known; total concentration measured unless noted (e.g., "extractable")
b Organism: N.S. = not stated
c Reference: 1 = Chapman 1966, 2 = Eisler 1988a, 3 = Patterson 1971, 4 = Adriano 1986, 5 = EPA 1987

APPENDIX B-3

TOXIC EFFECTS OF INORGANICS ON SOIL FAUNA

Element	Species	Effect	Value (mg/kg)	Reference
ARSENIC				
	Microbiota	Reduced growth & metabolism	375	Eisler 1988a
	Earthworms	None present	150	Eisler 1988a
CADMIUM				
	Eisenia fetida earthworm	2 wk LC50 in artificial soil	1,843	Neuhauser 1985
	Lumbricus rubellis earthworm	6 wk LC50	500	Ma and others 1983
	L. Rubellis	Threshold for growth, sexual develop.	20	Ma and others 1983
	L. Rubellis	50% reduction in growth, sexual develop.	60	Ma and others 1983
	E. fetida	Reduction in growth, reproduction	100	Neuhauser and others 1984
COPPER				
	E. fetida	2 wk LC50 in artificial soil	643	Neuhauser and others 1984
	L. rubellis	6 wk LC50	1,000	Ma 1982

APPENDIX B-3

TOXIC EFFECTS OF INORGANICS ON SOIL FAUNA
(Continued)

Element	Species	Effect	Value (mg/kg)	Reference
COPPER (CONTINUED)				
	L. rubellis	50% reduction in growth, sexual develop.	150	Ma 1982
	E. fetida	Reduction in growth, reproduction	2,000	Neuhauser and others 1984
	Earthworms	No effect on population density	5-60	Ma 1982
	Earthworms	50% reduction in density	88	Ma 1982
	Earthworms	75% reduction in density	116	Ma 1982
LEAD				
	E. fetida	2 wk LC50	5,491	Neuhauser and others 1984
	E. fetida	Reduction in reproduction (6 wk)	5,000	Neuhauser 1985
	E. fetida	Reduction in growth (6 wk)	40,000	Neuhauser 1985
	Inverterbrates	No decrease in abundance	0-95	Williamson and Evans 1972
ZINC				
	Earthworms	Criterion for protection	97	Eisler 1993
	Earthworms	Threshold for adverse effects	400	Eisler 1993
	E. fetida	2 wk LC50 in artificial soil	662	Neuhauser 1985
	E. fetida	Reduction in reproduction (6 wk)	2,500	Neuhauser 1985
	E. fetida	Reduction in growth (6 wk)	5,000	Neuhauser and others 1984

APPENDIX B-4

LEAD BCFs FOR MARINE ORGANISMS

Organism	BCF	Exposure Time (concentration, when available)	Reference[a]
Diatom *Phaeodactylum tricornutum*	582,000	<1 hour (20 μg Pb^{2+}/L)	1
American oyster (soft parts) *Crassostrea virginica*	6,000	140 days (1.0 μg Pb/L)	2
American oyster (soft parts) *Crassostrea virginica*	3,454	140 days (3.3 μg Pb/L)	2
Blue mussel (kidney) *Mylitus edulis*	12,580	63 days (10 μg Pb^{2+}/L)	3
Blue mussel (soft parts) *Mylitus edulis*	1,580	63 days (10 μg Pb^{2+}/L)	3
Blue mussel (soft parts) *Mylitus edulis*	25,670	150 days (500 μg Pb^{2+}/L)	4
Soft shell clam (soft parts) *Mya arenaria*	158 - 351	7 - 42 days (14 or 70 μg Pb/L)	5

Notes: Modified from Eisler (1988b).

a All references appear as cited by Eisler (1988b). 1 = Schulz-Baldes and Lewin 1976; 2 = Zaroogian and others 1979; 3 = Schulz-Baldes 1974; 4 = Schulz-Baldes 1972; 5 = Eisler 1977

