3.0 SITE CHARACTERIZATION – HISTORICAL DATA, HABITAT CHARACTERISTICS, AND SPECIES POTENTIALLY PRESENT

3.1 Overview

This section provides a site history, physical description of the floodplain wetland near the former Raytheon facility, Wayland, Massachusetts and characterizes the general habitats and species potentially present at the site and nearby areas.

3.2 Site History – Former Industrial Operations

Prior to 1955, available information indicates that the property was utilized for agricultural and residential purposes. The Raytheon Company (Raytheon) facility operated from 1955 to 1995. The primary activities included research and development (R&D) for prototype electronic equipment, operation of a small circuit board laboratory, and operation of small-scale chemical processes in support of R&D. Dry and wet laboratory process included photographic developing, plating and etching circuit boards, machining, welding, woodworking, spray painting, conformal coat assembling, environmental protocol testing, hydraulic testing, radar and antenna transmitter testing, and transformer epoxy coating and baking. The industrial wastewater treatment plant (IWWTP) was installed and the associated NPDES permit was granted in 1975. The IWWTP processes consisted of neutralization and chemical precipitation. Precipitates were removed in sand filter beds. Sludge was collected in a sludge thickening tank and was removed by a metals scavenger. Refer to the main Phase II report (ERM, 2000) for additional process information.

3.3 General Characteristics

The study area is approximately 15 acres and is part of a floodplain wetland encompassing approximately 3,000 acres (including the Great Meadows National Wildlife Refuge) that is primarily influenced by water levels in the Sudbury River. This river originates in Cedar Swamp Pond and surrounding wetlands in Westborough, Massuchusetts, 18 miles to the west, before flowing east to Ashland, then north through Wayland, and on to its confluence with the Assabet River. In Ashland, the Sudbury River passes by the Nyanza Superfund site, and then flows through two major impoundments, which are reserve water supplies controlled by the Metropolitan District Commission. The river then bends northeasterly where it is impounded by the Saxonville Dam.

The watershed of the river upstream of the study area is roughly 70,000 acres in size, with altitudes ranging from about 480 ft in the headwaters area of the Sudbury River to about 420 ft in the headwaters area of the Assabet River. Average flow rates above the study area at the Saxonville Dam average 220 cubic feet per second (cfs) (USGS data). Snake Brook and Hayward Brook, located upstream of the Study Area, contribute on average approximately 50 cfs and 6 cfs, respectively. In the study area, the Sudbury River has a stream gradient of approximately 1 foot per 12 miles (Bickford and Dyman 1990).

One notable physical feature of the study area (site) is a drainage swale that has changed in character over time. For example, prior to installation of the industrial wastewater treatment plant (IWWTP), there was not a well-defined drainage swale. In earlier aerial photographs, there is a resemblance of the wetland near the outfall to a "bird's foot delta" that likely represents the primary depositional environment before installation of the IWWTP. As the volume of effluent discharged following installation of the IWWTP increased, there was a notable presence of a more defined channel over time.

3.4 Habitat Characteristics

The floodplains in the study area are periodically inundated, usually during high flows in the spring and following major storm events. Regular inundation by riverine floodwaters keeps most of the floodplain from developing into a forested or scrub-shrub wetland. Based on field visits conducted when the site was partially flooded and flooded, the site was estimated to be inundated when flow exceeds 254 cfs at a United States Geological Survey (USGS) gauging station number 01098530 on the Sudbury River near Saxonville, Massachusetts which is located upstream of the site (Appendix A; Woodlot Alternatives, Inc., 2000). Data available from 1979 to current indicate that inundation of the site has occurred approximately 29% of the time (data not shown). Over the last five years, for example, the site has typically been inundated from approximately February to early May, with occasional, short-duration periods of inundation throughout the year following substantial rain events (Figure 3-1 and Figure 3-2). Emergent wetlands dominate the site, although pockets of scrub-shrub wetland also occur. For descriptive purposes, the study area can be classified into four communities: Low Gradient Stream Community (*i.e.* the Sudbury River), Deep Emergent Marsh Community, Shrub Swamp Community, and Alluvial Red Maple Swamp Community. These communities were mapped as part of an ecological survey that was conducted at the site (refer to Appendix A for more details including maps and photographs).

3.5 Sediment and Wetland Soil Characteristics and Definitions

Sediments and soils are typically very distinct from each other based, in part, on differences in physical characteristics, functions, and influences on fate and transport and exposure pathways for COPECs. However, for a wetland such as this site, in which the site is periodically inundated but then not covered with water for substantial amounts of time each year, the definitions and distinctions for sediments and soils are less distinct.

The MCP (310 CMR 40.0006 and MCP Chapter 9, p. 9-92) gives the following definition for sediment:

> *Sediment means all detrital and inorganic matter situated on the bottom of lakes, ponds, streams, and rivers...Sediments are found...below the upper boundary of a bank, as defined in 310 CMR 10.54(2) which abuts and confines a water body. All other unconsolidated earth in wetlands, including the 10 year floodplain, is considered soil.*

In addition, the MCP recognizes the distinction of sediments that are permanently flooded versus those that are not. For example, the MCP states that equilibrium partitioning methods are only applicable at sites that are permanently flooded (MCP Chapter 9, p. 9-94). For the purposes of this ERC, sediments at this site are defined as those portions of the site that are permanently flooded or are flooded for most of the time with little to no emergent vegetation present. These locations are generally located in and near the drainage swale that traverses the site.

It is important to note that intermittently flooded and relatively dry soils in a wetland have significantly different ecological functions compared to sediments. Furthermore, chemical fate, transport, and availability is significantly different between wetland soils and true sediments. USEPA acknowledges in recent guidance (USEPA, 2000a; Section 7.6 Site-Specific Considerations for Wetlands) that it is important to distinguish wetland soils from wetland sediments. USEPA recommends consideration of the regularity, depth, and duration of flooding as well as the presence or absence of emergent vegetation in making the determination. If the soils are flooded enough to qualify as sediments and are not vegetated with emergent species, then Ecological Soil Screening Levels (Eco-SSLs) should not used (USEPA, 2000a). However, at this site there are large areas of soils that are non-inundated for a considerable portion of the year and these areas are vegetated with emergent species. Thus, significant portions of this site are classified as wetland soil which, for the purposes of the ERC at this site, is defined as soil that

supports emergent vegetation and is typically non-inundated (although it can be moisture-saturated to relatively dry) for substantial amounts of time each year.

This distinction between sediment and soil is important not only for consideration of fate and transport characteristics, but also in the determination of exposure pathways (see Sections 4.3.2 and 4.3.3), screening-level benchmarks (see Sections 6.2.3 and 6.2.4), and selection of potential ecological receptors (see Sections 7.3 and 7.7). For example, since this site fluctuates between inundation and non-inundation, the habitat is not likely to be suitable for terrestrial invertebrates (e.g., earthworms).

3.6 Species Present or Potentially Present at the Site

An ecological characterization was conducted by Woodlot Alternatives, Inc., to identify the animals, particularly insectivorous and herbivorous species, which may be found in the study area during different times of the year. A literature review was first conducted to identify species likely to be present in, or near, the study area, and then field surveys were performed to verify the occurrence of required habitats and the presence of individual species. Information on the distribution, natural history, and habitat requirments of birds in eastern Massuchusetts was collected from Brewster (1906), Griscom (1955), Veit and Peterson (1993), and from the survey conducted by Woodlot Alternatives, Inc. A matrix of reptiles and amphibian species that could occur within the study area was prepared using local and regional literature on species distributions and their habitat requirements (Conant 1986, Hunter *et al.* 1992, Degraaf and Rudis 1986, Ernst *et al.* 1994). For all groups of animals, a matrix (Appendix A) was prepared listing the species present (or potentially present), relative abundance during each season, state and federal status, use by study area habitat, and special habitat needs. The overall results of this ecological survey and a review of relevant literature illustrate that the habitats and biota are qualitatively similar to surrounding wetlands, including the Great Meadows National Wildlife Refuge.

Floodplain wetlands in and near the study area provide habitat for a wide variety of birds, mammals, and amphibians and reptiles including an estimated 274 total number of species, including birds (193), mammals (42), reptiles and amphibians (24), and fish (15). Species expected to be most common in the floodplain include tree swallow (*Tachycineta bicolor*), barn swallow (*Hirundo rustica*), American crow (*Corvus brachyrhynchos*), American robin (*Turdus migratorius*), European starling (*Sturnus vulgaris*), common yellowthroat (*Geothylpis trichas*) song sparrow (*Melospiza melodia*), swamp sparrow (*Melaspiza georgiana*), red-winged blackbird (*Agelaius phoeniceus*), common grackle (*Quiscalus quiscula*), mallards (*Anas platyrhynchos*), muskrat (*Ondatra zibethica*), meadow vole (*Microtus pennsylvanicus*), raccoon (*Procyon lotor*), green frog (*Rana clamitans*), northern leopard frog (*Rana pipiens*), and common garter snake (*Thamnophis sirtalis*).

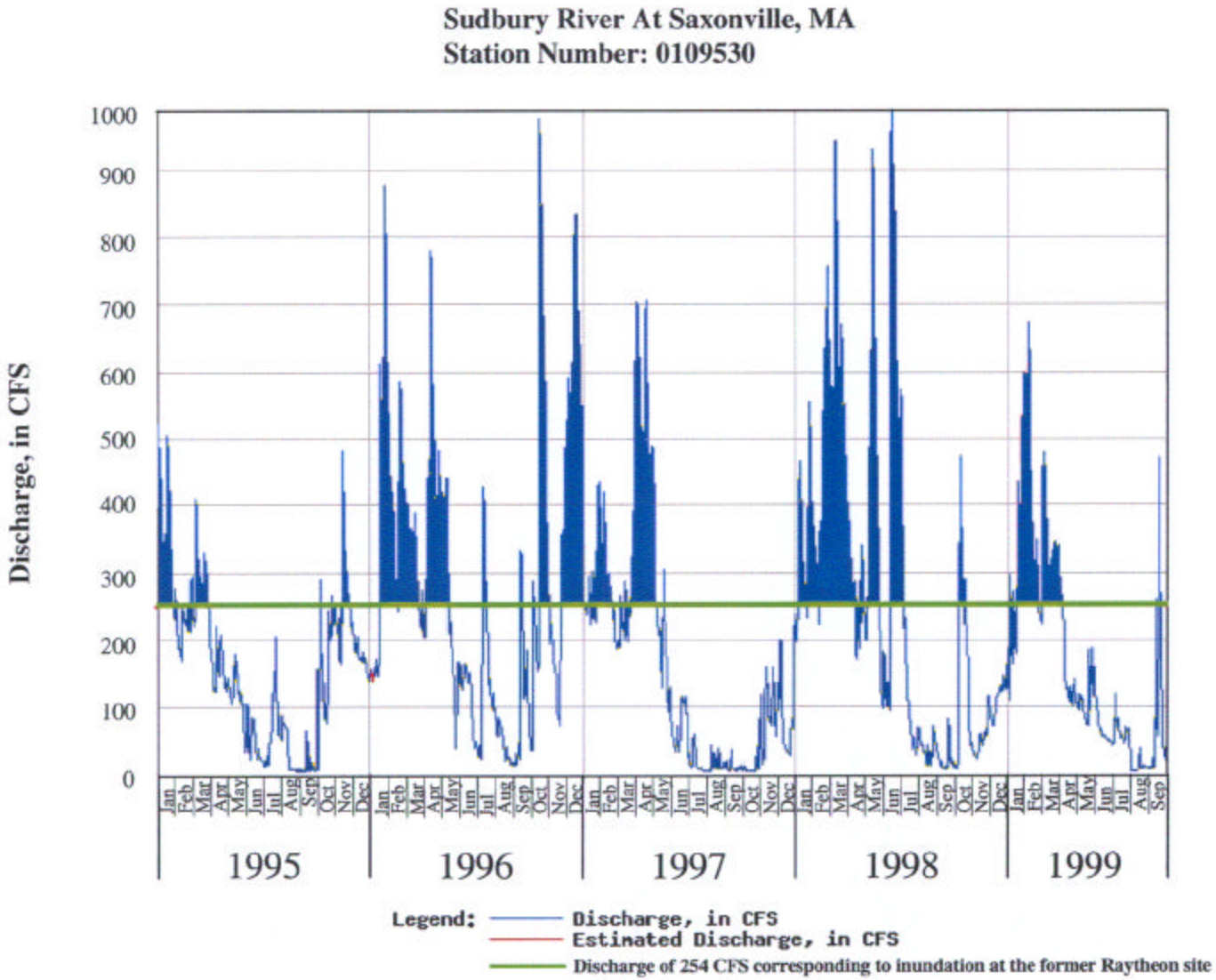

Figure 3-1. Streamflow data in cubit feet per second (cfs) from USGS gauging station number 01098530 on the Sudbury River in Saxonville, Massachusetts over the years 1995-1999. Shaded areas of the graph represents flow rates that are greater than 254 cfs which corresponds to periods of inundation of the wetlands near the former Raytheon facility in Wayland, Massachusetts.

