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October 26, 2012

Mr. Scott Hansen
Remedial Project Manager
USEPA, Superfund Division
Mail Code SR-6J
77 West Jackson Blvd.
Chicago, Illinois 60604-3590

Re: Draft Alternatives Array Document – Cedar Creek, Cedarburg, Wisconsin
Project Number: 120862-01.01

Dear Mr. Hansen:

Attached please find the *Draft Alternatives Array Document* (AAD) for the referenced site. The alternatives in the Draft AAD were first presented to the agencies in our July 16, 2012 submittal. Anchor QEA would like to meet with you to discuss the Draft AAD and its incorporation into the Feasibility Study. I will be in contact with you soon to arrange a meeting.

Sincerely,

Stuart D Messur

Stuart Messur
Anchor QEA, LLC

cc: Mark Thimke, Esq., Foley & Lardner
Tom Baumgartner, Mercury Marine
Margaret Brunette, Wisconsin Department of Natural Resources

REPORT

DRAFT ALTERNATIVES ARRAY DOCUMENT
CEDAR CREEK SITE FEASIBILITY STUDY

Prepared for

Mercury Marine

W6250 Pioneer Road

P.O. Box 1939

Fond du Lac, WI 54936-1939

Prepared by

Anchor QEA, LLC

290 Elwood Davis Road

Suite 340

Liverpool, NY 13088-2104

October 2012

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October 2012

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LIST OF ACRONYMS AND ABBREVIATIONS

AAD	Alternatives Array Document
Amcast	Amcast Industrial Corporation Cedarburg facility
AOC	Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirement
AUF	area use factor
BBL	Blasland, Bouck and Lee, Inc.
BERA	Baseline Ecological Risk Assessment
BSAF	biota-sediment accumulation factor
CERCLA	Comprehensive Environmental Response, Compensation, and Recovery Act
cfs	cubic feet per second
CSM	conceptual site model
CTE	central tendency exposure
cy	cubic yards
DOC	dissolved organic carbon
ELCR	excess lifetime cancer risk
EMNR	Enhanced Monitored Natural Recovery
FS	Feasibility Study
g/day	grams per day
GIS	Geographic Information System
GRA	General Response Action
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
LOAEL	low observed adverse effects level
Mercury Marine	Mercury Marine, a Division of Brunswick Corporation
mg/kg	milligrams per kilogram
MNR	Monitored Natural Recovery
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ng/L	nanogram per liter

NOAEL	no observed adverse effect level
NR	Natural Resources
PCB	polychlorinated biphenyl
POC	particulate organic carbon
POM	particulate organic matter
PRG	preliminary remediation goal
QEA	Quantitative Environmental Analysis
RAO	Remedial Action Objective
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
Site	Cedar Creek Operable Unit of the Cedar Creek Superfund Alternative Site
SOW	Statement of Work
SSL	Soil Screening Level
SWAC	surface-weighted average concentration
TBC	to-be-considered criteria
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TRV	toxicity reference value
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UCL	upper confidence limit
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VSS	volatile suspended solids
WAC	Wisconsin Administrative Code
WDNR	Wisconsin Department of Natural Resources

1 INTRODUCTION

This Alternatives Array Document (AAD) presents the development of potential remedial alternatives to address polychlorinated biphenyls (PCBs) within the Cedar Creek Operable Unit of the Cedar Creek Superfund Alternative Site (Site) located in Cedarburg, Wisconsin. The AAD was prepared in accordance with the Administrative Settlement Agreement and Order on Consent (2008 AOC) for Remedial Investigations (RIs) and Feasibility Studies (FSs; Comprehensive Environmental Response, Compensation, and Recovery Act [CERCLA] Docket No. V-W-'08-C-892) issued to Mercury Marine, a Division of Brunswick Corporation (Mercury Marine), in March 2008 (United States Environmental Protection Agency [USEPA] and Mercury Marine 2008) and amended from the Administrative Order on Consent (2002 AOC) issued in September 2002 (USEPA and Mercury Marine 2002). The Site is located in Ozaukee County, just north of Milwaukee, Wisconsin, and the Cedar Creek Operable Unit consists of the creek and its impoundments, raceways, free flowing reaches, and floodplain soils starting after the Ruck Pond Dam and continuing 4.6 miles to its confluence with the Milwaukee River (Figure 1-1).

The information presented in this AAD was prepared in accordance with CERCLA, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), and USEPA's Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final (USEPA 1988).