BCF Bioconcentration factor

APPENDIX B-5

REPORTED BCFs FOR DDT RESIDUES IN AQUATIC AND TERRESTRIAL ORGANISMS

Environment and Organism	BCF		Reference[a]
	Max BCF	Min BCF	
Terrestrial-Aquatic Microcosm			
Snail	3.4×10^4		1
Mosquito larvae	8.2×10^3		1
Mosquito fish	8.5×10^4		1
Snail	1.1×10^5		2
Mosquito larvae	930		2
Mosquito fish	2.6×10^4		2
Daphnia	6.2×10^3		2
Algae	5.9×10^3		2
Soil			
Earthworm	73	0.67	3
Beetle	2.81	0.31	3
Slug	3.70	2.33	3
Crop root	0.13	0.04	3
Crop foliage	0.08		3
Water			
Sea squirt	1×10^6	200	3
Sea hare	1.78×10^5		3
Eastern oyster, clam	7.0×10^4	60	3
Shrimp	2.8×10^3	280	3
Crab	144		3
Crayfish	97	17	3
Snail	1.48×10^3		3
Plankton	16,666	250	3
Fish	829,300	5 - 1450	3
Fish (DDD)	9,214	417	3
Algae	33	0.34	3

Environment and Organism	BCF		Reference[a]
	Max BCF	Min BCF	
Aquatic plants	1.0×10^5	0.45	3
Diet			
Pheasant	2.91		3
Woodcock	4.5	2.6	3
Bald eagle (brain)	0.1		3
Bald eagle (liver)	1.9		3
Bald eagle (fat)	35.7		3

Notes:

a 1 = Metcalf and others 1973, as cited in Callahan and others 1979; 2 = Booth 1975, as cited in Callahan and others 1979; 3 = Amdur and others 1993

APPENDIX B-6

SELENIUM LOAELs AND NOAELs FOR AQUATIC AND TERRESTRIAL RECEPTORS

Organism	LOAEL (μg/g dry weight)	NOAEL (μg/g dry weight)	Effect	Selenium Form
Chinook salmon[1]		< 6.5	Parr-smolt transition	Organic selenium
Chinook salmon[2]	9.6	5.3 (estimated)	Survival	Organic selenium
Mallard[3,4]	8	4 (estimated)	Hatchability	Organic selenium
Mammals[4]		5	Growth	Inorganic and organic selenium

Notes:

Estimated NOAELs were estimated from LOAELs.

References:

1 Hamilton and others 1986, as cited in Taylor and others 1992
2 Hamilton and others 1990, as cited in Taylor and others 1992
3 Heinz and others 1990, as cited in Taylor and others 1992
4 Peterson and Nebeker 1992, as cited in Taylor and others 1992

APPENDIX C

C-1 HAZARD QUOTIENTS AND HAZARD INDEX FOR 5 METALS AT RASS AND REFERENCE SITES

C-2 HAZARD QUOTIENTS FOR SELENIUM AT RASS AND REFERENCE SITES

APPENDIX C-1
HAZARD QUOTIENTS AND HAZARD INDEX FOR 5 METALS
AT RASS AND REFERENCE SITES
Based on ER-L Values (1)