Typical "low-flow" or non-inundated condition (photo taken on 6/28/70)

Typical "high-flow" or inundated condition (photo taken on 3/25/68)

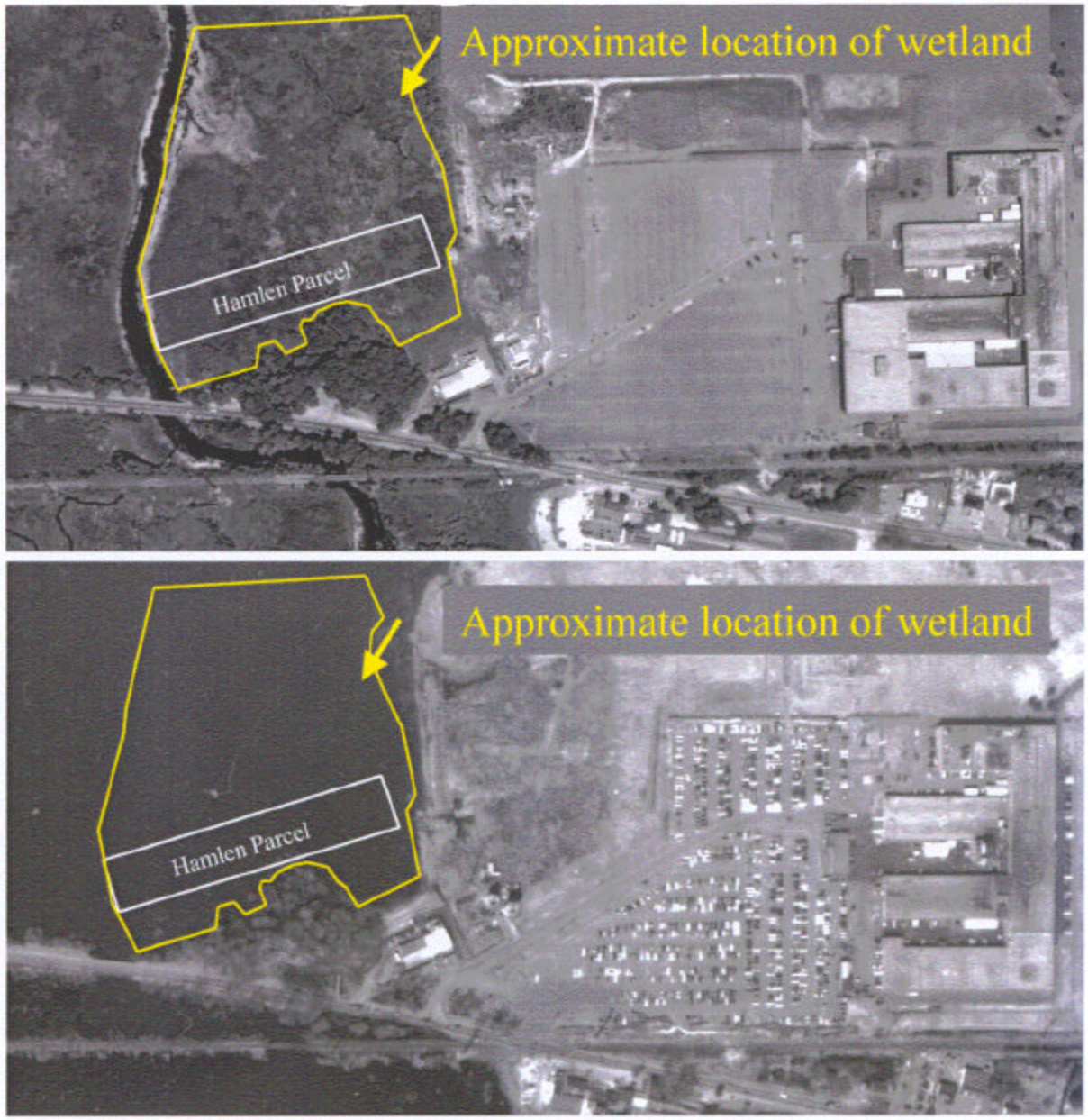

Figure 3-2. Aerial photographs of site depicting "low-flow and "high-flow" conditions for the Sudbury River.

3.6.1 Plants

The study area is dominated by floodplain wetland communities including deep emergent marsh, low gradient stream, shrub swamp, and floodplain forest, which are regularly inundated by water during storm events and spring run-off. Deep emergent marsh accounts for approximately eighty-eight percent of the wetland habitat. The deep emergent march community is dominated by several plant species growing in patches including broad-leaved cattail (*Typha latifolia*), purple loosestrife (*Lythrum salicaria*), common reed (*Phragmites australis*), reed canary grass (*Phalaris arundinacea*), and river bulrush (*Bolboschoenus fluvialtilis*). The shrub swamp community is dominated by buttonbush (*Cephalanthus occidentalis*) and silky dogwod (*Cornus amamum*). One species of rare plant (refer to Appendix A for details), the river bulrush (*Bolboschoenus fluviatilis*), was observed in the study area primarily along the edge of the Sudbury River. Several other rare plants could potentially occur in or near the study area but were not observed on the site. These include Long's bulrush (*Scirpus longii*), slender water-milfoil (*Myriophyllum alterniflorum*), and many-fruited false loosestrife (*Ludwigia polycarpa*) (refer to Appendix A for more details).

Within the deep emergent marsh community is an area of stunted vegetation which consists primarily of cattails. This area generally coincides with the area of greatest concentrations of chemicals in the wetland soils.

3.6.2 Birds

One hundred ninety-one bird species could occur in the study area at some time of the year (Appendix A). The study area and the much larger surrounding Great Meadows National Wildlife Refuge provide habitat for feeding, breeding, nesting, and migratory activities for many species of waterbirds and landbirds. The robust emergent marsh and shrub swamp provides nesting habitat for wetland dependent species including red-winged blackbirds (*Agelaius phoenicus*) and swamp sparrows (*Melospiza georgiana*). Two raptors, the red-tailed hawk (*Buteo jamaicensis*) and northern harrier (*Circus cyaneus*) were observed adjacent to the study area during surveys in October, 1999.

3.6.3 Mammals

Forty-two species of mammals may occur in, or near, the study area (Appendix A). However, it is unlikely that all of these animals would use the study area regularly, based on the habitat present and individual life history characteristics. One muskrat (*Ondatra ziebethicus*) and signs of deer were observed in the drainage swale during field surveys. In addition, during a previous site investigation, meadow voles (*Microtus pennsylvanicus*) and meadow jumping mice (*Zapus hudsonius*) were captured (Eaton and Carr 1991).

Of the mammals that may occur on site, insectivorous species that may be common would include short-tailed shrew (*Blarina brevicaudata*), masked shrew (*Sorex cinereus*), star-nosed mole (*Condylura cristata*), and white-footed mice (*Peromyscus leucopus*). However, none of these species would be expected to spend significant amounts of time in the regularly inundated or saturated parts of the study area because they prefer upland habitat (Whitaker and Hamilton 1998), which is adjacent to, but not in, the study area. These species may make foraging forays into the shrub swamp or emergent wetland, but because these habitats are periodically flooded, animals in the floodplain would be expected to flee as water levels rise during flood events.

3.6.4 Reptiles and Amphibians

Twenty-four species of reptiles and amphibians could potentially occur within the study area including nine snakes, eight frogs or toads, five turtles, three salamanders, and one newt (Appendix A). Of the 24 species that potentially occur, the northern leopard frog (*Rana pipiens*), green frog (*Rana clamitans*),

snapping turtle (*Chelydra serpentina*), and painted turtle (*Chrysemys picta*) were observed. Six turtle nests were observed near the radio tower in the upland next to the floodplain. Leopard frogs and green frogs are likely to breed in the study area. Leopard frogs lay their eggs in April and May among vegetation in shallow water. The eggs hatch in 13-20 days and metamorphosis occurs 60-80 days after hatching. Leopard frogs are semi-terrestrial, spending summer months in meadows and damp wooded areas. Green frogs breed from May to August, and their eggs hatch within 5 days.

3.6.5 Fish

Fifteen species of fish may occur in, or near, the study area (Appendix A). The timing of inundation of the wetlands coincides with spawning times of four species that could potentially spawn in the study area including chain pickerel (*Esox niger*), redfin pickerel (*Esox americanus* ssp. *americanus*), northern pike (*Esox lucius*), and yellow perch (*Perca flavescens*). These species deposit their eggs over submerged vegetation in early spring. Other species that may feed in the study area, but would likely spawn in or along the main channel of the Sudbury river include common carp (*Cyprinus carpio*), golden shiner (*Notemigonus crysoleucas*), white sucker (*Catostomus commersoni*), creek chubsucker (*Erimyzon oblongus*), brown bullhead (*Ameiurus nebulosus*), white perch (*Morone americana*), largemouth bass (*Micropterus salmoides*), pumpkinseed sunfish (*Lepomis gibbosus*), bluegill sunfish (*Lepomis macrochirus*), banded sunfish (*Enneacanthus obesus*), and black crappie (*Pomoxis nigromaculatus*).

3.6.6 Rare, Threatened, and Endangered Species

One of the 12 potentially occurring rare, threatened, and endangered animals in, or near, the study area was documented during the October 1999 field surveys. This was the northern harrier, a state-listed threatened species, which was observed during the species traditional migration period, and it is expected that the observed individual was indeed undertaking migrational movements. As mentioned previously, one species of rare plant was observed on site, the river bulrush. Approximate locations of the river bulrush are adjacent to the Sudbury River in shrub swamp and deep emergent marsh communities (Figure 3-3).

Figure 3-3. Location of natural communities, area of stunted vegetation, and River Bulrush (rare plant species) at the wetlands near the former Raytheon facility, Wayland, Massachusetts. (Map designed by Woodlot Alternatives, Inc.)

aluminum, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc.

The data presented in this USFWS report are the only usable data set that was identified that measured chemical concentrations at points upstream and downstream of the former Raytheon facility along the Sudbury River. Furthermore, this is the only identified data set that measured chemical concentrations in fish, birds, and mammals in this region. The primary use of this data set is to distinguish between the potential for biologically significant harm associated with local or regional conditions as opposed to those potentially attributable to the site. There was one other source of data that evaluated upstream and downstream surface water concentrations. Surface water data (one sample collected from upstream and one from downstream from the site) was collected in the Sudbury River by ERM in 1990. Of the COPECs to be evaluated at this site, only copper and zinc were measured in these two samples. The concentrations of copper and zinc were not detected in either sample and the detection limits for copper were greater than its respective national ambient water quality criteria.

The distribution of concentrations of chemicals in the river sediments (particularly PCBs, PAHs, mercury, lead, cadmium, and chromium), indicate there are several major sources of these residues within the USFWS study area. Heavy metals appear to be distributed throughout the river system with some notable trends. Elevated concentrations of mercury, arsenic, lead, cadmium, and chromium were observed in sediments at station SU2 (refer to Appendix C for a map that includes the location of this sample). These elevated concentrations may be attributable to the Nyanza Superfund site located a short distance upriver. Other point sources that were identified based on elevated concentrations of chemicals in sediment samples were the wetlands near the former Raytheon facility and the Wayland landfill site. Sediment data from the USFWS report were utilized later in this ERC (refer to the Stage I Screening-Level ERC in the assessment of local conditions).

Sampling of biota was not as extensive as that for sediment in the USFWS report. However, the data are useful to evaluate bioavailability and regional trends. Three species of fish were analyzed from locations upstream and downstream of the site throughout the entire Sudbury, Assabet, and Concord watershed in 1986 and 1987. Elevated concentrations of heavy metals were not found in fish, "although the concentrations of mercury, and potentially lead, may be approaching levels worthy of concern." However, none of the fish sampled were found to contain greatly elevated concentrations of mercury or lead (mean = 0.32 mg/kg and 0.37 mg/kg, respectively). These values are greater than the geometric mean for mercury and lead concentration of 0.10 mg/kg (for both mercury and lead) in fish collected as part of the National Contaminant Biomonitoring Program (Schmitt and Brumbaugh, 1990). Concentrations of arsenic and cadmium in fish were 0.06 and 0.03 mg/kg, respectively, compared to concentrations of arsenic and cadmium of 0.14 and 0.03 for collected as part of the NCBP (Schmitt and Brumbaugh, 1990). Thus, the USFWS report concluded that the concentrations of heavy metals in fish in the Sudbury River are less than concentrations of concern with the possible exception of mercury which is potentially posing a risk to piscivorous birds and mammals. Fish sampled in 1986 and 1987 harbored concentrations of PCBs between 2 and 4 mg/kg, whole body at locations from the Cedar Swamp Pond near the headwaters of the Sudbury River to the confluence with the Assabet River. The greatest concentrations of PCBs in fish (6.62 mg/kg) were found at Heard Pond which is upstream of the former Raytheon facility. Thus, PCB contamination of fish appears to be elevated in the late 1980s throughout the watershed.

