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FINAL REMEDIAL INVESTIGATION REPORT VOLUME 1 OF 3 SITE 41 WETLANDS NAS
PENSACOLA FL
08/31/2000
ENSAFE, INC

**FINAL REMEDIAL INVESTIGATION REPORT
SITE 41, NAS PENSACOLA WETLANDS
NAVAL AIR STATION
PENSACOLA, FLORIDA**



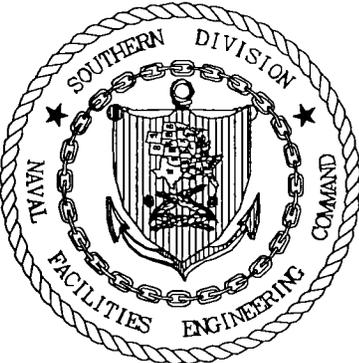
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CTO-036

**Volume I of III
Sections 1 to 9**

Prepared for:

**Comprehensive Long-Term
Environmental Action Navy
Naval Air Station
Pensacola, Florida**



Prepared by:

**EnSafe Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901) 372-7962**

August 31, 2000

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SITE 41
EXECUTIVE SUMMARY

A remedial investigation was conducted for Naval Air Station (NAS) Pensacola Site 41, The NAS Pensacola Wetlands, assessing the nature and extent of contaminants resulting from Navy activities and Installation Restoration (IR) program sites discharging to wetlands within the NAS Pensacola boundary. Site 41 encompasses the approximately 81 wetlands or wetland complexes, both tidal and nontidal, that are within the base boundary. These wetlands are either palustrine or estuarine and drain directly into either Pensacola Bay or Bayou Grande. The investigation was conducted in three phases. Phase I was an analysis of existing data to identify those wetlands of greatest concern and identify sample locations for Phase IIA. Samples collected during Phase IIA showed metals, pesticides, polychlorinated biphenyls, and semivolatile and volatile organic compounds in particular wetlands. Phase IIB and Phase III samples for toxicity, bioaccumulation, and diversity analysis were collected in wetlands thought to pose a risk from toxicological and bioaccumulative effects to estuarine and marine fauna.

As a result of Phase IIA, wetlands were ranked as either Red, Orange, or Blue based on detected concentrations in sediment. Red-coded wetlands had contamination that appeared directly related to nearby IR sites and had consistent exceedances of SSVs and reference levels. The nine red-coded wetlands identified were Wetlands 64, 5, 3, 4D, 16, 18, 10A, 12, and W1. Contaminants detected in these wetlands were also considered to be possible sources of ecological risk. Orange-coded wetlands had limited contamination above SSVs and reference levels which in some cases did not appear to be related to nearby IR sites. The six orange-coded wetlands identified were Wetlands 1, 15, 6, 63A, 48, and 49. Blue-coded wetlands had contaminants which in most cases were below benchmark values, or which did not appear to be site-related. The 12 blue-coded wetlands included Wetlands 10B, 13, 17, 19, 52, 56, 57, 58, 63B, 72, 79, and W2.

In addition, reference wetlands were identified for comparison to the potentially impacted wetlands. These wetlands were selected because they had similar vegetation, topography,

geology, and hydrology to the wetlands potentially impacted by IR sites. They were also located away from any IR site or other potential sources of contamination. The four reference wetlands included Wetlands 25, 27, 32, and 33.

For Phase IIB/III of the field investigation, the wetlands were further subdivided according to the nature and extent of sediment contamination and several physical characteristics that could affect contaminant fate and habitat use. By subdividing these wetlands, any risk quantified in one wetland could be extrapolated to determine potential risk in other wetlands in that group. Because Wetland 64 is considered to be unique among the other wetlands, it was grouped by itself in Group A. Group B included Wetlands 3 and 5A. Group C included Wetlands 4D, 15, 16, 18A/B and 63A. Wetlands 16 and 18 were chosen as the representative wetlands for Group C. Group D included Wetlands 10, 6, 5B, W1, and 1, as these wetlands appear as man-made drainage ditches and are in developed areas of the base. Group E included Wetlands 48 and 49, and because of their intermittent levels of surface water, neither was expected to have a significant ecological concern. Based on HQs and potential receptor species, wetlands in Groups A, B, and C (Wetlands 16 and 18 only in Group C) were selected for sampling priority in Phase IIB/III. Groups D and E, along with those wetlands not placed in a group, were not considered for Phase IIB/III.

Assessment endpoints studied during Phase IIB/III included survival, growth and reproduction of macroinvertebrates associated with the benthic environment (Wetlands 64, 3, 5A, 16, and 18); protection of fish viability using the fathead minnow (*Pimephales promelas*) (Wetlands 3 and 5A); and health of piscivorous birds (great blue heron — Wetland 18 only). Decision making triad analyses were used to round-out the ecological assessment of each wetland studied in Phase IIB/III, to determine if the ecological impacts to sediment and surface water were acceptable or not. At wetlands determined to have chemicals of potential concern (COPCs), a human health risk evaluation was conducted.

Phase IIB/III analyses revealed there were limited impacts to ecological receptors in most of the wetlands evaluated. At wetlands determined to have chemicals of concern (COCs), the

human health risks were considered to be low, because most wetlands have restricted access to trespassers. Therefore, most of the wetlands are recommended for no further action. Wetland 12 is recommended for transfer to the State of Florida's petroleum program, as documented in the September 19-20, 1996 Partnering Meeting Minutes. Wetland 64 is recommended for no further action under the IR program, since contaminants in this wetland are related to storm water runoff and spills of petroleum products, and should be addressed under the base storm water program and the State of Florida petroleum program.

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1.0 INTRODUCTION

As part of the U.S. Navy Comprehensive Long-Term Environmental Action Navy (CLEAN) program, a Remedial Investigation (RI) was completed at Site 41, the Naval Air Station (NAS) Pensacola wetlands. This site is listed in the Site Management Plan (SMP) of the Installation Restoration (IR) program for NAS Pensacola (U.S. Navy, 1997). Site 41 encompasses all of the wetlands, both tidal and nontidal, within the NAS Pensacola boundary. Field work for the RI took place during three events. Phase I was performed during August 1994; Phase IIA was performed from November 1995 through January 1996; and Phase IIB/III were performed during August and September 1997. This RI Report has been developed by EnSafe Inc. (EnSafe) as tasked by the Southern Division, U.S. Navy, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM) under Contract Number N62467-89-D-0318/CTO-36.

This investigation was completed in accordance with the primary site documents. These include the *Final Remedial Investigation/Feasibility Study (RI/FS) Work Plan, Site 41, NAS Pensacola Wetlands* (EnSafe/Allen and Hoshall [E/A&H], 1995a), the *Final RI/FS Sampling and Analysis Plan (SAP), Site 41, NAS Pensacola Wetlands* (E/A&H, 1995b), the *Final Comprehensive Sampling and Analysis Plan for Naval Air Station Pensacola (CSAP)* (E/A&H, 1994), and the *Site 41 SAP Addendum* (E/A&H, 1997a).

The investigation was undertaken by EnSafe to meet the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) program, which administers the investigation and cleanup of former hazardous waste sites. This RI report summarizes the activities, results, and conclusions of the investigation and provides the basis for a future feasibility study (FS) to be completed at the site. The RI objectives are outlined below:

- To determine the sources, nature, magnitude, and horizontal extent of sediment and surface water contamination associated with the identified IR sites.
- To evaluate human health and ecological risk posed by contaminated media onsite through the baseline risk assessment (BRA) process.

1.1 Project Organization

The RI was organized into three phases. Phase I focused on a qualitative review of each wetland and development of a sampling strategy, including selecting sample locations, for Phase II of the investigation. Tasks completed in Phase I included:

- Site reconnaissance
- Review of data from previous investigations
- Review of site history, past and present activities, potential sources of contamination, locations of any known surface spills, and historical outfalls or other releases
- Habitat and Biota Survey
- Review of potential endangered species habitat
- Review of fisheries information
- Review of aerial photographs, topographic maps, and wetland maps

Once the above tasks were completed, Phase IIA of the RI was planned for wetlands identified as potentially contaminated by an IR site. The purpose of Phase IIA was to verify whether suspected contamination identified during Phase I actually existed. Phase IIA involved the collection of sediment and surface water samples in wetlands of concern and analysis for chemical and physical parameters. Sample locations were biased toward those locations with the greatest likelihood of contamination (i.e., high total organic carbon [TOC], small grain size). After sample collection, the data were tabulated and reviewed.

Based on contaminant exceedances of sediment screening values and surface water quality criteria, certain wetlands were prioritized for further analysis in Phase IIB/III. The purpose of Phase IIB/III was to link contamination identified in Phase IIA to toxicological or bioaccumulative effects, and to conclude which wetlands and contaminants appeared to pose an unacceptable ecological or human health risk. Phase IIB/III included the collection and analysis of sediment and surface water samples for acute and chronic toxicity, chemical and physical parameters, and benthic diversity. Phase IIB/III also involved the collection and analysis of fish tissue samples for contaminant body burden and contaminant food chain transfer potential.

1.2 Scope of Report

This RI report summarizes the activities, results, and conclusions of the investigation and provides the basis and justification for an FS and Record of Decision (ROD). The report is divided into sections which address the major phases of the RI. The actions and results of each phase, how these results affected the actions taken in subsequent phases, and how the results formed the basis for determining risk, are detailed. In Section 10, each wetland is assessed. The report also details the data collection and analytical methods used during the investigation.

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2.0 ENVIRONMENTAL SETTING

This section describes the physical and ecological setting of the Florida Panhandle and the NAS Pensacola wetlands. This information was incorporated into the Phase I portion of the RI.

2.1 Regional Ecological Setting

According to Wolfe et al. (1988), the Florida Panhandle has a wide variety of surface waters and physiographic regions, leading to an ecological diversity found in few other areas of the United States. Watersheds of the panhandle support a diverse array of habitats and vegetative communities. Bottomland hardwoods and wetlands predominate in river floodplains. Pines, mixed with a variety of other shrubs, prevail in upland areas. Barrier islands support dune vegetation communities and salt marshes. Bays supporting seagrass meadows and oyster reefs are present in intertidal and subtidal areas.

Seven major rivers in the region discharge into seven estuaries formed at the mouths of the rivers. The Florida Panhandle is a crossroads where animals and plants from the Gulf Coastal Plain reach their eastward distributional limits, and where many northern species reach their southern limits. Many peninsular Florida species are also distributed in this area. Due to the wet temperate climate of the region, the panhandle area may support a higher diversity of species than any other similarly sized territory in the United States.

The high annual rainfall and low, gently sloping terrain create numerous wetlands in the region. Bogs, swamps, marshes, wet prairies, and wet flatwoods provide a diversity of wetland types that support a wide variety of flora and fauna. Terrestrial vegetation includes mostly second-growth pine forests and encroaching hardwoods.

The Florida Panhandle's estuaries and near-shore marine habitats are among the greatest natural and economic assets of the region. Important commercial organisms (such as oysters and fish)

abound in these areas and contribute to the region's economy. Coastal saltmarsh habitats provide critical nursery, feeding, and refuge habitat for these important commercial species. Seagrass beds within estuaries also are vital to the seafood industry.

2.2 Physical Setting

NAS Pensacola is in the Gulf Coast lowlands physiographic province, on a peninsula bounded by Pensacola Bay to the south and east and Bayou Grande to the north. The main topographic feature is a bluff which parallels the southern and eastern shorelines of the peninsula. Landward of the bluff is a gently rolling upland with elevations up to 40 feet above mean sea level (msl) (U.S. Geological Survey [USGS], 1970a and 1970b). In the eastern part of the base, a low and nearly level marine terrace lies east of the bluff with elevations of approximately 5 feet or less above msl, constituting the areas of the former Chevalier Field and Magazine Point.

Site 41 encompasses approximately 81 wetlands and wetland complexes located throughout the base. Most wetlands on base are estuarine and drain directly into either Pensacola Bay or Bayou Grande. Less prevalent, exclusively freshwater wetlands on base are not tidally influenced and drain into other wetlands. The wetlands identified at NAS Pensacola are shown on Figure 2-1.

2.3 Ecological Setting at NAS Pensacola

NAS Pensacola, which occupies approximately 5,800 acres, is bounded by Bayou Grande to the north and Pensacola Bay to the east and south. To the west, the land changes to less developed swampy lowlands, forests, and beaches. NAS Pensacola's eastern portion is largely developed, with military and industrial facilities and historical/cultural sites. Most of the installation's activities are on the eastern side of the base.

NAS Pensacola is the setting for numerous aquatic and terrestrial habitats, from coastal strand and estuarine environments along the bay and bayou to inland pine flatwood communities. Wetland environments include a broad spectrum of both estuarine and palustrine (freshwater) wetlands, many in states of recovery as they undergo reforestation or return to their natural condition.

Vegetation Communities

NAS Pensacola's natural vegetation communities fall into several broad categories:

1. Coastal dune scrub communities are associated with shorelines and subject to high-energy waves.
2. Pine flatwood communities in coastal lowlands are characterized by trees tolerant to various soil moisture conditions. Tree species in flatwood communities are short, with a wide variety of small shrubs and herbaceous plants in the understory.
3. Hardwood/pine communities are highly diverse and are considered biologically productive ecosystems.
4. Sand pine scrub communities on well-drained sandy soil contain sand pines, oaks, and various shrubs.
5. Bay swamps, which are wetlands with titi and cypress are known to contain permanent standing water and high accumulations of organic peat.
6. Freshwater marshes occur as grass/sedge/rush/herb communities in areas with high soil saturation or standing water.

7. Estuarine coastal marshes consist of salt-tolerant plants able to establish themselves in shifting sands. Estuarine coastal marshes, including salt marshes, occur along low-energy shorelines and in tidal bayous (U.S. Fish and Wildlife Service [USFWS], 1987).

Wildlife

NAS Pensacola habitats provide potential ranges for a wide variety of animal life such as deer, squirrel, opossum, raccoon, fox, beaver, and bobcat. The station's beaches serve as resting, feeding, and nesting areas for various shorebirds. Ospreys have been observed nesting along undeveloped shoreline areas of the Big Lagoon, southeast of the Forrest Sherman Airfield. Numerous small mammals, amphibians, and reptiles also inhabit the base. The coastal marsh, submerged grass bed, and shallow water habitats at NAS Pensacola help support fishery communities within the Pensacola Bay estuarine complex. Approximately 180 species of bony fishes form the basis of the Pensacola Bay fish community (USFWS, 1987).

Threatened and Endangered Species

Appendix A of the *Comprehensive Natural Resources Management Plan for NAS Pensacola and Outlying Field Bronson* (USFWS, 1987) lists the rare, threatened, and endangered species that may be found within NAS Pensacola boundaries. EnSafe investigations of different areas at NAS Pensacola have identified the osprey, great blue heron (as well as other shorebirds), alligator, snapping turtle, Godfrey's golden aster, Carolina lilaeopsis, white-top pitcher plant, and narrow-leaved sundew (E/A&H, 1995b). Some of these species are considered candidates for listing as rare, threatened, or endangered by the Florida Natural Areas Inventory (FNAI), 1995. These candidate species are not yet officially listed and thus have no legally protected status.

Wetlands at NAS Pensacola

Wetlands are organized by those found in the western and eastern portion of the base. Each wetland is considered equally attractive for recreational use. This assumption is important in quantifying human health risk, which is addressed by wetland in Section 10.

Western Portion

The western portion of the base contains heavily forested or marginally altered zones west of Sherman Field. The area contains palustrine forested wetlands, or forested wetlands mixed with scrub-shrub vegetation. Also west of Sherman Field are heavily altered areas particularly along runway overrun areas which have been cleared of trees and are dominated by scrub-shrub vegetation. Many of these altered areas appear to be dry but contain common wetland plant species. Portions of the forested and scrub-shrub areas have standing water and saturated soil; these conditions support emergent wetland plant species, some of which are considered threatened. Several drainage ditches in the area also support wetland species; the ditches drain surface runoff from the airfield area into either Bayou Grande or the Intercoastal Waterway/Pensacola Bay.

Additional palustrine wetlands, as well as estuarine wetlands and aquatic beds, are present in the shoreline areas to the south and southwest of Sherman Field. Estuarine emergent wetlands are present in the inlets off the Intercoastal Waterway/Pensacola Bay, with palustrine emergent species in the more brackish upper-water reaches. Estuarine submerged aquatic plant beds can be found in the larger coves and immediate offshore areas. Areas of saturated soil inland from the shoreline accommodate palustrine forested and scrub-shrub wetlands, sometimes mixed with emergent plants. Standing water in the same area supports trees, shrubs, and emergent/floating leaf vegetation. Small inlets to Bayou Grande north of Sherman Field support estuarine emergent wetlands. Many of the estuarine emergent wetlands are fed by palustrine wetlands, especially where the inlet is fed by drainage ditches or intermittent streams.

Eastern Portion

About one-third of the wetlands are in the more developed eastern portion of the NAS Pensacola peninsula, and these are almost exclusively smaller remnants. These wetlands have been heavily impacted by base activities (Ecology and Environment, Inc. [E&E], 1992). There are isolated palustrine wetlands near Site 1, the Sanitary Landfill, directly west of the NAS Pensacola golf course. Several ponds on the golf course drain into Bayou Grande and support palustrine wetlands inland from the bayou and estuarine wetlands along the bayou shoreline. Areas near the former Chevalier Field and the wastewater treatment plant contain several small wetlands. Many occur as palustrine forested wetlands in small, isolated wooded areas. Emergent wetland plants occur in several drainage ditches and a channelized stream; these channels direct surface runoff from the area surrounding the former Chevalier Field into the Yacht Basin, which is west of Magazine Point Peninsula. There are estuarine and palustrine emergent wetlands at the upper end of the Yacht Basin. Two isolated emergent wetlands lie on the eastern fringe of the former Chevalier Field, next to the Dredge Spoil Fill Area.

2.4 Area Climate

The Pensacola area has a mild, subtropical climate with average annual temperatures ranging from 55°F in the winter to 81°F in the summer. Daily temperatures can be more extreme, ranging from less than 7°F in the winter to more than 102°F in the summer. Convective thunderstorms, which occur on approximately half the summer days, can cause a precipitous drop in temperature of 10° to 20° in a matter of minutes (E&E, 1992).

Rainfall averages approximately 60 inches a year, with the highest amounts in July and August, when thunderstorms occur almost daily. Thunderstorms resulting in 3 to 4 inches of rain in an hour are common. Rainfall is lowest during spring and fall (4 inches average per month). In general, spring and fall rains are less intense, last longer, and produce less surface runoff but

higher rates of infiltration and net recharge (E&E, 1992). Based on climatological data, November is the driest month of the year, with an average rainfall of 3.2 inches.

Winds, which prevail from the north during the winter and the south during the summer, are generally moderate in velocity, except during thunderstorms. A difference in the ocean-land temperature produces the sea-breeze effect, a daily clockwise rotation in the surface wind direction near the coast.

In addition, hurricanes and tornadoes can substantially damage the near-shore environment. Hurricanes Erin and Opal made landfall in Pensacola in August and October 1995, respectively. Hurricane Georges made landfall about 50 miles west of Pensacola near Mobile, Alabama in September 1998.

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3.0 PHASE I METHODS AND RESULTS

Phase I focused the Site 41 investigation towards those wetlands considered to be of greatest concern and determined sample locations for Phase IIA. The Phase I tasks are described below.

3.1 Document Review

Before visiting the wetlands to choose sample locations, existing information was reviewed to better focus the investigation on those wetlands with the greatest apparent risk potential. This review was performed using the following information:

- Data from terrestrial site investigations associated with the wetlands of concern;
- Site history, past and present activities, and potential sources of contamination;
- Reported locations of any known surface spills, historical outfalls, or other releases;
- Existing habitat and biota surveys which identify vegetation patterns, endangered species habitat, fisheries information, and other special concerns; and
- Aerial photographs, topographic maps, and wetland maps.

This information above was used to identify potential wetlands of concern, possible risk from contaminants in those wetlands, likely contaminant pathways, and key potential ecological receptors.

3.2 Site Reconnaissance

The site reconnaissance was performed during August 1994 to physically survey each wetland on base, compare site observations with the data gathered during the document review, and select

suitable sample locations in identified wetlands of concern. Sample locations were biased to areas of likely contamination near outfalls and natural drainage features, and to areas of high contaminant deposition (i.e., low grain size, high TOC).

The Phase I document review and site reconnaissance identified other important features needed to complete the RI. The identification of potential contaminants of concern and potential receptors enabled development of measurement and assessment endpoints, a general conceptual model, and the wetland-specific conceptual models. Measurement endpoints were selected to best represent key exposure and effects pathways in relation to assessment endpoints and the conceptual model. In turn, these endpoints and models provided the technical basis for choosing toxicity, diversity, and bioaccumulation analyses in Phase IIB/III, to link contaminant levels with observed effects.

3.3 Phase I Results

Phase I results included the identification of wetlands which required further study and a justification for Phase IIA, sediment and surface water sample locations in those wetlands. This information is detailed extensively in Section 4 of the Final Site 41 RI/FS SAP (E/A&H, 1995b). Table 3-1 (E&E, 1992) summarizes the sites at NAS Pensacola that were initially suspected of impacting particular wetlands. Site locations are shown on Figure 2-1. Based on additional investigations, Sites 25, 27, 43, and 44 were added; these are described in Section 3.4.

Section 2 of the Final RI/FS SAP-Site 41 (E/A&H, 1995b) describes the general conceptual model and identifies the measurement and assessment endpoints developed based on Phase I activities. Following a review of the data collected during Phase IIA, assessment and measurement endpoints were reevaluated and revised. A wetland-specific conceptual model was developed for each wetland chosen for study in Phase IIB/III. The revised endpoints, conceptual models, and the justification for their selection are provided in the Final RI/FS Site 41 SAP Addendum (E/A&H, 1997a).

Table 3-1
Sources and Pathways of IR Site-Related Contamination
Potentially Impacting Site 41

Source (Site)	Site Name	Known or Suspected Contaminants	Years of Operation	Potential Pathway(s)	Specific Wetland(s) ^a Potentially Impacted	Selected Remedial Alternative
1	Sanitary Landfill	Metals, TRPHs, VOCs, PAHs, phenols	30 (1950-1980)	Groundwater, surface runoff	1-4, 15-18, W2 ^b	LUC for soil to restrict intrusive activities; MNA with a groundwater interception trench upgradient Wetland 3
3 (UST 18)	Crash Crew Training Area	Metals, TRPHs, VOCs, PAHs, phenols	37 (1955-present)	Surface runoff into storm water drain	39, 52, 54, 62, 72, W1 ^b	In situ landfarming for soil; MNA for groundwater
4	Army Rubble Disposal Area	Unknown	Unknown	Groundwater	52, 56-58	NFA
5	Borrow Pit	Unknown	Unknown	Groundwater, surface runoff	79, 55, W2 ^b	NFA
6	Fort Redoubt Rubble Disposal Area	Unknown	Unknown	Groundwater, surface runoff	79, W2 ^b	NFA
9	Navy Yard Disposal Area	Metals, TRPHs, PAHs	13 (1917-1930s)	Groundwater, surface runoff	6-8, 64	Pending
10	Commodore's Pond	Metals, TRPHs, PAHs, phenols	Unknown (1800s)	Groundwater, surface runoff	6-8, 64	NFA
11	North Chevalier Disposal Area	Metals, TRPHs, VOCs, PAHs, phenols	Unknown (1930s-present)	Groundwater, surface runoff, direct discharge	7-8, 64	Pending
12	Scrap Bins	Metals, TRPHs, PAHs, phenols, PCBs	60 (early 1930s-present)	Stormwater drain	6-8, 64	Pending

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Table 3-1
 Sources and Pathways of IR Site-Related Contamination
 Potentially Impacting Site 41

Source (Site)	Site Name	Known or Suspected Contaminants	Years of Operation	Potential Pathway(s)	Specific Wetland(s) ^a Potentially Impacted	Selected Remedial Alternative
13	Magazine Point Rubble Disposal Area	TRPHs, VOCs, PAHs, phenols ^c	Unknown	Groundwater	10	NFA
14	Dredge Spoil Fill Area	Metals, TRPHs, VOCs, PAHs, phenols	17 (1975-present)	Groundwater, stormwater overflow	63	NFA
16	Brush Disposal Area	Metals	Unknown (1960s-1973)	Groundwater, surface runoff	19, W2 ^b	NFA
19	Fuel Farm Pipeline Leak Area	Metals, TRPHs, PAHs, VOCs	Single Incident (1958)	Groundwater, surface runoff	49, 52, 54	Pending
23	Chevalier Field Pipeline Leak Area	Metals, TRPHs, PAHs, phenols	Two incidents (1965, 1970)	Groundwater, surface runoff	6-8	Pending
29	Soil South of Building 3460	Metals, TRPHs, PAHs, VOCs	Unknown (1970s-1980s)	Groundwater	6-8, 64	Pending
30	Buildings 649 and 755	Metals, TRPHs, VOCs, PAHs, phenols	30 (1940s-1970s)	Groundwater, surface runoff, direct discharge	5-8, 64	Pending
32,33,35	Industrial Wastewater Treatment Plant	Metals, VOCs, BNAs	11 + (1981-present)	Groundwater, surface runoff	7-13	Soil NFA; Groundwater recovery system
34	Solvent North of Building 3557	Metals, TRPHs, PAHs, phenols	Single incident (1984)	Groundwater	6-8, 64	NFA
36	Industrial Waste Sewer	Metals, TRPHs, VOCs, PAHs, phenols	21 + (1971-present)	Groundwater	5-13, 63	NFA

Table 3-1
 Sources and Pathways of IR Site-Related Contamination
 Potentially Impacting Site 41

Source (Site)	Site Name	Known or Suspected Contaminants	Years of Operation	Potential Pathway(s)	Specific Wetland(s) ^a Potentially Impacted	Selected Remedial Alternative
37	Sherman Field Area	Metals, TRPHs, VOCs, PAHs	Single Incident (1983)	Groundwater	48, 52, 54	Investigation Pending
39	Oak Grove Campground	TRPHs, VOCs	Unknown	Groundwater	56	NFA

Notes:

- ^a = Wetland number corresponds to U.S. Environmental Protection Agency (USEPA) wetland inventory (Parsons and Pruitt, 1991)
- ^b = Wetlands not identified in EPA wetland inventory (Parsons and Pruitt, 1991)
- ^c = Suspected source of these contaminants is the former Industrial Wastewater Treatment Plant (Sites 32, 33, and 35)
- LUC = Land Use Control
- TRPHs = Total Recoverable Petroleum Hydrocarbons
- PAHs = Polycyclic Aromatic Hydrocarbons
- VOCs = Volatile Organic Compounds
- PCBs = Polychlorinated Biphenyls
- MNA = Monitored Natural Attenuation
- NFA = No Further Action
- UST = Underground Storage Tank

Source: Ecology and Environment, Inc., 1992

3.4 Additional Sites

Sites 25, 27, 43, and 44 were evaluated after completion of the original Phase I site reconnaissance. Sites 25 and 27 are part of Operable Unit (OU) 2. Sampling and analysis to evaluate potential impacts from these sites were incorporated into Phase IIA. Investigations have not been performed for Sites 43 and 44. Each site is discussed below.

Site 25

Site 25 was investigated as a suspected radium spill area, based on the former activities associated with Building 780. Building 780 currently houses the Joint Oil Analysis Laboratory which analyzes oil samples from vehicles and aircraft from military activities nationwide.

Soil samples collected behind Building 780 revealed a wide range of primary/secondary metals and semivolatile organic compound (SVOC) contamination, but no radium was found. Groundwater samples collected at the site contained metals, chlorinated solvents, benzene and xylene.

Another location of concern at Site 25 is the storage yard behind Building 225, which is used as a metal prefabricating shop by the NAS Pensacola Public Works Center (PWC). Groundwater from the site contained metals and tetrachloroethylene (PCE). Activities in and around this building are the likely sources of groundwater contamination. Wetland 64, within the Yacht Basin, is potentially impacted by this site.

Site 27

At Site 27, the investigation focused on the former radium dial shop sewer beneath the former Building 709 slab. Wells were previously installed by ABB, Inc. to support the removal of underground storage tanks (USTs) at this location. SVOC exceedances were noted in the wells; the former USTs are likely contributors of contamination in these wells.

Contaminants in the soil at Site 27 included aluminum, arsenic, cadmium, chromium, iron, mercury, and dieldrin. Contaminants detected in groundwater were chromium, iron, manganese, dieldrin, chloroform, and chlorinated VOCs, including 1,4-dichlorobenzene, 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), PCE, and trichloroethene (TCE). Based on site topography, Wetland 5 may have been impacted by Site 27 activities.

Site 43

Site 43 is an area of drums and other debris near the corner of Murray and Taylor Roads, across from Site 10. The area, identified and fenced in January 1994, has not been investigated to date. The drum contents are unknown and it has not been determined if the site is contaminated. If so, the site could potentially impact downgradient Wetlands 6, 7, 8, and 64.

Site 44

This site was transferred from the Florida Petroleum Program to the IR program because chlorinated solvents were detected in groundwater. The site, near an active hangar (Building 3221) on Forrest Sherman Field, is currently used by the nearby aviation museum for aircraft restoration. This site has not been investigated to date, but could potentially impact downgradient Wetlands 79, 52, and W2.

3.5 Site Investigation Update

Following the Site 41 Phase I investigation, many of the sites identified as sources of wetland contamination have either been remediated, will be remediated under the state petroleum program, or have been designated as sites requiring no further action (NFA).

Investigation of the NFA sites has been designated as complete under the IR program, and no excess ecological risk was found at the sites. However, historical contamination associated with these sites may have impacted downgradient wetlands. Sites in this category are described below.

Specific details about these NFA sites can be found in the respective RI or preliminary site characterization reports.

Operable Unit 6: Sites 9, 29, and 34

Soil and groundwater contamination were delineated during the OU 6 RI. Most soil contamination at each site has been removed. At Sites 9 and 29, soil contamination appeared to be limited to small isolated concentrations of dieldrin in the surface and subsurface soil. Soils at Site 9A contaminated with metals and polycyclic aromatic hydrocarbons (PAHs) were remediated in 1998. Elsewhere at Site 9, soil contamination was limited to isolated inorganics, PAHs, and pesticides in surface and subsurface soil. Much of the area was covered with fill material during construction of the new training complex. Given the lack of correlation between contaminants in soil and groundwater, leaching of constituents from the soil into the groundwater is not considered substantial or significant. Transport of groundwater to surface water receptors at levels exceeding applicable standards is considered unlikely.

Site 10

Several detections of dieldrin above its risk-based goals were noted in soil and the area with the elevated concentrations was removed. Based on two groundwater sampling events, dieldrin did not appear to be leaching to nor impacting shallow groundwater. Detected concentrations in groundwater were below federal and state standards for drinking water.

Site 16

Inorganic constituents exceeding risk-based goals in site soil were similar to those identified at other sites in the area. Elevated soil PAH concentrations likely originated from a source not related to site activities. Detected concentrations of aluminum and iron in groundwater were below their respective reference concentrations at all locations but one for each constituent.

Site 36

Resources downgradient of Site 36 are the adjacent wetlands (Wetland 63) and Pensacola Bay. Since most of the site area is paved or covered by a building or fill material, leaching and sediment transport were not considered to be viable pathways for constituent transport. Groundwater transport, the only viable transport pathway, contained low concentrations of contaminants.

Site 4

Inorganic constituents exceeding preliminary remediation goals (PRGs) in site soil were similar to those identified at previously investigated sites in the eastern portion of NAS Pensacola. The detected PAH contaminants are likely associated with routine activities, such as automobile traffic, or the asphalt pavement.

Site 5

Concentrations detected at Site 5 were below regulatory standards. A previous UST investigation at Site 3221NE, adjacent to the northwest corner of Site 5, showed that the contaminants there were not associated with Site 5. Site 3221NE will be addressed under the Florida Petroleum Program.

Site 14

Site 14 was determined to be an NFA site after the berms of the site were collapsed into the sediment basins, eliminating potential exposure pathways.

Site 6

Site 6 has been determined to be an active construction rubble debris landfill that is subject to State of Florida solid waste regulations. The site is being monitored by the NAS Pensacola Environmental Department. No investigation was performed at this site.

3.6 Petroleum Sites

In addition to the IR sites, petroleum sites also have the potential to impact NAS Pensacola wetlands. The sites, tanks, contents, and identified groundwater contaminants are summarized in Table 3-2. Petroleum site locations are shown on Figure 2-1. Their potential impact to individual wetlands is discussed in the Section 10.

Table 3-2
 Petroleum Sites Potentially Impacting NAS Pensacola Wetlands

Map Label	Site Name	Tanks/Size	Contents	Groundwater Contaminants
UST A	3221 SW	1/1000 Gal	Waste Oil, PD-680	TCE, PCE, Methylene Chloride
UST B	PWC Site 4	Sludge Disposal	Waste Oil, Jet Fuel	Petroleum Hydrocarbons
UST C	PWC Site 1	Pipeline	JP-5	Petroleum Hydrocarbons
UST D	Building 604	Unknown	TCE	Chlorinated Solvents
UST E	DFM Pipeline	Pipeline	Diesel	None
UST F	607NE	2/500 Gal	Waste Oil, Jet Fuel	Lead
UST G	2662W	1000 Gal	Used Oil, Jp-5	BTEX
UST H	3557	2/500 Gal	Waste Oil	None
UST I	3220	Multiple Tanks/Unknown Size	Diesel, Waste Oil, TCE	Unknown
UST J	2450W	Multiple/1000 Gal	Gasoline	Unknown
UST K	PWC Site 3/3810N	1/500 Gal	Fuel Oil	TRPHS, PAHS
UST L	3644	2/8000 Gal	Diesel	Petroleum Hydrocarbons
UST M	709N,S	3/2000 Gal	Fuel Oil	Unknown
UST N	647, 648, 649, 692	3/1000 Gal, 3/500 Gal	Waste Oil, Kerosene	Unknown
UST O	UST 18	Open Pits	Jet Fuel, Waste Oil	BTEX, Lead
UST P	Sites 1 to 13	AVGAS Line and 12 Tanks/500 Gal	Jet Fuel	Lead, Petroleum Hydrocarbons
UST Q	Radar Site 3255	1/300 Gal	Diesel	Petroleum Hydrocarbons
UST R	3221 NE	1/500 Gal	Waste Oil, Water Tainted JP-5	None

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Table 3-2
 Petroleum Sites Potentially Impacting NAS Pensacola Wetlands

Map Label	Site Name	Tanks/Size	Contents	Groundwater Contaminants
UST S	Site 19	Pipeline	Jet Fuel	Petroleum Hydrocarbons
UST T	Site 20	1/1,511,580 Gal, AST	JP-5	Petroleum Hydrocarbons
UST U	Site 26	Unknown	Jet Fuel	Petroleum Hydrocarbons
UST V	Site 23	Unknown	Jet Fuel	Petroleum Hydrocarbons
UST W	Site 26	Unknown	Jet Fuel	Petroleum Hydrocarbons
UST X	Site 27	Unknown	Jet Fuel	Petroleum Hydrocarbons

4.0 PHASE IIA AND IIB/III METHODS

The phased RI process, which includes investigation of sediment, surface water, and biota for the Site 41 wetlands, is described in the Work Plan (E/A&H, 1995a), SAP (E/A&H, 1995b), and SAP addendum (E/A&H, 1997a). Each document and phase of the investigation was approved by the Navy, United States Environmental Protection Agency (USEPA), Florida Department of Environmental Protection (FDEP), and National Oceanic and Atmospheric Administration (NOAA). As stated in the SAP, Phase I determined which wetlands required further sampling and analysis in Phase IIA. Based on the Phase IIA analytical data, wetlands considered to pose a potential risk were further analyzed in Phase IIB/III by correlating observed contaminant concentrations with toxicity and diversity results.

4.1 Sample Procedures

Sampling procedures for Phase IIA were performed in accordance with the Site 41 SAP. Sediment samples for chemical, physical, and toxicological analyses were collected with either a hand auger, scoop, or mini-Ponar grab in accordance with Section 4 or Section 7 of the CSAP (E/A&H, 1994). Sediment samples for benthic diversity analyses were collected according to Section 8.7 of the CSAP. The only deviation in Phase IIA from the Site 41 SAP involved moving sample locations based on site conditions.

Sample analyses in Phase IIB/III followed procedures in the Site 41 SAP. Sampling procedures for tissue collection are included in this section. A more appropriate toxicity analysis replaced the procedure listed in the Site 41 SAP addendum. Justification for this change is included in Section 4.5.

Sediment Sampling

Phase IIA samples for chemical and physical analysis were collected from the wetlands of concern from November 1995 through January 1996. Most sample locations in each wetland were identified using the global positioning system (GPS) described in Section 4.4. However, some sediment samples included in Phase IIA were collected as part of separate RIs at sites adjacent to Site 41, and GPS was not used. Specifically, 24 sediment samples were collected and analyzed from Wetlands 1, 3, 10, 6, 16, 18, and W1. Site 41 samples collected during Phase IIB/III in August and September of 1997 were mapped using GPS.

Surface Water Sampling

Surface water samples for chemical and toxicity analyses were collected by submerging the sample bottle according to Section 7.4.1 of the CSAP. Eleven surface water samples collected during other site investigations were incorporated in the Phase IIA data set. Turbidity and pH measurements collected during the surface water sampling are presented in Table 4-1.

Tissue Sampling

Using new fish traps, native foraging fish species from Wetlands 64 and 18 were collected for tissue analysis during Phase IIB/III. Control specimens were collected from reference Wetland 33. Wetland 75 was also used to collect control specimens, but it was later eliminated as a reference wetland and the fish tissue results were not used as a control.