Sample ID	Arsenic	Cadmium	Copper	Lead	Zinc	Hazard Index
RASS 1						
1M39-023-A1-031891	0.18	0.08	0.83	0.17	0.16	1.43
1M61-023-A1-031891	0.46	0.08	0.40	0.16	0.36	1.46
1M64-023-A1-031891	1.01	0.06	0.23	0.12	0.12	1.55
1M69-023-A1-031891	0.39	0.12	0.40	0.16	0.64	1.70
1M57-023-A1-061191	0.74	0.35	0.29	0.26	0.39	2.03
1M67-023-A1-031891	0.76	0.16	0.65	0.22	0.55	2.34
1M58-023-A1-032091	0.57	0.13	0.65	0.14	0.91	2.40
1M62-023-A1-031891	2.57	0.12	0.59	0.23	0.51	4.02
1M31-023-A1-031491	1.35	0.91	1.78	0.72	1.00	5.75
1M26-023-A1-031491	1.57	0.83	1.68	0.99	0.87	5.93
1M32-023-A1-031491	1.49	0.78	1.88	0.78	1.01	5.94
1P22-023-A1-031491	1.87	0.69	1.90	0.84	0.93	6.23
1P25-023-A1-031491	1.50	1.03	1.95	0.75	1.01	6.23
1M28-023-A1-031491	1.85	1.06	1.74	0.67	0.96	6.28
1M27-023-A1-031491	1.67	1.11	1.91	1.08	0.86	6.64
1P23-023-A1-031491	2.04	1.00	1.91	0.86	0.97	6.78
1M29-023-A1-031491	2.62	0.67	1.96	0.97	1.12	7.34
1P24-023-A1-031491	1.43	1.48	2.14	1.04	1.26	7.35
1M30-023-A1-031491	1.85	1.28	1.93	1.27	1.28	7.62
1P06-023-A1-031591	2.36	1.10	2.17	0.54	1.61	7.77
1M54-023-A1-031491	1.92	1.31	2.08	1.18	1.42	7.91
1M51-023-A1-061191	2.78	1.42	1.75	1.45	0.92	8.32
1M55-023-A1-031491	1.56	1.06	1.91	1.31	2.67	8.52
1M49-023-A1-031491	3.74	0.96	1.49	1.71	0.82	8.72
1M53-023-A1-061191	2.22	0.99	1.79	2.11	1.82	8.92
1M52-023-A1-031491	3.44	1.11	2.20	1.73	1.22	9.68
1M12-023-A1-031591	2.52	2.00	1.93	1.30	2.33	10.08
1M25-023-A1-031491	5.72	0.61	2.12	0.85	1.04	10.33
1M48-023-A1-061191	3.56	1.11	2.57	1.69	1.62	10.55
1M23-023-A1-031491	5.30	0.73	2.50	2.21	2.17	12.92
1P21-023-A1-031591	4.23	1.03	3.42	2.36	2.29	13.32
1M68-023-A1-031891	1.63	1.63	3.69	2.25	4.20	13.42
1M13-023-A1-050691	6.60	1.33	2.04	2.98	0.88	13.83
1M24-023-A1-031591	5.85	0.92	2.85	1.93	2.50	14.04
1M21-023-A1-050391	4.77	1.03	5.86	1.88	1.88	15.42
1M04-023-A1-031891	2.88	1.33	5.58	2.59	3.07	15.45
1M50-023-A1-031591	7.99	1.71	2.52	3.32	1.21	16.75
1P05-023-A1-031591	5.87	3.73	3.90	1.27	3.42	18.18

APPENDIX C-1
HAZARD QUOTIENTS AND HAZARD INDEX FOR 5 METALS
AT RASS AND REFERENCE SITES
Based on ER-L Values (1)