Small mammals were found to contain small concentrations of heavy metals, with slightly elevated concentrations of chromium and lead at some stations sampled in 1987. Concentrations of PCBs in small mammals from the wetlands near the former Raytheon facility were non-detectable (detection limit = 0.05 mg/kg) and concentrations of metals were small. Red-winged blackbird eggs were collected from four locations in the Sudbury River watershed. Since PCB concentrations (1.5 – 6.0 mg/kg) were detected in eggs at all locations and since red-winged blackbirds are migratory, the USFWS report concluded that "it

is likely that some of the PCB burden in the red-winged blackbirds is attributable to general 'background' accumulation from locations other than the Sudbury River".

4.2.2 ERM and ENTRIX Data

4.2.2.1 Phase I Data

The primary data sets that were considered in the development of this ERC are those collected by ERM and ENTRIX on behalf of Raytheon. The data used throughout this ERC for the calculation of exposure point concentrations are from sampling efforts conducted during the Fall, 1998 through Spring, 2000. The sampling was conducted in phases in which the initial phase (Phase I) was to attempt to confirm previous USFWS data that showed elevated concentrations of PCBs and some metals in the sediments and wetland soils at the site. Data collected in Phase I sampling focused on wetland sediment and soil samples from transects surrounding the drainage swale that traverses the wetlands portion of the site whereas data collected in Phase II focused on wetland soils, vegetation, and surface water (Figures 4-1 to 4-3). Measured parameters are listed in Table 4-2. Additionally, a subset of samples was analyzed for PCB congeners by Michigan State University to determine the potential analytical bias between older, less discriminatory Aroclor-based analytical methods and more current congener-specific methodology (MSU-ATL, 1999). Based on these data, an initial Stage I screening-level ERC was conducted for some of the potential chemicals of concern.

Table 4-2. Parameters measured during Phase I sampling by ERM for consideration in the ERC.

Matrix	Parameter
Sediment/Wetland Soil	Chromium, copper, and lead
	PCBs – Aroclor analysis
	PCBs – congener-specific (subset of samples)
	Organic carbon (subset of samples)