Within Wetland 64, two traps were placed near three Phase IIA sediment sample locations 6404, 6405, and 6406. Within Wetland 18, one trap was placed at its mouth in an area likely to be frequented by fish. Two traps were placed in Wetland 33 and one was placed in Wetland 75. All traps were baited with commercial dog food and placed on the wetland floor. Over a 10-day period, the traps were checked periodically and the fish were collected and frozen for preservation.

Table 4-1
Site 41 Surface Water Sample pH and Turbidity Measurements

Station	Sample Location	pH	Turbidity
	041W030101	6.41	1
	041W030201	5.78	470
	041W030301	5.99	690
	041W030401	5.96	3
40	041W040101	6.55	0
	041W040201	6.02	0
16	041W160101	6.86	10
	041W160201	7.01	17
8	041W18A201	5.47	185
	041W18B101	5.02	89
12	041W120101	6.21	1
11	041W080101	6.70	15
15	041W150101	6.01	> 1000
	041W150201	6.98	0
63A	041W63A201	6.79	2
48	041W430101	3.96	3
49	041W490101	3.21	25
	041W490301	4.95	25
13	041W130101	6.13	> 1000
17	041W170101	6.78	0
19	041W19A101	6.20	41
	041W19B101	5.57	19
52	041W52A101	4.61	63
	041W52B301	5.86	27
56	041W56A101	3.48	6
57	041W570101	6.41	280
58	041W580101	6.73	0
63B	041W63B201	6.35	5
	041W63B401	6.13	13
72	041W720101	6.21	9
W7	041W720201	6.32	6
25	041W250101	6.24	2
	041W250301	5.76	0
87	041W270101	6.33	282
80	041W320101	4.02	1
	041W320301	4.06	2
23	041W330101	5.11	1
	041W330301	4.21	1
W1	041WW10101	5.43	10
	041WW10201	5.22	102
	041WW10301	6.09	5

Notes:
 Turbidity measurements are in nephelometric turbidity units (NTU)

After the 10-day period, the fish species were identified, placed in resealable plastic bags, labeled with the sample number on the outside of the plastic bag and on an inside tag. The samples were transported on dry ice to the analytical laboratory where they were processed and analyzed for whole body contaminant levels.

4.2 Sample Management

All environmental samples were preserved, labeled, packed, and shipped under strict chain-of-custody procedures, in accordance with Section 12 of the CSAP. All temperature-sensitive sample shipments not analyzed locally were put on ice and sent via an overnight express courier to the appropriate laboratory. The laboratory was notified the day of shipment. Sample containers and preservatives for each type of analysis are listed in Table 4-2.

Quality Assurance/Quality Control (QA/QC) Samples

QA/QC samples for chemical analysis were collected to ensure the quality of field and laboratory procedures by confirming the level of reproducibility attainable in the sampling and analytical process, the quality of equipment decontamination, the quality of source waters and materials, sample exposure to ambient contamination during handling, and the level of laboratory precision. All field QA/QC samples were collected in accordance with Section 15 of the CSAP.

QA/QC samples for the toxicity, bioaccumulation, and diversity analyses were not collected because the laboratories performing these analyses followed their own internal quality procedures to ensure data usability.

Ancillary Data

Ancillary data pertinent to sampling activities were collected for each sampling event. Field information included personnel identification, sampling time, location and weather conditions, test equipment and sample containers used, sampling methods, physical/chemical parameters measured, problems encountered, and procedural deviations. This information was recorded in appropriate field logbooks.

Table 4-2
 Sample Containers and Preservation by Medium and Analysis

Medium	Analysis	Sample Container	Preservative
Surface Water	CLP TCL VOCs	40-ml glass vial	4°C - HCL, pH < 2
Surface Water	CLP TCL SVOCs, CLP TCL Pesticides/PCBs	1-liter amber bottle	4°C
Surface Water	CLP TAL Metals-unfiltered	1-liter Nalgene bottle	4°C - HNO ₃ , pH < 2
Surface Water	Cyanide	1-liter Nalgene bottle	4°C - NaOH, pH > 10
Surface Water	Hardness	120-ml polyethylene bottle	4°C - HNO ₃ , pH < 2
Sediment	CLP TAL/TCL VOCs	60-ml glass jar	4°C
Sediment	CLP TAL/TCL SVOCs	250 ml amber bottle	4°C
Sediment	CLP TAL metals/cyanide	120-ml glass jar	4°C
Sediment	Grain Size	500-ml plastic jar	4°C
Sediment	TOC	120-ml sterile polyethylene bottle	4°C
Sediment	Species enumeration to genus level for sediment macroinvertebrates	1-liter plastic bottles	10% formalin
Sediment	Midge larvae <i>Chironomus tentans</i> 28-day survival/growth	200-ml plastic jar	4°C
Sediment	Marine amphipod <i>Leptocheirus plumulosus</i> 10-day acute toxicity	1-gallon plastic container	4°C
Sediment	Marine polychaete <i>Neanthes arenacoedentata</i> 20-day chronic growth and fecundity	1-gallon plastic container	4°C
Surface Water	Fathead minnow <i>Pimephales promelas</i> 28-day survival and growth	2.5-gallon plastic container	4°C
Fish Tissue	Contaminant residues in whole body fish tissue (PAHs, pesticides/PCBs, and lead)	Aluminum foil/plastic bags	4°C

Notes:

- CLP = Contract Laboratory Program
- ml = Milliliter
- PAHs = Polycyclic Aromatic Hydrocarbons
- PCBs = Polychlorinated Biphenyls
- SVOCs = Semivolatile Organic Compounds
- TAL = Target Analyte List
- TCL = Target Compound List
- TOC = Total Organic Carbon
- VOCs = Volatile Organic Compounds

Decontamination

All sampling equipment used to collect chemical and toxicity data was decontaminated following procedures outlined in Section 11 of the CSAP.

Sample Identification

Due to the need to distinguish multiple wetlands within a single site designation, sample identification procedures were modified from those presented in the CSAP. The new sample identification scheme was used only for sediment and surface water samples and affected the fifth through eighth characters. The fifth and sixth characters referred to the wetland number, and the seventh and eighth characters referred to the sample number within that wetland. Since all samples were collected from the upper interval, the last two characters were "-01." For example, sediment sample location 2 within wetland 3 was designated "041M030201." For wetland numbers three characters long (18A, 18B, etc.), the wetland number was given in the fifth, sixth, and seventh characters. For example, sediment sample location 3 in Wetland 18A was designated "041M18A301."

All QC samples followed the identification procedure described above. The matrix identification numbers were consistent with the CSAP (E/A&H, 1994).

Sample Containers and Preservation

All laboratory-provided containers were precleaned and certified, as specified in Chapter 12 of the CSAP. All samples were preserved with ice to $4^{\circ} \pm 2^{\circ}\text{C}$ before shipment in accordance with the CSAP, except the samples for toxicity analysis and benthic diversity. The samples analyzed for toxicity were couriered on ice directly to the local laboratory twice a day during sample collection, where they were stored at 4°C before analysis. The samples for benthic diversity were preserved in 10% formalin and did not require temperature preservation to ensure sample integrity.

4.3 Analytical Parameters

Site 41 samples were collected for chemical, physical, toxicity, or diversity analysis. Chemical analyses provided a basis for determining the nature and extent of site contamination and contaminant bioaccumulation potential. Physical analyses helped assess the potential bioavailability of contaminants within the source media by evaluating the amount of total organic carbon and grain size of the sediment. Toxicity and diversity tests helped quantify impacts to endpoint species.

The number of Site 41 samples collected and the analytical requirements for Phases IIA and IIB/III are summarized in Table 4-3. Samples for chemical analysis were analyzed for Target Analyte List (TAL) inorganic and Target Compound List (TCL) organic parameters using USEPA Contract Laboratory Program (CLP) protocol. Phase IIA sediment and surface water analytical results are presented in Appendix A. Phase IIB/III sediment and surface water analytical results are presented in Appendix B. TAI Environmental Sciences, Inc. of Mobile, Alabama, followed an internal laboratory procedure for species enumeration using standard dissection microscope techniques. This procedure is included in Appendix C and the results are included in Appendix D. Procedures for toxicity analysis are included in Appendix E.

In addition to the CLP method analyses, a duplicate group of sediment samples was analyzed for metals by a modified method that used hydrofluoric acid for metals digestion instead of nitric acid, which is used in the CLP method. This modified method is cited in Section 5, data validation. The hydrofluoric acid digestion was performed at FDEP's request as a test case to compare the two digestion techniques. The results from the two methods were very comparable; therefore, only the CLP method data have been presented for evaluation in this report. A comparison of data from these two methods is included as Appendix F.

Table 4-3
 Analytical Parameters and Number of Samples

Medium	Number of Stations	Analysis	Phase	Method
Sediment	122	Chemistry	IIA	TCL/TAL
Surface Water	51	Chemistry	IIA	TCL/TAL
Sediment	13	Chemistry	IIB/III	TCL/TAL
Surface Water	9	Chemistry	IIB/III	TCL/TAL
Sediment	6	Midge larvae <i>Chironomus tentans</i> survival and emergence (10/28 days)	IIB/III	ASTM E 1706-95B
Sediment	7	Marine amphipod <i>Leptocheirus plumulosus</i> mean survival (10 days)	IIB/III	ASTM E 1367-92
Sediment	7	Marine polychaete <i>Neanthes arenaceodentata</i> survival and growth (20 days)	IIB/III	PSEP, 1991
Surface Water	5	Fathead minnow <i>Pimephales promelas</i> survival and growth (7 days)	IIB/III	EPA/600/4-89/001
Sediment	11	Species Richness/Diversity	IIB/III	See Appendix C
Fish Tissue	6	Whole body contaminant residue	IIB/III	SVOCs, Pesticide/PCBs and Appendix IX metals

Notes:

- TCL = Target compound list organic
- TAL = Target analyte list inorganic
- ASTM = American Society for Testing and Materials
- PSEP = Puget Sound Estuary Program

Sediments were also analyzed for physical parameters. All sediment samples were analyzed for TOC according to EPA method SW 846-9060, and grain size according to American Society for Testing and Materials (ASTM) method D422. These analyses were conducted by Ceimec Laboratories of Narragansett, Rhode Island, during Phase IIA and Savannah Laboratories of Savannah, Georgia, during Phase IIB/III.

4.4 Global Positioning System

GPS was used to identify sample locations at Site 41. At NAS Pensacola, the GPS unit required a stationary reference receiver which was placed at a surveyed location and continually recorded signals from satellites. Before field sampling, a rover unit was initialized. A stop-and-go survey

was performed by merely pausing for a few seconds at each sampling location (identified by stakes labeled with the sample identification number). Using the hand-held controller, the user recorded and appropriately described each point. This process of initialization and subsequent recording is termed a "chain". At each day's end, the memory cards were downloaded.

One advantage of using GPS for mapping water-based sampling locations is that re-sampling at the same location (+ 0.1 meter) is possible. Sample location 5A01 could not be resampled during Phase IIB/III because that area no longer contained surface water.

4.5 Deviations from the Site 41 SAP Addendum

Additional research into laboratory techniques was performed after the SAP addendum was finalized and distributed. Initially, the 10-day *Hyaella azteca* test for survival, growth, and reproduction was planned to be performed in sediment samples collected from Wetlands 5A and 3. However, based on the recommendation of the contract laboratory, the 28-day *Chironomus tentans* test (ASTM Method E1706-95B) for survival and emergence was performed instead. USEPA and FDEP concurred with this analysis change. The 10-day *Hyaella* test was discontinued because 10 days was considered insufficient to obtain adequate growth and reproduction response, both key measurement endpoints for this test. The longer test enabled the chronic endpoints to be measured more effectively.

In addition, full TCL/TAL analysis was originally proposed for the fish residue analysis. Due to a sampling error, the fish tissue was analyzed for pesticides/PCBs, SVOCs, and Appendix IX metals. This analysis did not include mercury, a parameter that has a potential to bioaccumulate. Therefore, a mercury exposure model was developed from the maximum and mean concentrations of mercury in the sediment of the Wetland 64 complex and to model the potential mercury concentration in predatory fish. This model was based on mercury bioaccumulation in the red drum (*Sciaenops ocellatus*). The results of the red drum mercury exposure model are presented in Appendix G.

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5.0 DATA VALIDATION

Site 41 data were validated by EnSafe personnel and Heartland Environmental Services, Inc. of St. Charles, Missouri. The analytical work was conducted by Ceimic Laboratories, Narragansett, Rhode Island, and Savannah Laboratory and Environmental Services, Inc., Savannah, Georgia. Sample analyses were performed in accordance with the following guidance documents:

- Naval Energy and Environmental Support Activity (NEESA) Level D QA/QC guidelines as stated in: *Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation and Restoration Program (NEESA 02.2-047B)*, June 1988 (USEPA, 1988).
- *USEPA CLP, Statement of Work (SOW) for Organic Analysis, Multi-Media, Multi-Concentration*, USEPA Office of Solid Waste and Emergency Response (OSWER), (CLP Organic SOW), OLM02.1, 1994 (USEPA, 1994a).
- *USEPA CLP, SOW for Inorganic Analysis, Multi-Media, Multi-Concentration* (CLP Inorganic SOW), USEPA OSWER, ILM03.0, 1993 (USEPA, 1993a).
- *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846)*, Third Edition, USEPA OSWER, revised July 1992 (USEPA, 1992a).
- *Methods for Chemical Analysis of Water and Wastes (MCAWW)*, USEPA Environmental Monitoring and Support Laboratory, EPA-600/4-79-020, March 1983 (USEPA, 1983).

Data were validated using the following documents:

- *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*, February 1994 (EPA-540/R-94/013) (Organic Functional Guidelines) (USEPA, 1994b).

- *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review*, February 1994 (EPA540/R-94/013) (Inorganic Functional Guidelines) (USEPA, 1994c).

The end of this section includes a list of data validation qualifiers. Appendix H provides detailed validation reports completed by EnSafe and Heartland Environmental Services, Inc.

Samples were collected at Site 41 from November 1995 through August 1997. All samples were received by the laboratory in good condition and with proper custody documentation. Samples were analyzed for VOCs, SVOCs, pesticides/polychlorinated biphenyls (PCBs), and inorganic parameters. Samples submitted to Ceimic Laboratories were analyzed using the CLP Organic and Inorganic SOWs. Samples submitted to Savannah Laboratory were analyzed using the CLP Inorganic SOW and SW-846 methodology. Selected samples also were analyzed for TOC using SW-846 method 9060, grain size using ASTM method D422, and hardness using MCAWW method 130.1. Four fish tissue samples were submitted to Savannah Laboratory and analyzed for SVOCs, pesticides/PCBs, and Appendix IX metals (aluminum, antimony, arsenic, chromium, cobalt, copper, iron, lead, manganese, nickel, selenium, silver, thallium, vanadium, and zinc).

Organic and inorganic results were reported by the laboratory in 30 sample delivery groups (SDGs): 030301, 041M10, 5A0101, 63A401, 640801, EA0101, EAH030, EAH031, EAH032, EAH033, EM0040, EM005, EM0050, EM0060, EMD0060, EW0010, M00901, M06010, M06070, M52A10, Z30301, Z42101, Z53301, PEN11, PEN12, PEN13, PEN14, and PEN15. SDGs Z13601 and Z30201 are not included because these two SDGs were analyzed for metals using a modified hydrofluoric acid digestion. Although samples prepared by the modified method were not used to quantify specific analyte concentrations, the validation results are presented in this section. TOC results were not validated because the data were used for qualitative purposes only.

5.1 Organic Analysis

5.1.1 Holding Times

All technical and contractual holding times were within QC requirements for the VOC fraction. No SDGs were outside holding times for the VOC fraction.

Several samples were analyzed outside holding times in the SVOC and pesticide/PCB fractions. When a sample was analyzed or extracted outside holding times, positive and undetected results were flagged as specified in CLP Organic SOW. Undetected values for samples that greatly exceeded holding times were rejected as "UR", based on professional judgment. Samples exceeding holding times and the corresponding flags are summarized below:

Fraction/SDG	Sample IDs	Days Exceeded	Flag(s)
SVOC / 041M10	041W130101	10	J, UJ
SVOC / M06070	041W250101, 041R250301, 041W270201	22	J, UR
PEST / EM0040	041M030101, 041N030101, 041M030101DL, 041N030101DL, 041M030201, 041W030201, 041M030201DL	1-4	J, UJ
PEST / EM0050	041M150101, 041W150101, 041M150101DL, 041M150201, 041M150201DL, 041M150301, 041M150301DL, 041M150401	3-4	J
PEST / M06010	041M250201	14	J, UJ
PEST / M06070	041M060701	8	J, UJ
PEST / Z53301	041M10A101, 041M10A201, 041M120101, 041M120101DL	2-3	J, UJ

5.1.2 Matrix Spike/Matrix Spike Duplicates

A matrix spike (MS) is used to determine the accuracy of the analysis for a given matrix. A matrix spike duplicate (MSD) is used to determine the precision and accuracy of an analysis for a given matrix. The MS and MSD are used to detect matrix effects caused by contaminants that may interfere with the compounds of interest and that may also be present within the sample.

Both the MS and MSD consist of a known quantity of stock solution added to the sample before its preparation and analysis.

MS/MSD data evaluation involves two calculations to measure accuracy and precision. Accuracy is measured using an estimate of the percent recovery, which is calculated by comparing the amount of the compound recovered by analysis to the amount added to the sample. Precision is measured with an estimate of relative percent difference (RPD), which is calculated using the recoveries for both the MS and MSD. No specific requirements have been established for qualifying MS/MSD data. However, guidelines in applying professional judgment are discussed in Organic Functional Guidelines.

All reported MS/MSD results appeared to be satisfactory for the Site 41 investigation.

5.1.3 Calibrations

Initial and continuing calibrations with standard solutions are used to check an instrument's ability to produce acceptable quantitative data for the compounds.

VOC and SVOC Initial Calibration — A five-point initial calibration is done to check the instrument's performance at the beginning of the analytical run and to establish a linear calibration curve. The initial calibration is verified by calculating the relative response factor (RRF) and the percent relative standard deviation (%RSD) for each compound. An RRF less than 0.05 or a %RSD greater than 30% is outside the quality control limits for the initial calibration.

Instruments were calibrated initially and continually with standard solutions to verify that they were capable of producing acceptable quantitative data for the analyzed compounds. All compound quantitation was analyzed against gas chromatograph/mass spectrometer (GC/MS) tunes which were within QC requirements for the VOC and SVOC fractions.

VOC and SVOC Continuing Calibration — Calibration standard solutions are run periodically to check the daily performance of the instrument and to establish the 12-hour RRF on which the sample quantitations are based. The initial calibration is verified by calculating the RRF and the percent difference (%D) for each compound. An RRF less than 0.05 or a %D greater than 25% is outside the quality control limits for the continuing calibration.

QC outliers were found for VOC continuing calibration RRFs for SDGs 030301, 5A0101, 63A401, 041M10, EM0040, EW0010, and Z53301. Details of the SDGs that had RRFs less than 0.050 are summarized below. For the following samples and noncompliant compounds, all positive results were estimated “J” and nondetect values were rejected and flagged “UR”.

SDG	Sample	Analytes
030301	041W030401	2-butanone, 2-hexanone
	041W030301	acetone
041M10	041W130101, 041W5A0501, 041TM00401	acetone, 2-butanone
5A0101	041W5A0101, 041W5A0201, 041W5A0401, 041W5A0701, 041W061001	acetone, 2-butanone
63A401	041M63A401	acetone
EM0040	041R030101	acetone, 2-butanone
EW0010	041W160101, 041W160201	acetone, 2-butanone, 2-hexanone
Z53301	041W120101	acetone, 2-butanone

QC outliers were found for SVOC continuing calibration RRFs for SDG EM0050. No other RRF exceedances were identified. The target compound 4-chloroaniline for samples 041M150201 and 041M150401 in SDG EM0050 was qualified as estimated, “J”, for positive results. Nondetect values were rejected and flagged “UR”.

Both the VOC and SVOC fractions contained several compounds with %RSDs and %Ds outside the continuing calibration QC criteria. These QC deficiencies are within the normal fluctuations of laboratory function. All affected sample results were qualified for %RSD and %D outliers per the Organic Functional Guidelines.

Pesticide/PCB Initial Calibration — Using two separate standard mixes, three-point calibrations are analyzed for single-component pesticide compounds, and calibration factors (CF) are established. The CF for single-component pesticides must be less than or equal to 20%. Multicomponent pesticide toxaphene and all PCBs (or Aroclors) are analyzed separately. Retention times and CFs are determined for three to five peaks. The only review criterion for multicomponent compounds is to verify that these steps were taken.

All initial calibration criteria were met for the pesticide/PCB analyses, except for SDGs 030301, 640801, EM0040, EM005, EM0050, EMD060, M06010, and M06070. Details of the SDGs that were outside pesticide/PCB initial calibration QC criteria are summarized below. For the following samples and noncompliant compounds, all positive results were estimated “J” and nondetect values were rejected and flagged “UR”.

SDG	Sample	Analytes
030301	All samples	alpha-BHC and delta-BHC
640801	All samples	endosulfan II
EM0040	All samples	alpha-BHC and delta-BHC
EM005	All samples	alpha-BHC
EM0050	All samples	alpha-BHC
EM0060	041M18A201, 041M18B101, 041M18A101DL, 041M18A201DL, 041M18A101, 041M18B101DL	alpha-BHC
M06010	041M250101, 041M270101, 041M270201, 041M641501, 041M640501DL, 041M060101DL	alpha-BHC

SDG	Sample	Analytes
M06070	041W060701, 041W320101, 041W320301, 041EM0010, 041FM00101, 041W330101, 041W330301, 041R250301, 041W060301, 041W250301, 041M060901, 041M320101, 041M320301, 041M330101,	alpha-BHC and delta-BHC
M06070	041W250101, 041W270201, 041M330201, 041M330301, 041M060801, 041M060801DL	alpha-BHC and delta-BHC
M06070	041M060701	alpha-BHC and 4,4'-DDT

Pesticide/PCB Continuing Calibration — To confirm the calibration and evaluate instrument performance, calibration is verified by analyzing instrument blanks, the performance evaluation mixture (PEM), and the midpoint concentration of the two standard mixes. The %D between the calculated amount and the true amount must not exceed 25%. Multicomponent compounds (e.g., PCBs) do not require continuing calibration verification.

No continuing calibration QC outliers were found for the SDGs analyzed for pesticides/PCBs.

5.1.4 Blanks

Laboratory method blanks are used to assess the existence and magnitude of potential contamination introduced during analysis. Additionally, field-derived *field blanks* and *trip blanks* were submitted to the laboratories. The field blank is a sample of water used during decontamination activities. The trip blank is a 40-milliliter (ml) volatile organic analysis vial filled with certifiable water used to assess cross-contamination during VOC sample shipment. When compounds are found in both samples and laboratory blanks analyzed within the same 12-hour period *and/or* field-derived blanks, the usability of the data depends on the reviewer's judgment and the origin of the blank. According to the Organic Functional Guidelines, a sample result should not be considered positive unless the concentration of the compound in the sample exceeds

10 times the amount in *any* blank for common laboratory compounds (i.e., methylene chloride, acetone, and 2-butanone), or five times the amount for other compounds. These concentrations are referred to as *action levels* (ALs). Because blank samples may not be prepared using the same weight of the sample, volume of sample, or dilution, these variables should be considered when using blank criteria. The specific actions to be taken are as follows:

- If a compound is found in the blank but not in the sample, no action is taken.
- If the sample concentration is greater than the AL, the concentration may be used unqualified.
- If the sample concentration is less than the practical quantitation limit (PQL) and less than the AL, the sample is reported as nondetect "U" at the PQL.

Example (using 10× rule):

Water Sample		Diluted Water Sample	
Blank result	= 1	Blank Result	= 1
Blank AL	= 10	Dilution Factor	= 5
PQL	= 5	Blank AL	= 50
Sample result	= 4J	Diluted PQL	= 25
Final result	= 5U	Sample result	= 4J
		Final result	= 25U

In this example, note that data are not reported as 4U because it is less than the PQL. Also note that the dilution factor is used to calculate an AL of 50 ($1 \times 5 \times 10$).

- If the sample concentration is greater than the PQL, but less than the AL, the concentration is reported as nondetect "U".

Example (using 10× rule):

Water Sample	Soil Sample	Diluted Soil Sample
Blank result = 6	Blank result = 6	Blank Result = 6
Blank AL = 60	% Solids = 80	% Solids = 80
PQL = 5	Blank AL = 75	Dilution Factor = 5
Sample result = 50	PQL = 5	Blank AL = 375
Final result = 50U	Sample result = 50	PQL = 25
	Final result = 50U	Sample result = 250
		Final result = 250U

In this example, water sample results less than 60 (or 10×6) would be qualified as not detected. Soil results of less than 75 would be qualified as not detected because percent solids are used to calculate the AL: $[(6 \div 0.8) \times 10]$. Results less than 375 would be qualified as not detected in the diluted soil sample because dilution factors and percent solids are used to calculate the AL: $[(6 \div 0.8) \times 10 \times 5]$.

Several compounds were detected in the blanks associated with the investigation of Site 41. Most compounds were considered to be common laboratory compounds: acetone, methylene chloride, and phthalate esters. Target analytes detected in investigative samples were qualified as recommended by the Organic Functional Guidelines. ALs were based on the highest concentration of any laboratory compound found in associated method blank(s) or QC sample(s). No positive sample result for a common laboratory compound was reported unless that compound's concentration exceeded the ALs. All results believed to be attributed to blank contamination were flagged as undetected "U".

5.1.5 Surrogates

Accuracy is the degree to which a given result agrees with the true value. To check the accuracy in VOC, SVOC, and pesticide/PCB analyses, the methods require the addition of known amounts of surrogate compounds. If the surrogate percent recoveries are close to the known concentrations, as defined by the limits set by the method, the reported target compound concentrations are assumed to be accurate.

All volatile and semivolatile fraction surrogate recoveries were within QC limits for the Site 41 investigation.

Pesticide/PCB SDGs had surrogate recoveries within QC criteria, except for 030301, 041M10, 5A0101, 63A401, 640801, EM0040, EM0050, EMD060, EW0010, M00901, M06010, M06070, M52A10, Z30301, Z42101, and Z53301. Pesticide/PCB surrogates outside QC criteria indicated that the sample results may have been influenced by matrix interference. Samples that had at least one surrogate recovery outside QC criteria are summarized below. When surrogate recoveries were above the QC limit, only positive results were estimated and qualified as estimated "J". When surrogate recoveries were less than the QC limit, all positive and undetected results were estimated and qualified "J" and "UJ", respectively.

5.1.6 Internal Standards

Internal standards (IS) are added to VOC and SVOC samples and used to calculate the concentrations of target compounds. Two IS QC criteria must be met when a sample is analyzed. The retention time of the IS must not vary by more than 30 seconds and the IS area counts must not vary by more than a factor of two (-50% to +100%) from the associated calibration standard. For Site 41 samples, all VOC and SVOC internal standard retention times were within QC limits.

The following SDGs had internal standard area recoveries outside QC criteria: 63A401, 640801, EM0040, EM005, EM0050, EMD060, M06010, M06070, M52A10, and Z30301. Details of these SDGs are summarized below. All associated positive results were flagged "J" and all nondetects as "UJ".

SDG	Sample	Noncompliant Internal Standard
VOC Fraction		
63A401	041M010201RE 041M010301, 041M010101RE	1, 4-difluorobenzene, chlorobenzene-d ₅ chlorobenzene-d ₅
EM005	041M63A301	chlorobenzene-d ₅
EM0050	041M150101RE	1, 4-difluorobenzene, chlorobenzene-d ₅
EMD060	041M18A301, 041M18A101RE	chlorobenzene-d ₅
EMD060	041M18A301RE	ALL
M06010	041M250201, 041M640301	chlorobenzene-d ₅
M06010	041M250201RE, 041M270101RE, 041M270101, 041M640301	1, 4-difluorobenzene, chlorobenzene-d ₅
M06070	041M320201	1, 4-difluorobenzene, chlorobenzene-d ₅
M06070	041M320201RE	1, 4-difluorobenzene, chlorobenzene-d ₅ , bromochloromethane
M52A10	041M52A101RE, 041M52A201	chlorobenzene-d ₅
640801	041M641901RE 041M641901	chlorobenzene 1,4-difluorobenzene, chlorobenzene-d ₅
EM0040	041M030201	chlorobenzene-d ₅
SVOC Fraction		
EMD060	041M18A201	perylene-d ₁₂
PEN13	041M640501, 041M640401	perylene-d ₁₂
PEN15	041J750101	chrysene-d ₁₂ , perylene-d ₁₂
PEN15	041J18B101, 041J330201, 041J640101	perylene-d ₁₂

5.1.7 Field Duplicates

The duplicate samples assist in indicating overall field and laboratory precision. A greater variance should be expected for soil sample duplicates than for water sample duplicates due to the differences in matrix. All Site 41 samples demonstrated good field duplicate correlation, except for the pesticide fraction of SDGs 041M10, EM0040, EM005, and M00901.

5.1.8 Compound Quantitation

For organic analyses, the data evaluator must assess the usability of values when multiple sample results are reported by the laboratory. The following paragraphs describe actions taken by the validator in these cases.

Reanalyzed Samples

Occasionally, organic samples may require reanalysis because of method requirements or QC results outside method criteria. Reasons for sample reanalysis include samples analyzed outside 12-hour tuning periods, extremely low surrogate %RSDs, and IS retention times and/or area counts outside QC limits. In these instances, the laboratory may report results for the original and reanalyzed samples. During validation, the reviewer evaluates QC associated with the original and reanalyzed samples and assesses which sample represents the preferable quality. The sample with the preferable QC should be used for interpretation. The preferred analysis is reported as a primary sample in the EnSafe database and analytical tables.

The following samples were reanalyzed. The laboratory reported two sample results and the preferred analyses were used for interpretation.

SDG	Preferred Samples	Reason
VOC Fraction		
041M10	041M5A0501RE	IS areas improved with reanalyses.
63A401	041M010101RE, 041M010201RE, 041M010301	IS areas improved with reanalyses.
640801	041M64901RE	IS areas improved with reanalyses.
EM0040	041M030201	Surrogate recoveries did not improve with reanalysis.
EM005	041M63A301	IS areas did not improve with reanalysis.
EM0050	041M150101RE	Surrogate recoveries improved with reanalysis.
EMD060	041M18A301	IS areas improved with reanalysis.
EMD060	041M18A101RE	IS areas improved with reanalysis.
M06010	041M250201, 041M270101, 041M640301RE	IS areas did not improve with reanalysis.

SDG	Preferred Samples	Reason
VOC Fraction		
M52A10	041M52A101RE 041M52E201	Surrogate recoveries improved with reanalysis. Surrogate recoveries did not improve with reanalysis.
PEN12	041M5A0601, 041M640601, 041N750101	IS areas did not improve with reanalysis.
SVOC Fraction		
EMD060	041M18A201	IS areas did not improve with reanalysis.
PEN13	041M640401, 041M640501	IS areas did not improve with reanalysis.

Diluted Samples

When an analyte response exceeds the linear calibration range of the instrument or is off-scale, the laboratory dilutes the sample. If one or more compounds are outside the calibration range during an initial analysis, the laboratory flags the analyte "E". When diluted, the sample results are qualified "D". Generally, values from the initial analysis will be used, except where they exceeded the calibration range. In this case, the initial analysis value will be substituted by the diluted value to ensure the most representative data. The "D" qualifier will remain on the value to alert the data user that the value from a secondary dilution was used.

The SDGs, samples and compound used from the secondary dilution and the corresponding samples are listed below.

SDG	Diluted Samples	Compounds Used from Secondary Dilution
5A0101	041M5A0101, 041M061101	acetone
EM005	041W170101, 041W04D401	methylene chloride
M00901	041WW10201	xylene
M06070	041M060901	acetone
	041R250301, 041W250301	methylene chloride
Z42101	041W5B0201	cis-1,2-dichloroethene
Z30301	041W570101	methylene chloride
030301	041M04D101	delta-BHC, 4,4'-DDE, 4,4'-DDD
	041M04D201	4,4'-DDE, 4,4'-DDD

SDG	Diluted Samples	Compounds Used from Secondary Dilution
041M10	041M5A0501	4,4'-DDE
5A0101	041M060601	4,4'-DDE, 4,4'-DDD
63A401	041M010301	4,4'-DDD, gamma-chlordane, Aroclor-1260
640801	041M010401	endrin, 4,4'-DDD, 4,4'-DDT
EM0040	041M030101, 041N030101	4,4'-DDE, 4,4'-DDD, 4,4'-DDT
	041M030201	4,4'-DDD, Aroclor-1260
EM005	041M19A101	heptachlor epoxide
	041C490101, 041M490101, 041M490201	4,4'-DDD
	041M63A301	4,4'-DDD, Aroclor-1260
EM0050	041M150101, 041M150201, 041M150301	4,4'-DDE, 4,4'-DDD
EM0060	041M790101	4,4'-DDD, alpha-chlordane
EMD060	041M18A101, 041M18A201	4,4'-DDE, 4,4'-DDD, 4,4'-DDT
	041M18B101	4,4'-DDE, 4,4'-DDT
M00901	041M480101, 041N480101	4,4'-DDE, 4,4'-DDD
M06010	041M060301	4,4'-DDE, 4,4'-DDD, 4,4'-DDT
	041M640201, 041M640501	4,4'-DDE, 4,4'-DDD
	041M060101	4,4'-DDE, 4,4'-DDT
M06070	041M060801	4,4'-DDE, 4,4'-DDD
M52A10	041M52E101, 041M56A101	4,4'-DDE, 4,4'-DDD
	041MW20101	4,4'-DDD
Z53301	041M120101	endrin ketone
PEN12	041M5A401	4,4'-DDE, 4,4'-DDD

Pesticide/PCB Quantitation

Pesticide analysis employs an electron capture detector (ECD) for quantitation; however, ECD detection is not a definitive means of discerning between different components. Pesticides are routinely analyzed using two dissimilar columns with retention time windows as the qualitative indicator. If a peak falls within the retention time windows on both columns, then it is reported as a positive hit for the appropriate target analyte. Target analytes and surrogates are generally quantitated and reported on both columns; however, only the lower of the two concentrations is

reported because, if present, co-eluting interferences are likely to increase the calculated concentration of any target analyte.

For detected analytes, the %D between the two columns is calculated. If the %D is greater than 25%, the laboratory flags the value with a "P" qualifier. This flag alerts the data user of the potential problems in quantitating the analyte. If there is a significant difference in the quantitated values on the two columns, an interference likely exists, suggesting that the detected concentration may be a false positive. This is particularly true at lower concentrations where uncertainty may increase because of instrument noise.

During the validation process, the laboratory's "P" flags are assessed. General guidelines are used to assess result %Ds. For data in SDGs other than PEN11, PEN12, PEN13, PEN14, and PEN15, %Ds greater than 25% were qualified as estimated. For SDGs PEN11, PEN12, PEN13, PEN14, and PEN15, the guidelines below were used, in conjunction with examination of the data provided, to ascertain the validity of single-component pesticide results:

Result %D	Validation Flag
$\leq 40\%$	Result is accepted unqualified.
$40\% > \%D < 100\%$	Analyte is estimated and flagged "J".
$> 100\%$	Analyte is flagged as undetected "U" if it is less than $10\times$ the PQL and data review indicates the result may be a false positive.

OR

Analyte is flagged "NJ" if the result is greater than $10\times$ the PQL. "NJ" flag indicates the presence of an analyte for which there is presumptive evidence to make a tentative identification at an estimated concentration.

5.2 Inorganic Analysis

5.2.1 Holding Times

All samples were received by the laboratory in good condition with proper custody documentation. From the date of collection to the date of sample analysis, holding times were within method and contractual requirements. The only exceptions were SDGs Z13601 and Z30201, which were prepared using a modified acid digestion. Because the analytical data for SDGs Z13601 and Z30201 were not used to quantify specific analyte concentrations, the holding time exceedances do not affect data quality or usability.

5.2.2 Calibrations

Initial and continuing calibrations are conducted to ensure that the instrument can produce acceptable and quantitative data throughout each analytical run. For the analysis of Site 41 inorganics, no initial or continuing calibrations exceeded method QC limits for the inorganic parameters.

5.2.3 Blanks

Laboratory method blanks are used to assess the existence and magnitude of potential contamination introduced during analysis. Additionally, *field blanks* may be collected to assess the potential contamination introduced during sample collection. When chemicals are found in both samples and laboratory blanks, the usability of the data depends on the reviewer's judgment and the origin of the blank. According to Inorganic Functional Guidelines, a sample result should not be considered positive unless the concentration of the analyte in the sample exceeds five times the amount in *any* blank. These concentrations are referred to as ALs. Because blank samples may not be prepared using the same weight of sample, volume of sample, or dilution, these factors should be also taken into consideration when using blank criteria. The specific actions to be taken are as follows:

- If an analyte is found in the blank but not in the sample, no action is taken.
- If the sample concentration is between the instrument detection limit (IDL) and the AL, the concentration is reported as “U”.
- If the sample concentration is greater than the AL, the concentration may be used unqualified.

When the blank concentration is less than the IDL (negative value), but had an absolute value greater than the IDL, the AL is 10 times the absolute value of the blank concentration. The specific actions are as follows:

- If the sample concentration is greater than the AL, the concentration may be used unqualified.
- If the concentration of any detected analyte is less than the AL, it is qualified as estimated “J” for positive results.
- If the result is nondetect, then it is qualified as estimated “UJ”.