Sample ID	Arsenic	Cadmium	Copper	Lead	Zinc	Hazard Index
1P07-023-A1-031591	7.77	1.61	5.08	0.81	3.05	18.32
1M01-023-A1-050191	3.42	1.64	6.35	3.43	3.52	18.36
1M14-023-A1-050691	10.53	1.28	2.68	3.60	0.92	19.02
1P09-023-A1-050291	8.80	2.75	3.93	0.66	4.33	20.46
1M15-023-A1-031591	8.13	1.23	3.46	1.11	6.97	20.91
1P19-140-A1-050391	9.00	1.31	6.81	1.94	2.76	21.81
1M10-023-A1-031891	3.80	1.56	7.52	2.93	6.65	22.46
1M56-023-A1-031591	6.98	1.08	4.17	2.17	8.22	22.63
1M18-023-A1-050391	5.40	1.53	7.19	2.66	7.32	24.09
1M16-023-A1-050691	8.45	1.61	7.84	2.69	7.41	28.00
1M07-023-A1-031891	13.25	1.20	9.53	1.48	3.02	28.47
1P01-023-A1-031891	1.71	0.87	22.94	3.58	4.60	33.69
1M19-023-A1-050391	12.17	1.75	12.34	1.96	7.02	35.25
1M20-023-A1-050391	16.14	1.58	10.33	3.05	5.42	36.52
1P67-023-A1-061291	7.82	3.50	8.04	1.34	16.71	37.40
1P18-023-A1-031591	22.51	1.94	12.42	3.36	3.88	44.12
1P03-220-A1-050191	7.04	3.73	22.42	4.78	6.57	44.54
1P02-023-A1-050191	11.28	2.89	23.44	2.64	4.75	44.99
1M22-023-A1-031591	28.29	1.08	11.63	3.76	1.58	46.34
1P13-023-A1-031591	41.79	1.41	3.30	1.55	1.28	49.34
1P17-023-A1-031591	31.13	1.17	13.15	4.29	1.42	51.16
1M03-023-A1-050191	14.23	6.50	21.93	3.96	6.82	53.45
1M08-023-A1-031891	27.54	2.04	11.27	8.48	6.95	56.27
1M02-023-A1-050191	21.43	5.32	24.52	4.62	3.60	59.49
1P16-023-A1-050291	45.37	2.08	5.27	1.77	6.55	61.04
1M11-023-A1-050691	55.92	1.39	6.86	3.62	3.12	70.91
1P20-023-A1-050391	45.61	1.81	17.50	5.90	1.84	72.65
1P63-023-A1-061291	51.99	2.69	18.65	2.81	6.63	82.77
1M17-023-A1-031591	38.41	2.06	28.69	2.23	12.21	83.60
1P15-023-A1-031591	67.32	2.39	5.79	1.31	7.46	84.27
1M05-023-A1-050191	44.39	2.39	28.00	4.65	8.69	88.12
1M06-023-A1-031891	53.82	1.56	30.84	5.94	2.15	94.31
1P66-023-A1-061291	74.96	1.53	12.80	3.28	2.24	94.80
1P64-023-A1-061291	80.28	1.56	13.10	3.53	2.50	100.97
1P08-023-A1-050291	58.66	10.69	24.13	3.18	19.24	115.91
1P65-023-A1-061291	87.03	2.92	23.26	6.57	5.51	125.29
1M09-023-A1-050191	109.11	1.08	18.90	7.25	3.40	139.74
1P14-023-A1-050291	138.82	3.36	11.00	2.55	6.24	161.97
1P10-023-A1-031591	152.83	2.63	16.05	4.13	6.52	182.15

APPENDIX C-1
HAZARD QUOTIENTS AND HAZARD INDEX FOR 5 METALS AT RASS AND REFERENCE SITES
Based on ER-L Values (1)

Sample ID	Arsenic	Cadmium	Copper	Lead	Zinc	Hazard Index
1P04-023-A1-031891	101.99	4.48	45.98	25.54	7.81	185.80
1P12-023-A1-050291	264.63	1.94	14.60	5.20	1.46	287.83
1P11-140-A1-050291	284.96	3.11	15.55	5.60	3.70	312.92
RASS 2						
2M13-023-A1-032091	1.57	0.68	0.95	1.47	1.51	6.20
2M18-023-A001-032091	0.65	0.57	2.85	0.53	1.79	6.39
2M24-023-A1-061391	2.02	0.63	1.56	2.08	1.51	7.81
2M14-023-A1-061391	1.90	0.92	1.81	2.72	2.48	9.83
2M17-023-A001-032091	3.48	1.18	2.37	1.02	3.39	11.42
2M09-023-A1-032091	1.98	2.03	3.51	2.28	11.02	20.82
2M15-023-A1-032091	7.37	3.73	4.97	2.17	4.35	22.59
2M12-023-A1-061391	3.87	2.64	7.03	5.86	5.95	25.35
2P06-023-A1-051491	3.54	1.56	8.22	5.80	7.62	26.74
2M10-023-A1-050991	2.47	2.48	7.32	4.33	10.42	27.01
2M08-023-A1-051491	3.47	1.86	7.30	4.60	10.34	27.57
2P07-023-A1-050991	2.81	1.64	8.34	3.95	10.96	27.70
2M06-140-A1-032091	2.74	2.52	8.14	6.23	12.18	31.81
2M16-023-A001-032091	8.54	4.02	6.34	8.79	9.49	37.18
2P02-023-A1-051591	3.80	12.06	4.63	2.71	20.29	43.48
2P05-023-A1-032091	8.52	4.14	15.03	4.61	20.20	52.51
2P01-023-A1-051591	5.14	9.61	10.71	4.78	24.89	55.12
2M03-140-A1-032091	10.15	17.17	5.32	2.23	21.69	56.55
2P03-140-A1-032091	4.83	7.06	12.34	9.99	24.67	58.89
2M04-023-A1-051591	4.69	10.31	16.27	10.21	20.80	62.28
2M05-023-A1-051591	2.07	18.23	4.38	4.02	36.29	64.99
2M11-023-A1-061391	10.20	10.28	21.19	10.67	15.24	67.57
2M02-023-A1-032091	3.11	8.03	12.22	21.78	25.04	70.18
2M01-023-A1-032091	5.82	8.53	13.59	20.28	23.82	72.03
2P04-023-A1-051591	3.77	27.58	4.46	3.18	47.52	86.52
2M07-023-A1-051591	11.36	19.92	15.98	9.21	45.40	101.87
RASS 3						
3M22-023-A001-032191	0.68	0.31	0.48	0.56	0.51	2.53
3M06-140-A1-031291	0.53	0.49	0.59	0.66	1.00	3.26
3P02-023-A1-031291	1.09	0.41	0.55	0.59	0.67	3.31
3M14-023-A1-031291	1.25	0.39	0.66	0.53	0.54	3.37
3M41-023-A001-031391	0.28	0.62	0.31	0.20	2.00	3.41
3M08-023-A1-031291	0.61	0.48	0.60	0.60	1.36	3.64
3M03-023-A1-031291	1.02	0.53	0.66	0.70	0.78	3.70
3M01-023-A1-031291	0.84	0.41	0.63	0.97	0.91	3.76