1.1 Purpose and Scope

As described under Task 5 – Development and Screening of Remedial Alternatives of the Statement of Work (SOW; Appendix A to the 2008 AOC), the purpose and scope of this AAD are to do the following:

- Establish Site-specific Remedial Action Objectives (RAOs) that are developed to protect human health and the environment.
- Establish General Response Actions (GRAs) for PCBs by defining removal and off-Site disposal, containment, treatment, excavation, pumping, or other actions, singly or in combination that satisfy the RAOs.
- Identify and screen remedial technologies that are applicable to PCBs and the physical matrix at the Site. The screening is to be based primarily on a technology's

ability to effectively address PCBs at the Site taking into consideration the technology's implementability and cost.

- Develop remedial alternatives in accordance with the NCP.
- Screen remedial alternatives for permanence, effectiveness, implementability, and cost by identifying a viable combination of potential technologies or process options that will be combined into Site-wide alternatives. Remedial alternatives will be defined with respect to the following:
  - Size and configuration of the representative options
  - Permanence
  - Acceptance by agencies, landowners, and impacted communities
  - Time for remediation
  - Rates of flow or treatment
  - Spatial requirements
  - Distances for disposal
  - Required permits
  - Imposed limitations
  - Other factors necessary to evaluate the alternatives

An FS will be developed to present a detailed analysis and comparative evaluation of the remedial alternatives identified in this AAD following its approval by USEPA.

1.2 Site Background

This section provides information on the background of the Site, including a brief overview of the Site history and a Site description. Additional information on the Site is provided in the RI Report (ARCADIS 2012).

1.2.1 Site History

PCBs entered Cedar Creek from two local sources via storm sewers—Mercury Marine's Plant 2 property and the Amcast Industrial Corporation Cedarburg facility (Amcast). The first source is the boat manufacturer, Mercury Marine, which operated a plant on St. John Avenue in Cedarburg, Wisconsin, from 1951 to 1982 (Figure 1-2). Fluids, some of which contained PCBs, are believed to have leaked from equipment and were subsequently washed into floor drains that emptied into storm sewers. Those sewers discharged into Ruck Pond, which is an impoundment on Cedar Creek adjacent to the former plant, and PCBs were transported to downstream reaches of the creek. Amcast, a local automotive industry supplier on Hamilton Road in Cedarburg, Wisconsin, is the second source of contamination in the area (Figure 1-2). There was also a plant that discharged PCBs via storm sewers into a stormwater basin known as Wilshire Pond, which was hydraulically connected to the creek at the Former Hamilton Pond. The Amcast facility itself and remaining portions of the Amcast property are now being investigated by USEPA following Amcast's filing for bankruptcy.

PCBs were originally detected in fillets from fish collected from the Cedar Creek impoundments in 1984 (Wawrzyn and Wakeman 1986). These results prompted a sediment investigation in four impoundments on Cedar Creek (from upstream to downstream: Ruck, Columbia, Wire and Nail, and Hamilton ponds, as shown on Figure 1-1) by the Wisconsin Department of Natural Resources (WDNR) in 1986. These and subsequent studies conducted by the WDNR and others confirmed the presence of PCBs in the creek system, including the stream channel and in portions of its surrounding floodplain. To address the PCB-containing sediment in the creek system, Mercury Marine undertook a removal action in Ruck Pond (the most upstream of the four impoundments on Cedar Creek) in 1994 (Blasland, Bouck and Lee, Inc. [BBL] 1995a). Additionally, the storm sewer located between Mercury Marine's Plant 2 and the storm sewer outfall discharging to Ruck Pond was cleaned and two laterals connecting the storm sewer to Plant 2 were sealed (BBL 1995b). In April 1996, following heavy rains and associated high creek flow, the Hamilton Pond Dam failed; remnants of the failed dam were subsequently removed. In 2001, Mercury Marine implemented a soil removal program along the Former Hamilton Pond, which entailed removing PCB-containing floodplain soils that became exposed following the dam failure (Mercury Marine 2001).

1.2.2 Site Description

The Site encompasses a 4.6-mile reach of Cedar Creek from Ruck Pond Dam to the creek's confluence with the Milwaukee River, downstream of the City of Cedarburg (Figure 1-2). The Site was divided into four reaches in the RI Report (ARCADIS 2012), as listed below:

- Columbia Pond
- Wire and Nail Pond
- Reach Between Wire and Nail Pond and Former Hamilton Pond
- Downstream of Former Hamilton Pond