Contamination was identified in blanks of all SDGs. Action levels were set for each affected analyte based on the highest concentration in any associated blank. Analytes attributed to blank contamination were flagged undetected “U”. No positive sample result was reported for an analyte detected in any blank unless that artifact’s concentration exceeded the action level of five times ($5\times$) the amount found in any blank, per the Inorganic Functional Guidelines.

5.2.4 Inductive Coupled Plasma Interference Check Sample Analyzes

The inductive coupled plasma (ICP) Interference Check Sample (ICS) analysis is performed to check the laboratory's instrument and background correction factors. All percent recovery criteria for the Site 41 samples were within the established criteria.

5.2.5 ICP Serial Dilutions

ICP serial dilutions assess matrix interference. One sample from each set of similar matrix type is diluted by a factor of five. For an analyte concentration that is at least 50 times above the IDL for CLP analyses and 10 times above the IDL for SW-846, the measured concentrations of the undiluted and diluted sample should agree within 10%. SDGs 030301, 5A0101, EM0040, M00901, Z30201, PEN13, and PEN14 had %Ds outside acceptable QC criteria. Elements that exceeded QC criteria are summarized below. When an element exceeded QC criteria, that analyte was qualified as estimated "J" for all positive sample values in the SDG, as specified in Inorganic Functional Guidelines. Nondetect results were accepted without qualification.

SDG	Affected Samples	Analyte(s)
030301	041M030301, 041M030401, 041M030501, 041M030601, 041M030701, 041M04D101, 041M04D201, 041M04D301, 041M04D401, 041M04D501	manganese
5A0101	041W061001, 041W5A0101, 041W5A0201, 041W5A0401, 041W5A0701	iron, magnesium
EM0040	041M030101, 041N030101, 041M030201	lead, calcium
M00901	041W480101, 041R480101, 041W490301, 041WW10101, 041WW10201, 041WW10301, 041W490101	calcium, magnesium
Z30201	041M10A101, 041M320301, 041M330201, 041M641401	iron, lead
PEN13	041M160301, 041M640401, 041M640501, 041M640601	aluminum
PEN14	041W640101, 041W640501, 041R640501	potassium
PEN15	041J400601, 041J18B101, 041J330201, 041J640101, 041J640601, 041J750101	copper, iron, manganese

5.2.6 Laboratory Control Samples

Laboratory control samples (LCS) are used to monitor the overall performance or accuracy of all steps in the analysis, including the sample preparation. All LCS criteria were met for all SDGs, except for SDG Z30201. Samples in this SDG were prepared using a hydrofluoric acid digestion method. Because the analytical data were not used to quantify specific analyte concentrations at Site 41, QC exceedances for this SDG do not affect data quality or usability.

5.2.7 Laboratory Matrix Spikes

Laboratory spiked samples are designed to provide information about the effects of the sample matrix on the digestion and measurement method. Many MS recoveries exceeded QC criteria for the Site 41 data. As specified by the CLP Inorganic SOW and SW-846 methods, the MS QC limits are 75% to 125%. When an element was outside MS QC limits, positive and undetected results for that analyte were qualified for all samples in the SDG, as specified in Inorganic Functional Guidelines. Spike results and the qualifiers applied to QC outliers are summarized below.

SDG	Affected Samples		Flag(s)
Antimony	EM0040, EMD060, 5A0101, 63A401 EM005, M52A10, Z53301, PEN12	> 30% < 75%	J, UJ
Antimony	030301, 041M10, Z30301, Z42101 (soils), 63A401, 640801, EM005 EM0050, EW0010, M06010, Z30301, Z42101, Z53301, PEN12	< 30%	J, UR
Cadmium	EM0040	> 30% < 75%	J, UJ
Chromium	Z30301	> 125%	J
Copper	M06010	> 30% < 75%	J, UJ
Cyanide	PEN12	> 30% < 75%	J, UJ
Lead	5A0101, Z42101	> 125%	J
Lead	Z42101 (soils)	> 30% < 75%	J, UJ
Mercury	EMD060	> 125%	J, UJ
Mercury	PEN14	> 30% < 75%	J, UJ

SDG	Affected Samples		Flag(s)
Selenium	041M10, EM0040 (soils), EM005 M52A10	> 30% < 75%	J, UJ
Selenium	Z42101 (soils), 030301, M06010	> 125%	J
Silver	041M10, EM0040 (soils), 030301, Z53301, Z22401 (soils), M06010, Z42101, PEN14	> 30% < 75%	J, UJ
Thallium	041M10, EM0040 (soils), 640801, Z30301 (soils)	> 30% < 75%	J, UJ
Zinc	PEN14	> 125%	J
Cyanide	PEN12	> 30%, < 75%	J, UJ

For SDGs Z13601 and Z30201, several elements exceeded the MS control limits. Because the data from these SDGs were not used to assess contamination at Site 41, the QC exceedances do not affect data quality and usability.

5.2.8 Laboratory Duplicates

Laboratory duplicate samples are used to determine the precision of analytical process for each parameter. The duplicate RPD analysis criteria were not met for SDGs 041M10, 63A401, M00901, EM0050, M06010, Z42101, and Z53301. A summary of the SDGs outside QC criteria and elements affected is provided below. When an element was outside QC criteria, that analyte was qualified as estimated "J" for all positive sample values in the SDG, as specified in Inorganic Functional Guidelines.

SDG	Analyte	Flag
041M10	calcium, lead	J
63A401	aluminum, calcium	J
M00901	aluminum	J
EM0050	calcium, chromium	J
M06010	calcium, lead, zinc	J
Z42101	antimony, lead, silver	J
Z53301	calcium	J

For SDGs Z13601 and Z30201, several elements exceeded the RPD control limits. Because the data from these SDGs were not used to assess contamination at Site 41, the QC exceedances do not affect data quality and usability.

5.2.9 Field Duplicates

Representativeness expresses the degree to which sample data represent the characteristic of a population, parameter variations at a sampling point, or an environmental condition. The duplicate samples assist in indicating overall field and laboratory precision. A greater variance should be expected for soil sample duplicates than for water duplicates due to matrix differences. RPDs for field duplicates were outside QC criteria for SDGs 041M10 (calcium), EM0040 (aluminum, iron, magnesium, manganese, vanadium, and zinc), EM0050 (calcium), M06010 (aluminum, calcium, iron and sodium), and Z42101 (calcium).

5.2.10 Atomic Absorption Spike Recoveries

Antimony, arsenic, lead, silver thallium, and selenium were analyzed by graphite furnace atomic absorption (GFAA). For elements analyzed by GFAA, every sample is spiked by the analyst to assess matrix interference. For the Site 41 samples, GFAA analytical spike recoveries met the control limits of 85 to 115% for all elements except antimony, silver, and thallium. QC criteria exceedances affected the following SDGs: 030301, 041M10, 5A0101, 63A401, 640801, EM0040, EM005, EM0050, EM0060, EMD060, EW0010, M00901, M06010, M06070, M52A10, Z30301, Z42101, Z53301, PEN11, and PEN14. Detections of antimony, silver, and thallium were flagged as estimated "J". Undetected antimony, silver, and thallium results were estimated "UJ" unless they were previously rejected and flagged "UR" for poor MS results.

5.3 Site 41 Data Summary

5.3.1 Completeness

Completeness is defined as the percentage of acceptable data points. Except for the results flagged "UR", all of the samples analyzed for the investigation of Site 41 were determined to be valid with some qualification. Table 5-1 presents the analytical completeness for Site 41 data by parameter.

Table 5-1
Analytical Completeness by Parameter

Fraction	Total Unusable Results	Total Results	Percent Completeness
Metal	33	8990	99.6
Pesticides/PCBs	128	10541	98.8
SVOC	86	23412	99.6
VOC	165	12957	98.7
TOTAL	412	56176	99.2

Note:

Analytical completeness was greater than 95% for each parameter analyzed for Site 41 sediment and surface water samples; therefore, the analytical completeness criterion of 95% was met for each fraction analyzed for this data set.

With the exception of Wetlands 13 and 25, all wetlands were within the analytical completeness criterion of 95% for each parameter. The low completeness percentages obtained for these two wetlands is due to the number of samples analyzed and the nature of the QC criteria that were not met. There were less than five samples collected at each wetland. Hence, if one sample was rejected because of noncompliant QC, the completeness was more impacted than if there were a larger number of samples. Pesticide/PCB sample 041W130101 was rejected because the surrogate recoveries were extremely low, indicating the possibility of matrix interference. SVOC sample 041W250101 was rejected because of missed holding times. In both instances the rejected data indicate that any analytes detected may be biased low and the reported quantitation limits may not be representative.

5.3.2 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. Comparability is assured through the use of established field sampling methods by experienced field personnel and performance of laboratory analyses as specified by USEPA protocols. All samples for Site 41 were collected in accordance with the USEPA Region IV Standard Operating Procedures and Quality Assurance Manual (SOP/QAM) and analyzed according to specified analytical protocols.

5.4 Conclusion

With the exception of the unusable data identified in Section 5.3, the data are considered complete and satisfactory for the investigation of Site 41. Antimony completeness was 83.8% because of low matrix spike recovery, a result of the acid used during the digestion process. The acid digestion procedure prescribed by the CLP analytical method tends to precipitate antimony from the sample, and problems with antimony matrix recovery are inherent in the CLP sample preparation method. EPA has acknowledged that this is a problem; in SW-846, it recommends a specific digestion process to reduce the amount of precipitation.

Validation Qualifiers

- U Undetected** — The analyte was analyzed for but not detected, or was also found in an associated blank at a concentration less than 10 times the blank concentration for common organic laboratory contaminants or five times the blank concentration for other target analytes or elements. The associated value shown is the quantitative limit.
- J Estimated Value** — At least one QC parameter was outside control limits.

NJ Presumptive Identification — NJ is used for pesticide/PCB analysis when the percent difference exceeds the QC limits by 100% or more. It indicates the presence of an analyte for which there is presumptive evidence to make a tentative identification at an estimated concentration. This qualifier is used for pesticide/PCB validation only.

UJ Undetected and Estimated — The analyte was analyzed for, but not detected above the listed estimated quantitation limit; the quantitation limit is estimated because one or more QC parameters were outside control limits.

D Diluted Result — The compound was reanalyzed at a secondary dilution factor. If one or more compounds are outside the calibration range during an initial analysis, the laboratory flags the analyte “E”. When diluted, the sample results are flagged “D”. Generally, values from the initial analysis will be used, except where the value exceeded the calibration range. In this case, the initial analysis value will be substituted by the diluted value to ensure the most representative data. The “D” flag will remain on the value to alert the data user that a secondary dilution value was used.

R/UR Unusable Data — One or more QC parameters grossly exceeded control limits.

6.0 NATURE AND EXTENT EVALUATION METHODS

This section presents the methods used to evaluate the nature and extent of contamination. Wetland-specific evaluations are presented in Section 10.

6.1 Phase IIA Sediment and Surface Water Screening Criteria

The purposes of methods followed for the phases of the Site 41 RI (Phases I, IIA, IIB/III) are discussed in Sections 1, 3, and 4 of this report. Phase I identified wetlands of potential concern by relating individual wetlands to adjacent or nearby IR sites which may have contaminated these wetlands, based on the history of activity at these sites. Phase IIA involved the collection of surface water and sediment samples within areas of likely contamination in the wetlands identified during Phase I. Phase IIA samples were compared to sediment and surface water screening values, identifying where sampling parameters exceeded applicable regulatory criteria. Screening criteria were as follows:

Sediment

- Sediment Screening Values (SSVs) (USEPA, 1995a).
- Sediment Quality Assessment Guidelines (SQAGs), Threshold Effects Levels (TELs) (MacDonald, 1994).

Surface Water

- Freshwater/Saltwater Screening Values (USEPA, 1995a).
- Surface Water Quality Standards (FDEP, 1996).

Freshwater criteria for cadmium, copper, lead, nickel, and zinc were calculated in accordance with the equations below. Hardness was averaged for all of the freshwater samples and used in the equation. Table 6-1 contains the freshwater samples and detected concentration for hardness.

Cadmium	$e^{(0.7852(\ln H)-3.49)}$
Copper	$e^{(0.8545(\ln H)-1.465)}$
Lead	$e^{(1.273(\ln H)-4.705)}$
Nickel	$e^{(0.846(\ln H)+1.1645)}$
Zinc	$e^{(0.8473(\ln H)+0.7614)}$

The following criteria were established:

Cadmium	0.774 $\mu\text{g/L}$
Copper	7.8 $\mu\text{g/L}$
Lead	1.71 $\mu\text{g/L}$
Nickel	104 $\mu\text{g/L}$
Zinc	70.2 $\mu\text{g/L}$

6.2 Wetland Rankings

Wetlands were ranked as either Red, Orange, or Blue based on detected concentrations in sediment. The rankings are defined as follows:

Red: Red-coded wetlands had contamination that appeared directly related to nearby IR sites and had consistent exceedances of SSVs, and reference levels. The nine red-coded wetlands identified were Wetlands 64, 5, 3, 4D, 16, 18, 10A, 12, and W1. Contaminants detected in these wetlands were also considered to be likely sources of ecological risk.

Table 6-1
Detected Hardness Concentrations for Freshwater Samples
Site 41, NAS Pensacola Wetlands
Pensacola, Florida

Sample ID	Hardness Result (mg/L)
041W010301	87.1000
041W030101	75.6000
041W030201	90.9000
041W030301	63.6000
041W030401	75.9000
041W060301	53.5000
041W060701	75.9000
041W061001	57.8000
041W120101	216.0000
041W130101	271.0000
041W18A201	31.1000
041W190101	71.8000
041W190201	193.0000
041W320101	16.9000
041W320301	24.5000
041W480101	6.6000
041W490101	14.3000
041W490301	6.3000
041W52A101	5.8000
041W52E301	30.4000
041W56A101	38.7000
041W570101	55.0000
041W580101	40.0000
041W5A0101	69.2000
041W5A0201	37.0000
041W5A0401	41.4000
041W5A0501	99.0000
041W5A0601	22.2000
041W5A0701	47.1000
041W5B0201	52.3000
041W720101	32.1000
041WW10101	21.2000
041WW10201	15.2000
041WW10301	11.2000
041w250101	63.0000
041W250201	101.0000
Average	63.2457

Note:
mg/L = milligrams per liter

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Orange: Orange-coded wetlands had contamination that was possibly related to nearby IR sites, but limited contaminants exceeded SSVs and reference levels. In some cases, contaminant levels exceeded these benchmarks but the contamination did not appear related to an IR site. The six orange-coded wetlands identified were Wetlands 1, 15, 6, 63A, 48, and 49. Contaminants detected in these wetlands were also considered to be possible sources of ecological risk.

Blue: Blue-coded wetlands had contaminants which: (1) were in most cases below benchmark values; or (2) did not appear to be site-related. The 12 Blue-coded wetlands were mostly in NAS Pensacola's undeveloped western portion, and included Wetlands 10B, 13, 17, 19, 52, 56, 57, 58, 63B, 72, 79, and W2.

Contaminants detected in these wetlands were not considered as sources of ecological risk.

Individual wetlands are discussed in detail in Section 10, Site Specific Evaluations. Full analytical results for the Phase IIA assessment are included in Appendix A.

6.3 Basewide DDT Concentrations

Although its use has been banned in the United States since 1972, DDT and its metabolites are still detected in the Florida coastal sediments (Delfino *et al.*, 1991). Although DDT is not naturally occurring, it appears to be ubiquitous in the environment, i.e., in surface water, sediment, and biological tissues. DDT and its metabolites are generally highly lipophilic, resistant to biodegradation, and bioconcentrate in biota. DDT is then transferred to humans through the food chain. Atmospheric transport from Central America continues to contribute to the DDT concentrations in the Florida coastal sediment. Therefore, studies of the Pensacola Bay system (National Status and Trends Program [NSTP]) and NAS Pensacola (Sites 40 and 41) were reviewed to establish a basewide concentration for DDT and its metabolites for NAS Pensacola coastal sediments. The NSTP results are detailed in *Magnitude and Extent of Sediment Toxicity in Four Bays of the Florida Panhandle: Pensacola, Choctawhatchee, St. Andrew, and Apalachicola* (Long *et al.*, 1997). The NAS Pensacola results are detailed in this report for Site 41 and in the Site 40 Remedial Investigation Report (EnSafe, 1999). The summary table from the NSTP study and a table presenting all the results from the Sites 40 and 41 investigation are

presented in Appendix I. The resulting basewide concentrations should be considered the maximum concentration at which concentrations may be detected based on widespread use.

The NSTP study analyzed 24 sediment samples from the Pensacola Bay system for pesticides/PCBs. In the Sites 40 and 41 investigations, 265 sediment samples were analyzed for pesticides/PCBs. The NAS Pensacola Site 41 samples were further evaluated based on the color coding established for the wetlands remedial investigation (Red, Orange, or Blue).

4,4-DDD

4,4-DDD was detected in 50% of the NSTP study locations at concentrations ranging from 2.58 ppb to 53.84 ppb. 4,4-DDD was detected in 29.7% of the NAS Pensacola sediment samples from Sites 40 and 41 from 0.2 ppb to 2,600 ppb (Wetland 48 of Site 41). In the blue-coded and reference wetlands, the concentrations ranged from 0.2 ppb in Wetland 72 to 24 ppb in Wetland 32. Based on the concentrations in the NSTP study and the blue-coded and reference wetlands, the basewide concentration is established at 50 ppb.

4,4-DDE

4,4-DDE was not analyzed for in the NSTP study. 4,4-DDE concentrations in the Sites 40 and 41 investigations ranged from 0.21 to 620 ppb (Wetland 48). The concentration of 4,4-DDE in the blue-coded and reference wetlands ranged from 0.24 ppb (Wetland 72) to 37 ppb (Wetland 32). Based on the concentrations in the NSTP study and the blue-coded and reference wetlands, the basewide concentration was established at 40 ppb.

4,4-DDT

4,4-DDT was detected in 41.7% of the NSTP study samples. The concentrations ranged from 2.02 ppb to 37.06 ppb in that study. 4,4-DDT was detected in 23.6% of the NAS Pensacola Sites 40 and 41 sediment samples and ranged from 0.21 ppb to 1,800 ppb (Wetland 18B). The blue-coded and reference wetland concentrations ranged from 0.26 ppb (Wetland 72) to 13 ppb

(Wetland 32). Based on the results of the NSTP study and the blue-coded and reference wetlands, a basewide concentration of 20 ppb was established for 4,4-DDT.

The detected concentrations for 4,4-DDD, 4,4-DDE and 4,4-DDT in the wetlands discussed will be compared to the above listed reference concentrations in the wetland-specific evaluations in Section 10.

6.4 Inorganic Sediment and Surface Water Reference Criteria

In addition to the Red, Orange and Blue-coded wetlands, reference wetlands were identified for comparison to the potentially impacted wetlands. These wetlands were selected because they had similar vegetation, topography, geology, and hydrology in contrast to the wetlands potentially impacted by an IR site. The reference wetlands were also distant from any IR site or other potential sources of contamination based on field observations and a historical study of adjacent areas. The four reference wetlands sampled were Wetlands 25, 27, 32, and 33.

In determining reference criteria, the sediment results from all four reference wetlands were considered together. Surface water samples from Wetlands 25 and 32 were used to derive fresh surface water reference concentrations. Surface water samples from Wetlands 27 and 33 were used to derive salt surface water reference values.

Reference criteria were calculated by first developing an adjusted value for each parameter result considered in the computations. Using a conservative approach, the adjusted values included one-half of each non-detect ("U" validation qualifier) as a detected result. The mean of each parameter's adjusted results were calculated, and the reference concentration was derived by multiplying the mean adjusted value by two.

Tables 6-2 through 6-4 show the reference concentrations for sediment, fresh surface water, and salt surface water, respectively.

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Table 6-2
 Site 41 Sediment Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	Benchmark
Aluminum	041M250101	4180	J	4180	5,136.82	10,273.64	NA
	041M250201	8780	J	8780			
	041M250301	12500	J	12500			
	041M270101	2900	J	2900			
	041M270201	3670	J	3670			
	041M320101	3670	J	3670			
	041M320201	3920	J	3920			
	041M320301	12100		12100			
	041M330101	2460		2460			
	041M330201	2190		2190			
Antimony	041M330301	135		135	7.12	14.23	NA
	041M320101	1.6000	UJ	0.8			
	041M320201	6.7000	UJ	3.35			
	041M320301	58.2000	U	29.1			
	041M330101	0.3600	UJ	0.18			
	041M330201	18.4000	U	9.2			
	041M330301	0.1300	UJ	0.065			
Arsenic	041M250101	1.1000	J	1.1	2.30	4.59	7.24
	041M250201	8.0000	J	8			
	041M250301	8.8000	U	8.8			
	041M270101	1.1000	U	1.1			
	041M270201	0.9800	UJ	0.98			
	041M320101	1.6000	UJ	0.8			
	041M320201	1.3000	U	0.65			
	041M320301	2.8000		1.4			
	041M330101	1.8000		1.8			
	041M330201	1.1000		0.55			
041M330301	0.1300		0.065				
Barium	041M250101	2.3000	J	2.3	5.75	11.49	NA
	041M250201	5.6000	J	5.6			
	041M250301	8.6000	J	8.6			
	041M270101	2.3000	J	2.3			
	041M270201	3.1000	J	3.1			
	041M320101	9.1000	J	9.1			
	041M320201	6.7000	J	6.7			
	041M320301	39.2000	U	19.6			
	041M330101	2.6000	J	2.6			
	041M330201	6.0000	U	3			
	041M330301	0.3000	J	0.3			

Table 6-2
 Site 41 Sediment Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	Benchmark				
Beryllium	041M250101	0.4600	U	0.23	0.28	0.56	NA				
	041M250201	0.4700	J	0.47							
	041M250301	0.5900	J	0.59							
	041M270101	0.1100	U	0.055							
	041M270201	0.1600	U	0.08							
	041M320101	0.7800	U	0.39							
	041M320201	0.6700	U	0.335							
	041M320301	1.3000	UJ	0.65							
	041M330101	0.1800	U	0.09							
	041M330201	0.3100	UJ	0.155							
	041M330301	0.0600	U	0.03							
	Cadmium	041M250101	1.4000	U				0.7	0.63	1.27	0.68
		041M250201	1.0000	U				0.5			
041M250301		1.3000	J	1.3							
041M270101		0.3300	U	0.165							
041M270201		0.4700	U	0.235							
041M320101		2.3000	U	1.15							
041M320201		2.0000	U	1							
041M320301		2.5000	UJ	1.25							
041M330101		0.5400	U	0.27							
041M330201		0.6300	UJ	0.315							
041M330301		0.1900	U	0.095							
Calcium		041M250101	1770.0000	J	1770	3,335.18	6,670.36	NA			
		041M250201	3700.0000	J	3700						
	041M250301	17900.0000	J	17900							
	041M270101	941.0000	J	941							
	041M270201	1260.0000	J	1260							
	041M320101	2150.0000	J	2150							
	041M320201	2430.0000	J	2430							
	041M320301	4020.0000	J	4020							
	041M330101	1470.0000	J	1470							
	041M330201	930.0000	J	930							
	041M330301	116.0000	J	116							

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Table 6-2
 Site 41 Sediment Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	Benchmark				
Chromium	041M250101	7.1000		7.1	13.52	27.05	52.3				
	041M250201	33.0000	J	33							
	041M250301	59.1000	J	59.1							
	041M270101	11.1000	U	11.1							
	041M270201	12.4000	U	12.4							
	041M320101	7.2000	U	7.2							
	041M320201	5.7000		5.7							
	041M320301	11.4000		5.7							
	041M330101	5.5000		5.5							
	041M330201	3.4000		1.7							
	041M330301	0.5100		0.255							
	Cobalt	041M250101	1.6000	J				1.6	1.12	2.23	NA
		041M250201	1.9000	J				1.9			
041M250301		2.0000	J	2							
041M270101		0.4600	J	0.46							
041M270201		0.5100	J	0.5100							
041M320101		2.3000	U	1.15							
041M320201		2.0000	U	1							
041M320301		4.5000	UJ	2.25							
041M330101		0.9900	J	0.9900							
041M330201		0.6300	UJ	0.315							
041M330301		0.1900	U	0.095							
Copper		041M250101	6.1000	J	6.1000	7.85	15.71	18.7			
		041M250201	12.2000	J	12.2000						
	041M250301	19.6000	J	19.6000							
	041M270101	4.2000	J	4.2000							
	041M270201	3.4000	J	3.4000							
	041M320101	5.7000	J	5.7000							
	041M320201	5.7000	J	5.7000							
	041M320301	15.1000	J	15.1000							
	041M330101	8.1000	J	8.1000							
	041M330201	5.8000	J	5.8000							
	041M330301	0.4900		0.4900							
	Cyanide (CN)	041M250101	4.8000	U	2.4				1.72	3.45	NA
		041M250201	3.5000	U	1.75						
041M250301		3.8000	U	1.9							
041M270101		1.1000	U	0.55							
041M270201		1.6000	U	0.8							
041M320101		7.5000	U	3.75							
041M320201		6.4000	U	3.2							
041M330101		1.7000	U	0.85							
041M330301		0.6300	U	0.315							

Table 6-2
 Site 41 Sediment Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	Benchmark				
Iron	041M250101	1780.0000	J	1780.0000	3,933.09	7,866.18	NA				
	041M250201	13500.0000	J	13500.0000							
	041M250301	18500.0000	J	18500.0000							
	041M270101	1440.0000	J	1440.0000							
	041M270201	1380.0000	J	1380.0000							
	041M320101	652.0000	J	652.0000							
	041M320201	471.0000	J	471.0000							
	041M320301	1790.0000		1790.0000							
	041M330101	2120.0000		2120.0000							
	041M330201	1480.0000		1480.0000							
	041M330301	151.0000		151.0000							
	Lead	041M250101	21.4000	J				21.4000	26.73	53.45	30.2
		041M250201	32.1000	J				32.1000			
041M250301		58.7000	J	58.7000							
041M270101		13.5000	J	13.5000							
041M270201		13.2000	J	13.2000							
041M320101		41.3000	J	41.3000							
041M320201		41.6000	J	41.6000							
041M320301		51.7000		51.7000							
041M330101		13.3000		13.3000							
041M330201		6.5000		6.5000							
041M330301		0.6900		0.6900							
Magnesium		041M250101	1420.0000	J	1420.0000	2,474.27	4,948.55	NA			
		041M250201	5490.0000	J	5490.0000						
	041M250301	6660.0000	J	6660.0000							
	041M270101	1200.0000	J	1200.0000							
	041M270201	2070.0000	J	2070.0000							
	041M320101	2230.0000	J	2230.0000							
	041M320201	2460.0000		2460.0000							
	041M320301	2260.0000		2260.0000							
	041M330101	2420.0000		2420.0000							
	041M330201	818.0000		818.0000							
	041M330301	189.0000		189.0000							

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 Site 41 Sediment Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	Benchmark				
Manganese	041M250101	2.6000	J	2.6000	13.45	26.89	NA				
	041M250201	30.7000	J	30.7000							
	041M250301	66.0000	J	66.0000							
	041M270101	5.1000	J	5.1000							
	041M270201	5.1000	J	5.1000							
	041M320101	5.5000	J	5.5000							
	041M320201	3.5000		3.5000							
	041M320301	14.4000		14.4000							
	041M330101	8.2000		8.2000							
	041M330201	6.2000		6.2000							
	041M330301	0.6200		0.6200							
	Mercury	041M250101	0.4400	U				0.22	0.16	0.33	0.13
		041M250201	0.3100	U				0.155			
041M250301		0.4000	U	0.2							
041M270101		0.0900	U	0.045							
041M270201		0.1200	U	0.06							
041M320101		0.6100	U	0.305							
041M320201		0.4900	U	0.245							
041M320301		0.3100	J	0.3100							
041M330101		0.1400	U	0.07							
041M330301		0.0600	U	0.03							
Nickel	041M250101	5.5000	U	2.75	3.69	7.38	15.9				
	041M250201	6.9000	J	6.9000							
	041M250301	6.5000	J	6.5000							
	041M270101	2.0000	J	2.0000							
	041M270201	3.0000	J	3.0000							
	041M320101	9.3000	U	4.65							
	041M320201	8.1000	U	4.05							
	041M330101	3.0000	J	3.0000							
	041M330301	0.7600	U	0.38							
	Potassium	041M250101	172.0000	J				172.0000	759.03	1,518.05	NA
041M250201		1430.0000	J	1430.0000							
041M250301		2060.0000	J	2060.0000							
041M270101		406.0000	J	406.0000							
041M270201		689.0000	J	689.0000							
041M320101		433.0000	J	433.0000							
041M320201		306.0000	J	306.0000							
041M320301		1540.0000	J	1540.0000							
041M330101		698.0000	J	698.0000							
041M330201		545.0000	J	545.0000							
041M330301	70.3000		70.3000								

Table 6-2
 Site 41 Sediment Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	Benchmark
Selenium	041M250101	1.4000	U	0.7	1.26	2.53	NA
	041M250201	1.9000	J	1.9000			
	041M250301	1.2000	U	0.6			
	041M270101	0.3900	J	0.3900			
	041M270201	0.4700	U	0.235			
	041M320101	2.3000	U	1.15			
	041M320201	2.4000	J	2.4000			
	041M320301	7.7000	UJ	3.85			
	041M330101	0.5400	U	0.27			
	041M330201	4.6000	UJ	2.3			
Silver	041M330301	0.1900	U	0.095	0.70	1.40	0.733
	041M250101	1.8000	UJ	0.9			
	041M250201	1.4000	UJ	0.7			
	041M250301	1.6000	UJ	0.8			
	041M270101	0.4300	UJ	0.215			
	041M270201	0.6300	UJ	0.315			
	041M320101	3.1000	U	1.55			
	041M320201	2.7000	U	1.35			
	041M330101	0.7200	U	0.36			
	041M330301	0.2500	U	0.125			
Sodium	041M250101	640.0000	J	640.0000	7,718.09	15,436.18	NA
	041M250201	22400.0000	J	22400.0000			
	041M250301	24700.0000	J	24700.0000			
	041M270101	3170.0000	J	3170.0000			
	041M270201	8610.0000	J	8610.0000			
	041M320101	3680.0000	J	3680.0000			
	041M320201	2980.0000	J	2980.0000			
	041M320301	2590.0000	J	2590.0000			
	041M330101	10100.0000	J	10100.0000			
	041M330201	5050.0000		5050.0000			
Thallium	041M330301	979.0000		979.0000	0.52	1.05	NA
	041M250101	1.4000	U	0.7			
	041M250201	1.0000	U	0.5			
	041M250301	1.2000	U	0.6			
	041M270101	0.3300	U	0.165			
	041M270201	0.4700	U	0.235			
	041M320101	2.3000	U	1.15			
	041M320201	2.0000	U	1			
	041M330101	0.5400	U	0.27			
	041M330301	0.1900	U	0.095			

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Table 6-2
 Site 41 Sediment Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result (µg/L)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	Benchmark				
Vanadium	041M250101	10.1000	J	10.1000	11.06	22.12	NA				
	041M250201	22.8000	J	22.8000							
	041M250301	33.7000	J	33.7000							
	041M270101	5.2000	J	5.2000							
	041M270201	6.9000	J	6.9000							
	041M320101	6.6000	J	6.6000							
	041M320201	5.2000	J	5.2000							
	041M320301	20.8000	J	20.8000							
	041M330101	4.7000	J	4.7000							
	041M330201	5.3000	J	5.3000							
	041M330301	0.3800	J	0.3800							
	Zinc	041M250101	7.3000	J				7.3000	12.72	25.44	124
		041M250201	21.7000	J				21.7000			
041M250301		57.1000	J	57.1000							
041M270101		8.2000	J	8.2000							
041M270201		4.7000	J	4.7000							
041M320101		6.8000	J	6.8000							
041M320201		7.9000	J	7.9000							
041M320301		10.4000	UJ	5.2							
041M330101		14.0000	J	14.0000							
041M330201		6.3000	U	6.3000							
041M330301	1.4000	J	0.7								

Notes:

- a = Sediment samples collected from Reference Wetlands 25, 27, 32, and 33.
- b = Adjusted values used to calculate the mean value for each parameter conservatively include one-half of each non-detect ("U" validation qualifier) as a detected result.
- c = Derived reference concentrations are equal to two-times the mean of the adjusted values for each sample location.

Table 6-3
 Site 41 Fresh Surface Water Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	USEPA Criteria	FDEP Criteria
Aluminum	041W250101	1820		1820				
	041W250301	221		221				
	041W320101	141	U	70.5	545.125	1090.25	87	NA
	041W320301	138	U	69				
Antimony	041W250101	2	UJ	1				
	041W250301	2	U	1	2	4	160	4300
	041W320101	2	UJ	1				
	041W320301	10	U	5				
Arsenic	041W250101	2.4	J	2.4				
	041W250301	2	U	1	1.35	2.7	190	50
	041W320101	2	U	1				
	041W320301	2	U	1				
Barium	041W250101	2.2	U	1.1				
	041W250301	1.9	U	0.95	1.8375	3.675	NA	NA
	041W320101	5.4	U	2.7				
	041W320301	5.2	U	2.6				
Beryllium	041W250101	1	U	0.5				
	041W250301	1	U	0.5	0.5	1	0.53	0.13
	041W320101	1	U	0.5				
	041W320301	1	U	0.5				
Cadmium	041W250101	3	U	1.5				
	041W250301	3	U	1.5	1.5	3	0.66	0.61
	041W320101	3	U	1.5				
	041W320301	3	U	1.5				
Calcium	041W250101	4620		4620				
	041W250301	6720		6720	3837.5	7675	NA	NA
	041W320101	1750	J	1750				
	041W320301	2260	J	2260				

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Table 6-3
 Site 41 Fresh Surface Water Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	USEPA Criteria	FDEP Criteria
Chromium	041W250101	8	U	4	4	8	11	11
	041W250301	8	U	4				
	041W320101	8	U	4				
	041W320301	8	U	4				
Cobalt	041W250101	3	U	1.5	1.5	3	NA	NA
	041W250301	3	U	1.5				
	041W320101	3	U	1.5				
	041W320301	3	U	1.5				
Copper	041W250101	4	U	2	2	4	6.54	7.8
	041W250301	4	U	2				
	041W320101	4	U	2				
	041W320301	4	U	2				
Cyanide (CN)	041W250101	5	U	2.5	2.5	5	5.2	5.2
	041W250301	5	U	2.5				
	041W320101	5	U	2.5				
	041W320301	5	U	2.5				
Iron	041W250101	4030		4030	1180	2360	1000	1000
	041W250301	317		317				
	041W320101	182		182				
	041W320301	191		191				
Lead	041W250101	4.9		4.9	1.6	3.2	1.32	1.71
	041W250301	1	U	0.5				
	041W320101	1	U	0.5				
	041W320301	1	U	0.5				
Magnesium	041W250101	12500		12500	10130	20260	NA	NA
	041W250301	20400		20400				
	041W320101	3050	J	3050				
	041W320301	4570	J	4570				

Table 6-3
 Site 41 Fresh Surface Water Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	USEPA Criteria	FDEP Criteria
Manganese	041W250101	4.2	J	4.2	6.6	13.2	NA	NA
	041W250301	2.9	J	2.9				
	041W320101	10	J	10				
	041W320301	9.3	J	9.3				
Mercury	041W250101	0.13	U	0.065	0.065	0.13	0.012	0.012
	041W250301	0.13	U	0.065				
	041W320101	0.13	U	0.065				
	041W320301	0.13	U	0.065				
Nickel	041W250101	12	U	6	6	12	87.71	81.32
	041W250301	12	U	6				
	041W320101	12	U	6				
	041W320301	12	U	6				
Potassium	041W250101	3980	J	3980	3497.5	6995	NA	NA
	041W250301	7060		7060				
	041W320101	1170		1170				
	041W320301	1780		1780				
Selenium	041W250101	3	U	1.5	1.5	3	5	5
	041W250301	3	U	1.5				
	041W320101	3	U	1.5				
	041W320301	3	U	1.5				
Silver	041W250101	4	U	2	2	4	0.012	0.07
	041W250301	4	U	2				
	041W320101	4	U	2				
	041W320301	4	U	2				
Sodium	041W250101	105000	J	105000	91100	182200	NA	NA
	041W250301	185000		185000				
	041W320101	30000		30000				
	041W320301	44400		44400				

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Table 6-3
 Site 41 Fresh Surface Water Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	USEPA Criteria	FDEP Criteria
Thallium	041W250101	3.9	J	3.9	2.1	4.2	4	6.3
	041W250301	3	U	1.5				
	041W320101	3	U	1.5				
	041W320301	3	U	1.5				
Vanadium	041W250101	6.4	J	6.4	2.35	4.7	NA	NA
	041W250301	2	U	1				
	041W320101	2	U	1				
	041W320301	2	U	1				
Zinc	041W250101	7.4	U	3.7	2.7625	5.525	58.91	54.61
	041W250301	5.4	U	2.7				
	041W320101	3.9	U	1.95				
	041W320301	5.4	U	2.7				

Notes:

- a = Freshwater surface water samples collected from Reference Wetlands 25 and 32.
- b = Adjusted values used to calculate the mean value for each parameter conservatively include one-half of each non-detect ("U" validation qualifier) as a detected result.
- c = Derived reference concentrations are equal to two-times the mean of the adjusted values for each sample location.