APPENDIX C-1
HAZARD QUOTIENTS AND HAZARD INDEX FOR 5 METALS
AT RASS AND REFERENCE SITES
Based on ER-L Values (1)

Sample ID	Arsenic	Cadmium	Copper	Lead	Zinc	Hazard Index
3P03-023-A1-031291	0.71	0.59	0.64	0.51	1.44	3.90
3P01-140-A1-050891	0.57	0.44	0.64	1.34	0.98	3.97
3M13-023-A1-031291	1.48	0.43	0.92	1.13	0.57	4.53
3M18-023-A1-031291	1.07	0.58	1.03	1.18	0.88	4.75
3M31-023-A001-032291	0.53	0.51	0.72	0.96	2.13	4.85
3M02-140-A1-050891	0.74	0.55	0.77	1.55	1.28	4.89
3M11-023-A1-050991	0.35	0.64	0.72	1.36	1.90	4.97
3M04-023-A1-050891	0.70	0.69	0.71	1.69	1.32	5.11
3M17-023-A1-031291	1.38	0.56	1.53	1.18	0.76	5.41
3P07-023-A1-032191	0.76	0.51	0.92	1.59	1.68	5.45
3M05-140-A1-050891	0.74	0.61	0.91	1.76	1.72	5.75
3M07-023-A1-050991	0.63	0.75	0.86	1.85	1.92	6.01
3M42-023-A1-061491	1.38	0.75	1.05	1.92	1.05	6.15
3M19-023-A1-031291	0.70	0.81	0.66	2.56	2.36	7.09
3P08-220-A1-050891	1.52	0.58	1.30	2.30	1.54	7.25
3M15-023-A1-031291	1.43	0.57	1.00	1.09	3.32	7.41
3P06-023-A1-050991	0.55	0.89	0.90	2.65	2.90	7.88
3M16-023-A1-032191	1.77	0.78	2.58	1.62	1.25	8.01
3P09-220-A1-050891	1.78	0.71	1.46	2.74	1.52	8.21
3P05-023-A1-031291	1.17	0.77	0.86	1.81	3.90	8.51
3P04-140-A1-050991	0.57	1.03	0.99	3.18	2.91	8.68
3M24-023-A001-032191	0.50	2.92	0.59	1.83	6.13	11.97
3M20-001-A1-031291	0.70	1.62	1.27	3.40	5.69	12.68
3M27-023-A001-032191	0.34	2.98	2.38	0.94	9.34	15.97
3M29-023-A001-032291	0.54	3.10	1.67	1.42	9.44	16.17
3M10-023-A1-032191	0.80	4.28	1.28	9.71	15.32	31.38
3M12-023-A1-031291	1.30	6.06	4.13	15.81	39.87	67.16
3M26-023-A001-032191	1.35	8.54	9.28	18.86	59.52	97.56
3M09-023-A1-031291	1.82	10.61	4.42	30.37	121.56	168.77
3M33-023-A001-031391	19.59	2.61	0.99	184.20	5.03	212.41
RASS 4						
4M11-035-A1-031191	1.11	0.50	0.63	0.91	0.46	3.62
4M15-023-A001-032191	2.11	1.58	0.32	0.31	0.44	4.75
4M13-023-A001-031191	2.22	1.83	0.71	0.28	0.56	5.60
4M12-023-A001-031191	2.44	1.64	0.75	0.32	0.76	5.91
4M23-023-A1-052091	1.15	1.50	0.97	1.32	1.06	6.00
4M03-140-A1-050791	1.50	1.17	1.24	1.65	1.21	6.76
4M14-023-A001-031191	2.65	3.62	0.42	0.24	0.63	7.56
4M09-023-A1-031191	2.41	2.89	0.82	1.22	0.55	7.90