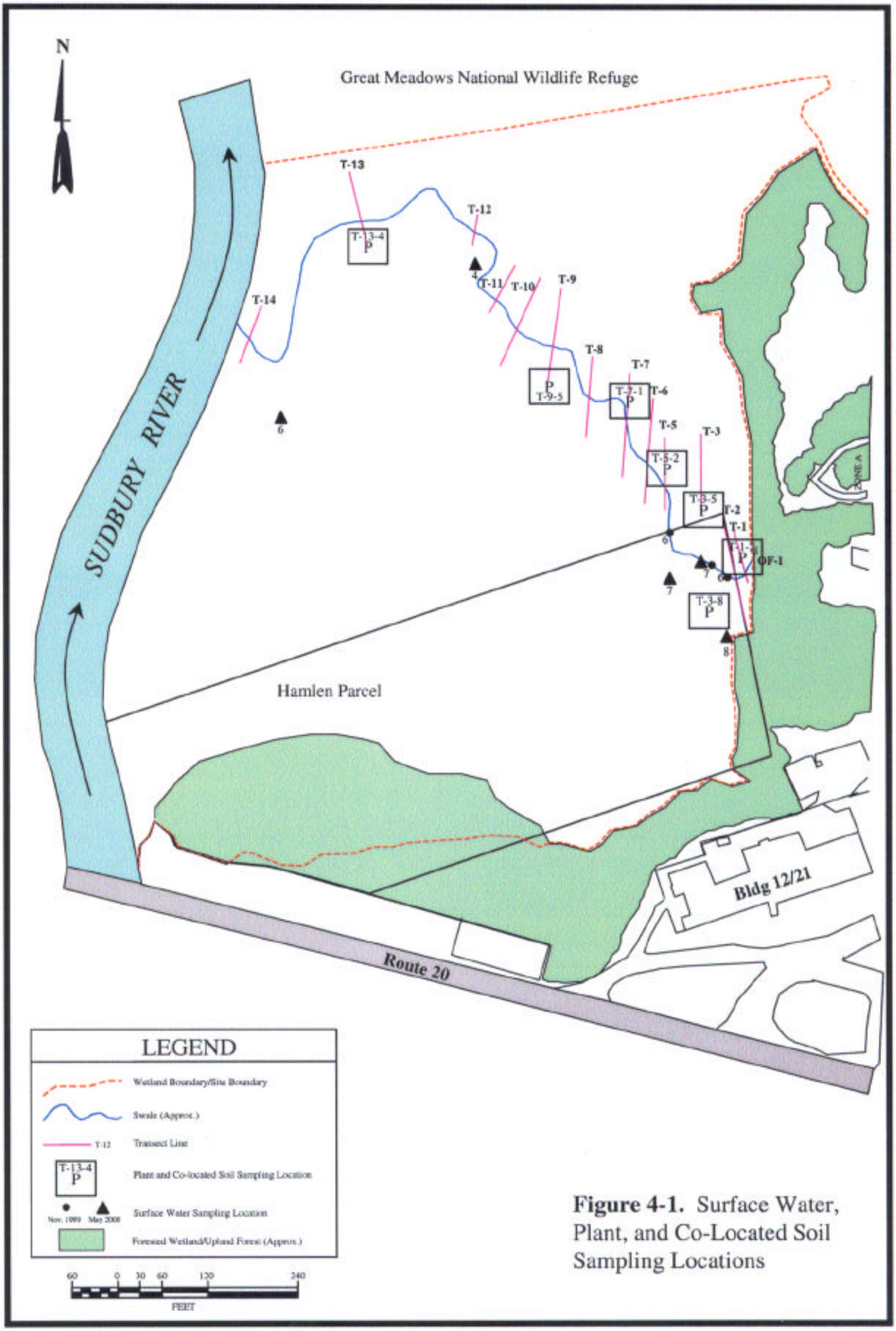

Figure 4-1. Surface Water, Plant, and Co-Located Soil Sampling Locations

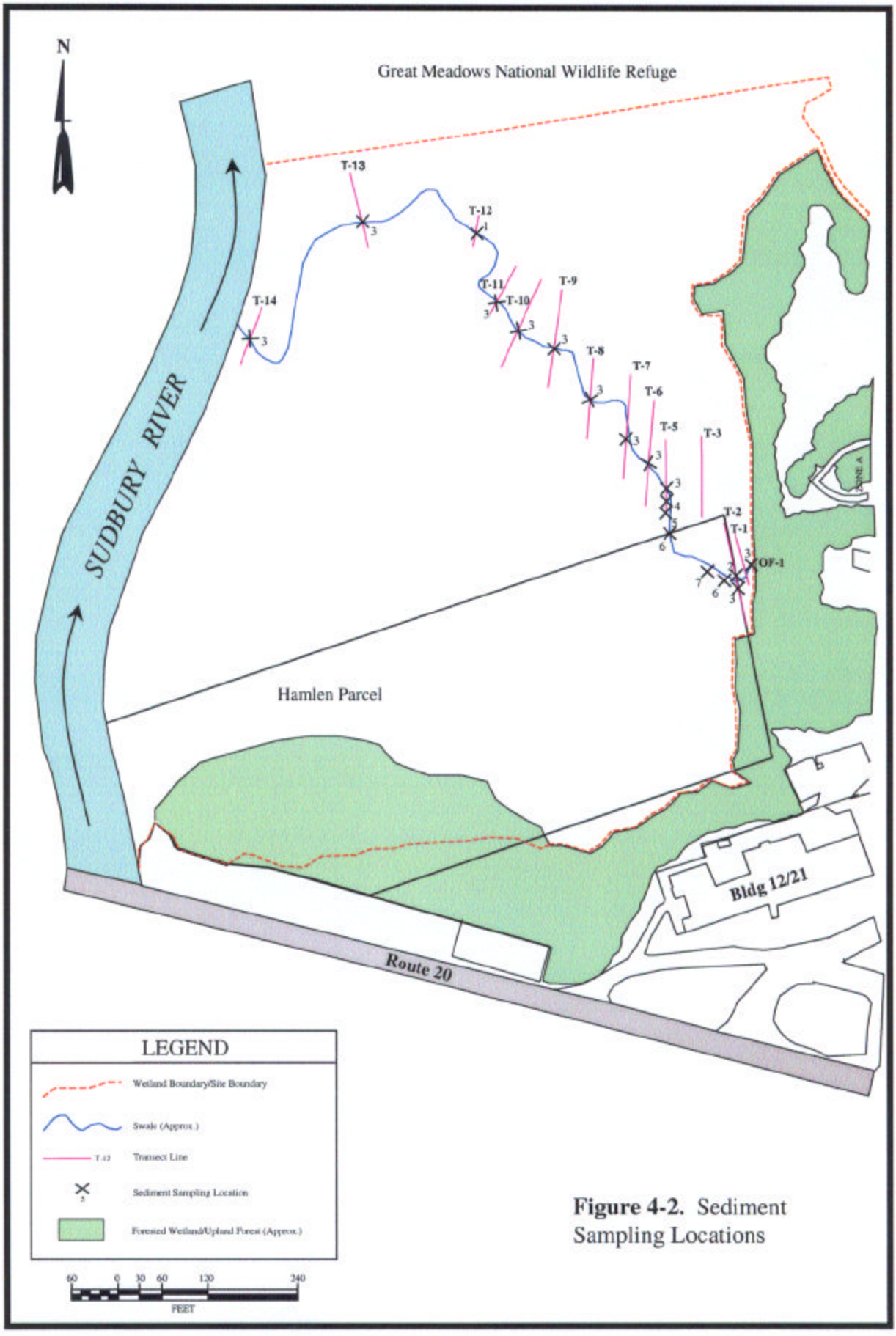

Figure 4-2. Sediment Sampling Locations

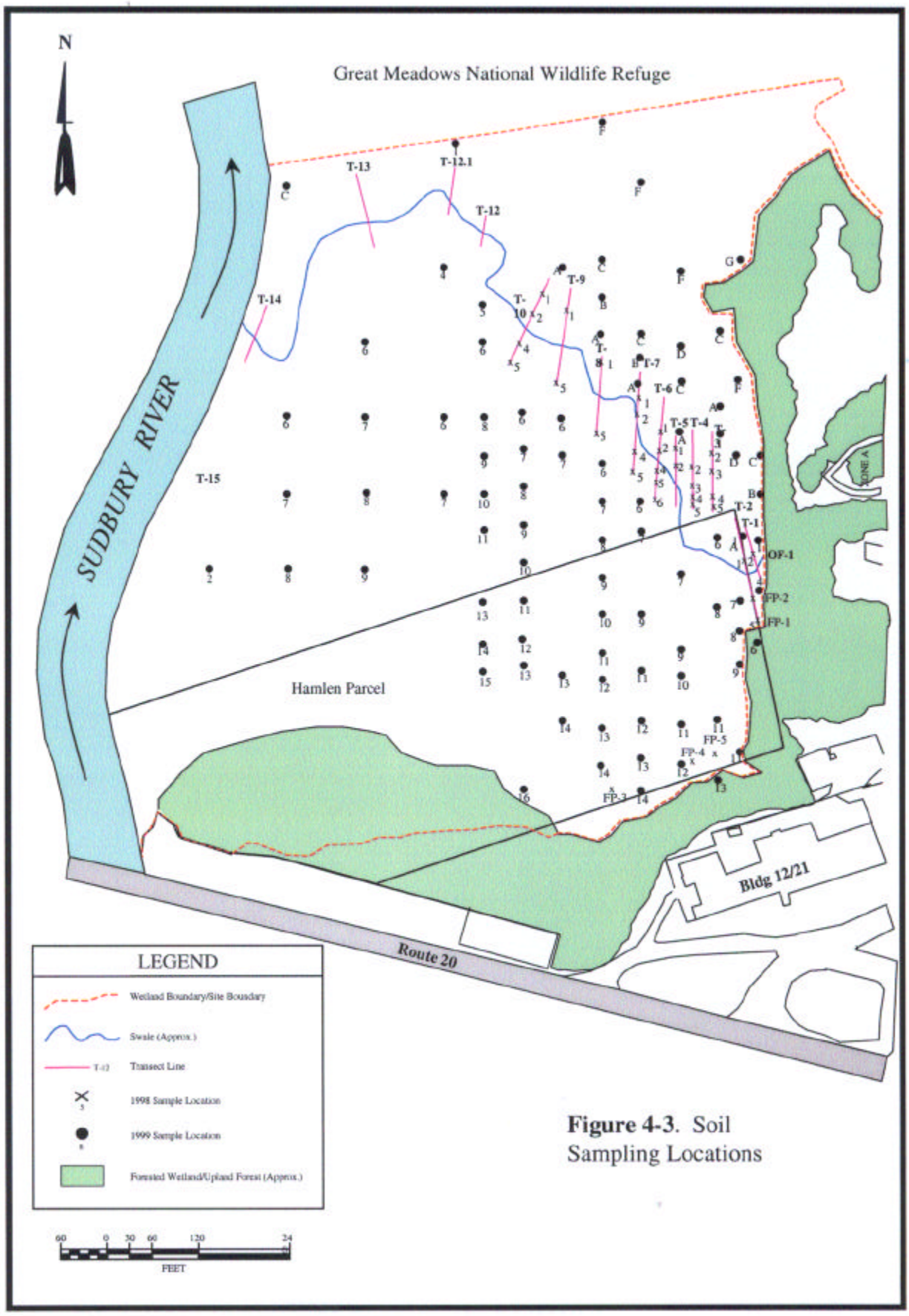

Figure 4-3. Soil Sampling Locations

4.2.2.2 Phase II Data

Phase I recommendations for further Phase II sampling and analysis (Table 4-3) were based on: 1) the results of previous analyses to determine the nature and extent of chemicals at the wetland portion of the site; 2) identification of data gaps; 3) consideration of human health issues (presented elsewhere); and 4) the results of a Stage I screening level environmental risk characterization, indicating the need for a Stage II environmental risk characterization for PCBs, chromium, copper, and lead. PCB data consists of concentrations of total PCBs based on Aroclor analysis for all samples and a congener-specific PCB analysis (MSU-ATL, 1999) for a subset of samples. In an effort to reduce uncertainty in exposure modeling, Phase II sampling focused on likely exposure pathways to ecological receptors including dietary items and exposure media. Attempts to collect earthworms and other terrestrial invertebrates yielded inadequate sample mass for chemical analysis. The primary reason stated for not finding adequate sample masses of earthworms and other invertebrates was habitat (ground saturation at time of sampling) and the season of the year in which sampling took place (late October, 1999) (Woodlot Alternatives, 2000). Data collected for specific exposure pathways included surface water (collected at different times of the year and at different water levels), co-located soil and edible portions of two plant species, cattails (*Typha latifolia*) and buttonbush (*Cephalanthus occidentalis*). Specifically, roots of cattails (tubers), which are often consumed by wildlife such as muskrats and deer, and the seedheads from buttonbush, which are often consumed by wildlife such as waterfowl were collected from several locations at the site (along a gradient of chemical concentrations) and analyzed for metals and PCBs.

The selection of non-chemical-parameters measured in Phase II (Table 4-3) was based on the ability of these parameters to affect toxicity or bioavailability of the potential chemicals of concern. For example, in wetland soils, pH, concentration of organic carbon, soil type, and cation exchange capacity are important parameters to assess the relative bioavailability of COPECs. Also, grain size distribution is a physical parameter that may affect the chemical sorption capacity of soils. All else being similar, particles of smaller grain size typically have greater surface area, and thus, greater sorptive capacity. For surface water samples, hardness is an important parameter since water quality criteria and toxicity for several metals are directly dependent on hardness. Similarly, concentrations of dissolved organic matter (DOM) in surface water samples were measured since DOM is known to affect bioavailability of certain COPECs (discussed in more detail in Section 9.0 on Stage II ERC – Analysis - Effects Assessment). Likewise, total organic carbon (TOC) in sediments is an important parameter to assess the bioavailability of neutral organic chemicals and some metals to biota.

Table 4-3. Parameters measured by Phase II sampling by ERM and ENTRIX for consideration in the ERC.

Matrix	Parameter/Analytes
Sediment/Wetland Soil	• **Total organic carbon** • **Grain size analysis** • **Percent sand, silt, and clay** • **Metals** - Aluminum, Antimony, Arsenic, Barium, Beryllium, Cadmium, Calcium, Chromium (Cr3+), Chromium (Cr6+), Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Nickel, Potassium, Selenium, Silver, Thallium, Tin, Vanadium, and Zinc • **Priority Pollutant Polycyclic Aromatic Hydrocarbons (PAHs)** – total PAHs, Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benz[a]anthracene, Chrysene, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene, Benzo[g,h,i]perylene, Dibenzo[a,h]anthracene, Indeno[1,2,3-cd]pyrene • **PCBs** – Aroclor analysis • **PCBs** – congener-specific (subset of sediment and wetland soil samples)
Surface Water	• **General water quality parameters** (pH, alkalinity, ammonia, dissolved oxygen, hardness, total suspended solids, specific conductance, and temperature) • **Metals (as listed above)** • **PAHs (as listed above)** • **PCBs** – congener-specific
Biota (plants) and Co-located soil	• **Lipid** (plants) and **organic carbon** (soil) • **Metals** (as listed above) • **PCBs** – congener-specific

4.2.3 Woodlot Alternatives Ecological Survey

Woodlot Alternatives conducted two ecological surveys (October, 1999 and May 2000), and assisted with plant and co-located soil sample collection. In these reports, the natural communities, including representative and observed flora and fauna, are described (refer to section 3.0 for a summary presentation and Appendix A for the full report). Based on the survey results, the wetland habitats and biota near the former Raytheon facility are consistent with wetland habitats and biota in the adjacent Great Meadows National Wildlife Refuge. Furthermore, the survey results were utilized to develop a site-specific conceptual site model (including identification of the exposure pathways and receptors of concern) and select assessment endpoints (refer to section 7.0 Stage II ERC Problem Formulation for more details).

4.3 Nature and Extent of Chemical Concentrations in Each Matrix

For reasons described later in this assessment (Section 6.1), part of the site has been defined as an "Area of Readily Apparent Harm". The summary tables for the nature and extent of chemical concentrations in each matrix (surface water, sediments, wetland soil, and vegetation) are presented separately in this section for: (1) the entire site including the "Area of Readily Apparent Harm" refer to as "sitewide" and (2) the areas outside of the "Area of Readily Apparent Harm".

4.3.1 Surface Water

Chemical concentrations in water collected from the site in 1999 and 2000 are summarized in Tables 4-4 and 4-5 (low flow or non-inundated) and Tables 4-6 and 4-7 (high flow or inundated) and Appendix B. Sample locations for surface water (Figure 4-1) were identified along a chemical concentration gradient in the soils/sediments. Samples have been collected within the area of concern from November 1999 through October 2000. Concentrations of PAHs, PCBs, and metals (dissolved) were generally lower across the site in samples collected during times of inundation compared to samples collected during non-inundated conditions. While background samples are not available for comparison, samples collected at locations that are proximal to the Sudbury River (*e.g.*, location T-14-6) at times of inundation are thought to be representative of local conditions with minimal site-related impacts from the areas of concern. Concentrations of residues generally decrease at locations closer to the Sudbury River and further from the outfall (OF-1) (Figure 4-4). Elevated concentrations of COPECs were measured at the outfall (OF-1) in October 2000 (Table 4-8). General water quality parameters were collected in October 2000 for all samples collected in the drainage swale (Table 4-9).

Table 4-4. Site-wide (including the Area of Readily Apparent Harm) concentrations of organic and inorganic residues in surface water samples collected in November 1999 and October 2000 during conditions of low flow.

	Chemical Concentration (µg/L)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	65.1	70.5	114	39.3	10.0	210	8
Antimony	1.92	0.87	2.52	1.66	0.55	2.50	8
Arsenic	4.21	6.64	8.81	2.26	0.72	20.5	8
Barium	43.6	21.6	58.5	39.2	21.9	76.0	8
Beryllium	0.17	0.11	0.25	0.11	0.01	0.25	8
Cadmium	1.57	1.45	2.57	1.12	0.54	4.00	8
Chromium (Cr3+)	4.50	4.70	7.76	2.64	0.50	15.0	8
Chromium (Cr6+)	2.50[A]	0	2.50[A]	2.50[A]	2.50[A]	2.50[A]	5
Cobalt	2.91	1.74	4.12	2.49	1.20	5.90	8
Copper	92.8	92.0	157	68.3	21.0	310	8
Iron	451	432	750	318	90.1	1410	8
Lead	1.49	0.96	2.15	1.17	0.25	3.10	8
Manganese	558	443	865	385	110	1100	8
Mercury	0.07	0.05	0.10	0.05	0.01	0.10	8
Nickel	13.0	4.0	15.8	12.5	8.00	19.6	8
Selenium	0.91	0.48	1.24	0.74	0.22	1.25	8
Silver	0.33	0.21	0.48	0.28	0.08	0.75	8
Thallium	0.17	0.11	0.25	0.13	0.03	0.25	8
Tin	7.92	3.24	10.2	6.80	1.25	10.0	8
Vanadium	1.37	0.30	1.57	1.35	1.25	2.10	8
Zinc	293	99.9	362	278	170	447	8
Hardness (mg/L)	122.4	28.1	141.9	119.6	91.0	160.0	8
PAHs							
Acenaphthene	0.067	0.047	0.120	0.048	0.013	0.100	3
Acenaphthylene	0.015	0.009	0.025	0.013	0.006	0.024	3
Anthracene	0.046	0.021	0.070	0.042	0.023	0.064	3
Benz[a]anthracene	0.145	0.078	0.233	0.129	0.065	0.220	3
Benzo[b]fluoranthene	0.282	0.182	0.488	0.235	0.097	0.460	3
Benzo[k]fluoranthene	0.105	0.067	0.181	0.088	0.036	0.170	3
Benzo[a]pyrene	0.172	0.117	0.304	0.141	0.057	0.290	3
Benzo[g,h,i]perylene	0.165	0.108	0.287	0.135	0.054	0.270	3
Chrysene	0.217	0.140	0.375	0.179	0.071	0.350	3
Dibenzo[a,h]anthracene	0.033	0.021	0.056	0.026	0.009	0.046	3
Fluoranthene	0.477	0.281	0.795	0.408	0.180	0.740	3
Fluorene	0.030	0.020	0.053	0.025	0.010	0.050	3
Naphthalene	0.011	0.007	0.019	0.010	0.006	0.019	3
Phenanthrene	0.229	0.132	0.379	0.193	0.077	0.320	3
Pyrene	0.303	0.186	0.513	0.257	0.110	0.480	3
Total PCBs	0.023	0.018	0.043	0.019	0.010	0.043	3

NA – Not analyzed.
[A]The chemical was not detected and one-half the detection limit is reported.

Table 4-5. Concentrations of organic and inorganic residues in surface water samples from outside the "Area of Readily Apparent Harm" collected in November 1999 and October 2000 during conditions of low flow.

	Chemical Concentration (µg/L)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	45.5	29.0	85.7	40.6	25.0	66.0	2
Antimony	2.50[A]	0	2.50[A]	2.50[A]	2.50[A]	2.50[A]	2
Arsenic	1.80	0.28	2.19	1.79	1.60	2.00	2
Barium	47.0	4.24	52.9	46.9	44.0	50.0	2
Beryllium	0.25[A]	0	0.25[A]	0.25[A]	0.25[A]	0.25[A]	2
Cadmium	1.16	0.63	2.03	1.07	0.71	1.60	2
Chromium (Cr3+)	5.05	0.49	5.74	5.04	4.70	5.40	2
Chromium (Cr6+)	2.50[A]	0	2.50[A]	2.50[A]	2.50[A]	2.50[A]	2
Cobalt	3.45	1.77	5.90	3.22	2.20	4.70	2
Copper	30.0	12.7	47.6	28.6	21.0	39.0	2
Iron	475	148	681	463	370	580	2
Lead	0.82	0.40	1.37	0.77	0.54	1.10	2
Manganese	770	325	1221	735	540	1000	2
Mercury	0.10[A]	0	0.10[A]	0.10[A]	0.10[A]	0.10[A]	2
Nickel	8.30	0.42	8.89	8.29	8.00	8.60	2
Selenium	1.25[A]	0	1.25[A]	1.25[A]	1.25[A]	1.25[A]	2
Silver	0.25[A]	0	0.25[A]	0.25[A]	0.25[A]	0.25[A]	2
Thallium	0.25[A]	0	0.25[A]	0.25[A]	0.25[A]	0.25[A]	2
Tin	10.00[A]	0	10.00[A]	10.00[A]	10.00[A]	10.00[A]	2
Vanadium	1.25[A]	0	1.25[A]	1.25[A]	1.25[A]	1.25[A]	2
Zinc	190	28.3	229	189	170	210	2
Hardness (mg/L)	125.0	7.1	134.8	124.9	120.0	130.0	2
PAHs							
Acenaphthene	No Data Available						
Acenaphthylene	No Data Available						
Anthracene	No Data Available						
Benz[a]anthracene	No Data Available						
Benzo[b]fluoranthene	No Data Available						
Benzo[k]fluoranthene	No Data Available						
Benzo[a]pyrene	No Data Available						
Benzo[g,h,i]perylene	No Data Available						
Chrysene	No Data Available						
Dibenzo[a,h]anthracene	No Data Available						
Fluoranthene	No Data Available						
Fluorene	No Data Available						
Naphthalene	No Data Available						
Phenanthrene	No Data Available						
Pyrene	No Data Available						
Total PCBs	No Data Available						

NA – Not analyzed.
[A]The chemical was not detected and one-half the detection limit is reported.