Table 6-4
 Site 41 Salt Surface Water Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	USEPA Criteria	FDEP Criteria
Aluminum	041W270201	5550		5550	1463.75	2927.5	NA	1500
	041W330101	151	U	75.5				
	041W330201	162	U	162				
	041W330301	135		67.5				
Antimony	041W270201	2	UJ	1	2.075	4.15	NA	4300
	041W330101	10	UJ	5				
	041W330201	2.6	U	1.3				
	041W330301	2	UJ	1				
Arsenic	041W270201	4.1	J	4.1	1.8	3.6	36	50
	041W330101	2	U	1				
	041W330201	2.2	UJ	1.1				
	041W330301	2	U	1				
Barium	041W270201	11.6	U	5.8	4.7125	9.425	NA	NA
	041W330101	6.7	U	3.35				
	041W330201	7.2	J	7.2				
	041W330301	5	U	2.5				
Beryllium	041W270201	1	U	0.5	0.41	0.82	NA	0.13
	041W330101	1	U	0.5				
	041W330201	0.28	U	0.14				
	041W330301	1	U	0.5				
Cadmium	041W270201	3	U	1.5	1.1975	2.395	9.3	9.3
	041W330101	3	U	1.5				
	041W330201	0.58	U	0.29				
	041W330301	3	U	1.5				
Calcium	041W270201	99000		99000	38400	76800	NA	NA
	041W330101	14100		14100				
	041W330201	18800		18800				
	041W330301	21700		21700				

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Table 6-4
 Site 41 Salt Surface Water Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	USEPA Criteria	FDEP Criteria
Chromium	041W270201	13.3		13.3	5.435	10.87	50	50
	041W330101	8	U	4				
	041W330201	0.88	UJ	0.44				
	041W330301	8	U	4				
Cobalt	041W270201	3	U	1.5	1.19125	2.3825	NA	NA
	041W330101	3	U	1.5				
	041W330201	0.53	UJ	0.265				
	041W330301	3	U	1.5				
Copper	041W270201	9.2	J	9.2	3.5125	7.025	2.9	2.9
	041W330101	4	U	2				
	041W330201	1.7	U	0.85				
	041W330301	4	U	2				
Cyanide (CN)	041W270201	5	U	2.5	2.05	4.1	1	1
	041W330101	5	U	2.5				
	041W330201	1.4	UJ	0.7				
	041W330301	5	U	2.5				
Iron	041W270201	2230		2230	676	1352	NA	300
	041W330101	189	J	189				
	041W330201	102		102				
	041W330301	183		183				
Lead	041W270201	25.9		25.9	6.875	13.75	8.5	5.6
	041W330101	1	U	0.5				
	041W330201	1.2	U	0.6				
	041W330301	1	U	0.5				
Magnesium	041W270201	327000		327000	121825	243650	NA	NA
	041W330101	40100		40100				
	041W330201	55600		55600				
	041W330301	64600		64600				

Table 6-4
 Site 4I Salt Surface Water Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	USEPA Criteria	FDEP Criteria
Manganese	041W270201	1	U	0.5	6.075	12.15	NA	NA
	041W330101	8.2	J	8.2				
	041W330201	9.3	J	9.3				
	041W330301	6.3	J	6.3				
Mercury	041W270201	0.17	J	0.17	0.105	0.21	0.025	0.025
	041W330101	0.13	U	0.065				
	041W330201	0.05	U	0.025				
	041W330301	0.16	J	0.16				
Nickel	041W270201	12	U	6	4.65	9.3	8.3	8.3
	041W330101	12	U	6				
	041W330201	1.2	U	0.6				
	041W330301	12	U	6				
Potassium	041W270201	106000		106000	40625	81250	NA	NA
	041W330101	12300		12300				
	041W330201	23300		23300				
	041W330301	20900		20900				
Selenium	041W270201	3	U	1.5	1.45	2.9	71	71
	041W330101	3	U	1.5				
	041W330201	2.6	U	1.3				
	041W330301	3	U	1.5				
Silver	041W270201	4	U	2	1.50375	3.0075	0.23	0.23
	041W330101	4	U	2				
	041W330201	0.03	U	0.015				
	041W330301	4	U	2				
Sodium	041W270201	2580000		2580000	976000	1952000	NA	NA
	041W330101	315000		315000				
	041W330201	462000		462000				
	041W330301	547000		547000				

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Table 6-4
 Site 41 Salt Surface Water Inorganic Reference Concentrations

Parameter	Sample Identifier ^a	Result ($\mu\text{g/L}$)	Validation Qualifier	Adjusted Value ^b	Mean Adjusted Value	Reference Concentration (2 X Mean ^c)	USEPA Criteria	FDEP Criteria
Thallium	041W270201	3	U	1.5	1.275	2.55	21.3	6.3
	041W330101	3	U	1.5				
	041W330201	1.2	U	0.6				
	041W330301	3	U	1.5				
Vanadium	041W270201	11	J	11	3.34625	6.6925	NA	NA
	041W330101	2	U	1				
	041W330201	0.77	UJ	0.385				
	041W330301	2	U	1				
Zinc	041W270201	19.6	J	19.6	6.4375	12.875	86	86
	041W330101	4.2	U	2.1				
	041W330201	3.7	U	1.85				
	041W330301	4.4	U	2.2				

Notes:

- a = Saltwater surface water samples collected from Reference Wetlands 27 and 33.
 b = Adjusted values used to calculate the mean value for each parameter conservatively include one-half of each non-detect ("U" validation qualifier) as a detected result.
 c = Derived reference concentrations are equal to two-times the mean of the adjusted values for each sample location.

7.0 ECOLOGICAL RISK ASSESSMENT METHODS

This section presents the methods used in the ecological risk assessment. Wetland-specific risk evaluations are presented in Section 10, Site-Specific Evaluations.

7.1 Introduction

The risk assessment evaluates potential risk to the environment from hazardous substances at Site 41 under current and future conditions. The assessment considers environmental media and exposure pathways that could result in unacceptable levels of exposure now or in the foreseeable future. The risk assessment is used as a basis for making remedial decisions and depends upon an adequate site characterization of chemical contamination, which is done in the RI report.

The ecological risk assessment was conducted during Phases IIA and IIB/III of the RI. Phase IIA involved the collection of sediment and surface water samples for chemical and physical analysis only. These samples were collected from wetlands identified during Phase I. After the Phase IIA data were collected, a screening level assessment compared sediment concentrations to the lower of the USEPA Region IV SSVs and State of Florida SQAGs. SSVs and SQAGs are considered critical exposure levels for estuarine fauna. Similar comparisons were made with the lower of the USEPA and Florida freshwater and saltwater water quality standards, which are considered critical exposure levels for aquatic species. After the comparisons were made, wetlands were prioritized to identify those requiring further study in Phase IIB/III.

Based on an evaluation of all potential exposure routes, ecological exposure was considered the most relevant. Screening contaminant concentrations against ecologically-based benchmark values was considered the most reasonable and conservative approach.

Phase IIB/III involved collection of sediment and surface water samples for chemical, physical, toxicity, diversity, and bioaccumulation analyses. The purpose of Phase IIB was to determine if

concentrations would produce measurable impacts on selected measurement endpoints and to establish a link between contaminant concentrations and possible risk.

The ecological risk assessment was prepared in accordance with the following guidance documents:

- *Framework for Ecological Risk Assessment (EPA/630/R-92/001)(USEPA,1992b).*
- *Ecological/Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments — Interim Final (USEPA, 1997a).*

The ecological risk assessment (ERA) of the BRA was performed to develop a qualitative and/or quantitative ecological appraisal of the actual or potential effects from Site 41 contaminants. The assessment considered environmental media and potential exposure pathways that could result in flora and fauna being exposed to contaminants now or in the foreseeable future.

7.2 Sediment and Surface Water Screening Values

To characterize risk to receptors, contaminant concentrations in all wetlands have been compared to sediment quality guidelines. The sediment benchmark value used to assess potential effects on benthic species is the lower of the USEPA Region IV SSV (USEPA, 1995a) and the FDEP SQAG (MacDonald, 1994). For aquatic organisms, including fish, USEPA and FDEP have each developed their own screening concentrations for fresh and salt water. For both sediment and surface water screening criteria, the lower of the USEPA (1995a) or FDEP (1996) criteria was used for making data comparisons. Since sediment quality criteria have been developed only recently, the technical basis for these values is described below. SSVs are based on contaminant concentrations associated with a low probability of unacceptable risk to ecological receptors. The USEPA Office of Health Assessment has developed them for use at Region IV hazardous waste

sites. Since these screening values are based on conservative endpoints and sensitive ecological effects data, they represent a preliminary screening of site contaminant levels to determine whether further investigations are needed. Ecological screening values are not remediation levels. SSVs are derived from statistical interpretation of effects databases obtained from State of Florida publications, the National Oceanic and Atmospheric Administration, and a joint publication by Long et. al. (1995). These values are based on observations of direct toxicity when available.

The preliminary SQAGs developed by MacDonald (1994) are guidelines for evaluating sediment contamination in coastal ecosystems. Defining the range of sediment contamination is a two-step process. First, a comparison is made to the TEL, which represents the upper limit of the range of sediment contaminant concentrations dominated by no-effects data entries (i.e., a minimal effects range). Within this range, sediment concentrations are not considered to represent a hazard to aquatic organisms. Next, a comparison is made to the probable effects level (PEL), defining the lower range of contaminant concentrations which are usually associated with adverse biological effects.

These SSVs have weaknesses that were recognized during their development. For example, none address the potential for bioaccumulation of persistent toxic chemicals and potential adverse effects on higher trophic levels of the food web. In addition, the lack of consistency among organisms used to develop these data sets could reduce their relevance to species studied at NAS Pensacola.

7.3 Reference Wetland Comparison

Although sediment and surface water benchmark values were the most important means of comparing contaminant levels within wetlands of concern, reference wetlands were also used for comparison. In addition to being useful in the risk assessment, reference comparisons can also be useful in developing remedial strategies.

In Phase IIA, Wetlands 25, 27, 32, and 33 were selected as reference wetlands because they are similar in vegetation, topography, and hydrology to most of the wetlands for impacts from an IR site. These reference wetlands all appeared to be free of contamination and were not anticipated to be impacted by an IR site or any other potential point source of contamination. Each wetland begins as a palustrine emergent wetland and changes to an estuarine emergent wetland as it enters either Pensacola Bay or Bayou Grande.

7.4 Preliminary Exposure Estimate

Benchmark values for comparison of observed contaminant concentrations assume that benthic fauna are present and will use the area surrounding a sample location exclusively for feeding and other life cycle requirements. This screening approach also assumes that 100% of the contamination found will be bioavailable to benthic organisms at the location. Applying both of these assumptions conservatively in the screening assessment is important in estimating a chemical's potential effects.

7.5 Preliminary Risk Calculation

Based on the conservative 100% exposure estimate for benthic infauna associated with the sample location, and by applying the most conservative effects benchmark, a hazard quotient (HQ) was determined for each sampling location. The HQ method compares the estimated exposure concentrations to the measured or predicted threshold value for effect (USEPA, 1992b). The following equation presents the calculation method:

$$\text{Equation 1} \quad \text{Hazard Quotient (HQ)} = \frac{\text{Contaminant Concentration}}{\text{Lowest Effect Level}}$$

An HQ greater than 1 is interpreted as a level at which adverse ecological effects are possible. An HQ less than 1 does not indicate a lack of risk, but should be interpreted based on the severity of the effect reported and the magnitude of the calculated quotient (USEPA, 1997a).

7.6 Phase IIA Screening-Level Ecological Risk Assessment

Initially, Phase IIA contaminant exceedances of sediment benchmark values, potential receptor species, and possible impacts to assessment endpoints were used to assess the potential ecological risk at each wetland sampled. Surface water data were also reviewed, but sediment data were selected because contaminants are more persistent in sediment than in surface water, and better correlate with long-term effects and the development of remedial options. This is particularly important when the surface water data were reviewed in comparison to benchmark values. In some cases HQ values were elevated for particular contaminants in surface water, even though similar contaminants were not detected in sediment and the contaminants did not appear associated with any impacts from an IR site. It was suspected that these elevated HQ values were due to elevated sediment turbidity or other possible non-site-related factors.

After review of the data, the wetlands were grouped either red, orange, or blue. These groupings are defined below:

- Red: Contamination appears to be related to an IR site with consistent exceedences of benchmark values and reference values. Wetlands 64, 5A, 3, 4, 16, 18, 10, 12, and W1 were initially considered as red-grouped wetlands. However, Wetland W1 was determined to be nonjurisdictional by FDEP and the Corps of Engineers and was subsequently removed from the red-grouped wetlands. However, it is included in Section 10 separate from the red-coded wetlands for completeness.
- Orange: Contamination that could be related to an IR site, but a limited number of contaminants exceeded benchmark and reference values. In some cases contaminants exceeded their benchmark level, but did not appear related to an IR site. Wetlands 1, 15, 6, 63A, 48, and 49 were considered as orange-grouped wetlands.
- Blue: No contaminants detected or isolated contaminants detected that in most cases were below benchmark values and reference values. Wetlands meeting this description were mostly in the base's undeveloped wester portion. Any contaminant exceedance did not appear to be related to an IR site. The eastern portion of wetland 10, 13, 17, 19, 52, 56, 57, 58, 63B, 72, 79, and W2 were considered as blue-grouped wetlands.

Reference wetlands sampled were 25, 27, 32, and 33.

7.7 Contaminant Results and Effect Characteristics

The following paragraphs discuss ecological effects of the three major contaminant types: metals, pesticide/PCBs, SVOCs and VOCs. This information, based on literature reviews for these contaminants, was used to develop a better understanding of how these contaminants interact in the environment and their potential for toxic effects. By using this information, the conceptual models and toxicity tests could be better planned and developed during Phase IIB/III.

Metals

Arsenic

According to Braman and Foreback (1973), the common forms of arsenic are arsenite, arsenate, methylarsonic acid (MAA), and dimethyl arsonic acid (DMAA). These forms can be co-precipitated with hydrated iron and aluminum oxides, or adsorbed/chelated by suspended organic matter. Arsenic in seawater is commonly detected at 2 $\mu\text{g}/\text{kg}$. Arsenic is readily absorbed, coprecipitates with other metal sulfides, and has a strong affinity for sulphur (Demayo, 1979).

Arsenic bioaccumulates in numerous aquatic biota, but has not been observed to biomagnify through other organisms (Jaagumagi, 1990). Arsenic is known for a variety of sublethal characteristics including effects on growth, reproduction, locomotion, behavior, and respiration (Eisler, 1988a).

Cadmium

Cadmium is used in a wide variety of industrial applications, including electroplating, batteries, telephone wires, and stabilizers in plastics (MacDonald, 1994). In surface waters, cadmium generally occurs in the Cd(II) form as a constituent of inorganic and organic compounds. Cadmium transport to sediment occurs mainly via sorption to organic matter, and through co-precipitation of iron, aluminum, and manganese oxides (Jaagumagi, 1990).

As a relatively rare heavy metal and known teratogen and carcinogen, cadmium has been implicated in severe deleterious effects on fish and wildlife (Eisler, 1985). Birds and mammals are comparatively resistant to the biocidal properties of cadmium. Freshwater organisms appear to be the most susceptible to cadmium toxicity, which is reduced by increased water hardness. Adsorption and desorption processes are likely to be major factors in controlling cadmium concentrations in natural waters. Cadmium adsorbs and desorbs rapidly on mud solids and particles of clay, silica, humic material, and other naturally occurring solids. The acid volatile sulfide concentration in water is also important in controlling cadmium's bioavailability.

Toxicological data indicate that elevated cadmium concentrations are associated with high mortality, reduced growth, inhibited reproduction, and other adverse effects (Eisler, 1985). Sublethal effects studies in crustaceans have shown decreased growth, respiratory disruption, molt inhibition, and shortened life span.

Biotransfer in aquatic systems may occur, but the evidence for cadmium transfer through various trophic levels suggests that only the lower trophic levels exhibit biomagnification (Eisler, 1985).

Chromium

Chromium is a trace metallic element that has been widely used in industrial processes (MacDonald, 1994). Hexavalent chromium compounds are used by the chemical industry in chrome plating and the production of paints, dyes, and explosives.

Hexavalent chromium (Cr VI) is more toxic to biota than trivalent chromium (Cr II/III). In clayey sediments, trivalent chromium dominates and benthic invertebrate bioaccumulation is limited (Neff et al., 1978). In a study by James and Bartlett (1983), the solubility and potential bioavailability of waste chromium added to soil through sewage sludge was modified by soil pH and organic complexing substances.

Adverse effects associated with chromium exposure include mortality and decreased growth (Canadian Council of Resource and Environment Ministers [CCREM], 1987). Although chromium does not appear to significantly accumulate in fish, algal communities have been found to bioconcentrate this substance to a high level.

Copper

Anthropogenic copper sources include copper and brass pipes corroded by acidic waters and copper compounds used in algicides, sewage plant effluents, fungicides, and pesticides (MacDonald, 1994). Industrial sources of copper include iron and steel production, mining, smelting, and refining (CCREM, 1987).

Under normal pH and redox conditions in sediment, copper is found as organic and cupric carbonate complexes, and coprecipitates with iron and manganese oxides (Jaagumagi, 1990). Copper, an essential micronutrient, can be accumulated by aquatic organisms. This broad-spectrum biocide may be associated with both acute and chronic toxicity. Varied effects have been observed in the sensitivity of aquatic organisms across taxonomic groups (CCREM, 1987).

Iron

Iron is commonly found in sediments throughout the Pensacola Bay System (PBS). Within the PBS, iron has been detected in sediment from 1,200 mg/kg to 57,500 mg/kg (Long, E.R. et al., 1997). A review of recent scientific literature did not show much information related to iron toxicity in sediment. Generally, iron associated with fresh or estuarine water will oxidize easily, thus making free ions less bioavailable.

In surface water, studies of *Daphnia magna* showed that development was inhibited in 50% of the population at concentrations between 64,000 $\mu\text{g/L}$ and 19,000 $\mu\text{g/L}$ in populations exposed to iron sulfide, and 128 $\mu\text{g/L}$ and 500 $\mu\text{g/L}$ in populations exposed to iron chloride (USEPA, 1997a).

Lead

The ecological and toxicological aspects of lead and its compounds have been extensively reviewed (Eisler, 1988b). The widespread broadcasting of lead through anthropogenic activities has increased lead residues throughout the environment. Lead is toxic to all phyla of aquatic biota, though effects are modified significantly by various biological and abiotic variables (Wong *et al.*, 1978). In aquatic environments, dissolved waterborne lead is the most toxic form. Lead has not been shown to biomagnify in food chains, and reaches the aquatic environment through industrial and municipal discharges and highway runoff (USEPA, 1980a).

Mercury

Mercury, a trace element most common in the sulfide mineral cinnabar, is generally sorbed to particulate matter in aquatic systems. Mercury can be found in three oxidation states: elemental Hg, Hg(I), and Hg(II). Both Hg(I) and Hg(II) can be methylated, mercury's most toxic form, by microorganisms under anaerobic and aerobic conditions. Mercury tends to associate with organic matter in sediments. In low dissolved oxygen conditions, mercury may combine with sulphur to form insoluble sulfides (Jaagumagi, 1990). Aquatic plants, invertebrates, and fish exhibit similar sensitivities to mercury, although a great deal of variability exists within each of these groups. Mercury can accumulate to high concentrations in aquatic organisms, with bioconcentration factors as high as 85,000 observed in some fish species (CCREM, 1987).

As a possible mercury antagonist, selenium has been shown to protect against adverse or lethal effects induced by inorganic and organic mercury salts in algae, aquatic invertebrates, fish, and

mammals. Selenite salts are known to release methylmercury from its linkage to proteins, although the precise mechanism for this antagonism has not been fully established (Eisler, 1987a).

Mercury is known to be persistent and widespread in aquatic environments. The source in most aquatic systems is deposition from the atmosphere, primarily during rainfall events. Primary human-related sources of this mercury include coal combustion, chlorine alkali processing, waste incineration, and metal processing. Estimates today suggest that atmospheric mercury from human activities has doubled or tripled (Krabbenhoft and Ricket, 1995). Data from 40 random sediment samples collected in the PBS as part of the National Status and Trends Program shows that mercury was detected above its SSV in 32 of the 40 samples, or 80% (Long et al., 1997).

Nickel

Like other heavy metals nickel occurs naturally, commonly bound with sulphur, arsenic, and antimony. Nickel is primarily used in stainless steel production, nickel plating, and in other nickel alloys (MacDonald, 1994). The most important anthropogenic sources of nickel are fossil fuel combustion, mining, refining, and electroplating (CCREM, 1987).

In aquatic systems, nickel occurs primarily in the Ni(II) form (MacDonald, 1994). It is deposited in sediments by coprecipitation with iron and manganese oxides and sorption to organic matter. In sediments, nickel tends to form complexes with iron and manganese oxides, although it can also form insoluble complexes with sulfides under low oxygen conditions (Jaagumagi, 1990).

Exposing aquatic organisms to nickel-contaminated sediments may result in adverse effects such as mortality, reduction in growth, and avoidance. Therefore, synergism with nickel may modify copper toxicity. While bioconcentration of nickel has been observed in various organisms, particularly annelids, biomagnification is not a significant concern in aquatic systems (CCREM, 1987).

Zinc

Zinc is a common crustal element, typically present as a sulfide, carbonate, or silicate ore (MacDonald, 1994). Principal sources in aquatic systems are municipal wastewater effluents, zinc mining, smelting, wood combustion, and iron and steel production (CCREM, 1987). Total zinc concentrations in soil and sediment seldom exceed 200 mg/kg (Eisler, 1993).

As an essential micronutrient, zinc uptake in most aquatic organisms appears to be independent of environmental concentrations (MacDonald, 1994). Although it has been found to bioaccumulate in some organisms, no evidence of biomagnification exists (Jaagumagi, 1990). In aquatic systems, zinc occurs primarily as Zn(II), but can also form organozinc compounds. At neutral pH, zinc may be deposited in sediments by sorption to hydrous iron and manganese oxides, clay minerals, and organic matter. However, adsorption is very low at pHs below 6 (MacDonald, 1994). Most zinc introduced into aquatic environments is eventually partitioned into the sediment. Zinc bioavailability from sediment is enhanced under high dissolved oxygen, low salinity, low hydrogen ion concentration (pH), high inorganic oxides, and humic substance (Eisler, 1993).

Zinc adversely affects growth, survival, and reproduction in sensitive aquatic organisms. In freshwater fish, the BCF value was between 51 and 500 times the surface water concentrations for whole-body residue levels (USEPA, 1987), but exposure duration and extrinsic factors such as water chemistry are important variables in uptake potential.

Pesticides/PCBs

Organochlorine Pesticides (DDT and Metabolites)

Organochlorine pesticides have been used extensively in the United States since the 1940s. They appear to be ubiquitous in the environment, i.e., in surface water, sediment, and biological tissues. They are readily absorbed by warm-blooded species, and degradation products are frequently more toxic than the parent form. Transport in the aquatic system is dynamic in that continuous

interchange of pesticides occurs between land, sediment, sediment-water interface, interstitial waters, aquatic organisms, and air-water interface (Cooper, 1991). Pesticides with a high potential to bioconcentrate in aquatic ecosystems are generally highly lipophilic and resistant to biodegradation, such as DDT and its metabolites. DDT is highly toxic and persistent in the environment and has been detected in Florida coastal sediments (Delfino, et al., 1991). DDT adsorbs to sediments and biotransfers to upper-level vertebrate species through the food web, where exposure can result in reproductive impairment.

Dieldrin

Dieldrin, an organochlorine pesticide, was widely used in the United States (CCREM, 1987) to control soil, fruit, and vegetable pests. It appears to adsorb strongly to sediments, bioconcentrate in fish, and degrade slowly in the presence of sunlight. Dieldrin can bioconcentrate from 100 to 10,000 times in aquatic species.

Gamma-BHC (Lindane)

Lindane, one of the 45 components of technical grade chlordane, has an affinity for organic sediments and bioaccumulates in aquatic species. Toxicological effects can include reduced survival, immobilization, impaired reproduction, and histopathology.

Polychlorinated Biphenyls

PCB is the generic term for a group of 209 congeners with a varying number of substituted chlorine atoms in a biphenyl ring. Mixtures containing 21% to 54% chlorine by weight were used extensively in closed electric systems as dielectric fluids (MacDonald, 1994). In aquatic systems, PCBs tend to be associated with fine-grained particles and organic matter in sediments. Trace concentrations of the more persistent, more highly chlorinated PCBs have been detected in fish from almost every major river in the United States (Schmitt et al., 1983 and 1985). Maximum

concentrations in whole fish have not changed much in recent years; concentrations near 100 ppm (fresh wet) were measured in 1978 by Schmitt *et al.*, (1983).

PCB exposure can produce a variety of deleterious effects on aquatic organisms, including acute and chronic lethality, developmental abnormalities, growth retardation, and reproductive toxicity (Moore and Walker, 1991). Aquatic species such as fish may exhibit reproductive toxicity, especially when exposed to the higher chlorinated, more lipophilic congeners. Bioconcentration ratios of Aroclor-1254 in aquatic organisms varied from 60 to 340,000 (Eisler, 1986). In fish, biochemical perturbations such as induced hepatic mixed function oxidase systems can occur from PCB exposure. USEPA (1980b) has published maximum acceptable toxicant concentrations (MATC) values for Aroclor PCBs in water, based on life cycle, partial life cycle, or early life stages. In avian species, PCBs can disrupt normal patterns of growth, reproduction, metabolism, and behavior. Diet appears to be an important route for PCB accumulation; the highest liver concentrations have been found in birds that feed on fish (National Academy of Science, 1979).

Semivolatile Organic Compounds

PAHs

PAHs is the general term applied to a group of several hundred organic substances with two or more benzene rings. Their occurrence in the environment is primarily a result of incomplete organic matter combustion (i.e., forest fires, internal combustion engines, wood stoves, coal, coke). They are also major constituents of petroleum and its derivatives, with oil spills and refinery effluents as major sources of PAH contamination in the aquatic environment (MacDonald *et al.*, 1992). In addition, wastewater treatment plant effluents and runoff from urban areas, particularly roads, are known to contain significant quantities of PAHs.

PAHs in aquatic environments tend to associate with suspended and deposited particulate matter (Eisler, 1987b). This sorption to sediments is strongly correlated with the sediment TOC content (Gillam, 1991). Substances detected most frequently in sediments are acenaphthylene, anthracene,

benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene (Delfino et al., 1991). In general, elevated levels of sediment-associated PAHs are found near urban areas.

PAH exposure can result in a wide range of effects on biological organisms. Although some PAHs are known to be carcinogenic, others produce little or no carcinogenic, mutagenic, or teratogenic effects (Neff, 1979; USEPA, 1980c; National Research Council of Canada [NRCC], 1983). Some carcinogenic PAHs also exhibit teratogenic and mutagenic effects. Sediment-associated PAH compounds can, in some cases, contribute a large percentage of the steady-state body burden in freshwater amphipods (Landrum and Scavia, 1983). When PAH concentrations are elevated, benthos metabolize them from the sediment/pore water matrix, thus providing a significant source of PAHs to predator fishes (Eadie *et al.*, 1983).

Volatile Organic Compounds

There are no sediment benchmark values for VOCs. Concentrations detected during Phase IIA/IIB/III are presented in Section 10. The limited distribution and low values detected suggest limited potential risk to ecological receptors. VOCs are also extremely mobile and tend to disassociate from sediment or surface water much more rapidly than SVOCs and pesticides.

Uncertainties

All sampling programs may produce unavoidable design variations. Uncertainty factors in field conditions, laboratory procedures, or other circumstances that may have resulted in overestimation or underestimation of risk include:

- Analytical matrix interferences, due to excess organic material in sediment, could underestimate risk. Some wetland samples included roots and other benthic organisms.
- The lack of criteria or benchmark values underestimate risk and increases the uncertainty for screening level assessments.

- The HQ approach does not consider natural metal concentrations, synergistic effects, antagonistic effects, sediment grain size, and TOC effects as they relate to bioavailability. These effects could lead to overestimating or underestimating risk.

7.8 Phase IIB/III Wetland Groupings

After reviewing Phase IIA sediment and surface water contaminant distribution and other characteristics in the red- and orange-grouped wetlands, they were further subdivided according to the nature and extent of sediment contamination and several physical characteristics that could affect contaminant fate and habitat use. Physical characteristics included salinity, depth of surface water, sediment total organic carbon, and riparian habitat (Table 7-1). Surface water exceedances were evaluated, but they appeared isolated and not IR site-related. The surface water samples were not filtered, and many were highly turbid. By subdividing these wetlands, any risk quantified in one wetland could be extrapolated to determine potential risk in other wetlands in that group.

The groupings and rationale for selection are summarized below:

Group A, Wetland 64: This estuarine wetland is unique, primarily because it receives runoff from a large area of the base and has high concentrations of several metals, PAHs, and pesticides. The sediment in this wetland has high TOC values. Benthic macroinvertebrates are suspected to be prominent in this wetland, unlike most wetlands on base that have intermittent levels of surface water.

Group B, Wetlands 5A and 3: These wetlands have similar contaminants and unique physical characteristics, although Wetland 3 had relatively little PAH contamination compared to Wetland 5A. These wetlands have similar species which live and feed in them. Each wetland in this group was sampled.

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Table 7-1
 Wetland Groupings
 Red- and Orange-Coded Wetlands

Characteristics	64	5A	3	4D	15	16	18A	18B	63A	10	6	5B	1	W1	48	49
Estuarine	A			C	C	C		C	C							
Fresh		B	B				C			D	D	D	D	D	E	E
TOC > 1%	A	B	B	C	C	C	C	C				D	D	D		
TOC < 1%									C	D	D				E	E
Metals	A	B	B	C	C	C	C	C	C	D	D	D	D	D		
SVOCs	A	B		C									D			
Pest/PCBs	A	B	B	C	C	C	C	C	C	D	D		D	D	E	E
Shallow (<3')	A	B	B	C	C		C	C	C	D	D	D	D	D	E	E
Deep (>3')						C										
Predominant Silt	A		B		C		C	C								
Predominant Sand		B		C		C			C	D	D	D	D	D	E	E
Juncus sp.	A				C			C								
Cattails		B	B						C							
Hardwoods		B	B			C	C	C					D			
Mowed Grass				C						D	D			D	E	E
Disturbed Vegetation	A			C	C	C			C	D	D	D		D		
Limited Receptors										D	D	D	D	D	E	E

Note:
 The letters A-E in the table refer to the wetland grouping and whether that characteristic applies to a particular wetland.

Group C, Wetlands 4D, 15, 16, 18A, 18B, and 63A: These wetlands have similar types of contaminants (metals and pesticides/PCBs) and are adjacent to and are tidally influenced by either Pensacola Bay or Bayou Grande. Most of these wetlands are surrounded by disturbed vegetation. Therefore, the types of receptors present in these wetlands are expected to be similar. Wetlands 18 and 16 were selected to represent Group C because they had the highest levels of contamination in comparison to the other Group C Wetlands; 4D, 15, and 63A.

Group D, Wetlands 10, 6, 5B, W1, and 1: These wetlands are similar in physical characteristics and chemical contamination. All of these wetlands appear as man-made drainage ditches and are in developed areas of the base. Due to their channelized features and proximity to developed areas, they have limited ecological receptors.

Group E, Wetlands 48 and 49: These freshwater wetlands are on the western side of the base and have pesticide and inorganic detections. Because of their intermittent levels of surface water, neither is expected to be a significant source of food, water, or habitat to any species of concern.

Wetlands Selected for Study in Phase IIB/III

Based on HQs and potential receptor species, Wetlands 64, 5A, 3, 16, and 18 were selected for highest sampling priority in Phase IIB/III. If contamination in Wetlands 16 and 18 was determined to be at levels producing adverse ecological effects, then the potential for effects in the remaining Group C wetlands (4D, 15, 63A) can also be determined by back-calculation or regression analysis.

Wetlands in Groups D and E both contained elevated levels contaminants, mostly pesticides. The primary reason both wetland groups were not considered further was the lack of sufficient receptors, such as fish or bird species which could possibly be exposed to the contaminants. Wetlands in Group D are channelized drainage ditches that did not contain a viable aquatic community and were not considered a viable source of food or habitat for any receptor species.

The Group E Wetlands, 48 and 49, were both heavily influenced by seasonal fluctuations in rainfall and appeared dry for most of the year. Because they did not support a viable aquatic or terrestrial community, Group E wetlands were not sampled further.

7.9 Phase IIB/III Conceptual Model Development

The ecological risk assessment relates contaminant levels to specific toxicological or bioaccumulative effects. This information, where appropriate, was incorporated into the conceptual models for each wetland of concern to predict impacts on assessment endpoint species at other levels of the food chain. This section describes how the assessment and measurement endpoints were selected and the modeling approaches used to quantify risk.

Problem Formulation

The Phase IIA data analysis (Section 10) indicated that contamination may pose a risk to receptors in Wetland Groups A, B, and C. The objective of the problem formulation phase is to help establish a link between contamination and effects. The conceptual model developed for each of these wetlands identified exposure pathways and used assessment and measurement endpoints to evaluate potential impacts through those pathways. The Site 41 SAP addendum (E/A&H, 1997) describes the technical basis for the following factors, which must be addressed as part of the BRA: the specific functional uses and conceptual models for each wetland selected for further study, selected assessment endpoints, measurement endpoints, food-chain models, and scientific decision points.

Wetland-Specific Functional Uses and Conceptual Models

The conceptual models represent all possible exposure routes to particular receptor species from each wetland of concern. However, not all receptors were selected as assessment and measurement endpoints because some exposure routes were considered more likely than others. For example, some wetlands were considered suitable habitats for diving bird species. However, due to the prevalence of the great blue heron throughout the area and the wealth of information

about its life cycle, the heron was selected as an assessment endpoint to represent impacts on wading bird species instead of potential impacts on diving bird species.

The conceptual models were developed according to site contaminants, receptors identified within the NAS Pensacola estuarine system, and complete predicted contaminant exposure pathways. Specific conceptual models were based on a functional use assessment of the red- and orange-coded wetlands and their prevalent contaminants. The functional uses of the red- and orange-coded wetlands selected for further study are summarized on Figure 7-1. Conceptual models are provided in the site-specific evaluations in Section 10.

Benthic macroinvertebrates, fish, and piscivorous (fish-eating) birds were considered the most critical receptors. Likewise measurement endpoints, selected to determine impacts on these groups, included toxicity tests, benthic community population indices, and whole body fish contaminant levels for use in a dietary exposure model for piscivorous birds and higher trophic-level fish. The following information details assessment and measurement endpoints selected for Wetlands 64, 5A, 3, 16, and 18.

Assessment Endpoints

After the functional uses of the selected red- and orange-coded wetlands were determined, assessment endpoints were selected based on the following assumptions:

- Contaminants in wetland sediment may impact the overall benthic ecosystem and other lower food chain organisms.
- Upper trophic-level species can be exposed to elevated contaminant concentrations in sediment and contaminated prey species.

Assessment endpoints, selected according to the wetland-specific conceptual models, represent different levels of the food chain and are specific for the wetland group selected for further study

(Table 7-2). Each assessment endpoint lists the or group of species selected to represent that endpoint. For example, the great blue heron was selected to represent impacts on piscivorous birds. Each of the selected assessment endpoints is summarized below.

Table 7-2
 Wetlands and Assessment and Measurement Endpoints

Wetland Groups and Representative Wetland(s)	Assessment Endpoints	Measurement Endpoints
Group A (Wetland 64)	A) Piscivorous Bird Health and Reproduction (great blue heron)	A) Whole-body contaminant levels in a foraging fish species used in a food chain model and residue effects analysis
	B) Survival and growth of macroinvertebrates associated with the benthic environment (general benthic community)	B1) 10-day marine amphipod <i>Leptocheirus plumulosus</i> acute toxicity sediment test B2) 20-day marine polychaete <i>Nereis arenacoedentata</i> chronic toxicity test B3) Benthic community indices
	C) Protection of fish viability (foraging and predatory fish species)	C1) Correlation of fish body burden values with effects values in literature C2) Comparison of surface water data with state and federal water quality standards C3) Fish trophic transfer model and residue effects analysis
Group B (Wetlands 5A and B)	A) Survival, growth and emergence of macroinvertebrates associated with the benthic environment (general benthic community)	A1) 28-day midge larvae <i>Chironomus tentans</i> survival, growth and emergence A2) Benthic community indices
	B) Protection of fish viability using fathead minnow (<i>Pimephales promelas</i>)	B) 7-day fathead minnow <i>Pimephales promelas</i> survival and growth
Group C (Wetlands 16 and 18)	A) Survival and growth of macroinvertebrates associated with the benthic environment (general benthic community)	A1) 10-day marine amphipod <i>Leptocheirus plumulosus</i> acute toxicity sediment test A2) 20-day marine polychaete <i>Nereis arenacoedentata</i> chronic toxicity test A3) Benthic community indices
	B) Survival and growth of macroinvertebrates associated with the benthic environment (general benthic community)	B) Whole-body contaminant levels in foraging fish species (selected for assessment in a food chain model)
	C) Protection of fish viability (foraging and predatory fish species)	C) Fish trophic transfer model and residue effects analysis

	WETLAND	64	5	3	16	18
FLOOD CONTROL			X	X		X
GROUNDWATER TREATMENT			X	X		
FISHERY HABITAT		X	X	X	X	(X)
WADING BIRD HABITAT		X			X	(X)
DIVING BIRD HABITAT		X			X	
BENTHIC MACRO INVERTEBRATE HABITAT		X	(X)	(X)	X	(X)
MAMMAL USAGE						(X)

LEGEND



- VARIABLE CONDITION



- CONSISTENT CONDITION



SITE 41 RI REPORT
NAVAL AIR STATION
PENSACOLA,
PENSACOLA, FLORIDA

FIGURE 7-1
WETLAND FUNCTIONAL
USE ASSESSMENT

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Assessment Endpoint: Piscivorous Bird Health and Reproduction

The great blue heron was selected for several factors relevant to assessing risk in Bayou Grande. The great blue heron is common throughout NAS Pensacola and data are readily available on its habitat use and feeding characteristics. The heron is considered an ideal assessment endpoint species for assessment of aquatic food chain contaminant transfer based on diet, feeding characteristics, and limited home range. For example, the heron feeds on some of the measurement endpoint species selected for the study. Any impacts to these measurement endpoint species, either through toxicity or body burden effects, may help establish a correlation between effects to the measurement endpoint and effects in the heron. Specific factors making the heron an attractive assessment endpoint species include:

- **Diet** — The great blue heron feeds primarily on fish, but it also eats amphibians, reptiles, and other organisms. Fish consumed by the heron are less than 20 centimeters in length with small home ranges. The limited home range of the fish prey species simplifies the prediction of sediment impacts from these fish species. The limited migration increases the certainty in predicting impacts to species consuming fish in their diet from specific portions of the bayou and the adjacent wetlands. Food, body weight, and water ingestion rates for the heron are also readily available.
- **Feeding Characteristics** — Herons consume fish in shallow waters by slow wading to catch their prey. This characteristic makes the shallow areas of Bayou Grande and adjacent wetlands ideal for catching prey and thus an area of high exposure potential.
- **Limited Home Range** — The great blue heron is widely distributed in both saltwater and freshwater environments, making the bayou and adjacent wetlands a suitable, attractive habitat. Herons have a limited home range and do not venture far from their nesting sites, thus it is assumed that they spend a significant amount of time in portions of the bayou and

the adjacent wetlands where they have been observed. Also, herons do not appear to be sensitive to human presence, feeding in portions of the bayou and wetlands near the more developed parts of the base.