APPENDIX C-1
HAZARD QUOTIENTS AND HAZARD INDEX FOR 5 METALS AT RASS AND REFERENCE SITES
Based on ER-L Values (1)

Sample ID	Arsenic	Cadmium	Copper	Lead	Zinc	Hazard Index
4M16-023-A001-032191	3.07	4.90	0.51	0.29	1.05	9.82
4M10-140-A1-031191	2.77	4.38	0.92	1.29	0.63	9.99
4M01-140-A1-031191	1.05	0.83	1.59	4.93	3.13	11.53
4M02-035-A1-050791	0.98	1.14	1.23	5.10	3.50	11.94
4M06-023-A1-050791	3.73	5.17	1.44	1.02	1.25	12.60
4P01-035-A1-050791	1.39	1.38	1.82	5.84	3.53	13.96
4P02-140-A1-050791	4.79	5.92	1.57	1.03	1.39	14.70
4M08-023-A1-031191	5.31	8.31	1.21	0.86	0.92	16.61
4M05-023-A1-050791	4.81	7.61	2.50	1.42	1.78	18.12
4P03-023-A1-050791	4.50	9.31	2.27	1.07	1.63	18.78
4P05-023-A1-050791	5.11	8.10	3.10	1.27	1.88	19.46
4M04-023-A1-050791	7.50	6.44	2.59	1.55	1.46	19.53
4M07-023-A1-031191	3.72	4.13	2.03	25.39	1.28	36.55
4P04-023-A1-050791	10.04	6.39	2.91	48.26	1.16	68.76
Reference Site 1 (Upland)						
R101-023-A1-051791	0.64	0.35	0.61	0.67	0.82	3.08
R104-023-A1-051791	0.54	0.39	0.66	0.88	0.69	3.16
R103-023-A1-051791	0.56	0.42	0.62	0.97	0.68	3.26
R102-023-A1-051791	0.56	0.55	0.66	0.96	0.74	3.47
Reference Site 2 (Marsh)						
R203-023-A1-051691	1.58	0.98	2.29	0.79	1.21	6.84
R205-023-A1-051691	2.26	0.85	3.20	1.57	1.33	9.22
R209-023-A1-051691	3.88	1.73	3.43	2.20	0.79	12.02
R210-023-A1-051691	3.49	1.00	5.78	2.13	1.14	13.55
R204-023-A1-051691	3.21	1.14	5.28	3.38	1.50	14.51
R206-023-A1-051691	3.39	0.84	6.26	3.48	1.72	15.69
ER-L Value (1)						
	8.2 ppm	1.2 ppm	34.0 ppm	46.7 ppm	150 ppm	

1 NOAA 1991; Mac Donald 1993

APPENDIX C-2
HAZARD QUOTIENTS FOR SELENIUM AT RASS AND REFERENCE SITES
Based on Amphipod AET(1)