Columbia Pond Reach

The Columbia Pond reach is the upper portion of the Site. It is approximately 1 mile in length and includes a free-flowing portion of Cedar Creek just downstream of Ruck Pond Dam, Columbia Pond, and the Ruck Pond Raceway, a diversion conduit/channel that receives storm sewer discharge from the City of Cedarburg and can serve to divert flow from Ruck Pond to Columbia Pond (Figure 1-2). Columbia Pond is impounded by the Columbia Mills Dam, which has a small raceway along its northern end. The Columbia Mills Dam was constructed in 1855, together with an adjacent grist mill that used power generated by the dam. A water wheel also was installed at the five-story mill, where grain was ground into flour. The dam was later converted to produce hydroelectric power. The Columbia Mills Dam consists of an approximately 83-foot-long by 10-foot-high uncontrolled overflow arched spillway and a 10-foot-wide rectangular concrete millrace, which is divided into two 5-foot-wide stoplog gated bays (Mead and Hunt 2007a). The Columbia Mills Dam is owned and maintained by the City of Cedarburg.

The 10-year floodplain, which is the approximate extent of PCB-containing floodplain soils as described in the RI Report, is generally in close proximity with the water's edge (i.e., within 100 feet along the northern shoreline of Columbia Pond and within 50 feet along the southern shoreline of Columbia Pond), except near Adlai Horn and Cedar Creek City parks (Figure 1-2). Columbia Pond is largely surrounded by northern mesic forest cover type with a medium habitat quality (see Section 3.4.5.4 of the RI Report). No wetlands were identified in this reach. Land use along Columbia Pond and the upstream raceway includes commercial facilities and private residences, together with Adlai Horn and Cedar Creek City parks.

Wire and Nail Pond Reach

Downstream of Columbia Pond is the Wire and Nail Pond reach. Wire and Nail Pond reach is composed entirely of Wire and Nail Pond (Figure 1-2). Wire and Nail Pond is an elongated and narrow impoundment composed of two distinct basins that are impounded by the Wire and Nail Factory Dam. The entire pond is approximately a third of a mile long, and a partial control structure is associated with the dam raceway. The Wire and Nail Factory Dam, originally associated with the adjacent mill, was built in the 1860s to grind grain into flour. The mill was later (circa 1900) converted to a nail manufacturing operation. In 1931, a hydroelectric plant was installed and the water wheel was removed. The Wire and Nail Factory Dam consists of an 80-foot-long by 24-foot-high overflow arched spillway with an 8-foot-wide concrete millrace with an entrance controlled by a steel slide gate (Mead and Hunt 2007b). The Wire and Nail Factory Dam is currently owned and maintained by a private entity.

Due to the steep banks throughout Wire and Nail Pond, the 10-year floodplain is generally within 50 feet of the water's edge. The floodplain is also characterized by northern mesic forest cover type of medium habitat quality (ARCADIS 2012). No wetlands were identified in the reach. Land use to the north of the pond is commercial, whereas the south is wooded and undeveloped. Areas of steep terrain and dense vegetation appear to restrict human access to the pond.

<u>Reach Between Wire and Nail Pond and Former Hamilton Pond</u>

The Reach Between Wire and Nail Pond and Former Hamilton Pond includes the approximate 1.6-mile-long portion of free-flowing stream that extends down to the former pool (i.e., the Former Hamilton Pond) that was formed by the Hamilton Pond Dam (Figure 1-2).

The width of the 10-year floodplain in this reach varies from greater than 600 feet in large low-lying areas near braided portions of the creek to less than 200 feet (including the width of Cedar Creek) in areas with steep banks. In fact, approximately half of the area within the 10-year floodplain is composed of wetlands of medium to high habitat quality. Land use along this reach includes residential properties along the top of the east bank, with the west bank being undeveloped and wooded in many places. The Former Hamilton Pond generally is bordered by banks supporting mature vegetation. The properties bordering the former pond are owned by private residents, the City of Cedarburg, and a few businesses.

Downstream of Former Hamilton Pond

Below the Former Hamilton Pond is another free-flowing stretch that extends from the Green Bay Road Bridge down to the confluence with the Milwaukee River (Figure 1-2). This stretch of Cedar Creek is approximately 1.3 miles in length. Similar to the Reach Between Wire and Nail Pond and the Former Hamilton Pond, this reach contains a 10-year floodplain of variable width due to the braided channel and low-lying areas. Approximately half of the area of this reach was also identified as wetlands of medium habitat quality. Land use adjacent to this area includes a mix of residential parcels and undeveloped, wooded areas.