Table 4-6. Site-wide (including the Area of Readily Apparent Harm) concentrations of organic and inorganic residues in surface water samples collected in May 2000 during conditions of inundation by the Sudbury River.

	Chemical Concentration (µg/L)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	13.6	5.19	18.2	13.0	11.3	22.9	5
Antimony	0.43	0.14	0.57	0.41	0.31	0.64	4
Arsenic	1.03	0.40	1.38	0.98	0.72	1.70	5
Barium	24.5	3.20	27.3	24.4	22.0	30.0	5
Beryllium	0.34	0.14	0.47	0.32	0.22	0.50	5
Cadmium	0.12	0.053	0.17	0.11	0.06	0.19	5
Chromium (Cr3+)	2.30	1.62	3.72	1.85	0.84	4.80	5
Chromium (Cr6+)	2.50[A]	0	2.50[A]	2.50[A]	2.50[A]	2.50[A]	5
Cobalt	0.25	0.16	0.39	0.22	0.12	0.52	5
Copper	30.4	28.5	55.4	16.7	3.2	68.2	5
Iron	246	91.0	325	233	166	385	5
Lead	0.74	0.22	0.94	0.72	0.43	1.00	5
Manganese	114	53.9	162	106	73.5	207	5
Mercury	0.010[A]	0	0.010[A]	0.010[A]	0.010[A]	0.010[A]	5
Nickel	2.08	0.45	2.48	2.04	1.60	2.80	5
Selenium	0.70[A]	0	0.70[A]	0.70[A]	0.70[A]	0.70[A]	5
Silver	0.16	0.075	0.23	0.15	0.074	0.28	5
Thallium	0.15[A]	0	0.15[A]	0.15[A]	0.15[A]	0.15[A]	5
Tin	8.90[A]	0	8.90[A]	8.90[A]	8.90[A]	8.90[A]	5
Vanadium	0.89	0.12	0.99	0.88	0.72	1.00	5
Zinc	17.6	4.75	21.8	17.1	12.6	23.4	5
Hardness (mg/L)	49.4	3.2	52.3	49.3	45.8	54.7	5
PAHs							
Acenaphthene	0.014	0.007	0.020	0.013	0.010	0.027	5
Acenaphthylene	0.010	0.001	0.011	0.010	0.010	0.011	5
Anthracene	0.015	0.011	0.024	0.013	0.010	0.034	5
Benz[a]anthracene	0.055	0.098	0.141	0.020	0.009	0.230	5
Benzo[b]fluoranthene	0.127	0.242	0.339	0.033	0.010	0.560	5
Benzo[k]fluoranthene	0.090	0.168	0.237	0.028	0.010	0.390	5
Benzo[a]pyrene	0.085	0.159	0.225	0.025	0.010	0.370	5
Benzo[g,h,i]perylene	0.083	0.155	0.219	0.026	0.010	0.360	5
Chrysene	0.112	0.212	0.297	0.031	0.010	0.490	5
Dibenzo[a,h]anthracene	0.017	0.014	0.029	0.014	0.010	0.042	5
Fluoranthene	0.266	0.523	0.724	0.050	0.009	1.200	5
Fluorene	0.014	0.008	0.021	0.013	0.010	0.029	5
Naphthalene	0.045	0.018	0.061	0.041	0.022	0.071	5
Phenanthrene	0.147	0.287	0.399	0.032	0.008	0.660	5
Pyrene	0.186	0.366	0.507	0.034	0.006	0.840	5
Total PCBs	0.008	0.004	0.012	0.007	0.004	0.011	3

NA – Not analyzed.
[A]The chemical was not detected and one-half the detection limit is reported.

Table 4-7. Concentrations of organic and inorganic residues in surface water samples from outside the "Area of Readily Apparent Harm" collected in May 2000 during conditions of inundation by the Sudbury River.

	Chemical Concentration (µg/L)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	17.1	8.20	28.5	16.1	11.3	22.9	2
Antimony	0.35	0.05	0.41	0.34	0.31	0.38	2
Arsenic	0.74	0.02	0.76	0.73	0.72	0.75	2
Barium	22.3	0.42	22.9	22.3	22.0	22.6	2
Beryllium	0.50	0	0.50	0.50	0.50	0.50	2
Cadmium	0.079	0.021	0.107	0.077	0.064	0.093	2
Chromium (Cr3+)	0.85	0.014	0.87	0.85	0.84	0.86	2
Chromium (Cr6+)	2.50[A]	0	2.50[A]	2.50[A]	2.50[A]	2.50[A]	2
Cobalt	0.14	0.03	0.18	0.14	0.12	0.16	2
Copper	3.85	0.92	5.12	3.79	3.20	4.50	2
Iron	168	2.83	172	168	166	170	2
Lead	0.58	0.21	0.86	0.56	0.43	0.72	2
Manganese	78.7	7.28	88.7	78.5	73.5	83.8	2
Mercury	0.01[A]	0	0.01[A]	0.01[A]	0.01[A]	0.01[A]	2
Nickel	1.85	0.35	2.34	1.83	1.60	2.10	2
Selenium	0.70[A]	0	0.70[A]	0.70[A]	0.70[A]	0.70[A]	2
Silver	0.18	0.15	0.38	0.14	0.07	0.28	2
Thallium	0.15[A]	0	0.15[A]	0.15[A]	0.15[A]	0.15[A]	2
Tin	8.90[A]	0	8.90[A]	8.90[A]	8.90[A]	8.90[A]	2
Vanadium	0.78	0.08	0.88	0.77	0.72	0.83	2
Zinc	18	7.64	28.6	17.2	12.6	23.4	2
Hardness (mg/L)	47.1	1.8	49.6	47.1	45.8	48.4	2
PAHs							
Acenaphthene	0.011	0.001	0.011	0.010	0.010	0.011	2
Acenaphthylene	0.011	0.001	0.011	0.010	0.010	0.011	2
Anthracene	0.011	0.001	0.011	0.010	0.010	0.011	2
Benz[a]anthracene	0.011	0.001	0.011	0.010	0.010	0.011	2
Benzo[b]fluoranthene	0.011	0.001	0.011	0.010	0.010	0.011	2
Benzo[k]fluoranthene	0.011	0.001	0.011	0.010	0.010	0.011	2
Benzo[a]pyrene	0.011	0.001	0.011	0.010	0.010	0.011	2
Benzo[g,h,i]perylene	0.011	0.001	0.011	0.010	0.010	0.011	2
Chrysene	0.011	0.001	0.011	0.010	0.010	0.011	2
Dibenzo[a,h]anthracene	0.011	0.001	0.011	0.010	0.010	0.011	2
Fluoranthene	0.010	0.001	0.010	0.009	0.009	0.010	2
Fluorene	0.011	0.001	0.011	0.010	0.010	0.011	2
Naphthalene	0.058	0.019	0.084	0.056	0.044	0.071	2
Phenanthrene	0.008	0.000	-	0.008	0.008	0.008	2
Pyrene	0.006	0.000	-	0.006	0.006	0.006	2
Total PCBs	No Data Available						

NA – Not analyzed.

[A]The chemical was not detected and one-half the detection limit is reported.

Table 4-8. Concentrations of organic and inorganic residues in surface water samples from the outfall (OF-1) collected in October 2000 during conditions of low flow in the Sudbury River (non-inundation of site).

Chemical	Chemical Concentration (µg/L)
Metals	
Aluminum	310
Antimony	2.5[A]
Arsenic	0.71
Barium	82
Beryllium	0.25[A]
Cadmium	0.56
Chromium (Cr3+)	0.5[A]
Chromium (Cr6+)	2.5[A]
Cobalt	1.5
Copper	90
Iron	200
Lead	1.8
Manganese	110
Mercury	0.1
Nickel	18
Selenium	1.25[A]
Silver	0.25[A]
Thallium	0.25[A]
Tin	10[A]
Vanadium	1.25[A]
Zinc	360
Hardness (mg/L)	160

[A]The chemical was not detected and one-half the detection limit is reported.

Table 4-9. Water quality parameters for surface water samples from the drainage swale collected in October 2000 during conditions of low flow in the Sudbury River (non-inundation of site).

location	DOM (mg/L)	pH	Temperature (^{0}F)	Conductivity
OF-1	6.5	4.4	64.2	2.27
T-2-6	6.2	4.55	65.2	0.85
T-3-7	8.4	4.25	66.0	1.2
T-5-4	11	4.85	68.5	0.42
T-12-1	5.4	5.46	66.4	0.65
T-14-6	7.1	4.73	70.8	0.44
Mean	7.4	4.71	66.9	0.97
s.d.	2.0	0.43	2.4	0.70

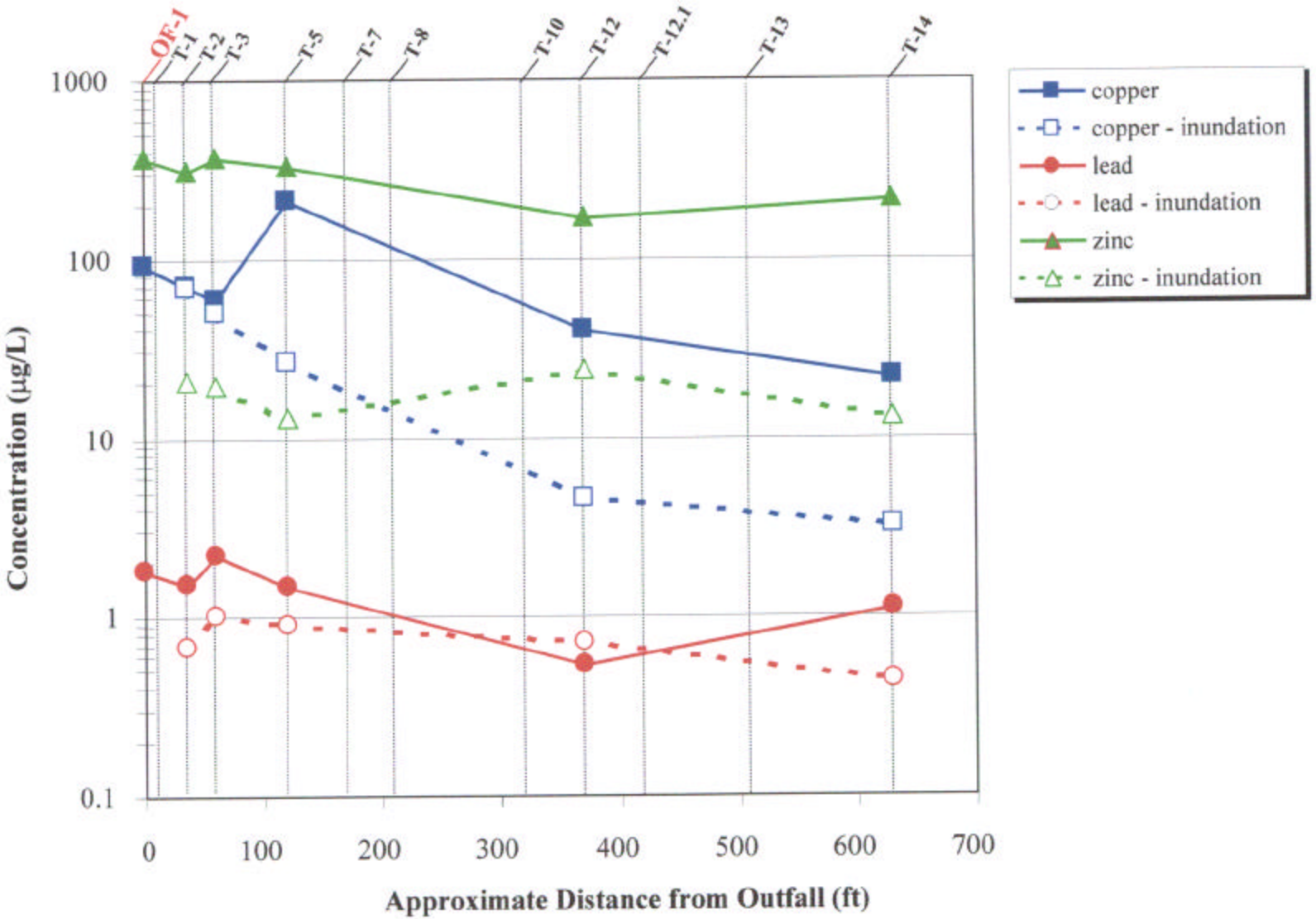

Figure 4-4. Concentrations of copper, lead, and zinc in surface water across the wetland at times of inundation and non-inundation.