Sample ID	Selenium Hazard Quotient
RASS 1	
1M64-023-A1-031891	0.37
1M60-023-A1-031891	0.45
1M59-023-A1-031891	0.46
1M67-023-A1-031891	0.64
1M39-023-A1-031891	0.64
1M69-023-A1-031891	0.69
1M58-023-A1-032091	0.72
1M62-023-A1-031891	0.76
1M68-023-A1-031891	0.94
1M57-023-A1-061191	2.25
1M01-023-A1-050191	2.55
1M04-023-A1-031891	2.55
1P01-023-A1-031891	2.55
1P03-220-A1-050191	2.70
1M07-023-A1-031891	3.25
1P05-023-A1-031591	3.35
1M61-023-A1-031891	3.46
1P06-023-A1-031591	3.55
1P09-023-A1-050291	4.25
1M32-023-A1-031491	4.90
1M23-023-A1-031491	5.20
1M30-023-A1-031491	5.20
1P24-023-A1-031491	5.35
1M26-023-A1-031491	5.55
1M29-023-A1-031491	5.60
1M24-023-A1-031591	5.65
1M28-023-A1-031491	5.65
1M31-023-A1-031491	5.65
1P21-023-A1-031591	5.85
1M52-023-A1-031491	5.90
1M22-023-A1-031591	6.00
1M56-023-A1-031591	6.00
1P22-023-A1-031491	6.00
1M49-023-A1-031491	6.18
1M53-023-A1-061191	6.45
1P23-023-A1-031491	6.50
1P25-023-A1-031491	6.50

APPENDIX C-2
HAZARD QUOTIENTS FOR SELENIUM AT
RASS AND REFERENCE SITES
Based on Amphipod AET(1)

Sample ID	Selenium Hazard Quotient
1M16-023-A1-050691	6.65
1P13-023-A1-031591	6.65
1M55-023-A1-031491	6.85
1M27-023-A1-031491	7.15
1P67-023-A1-061291	7.15
1M48-023-A1-061191	7.35
1P63-023-A1-061291	7.55
1M11-023-A1-050691	8.15
1P16-023-A1-050291	8.15
1M15-023-A1-031591	8.35
1P07-023-A1-031591	8.55
1M13-023-A1-050691	8.65
1M14-023-A1-050691	8.85
1M51-023-A1-061191	9.00
1M54-023-A1-031491	9.00
1M25-023-A1-031491	9.30
1M10-023-A1-031891	10.15
1M50-023-A1-031591	10.60
1P64-023-A1-061291	10.65
1P66-023-A1-061291	10.85
1P18-023-A1-031591	11.00
1P11-140-A1-050291	12.35
1M08-023-A1-031891	13.00
1M12-023-A1-031591	13.35
1P65-023-A1-061291	14.50
1M09-023-A1-050191	14.76
1M02-023-A1-050191	16.30
1M17-023-A1-031591	19.70
1M05-023-A1-050191	21.25
1P14-023-A1-050291	25.50
1P02-023-A1-050191	27.35
1P19-140-A1-050391	27.85
1M03-023-A1-050191	28.45
1M06-023-A1-031891	32.75
1P08-023-A1-050291	33.35
1M20-023-A1-050391	45.35
1M18-023-A1-050391	45.65
1P10-023-A1-031591	50.55

APPENDIX C-2
HAZARD QUOTIENTS FOR SELENIUM AT
RASS AND REFERENCE SITES
Based on Amphipod AET(1)