1.3 Report Organization

This AAD is organized into six sections as follows:

- Section 1 (this section) presents the purpose and scope of the AAD and relevant background information, including a brief Site history and Site description.
- Section 2 provides a summary of the RI, summarizes information on lateral and vertical extent of PCBs in sediment and floodplain soils at the Site, and concludes with a refined conceptual site model (CSM) that builds on that presented in the RI.
- Section 3 describes the process of developing RAOs and includes an overview of the baseline risk assessments, summarizes Applicable or Relevant and Appropriate Requirements (ARARs), provides proposed RAOs, and discusses the development of preliminary remediation goals (PRGs).
- Section 4 presents GRAs and identifies and screens potential remedial technologies.
- Section 5 assembles the technologies that were retained following the screening process presented in Section 4 into potential remedial alternatives for the Site.
- Section 6 provides the list of references cited in this document.

2 CHARACTERIZATION OF CEDAR CREEK

2.1 Site Investigations

In 1984, the WDNR detected PCBs in fish fillets collected in the Cedar Creek impoundments, which prompted additional studies that led to the discovery of PCBs in sediments of the four impoundments (Ruck, Columbia, Wire and Nail and Hamilton ponds). Since the 1980s, several PCB-related investigations have been conducted at the Site, led both by Mercury Marine and others. This section presents a brief summary of the investigations used to develop this AAD; Section 3 of the RI Report (ARCADIS 2012) provides a comprehensive list of all Site-related investigations.

2.1.1 Site Investigations Conducted by Mercury Marine

As part of the RI data collection activities, sediment, floodplain soil, water column, and fish samples were collected from the Site between 1997 and 2005. These investigations, along with additional data collection activities (e.g., engineering analysis of the dams), are briefly discussed below.

- Sediment sampling was performed in Ruck Pond Raceway, Columbia Pond, Wire and Nail Pond, Former Hamilton Pond and its raceway, and the reach between Former Hamilton Pond and the creek's confluence with the Milwaukee River in 1997, 1998, and 2003. Analytical parameters included PCBs and total organic carbon (TOC), and a subset of samples were analyzed for dioxins, radiochemical parameters (for geochronological dating), and geotechnical parameters.
- Floodplain sampling was performed in 2003 on transects established along the creek from just below Ruck Pond Dam to the creek's confluence with the Milwaukee River. (Floodplain soil sampling was not performed in the Former Hamilton Pond area because that area was previously remediated as described above.) Supplemental floodplain soil sampling was performed in 2004 around Columbia Pond. Analytical parameters included PCBs and TOC.
- One round of water column sampling was performed in 2003 as part of the RI, which included collection of surface water samples from Columbia Pond, Wire and Nail Pond, and Former Hamilton Pond for analysis of filtered and unfiltered PCBs and TOC, as well as total suspended solids (TSS).

- Resident fish sampling was performed in 2003 and 2004. During each event, fish were collected from an upstream reference location (Cedarburg Pond), Columbia Pond, Wire and Nail Pond, the Reach Between Wire and Nail Pond and Former Hamilton Pond, and the Reach Downstream of Former Hamilton Pond. Samples were analyzed for PCBs and lipid content. Resident fish sampling was also conducted at similar locations in 2010.
- Caged fish studies were performed in 2003, 2004, and 2005 in Cedarburg Pond (upstream reference location), Columbia Pond, and Wire and Nail Pond. The second and third rounds of sampling (i.e., 2004 and 2005) were expanded to include locations in the downstream free-flowing reaches of Cedar Creek to further support evaluations of spatial trends. Samples were collected at 3- and 6-week intervals after each study began and analyzed for PCBs and lipid content.
- A habitat characterization was performed in 2003 to describe the habitat and ecological characteristics of the Site and surrounding areas. As part of this study, assessments were performed to determine the occurrence of threatened or endangered species within the immediate vicinity of the Site and to identify potential wetland areas within the floodplain.
- The structural and hydraulic integrity of the dams on Columbia and Wire and Nail ponds were investigated in 2004, and again in 2005 for Columbia Mills Dam (Mead and Hunt 2007a, 2007b).
- A review of historic properties (e.g., properties included on the National Register of Historic Places) in the vicinity of the Site was performed in 2004.

2.1.2 Site Investigations Conducted by Others

In addition to the RI datasets described above, water column data from two other studies (conducted by WDNR and U.S. Geological Survey [USGS]) were used to supplement the RI data in the development of the refined CSM (Section 2.3) and the Site-specific mathematical model (see Section 3.5). Each of these investigations is briefly described below.

- As part of a study conducted between June 1993 and August 1995, the WDNR collected surface water samples from Cedar Creek at locations downstream of Ruck Pond and Columbia Pond (Steuer et al. 1999). Samples were analyzed for particulate and dissolved PCB congeners, as well as particulate organic carbon (POC), dissolved organic carbon (DOC), TSS, volatile suspended solids (VSS), chloride, and chlorophyll-a. A portion of the study was performed during the active upstream remediation of Ruck Pond (1994), which could have potentially biased the results.