4.3.2 Sediments

Sediments at this site are defined as those portions of the site that are permanently flooded or are flooded for most of the time with little to no emergent vegetation present (refer to Section 3.5 for more details). These locations are generally located in and near the drainage swale that traverses the site (Figure 4-2). Summaries of chemical concentrations for all the chemicals that were measured in wetland sediments are presented in Tables 4-10 and 4-11 (refer to Appendix B for all data). A concentration gradient for most chemicals at the site generally exists with the greatest concentrations at locations that are proximal to the outfall and decreasing concentrations at locations that are further from the outfall (refer to the following section on wetland soil for additional information on chemical gradients at the site).

Table 4-10. Site-wide (including the Area of Readily Apparent Harm) concentrations of organic and inorganic residues in sediment samples collected in 1998 and 1999.

	Chemical Concentration (mg/kg, dry weight)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	7,700	1,476	9,147	7,587	5,800	9,100	4
Antimony	15.7	23.7	42.5	5.49	1.60	43.0	3
Arsenic	12.7	7.11	19.7	11.5	7.80	23.0	4
Barium	137	155	289	93.6	53.0	370	4
Beryllium	0.52	0.13	0.64	0.51	0.34	0.62	4
Cadmium	10.9	15.7	28.6	4.64	1.50	29.0	3
Calcium	2,825	954	3,759	2,687	1,600	3,800	4
Chromium (Cr3+)	2,111	6,610	5,007	219	8.70	29,000	20
Chromium (Cr6+)	3.2	4.16	7.91	1.69	0.60	8.00	3
Cobalt	5.08	1.80	6.84	4.76	2.50	6.50	4
Copper	2,035	5,208	4,317	381	17.4	22,000	20
Iron	13,750	1,708	15,424	13,672	12,000	16,000	4
Lead	327	424	513	132	3.70	1,700	20
Magnesium	2,555	1,170	3,701	2,271	920	3,400	4
Manganese	293	287	574	217	100	720	4
Mercury	6.54	9.93	17.8	2.09	0.42	18.0	3
Nickel	20.5	6.56	26.9	19.7	14.0	29.0	4
Potassium	833	232	1096	814	680	1100	3
Selenium	1.40	0.96	2.49	1.21	0.70	2.50	3
Silver	153	240	425	42.2	9.20	430	3
Thallium	2.97	3.67	7.12	1.71	0.70	7.20	3
Tin	133	238	366	33.1	11.0	490	4
Vanadium	110	127	235	72.5	33.0	300	4
Zinc	320	168	485	277	110	470	4
Total PAHs	466	561	1,101	266	82.0	1,110	3
Acenaphthene	8.04	12.1	21.7	2.31	0.31	22.0	3
Acenaphthylene	1.04	1.10	2.28	0.71	0.31	2.30	3
Anthracene	13.4	18.8	34.7	5.17	0.92	35.0	3
Benz[a]anthracene	32.3	39.9	77.5	16.7	4.00	78.0	3
Benzo[b]fluoranthene	37.0	40.9	83.2	24.3	10	84.0	3
Benzo[k]fluoranthene	30.4	32.7	67.4	20.3	8.20	68.0	3
Benzo[a]pyrene	34.4	39.8	79.4	20.9	7.10	80.0	3
Benzo[g,h,i]perylene	25.3	26.7	55.5	17.4	7.80	56.0	3
Chrysene	40.8	47.2	94.3	24.8	8.40	95.0	3
Dibenzo[a,h]anthracene	8.07	8.63	17.8	5.48	2.40	18.0	3
Fluoranthene	74.9	91.9	179	39.4	9.70	180	3
Fluorene	6.97	10.4	18.8	2.11	0.31	19.0	3
Indeno[1,2,3-cd]pyrene	26.0	27.8	57.4	17.7	7.90	58.0	3
Naphthalene	2.28	3.39	6.12	0.87	0.31	6.20	3
Phenanthrene	54.9	74.2	139	22.4	3.80	140	3
Pyrene	58.6	71.2	139	31.4	7.90	140	3
Total PCBs (Aroclor)*	49.2	130	111	10.1	1.27	540	17

*Refer to discussion of PCB bias by Aroclor analysis in the section on Uncertainty Analysis

Table 4-11. Concentrations of organic and inorganic residues in sediment samples from outside the "Area of Readily Apparent Harm" collected in 1998 and 1999.

	Chemical Concentration (mg/kg, dry weight)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	7,300	-	-	7,300	7,300	7,300	1
Antimony	-	-	-	-	-	-	0
Arsenic	8.10	-	-	8.10	8.10	8.10	1
Barium	62.0	-	-	62.0	62.0	62.0	1
Beryllium	0.62	-	-	0.62	0.62	0.62	1
Cadmium	-	-	-	-	-	-	0
Calcium	3,800	-	-	3,800	3,800	3,800	1
Chromium (Cr3+)	139	131	221	71.4	8.70	376	10
Chromium (Cr6+)	-	-	-	-	-	-	0
Cobalt	6.10	-	-	6.10	6.10	6.10	1
Copper	221	212	352	109.2	17.4	607	10
Iron	12,000	-	-	12,000	12,000	12,000	1
Lead	103	112	172	44.5	3.70	340	10
Magnesium	920	-	-	920	920	920	1
Manganese	720	-	-	720	720	720	1
Mercury	-	-	-	-	-	-	0
Nickel	14.0	-	-	14.0	14.0	14.0	1
Potassium	-	-	-	-	-	-	0
Selenium	-	-	-	-	-	-	0
Silver	-	-	-	-	-	-	0
Thallium	-	-	-	-	-	-	0
Tin	14.0	-	-	14.0	14.0	14.0	1
Vanadium	33.0	-	-	33.0	33.0	33.0	1
Zinc	110	-	-	110	110	110	1
Total PAHs			No site data available				
Acenaphthene			No site data available				
Acenaphthylene			No site data available				
Anthracene			No site data available				
Benz[a]anthracene			No site data available				
Benzo[b]fluoranthene			No site data available				
Benzo[k]fluoranthene			No site data available				
Benzo[a]pyrene			No site data available				
Benzo[g,h,i]perylene			No site data available				
Chrysene			No site data available				
Dibenzo[a,h]anthracene			No site data available				
Fluoranthene			No site data available				
Fluorene			No site data available				
Indeno[1,2,3-cd]pyrene			No site data available				
Naphthalene			No site data available				
Phenanthrene			No site data available				
Pyrene			No site data available				
Total PCBs (Aroclor)*	3.20	2.56	5.09	2.53	1.27	7.80	7

*Refer to discussion of PCB bias by Aroclor analysis in the section on Uncertainty Analysis

4.3.3 Wetland Soils

Wetland soil, for the purposes of the ERC at this site, is defined as soil that supports emergent vegetation and is typically non-inundated (moisture-saturated to relatively dry) for significant amounts of time each year (refer to Section 3.5 for more details). These locations are generally located throughout the site except those locations in and near the drainage swale that traverses the site (Figure 4-3). Summaries of chemical concentrations for all the chemicals that were measured in wetland soils are presented in Tables 4-12 and 4-13 (refer to Appendix B for all data). Similarly to sediments, a concentration gradient for most chemicals at the site generally exists with the greatest concentrations at locations that are proximal to the outfall and decreasing concentrations at locations that are further from the outfall (Figures 4-5 and 4-6). In wetland soils, pH, concentration of organic carbon, soil type, and cation exchange capacity are important parameters to assess the relative bioavailability of COPECs. The pH of the soil is moderately acidic, with relatively great concentrations of organic carbon, and greatly elevated concentrations of cation exchange capacity (Table 4-14). Also, grain size distribution is a physical parameter that may affect the chemical sorption capacity of soils. All else being similar, particles of smaller grain size typically have greater surface area, and thus, greater sorptive capacity. At this site, the average composition of wetland soil at the site can be qualitatively described as mostly sand (approximately 50-75%), with some silt (approximately 25-50%), with lesser amounts of clay (1-6%) (Table 4-15).

Table 4-12. Site-wide (including the Area of Readily Apparent Harm) concentrations of organic and inorganic residues in soil samples collected in 1998 and 1999.

Chemical	Chemical Concentration (mg/kg, dry weight)						
	mean	std dev	95% UCL	geomean	min	max	n
Metals							
Aluminum	8,288	3,303	8,963	7,793	3,000	25,000	92
Antimony	8.84	13.7	11.6	5.30	1.10	100	92
Arsenic	17.3	25.2	22.4	10.9	2.70	160	92
Barium	107	85.5	124.7	83.0	14.0	490	92
Beryllium	0.69	0.30	0.75	0.62	0.10	1.80	92
Cadmium	4.09	4.06	4.92	2.75	0.11	32.0	92
Calcium	3,243	1,693	3,589	2,864	620	11,000	92
Chromium (Cr3+)	2,803	5,401	3,739	516	7.40	37,000	128
Chromium (Cr6+)	71.8	180	109	18.7	0.27	1,600	92
Cobalt	4.40	2.50	4.91	3.80	0.70	13.0	92
Copper	1,932	2,754	2,409	570	10.0	15,000	128
Iron	10,534	8,425	12,255	8,654	3,400	57,000	92
Lead	436	372	500	291	11.0	2300	128
Magnesium	1,827	1,180	2,068	1,540	500	6,400	92
Manganese	292	249	343	222	27.0	1,500	92
Mercury	2.59	2.77	3.15	1.33	0.03	14.0	92
Nickel	18.0	7.49	19.5	16.3	4.00	40.0	92
Potassium	406	243	456	349	90.0	1,400	92
Selenium	1.84	0.79	2.00	1.65	0.43	4.00	92
Silver	73.6	127	99.6	11.5	0.11	560	92
Thallium	1.94	1.26	2.20	1.67	0.43	11.0	92
Tin	57.3	115.6	81.0	18.3	1.50	660	92
Vanadium	63.2	58.0	75.1	45.2	9.70	330	92
Zinc	152	101	173	120	15.00	470	92
Total PAHs	29.2	58.1	44.4	7.77	0.32	364	56
Acenaphthene	0.12	0.18	0.17	0.053	0.0039	0.84	56
Acenaphthylene	0.13	0.22	0.19	0.064	0.0039	1.20	56
Anthracene	0.36	0.66	0.54	0.099	0.0039	3.30	56
Benz[a]anthracene	1.77	3.27	2.63	0.42	0.015	18.0	56
Benzo[b]fluoranthene	3.19	6.72	4.95	0.73	0.015	44.0	56
Benzo[k]fluoranthene	2.60	5.28	3.99	0.62	0.015	33.0	56
Benzo[a]pyrene	2.45	4.98	3.75	0.65	0.015	32.0	56
Benzo[g,h,i]perylene	2.23	4.99	3.53	0.49	0.015	33.0	56
Chrysene	3.01	5.91	4.55	0.75	0.024	37.0	56
Dibenzo[a,h]anthracene	0.63	1.31	0.97	0.15	0.0039	8.40	56
Fluoranthene	4.27	8.56	6.51	0.98	0.024	52.0	56
Fluorene	0.12	0.19	0.17	0.053	0.0039	0.89	56
Indeno[1,2,3-cd]pyrene	2.30	5.12	3.64	0.51	0.015	34.0	56
Naphthalene	0.077	0.086	0.10	0.044	0.0039	0.36	56
Phenanthrene	1.65	3.43	2.55	0.37	0.015	18.0	56
Pyrene	3.54	6.92	5.35	0.87	0.024	42.0	56
Total PCBs (Aroclor)*	14.6	34.8	20.7	3.36	0.09	330	125

*Refer to discussion of PCB bias by Aroclor analysis in the section on Uncertainty Analysis

Table 4-13. Concentrations of organic and inorganic residues in soil samples from outside the "Area of Readily Apparent Harm" collected in 1998 and 1999.