- **Correlation with Accepted Measurement Endpoints** — Based on their diet, feeding habits, and feeding range, effects to the great blue heron may be correlated with a measurement endpoint. For example, body burdens in particular fish species may be used to predict reproductive impacts to herons. Toxicity results on amphipods and fish can also be related to losses in potential food sources.

Assessment Endpoint: Survival, Growth, and Reproduction of Macroinvertebrates Associated with the Benthic Environment

This assessment endpoint is measurable and may significantly affect higher trophic level organisms. Benthic macroinvertebrates are an important biomonitoring tool. They are relatively sessile, have long life cycles, and represent a range of ecological niches. In addition to showing acute and chronic toxic effects, benthic organisms also accumulate metals and other contaminants at several orders of magnitude above ambient concentrations in the sediment or surface water. Benthic macroinvertebrates are very localized in their habitat, meaning that effects to benthic organisms can usually be directly related to contamination in that area. The ability to focus on effects in particular areas may help focus remedial decisions.

Assessment Endpoint: Protection of Fish Viability

Fish were selected as an assessment endpoint species based on their potential for exposure through diet and/or absorption. They occupy a significant niche in an estuarine community and effects to populations can alter overall community structure. Body burden and toxicity data from fish species will be important for these reasons:

- Higher Food Chain Impacts — Fish are prey for a variety of other species, such as the great blue heron and predatory fish, assessment endpoints.
- Biotransfer — Fish may ingest sediment during feeding and thus become a direct transfer pathway for contaminants present in the sediment to other species.
- Toxicity from Direct Exposure — Toxicity to fish species may be correlated with contaminant concentrations in sediment.

Measurement Endpoints

Measurement endpoints provide quantifiable responses to a stressor that can be directly related to the assessment endpoint. Measurement endpoints were selected for best correlation with the assessment endpoints (Table 7-2).

Decision Points

Decision points are defined as toxicological or bioaccumulative effects that indicate ecological risk, meaning that a decision is required about whether risk is assumed or additional analysis is needed. A decision point was selected for each measurement endpoint test. For all toxicity tests, the decision point is defined as statistically significant differences in mortality, growth, or fecundity compared to a control. After these differences were established, they were also compared to effects seen in the reference wetlands. For the bioaccumulation analysis, the decision point is whole-body contaminant levels associated with an adverse effect. These are defined as tissue concentrations which exceed a defined threshold effects level in the assessment endpoint species.

7.10 Phase IIB/III Contaminant Modeling Approaches

After the conceptual model, assessment endpoints, and decision points were finalized, modeling techniques were researched to determine which ones would yield an accurate analysis of risk.

Contaminant residues in foraging fish tissue were modeled to predict effects on both the great blue heron and fish species.

Conservative exposure estimates were used in each model to yield an overall conservative risk estimate. For both the heron and fish, it is assumed that feeding occurs exclusively in areas of elevated contamination. In addition, the maximum contaminant residue concentrations used in the model are from the maximum detected in whole-body fish samples.

Great Blue Heron Food Chain Model

For the assessment endpoint “piscivorous bird health and reproduction,” contaminant uptake into the great blue heron from ingestion of contaminated fish in Wetland 64 and Wetland 18B was estimated based on the following assumptions:

- Uptake of compounds in surface water via ingestion is not considered to be a relevant pathway, because none of the constituents present in fish tissue were detected in the surface water.
- Fish is conservatively assumed to comprise 100% of the heron’s diet. Non-fish species have been shown to comprise the heron’s diet in some studies, but others have shown fish to comprise 94% to 98% of the heron’s diet.
- One hundred percent (100%) of the contaminant found in fish tissue is bioavailable to the receptor species.

Presented below is Equation 1 that was used to derive a potential dietary exposure (PDE) to the heron. For contaminants having a similar mode of toxicity (such as 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD), concentrations have been summed to generate the PDE.

$$PDE = \frac{IR \times f \times Ct \times SFF}{BW} \text{ (Equation 1)}$$

where:

- PDE* = Potential dietary exposure (mg of compound per kg body weight per day, mg/kg-day)
- IR* = Food ingestion rate of receptor (kg of food per day)
- f* = Fraction of diet composed of fish tissue (assumed to be 100%)
- Ct* = Fish tissue contaminant concentration (mg of compound per kg body weight, mg/kg)
- SFF* = Site foraging factor (unitless)
- BW* = Mean body weight (kg)

The ingestion rate (*IR*), percent diet (*f*), and body weight (*BW*) assumed for the heron were based on information found in the USEPA *Wildlife Exposure Factors Handbook* (USEPA, 1993b). For the great blue heron, the *IR* is calculated to be 0.401 kg/day, based on the average ingestion rate being 0.18 gram food/gram body weight-day and the average heron body weight of 2,229 grams. The fish tissue contaminant concentration (*Ct*) is based on the analytical results obtained from the fish tissue data for either total DDT (4,4'-DDT, 4,4'-DDD, and 4,4'-DDE) or total PCBs (all congeners).

Two different site foraging factor (*SFF*) values are used in the model for Wetland 64 and 18B. The *SFF* value of 1 assumes that 100% of the heron's diet is contaminated fish tissue from the particular wetland. The second *SFF* value used is a fraction based on the potential habitat area in Wetlands 64 and 18B divided by the known feeding territory of the great blue heron. This fraction has a range based on variability in heron's feeding territory in the fall and winter seasons as reported in USEPA, 1993b. For example, the known heron feeding territory in the fall is 1.23 to 1.73 acres and in winter is 7.42 to 34.1 acres. The potential habitat area in Wetlands 64 and 18B for the great blue heron is 9.5 acres and 0.6 acres, respectively. Therefore, the *SFF* for Wetland 64 ranges from 0.28 (9.5 acres divided by 34.1 acres) to 1 (9.5 acres divided by 1.23 acres, with

a maximum value of 1). The SFF for Wetland 18B ranges from 0.02 (0.6 acres divided by 34.1 acres) to 0.49 (0.6 acres divided by 1.23 acres).

To assess the potential risk present to the heron, the PDE value is then divided by the No-Observed-Adverse-Effects-Levels (NOAEL) (Sample *et al*, 1996) to derive an HQ for the receptor species. The HQ is a numerical representation of potential risk to the assessment endpoint selected. An HQ greater than 1 (i.e. $PDE > NOAEL$) suggests that the contaminant or contaminant group may cause adverse effects to the receptor group in question.

Fish Exposure Model

A fish exposure model was used to predict contaminant effects to higher trophic level piscivorous fish (level 4 fish species) in Wetland 18B and Wetland 64 based on the contaminants detected in the whole body tissue of foraging level fish (level 3 fish species) from these wetlands. In evaluating these effects, food chain interactions are considered the most significant exposure route. This is because most level 4 fish species, which spend most of their life cycle in open water, are not typically exposed to the sediment. In addition, Phase IIB/III surface water samples did not show significant concentrations of pesticides. Only exposure to organochlorine compounds was considered in the model because metals, except for mercury, do not typically biomagnify. This model was not performed in Wetland 75 because, as a small and isolated freshwater wetland, it does not support level 4 fish species.

The model is performed in three steps. The first step, exposure assessment, involves determining a trophic transfer coefficient (TTC). The TTC is defined as the increase in tissue concentration of a particular contaminant as that contaminant moves through the food chain from level 3 to level 4 fish, and is used to predict the contaminant tissue concentration in level 4 fish species.

The USEPA (1998a) has published Food Chain Multipliers (FCMs) to predict the transfer of contaminants from one trophic level to another. The FCMs are based on the log octanol/water partitioning coefficient (K_{ow}) of the compound of concern. For this study, the log K_{ow} was obtained from the ASTDR Toxicological Profiles published for each compound. The FCMs are divided into several categories based on food web structure. Since this study is evaluating the transfer of contaminants from trophic level 3 fish to trophic level 4 fish, the FCMs for pelagic structure for trophic level 4 were utilized. The maximum detected concentrations in level 3 fish collected from the wetland were used in this model.

As part of the exposure assessment, a SFF was also calculated for level 4 fish and incorporated into the model. The SFF represents the percent diet of the level 4 fish species from the wetlands of concern and is apportioned based on surface area. The SFF is calculated by dividing the total surface area of Wetland 18B (0.6 acres) and Wetland 64 (41 acres) by the total surface area of Bayou Grande (960 acres). Therefore, the SFF for Wetland 18B is 0.000625 and the SFF for Wetland 64 is 0.043. Based on life cycle information of the red drum (*Sciaenops ocellatus*) found in NOAA (1992), the juvenile red drum prefers shallow, protected open waters of estuaries before it moves into deeper, open waters in adulthood. Therefore, the calculated SFF assumes that a juvenile red drum spends all of its life cycle in Bayou Grande and finds each portion of Bayou Grande, including Wetlands 18B and 64, equally attractive for feeding. In addition, an SFF of 1 which assumes the fish spends its entire life cycle in the wetland of concern is also presented.

The second step, the effects assessment, involves selecting a screening ecotoxicity value (SEV) for each organochlorine compound where no toxic effects were reported. SEVs were determined through a review of the U.S. Army Corps of Engineers Environmental Residue Effects Database (ERED).

The third step, risk characterization, involved calculating the HQ values. The HQ is calculated by dividing the predicted contaminant tissue concentration in the Level 4 species by the SEV. Any HQ values greater than one, which means that the tissue concentrations exceeded the SEV, suggest a potential risk to the receptor organism, in this case a Level 4 fish.

Risk to level 3 fish was also evaluated using a simplified version of the above model. Since tissue residue concentrations were directly measured during Phase IIB/III, these maximum concentrations were compared directly to SEV values reported in Level 3 fish. SFF values were assumed to be 1 since these species have a limited home range and spend all or most of their life cycle in protected estuarine areas. HQ values were derived as explained above.

7.11 Phase IIB/III Sample Locations

This section explains the selection of Phase IIB/III sediment and surface water sample locations. Sample locations were selected in wetland areas where Phase IIA data showed relatively high, medium, and low levels of contamination. Sampling a contaminant level gradient was selected to yield a risk gradient posed in certain portions of the wetland. In wetlands where only one Phase IIB/III sediment sample was collected, the most contaminated Phase IIA location that corresponded to the conceptual model was sampled. Proposed sample locations in each selected wetland were selected from the existing Phase IIA sample locations. In addition, a sediment sample was collected from each Phase IIB/III location and analyzed for TCL organics (USEPA, 1994b), TAL inorganics (USEPA, 1994c), total organic carbon, and grain-size analysis to better correlate the sediment contaminants with the toxicity results. In collecting Phase IIB/III samples from the Phase IIA locations, deviations in sediment chemistry were expected due to changes in sediment conditions and sample placement.

Benthic Community Analysis

Benthic community analysis is one link in the sediment quality triad. These data show what effects are actually occurring in the area sampled, possibly due to site contamination. Species diversity results on their own are not considered as reliable an indicator of ecological risk due to the many influencing factors such as sediment type, sediment deposition rates, water temperature, salinity, waterborne nitrates and phosphates, dissolved oxygen, or a host of other factors not directly related to site contamination. Therefore, it is important to view species diversity in context with contaminant concentrations and toxicity test results. The three methods (Shannon-Weiner, Pielou's Evenness, and Margalef's Richness Diversity) that were run on the results are described below.

The Shannon Weiner Diversity Index refers the diversity of a community taking into account the evenness and richness of individuals and species collected. The Shannon Weiner Diversity Index is always shown with the evenness and richness (because they influence the diversity) and may range from 1.3 (low diversity) to 6.5 (high diversity). A low value would indicate a higher chance that one or two species dominate a particular site.

Pielou's Evenness Index measures the abundance of species. In an ideal setting, a community of 100 individuals would be composed of 100 species. The Pielou Evenness Index ranges from 0 to 1.0, with 1.0 indicating perfect evenness.

Margalef's Species Richness Index refers to species abundance and distribution over a given area. An example of this would be a community of 100 individuals composed of ten species, of which 90% of those individuals belong to a single species. The remaining 10% of the community are distributed among the nine species, which would indicate low evenness. Margalef's Species Richness Index ranges from 1.0 to 10, with 10 being the best range.

The Shannon Weiner Diversity Index should be evaluated by itself, and not averaged with Pielou's Evenness Index or Margalef's Species Richness Index, as they are components in the diversity index. From this type of data, it is possible to assess whether a particular habitat is healthy, in a recovery state, or impacted.

Toxicity Tests

Toxicity tests were performed on sediment and surface water samples collected at selected locations from Phase IIB/III wetlands. The test species used, *Pimephales promelas* (fathead minnow), *Leptocheirus plumulosus* (marine amphipod), *Neanthes arenaceodentata* (marine polychaete), and *Chironomus tentans* (midge larvae) were considered surrogate species for naturally occurring fish, benthic macroinvertebrates, and polychaetes. Acute (survival endpoint) and chronic (survival and sublethal endpoints) were performed on the freshwater and estuarine sediments. Statistical analysis is then performed on the results to determine differences between the subject samples and the control samples.

Bioaccumulation Tests

Level 3 fish from Wetlands 18 and 64 were sampled and analyzed for piscivorous bird uptake and level 4 fish modeling. Based on the Phase IIA data, Wetlands 18 and 64 had significantly higher concentrations of biomagnifying pesticides and were sampled for prey fish.

7.12 Phase IIB/III: Results

Sediment samples were collected in Wetlands 64, 5A, 3, 18B, 16, 33, and 75. Surface water samples were collected in Wetlands 64, 5A, 3, 33, and 75. GPS coordinates used to mark Phase IIA sample locations were also used to locate and collect the Phase IIB/III samples. As expected, the sediment and surface water chemistry results varied between Phases IIA and IIB/III due to changes in sediment conditions between phases and the impossibility of sampling exactly the same location in each phase. These natural changes in sediment distribution and the low level

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7.12 Phase IIB/III Results

Sediment samples were collected in Wetlands 64, 5A, 3, 18B, 16, 33, and 75. Surface water samples were collected in Wetlands 64, 5A, 3, 33, and 75. GPS coordinates used to mark Phase IIA sample locations were also used to locate and collect the Phase IIB/III samples. As expected, the sediment and surface water chemistry results varied between Phases IIA and IIB/III due to changes in sediment conditions between phases and the impossibility of sampling exactly the same location in each phase. These natural changes in sediment distribution and the low level

of precision inherent in sediment sampling mean that the contaminant gradients detected in Phase IIA may not be shown in Phase IIB/III. These changes could lead to an underestimate of risk based on higher contaminant levels possibly present in other portions of the wetland sediment. Tissue bioaccumulation results are not expected to vary as much between phases, since the fish species collected represent exposure to the entire wetland and not just a single point location. However, there will likely be some variability due to contaminants being covered by less contaminated sediment deposits or otherwise being naturally removed as a possible exposure route. Detailed evaluation of the analytical results is provided in Section 10.

7.13 Phase IIB/III Data Evaluation Methods

Ecological risk in each wetland was evaluated through impacts on its assessment endpoints. The methods used to quantify risk to each of these assessment endpoints are described below. The data evaluation is provided in Section 10.

Assessment Endpoint: Piscivorous Bird Health and Reproduction

Impact to piscivorous birds was evaluated by comparing the predicted contaminant concentrations in heron tissue to known residue effects levels. This procedure is described in Section 7.10. HQ values greater than 1 were considered to represent a potential risk to piscivorous birds.

Assessment Endpoint: Survival, Growth, and/or Emergence of Macroinvertebrates Associated with the Benthic Environment

Risk to the benthic macroinvertebrate community is evaluated through the sediment quality triad approach, which refers to three sources of data that are viewed concurrently in relation to particular sample locations when quantifying risk. These data are: (1) chemicals in sediment suggest which contaminants may be driving risk, (2) toxicity represents likely effects on receptors in the area sampled, and (3) benthic diversity shows actual effects of contamination on organisms living in a particular area.

To assist in the evaluation of these processes, a triad matrix has been developed which gives equal weight to the sediment chemistry, toxicity tests, and benthic assessments. Interpretation of the matrix and the logical steps to be followed are shown in the decision flow-charts discussed later in this section.

Decision making for sediment assessment will proceed based on the triads of assessment results presented in the matrices below. Sediment chemistry is evaluated by comparing the detected concentrations to the USEPA SSVs and the FDEP SQAGs as previously described in Section 7.2. Benthic diversity is assessed by measures in abundance, diversity, or the presence of pollution indicator species as previously described in Section 7.11. Biological decision making triads will be used to assess biological test results. These will be processed through the Project Decision Making Triad to establish decisions at the project level.

“Hits” and “adverse effects” (terms used below) mean “statistically different” using methods accompanying each test protocol. “OK” means that results were not statistically significant. For weighting purposes, “Hits” on survival are considered twice as important as “Hits” on reproduction or growth. This is because survival (i.e., mortality) is irreversible, whereas reproduction and growth endpoints are potentially reversible; therefore, two sublethal hits equal one lethal hit. After the bioassays are considered individually, their results will be combined for input to the triad matrix assuming the compounding of cumulative adverse effects.

Within the triad matrix, +’s and —’s are used to reflect the continuum of chemistry, toxicity, and benthic community response one normally encounters. In the interpretation, multiple +’s reflect a higher score for a particular interpretation. These scores consider the strength or weakness one should associate with a particular interpretation.

Sediment Toxicity Tests

The boxes below chart the possible outcomes for the *Leptocheirus plumulosus* amphipod test, the *Neanthes* polychaete test, and the *Chronimid tentans* midge test, conducted to analyze the sediments of a particular wetland:

Possible Outcomes from the *Leptocheirus plumulosus* Amphipod Test:

Survival	Scoring
OK	—
Hit	+

Possible Outcomes from the *Neanthes* Polychaete Test:

Survival	Weight	Scoring
OK	OK	—
OK	Hit	+
Hit	OK	++
Hit	Hit	+++

Possible Outcomes from the *Chronimid tentans* Midge Test:

Survival	Weight	Emergence	Scoring
OK	OK	OK	—
OK	OK	Hit	+
OK	Hit	Hit	++
OK	Hit	Hit	++
OK	Hit	OK	++
Hit	OK	OK	++

Survival	Weight	Emergence	Scoring
Hit	OK	Hit	+++
Hit	Hit	OK	+++
Hit	Hit	Hit	++++

At locations with more than one toxicity test result for sediment, the results are integrated as shown in the box below:

Combined Score	Biological Interpretation Considering both Bioassays	Input to Triad Matrix		
—	No adverse effects	—	=	—
+	No survival hits in either species. 1 sublethal hit in one species	—	=	—
++	1 survival hit in one species or 2 sublethal hits.	+	=	+
+++	1 survival hit in one species and/or adverse sublethal effects.	+	=	+
++++	Survival hits in 1-2 species and/or adverse sublethal effects.	++	=	+
+++++	Survival hits in both test species and adverse sub lethal endpoints.	+++	=	+

Project Decision Making Triad

By combining scores for sediment chemistry, benthic assessment and toxicity tests (the “triad” for decision making), a condition for a particular wetland sediment can be interpreted, along with the type of degradation which may be impacting the wetland. The conditions and their interpretations are explained in the box below. Surface water conditions and their interpretations are also presented below but will be explained in the Assessment of Fish Viability Endpoint.

Sediment (conditions 1-8; considers all results)	Surface Water (conditions 1-4; considers chemistry/toxicity results only)	Condition	Chemistry	Toxicity Tests	Benthic Assessment	Interpretation
		1	+	+	+	+
2	-	-	-	-	Strong evidence for the absence of pollution-induced degradation.	
3	+	-	-	-	Contaminants are not bioavailable.	
4	-	+	-	-	Unmeasured contaminants or conditions exist that have the potential to cause degradation.	
5	-	-	-	+	Alteration of benthic community is probably not due to toxic chemical contamination.	
6	+	+	+	-	Toxic chemicals are probably stressing the system.	
7	-	+	+	+	Unmeasured toxic chemicals are causing degradation.	
8	+	-	-	+	Benthic community degraded by toxic chemicals but toxicity test not sensitive to toxic chemicals present or chemicals are not bioavailable or alteration is not due to toxic chemicals.	

Notes:

- + = Measured difference between test and control or reference conditions.
- = No measurable difference between test and control or reference conditions.

The shaded area relates to surface water acute tests and are described in Figure 7-3.

Once the decision making matrix has been interpreted, this information can now be applied to the simplified decision flow chart for sediment for a particular wetland, as appropriate. Figure 7-2 provides the simplified decision flow for sediments from a freshwater wetland.

Assessment Endpoint: Protection of Fish Viability

Determining impact to the fish community involved a more complex analysis of different lines of evidence depending on the wetland. One line of evidence is the comparison of surface water concentrations to surface water quality criteria to estimate the effect of contaminant concentrations. Surface water data are presented in Section 10. Where collected, one line of evidence is the comparison of body burden values in foraging fish species to ERED values, then calculating HQ values and determining whether these whole-body residue concentrations were associated with any adverse effects. The second line of evidence, described in Section 7.10, was similar to the first but incorporated the trophic transfer factor, which predicts effects on predatory fish species based on the whole-body residue concentrations in foraging fish tissue (a mercury exposure model using the red drum is presented in Appendix G). In the fourth line of evidence, toxicity were evaluated for the fathead minnow also presented in Section 10 where collected. For Wetlands 64 and 18, all four lines of evidence were applied. For Wetland 3, only toxicity and chemistry data were analyzed because the shallow depth of the surface water does not support upper trophic level fish.

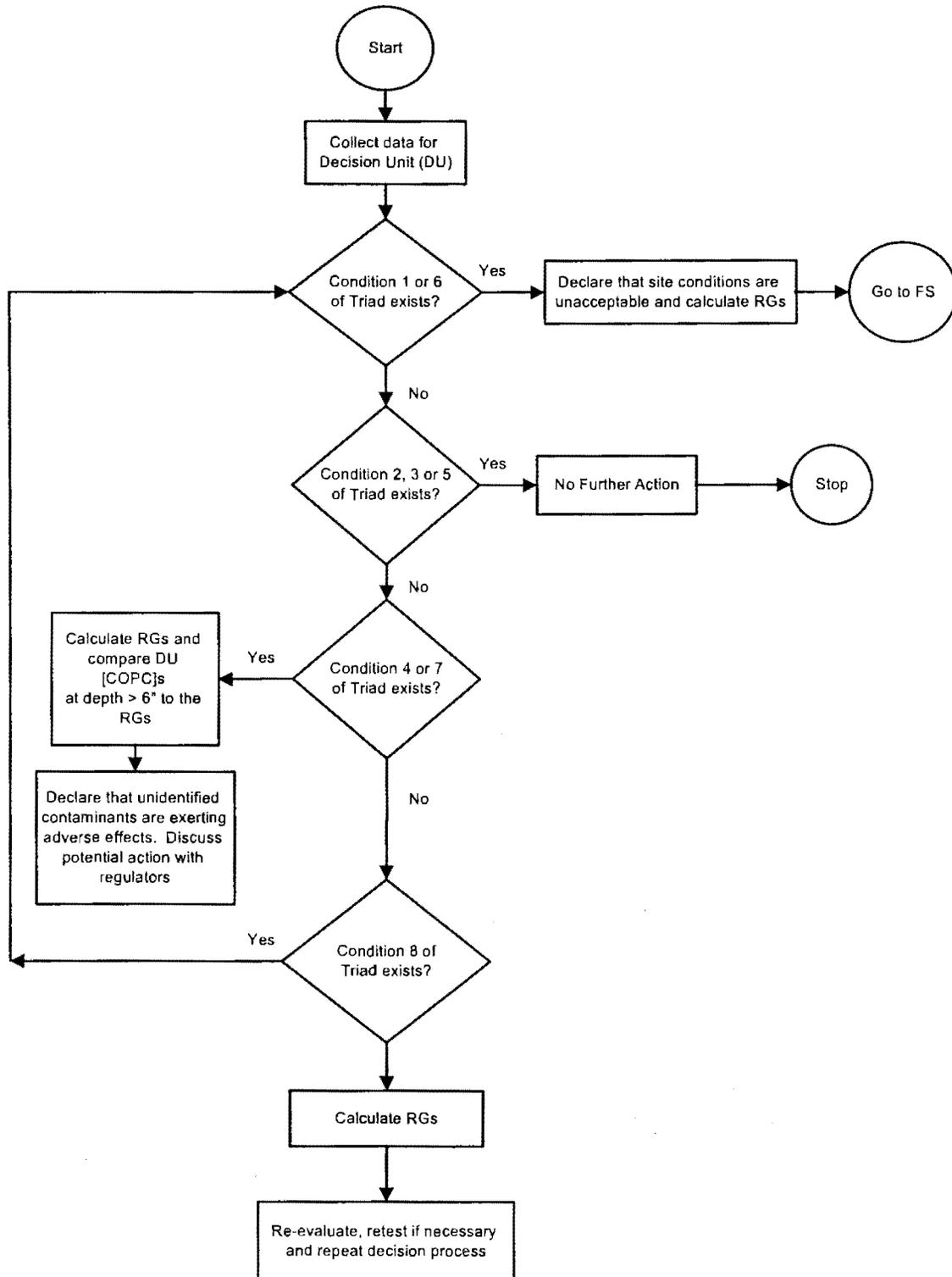
Surface Water Toxicity Test

The box below charts the possible outcomes for the *Pimephales promelas* fathead minnow test conducted to analyze surface water conditions:

Possible Outcomes from the *Pimephales promelas* Fathead Minnow Test:

Survival	Growth	Scoring
OK	OK	—
OK	Hit	+
Hit	OK	++
Hit	Hit	+++

Figure 7-2 Simplified Decision Flow for Sediments from Freshwater Wetland



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Because only one surface water toxicity test was performed at each location, the above scorings will be put directly into the Triad Matrix. Multiple +’s will be input as a single +.

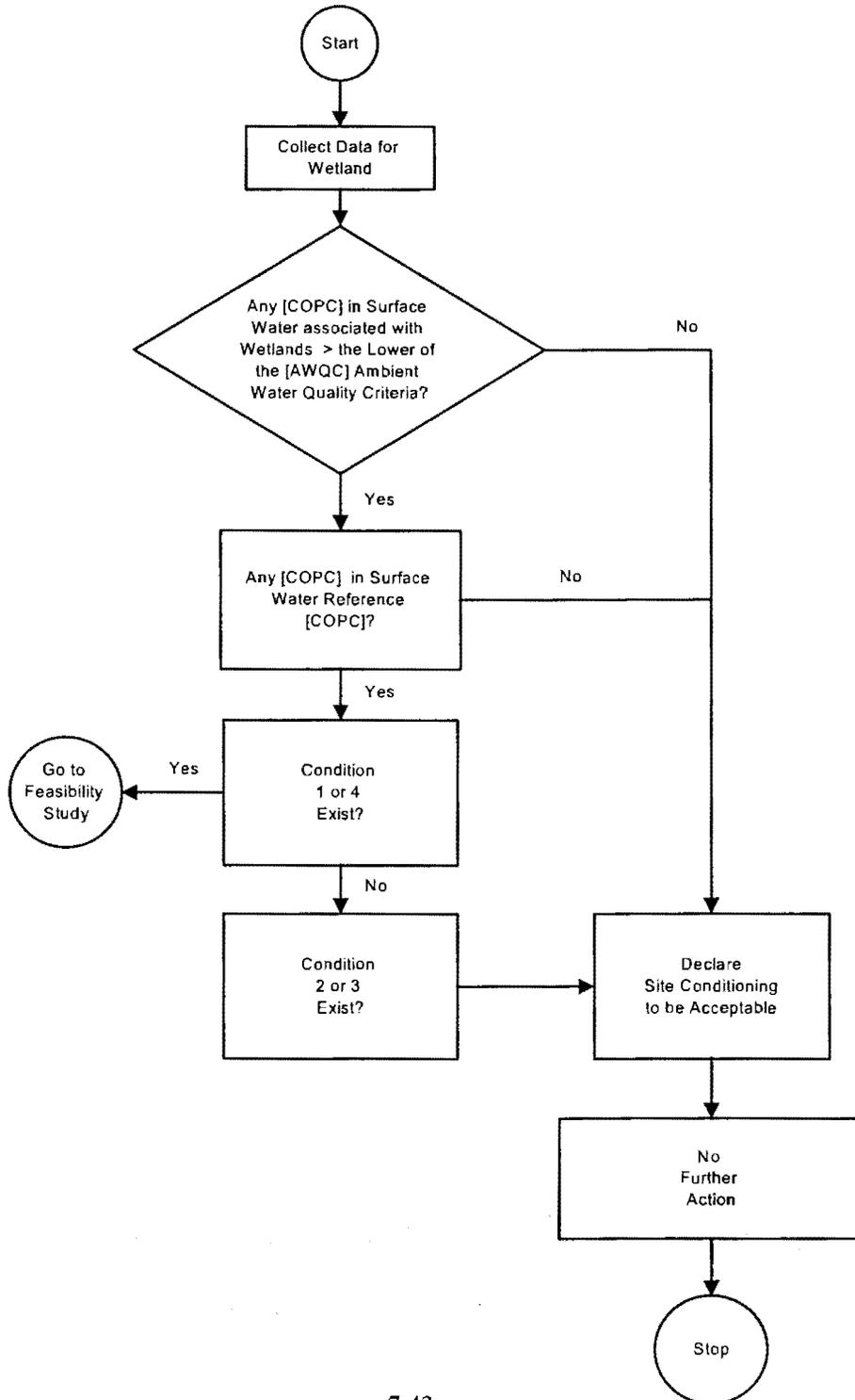
Project Decision Making Triad

By combining scores for surface water chemistry, benthic assessment and toxicity tests (the “triad” for decision making), a condition for a particular wetland surface water can be interpreted, along with the type of degradation which may be impacting the wetland.

Once the decision making matrix has been interpreted, this information can now be applied to the simplified decision flow chart for surface water for a particular wetland, as appropriate. Figure 7-3 provides the simplified decision flow for surface water from a freshwater wetland.

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Figure 7-3 Simplified Decision Flow for Surface Water from each Wetland



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8.0 HUMAN HEALTH RISK ASSESSMENT METHODS

This section presents the methods used in the human health risk assessment (HHRA). Wetland-specific risk evaluations are presented in Section 10, Site-Specific Evaluations.

8.1 Introduction

A BRA estimates current and future risk assuming no remedial actions are undertaken to facilitate risk management and remedial decisions. "Risk" is the estimated potential for toxic effects on actual or hypothetical human or ecological receptors, while "baseline risk" refers to risk arising from exposure to chemicals assuming overall site conditions remain unchanged. Baseline risk can vary with time as a result of changing fate and transport conditions or changing source amounts and properties. Risk may be reduced to acceptable levels by remediation or removal, engineered barriers and/or institutional controls to prevent or limit exposure, or natural attenuation over time.

Generally, a BRA contains two parts, one assessing human health risk and a second part addressing ecological risk. Because ecological risk is expected to be the risk driver at these sites, human health risk assessment is limited in scope to human health risk posed by exposure to contaminants in sediment, fish tissue, and surface water based on current and future land use scenarios. Fish tissue data were screened to address these scenarios and assist risk managers in identifying potential data gaps.

Acceptable risk and hazard levels and remedial actions are determined by the FDEP, the USEPA, and the Navy, who are the risk managers that use risk assessments in their decision-making process. USEPA's acceptable incremental cancer risk range is 1E-6 to 1E-4, which reflects one in one million to one in ten thousand chances of contracting cancer. FDEP's threshold is 1E-6. Both agencies' hazard index (HI) threshold is 1. An HI greater than 1 could indicate the potential for toxic effects other than cancer. This report presents risk and hazard estimates for land use scenarios and exposure pathways described in this section, while the risk managers decide which

thresholds are acceptable for those scenarios and if remedial actions will be necessary to reduce risk estimates.

8.1.1 Site Background

Various releases from industrial activities throughout the base could have impacted wetlands at NAS Pensacola, including activities such as plating operations, landfills, spills, pesticide use, and other operations. All on-base wetlands are grouped into one report, *Site 41, NAS Pensacola Wetlands*, which facilitates the ERA.

Wetlands 64, 5A, 3, 16, and 18 were sampled most recently during Phase IIB at previous Phase IIA locations. This was done to correlate chemical concentrations with toxicity, diversity, and bioaccumulation samples from those wetlands. In addition, whole baitfish body tissue samples were collected and analyzed from Wetlands 18, 33, 64, and 75 to support the ERA. This section summarizes these data, along with associated risks and uncertainties. In Section 10, each wetland will be briefly summarized where chemicals of potential concern (COPCs) were identified, including potential sources of contamination. Risks will be estimated for COPCs, and cumulative risk will be estimated for NAS Pensacola 41 Wetlands.

8.1.2 Objectives of the HHRA

The objectives of this section are to:

- Characterize the source media and data sources.
- Identify potential receptors and quantify their potential exposure under current and future conditions to all affected environmental media.
- Determine the COPCs for affected environmental media.

- Qualitatively and quantitatively evaluate adverse effects associated with the site-specific COPCs in each medium.
- Characterize the baseline carcinogenic and noncarcinogenic risks associated with exposure to environmental media at the sites under current and future land use conditions.
- Evaluate the uncertainties related to exposure predictions, toxicological data, and resulting carcinogenic risk and noncarcinogenic hazard estimations.
- Establish Remedial Goal Options (RGOs) for chemicals of concern (COC) in each environmental medium, based on risk/hazard, to facilitate risk management decision-making.

8.1.3 Citation of Applicable Guidance

This report was written in accordance with the following guidance documents:

- *Risk Assessment Guidance for Superfund (RAGS), Volume I — Human Health Evaluation Manual, Part A*, U.S. Environmental Protection Agency/Office of Emergency and Remedial Response (OERR), EPA/540/1-89/002, December 1989 (Interim) (RAGS Part A)(USEPA, 1989).
- *RAGS, Volume I — Human Health Evaluation Manual, Part B, Development of Risk-Based Preliminary Remediation Goals*, USEPA/OERR, EPA/540/R92/003, December 1991 (Interim) (RAGS Part B)(USEPA, 1991a).
- *RAGS, Volume I — Human Health Evaluation Manual, Supplemental Guidance — Standard Default Exposure Factors — Interim Final*, EPA/OERR, Office of Solid Waste

and Emergency Response (OSWER) Directive: 9285.6-03, March 25, 1991. (RAGS Supplement) (USEPA, 1991b).

- *RAGS, Volume I — Human Health Evaluation Manual, Supplemental Guidance-Dermal Risk Assessment — Interim Guidance*, EPA/OERR, August 18, 1992. (Supplemental Dermal Guidance) (USEPA, 1992c).
- Supplemental Guidance to RAGS: *Region 4 Bulletin 1, Data Collection and Evaluation, Bulletin 2, Toxicity Assessment; Bulletin 3, Exposure Assessment; Bulletin 4, Risk Characterization; Bulletin 5, Development of Risk-Based Remedial Goal Options*. (Region 4 RAGS Supplement)(USEPA, 1996a).
- Supplemental Guidance to RAGS: *Region 4 Bulletin, Provisional Guidance of Quantitative Risk Assessment of PAHs* (EPA Document EPA/600/R-93-089 July 1993)(USEPA, 1993c).
- *Supplemental Guidance to RAGS: Calculating the Concentration Term*, May 1992 (USEPA, 1992d).
- USEPA Region III *Selecting Exposure Routes and Contaminants of Concern by Risk-Based Table*, March 18, 1994 (RBC Screening Methods) (USEPA, 1994e).
- USEPA Region III April 15, 1998 *Risk-Based Concentration (RBC) Table* (USEPA, 1998b).

In addition, *RAGS, Volume I — Human Health Evaluation Manual, Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments*, USEPA/OERR, 9285.7-01D,

January, 1998 (Interim) (RAGS Part D)(USEPA, 1998c), was followed as much as possible, given that much of the preliminary work was completed before RAGS Part D was issued.

8.2 Site Characterization

When performing a risk assessment, environmental data are compiled to determine potential site-related chemicals and exposures as outlined in RAGS Part A. The data used in this risk assessment are summarized in the following section.