Sample ID	Selenium Hazard Quotient
1P15-023-A1-031591	50.85
1M21-023-A1-050391	54.65
1P04-023-A1-031891	56.00
1P17-023-A1-031591	57.50
1M19-023-A1-050391	63.65
1P20-023-A1-050391	73.15
1P12-023-A1-050291	100.35
RASS 2	
2M18-023-A001-032091	0.89
2M17-023-A001-032091	1.07
2M16-023-A001-032091	1.36
2M24-023-A1-061391	2.50
2M12-023-A1-061391	2.70
2M05-023-A1-051591	3.75
2P01-023-A1-051591	4.45
2P02-023-A1-051591	4.60
2M14-023-A1-061391	5.60
2M10-023-A1-050991	6.10
2M08-023-A1-051491	6.55
2P07-023-A1-050991	7.00
2M09-023-A1-032091	7.65
2P06-023-A1-051491	7.65
2M02-023-A1-032091	8.00
2M06-140-A1-032091	8.65
2P03-140-A1-032091	8.85
2M01-023-A1-032091	9.15
2P04-023-A1-051591	9.85
2P05-023-A1-032091	10.00
2M15-023-A1-032091	10.32
2M11-023-A1-061391	11.45
2M03-140-A1-032091	19.10
2M04-023-A1-051591	51.15
2M07-023-A1-051591	86.85
2M13-023-A1-032091	255.00
RASS 3	
3M41-023-A001-031391	0.80
3M33-023-A001-031391	1.03
3M27-023-A001-032191	1.52

APPENDIX C-2
HAZARD QUOTIENTS FOR SELENIUM AT
RASS AND REFERENCE SITES
Based on Amphipod AET(1)

Sample ID	Selenium Hazard Quotient
3M31-023-A001-032291	1.61
3M24-023-A001-032191	1.71
3M22-023-A001-032191	1.72
3M29-023-A001-032291	1.96
3M11-023-A1-050991	2.00
3P04-140-A1-050991	2.15
3P06-023-A1-050991	2.15
3M05-140-A1-050891	2.20
3P01-140-A1-050891	2.20
3P08-220-A1-050891	2.20
3M02-140-A1-050891	2.25
3M04-023-A1-050891	2.25
3M07-023-A1-050991	2.25
3P03-023-A1-031291	2.30
3M08-023-A1-031291	2.35
3M09-023-A1-031291	2.45
3P09-220-A1-050891	2.45
3M06-140-A1-031291	2.50
3P05-023-A1-031291	2.50
3M13-023-A1-031291	2.55
3M14-023-A1-031291	2.55
3M42-023-A1-061491	2.57
3M19-023-A1-031291	2.60
3P07-023-A1-032191	2.60
3M10-023-A1-032191	2.65
3M15-023-A1-031291	2.70
3M18-023-A1-031291	2.80
3M20-001-A1-031291	2.90
3M03-023-A1-031291	3.30
3M16-023-A1-032191	3.40
3M12-023-A1-031291	3.80
3P02-023-A1-031291	3.90
3M26-023-A001-032191	4.47
3M17-023-A1-031291	4.80
3M01-023-A1-031291	5.55
RASS 4	
4M12-023-A001-031191	1.64
4M14-023-A001-031191	1.76

APPENDIX C-2
HAZARD QUOTIENTS FOR SELENIUM AT
RASS AND REFERENCE SITES
Based on Amphipod AET(1)

Sample ID	Selenium Hazard Quotient
4P05-023-A1-050791	2.35
4P03-023-A1-050791	2.40
4M06-023-A1-050791	2.45
4M13-023-A001-031191	3.13
4M16-023-A001-032191	4.31
4M23-023-A1-052091	5.55
4M11-035-A1-031191	6.25
4P02-140-A1-050791	7.95
4M05-023-A1-050791	10.60
4M03-140-A1-050791	12.55
4M15-023-A001-032191	17.50
4M09-023-A1-031191	24.00
4M10-140-A1-031191	26.45
4M02-035-A1-050791	27.15
4M08-023-A1-031191	29.85
4M01-140-A1-031191	34.65
4M04-023-A1-050791	35.50
4P01-035-A1-050791	79.35
4M07-023-A1-031191	666.85
4P04-023-A1-050791	803.35
Reference Site 1 (Upland)	
R102-023-A1-051791	2.00
R101-023-A1-051791	2.05
R104-023-A1-051791	2.05
R103-023-A1-051791	2.10
Reference Site 2 (Marsh)	
R205-023-A1-051691	5.65
R206-023-A1-051691	5.65
R204-023-A1-051691	7.25
R209-023-A1-051691	12.15
R210-023-A1-051691	20.50
R203-023-A1-051691	79.35
Amphipod AET (1)	
	0.2 ppm

1 PTI 1989