	Chemical Concentration (mg/kg, dry weight)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	8,400	3,493	9,213	7,889	3,000	25,000	71
Antimony	4.33	2.22	4.85	3.85	1.10	17.0	71
Arsenic	14.9	25.5	20.9	9.43	2.70	160	71
Barium	78.9	44.2	89.2	67.6	14.0	240	71
Beryllium	0.71	0.31	0.78	0.64	0.10	1.80	71
Cadmium	3.34	2.33	3.88	2.39	0.11	10.0	71
Calcium	3,106	1,197	3,384	2,827	620	5,600	71
Chromium (Cr3+)	551	890	739	183	7.40	4,300	86
Chromium (Cr6+)	50.9	50.0	62.5	20.3	0.27	230	71
Cobalt	4.73	2.69	5.35	4.03	0.70	13.0	71
Copper	585	748	743	243	10.0	3,300	86
Iron	7,975	4,117	8,932	7,164	3,400	24,000	71
Lead	267	182	306	199	11.0	1,210	86
Magnesium	1,593	1,141	1,859	1,343	500	6,400	71
Manganese	311	262	372	236	27.0	1,500	71
Mercury	1.68	1.44	2.02	0.97	0.03	7.20	71
Nickel	16.9	6.65	18.5	15.5	4.00	35.0	71
Potassium	383	238	438	328	90.0	1,400	71
Selenium	1.69	0.67	1.84	1.53	0.43	3.40	71
Silver	23.7	46.9	34.7	5.23	0.11	250	71
Thallium	1.69	0.67	1.84	1.53	0.43	3.40	71
Tin	22.5	33.5	30.3	12.2	1.50	200	71
Vanadium	39.1	22.7	44.4	33.5	9.70	130	71
Zinc	130	80.1	149	105	15.0	410	71
Total PAHs	12.0	20.8	18.5	4.27	0.32	92.5	40
Acenaphthene	0.06	0.07	0.08	0.03	0.00	0.31	39
Acenaphthylene	0.09	0.19	0.15	0.05	0.00	1.20	40
Anthracene	0.13	0.27	0.22	0.05	0.00	1.40	40
Benz[a]anthracene	0.78	1.63	1.29	0.23	0.02	7.80	40
Benzo[b]fluoranthene	1.33	2.39	2.07	0.38	0.02	10.0	40
Benzo[k]fluoranthene	1.05	1.83	1.62	0.33	0.02	7.30	40
Benzo[a]pyrene	1.03	1.72	1.57	0.37	0.02	8.70	40
Benzo[g,h,i]perylene	0.82	1.48	1.28	0.25	0.02	6.80	40
Chrysene	1.28	2.25	1.98	0.40	0.02	9.00	40
Dibenzo[a,h]anthracene	0.24	0.45	0.38	0.08	0.00	2.00	40
Fluoranthene	1.75	3.32	2.77	0.53	0.02	15.0	40
Fluorene	0.06	0.07	0.08	0.03	0.00	0.31	40
Indeno[1,2,3-cd]pyrene	0.87	1.54	1.35	0.26	0.02	6.90	40
Naphthalene	0.05	0.07	0.08	0.03	0.00	0.31	40
Phenanthrene	0.55	1.08	0.89	0.20	0.02	6.00	40
Pyrene	1.53	2.89	2.43	0.48	0.02	13.0	40
Total PCBs (Aroclor)*	2.92	3.52	3.68	1.42	0.09	18.6	82

*Refer to discussion of PCB bias by Aroclor analysis in the section on Uncertainty Analysis

Table 4-14. Wetland soil properties at the site.

location	pH	CEC (meq/100 g)	TOC (%)
T-1-2-TL	6.5	8.6	5.3
T-1-2-CA	6.1	20.4	3.1
T-3-5	5.8	40.6	4.5
T-3-8	6.8	162.7	24.9
T-5-2	5.7	111.7	15.1
T-7-1	5	136.6	16.9
T-9-5	5.3	355.3	20.6
T-13-4	5.2	346.8	18
T-13-4-TL	5.5	195.8	14.2
mean	5.8	153.2	13.6
s.d.	0.6	129.2	7.7

Table 4-15. Grain size analysis of representative wetland soil samples at the site.

Sample Description	Sand	Coarse Silt	Medium Silt	Fine Silt	Clay
Peat w/ Decay Roots	69	14	11	-	6.2
Fine Gray Silt	52	31	17	-	-
Dark Brown/Black Peat	72	15	11	1.7	0.7
Plant Decay Mat	73	19	7.6	-	-
Medium Sand	98	2.5	-	-	-

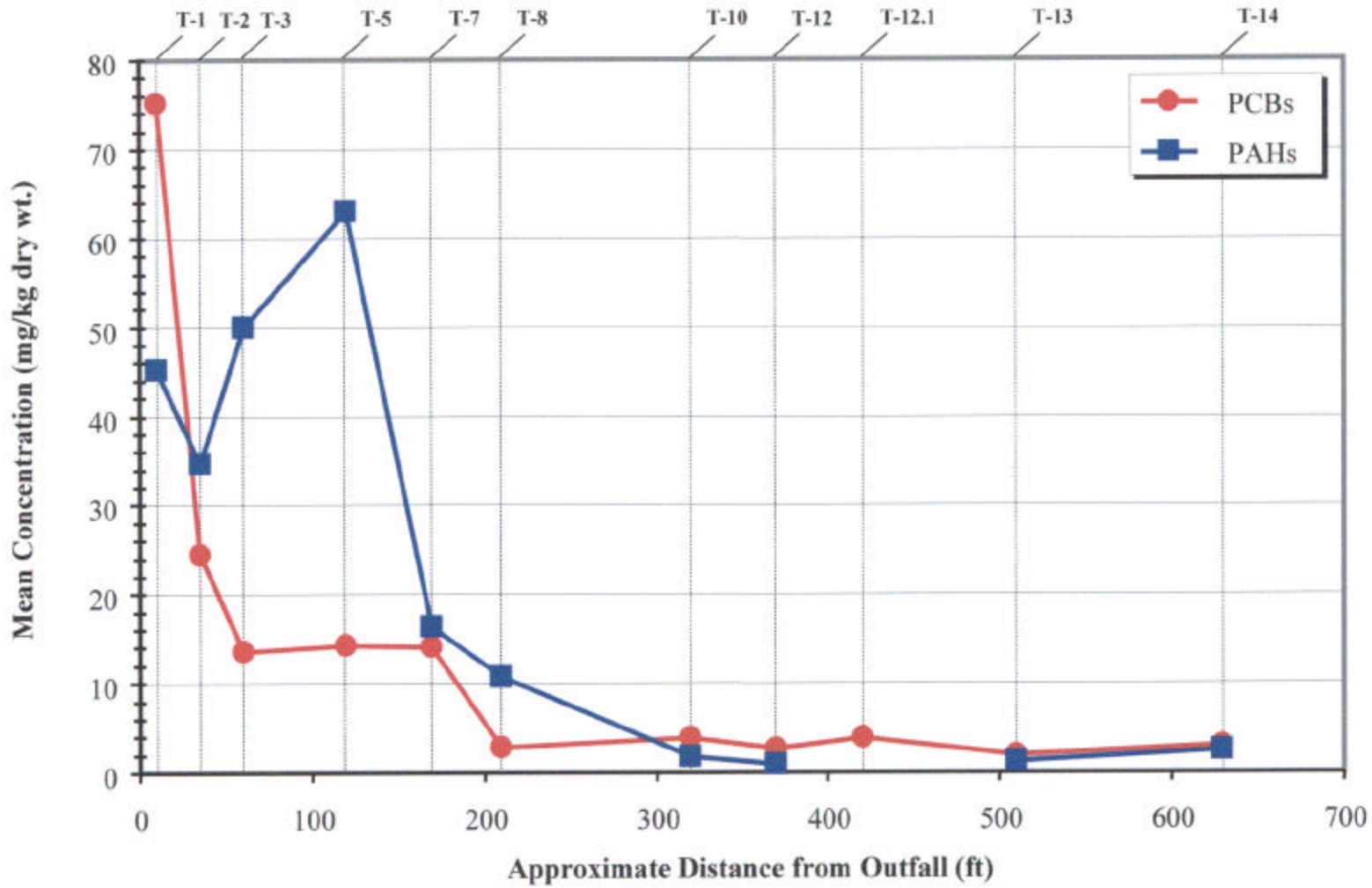

Figure 4-5. Concentration gradient for PCBs and PAHs in wetland soil. Each point represents the arithmetic mean concentration of all of the sample locations for each transect.

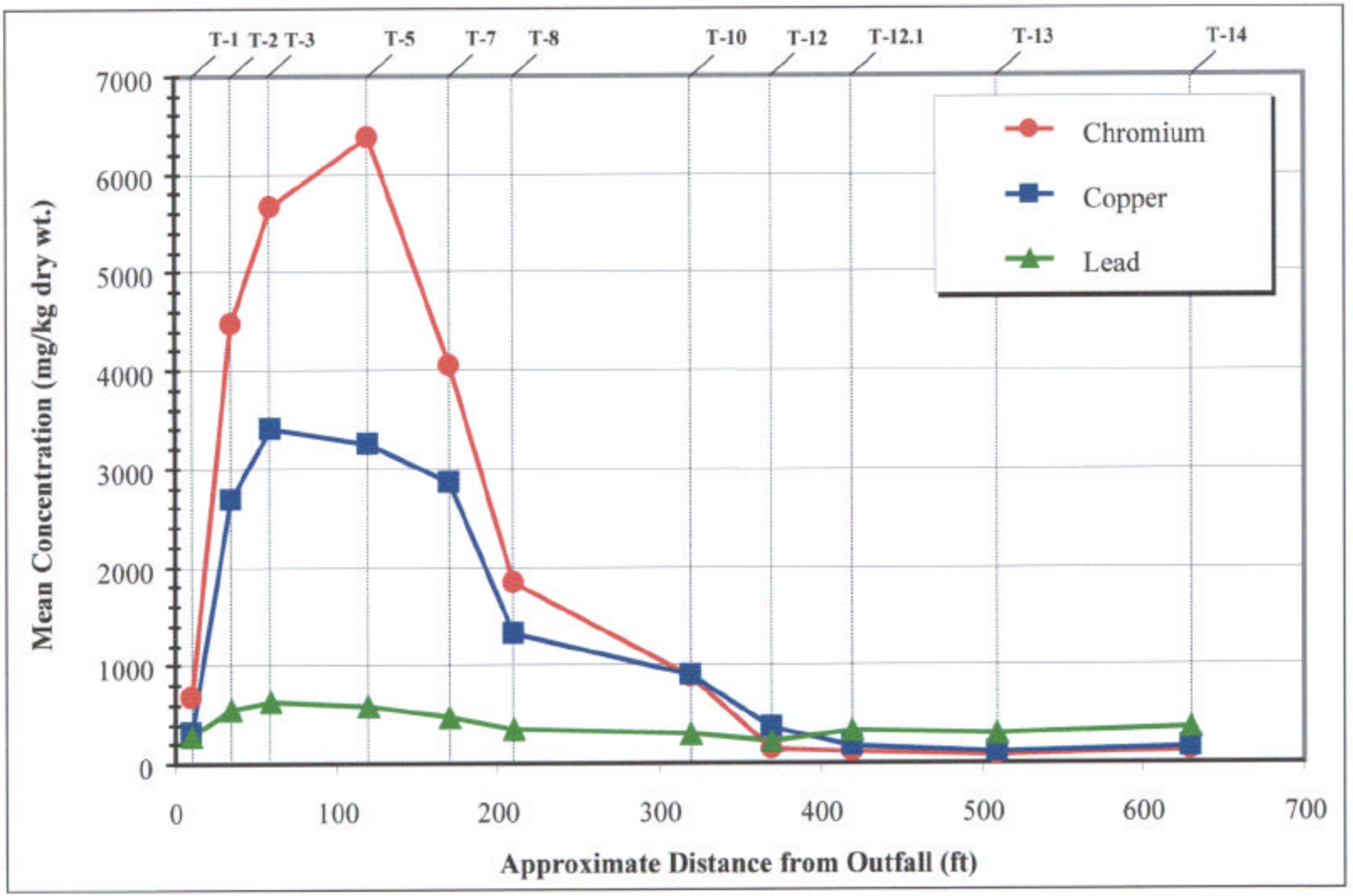

Figure 4-6. Concentration gradient for chromium, copper, and lead in wetland soil. Each point represents the arithmetic mean concentration of all of the sample locations for each transect.

4.3.4 Biological Tissues

Edible portions of two species of wetland plants, root tissue of cattails (*Typha latifolia*) and seedheads of buttonbush (*Cephalanthus occidentalis*) were sampled to better elucidate uptake of chemicals into vegetation and to be utilized in wildlife dietary exposure calculations. Wetland plant tissues and co-located soils were collected from seven locations along existing transects. Specifically, sample locations were located as close as possible to previous Phase I soil sampling locations (*e.g.*, T-1-2; T-3-5; T-3-8, T-5-2; T-7-1; T-9-5; and T-13-4). The rationale for selecting these sample locations was based primarily on concentration gradients for some of the COPECs. For example, the sample locations included a concentration gradient in soil (0-6", based on Phase I and II sampling) that was approximately 219-fold for PCBs (range = 1.3 to 285 mg/kg), 167-fold for copper (range = 89 to 15,000 mg/kg), 638-fold for chromium (range = 58 to 37,000 mg/kg), and 17-fold for lead (range = 137 to 2,300 mg/kg).