8.2.1 Data Sources

Data collection methods are described in Section 4 of this RI report.

8.2.2 Data Validation

Data validation is an independent, systematic process of evaluating data and comparing them with established criteria to confirm they are of the technical quality necessary to support the decisions made in the RI process. Parameters specific to the data are reviewed to determine whether they meet the stipulated data quality objectives (DQOs). These quality objectives address five principal parameters: precision, accuracy, completeness, comparability, and representativeness. To verify that these objectives are met, field measurements, sampling and handling procedures, laboratory analysis and reporting, and nonconformances and discrepancies in the data are examined to determine compliance with appropriate and applicable procedures.

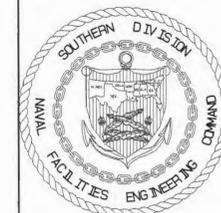
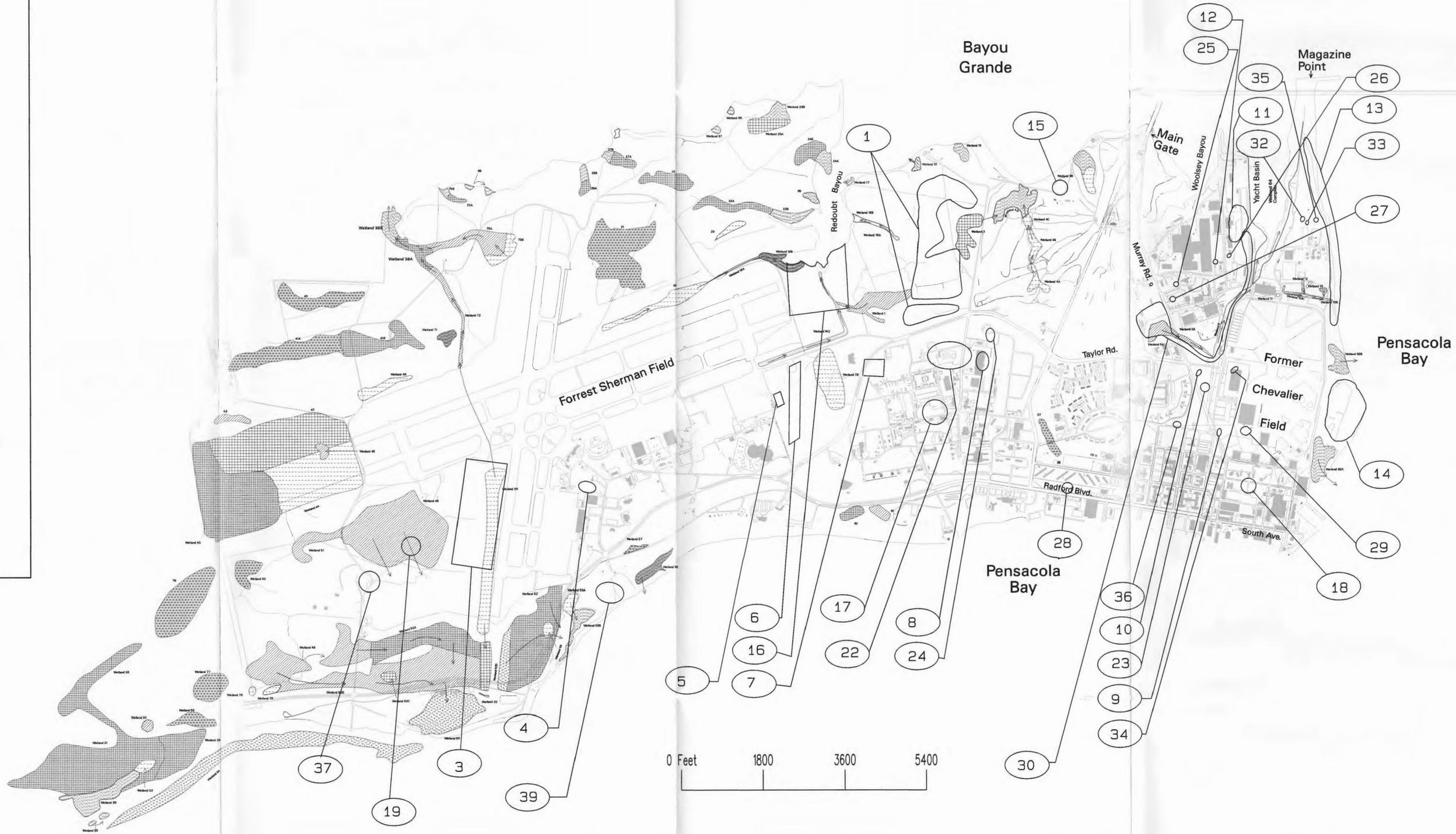
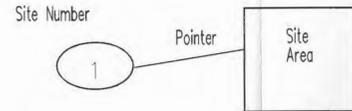
Data validation methods and results are described in Section 5 of this RI report.

Uncertainty and variability are inherent in most analytical results for environmental samples. This is a function of the matrix characteristics and heterogeneity, the precision and accuracy of sampling, and preparation and analysis methods used. Although data are typically considered exact values, they are in reality the laboratory's best estimate within a range defined by method

WETLANDS LEGEND

-  Palustrine Forested
-  Palustrine Forested/Emergent
-  Palustrine Scrub Shrub
-  Palustrine Forested/Scrub Shrub
-  Palustrine Scrub Shrub/Emergent
-  Palustrine Emergent
-  Estuarine Emergent
-  Estuarine Aquatic Bed
-  Site 36 Sewer Line
-  Wetland Surface Water Flow Direction
-  Wetlands that are of potential concern for human health
-  Wetlands that are of potential concern human health and where risk could be underestimated due to Potential Bioaccumulation in game fish species.

SITES LEGEND



Remedial Investigation Report
 Naval Air Station Pensacola
 Pensacola, Florida

**FIGURE 8-
 NAS Pensacola -
 Conceptual Surface
 Migration Path**

control limits. As a result, reported concentrations for any chemical can under- or overestimate actual concentrations.

8.2.3 Management of Site-Related Data

All environmental sampling data were evaluated for suitability for use in the quantitative BRA. Data obtained by the following methods were considered inappropriate:

- Analytical methods were not specific to a particular chemical, such as total organic carbon, total organic halogen, or total petroleum hydrocarbons (TPH).
- Field screening instruments, including total organic vapor monitoring units and organic vapor analyzers.

8.2.3.1 Explanation of Nondetects and Assumed Concentrations

Chemicals are often reported in few samples relative to the number collected. These nondetects indicate the chemicals were not detected at the sample quantitation limit, although the chemicals could be present at concentrations between zero and the sample quantitation limit. In accordance with RAGS Part A, half the sample quantitation limit will be assumed when estimating exposure in a given area or when calculating benzo(a)pyrene equivalent (BEQ) concentrations.

8.2.3.2 Benzo(a)pyrene Equivalent Concentrations

USEPA recommends using equivalent concentrations to assess carcinogenic polycyclic aromatic hydrocarbons (cPAHs) (USEPA, 1993c). Calculating equivalent concentrations is a common method of assessing chemicals with similar toxicology. Benzo(a)pyrene is assumed to be the standard, and the relative toxicities of other similar chemicals are determined through research.

The relative toxicity is reflected in the toxicity equivalence factors (TEFs) (USEPA, 1993c), listed in Table 8-1. The equivalent concentration is calculated by multiplying the TEF by the reported concentration of a given chemical. For example, if benzo(b)fluoranthene is reported at 5 mg/kg and the TEF for this chemical is 0.1, the equivalent concentration would be 0.5 mg/kg. After equivalent concentrations were calculated for each cPAH, the adjusted concentrations were summed to provide a BEQ for each sample location. As explained in Section 8.2.3.1, assumed concentrations will be used to account for nondetects when at least one cPAH is detected at a specific sample location. At locations where no cPAHs are reported, BEQs will not be quantified.

**Table 8-1
 Toxic Equivalents for Carcinogenic PAHs**

PAH	TEF
Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Chrysene	0.001
Dibenz(a,h)anthracene	1.0
Indeno(1,2,3-cd)pyrene	0.1

8.3 Exposure Assessment

This section of the HHRA will determine the magnitude of contact that a potential receptor may have with site-related chemicals. Exposure assessment involves several stages:

- Characterizing the physical setting and land use of the site.
- Identifying potential receptors, under various land use or site condition scenarios, and the pathways through which they might be exposed.

- Identifying appropriate screening values and resulting COPCs.
- Quantifying the intake rates, or contact rates, of COPCs.

8.3.1 Exposure Setting

Site setting and land use are detailed in Section 2 of this RI report. The setting of each wetland is generally similar, with some wetlands being more attractive to trespassers than others. However, each was assumed to be equally attractive for the purposes of quantifying risk. Exposure pathways and land use scenarios are summarized in Table 8-2. As shown in Figure 8-1, some wetlands could be impacted by NAS Pensacola sites, with effects potentially migrating from one wetland to another. Other wetlands remain relatively isolated. Specific site characterization information is summarized in Section 10.

8.3.2 Exposed Populations

For this assessment, sediment exposure was addressed using typical soil exposure methods. Trespassers and site maintenance workers would be the most likely current and future receptors because the sites are generally unused. Trespassers can be characterized as individuals who infrequently visit any given wetland to fish or collect frogs or crabs. The site maintenance worker can be characterized as an individual who infrequently performs landscaping in and around the wetlands. Exposure assumptions for the trespasser were selected based on a reasonable maximum exposure (RME) scenario as recommended by USEPA. The maintenance worker scenario is similar to the default commercial/industrial worker scenario provided in RAGS Part B, except that the exposure frequency is expected to be much less for the maintenance worker.

Potential human receptors for the ingestion of contaminated fish species include recreational fishermen and subsistence fishermen. Parts of these wetlands are used as recreational fishing areas, and the potential for human exposure exists. Commercial fishing does not occur in Pensacola Bay

or any Florida coastal water because of the net ban, so fishing is limited to a recreational activity pattern. Despite this evidence that subsistence fishing does not occur in the bayou, this pathway was evaluated in this site-specific risk assessment for comparison.

8.3.3 Exposure Pathways and Media

Exposure pathways and media are explained in Table 8-2 and are summarized below:

Table 8-2
Summary Justification for Eliminating Human Exposure Pathways Site 41
NAS Pensacola

Potentially Exposed Population	Medium and Exposure Pathway	Pathway Selected for Evaluation	Reason for Selection or Exclusion
Current & Future Site Trespassers (Adolescents)	Air/ Inhalation of gaseous contaminants emanating from soil	No	Site 41 contains no soil. As a result, this pathway was considered insignificant.
	Air/ Inhalation of chemicals entrained in fugitive dust	No	Site 41 contains no soil. As a result, this pathway was considered insignificant.
	Groundwater/Ingestion of contaminants during potable or general use	No	Direct exposure to groundwater was considered an incomplete pathway for Site 41 wetlands.
	Groundwater/ Inhalation of volatilized groundwater contaminants	No	Direct exposure to groundwater was considered an incomplete pathway for Site 41 wetlands.
	Surface Water/ Incidental Ingestion of contaminants during recreational activities or maintenance events	Yes	Swimming is allowed near some wetland areas. The natural salinity of surface water precludes ingestion as a drinking water source, but incidental ingestion while swimming or wading could occur.
	Surface Water /Inhalation of volatilized contaminants	No	Exposure via this pathway is possible during swimming or wading activities. However, this pathway was considered insignificant.
	Soil/ Incidental Ingestion	No	Site 41 contains no soil. As a result, this pathway was considered insignificant.
	Soil /Dermal Contact	No	Site 41 contains no soil. As a result, this pathway was considered insignificant.
	Sediment /Incidental Ingestion	Yes	Site 41 sediment is submerged during part of the year. However, exposure was assumed to occur year-round in order to quantify exposure.
	Sediment /Dermal Contact	Yes	Despite the uncertainties in this exposure pathway, it was quantified for sediment.

Table 8-2
 Summary Justification for Eliminating Human Exposure Pathways Site 41
 NAS Pensacola

Potentially Exposed Population	Medium and Exposure Pathway	Pathway Selected for Evaluation	Reason for Selection or Exclusion
Recreational and Subsistence Fishermen	Fish/Ingestion of tissue impacted by media contamination	Yes	Fishing and crabbing do occur in some Site 41 wetlands. However, little data was available. Despite the uncertainties associated with this pathway, a quantitative assessment was performed for the recreational and hypothetical subsistence fisherman.
	Fruits and Vegetables / Ingestion of plant tissues grown in media	No	No vegetation for human consumption exists. Aquaculture is not a proposed land use and would not be expected to be a concern at this site.

- *Sediment* — Incidental ingestion assuming soil and sediment exposures would be similar. Although the screening method (described in Section 8.3.4) is conservative, inhalation exposure is not incorporated into the soil screening values used to select COPCs. Inhalation was considered an insignificant pathway for two reasons: since the sediments are submerged or partially submerged, no appreciable dust formation is anticipated, and due to the open nature of the site, appreciable buildup of VOCs is not anticipated.
- *Tissue* — Ingestion of game fish tissue could be a complete pathway for Wetlands 18, 19 and 64. However, the only fish tissue data available for Site 41 are whole baitfish data collected from Wetlands 18, 33, 64 and 75 for the ecological risk assessment. Ingestion of fish tissue was evaluated by adjusting bait fish (whole organism) data to represent predator species (i.e., higher trophic level game fish), and assuming predator species would be ingested on a recreational or subsistence basis.
- *Surface Water* — Incidental ingestion of surface water and dermal contact with surface water while wading. The open nature of the wetlands is not likely to allow for an appreciable buildup of VOCs. The inhalation pathway was therefore considered insignificant relative to incidental ingestion and dermal contact. Any future use scenarios

involving enclosure of a Site 41 wetland should consider the potential for increased importance of the inhalation pathway.

8.3.4 Identification of Chemicals of Potential Concern

COPCs, identified based on screening comparisons, are those quantified in this assessment. Most chemicals detected pose little risk and would greatly increase the level of effort in this assessment without adding much value for risk management decisions. In accordance with RAGS, site screening was performed to focus this assessment on the chemicals most likely to pose significant excess risk based on likely exposure pathways, land use scenarios, and the chemical's toxicity and reported concentrations, as characterized in Section 9.

8.3.4.1 Screening Comparisons

In accordance with USEPA Region 4's *Supplemental Guidance to RAGS: Bulletin 1, Data Collection and Evaluation* (USEPA, 1995a), screening values were excerpted from USEPA Region III's 1998 *RBCs Tables* for residential land use (USEPA 1998b). RBCs were used in some risk assessments to provide a conservative frame of reference for the screening step. In general, RBCs are based on an incremental risk of 1E-6 for carcinogenic effects and an HQ of 1 for noncarcinogenic effects. In accordance with USEPA Region 4 *Supplemental Guidance to RAGS: Bulletin 1, Data Collection and Evaluation* (USEPA, 1996a), the target HQ was adjusted from 1 to 0.1 for RBCs that are based on noncarcinogenic effects of concern.

Fish Tissue Data

The data set for this exposure pathway is limited to whole fish data collected from bait fish. The uncertainties regarding bioaccumulation and concentrations in larger specimens are discussed in Section 10. To account for the uncertainty associated with using bait fish tissue to evaluate the fish ingestion exposure route, a trophic transfer coefficient (TTC) (Suedel, et.al., 1994) was applied to the bait fish tissue in order to model the expected concentration in game fish.

Sediment and Surface Water Data

A quantitative assessment was performed for sediment and surface water data independently of the fish consumption analysis since consumption of fish tissue would not be expected to coincide with exposure to sediment and surface water (fishing in this area would involve the use of a boat). Preliminary remediation goals (PRGs) were calculated to reflect potential exposures of adolescent trespassers and maintenance workers. The calculations are shown in the equations below, and specific exposure assumptions are listed in Table 8-3. In each wetland's specific section, tables summarize chemicals present in site sediment and surface water samples (CPSSs) and compare their concentrations with corresponding PRGs. For screening purposes, the lowest of the PRGs (e.g. hazard-based or risk-based) is used for comparison. For wetlands maintained by groundskeepers, maximum constituent concentrations were compared to both adolescent trespasser and maintenance worker PRGs. This included Wetlands 4D, 15, 6, 49, 19, 52, 56, 72, W2, and 75. For wetlands where grounds upkeep is not routinely performed, the maximum constituent concentrations were compared to the adolescent trespasser PRGs. These tables also list frequency of detections, number of exceedances, and other summary information in accordance with RAGS Part D (USEPA, 1998c). Sediment PRGs are summarized in Table 8-4 and surface water PRGs are summarized in Table 8-5. Concentrations of lead reported in soil were compared to 400 mg/kg, which is protective of a resident child as described in USEPA's OSWER lead guidance. Concentrations of lead reported in surface water were compared to 15 $\mu\text{g/L}$ the treatment technique action level (TTAL). Reported concentrations of lead in sediment or surface water above these screening levels were evaluated using USEPA's IEUBK Lead Model.

**Table 8-3
 Parameters Used to Calculate PRGs
 and Estimate of Chronic Daily Intake**

Pathway Parameters	Maintenance Worker	Trespassing Adolescent (age 7-16)	Fishermen	Units
Ingestion Rate (sediment) (IR _{sd})	100 ^a	100 ^a	Not applicable	mg/day
Ingestion Rate (surface water) (IR _{sw})	0.05 ^a	0.05 ^b	Not applicable	L/hour
Ingestion Rate (fish) ^j	Not applicable	Not applicable	4.3 (recreational) 19.5 (subsistence)	g/day
Skin Surface Area (SA) contact with sediment	4,100	4,100	Not applicable	cm ² /event
Skin Surface Area (SA) contact with surface water	0.5 ^b	1.04 ^b	Not applicable	m ²
Absorption Factor ⁱ (ABS)	0.01 (organics) 0.001 (inorganics)	0.01 (organics) 0.001 (inorganics)	Not applicable	unitless
Oral Absorption Efficiency ⁱ (OAE)	0.2 (inorganics) 0.8 (VOCs) 0.5 (others)	0.2 (inorganics) 0.8 (VOCs) 0.5 (others)	Not applicable	unitless
Exposure Time (ET)	2.6	2.6	Not applicable	hours/day
Exposure Frequency (EF)	52 ^b	52 ^f	350 ^a	days/year
Exposure Duration (ED)	25 ^c	10 ^g	30 ^a	years
Body Weight (BW)	70 ^a	45 ^a	70 ^a	kg
Averaging Time, Noncancer (AT _n)	9,125 ^d	3,650 ^d	10,950 ^d	days
Averaging Time, Cancer (AT _c)	25,550 ^e	25,550 ^e	25,550 ^e	days

Notes:

- a = USEPA (1989) *Risk Assessment Guidance for Superfund Vol. I, Human Health Evaluation Manual (Part A)*.
- b = USEPA (1991b) *Risk Assessment Guidance for Superfund Vol. I: Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors, Interim Final*, OSWER Directive: 9285.6-03.EPA/600/8-89/043.
- c = USEPA (1991a), *Risk Assessment Guidance for Superfund: Vol. I — Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals)*, OSWER Directive 9285.7-01B.
- d = Calculated as the product of ED (years) x 365 days/year.
- e = Calculated as the product of 70 years (assumed lifetime) x 365 days per year.
- f = Assuming one day per week exposure.
- g = Assuming trespassing occurs during the 10-year adolescent/teenage period.
- h = USEPA (1997b) *Exposure Factors Handbook*, ORD, EPA 600/P-95/002Fa. Maintenance worker exposed skin surface area is the 50th percentile value from Table 6.16. Adolescent exposed skin surface area includes the 50th percentile arms, legs, hands, and feet for the 16 to 17 year old (male) adolescent (Tables 6-8 and 6-6).
- i = USEPA (1995b) *Supplemental Guidance to RAGS Bulletins 2 and 3, Exposure Assessment and Toxicity Assessment*.
- j = Subsistence fisherman ingestion rate for residents; RBCs were not modified to reflect a trespasser scenario, and reflect a residential subsistence scenario. A study used by FDEP is available that indicates higher ingestion rates could be possible in Florida; therefore, tables using an alternate ingestion rate are included in the Uncertainty Section.

**Table 8.3-4
Preliminary Remediation Goals for Sediment
NAS Pensacola, Site 41 Wetlands
Pensacola, Florida**

	Oral	Oral	Adolescent Trespasser		Maintenance Worker PRGs		Exposure Parameters	
	RfD (mg/kg-day)	SF (kg-day/mg)	Hazard based (mg/kg)	Risk based (mg/kg)	Hazard based (mg/kg)	Risk based (mg/kg)		
Acenaphthene	0.06	NA	18952	NA	29481	NA		
Acetone	0.1	NA	31587	NA	49135	NA		
Aldrin	3E-05	17	9.5	1.3	14.7	0.81	Target Hazard Quotient	0.1
Aluminum	1	NA	315865	NA	491346	NA	Target Risk	1E-06
Anthracene	0.3	NA	94760	NA	147404	NA		
Antimony	0.0004	NA	126	NA	197	NA	Ingestion Rate - adoles.	100 mg/day
Aroclor 1254	2E-05	2	6.3	11.1	9.8	6.9	Ingestion Rate - worker	100 mg/day
Aroclor 1260	NA	2	NA	11.1	NA	6.9	Exposure Frequency	52 days/yr
Arsenic	0.0003	1.5	94.8	14.7	147	9.2	Exposure Duration - adoles.	10 yrs
Barium	0.07	NA	22111	NA	34394	NA	Exposure Duration - worker	25 yrs
Benzene	0.003	0.029	948	762	1474	474	Conversion Factor	1E-06 kg/mg
Benzo(a)anthracene	NA	0.73	NA	30.3	NA	18.8	Body Weight - adoles.	45 kg
Benzo(b)fluoranthene	NA	0.73	NA	30.3	NA	18.8	Body Weight - adult	70 kg
Benzo(k)fluoranthene	NA	0.073	NA	303	NA	188	Avg. Time, noncancer -adoles.	3650 days
Benzo(g,h,i)perylene	0.03	NA	9476	NA	14740	NA	Avg. Time, noncancer -worker	9125 days
Benzo(a)pyrene	NA	7.3	NA	3.0	NA	1.9	Avg. Time, cancer	25550 days
Beryllium	0.002	NA	632	NA	983	NA		
alpha-BHC	NA	6.3	NA	3.5	NA	2.2		
beta-BHC	NA	1.8	NA	12.3	NA	7.6		
delta-BHC	NA	1.8	NA	12.3	NA	7.6		
2-Butanone	0.6	NA	189519	NA	294808	NA		
Butylbenzylphthalate	0.2	NA	63173	NA	98269	NA		
Cadmium	0.001	NA	316	NA	491	NA		
Calcium	NA	NA	NA	NA	NA	NA		
Carbazole	NA	0.02	NA	1106	NA	688		
alpha-Chlordane	0.0005	0.35	158	63.2	246	39.3		
gamma-Chlordane	0.0005	0.35	158	63.2	246	39.3		
Chlorobenzene	0.02	NA	6317	NA	9827	NA		
Chloroethane	0.4	0.0029	126346	7624	196538	4744		
Chloromethane	NA	0.013	NA	1701	NA	1058		
Chromium	0.003	NA	948	NA	1474	NA		
Chrysene	NA	0.0073	NA	3029	NA	1885		
Cobalt	0.06	NA	18952	NA	29481	NA		
Copper	0.04	NA	12635	NA	19654	NA		
Cyanide	0.02	NA	6317	NA	9827	NA		
4,4'-DDD	NA	0.24	NA	92.1	NA	57.3		
4,4'-DDE	NA	0.34	NA	65.0	NA	40.5		
4,4'-DDT	NA	0.34	NA	65.0	NA	40.5		
Di-n-butylphthalate	0.1	NA	31587	NA	49135	NA		
1,2-Dichlorobenzene	0.09	NA	28428	NA	44221	NA		
1,4-Dichlorobenzene	0.03	0.024	9476	921	14740	573		
1,1-Dichloroethane	0.1	NA	31587	NA	49135	NA		
1,1-Dichloroethene	0.009	0.6	2843	36.9	4422	22.9		
Dieldrin	5E-05	16	16	1.4	25	0.86		
Diethylphthalate	0.8	NA	252692	NA	393077	NA		
2,4-Dimethylphenol	0.02	NA	6317	NA	9827	NA		
Di-n-octylphthalate	0.02	NA	6317	NA	9827	NA		
Endosulfan sulfate	0.006	NA	1895	NA	2948	NA		
Endrin	0.0003	NA	95	NA	147	NA		
Endrin aldehyde	0.0003	NA	95	NA	147	NA		
Endrin ketone	0.0003	NA	95	NA	147	NA		
bis(2-Ethylhexyl)phthalate	0.02	0.014	6317	1579	9827	983		
Fluoranthene	0.04	NA	12635	NA	19654	NA		
Fluorene	0.04	NA	12635	NA	19654	NA		
Indeno(1,2,3-cd)pyrene	NA	0.73	NA	30.3	NA	18.8		
Heptachlor	0.0005	4.5	158	4.9	246	3.1		
Heptachlor epoxide	1.3E-05	9.1	4.1	2.4	6.4	1.5		
Iron	NA	NA	NA	NA	NA	NA		
Lead	NA	NA	NA	NA	NA	NA		
Magnesium	NA	NA	NA	NA	NA	NA		
Manganese	0.047	NA	14846	NA	23093	NA		
Mercury	0.0003	NA	95	NA	147	NA		
Methylene chloride	0.06	0.0075	18952	2948	29481	1834		
4-Methylphenol	0.005	NA	1579	NA	2457	NA		
Naphthalene	0.04	NA	12635	NA	19654	NA		
Nickel	0.02	NA	6317	NA	9827	NA		
Phenanthrene	0.03	NA	9476	NA	14740	NA		
Phenol	0.6	NA	189519	NA	294808	NA		
Potassium	NA	NA	NA	NA	NA	NA		
Pyrene	0.03	NA	9476	NA	14740	NA		
Selenium	0.005	NA	1579	NA	2457	NA		
Silver	0.005	NA	1579	NA	2457	NA		
Sodium	NA	NA	NA	NA	NA	NA		
Tetrachloroethene	0.01	0.052	3159	425	4913	265		
Thallium	7E-05	NA	22	NA	34	NA		
Toluene	0.2	NA	63173	NA	98269	NA		
1,1,1-Trichloroethane	0.02	NA	6317	NA	9827	NA		
Trichloroethene	0.006	0.011	1895	2010	2948	1251		
Vanadium	0.007	NA	2211	NA	3439	NA		
Zinc	0.3	NA	94760	NA	147404	NA		

NOTES:
RfD - Reference Dose
SF - Slope Factor

**Table 8.3-5
Preliminary Remediation Goals for Surface Water
NAS Pensacola, Site 41 Wetlands
Pensacola, Florida**

	Oral RfD (mg/kg-day)	Oral SF (kg-day/mg)	OAE (-)	Kp (cm/hr)	Adolescent Trespasser PRGs		Maintenance Worker PRGs		Exposure Parameters
					Noncarc. (mg/L)	Carc. (mg/L)	Noncarc. (mg/L)	Carc. (mg/L)	
Acetone	0.1	NA	0.8	0.00057	21	NA	35	NA	Adolescent Trespasser Target Hazard Quotient 0.1 Target Risk 1E-06 Ingestion Rate 0.05 L/hr Skin Surface Area 1.04 m2 Exposure Time 2.6 hr/day Exposure Frequency 52 days/year Exposure Duration 10 years Conversion Factor 10 L/cm²m2 Body Weight 45 kg Avg Time - noncancer 3650 days Avg Time - cancer 25550 days
Aluminum	1	NA	0.2	0.001	119	NA	252	NA	
Antimony	0.0004	NA	0.2	0.001	0.048	NA	0.10	NA	
Aroclor 1260	NA	0.4	0.5	1.1	NA	0.000093	NA	0.00012	
Arsenic	0.0003	1.5	0.2	0.001	0.036	0.0056	0.076	0.0047	
Barium	0.07	NA	0.2	0.001	8.3	NA	17.6	NA	
Benzene	0.003	0.029	0.8	0.021	0.11	0.091	0.31	0.10	
Beryllium	0.002	NA	0.2	0.001	0.24	NA	0.50	NA	
alpha-BHC	NA	6.3	0.5	0.019	NA	0.00030	NA	0.00035	
Bromodichloromethane	0.02	0.062	0.8	0.0058	1.9	0.11	4.4	0.10	
2-Butanone	0.6	NA	0.8	0.0011	113	NA	199	NA	
Cadmium	0.0005	NA	0.2	0.001	0.060	NA	0.13	NA	
Calcium	NA	NA	NA	NA	NA	NA	NA	NA	
Chlordane	0.0005	0.35	0.5	0.052	0.0054	0.0021	0.017	0.0027	
Chlorobenzene	0.02	NA	0.8	0.041	0.42	NA	1.2	NA	
Chloroform	0.01	0.0061	0.8	0.0089	0.73	0.84	1.8	0.82	
2-Chlorophenol	0.005	NA	0.5	0.033	0.082	NA	0.25	NA	
Chromium	0.003	NA	0.2	0.001	0.36	NA	0.76	NA	
Cobalt	0.06	NA	0.2	0.001	7.1	NA	15.1	NA	
Copper	0.04	NA	0.2	0.001	4.8	NA	10.1	NA	
Cyanide	0.02	NA	0.2	0.0075	0.55	NA	1.6	NA	
4,4'-DDD	NA	0.24	0.5	0.28	NA	0.00060	NA	0.00077	
4,4'-DDE	NA	0.34	0.5	0.24	NA	0.00050	NA	0.00064	
4,4'-DDT	0.0005	0.34	0.5	0.43	0.00068	0.00028	0.0022	0.00036	
Dibromochloromethane	0.02	0.084	0.8	NA	4.9	0.20	7.6	0.13	
Di-n-butylphthalate	0.1	NA	0.5	0.12	0.48	NA	1.5	NA	
1,2-Dichlorobenzene	0.09	NA	0.8	0.061	1.3	NA	3.9	NA	
1,4-Dichlorobenzene	0.03	0.024	0.8	0.062	0.43	0.041	1.3	0.050	
1,1-Dichloroethane	0.1	NA	0.8	0.0089	7.3	NA	17.9	NA	
1,1-Dichloroethene	0.009	0.6	0.8	0.0089	0.66	0.0086	1.6	0.0083	
cis-1,2-Dichloroethene	0.01	NA	0.8	0.01	0.67	NA	1.7	NA	
Dieldrin	5E-05	16	0.5	0.016	0.0016	0.00014	0.0045	0.00016	
Endosulfan I	0.006	NA	0.5	0.0021	0.78	NA	1.6	NA	
Endrin ketone	0.0003	NA	0.5	0.016	0.010	NA	0.027	NA	
Ethylbenzene	0.1	NA	0.8	0.074	1.2	NA	3.7	NA	
bis(2-Ethylhexyl)phthalate	0.02	0.014	0.5	0.023	0.46	0.11	1.3	0.13	
Heptaclor	0.0005	4.5	0.5	0.011	0.022	0.00068	0.059	0.00073	
Heptaclor epoxide	1.3E-05	9.1	0.5	0.055	0.00013	0.000078	0.00041	0.00010	
Iron	NA	NA	NA	NA	NA	NA	NA	NA	
Lead	NA	NA	NA	NA	NA	NA	NA	NA	
Magnesium	NA	NA	NA	NA	NA	NA	NA	NA	
Manganese	0.02	NA	0.2	0.001	2.4	NA	5.0	NA	
Mercury	0.0003	NA	0.2	0.001	0.036	NA	0.076	NA	
Methylene chloride	0.06	0.0075	0.8	0.0045	6.7	1.0	14.5	0.9	
Naphthalene	0.04	NA	0.5	0.069	0.33	NA	1.0	NA	
Nickel	0.02	NA	0.2	0.001	2.4	NA	5.0	NA	
N-Nitroso-di-n-propylamine	NA	7	0.5	0.0028	NA	0.0011	NA	0.0010	
Potassium	NA	NA	NA	NA	NA	NA	NA	NA	
Pyrene	0.03	NA	0.5	0.32	0.054	NA	0.17	NA	
Selenium	0.005	NA	0.2	0.001	0.60	NA	1.3	NA	
Silver	0.005	NA	0.2	0.001	0.60	NA	1.3	NA	
Sodium	NA	NA	NA	NA	NA	NA	NA	NA	
Thallium	7E-05	NA	0.2	0.001	0.0083	NA	0.018	NA	
Toluene	0.2	NA	0.8	0.045	3.8	NA	11.4	NA	
1,1,1-Trichloroethane	0.2	NA	0.8	0.017	9.0	NA	24.2	NA	
Trichloroethene	0.006	0.011	0.8	0.016	0.28	0.30	0.76	0.32	
Vanadium	0.007	NA	0.2	0.001	0.83	NA	1.8	NA	
Vinyl chloride	NA	1.9	0.8	0.0073	NA	0.0031	NA	0.0029	
Xylene	2	NA	0.8	0.095	19	NA	59	NA	
Zinc	0.3	NA	0.2	0.001	35.7	NA	76	NA	

NOTES:

RfD - Reference Dose

SF - Slope Factor

OAE - Oral absorption efficiency; adjustment from administered to absorbed dose

ABS - Dermal absorption factor

Kp - Dermal permeability constant (these values were obtained from the ORNL Risk Assessment Information System)

Sediment

For noncarcinogens:

$$PRG = \frac{THQ * BW * AT_{nc} * RfD}{ET * EF * ED * IR_s * CF}$$

For carcinogens:

$$PRG = \frac{TR * BW * AT_c}{ET * EF * ED * IR_s * SF * CF}$$

where:

- THQ = target HQ (0.1)
- TR = target risk (1E-6)
- IR_s = ingestion rate (mg/day)
- ET = exposure time (hours/day)
- EF = exposure frequency (days/year)
- ED = exposure duration (years)
- CF = conversion factor (1E-6 kg/mg)
- RfD = reference dose (mg/kg-day)
- SF = oral slope factor (mg/kg-day)⁻¹
- BW = body weight (kg)
- AT_{nc} = noncancer averaging time (days)
- AT_c = cancer averaging time (days)

Surface water

For noncarcinogens:

$$PRG = \frac{THQ * BW * AT_{nc}}{EF * ED \left[\left(\frac{SA * K_p * CF * ET}{RfD * OAE} \right) + \left(\frac{IR_{sw} * ET}{RfD} \right) \right]}$$

For carcinogens:

$$PRG = \frac{TR * BW * AT_c}{EF * ED \left[\left(\frac{SA * K_p * ET * CF * SF}{OAE} \right) + (IR_{sw} * ET * SF) \right]}$$

where:

THQ	=	target HQ (0.1)
TR	=	target risk (1E-6)
SA	=	skin surface area (m ²)
IR _{sw}	=	ingestion rate (L/hour)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
Kp	=	dermal permeability constant (chemical specific, cm/hr)
OAE	=	oral absorption efficiency
CF	=	conversion factor (10 L-m/cm-m ³)
RfD	=	oral reference dose (mg/kg-day) ⁻¹
SF	=	oral slope factor (mg/kg-day)
AT _{nc}	=	noncancer averaging time (days)
AT _c	=	cancer averaging time (days)
BW	=	body weight (kg)

Essential Nutrients

In accordance with RAGS Part A, essential elements that are potentially toxic only at extremely high concentrations may be eliminated as COPCs in a risk assessment. Specifically, an essential nutrient may be screened out if it is present at concentrations not associated with adverse health effects. The following essential nutrients were excluded because their potential for toxicity is low relative to the COPCs identified, and no sources were identified:

- calcium
- iron
- magnesium
- potassium
- sodium

8.3.5 Quantification of Exposure

This section describes the additional models used to quantify doses or intakes of COPCs for the cumulative Site 41 assessment. Dermal contact was included for the sediment exposure pathway.

The models are designed to estimate route- and medium-specific factors, which are multiplied by the Exposure Point Concentrations (EPCs) to estimate chronic daily intakes (CDIs). The intake model variables generally reflect 90th or 95th percentile values, which are assumed to represent the RME. The calculation was derived from RAGS Part A.

8.3.5.1 Incidental Ingestion of COPCs in Sediment

The following equation is used to estimate intake due to incidental ingestion of COPCs in sediment:

$$CDI = (EPC_{sd})(IR_{sd})(EF)(ED)(CF)/(BW)(AT)$$

where:

- CDI = sediment ingestion dose (mg/kg-day)
- EPC_{sd} = exposure point concentration of contaminant in sediment (mg/kg)
- IR_{sd} = sediment ingestion rate (mg/day)
- EF = exposure frequency (days/year)
- ED = exposure duration (years)
- CF = conversion factor (1E-6 kg/mg)
- BW = body weight (kg)
- AT = averaging time (days)

8.3.5.2 Dermal Contact with COPCs in Sediment

The following equation is used to estimate intake due to dermal contact with COPCs in sediment:

$$CDI_{sd} = (EPC_s)(SA)(EF)(ED)(CF)(ABS)(AF)/(BW)(AT)$$

where:

- CDI_{sd} = sediment dermal contact dose (mg/kg-day)
- EPC_{sd} = exposure point concentration of contaminant in sediment (mg/kg)
- SA = skin surface area (cm²/event; converted to cm²/day assuming one event/day)
- EF = exposure frequency (days/year)
- ED = exposure duration (years)
- CF = conversion factor (1E-6 kg/mg)
- ABS = absorption factor (unitless, value specific to organic versus inorganic compounds)
- AF = adherence factor (mg/cm²)
- BW = body weight (kg)
- AT = averaging time (days)

8.3.5.3 Dermal Contact with COPCs in Surface Water

The following equation is used to estimate the intake of COPCs in surface water via dermal contact:

$$CDI_{sw} = (EPC_{sw})(SA)(Kp)(ET)(EF)(ED)(CF) / (BW)(AT)$$

where:

CDI_{sw}	=	surface water dermal contact dose (mg/kg-day)
EPC_{sw}	=	exposure point concentration of contaminant in surface water (mg/L)
SA	=	body surface area (m ²)
Kp	=	permeability constant (cm/hr)
ET	=	exposure time (hr/day)
EF	=	exposure frequency (day/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (L-m/cm-m ³)
BW	=	body weight (kg)
AT	=	averaging time (days)

8.3.5.4 Incidental Ingestion of COPCs in Surface Water

The following equation and parameters are used to estimate the intake of COPCs in surface water via incidental ingestion:

$$CDI = (EPC_{sw})(IR)(ET)(EF)(ED) / (BW)(AT)$$

where:

CDI	=	surface water ingestion dose (mg/kg-day)
EPC_{sw}	=	exposure point concentration of contaminant in surface water (mg/L)
IR	=	ingestion rate for incidental ingestion (L / hr)
ET	=	exposure time (hr/day)
EF	=	exposure frequency (day/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (days)

8.3.5.5 Ingestion of Edible Fish Tissue

Estimated intakes for identified receptor groups (recreational fishermen and subsistence fishermen) were calculated according to the following general equation:

$$CDIf = Cf * IR * EF * ED / BW * AT$$

where:

- CDIF = Chronic Daily Intake from fish (mg/kg-day) (contaminant specific)
 Cf = Concentration in Level 4 fish (mg/kg) (contaminant specific)
 IR = Ingestion Rate of Level 4 fish (kg/day)
 recreational fishermen = 0.026 kg/day (95th percentile value)
 subsistence fishermen = 0.039 kg/day
 EF = Exposure Frequency (350 days/year)
 ED = Exposure Duration (30 years)
 BW = Body Weight (70 kg)
 AT = Averaging Time (25,550 days for carcinogens and 10,950 days for noncarcinogens)

The ingestion rates for the various receptor populations were based on information provided by the USEPA (*USEPA Exposure Factors Handbook*, 1997). The model involves several steps. The first step is determining a compound-specific TTC. The TTC is defined as the increase in tissue concentration of a particular contaminant as it moves through the food chain from Level 3 (e.g., bait fish) to Level 4 fish (e.g., game fish), and is used to predict the contaminant tissue concentration in Level 4 fish species. For this evaluation, the TTCs were obtained from the USEPA (1998) and are based on the log Kow for each organic compound. The TTC is multiplied by the concentration found in prey fish to estimate concentration in game fish. The following is a list of compounds detected at Site 41 and their corresponding TTCs.

Chemical	Trophic Transfer Coefficient
4,4'-DDD	3.254
4,4'-DDE	3.602
4,4'-DDT	3.536
Aldrin	1.006
Dieldrin	1.063
Endosulfan	1.04
Heptachlor epoxide	1.342
Aroclor-1016	2.337
Aroclor-1260	3.733
Chlordane	1.999
gamma-BHC (Lindane)	1.021

Note:

* TTCs from USEPA 1998, Draft Water Quality Criteria Methodology Revisions: Human Health, Federal Register, pp. 43756-43828. August 14, 1998.

Mercury is one of a few inorganic compounds that has the potential to bioaccumulate when methylated. However, because mercury tissue concentrations were not measured in Level 3 fish, a model was performed which predicts mercury tissue concentration in the red drum (*Sciaenops ocellatus*) based on the mean concentration of mercury in Wetland 64 sediment. The model is based on a mercury bioaccumulation model developed by NOAA (Evans and Engel, 1994). The model assumes that mercury uptake into the red drum occurs via prey ingestion exclusively. The three prey sources are small fish, crustaceans, and infaunal invertebrates.

The mercury model is developed and performed in four steps which are detailed in Appendix G. It was only performed if mercury was detected in the sediments of a particular wetland.

A site-specific foraging factor (SFF) was also incorporated into the calculation of intakes of compounds in fish tissue. The SFF represents the percent diet of the Level 4 fish species from a particular wetland and is apportioned based on the estimated foraging area of the Level 4 fish species. For simplicity, it was assumed that Level 4 fish species find all of the Bayou Grande equally attractive for foraging. The SFF is calculated by dividing the total surface area of a wetland by the total surface area of Bayou Grande (960 acres). The SFF for Wetland 64 of 0.043 is based on a 41 acre site. For wetland 18, a SSF of 0.001 was determined based on a 1 acre site (the actual size of the wetland is closer to 1/2 acre, so this is a conservative assumption). The modeled concentration of a chemical in level 4 fish was determined by multiplying the detected concentration in level 3 fish with the TTC and the SFF.

8.3.5.5.1 Chronic Daily Intake for a Recreational Fisherman

For recreational fishermen in the Gulf of Mexico, the 95th percentile for fish ingestion is 26 g/day and 7.2 g/day is the mean fish ingestion rate (USEPA, 1997). The USEPA Exposure Factors Handbook also states that only 33% of the total fish consumed by recreational fishermen is actually caught locally. The rest is bought commercially. Therefore, the fish ingestion rates for

recreational fishers were modified by one-third to reflect that 67% of the fish they consumed was commercially purchased. The modified fish ingestion rates for recreational fishers is therefore 8.6 g/day (95th percentile), and 2.4 g/day (mean value).

Additionally, the USEPA (1997) reports that only between 25 to 50 % of whole fish is edible. The exact percentage depends on the fish species. The bulk of the fish, e.g., bones and organs, are not edible and therefore would not be consumed by receptors. As a result, the fish ingestion rates were further modified by 50 % to reflect how much of the entire fish is edible. The final modified fish ingestion rates for recreational fishermen were therefore 4.3 g/day (95th percentile) and 1.2 g/day (mean value).

8.3.5.5.2 Chronic Daily Intake for a Subsistence Fisherman

For subsistence fishermen, the recommended default fish ingestion rate is 170 g/day for the 95th percentile. This rate is from the *Exposure Factors Handbook* (USEPA, 1997) for Native American subsistence fishers living along the Columbia River. It should be emphasized that the rates above refer only to Native American subsistence fishing populations, not the general Native American population generally. Several studies show that intake rates of recreationally caught fish among Native Americans with state fishing licenses are 50 to 100 % higher than intake rates among other anglers, but far lower than the above rates for Native American subsistence populations. Therefore, based on the ingestion rates for recreational fishers in the Gulf (i.e., the 95th percentile value of 26 g/day), the estimated fish ingestion rate for subsistence fishers in Florida is 39 g/day (26 g/day x 1.5). As with recreational fishers, this ingestion rate was further modified by 50 % to reflect how much of the fish is actually edible. Therefore, the fish ingestion rate used for subsistence fishermen was 19.5 g/day. It is assumed that all of the fish consumed by subsistence fishermen is caught locally.

8.3.6 Toxicity Assessment

Risk information, usually obtained from the Integrated Risk Information System (IRIS) or Health Effects Assessment Summary Tables (HEAST), is necessary to calculate risk and hazard estimates (and risk-based screening values). This information is based on toxicological and epidemiological data critiqued and approved by the scientific and regulatory community.

There is a generally recognized uncertainty in human toxicological risk values developed from experimental data, due primarily to the uncertainty of data extrapolation from high to low-dose exposure and animal data to human experience. The site-specific uncertainty is mainly in the degree of accuracy of the exposure assumptions. Most assumptions used in this and any risk assessment have not been verified. For example, the degree of chemical absorption from the gut or through the skin or the amount of soil contact is not known with certainty.

The uncertainty of toxicological values from the IRIS and HEAST databases provided by USEPA is summarized (where available) in Tables 8-6 and 8-7. The uncertainty factors assigned to these values account for acute to chronic dose extrapolation, study inadequacies, and sensitive subpopulations, among other factors. Although the uncertainty factor for a specific chemical may be 1,000 or higher, these safety factors are applied by USEPA to ensure a conservative assessment of human health concerns. In the presence of such uncertainty, the USEPA and the risk assessor are obligated to make conservative assumptions to minimize the chance that the actual health risk will be greater than what the process determines. Conversely, the process is not intended to yield overly conservative risk values which have no basis in actual conditions. This balance was kept in mind while developing exposure assumptions and pathways and interpreting data and guidance.

USEPA has established a classification system for rating the potential carcinogenicity of environmental contaminants based on the weight of scientific evidence. The "A" classification (i.e., human carcinogens) means that human toxicological data have shown a correlation between

TABLE 8-6
NON-CANCER TOXICITY DATA -- ORAL/DERMAL
NAS PENSACOLA SITE 41

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal RfD (2)	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ
Aldrin	Chronic	3.00E-05	mg/kg-day	50%	1.50E-05	mg/kg-day	liver	1000	IRIS	01/01/98
Arsenic	Chronic	3.00E-04	mg/kg-day	20%	6.00E-05	mg/kg-day	skin	3	IRIS	01/01/98
Beryllium	Chronic	5.00E-03	mg/kg-day	20%	1.00E-03	mg/kg-day	whole body/organ	100	IRIS	01/01/98
alpha-Chlordane	Chronic	5.00E-04	mg/kg-day	50%	2.50E-04	mg/kg-day	liver	N/A	IRIS	01/01/98
gamma-Chlordane	Chronic	5.00E-04	mg/kg-day	50%	2.50E-04	mg/kg-day	liver	N/A	IRIS	01/01/98
DDT	Chronic	5.00E-04	mg/kg-day	50%	2.50E-04	mg/kg-day	liver	100	IRIS	01/01/98
Dieldrin	Chronic	5.00E-05	mg/kg-day	50%	2.50E-05	mg/kg-day	liver	100	IRIS	01/01/98
Endosulfan I	Chronic	6.00E-03	mg/kg-day	50%	3.00E-03	mg/kg-day	whole body	100	IRIS	01/01/98
Endrin ketone	Chronic	3.00E-04	mg/kg-day	50%	1.50E-04	mg/kg-day	liver	NAV	IRIS	01/01/98
Endrin aldehyde	Chronic	3.00E-04	mg/kg-day	50%	1.50E-04	mg/kg-day	liver	NAV	IRIS	01/01/98
Heptachlor	Chronic	5.00E-04	mg/kg-day	50%	2.50E-04	mg/kg-day	liver	300	IRIS	01/01/98
Heptachlor epoxide	Chronic	1.30E-05	mg/kg-day	50%	6.50E-06	mg/kg-day	liver	1000	IRIS	01/01/98
Aroclor - 1016	Chronic	7.00E-05	mg/kg-day	50%	3.50E-05	mg/kg-day	liver	NAV	IRIS	01/01/98
Cadmium	Chronic	5.00E-04	mg/kg-day	20%	1.00E-04	mg/kg-day	kidney	10	IRIS	01/01/98
Methylene chloride	Chronic	6.00E-02	mg/kg-day	80%	4.80E-02	mg/kg-day	liver	100	IRIS	01/01/98

(1) Oral to Dermal adjustment factors taken from Risk Assessment Guidance for Superfund Part A (1989).

(2) Adjusted dermal RfD calculated using the following equation: Adjusted Dermal RfD = RfD x adjustment factor.

N/A = Not Applicable

NAV = Not Available

IRIS - Integrated Risk Information System

TABLE 8-7
 CANCER TOXICITY DATA -- ORAL/DERMAL
 NAS PENSACOLA SITE 41

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor	Adjusted Dermal Cancer slope Factor (1)	Units	Weight of Evidence/Cancer Guideline Description	Source	Date
Aldrin	1.70E+01	50%	3.40E+01	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
Arsenic	1.50E+00	20%	7.50E+00	(mg/kg-day) ⁻¹	A	IRIS	01/01/98
Beryllium	4.30E+00	20%	2.15E+01	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
alpha-Chlordane	3.50E-01	50%	7.00E-01	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
gamma-Chlordane	3.50E-01	50%	7.00E-01	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
DDD	2.40E-01	50%	4.80E-01	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
DDE	3.40E-01	50%	6.80E-01	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
DDT	3.40E-01	50%	6.80E-01	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
Dieldrin	1.60E+01	50%	3.20E+01	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
Heptachlor	5.00E-04	50%	1.00E-03	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
Heptachlor epoxide	1.30E-05	50%	2.60E-05	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
gamma-BHC	1.30E+00	50%	2.60E+00	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
Aroclor - 1260	2.00E+00	50%	4.00E+00	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
Methylene chloride	7.50E-03	80%	9.38E-03	(mg/kg-day) ⁻¹	B2	IRIS	01/01/98
Vinyl chloride	1.90E+00	80%	2.38E+00	(mg/kg-day) ⁻¹	A	IRIS	01/01/98

IRIS = Integrated Risk Information System (IRIS)

ND = Not determined due to lack of information

EPA Group:

A - Human Carcinogen

B1 - Probable Human Carcinogen - Indicates that limited human data are available

B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans

C - Possible human carcinogen

D - Not classifiable as a human carcinogen

E - Evidence of noncarcinogenicity

exposure and the onset of cancer in varying forms. The "B1" classification indicates that some human exposure studies have implicated the compound as a probable carcinogen. The "B2" classification indicates a possible human carcinogen based on sufficient animal data and inadequate or no human data. The "C" classification identifies possible human carcinogens, and class "D" indicates a compound not classifiable according to its carcinogenic potential. There is more uncertainty in the lower classifications, so the weight-of-evidence should be used by risk managers when making risk management decisions based on cancer risk.

USEPA has established slope factors (SFs) for carcinogenic compounds. The SF is defined as a "plausible upper-bound estimate of the probability of a response (cancer) per unit intake of a chemical over a lifetime" (RAGS, Part A). Upper-bound estimates are likely to overestimate cancer potential.

In addition to potential carcinogenic effects, most substances may also produce other toxic responses at doses greater than experimentally derived threshold concentrations. USEPA has derived reference dose (RfD) values for these substances. A chronic RfD is defined as "an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure concentration for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime." These toxicological values are used in risk formulae to assess the upper-bound level of noncancer hazard associated with exposure to a given chemical concentration.

For carcinogens, the potential risk posed by a chemical is computed by multiplying the CDI (as mg/kg-day) by the SF (in kg-day/mg). The HQ (for noncarcinogens) is computed by dividing the CDI by the RfD (in mg/kg-day). USEPA has set points of departure to evaluate whether significant risk is posed by a chemical (or combination of chemicals). For carcinogens, a risk range of 1E-6 to 1E-4 is generally considered acceptable, corresponding to one in 10,000 (1E-4)

and one in 1 million (1E-6) excess cancer incidences resulting from exposure to toxic compounds from outside the body.

For noncarcinogens, other toxic effects are generally considered possible if the HQ (or sum of HQs for a pathway-hazard index) exceeds the threshold value of 1. Although both cancer and noncancer risks are generally additive only if the target organ is common to multiple chemicals, a most conservative estimate of each may be obtained by summing the individual risks or hazards, regardless of target organ. This assessment used the universal summation approach for each class of toxicant. Details regarding the risk formulae applied to site data are provided in Section 8.3.5, Quantification of Exposure.

Critical studies used by USEPA in establishing toxicity criteria are shown in the IRIS database, which is the primary source for information necessary to estimate risk (HEAST, Fiscal Year 1995, is the secondary source). In addition, USEPA's National Center for Environmental Assessment (NCEA) will be used as a source when necessary. In accordance with RAGS, Tables 8-6 and 8-7 summarize toxicological data, presenting RfDs and SFs for COPCs identified at Site 41, as well as uncertainty/modifying factors, target organs, and cancer classes (where available). It is important to note that toxic effects reported in IRIS and HEAST are generally based on studies using single compounds, rather than mixtures. Therefore, synergistic or antagonistic mechanisms are possible when compound mixtures are involved. USEPA recommends the additive approach used in this assessment.

8.3.6.1 Evaluating Dermal Exposure and Resulting Toxicity

In accordance with RAGS Part A, dermal RfD values and SFs are derived from the corresponding oral values. The oral absorption efficiency (OAE) is expressed as a decimal to account for the oral absorption efficiency relative to the gastro-intestinal (GI) system. Absorption efficiencies used

were 0.8 for VOCs, 0.2 for inorganics, and 0.5 for all other compounds, as recommended by USEPA for assessing other federal RCRA and CERCLA sites.

Because dermal doses are expressed as absorbed rather than administered (intake) doses, the oral RfD is multiplied by an OAE to convert the oral RfD, which is based on the administered dose, to a dermal RfD. For the same reasons, a dermal SF that is based on an administered dose is derived by dividing the oral SF by the OAE. The oral SF is divided by an OAE rather than multiplied because SFs are expressed as reciprocal doses.

8.3.6.2 Toxicity Profiles for COPCs

In accordance with RAGS, toxicological summary paragraphs are presented below for all COPCs. Most information for the profiles was obtained from IRIS and HEAST with NCEA as a supplemental source. Any additional references are noted in the text. The profiles summarize adverse effects of COPCs and the chemical quantities associated with such effects.

8.3.6.2.1 Aldrin

Aldrin is a man-made insecticide that was used widely by farmers from the 1950s to the early 1970s. Aldrin was also used for soil treatment as well as by exterminators to kill termites by treating soil under houses. The main effects of short-term exposure to high levels of aldrin are headaches, dizziness, irritability, loss of appetite, nausea, muscle twitching, convulsions, loss of consciousness, and death. Most symptoms disappear with time after removal from exposure. The effects of long-term exposure to aldrin in humans have not been clearly demonstrated, but aldrin fed to mice has caused liver cancer.

There is inconclusive evidence in humans, but more evidence in animals, that exposure of a pregnant mother to aldrin may harm the fetus. Aldrin is absorbed into the blood from the GI tract, through the skin, or by inhalation. The percentage of an oral dose absorbed has not been

accurately determined because of the enterohepatic circulation system. In humans, 20 to 50% of inhaled aldrin is retained, and about 8% of a dermal dose is absorbed (5 days). Aldrin converts rapidly to the epoxide dieldrin, and thus aldrin is rarely found in blood or tissue. Aldrin is excreted primarily in the feces via the bile; urinary excretion in humans and animals is minor. An oral RfD of $3.0\text{E-}05$ mg/kg-day has been determined based on a Lowest Observed Adverse Effects Level (LOAEL) of 0.025 mg/kg-day and an uncertainty factor of 1,000 in a hepatic-effects study performed on rats. The modifying factor is 1. Cancer Slope Factors determined for aldrin are $1.7\text{E}+01$ (mg/kg-day)⁻¹ (oral SF) and $1.71\text{E}+01$ (mg/kg-day)⁻¹ (inhalation SF) (IRIS).

8.3.6.2.2 Arsenic

Arsenic exposure via ingestion darkens and hardens the skin in chronically exposed humans. Inhalation exposure to arsenic causes neurological deficits, anemia, and cardiovascular effects (Klaassen *et al.*, 1986). USEPA set $3\text{E-}04$ mg/kg-day as the oral RfD for arsenic based on a NOAEL of $8\text{E-}04$ mg/kg-day in a human exposure study. The critical effect of this chemical is hyperpigmentation, keratosis, and possible vascular complications. The uncertainty factor is 3 and the modifying factor is 1 (IRIS). Arsenic's effects on the nervous and cardiovascular systems are primarily associated with acute exposure to higher concentrations. Exposure to arsenic-containing materials has been shown to cause cancer in humans. Inhaling these materials can lead to increased lung cancer risk, and ingestion is associated with increased skin cancer rates. Arsenic has been classified as a group A carcinogen by USEPA, and a slope factor of 1.5 (mg/kg-day)⁻¹ has been determined. As listed in IRIS, this classification is based on sufficient evidence from human data. An increased lung cancer mortality was observed in multiple human populations exposed primarily through inhalation. Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of skin cancer were observed in populations consuming drinking water high in inorganic arsenic. Human milk contains about 3 µg/L arsenic (Klaassen *et al.*, 1986).

8.3.6.2.3 Beryllium

Beryllium exposure via inhalation can inflame the lungs, a condition known as Acute Beryllium Disease, as a result of short-term exposure to high concentrations. Removal from exposure reverses the symptoms. Chronic exposure to much lower concentrations of beryllium or beryllium oxide by inhalation has been reported to cause chronic beryllium disease, with symptoms including shortness of breath, scarring of the lungs, and berylliosis (noncancerous growths in the lungs of humans). Both forms of beryllium disease can be fatal, depending on the severity of the exposure. Additionally, a skin allergy may develop when soluble beryllium compounds come into contact with the skin of sensitized individuals (Gradient, 1991). Using a dog dietary study, an oral RfD of 0.002 mg/kg-day has been set for beryllium based on a benchmark dose of 0.46 mg/kg-day, an uncertainty factor of 300, and a modifying factor of 1 (IRIS). The critical effect is listed as intestinal lesions. Beryllium has been classified by USEPA as a group B1 carcinogen based on the limited evidence of carcinogenicity in humans exposed to airborne beryllium, and sufficient evidence of carcinogenicity in animals. As listed in IRIS, this classification is based on beryllium being shown to induce lung cancer via inhalation in rats and monkeys, and to induce osteosarcomas in rabbits via intravenous or intramedullary injection. An inhalation SF of 8.4 (mg/kg-day)⁻¹ has been set by USEPA. The data were considered inadequate for assessment of oral carcinogenicity.

8.3.6.2.4 Cadmium

Cadmium can upset the stomach, leading to vomiting and diarrhea in acute exposure; acute inhalation of cadmium-containing dust can irritate the lungs. Chronic exposure to cadmium, either via inhalation or ingestion, has been shown to cause kidney damage (including kidney stones), emphysema, and high blood pressure. Other tissues reportedly injured by cadmium exposure in animals and humans include the lungs, testes, liver, immune system, blood, and nervous system (Klaassen *et al.*, 1986). An oral RfD of 0.001 mg/kg-day has been determined by USEPA, based on human studies (food) involving chronic exposure, in which significantly increased protein was

found in the urine. A separate oral RfD for water has been determined by USEPA to be 0.0005 mg/kg-day. As listed in IRIS, the critical effect of this chemical is significant proteinuria. The uncertainty factor was 10 and the modifying factor was 1. For inhalation exposure, cadmium has been classified by USEPA as a group B1 or probable human carcinogen, based on limited evidence from epidemiological studies in which an excess risk of lung cancer was observed in cadmium smelter workers. As listed in IRIS, this classification is based on limited evidence from occupational epidemiologic studies consistent across investigations and study populations, and sufficient evidence of carcinogenicity in rats and mice by inhalation and intramuscular and subcutaneous injection. Seven rat and mice studies where cadmium salts (acetate, sulfate, chloride) were administered orally have shown no evidence of carcinogenic response. There is also sufficient evidence of increased risk of lung cancer in rats and mice exposed to cadmium via inhalation.

8.3.6.2.5 Chlordane

Chlordane is a polycyclic chlorinated pesticide. Acute exposure to high doses of chlordane causes tremors and convulsions, and chronic exposure can cause emotional and neuromuscular disturbances. Exposed individuals revert to normal approximately one week after the source is removed (Dreisbach *et al.*, 1987). USEPA has established an oral RfD of 6E-5 mg/kg-day based on a NOAEL of 0.15 mg/kg-day, an uncertainty factor of 300, and a modifying factor of 1. Chlordane is classified as a B2 probable human carcinogen, using the 1986 Guidelines for Carcinogen Risk Assessment. Under the 1996 Proposed Guidelines, it would be characterized as a likely carcinogen by all routes of exposure. An oral SF of 0.35 (mg/kg-day)⁻¹ was set by USEPA, with the carcinogenic effect listed as non-Hodgkin's lymphoma (IRIS).

8.3.6.2.6 DDD, DDE, and DDT

DDT, or *1,1,1-trichloro-2,2-bis-(p-chlorophenyl)ethane*, was one of the most widely used chemicals for controlling insect pests on agriculture crops and controlling insects that carry such

diseases as malaria and typhus. Technical DDT is primarily a mixture of three forms (p,p'-DDT, o,p'-DDT, and o,o'-DDT), all of which are white, crystalline, tasteless, and almost odorless solids. DDT does not occur naturally in the environment; its presence in the environment is a result of contamination from past production, use and subsequent movement from sites of application to land, water, and air. Several waste sites contain these compounds and might act as additional sources of environmental contamination. Some DDT may degrade in air, but the compound may persist for a long time bound to certain soils. *DDE (1,1-dichloro-2,2-bis [p-chlorophenyl] ethylene)* and *DDD (1,1-dichloro-2,2-bis [p-chlorophenyl] ethane)* are found in small amounts as contaminants in technical grade DDT. DDD has had some use as a pesticide and also as a treatment for cancer of the adrenal gland. The use of DDD, DDE, and DDT is banned in the United States (ATSDR, 1992).

With acute exposure to high doses, the nervous system appears to be the major target in both humans and experimental animals (Herr and Tilson, 1987; Hayes, 1982). Information on health effects in humans following acute inhalation exposure to DDD or DDE is limited (ATSDR, 1992). Chronic exposure of experimental animals to DDT is associated with tremors and general hyperirritability (NCI, 1978; Rossi *et al.*, 1977). In male and female mice a single oral dose of 237 to 32 mg DDT/kg caused death of all the mice (Bathe *et al.*, 1976; Kashyap *et al.*, 1977; Tomatis *et al.*, 1972). There is evidence of mild to severe hepatic effects in experimental animals as a result of acute, subchronic, or chronic oral administration of DDT (Pasha, 1981). Epidemiological evidence is inconclusive for establishing, with reasonable certainty, if DDT is a human carcinogen. Evidence exists from animal studies to consider DDT, DDE, and DDD probable human carcinogens based on USEPA's B2 classification (IRIS). For example, DDT is carcinogenic in most strains of mice tested (Innes *et al.*, 1969; Thorpe and Walker, 1973; Tomatis *et al.*, 1972; Kashyap *et al.*, 1977; Shabad *et al.*, 1973) and in a few studies was carcinogenic in rats (Cabral *et al.*, 1982a; Rossi *et al.*, 1977). However, several other rat studies reported negative results (Legator *et al.*, 1973; Palmer *et al.*, 1973; Cameron and Cheng, 1951; Shivapurkar *et al.*, 1986), as were most of those in hamsters (Agthe *et al.*, 1970; Cabral *et al.*, 1982b; Graillot *et al.*, 1975), and the one study in monkeys (Adamson and Sieber, 1979, 1983).

One area of uncertainty is the significance of liver tumors in certain strains of mice and the appropriateness of extrapolating this information to humans. Several studies in rats, mice and hamsters have been conducted to determine the potential carcinogenicity of DDD and DDE. A chronic feeding study in mice has shown DDE to produce liver tumors at doses of 19 to 34 mg/kg-day for 124 weeks (NCI, 1978; Tomatis *et al.*, 1974). A similar study produced liver tumors in hamsters given 40 mg/kg-day for 124 weeks (Rossi *et al.*, 1983). However, DDE did not induce significant increases in rats given 12 to 42 mg/kg-day for 78 weeks (NCI, 1978). DDD induced liver tumors and lung adenomas in CF-1 mice (Tomatis *et al.*, 1974) and thyroid follicular cell tumors in Fischer-344 rats (NCI, 1978), but was not tumor-producing in B6C3F1 mice (NCI, 1978).

Oral SFs are $2.4E-01$ (mg/kg-day)⁻¹ (DDD), $3.4E-01$ (mg/kg-day)⁻¹ (DDE), and $3.4E-01$ (mg/kg-day)⁻¹ (DDT). The carcinogenic effect listed is liver tumors. An oral RfD of $5E-04$ mg/kg-day has been issued for DDT based on a NOAEL of $5E-02$ mg/kg-day, an uncertainty factor of 100, and a modifying factor of 1. The critical effect is listed as liver lesions (IRIS).

8.3.6.2.7 Dieldrin

Dieldrin is a polycyclic chlorinated pesticide. Short-term exposure to high doses of dieldrin causes tremors and convulsions, and chronic exposure can cause emotional and neuromuscular disturbances. Exposed individuals revert to normal approximately one week after the dieldrin source is removed (Dreisbach *et al.*, 1987). Dieldrin is classified as a B2 carcinogen by USEPA. The oral SF is listed as 16 (mg/kg-day)⁻¹ and the inhalation SF as 16.1 (mg/kg-day)⁻¹. The oral RfD is listed as $5E-05$ mg/kg-day, based on a NOAEL of $5E-03$ mg/kg-day, an uncertainty factor of 100, and a modifying factor of 1. The critical effect is listed as liver lesions (IRIS).

8.3.6.2.8 Endosulfan I

Endosulfan is an insecticide used to control a number of insects on food crops such as grains, tea, fruits, and vegetables and on nonfood crops such as tobacco and cotton. Endosulfan may be lethal

to humans and animals by all routes of exposure studied, depending on dosage. The main target of toxicity in humans and animals following acute, high-level exposure by any route is the central nervous system (Aleksandrowicz, 1979; Tiberin *et al.*, 1970; Ely *et al.*, 1967). Initial clinical signs observed following acute lethal poisoning in humans were digestive, respiratory, and nervous system effects which included gagging, vomiting, diarrhea, agitation, writhing, loss of consciousness, cyanosis, dyspnea, foaming at the mouth, and noisy breathing (Terziev *et al.*, 1974). The liver, kidney, hematopoietic, reproductive, and immune systems also appear to be targets of endosulfan toxicity following acute exposure in experimental animals, but adverse effects on these organs or systems have not been reported in humans (Banerjee and Hussain, 1986, 1987; Boyd *et al.*, 1970; Siddiqui *et al.*, 1987). No information is available on the toxicity of endosulfan to humans following chronic-duration exposure by any route. The target of toxicity in animals following chronic oral exposure appears to be the kidney. Hyperplasia of the parathyroid gland has also been observed in male rats following chronic oral administration of endosulfan (NCI, 1978). Due to a lack of data, USEPA has not specified a weight-of-evidence classification for endosulfan. An oral RfD has been assigned as 6.0E-03 mg/kg-day based on a NOAEL of 0.6 mg/kg-day, an uncertainty factor of 100, and a modifying factor of 1. The critical effect listed is reduced body weight gain in males and females (IRIS).

8.3.6.2.9 Endrin, Endrin Aldehyde, and Endrin Ketone

Endrin is a solid white substance that has been used as a pesticide to control insects and rodents. Measurable levels have not been found in adipose tissue of the general population (Stanley *et al.*, 1986; Williams *et al.*, 1984), but measurable tissue concentrations have been observed in cases of acute poisoning. The time of sample collection is critical as endrin residues in tissue decline rapidly after exposure has ceased. A patient that consumed endrin-contaminated bread had serum levels of 0.053 ppm, with none in cerebrospinal fluid. The sample was taken 30 minutes after a convulsion (Coble *et al.*, 1967). An outbreak of acute human endrin poisoning associated with central nervous system toxicity and 19 deaths in 192 known cases occurred in

Pakistan in 1984 (Rowley *et al.*, 1987). The vector for exposure was not identified, but contamination of a food item was the likely cause of poisoning. Endrin has a USEPA weight-of-evidence classification of D, not classifiable as a human carcinogen. Endrin has an oral RfD of 3.0E-04 mg/kg-day based on a NOAEL of 0.025 mg/kg-day, an uncertainty factor of 100, and a modifying factor of 1. The critical effect listed are liver lesions and occasional convulsions (IRIS).

8.3.6.2.10 Heptachlor

Heptachlor is a man-made chemical that was used in the past for killing insects in homes, buildings, and on food crops. Pure heptachlor is a white powder. Technical-grade heptachlor is a tan powder with a lower level of purity than pure heptachlor. Heptachlor smells somewhat like camphor, and does not burn easily or explode (ATSDR, 1991).

No studies were found regarding lethal effects in humans after oral exposure, but since heptachlor is a major component of the insecticide chlordane, chlordane poisoning can be considered when evaluating heptachlor toxicity data. There are no data on chronic oral exposures in humans, but occupational studies of workers engaged in the manufacture of heptachlor identified no adverse health effects. Exposure routes were presumed to be predominantly inhalation with contributions from the dermal route.

Heptachlor has been issued the USEPA classification of B2, probable human carcinogen, and has an oral SF of 4.5 (mg/kg-day)⁻¹. The carcinogenic effect is listed as liver tumors. Heptachlor has an oral RfD of 5E-04 mg/kg-day based on a NOAEL of 0.15 mg/kg-day, an uncertainty factor of 300, and a modifying factor of 1. The critical effect listed is liver weight increases (IRIS).

8.3.6.2.11 Heptachlor epoxide

Heptachlor epoxide is the more toxic form of the insecticide heptachlor which was used to control flies, mosquitoes, and field insects. Benign and malignant liver tumors were induced in three strains of mice of both sexes. Heptachlor epoxide has been linked to liver carcinoma (Dreisbach, *et al.*, 1987). USEPA determined this compound to be a class B2 carcinogen, and

the oral SF to be $9.1 \text{ (mg/kg-day)}^{-1}$. The primary target organs for this pesticide are the liver and kidneys, and USEPA determined the oral RfD to be $1.3\text{E-}05 \text{ mg/kg-day}$ based on an LEL of $1.25\text{E-}02 \text{ mg/kg-day}$, an uncertainty factor of 1,000, and a modifying factor of 1 (IRIS).

8.3.6.2.12 Lindane (gamma-BHC)

Hexachlorocyclohexane (HCH) is made by chlorinating benzene, and was previously erroneously called *benzenehexachloride (BHC)*. HCH is a synthetic chemical that exists in eight isomers. One of the isomers, gamma (γ)-HCH (commonly called *lindane*), was once used as an insecticide on fruit, vegetable, and forest crops. It is still used today in the United States and in other countries as a human medicine to treat head and body lice and scabies. Although HCH is no longer used as an insecticide in the United States, alpha (α), beta (β), γ , and delta (δ)-HCH have been found in the soil and surface water at hazardous waste sites.

Exposure to excessive amounts of HCH, primarily γ -HCH, by inhalation or ingestion has reportedly caused death in humans. The cause of acute lethality in animals may be HCH's effects on the central nervous system since convulsions and coma were often observed prior to death. Dosages associated with death and increased mortality in animals are much higher than would be found in the environment or in water or soil surrounding waste sites, so it is not likely that humans would die following brief or prolonged exposure to HCH in food, water, or soil.

Blood disorders including anemia, leukopenia, leukocytosis, granulocytopenia, granulocytosis, eosinophilia, monocytosis, pancytopenia, and thrombocytopenia have been observed in individuals exposed to γ -HCH from HCH vaporizers (Brassow *et al.*, 1981). In animals, hematological effects were observed in rats fed δ -HCH for 13 weeks (Van Velsen *et al.*, 1986). Hepatic effects, such as increased liver enzymes, have been reported in individuals exposed to technical-grade HCH principally by inhalation in a pesticide formulating plant (Kashyap, 1986); similar effects were not reported in individuals who ingested HCH or applied γ -HCH to their skin.

In humans, neurological effects including parathesis of the face and extremities, headaches, vertigo, abnormal electroencephalogram patterns and often seizures and convulsions have been reported in individuals occupationally exposed to γ -HCH or exposed to large amounts through ingestion or dermal application (Czegledi-Janko and Avar, 1970; Davies *et al.*, 1983; Harris *et al.*, 1969; Heiberg and Wright, 1955; Kashyap, 1986; Lee and Groth, 1977; Matsuoka, 1981; Munk and Nantel, 1977; Nantel, 1977; Powell, 1980; Starr and Clifford, 1972; Telch and Jarvis, 1982). Acute- and intermediate-duration exposure of animals to high oral or dermal doses of γ - or β - HCH affects the central nervous system, as evidenced by behavior disorders, decreased nerve velocity, convulsions and seizures, and coma (Albertson *et al.*, 1985; Desi, 1974; Hanig *et al.*, 1976; Muller *et al.*, 1981; Tilson *et al.*, 1987; Tusell *et al.*, 1987; Van Velsen *et al.*, 1986). No histological examinations of the brain or nervous system were conducted on animals exposed by any route for any duration. There is no evidence available regarding the presence or absence of carcinogenic effects in humans following exposure by any route. Weight of evidence, cancer SFs and RFs for each of the HCH isomers are shown in Table 8-8.

Table 8-8
 Weight of Evidence, Cancer Slope Factors and Reference Doses for HCH Isomers

HCH isomer	Weight-of-evidence Class	Oral RfD (mg/kg-day)	Oral SF (mg/kg-day) ⁻¹	Inhalation SF (mg/kg-day) ⁻¹
α - HCH	B2 _i	NA	6.3E+00 _i	6.3E+00 _i
β - HCH	C _i	NA	1.8E+00 _i	1.8E+00 _i
γ - HCH	B2-C _H	3.0E-04 _i	1.3E+00 _H	NA
δ - HCH	NA	NA	NA	NA
-technical	NA	NA	1.8E+00 _i	1.8E+00 _i

Notes:

- _i = taken from IRIS
- _H = taken from HEAST, 1996
- NA = Not available

8.3.6.2.13 Methylene chloride

Methylene chloride, also known as *dichloromethane*, is a colorless liquid that is widely used as a solvent for a variety of purposes. Available data indicate that the central nervous system is the primary target of inhaled methylene chloride in humans, rats, mice, guinea pigs, and dogs (Fodor and Winneke, 1971; Winneke, 1974; Rebert *et al.*, 1989; Savolainen *et al.*, 1981). Other acute human effects following exposure to methylene chloride include irritation of the eyes, skin, and respiratory tract, elevated carboxyhemoglobin levels, and circulatory disorders that may be fatal. No human studies have been conducted on the effects of acute oral exposure to methylene chloride, and no data are available on the adverse health effects from chronic exposure to methylene chloride via any route. Studies in animals suggest that the liver is a target organ following chronic inhalation and oral exposure (Kirschman *et al.*, 1986; Serota *et al.*, 1986b).