The concentrations of residues measured in plant tissues are presented in Tables 4-16 through 4-19. Co-located soil samples were used to calculate soil to plant uptake factors for each of the measured chemicals (Table 4-20). Not surprisingly, the concentrations of many chemicals were greater in roots than seedheads because many chemicals are not translocated through plant tissues very well.

Table 4-16. Site-wide (including the Area of Readily Apparent Harm) concentrations of organic and inorganic residues in root tissue of cattails (*Typha latifolia*).

	Chemical Concentration (mg/kg, dry weight)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	44.8	40.7	75.0	31.6	5.8	130.0	7
Antimony	0.0231	0.0215	0.0160	0.0145	0.0034	0.0600	7
Arsenic	0.474	0.376	0.753	0.378	0.180	1.200	7
Barium	3.0	1.3	4.0	2.8	1.7	5.1	7
Beryllium	0.0084	0.0030	0.0106	0.0080	0.0050	0.0130	7
Cadmium	0.2677	0.2124	0.1573	0.1993	0.0760	0.6100	7
Calcium	1084.9	612.0	1538.2	949.0	505.0	2140.0	7
Chromium (Cr3+)	18.6	27.9	39.2	5.0	1.0	62.1	7
Cobalt	0.192	0.087	0.257	0.158	0.026	0.270	7
Copper	27.8	34.8	53.6	13.7	2.5	94.0	7
Iron	143.7	97.1	215.6	107.4	26.3	275.0	7
Lead	4.787	4.364	8.020	2.831	0.600	11.900	7
Magnesium	214.9	46.6	249.3	210.5	164.0	272.0	7
Manganese	66.4	14.2	76.9	65.0	46.8	87.6	7
Mercury	0.0410	0.0673	0.0909	0.0167	0.0034	0.1900	7
Nickel	0.49	0.19	0.63	0.46	0.29	0.81	7
Potassium	1256.9	635.1	470.5	1052.1	241.0	1960.0	7
Selenium	0.123	0.089	0.189	0.106	0.061	0.320	7
Silver	0.724	1.047	1.500	0.230	0.021	2.400	7
Thallium	0.015	0.002	0.016	0.015	0.012	0.016	7
Tin	0.97	0.18	1.10	0.96	0.72	1.30	7
Vanadium	0.891	0.755	1.45	0.65	0.2	2.10	7
Zinc	24.1	15.8	35.8	19.0	6.2	46.7	7
Total PCBs	0.033	0.046	0.067	0.016	0.004	0.132	7

Table 4-17. Concentrations of organic and inorganic residues in root tissue of cattails (*Typha latifolia*) from outside the "Area of Readily Apparent Harm".

	Chemical Concentration (mg/kg, dry weight)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	33.40	12.20	47.21	31.82	21.00	45.40	3
Antimony	0.0271	0.0287	0.0596	0.0183	0.0073	0.0600	3
Arsenic	0.29	0.10	0.40	0.28	0.18	0.37	3
Barium	3.03	1.81	5.09	2.71	1.70	5.10	3
Beryllium	0.0093	0.0040	0.0139	0.0087	0.0050	0.0130	3
Cadmium	0.32	0.17	0.52	0.28	0.12	0.44	3
Calcium	1041.33	547.71	1661.11	942.41	531.00	1620.00	3
Chromium (Cr3+)	1.22	0.27	1.52	1.20	0.97	1.50	3
Cobalt	0.24	0.04	0.28	0.23	0.19	0.27	3
Copper	6.43	5.49	12.64	5.07	2.50	12.70	3
Iron	136.77	96.84	246.34	98.77	26.30	207.00	3
Lead	3.70	2.96	7.05	2.50	0.60	6.50	3
Magnesium	233.00	57.47	298.03	227.73	167.00	272.00	3
Manganese	66.30	9.60	77.16	65.84	57.60	76.60	3
Mercury	0.0108	0.0073	0.0191	0.0088	0.0034	0.0180	3
Nickel	0.40	0.05	0.46	0.40	0.35	0.43	3
Potassium	840.33	626.02	1548.73	657.07	241.00	1490.00	3
Selenium	0.08	0.02	0.10	0.08	0.06	0.10	3
Silver	0.08	0.05	0.14	0.06	0.02	0.12	3
Thallium	0.0147	0.0023	0.0173	0.0145	0.0120	0.0160	3
Tin	0.90	0.16	1.08	0.89	0.72	0.99	3
Vanadium	0.53	0.32	0.89	0.45	0.20	0.84	3
Zinc	33.00	17.42	52.71	28.98	13.40	46.70	3
Total PCBs	10.46	5.90	17.14	9.01	3.94	15.42	3

Table 4-18. Site-wide (including the Area of Readily Apparent Harm) concentrations of organic and inorganic residues in seedheads of buttonbush (*Cephalanthus occidentalis*).

	Chemical Concentration (mg/kg, dry weight)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	16.6	13.5	26.6	12.4	5.2	40.1	7
Antimony	0.0112	0.0106	0.0191	0.0079	0.0020	0.0320	7
Arsenic	0.047	0.029	0.068	0.041	0.020	0.100	7
Barium	20.5	13.2	30.2	17.5	8.3	46.1	7
Beryllium	0.0066	0.0005	0.0070	0.0066	0.0056	0.0069	7
Cadmium	0.0193	0.0184	0.0330	0.0149	0.0071	0.0600	7
Calcium	4111.4	1774.4	5425.9	3856.2	2720.0	7810.0	7
Chromium (Cr3+)	2.5	0.9	3.2	2.3	1.3	3.7	7
Cobalt	0.035	0.022	0.051	0.030	0.014	0.064	7
Copper	9.8	2.6	11.7	9.5	5.9	12.5	7
Iron	42.1	8.0	48.0	0.105	0.058	0.360	7
Lead	0.133	0.113	0.217	0.105	0.058	0.360	7
Magnesium	1233.1	194.7	1377.4	1219.4	952.0	1470.0	7
Manganese	135.2	92.9	204.1	112.0	54.8	311.0	7
Mercury	0.0059	0.0010	0.0067	0.0058	0.0046	0.0076	7
Nickel	0.74	0.38	1.02	0.67	0.36	1.40	7
Potassium	2604.3	645.4	3082.4	2537.5	1860.0	3460.0	7
Selenium	0.110	0.103	0.186	0.083	0.042	0.330	7
Silver	0.224	0.163	0.345	0.173	0.037	0.540	7
Thallium	0.015	0.001	0.016	0.015	0.013	0.016	7
Tin	0.94	0.07	0.99	0.94	0.80	0.99	7
Vanadium	0.042	0.028	0.063	0.036	0.019	0.100	7
Zinc	17.7	4.7	21.2	17.2	11.9	25.8	7
Total PCBs	0.002	0.001	0.003	0.002	0.001	0.004	7

Table 4-19. Concentrations of organic and inorganic residues in seedheads of buttonbush (*Cephalanthus occidentalis*) from outside the "Area of Readily Apparent Harm".

	Chemical Concentration (mg/kg, dry weight)						
Chemical	**mean**	**std dev**	**95% UCL**	**geomean**	**min**	**max**	**n**
Metals							
Aluminum	29.73	9.51	40.50	28.75	21.40	40.10	3
Antimony	0.0092	0.0088	0.0192	0.0063	0.0020	0.0190	3
Arsenic	0.0323	0.0180	0.0527	0.0294	0.0200	0.0530	3
Barium	29.17	16.90	48.29	25.46	12.30	46.10	3
Beryllium	0.0064	0.0007	0.0072	0.0064	0.0056	0.0069	3
Cadmium	0.0300	0.0260	0.0594	0.0238	0.0150	0.0600	3
Calcium	5246.67	2300.88	7850.30	4931.38	3360.00	7810.00	3
Chromium (Cr3+)	2.33	1.00	3.47	2.18	1.30	3.30	3
Cobalt	0.0577	0.0093	0.0682	0.0571	0.0470	0.0640	3
Copper	11.70	0.70	12.49	11.69	11.20	12.50	3
Iron	42.90	12.32	56.84	41.73	31.40	55.90	3
Lead	0.2113	0.1480	0.3788	0.1691	0.0640	0.3600	3
Magnesium	1340.00	65.57	1414.20	1338.94	1280.00	1410.00	3
Manganese	220.33	79.76	310.59	211.52	161.00	311.00	3
Mercury	0.0057	0.0012	0.0071	0.0056	0.0046	0.0070	3
Nickel	0.99	0.47	1.52	0.90	0.48	1.40	3
Potassium	2156.67	256.97	2447.45	2145.94	1860.00	2310.00	3
Selenium	0.0907	0.0447	0.1413	0.0817	0.0420	0.1300	3
Silver	0.1523	0.1413	0.3123	0.1081	0.0370	0.3100	3
Thallium	0.0150	0.0017	0.0170	0.0149	0.0130	0.0160	3
Tin	0.91	0.10	1.02	0.91	0.80	0.98	3
Vanadium	0.0250	0.0066	0.0324	0.0244	0.0190	0.0320	3
Zinc	21.30	3.91	25.73	21.07	18.70	25.80	3
Total PCBs	1.98	0.96	3.07	1.80	0.96	2.86	3

4.0 SITE CHARACTERIZATION - CHEMICAL, PHYSICAL, AND BIOLOGICAL DATA

4.1 Overview

This section examines and provides a summary of relevant chemical, physical, and biological information pertaining primarily to the wetland site near the former Raytheon facility with additional historical information on the adjoining Sudbury River. This historical information is an important consideration when attempting to identify potential chemicals of concern in environmental media at the site. The available data sets that were evaluated are presented in Table 4-1. The data is summarized in this section (refer to Appendix B for complete data sets).

Table 4-1. Data availability and location. Refer to text for full descriptions of data.

	Data Source	
Sample type	**USFWS**	**ERM**
Wetland Soil[1]	√	√
Sediment[1]	√	√
Surface Water (low water)[2]		√
Surface Water (high water)[3]		√
Fish	√	
Red Wing Blackbird	√	
Small Mammals	√	
Wetland Plants		√

[1]Wetland soil and sediments are defined in section 3.5.

[2]Surface water collected during low water conditions (November 1999 and October 2000) in or near the drainage swale.

[3]Surface water collected during flooded water conditions (May 2000) in or near the drainage swale.

4.2 Description of Investigations Considered in this ERC

4.2.1 USFWS Data

In a report entitled, "Contaminant Levels in the Sudbury River: Massachusetts", USFWS report chemical concentrations in sediment, fish, small mammals, and red-winged blackbird eggs from several locations along the Sudbury, Assabet, and Concord Rivers from studies conducted between 1986 and 1990 (Eaton and Carr, 1991). The stated purpose of that study was to determine if the Great Meadows National Wildlife Refuge (GMNWR) had been impacted by contaminants and to evaluate the extent of injury. The GMNWR is located adjacent to the Concord and Sudbury Rivers in portions of the towns of Bedford, Billerica, Lincoln, Carlisle, Concord, and Sudbury, Massachusetts, which are suburban communities that lie west of the Boston Metropolitan area. The USFWS report acknowledges that this area potentially receives chemical loadings from a variety of sources including industrial effluents, sewage treatment effluents, road runoff, impact from Superfund sites, and landfill leachate. The chemicals for which analyses were conducted include PCBs, PAHs, organochlorine pesticides (*e.g.*, dieldrin, DDT, *etc.*),

Table 4-20. Soil to plant uptake factors for cattail roots (*Typha latifolia*) and seedheads of buttonbush (*Cephalanthus occidentalis*)

Chemical	Mean Soil to Plant Uptake Factors[1] *Typha laterifolia*	*Cephalanthus occidentalis*
Metals		
Aluminum	0.0060	0.0017
Antimony	00838	0.0331
Arsenic	0.0260	0.0032
Barium	0.0394	0.2208
Beryllium	0.0145	0.0115
Cadmium	0.1216	0.0143
Calcium	0.4300	1.7150
Chromium (Cr3+)	0.0321	0.0064
Cobalt	0.0312	0.0055
Copper	0.0278	0.0247
Iron	0.0102	0.0026
Lead	0.0236	0.0004
Magnesium	0.0904	0.5166
Manganese	0.1949	0.3623
Mercury	0.0205	0.0053
Nickel	0.0245	0.0398
Potassium	1.8453	4.0867
Selenium	0.2786	0.1556
Silver	0.0190	0.0097
Thallium	0.0930	0.0960
Tin	0.0138	0.0176
Vanadium	0.0185	0.0010
Zinc	0.1599	0.1585
Total PCBs	0.0258	0.0016

[1]Calculated by dividing the chemical concentration in plant tissue (mg/kg, dry weight) by the chemical concentration in co-located soil (mg/kg, dry weight).