There have been several chronic studies in which methylene chloride was administered to experimental animals either orally or by inhalation. The inhalation studies show a dose-dependent, statistically significant increase in liver and lung adenomas and carcinomas in mice, and benign mammary gland tumors in rats following two year's exposure to methylene chloride (Serota *et al.*, 1986a,b; Burek *et al.*, 1984; Nitschke *et al.*, 1988a; NTP, 1986). However, there is only suggestive evidence from drinking water studies (USEPA 1985a,b) of a treatment-associated increase in combined hepatocellular carcinomas and neoplastic nodules. An *in vivo* screening test for carcinogenicity induction of lung adenomas in strain A mice, suggested positive results for methylene chloride (USEPA, 1980d). USEPA's weight-of-evidence classification is B2, a probable human carcinogen. Oral and inhalation SFs are $7.5E-03$ (mg/kg-day)⁻¹ and $1.64E-03$ (mg/kg-day)⁻¹, respectively (IRIS). An oral RfD has been set at $6E-02$ mg/kg-day based on a NOAEL of 5.85 mg/kg-day, an uncertainty factor of 100, and a modifying factor of 1 (IRIS). An inhalation RfD has been set at $8.57E-01$ mg/kg-day (HEAST).

8.3.6.2.14 PCB Aroclors-1016 and 1260

PCB Aroclors are a group of chlorinated hydrocarbons (such as *Aroclors-1016 and 1260*) that accumulate in fat tissue. Occupational exposure (both inhalation and dermal) to PCBs causes eye and lung irritation, loss of appetite, liver enlargement, increased serum liver enzyme levels, rashes and chloracne, and decreased birth weight of infants in heavily exposed worker/mothers. Of the effects listed above, the liver is the primary target organ (Klaassen *et al.*, 1986; Dreisbach *et al.*, 1987). USEPA classified PCB Aroclors as group B2 carcinogens, primarily based on animal data. As listed in IRIS, this classification is based on hepatocellular carcinomas in three strains of rats and two strains of mice and inadequate yet suggestive evidence of excess risk of liver cancer in humans by ingestion and inhalation or dermal contact. Oral ingestion of PCBs causes liver and stomach tumors in rat studies. USEPA set $2.0 \text{ (mg/kg/day)}^{-1}$ as the upper-bound oral SF for PCB Aroclors. USEPA has set an oral RfD of $7\text{E-}05 \text{ mg/kg-day}$ for Aroclor, based on a NOAEL of 0.007 mg/kg-day , an uncertainty factor of 100, and a modifying factor of 1.

8.3.6.2.15 Vinyl chloride

Vinyl chloride is a volatile organic that can cause Raynaud's Phenomenon or white finger disease. It has been shown to cause angiosarcoma, a cancer. It has also been associated with reproductive dysfunction in men and women. The primary target organs for noncarcinogenic effects are the liver, kidney, and nervous system. This compound inhibits one of the main metabolic pathways of the body (a group of enzymes), and can thus influence the toxicity of other compounds (Klaassen *et al.*, 1986; Dreisbach *et al.*, 1987). Due to this compound's carcinogenicity, USEPA classified vinyl chloride as a class A carcinogen and set the inhalation SF and the oral SF at $0.3 \text{ (mg/kg-day)}^{-1}$ and $1.9 \text{ (mg/kg-day)}^{-1}$, respectively (IRIS).

8.3.7 Uncertainty and Variability

Uncertainty and variability are inherent in the risk assessment process and are addressed as a whole in this section. Most issues are common to all wetlands, but wetland-specific issues are also included. In general, conservative exposure assumptions would likely overestimate risk for the trespasser and maintenance worker land use scenarios in this HHRA; however, the lack of game fish tissue data could result in underestimates of risk. Analytical data and different toxicological effects, test organisms, and endpoints introduce a wide range of variability, which is compounded when multiplied by many conservative assumptions.

8.3.7.1 Exposure

Sources of uncertainty and variability are addressed in this section relative to fish tissue, sediment, and surface water.

8.3.7.1.1 Fish Tissue

Uncertainty and potential variability are high in this medium. As described in Section 10, ingestion of game fish tissue could be a complete exposure pathway for Wetlands 18, 19, and 64. As previously discussed, fish tissue data were collected from Wetlands 18, 33, 64, and 75 for the ecological risk assessment. Whole baitfish were collected. Therefore, bioaccumulation in game fish is an uncertainty that could span orders of magnitude, over- or underestimating human exposure. In addition, the baitfish collected have relatively low lipid content when compared to popular game fish such as mullet. More bioaccumulation would be expected in species higher in the food chain and with higher lipid content. This is an additional source of uncertainty that could underestimate human exposure to chemicals in fish tissue. Interspecies variability in lipids, metabolism, and ultimately accumulation, as well as preparation methods by human receptors could over- or underestimate human exposure to tissue. The available data were compared with USEPA Region III RBCs based on subsistence fishermen. Subsistence fishing at site 41 would be unlikely because areas that would be more attractive to fishermen can be found

around Bayou Grande and in Pensacola Bay. With so many sources of uncertainty and variability, a qualitative/semiquantitative assessment is presented in Section 10.

8.3.7.1.2 Sediment

Sediment exposure was assumed to be equivalent to soil exposure. Uncertainty and variability in the ingestion rate, exposure frequency and duration, bioavailability of chemicals in sediment, dermal contact uptake assumptions, and rinsing action of surface water result in highly uncertain exposure estimates. Variability among individuals as well as day-to-day variability in the same individual would influence these factors. Most wetlands would not likely be attractive to swimmers due to physical and biological hazards, so exposure would likely be overestimated.

8.3.7.1.3 Surface Water

Incidental ingestion of and dermal contact with surface water were assessed assuming a trespasser would swim or wade in a wetland for 2.6 hours, with an ingestion rate of 50 ml/hour. A similar rate of exposure to surface water was assumed for maintenance workers who may be required to provide grounds upkeep in the vicinity of certain wetlands. Most wetlands would not be attractive to swimmers nor conducive to intensive exposure to surface water, primarily due to most wetland's shallow depth and physical and biological hazards. Consequently, surface water exposure would be overestimated. Like sediment, variability between individuals and daily variability in the same individual could over- or underestimate exposure.

For surface water exposures it was assumed that the VOC inhalation pathway was insignificant due to the unlimited dilutional capacity of the ambient air. Should these wetlands ever be contained in some manner, risks associated with VOCs could be underestimated in this risk assessment.

8.3.7.2 Toxicological Data

There is a generally recognized uncertainty in human risk values developed from experimental data, due primarily to the uncertainty of data extrapolation in the areas of: (1) high- to low-dose exposure and (2) animal effects data to human effects data. The site-specific uncertainty is mainly in the degree of accuracy of the exposure assumptions. Most of the assumptions used in this and any risk assessment have not been verified. For example, the degree of chemical absorption from the gut or through the skin or the amount of soil contact is not known with certainty.

The uncertainty of toxicological values from the IRIS and HEAST databases provided by USEPA is summarized (where available) in Tables 8-6 and 8-7. The uncertainty factors assigned to these values account for acute to chronic dose extrapolation, study inadequacies, and sensitive subpopulations, among other factors. Although the uncertainty factor for a specific chemical may be 1,000 or higher, these safety factors are applied by USEPA to ensure a conservative assessment of human health concerns. In the presence of such uncertainty, USEPA and the risk assessor are obligated to make conservative assumptions to minimize the chance that the actual health risk will be greater than what the process determines.

8.3.7.3 Qualitative Fish Tissue Assessment

In light of the fish tissue discussion, the risk posed by fish tissue ingestion is uncertain. As shown in Tables 10.1-A, 10.6-A, 10.30-A, and 10.31-A, pesticides and PCBs were reported in fish tissue in Wetlands 18, 33, 64, 75. Wetland 33 is a reference wetland, so there is also some uncertainty about the source of these chemicals. Wetland 75 was designated a reference wetland, but was subsequently deemed unsuitable because of the detected concentrations. Mosquito control and related applications are a likely source of these pesticides considering the absence of industrial activities in the area. Crabbing and mullet fishing could occur in some wetlands year-round, although the Marine Patrol Office indicated very limited fishing in Site 41 wetlands

relative to Pensacola Bay and Bayou Grande, which would be considered more attractive to fishermen.

PCBs, aldrin, dieldrin, endosulfan I, and lindane were reported in tissue samples from Wetlands 18 and 64, but not in reference area fish tissue. However, game fish could contain these chemicals from bioaccumulation and bioconcentration due to various sources. Except lead, all concentrations reported in fish tissue exceeded corresponding RBCs. Lead intake from this source would need to be assessed as an additional lead source in USEPA's IEUBK Lead Model. Only baitfish data are currently available from a limited number of samples. In addition, tissue data were not normalized for percent lipid content. Game fish data normalized for percent lipid content would be necessary to put risk estimates in perspective for risk managers.

Uncertainty exists about the potential for bioaccumulation in game species, which could result in higher risk estimates because most of these pesticides and PCBs tend to bioaccumulate. The limited sample size and lack of identified sources contribute to uncertainty and could result in over- or underestimated risk, with variability potentially spanning orders of magnitude. However, the tissue data used in the risk assessment are from whole-body analysis, not edible tissue only. Bones, lipids, and organs which are not typically eaten by humans are where many contaminants accumulate, and food preparation methods are also unknown.

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9.0 FATE AND TRANSPORT ANALYSIS METHODS

This section presents the methods used to evaluate fate and transport of contaminants. Wetland-specific evaluations are presented in Section 10.

The fate and transport assessment evaluates the ability of chemical constituents to become mobile or change in the environment, based on their chemical and physical properties, and also evaluates processes that govern their interaction with environmental media. This evaluation helps identify receptors that may be impacted by constituent movement in the environment.

This section describes media and contaminant properties that affect fate and transport, and concludes with a discussion of the potential pathways and sources presumed to affect the NAS Pensacola wetlands. Section 10 presents the wetland-specific evaluation and validation of migration pathways.

9.1 Contamination Summary

Chemical and physical analyses were performed on Site 41 sediment and surface water samples. A wide range of SVOCs, pesticides/PCBs, and inorganics were detected. Section 10 evaluates the nature and extent of sediment and surface water contamination and compares the results to sediment and surface water criteria.

9.2 Contaminant Migration

9.2.1 Properties Affecting Fate and Transport

Numerous chemical and physical properties of both the chemical constituents and the surrounding media are used to evaluate fate-transport mechanisms. The primary mechanisms in estuarine and freshwater environments are sediment transport and aqueous solubility of an analyte. Chemical and physical properties of constituents used to evaluate fate and transport are vapor pressure, density, solubility, Henry's law constant, half-life, organic carbon-water partitioning coefficient

(K_{oc}), and molecular weight (see Table 9-1). Compounds with similar chemical and physical properties display similar fate-transport behavior. These characteristics facilitate the general grouping of contaminants, into the following categories: VOCs, SVOCs, pesticides/PCBs, and inorganics.

Table 9-1
 Constituent Characteristics Based on
 Chemical and Physical Properties

Property	Critical Value	High (>)	Low (<)
Vapor Pressure	10^{-3} mm Hg	Volatile	Nonvolatile
Density ^a	1.0 g/cm ³	Sinks/falls	Floats/rises
Solubility ^a	0 to 100 mg/L	Leaches from sediment; mobile in water; does not readily volatilize from water	Sorbs to sediment; immobile in water; volatilizes from water
Henry's Law Constant	5×10^{-6} to 5×10^{-3} atm-m ³ /mole	Resistant to mass transfer in the aqueous phase	Resistant to mass transfer in the gas phase
Half-life ($T_{1/2}$)	biologically dependent	Does not degrade readily	Degrades readily
Organic Carbon/Water Partitioning Coefficient ^a (K_{oc})	10 to 10,000 kg _{oc} /L _{water}	Tends to sorb to organic material in sediment; immobile in the sediment matrix	Tends not to sorb to organic material in sediment; mobile in the sediment matrix
Molecular Weight	400 g/mole	Characteristics listed above may not hold true; more detailed evaluation necessary	All of the above generally hold true

Notes:

- a = Determinations of the Critical Values were based on literature review and professional judgment
- mmHg = millimeters of mercury
- g/cm³ = grams per cubic centimeter
- atm-m³/mole = atmospheres per cubic meter per mole
- g/mole = grams per mole

9.2.2 Media Properties Affecting Fate and Transport

The properties of environmental media used to evaluate fate and transport are TOC, normalized partition coefficient (K_d), cation-exchange capacity (CEC), oxidation/reduction (redox) conditions, pH, and sediment type. The following paragraphs briefly discuss these properties.

Total Organic Carbon

TOC indicates the sediment's sorptive capabilities. The higher the TOC, the higher the potential for a chemical, particularly an organic compound, to sorb to sediment particles and become less bioavailable. For example, it is possible for a sediment sample to have a very high concentration of a particular organic constituent, but show no observable toxic effect typically associated with that constituent. If the TOC for that sample happened to be elevated compared to other samples in the wetland, then the contaminant would most likely be bound to the sediment and not bioavailable, reducing the net toxic effect. TOC is particularly relevant to contamination found in Wetlands 64, 5A, 4, 4D, and many other wetlands throughout the base where elevated pesticide concentrations were detected.

Normalized Partition Coefficient

K_d is used to predict the capacity for a constituent to partition between sediment and water; it is a function of both the constituent and the sediment. To estimate K_d , the constituent's constant K_{oc} is adjusted by the sediment's TOC: $K_d = K_{oc} \times f_{oc}$, where f_{oc} is a function of the organic carbon content fraction of the sediment. Sediments with a higher K_d have a higher potential to sorb organic compounds.

Most wetlands at NAS Pensacola have depositional areas of high TOC, and these areas tended to have the highest detected contaminant concentrations. These areas were purposely sampled during Phase IIA to give an idea of maximum contaminant concentrations. As stated above, high contaminant concentrations do not necessarily translate into adverse ecological effects.

Cation-Exchange Capacity

CEC reflects the sediment's capacity to adsorb ions, neutralizing ionic deficiencies on the surfaces of its particles. Generally, trivalent ions are preferentially adsorbed to sediment over divalent

ions, and divalent ions are preferentially adsorbed over monovalent ions. Although this relationship generally holds true, the process also depends on sediment pH.

Sediment with high CEC values has the potential to adsorb inorganic ions, although organic compounds with dipole moments are also affected by CEC. However, in estuarine environments, the excess of alkali metals in seawater out-competes other metals for these cationic binding sites. As a result, cations in estuarine wetlands can either stay in solution or bind with a stable anion and precipitate out of solution. Therefore, the estuarine wetlands at NAS Pensacola may have lower concentrations of particular metals due to alkali metals competing for binding sites within the sediment. Other factors such as TOC can ameliorate the effects of CEC in sediment in estuarine wetlands.

Oxidation/Reduction Conditions

Redox is the process that includes oxidation (the loss of electrons) and reduction (the gain of electrons). The resultant change in valence generates products that are different from the parent reactants in solubility, toxicity, reactivity, and mobility. Extreme redox conditions tend to mobilize chemicals, especially transition metals. However, in an estuarine environment, the excess of alkali metals in seawater reduces the effect of redox conditions. Cations either stay in solution or bind with a stable anion and precipitate out of solution. Therefore, redox conditions are most likely to be a factor in the freshwater wetlands at NAS Pensacola.

pH

pH measures the negative logarithm of the hydrogen ion concentration in water, indicating the medium's acidity or alkalinity. Chemicals react differently as pH changes. Low pH conditions tend to mobilize most metals and facilitate substitution in organic compounds. High pH conditions may cause metals to precipitate and organic molecules to degrade. In general, pH conditions are

uniform in the estuarine environment. Within the freshwater environment, pH conditions generally appeared in the 7.0 to 7.5 range, which is slightly acidic to neutral pH.

Sediment Type

Sediment mineral composition, particle-size distribution, and organic content affect chemical fate and transport. Sediment characteristics influence or determine hydraulic conductivity, effective porosity, and hydraulic gradient which, in turn, dictate groundwater flow. In wetland environments, smaller particle sizes are observed in areas of deposition. Because smaller sediment types have a large surface area relative to total particle size, they tend to absorb more contaminants than larger sediment types. Each wetland at NAS Pensacola had a wide range of sediment particle sizes. Again, sediment samples were biased toward areas of highest deposition, as they would likely have the highest concentrations of contaminants.

9.3 Contaminant Properties

This section describes the properties of the major contaminant classes and how these properties relate to interactions in the environment.

9.3.1 VOCs

The chemical and physical properties that most influence fate and transport of VOCs are solubility, Henry's law constant, and vapor pressure. The mechanisms for transportation of VOCs include the following:

- VOCs can sorb to sediment from groundwater or surface water.
- VOCs tend to be highly mobile in both sediment and water.
- VOCs tend to dissipate relatively quickly via diffusion.

VOCs have low molecular weights, high solubilities, and high vapor pressures. Because of these properties, VOCs are expected to be highly mobile in the environment and, therefore, quick to migrate from sediment and groundwater. For these reasons, VOCs were not a particular concern within the wetlands at NAS Pensacola.

9.3.2 Metals

For metals, the adsorption potential for sediment is related to grain size and, to a lesser extent, organic carbon. Fine-grained particles, particularly aluminosilicate clays, provide a greater surface area relative to total particle size, and the crystalline microstructure is conducive to the adsorption of inorganic contaminants. Fine-grained sediments are also much more susceptible to current movements and may hold relatively higher metal concentrations than coarse-grained sediments.

Mobilization of metals in sediments is a function of pH, temperature, and redox potential. Higher pH surface water, as found in estuarine wetlands, favors precipitation from solution and results in increased sediment concentrations. Lower pH surface water, typical of freshwater wetlands in Florida, favors dissolution and inhibits the absorption of metals from sediments.

The primary transport mechanism for metals bound to sediment is through physical movement of the sediment itself. When metals are tightly bound within the mineral structure, currents are the predominant transport mechanism. Over time, sediments will most likely be transported into natural depositional locations.

The fate of metals in sediments involves both chemical and biological transformation. Chemical transformation may involve formation of organo-metallics and sulfide complexes, or methylation from microbial processes. Transfer of metals through biological uptake by benthic infauna is also a possibility. Biomagnification of metals is not considered a critical pathway in estuarine

wetlands, but may occur in acidic freshwater wetlands. Bioaccumulation and biomagnification of contaminants are discussed in the ecological risk assessment, Section 10.

Wetlands 64, 5A, 3, and 4D had some of the highest concentrations of metals, particularly in depositional areas with small grain size. Many of the activities associated with this contamination ceased years ago, demonstrating how metals can become persistent in sediment.

9.3.3 Organics

Organic contaminants, particularly hydrophobic compounds, tend to sorb to water-borne particulates (clays, colloids, and humic substances) that eventually end up as bottom deposits. From there, they may be transformed into more or less toxic forms, migrate from the sediment into benthic organisms via respiration, or reach overlying waters as physicochemical conditions change.

Sediment organic carbon, in the form of humic substances (measured by TOC), is the primary storage site for neutral organic chemicals in sediments. Also, particle size and chemical hydrophobicity are important environmental influences affecting sorption rates. As particle size decreases and hydrophobicity increases, there is increased binding of organic contaminants to sediment organic carbon. Increased surface area, resulting from decreased particle size, provides more adsorption sites for neutral organic chemicals.

For PAHs in sediments, photolytic degradation rates are a function of the available penetrating sunlight and oxygen. PAHs may persist indefinitely in low light/low oxygen environments common in many of the wetlands on base. PAHs may also persist when they are tightly bound to organic substances.

Fate of organic constituents in sediments is also influenced by biotransformation and biodegradation by benthic organisms. Neutral organics that are more hydrophobic tend to be more persistent in the food chain due to their accessibility when they bind with organic substances. Some organic compounds, particularly pesticides such as DDT, are inherently stable due to their chemical structure and are very slow to undergo any type of degradation. Their persistence is demonstrated by the concentrations of DDT detected throughout the base long after its use was banned in the United States.

As with metals, organics have been detected throughout the NAS Pensacola wetlands in many forms. The highest concentrations of organics detected tended to be in depositional areas with high TOC values.

9.4 Water Transport Characteristics

In water, the likelihood that a dissolved contaminant will be retained within the medium is dependent on that chemical's fugacity, or escaping tendency. The fugacity potential is based on both the chemical specific traits and medium thermodynamic influences. The partitioning coefficient of a chemical indicates its affinity for water or another medium (sediment, tissue or suspended particles). Under ideal conditions the partitioning coefficient for a chemical is constant, but the environmental parameters that can influence partitioning vary with site conditions.

Environmental variables include suspended and dissolved materials, light attenuation, pH, and redox. Redox and pH have a strong influence on metals but little effect on neutral organic chemicals. In freshwater wetlands, acidic water will result in a greater abundance of free metal ions which, under oxidizing conditions, are more bioavailable. Under reducing conditions, these metals will be present as insoluble sulfides, and generally less bioavailable. Generally, higher pH environments have more particulate matter and metals can be precipitated out. In saltwater, the presence of divalent cations of magnesium (Mg^{++}) and calcium (Ca^{++}) can cause suspended

fine-grained sediments, colloids, and dissolved organic matter to flocculate and settle from the water column. Organic contaminants may co-precipitate with metal complexes on these flocculated materials. Dissolved organic carbon (DOC) in water, composed primarily of humic substances produced by the degradation of dead plant material, can also provide binding sites for metal ions and neutral organics. DOC concentrations also affect bioavailability and bioconcentration of chemicals by aquatic organisms like that of suspended sediment (Carlberg *et al.*, 1986).

9.5 Pathways and Sources

The factors influencing fate and transport of contaminants into, within, and out of wetlands at NAS Pensacola are complex. This section describes the pathways and sources for those pathways aside from chemical factors which influence contaminant distribution. Section 10 presents the validation of these pathways with respect to the individual wetlands.

9.5.1 Pathways

Four primary migratory routes for transport are evident for the NAS Pensacola wetlands:

- Surface water: surface water runoff from adjacent terrestrial areas, natural surface water drainage into wetlands, and natural drainage out of wetlands
- Sediment transport: physical sediment movement into, within, and out of wetlands through entrainment within surface water influx and outflow
- Groundwater discharge to wetlands from adjacent upgradient areas
- Leaching of sediment contamination to surface water

Surface Water Migration

Surface water migration into the wetlands can be evaluated by considering the physical properties of the area. Many wetlands lie immediately adjacent to, or within proximity of, paved areas or stormwater outfalls. In these cases, it is expected that surface runoff (or rejected recharge) will enter the wetlands during periods of heavy rainfall. For wetlands that are not adjacent to impervious surfaces or outfalls, the high permeability of the surficial sand deposits precludes direct surface runoff into the wetlands. It can be expected, however, that in this case precipitation will evaporate or enter the surficial aquifer as recharge, and may eventually discharge to the wetlands as groundwater.

In addition to surface runoff, some wetlands at NAS Pensacola receive surface water influx directly as a result of natural drainage patterns. In these cases, upgradient wetlands or drainage patterns receive discharge from nearby groundwater, and this discharge then follows the natural direction of flow to the receiving wetland. A special circumstance involves those wetlands that are connected directly to the Bayou Grande or Pensacola Bay through tidal channels. In these cases, tidal flux will allow a backflow of seawater to enter the wetland.

Flow within and out of the wetlands is considered to be consistent with the direction of base flow or topography. None of the wetlands is sufficiently large to expect a complex flow configuration. In cases where no surface water outlet is observed for a wetland, surface water is assumed to infiltrate into the aquifer on the downgradient side of the wetland (in essence, the wetland is a "window" into the aquifer). The surface water transport pathway is evaluated in Section 10 for each wetland with respect to its location and hydrologic and topographic configuration.

Sediment Transport

Sediment transport is expected to be coincident with and a consequence of surface water transport. Sediment will become entrained within the surface water runoff stream and enter the wetland.

Sediment entrainment is also expected to be a mechanism for transport into, within, and out of the wetlands as natural drainage moves through the system. With natural drainage, sediment movement is expected to be governed more through bottom transport, whereby sediment load is redistributed en masse by current movement along the bottom and sides of the drainage watercourses and wetlands. Data regarding the rate and mass of sediment movement into and through the wetland systems are not available; therefore, in Section 10, this mechanism of transport is treated qualitatively by considering the physical configuration of the wetland system.

Groundwater Discharge

Groundwater discharge is expected to occur at most of the NAS Pensacola wetlands. Exceptions are those wetlands that occupy broad areas of the southwestern portion of the base. These wetlands tend to be floored with thick mats of decaying vegetation which are at or slightly above the elevation of the water table. It is believed that these wetlands serve as a primary area of local recharge to the aquifer, although the thick mat of vegetation may inhibit the downward percolation of recharge to the surficial aquifer. Drainage within this area of the base is controlled by numerous drainage ditches which serve as central drains for the system and permit the operation of Sherman Field.

Most of the wetlands of concern are located in the eastern half of the base, and most are considered to receive groundwater discharge on their upgradient sides. Another potential mechanism of transport associated with groundwater is nearshore mixing. In wetlands immediately adjacent, but not connected, to the Bayou Grande or Pensacola Bay, groundwater discharge received during low tide may become mixed with infiltrating seawater during high tide. Section 10 validates the groundwater discharge pathway for each wetland.

Leaching of Contaminants to Surface Water

The significance and direction of sediment movement can generally be evaluated using appropriate geographical indicators. Partitioning of contamination from sediment to surface water is significantly less predictable. Contaminant mobility, both organic and inorganic, will to a great extent be governed by how strongly adsorbed they are to the sediment media. This adsorption is governed by a number of factors, including TOC, redox conditions in the sediment, porosity (both connected and closed), bulk density, temperature, pH and cation exchange capacity.

Organic partitioning is somewhat easier to treat, as the primary factor governing mobility is the fraction of organic carbon in the sediment: higher carbon content emphasizes contaminant adsorption. Inorganic adsorption is governed primarily by redox conditions as well as organic content: organic content provides adsorptive surface area, and the generally oxidizing conditions provide for inorganic oxide precipitation. However, anaerobic conditions can prevail, especially with depth within the sediment column, reducing inorganics and releasing them into pore water. Clearly, the mechanisms governing sediment to water partitioning are complex, and a screening tool is required for further analysis of sediment transport within the wetlands.

USEPA's *Soil Screening Guidance: Technical Background Document* (USEPA, 1996b), provides a basis for evaluating soil to groundwater cross-media transport. The process of sediment to surface water partitioning is governed by the same general principles. Therefore, this pathway analysis uses the principles presented in that document to derive quantitative Sediment Screening Levels (SSLs). The SSL is defined as a conservative concentration of a given parameter that has the potential to leach from sediment to surface water, resulting in a surface water concentration equal to or less than the surface water standard. The *Technical Background Document* (USEPA, 1996b), describes the theory behind the partitioning equation as well as considerations and limitations regarding the partitioning principles. The following describes the approach taken in this analysis is described below.

The partitioning equation is widely used to describe the transfer of constituents from a solid media to a liquid media. The equation is the basis for development of soil screening levels in USEPA (1996b). Its basic form is:

$$\text{Screening level} = \text{Target concentration (distribution coefficient [Kd] + water-filled porosity/dry bulk density)}$$

where:

Target Concentration	=	Surface water standard x dilution factor
Distribution Coefficient	=	Kd (normalized for organics using a fraction of organic carbon content of 0.127)
Water-filled porosity	=	20%
Dry Bulk Density	=	1.5 kilograms per liter (kg/L)

For this analysis, the target concentration used incorporates the USEPA or FDEP surface water standard for a given parameter. In vadose zone calculations for leachate dilution, standard USEPA procedure is to use a dilution/attenuation factor of 20 (USEPA, 1996b); this assumes leachate enters an aquifer matrix. However, the sediment to surface water pathway allows leachate to enter a volume of water devoid of matrix allowing a greater dilution. An aquifer with 20% porosity (a typical value) has approximately 80% of its mass as solid matrix; thus leachate is diluted only by the water residing in the remaining 20% porosity. Surface water, however, has no solid matrix allowing greater dilution. Assuming an aquifer matrix porosity of 20%, the comparative dilution for an equivalent mass of surface water is 100% (no solid matrix) versus 20% for the aquifer. This is an increase in dilutional capacity by a factor of five. Applying this increase to the standard dilution/attenuation factor of 20 used in vadose zone calculations results in a dilution factor of 100, a value that approximates the greater dilutional capacity of surface water. Therefore, for these calculations, the surface water standard is multiplied by 100 to account for the increased potential for leachate dilution.

Distribution coefficients are obtained from several sources; the preferred source is USEPA (1996b). Coefficients for organic constituents were normalized with respect to the measured TOC within each wetland; the calculated average for all sediment samples equates to a fraction organic carbon content that was used for that wetland. The water-filled porosity of sediment was assumed to be 20%, and a typical literature value of 1.5 kg/L was utilized for dry bulk density (USEPA, 1996b). In most cases, the distribution coefficients are of such high magnitude that porosity and bulk density are not critical to the resulting screening level.

The SSL calculated for each wetland is presented in Section 10 as part of the validation of this pathway. Only those contaminants which exceeded an SSV within the wetland are included.

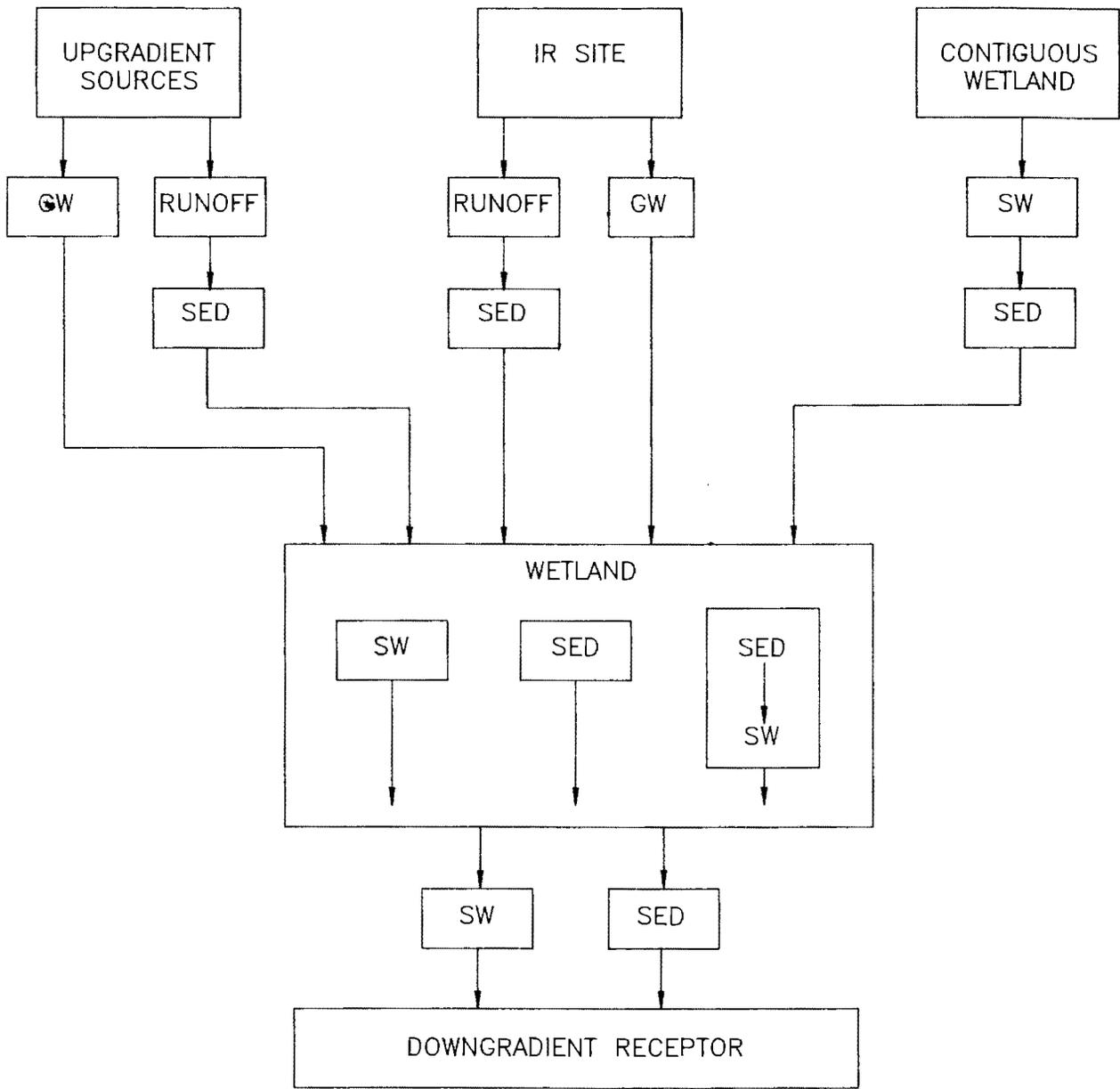
9.5.2 Sources

There are many sources of influx to the NAS Pensacola wetlands, including adjacent sites of environmental concern and adjacent areas of the base which contribute runoff. Table 9-2 provides a compilation of known or suspected sources for each wetland, accompanied by the presumed pathways for transport and pertinent remarks. Figure 2-1 shows the locations of wetlands and environmental sites.

9.6 Wetland Specific Fate and Transport

The wetland specific fate and transport evaluations will deal solely with the physical and chemical aspects of contaminant transport, and will be integrated with the data presented in Section 10. Figure 9-1 presents a conceptual model of the pathways that will be evaluated for each wetland. These include: surface water/sediment transport into the wetland, groundwater discharge into the wetland; surface water/sediment transport within the wetland, sediment leaching to surface water within the wetland; and surface water/sediment transport out of the wetland. Importantly, data for surface water flow, stormwater runoff, and sediment load is lacking: thus where these mechanisms are important pathway validation will be qualitative. To provide a focus for sediment contamination, only those constituents present above an SSV will be evaluated. For surface water, only those constituents above a surface water standard will be evaluated.

CONCEPTUAL MODEL OF TRANSPORT PATHWAYS NASP WETLANDS



LEGEND

- GW - GROUNDWATER PATHWAYS
- SED - SEDIMENT TRANSPORT
- SW - SURFACE WATER TRANSPORT



SITE 41 RI REPORT
NAVAL AIR STATION
PENSACOLA
PENSACOLA, FLORIDA

FIGURE 9-1
CONCEPTUAL MODEL OF
TRANSPORT PATHWAYS
NAS PENSACOLA WETLANDS

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**Table 9-2
 Known or Suspected Sources for Each Wetland**

Wetland	Associated Site(s) and/or Concerns	Transport Pathways	Remarks
64	OU2, OU6, OU10, Yacht Basin activities	SW, ST, GW, SL	Drainage from OU2; stormwater runoff from OU2, OU6 and Yacht Basin; Groundwater discharge from all sites. Sediment leaching from Yacht Basin contamination.
5	OU2	SW, ST, GW	Stormwater runoff and GW discharge from OU2.
3	Site 1	SW, ST, GW	Intermittent drainage from Site 1; GW discharge from Site 1.
4D	Site 15, Site 1, Site 40, Wetland 3	SW, ST, GW, SL	Drainage from Site 1 and Wetland 3; tidal drainage and sediment leaching from Site 40; GW discharge from Sites 1 and 15.
16 & 18	Site 1, Site 40	SW, ST, GW, SL	Tidal drainage, sediment leaching from Site 40; GW discharge from Site 1.
10 & 12	OU10, OU6	SW, ST	Runoff from southern portion of former IWTP, Bilgewater plant, and Chevalier Field.
W1	Site 3 (UST 18), Sherman Field	SW, ST, GW	Runoff from site and airfield; GW discharge from Site 3.
1	Site 16, Sherman Field, Site 1, Site 40, Site 7, Site 5, Site 22 (UST 26)	SW, ST, GW	Runoff and drainage from Site 16 and airfield; GW discharge from Sites 1, 7, 5, 22; GW mixing with Site 40.
15	Site 1, Site 40, Golf Course	SW, ST, GW	Runoff from Golf Course; GW discharge from Site 1 and mixing from Site 40.
6	OU2, OU6, Site 10, Chevalier Field	SW, ST, GW	Drainage from OU2; runoff from OU2, OU6, Site 10, and Chevalier Field; GW discharge from OU2 and OU6.
63A & 63B	Site 13, Site 14, Site 42, Chevalier Field	SW, ST, GW	Runoff from Chevalier Field, Site 13, and Site 14; GW discharge from Site 14; GW mixing from Site 42.
48, 49, 52	USTs S, O, X, Sherman Field	SW, ST, GW	Runoff from Sherman Field; GW discharge from UST sites.
13	OU10, Chevalier Field	SW, ST	Runoff from southern portion of former IWTP and Chevalier Field.

Table 9-2
 Known or Suspected Sources for Each Wetland

Wetland	Associated Site(s) and/or Concerns	Transport Pathways	Remarks
17	Site 1, Site 40	GW	GW discharge from Site 1; GW mixing from Site 40.
19	Sherman Field	SW, ST	Runoff from Sherman Field.
56	Site 39, Site 42	GW	GW discharge from Site 39; GW mixing with Site 42.
57 & 58	Site 4	GW	GW discharge from Site 4.
72	Sherman Field	SW	Runoff from Sherman Field.
W2	Site 5, Site 6, Site 16, Sherman Field	SW, ST, GW	Runoff from Sherman Field; GW discharge from Sites 5, 6, and 17.

Notes:

- SW = Surface Water
- ST = Sediment Transport
- GW = Groundwater Discharge
- SL = Sediment Leaching