- From December 2000 to October 2001, the USGS collected surface water samples from Cedar Creek at locations downstream of Ruck and Columbia ponds (USEPA 2002a, 2002b). Samples were analyzed for particulate and dissolved PCB congeners, as well as TSS and chlorophyll-a.

2.2 Lateral and Vertical Extent of PCBs in Sediment and Floodplain Soils

This section presents a brief overview of the RI data, observed PCB concentration trends, and surface-weighted average concentrations (SWACs) for sediments and floodplain soils computed for use in further analyses to support development of this AAD and the forthcoming FS Report. Additional information regarding the nature and extent of RI data collected at the Site is provided in Section 4 of the RI Report (ARCADIS 2012).

2.2.1 Sediment

Since 1997, a total of 293 sediment samples (duplicates averaged) were collected from 96 locations in the area from Ruck Pond Dam downstream to the confluence with the Milwaukee River. PCB concentrations in those samples ranged from non-detect (60 samples) to 345 milligrams per kilogram (mg/kg), reported in a sediment sample from the 0- to 1-foot interval collected from Columbia Pond near where the Ruck Pond Raceway joins the pond. Within Columbia Pond and Wire and Nail Pond, samples were generally collected in 1-foot increments for the top 2 feet and up to 2-foot increments below 2 feet. Below Wire and Nail Pond, a single sample was generally collected within select sediment pockets. The sediment thickness, and thus sample interval, was variable in these areas. Sediment PCB concentrations are presented in 1-foot increments from the surface to 5 feet below the sediment bed on Figures 2-1a through 2-8. If a sample interval was greater than 1 foot in thickness (e.g., 2-foot increments), the result of the sample was presented for each 1-foot increment. For example, if a sample was collected from 2 to 4 feet below sediment surface, the result was presented on both the panels displaying 2- to 3-foot and 3- to 4-foot intervals. General lateral and vertical trends in PCB concentrations are described below.

- PCB concentrations are greater than 1 mg/kg at all depths in the Ruck Pond Raceway (Figures 2-1a and 2-1b) and range from 4.5 to 107 mg/kg.
- Within Columbia Pond, the highest PCB concentration (345 mg/kg) is located just downstream of and adjacent to Ruck Pond Raceway (Figure 2-2a). Laterally, similar PCB concentrations were detected throughout the pond, with concentrations mostly in the range of 5 to 50 mg/kg. However, vertically, PCB sediment concentrations are greatest within the top 2 feet and are generally low (e.g., less than 1 mg/kg) at depths of approximately 3 feet and greater (Figures 2-2a and 2-2b).
- As observed in Columbia Pond, PCB concentrations are generally consistent laterally within Wire and Nail Pond, with a maximum detected concentration of 49.5 mg/kg (average results for duplicate analyses) and most of the data ranging from 1 to 10 mg/kg. Vertically, PCB concentrations exhibit a subsurface maximum concentration, where the PCB concentrations are generally lower at the surface (e.g., 0 to 0.5 feet and 0 to 1 foot), increasing to the maximum concentration per location at approximately 1 to 3 feet, and decreasing to PCB concentrations generally below 1 mg/kg by 4 feet (Figures 2-3a and 2-3b). This subsurface maximum concentration trend is typical of impounded areas receiving lower concentration sediments following an initial source of greater strength, and is a key indicator of natural recovery within a depositional environment.
- Cedar Creek between Wire and Nail Pond and the Former Hamilton Pond is characterized as a riffle and pool system with stretches of steep gradient, hard substrate (e.g., cobbles and gravel) followed by braided sections of creek channel that contain small, dispersed sediment pockets. PCB concentrations are much lower in these sediment pockets than in the upstream ponds, ranging from non-detect to approximately 6 mg/kg (Figures 2-4a to 2-5b). Sediment thickness within the sampled pockets ranged from approximately 1 to 3 feet. One vertical composite sample was collected per sediment pocket; therefore, vertical variations in PCBs over the sampled thickness are unknown.
- Within the Former Hamilton Pond, PCB concentrations are below 1 mg/kg at all locations except two (HP10-3 and HP11-8), where concentrations are 10.1 and 4.33 mg/kg, respectively (Figure 2-6; see Figure 3-7 of the RI Report of sample IDs and PCB concentrations). All samples collected below a depth of 1 foot were non-detect in this reach.

- The reach downstream of the Former Hamilton Pond is characterized by braided channels with small, dispersed sediment pockets. PCB concentrations in this reach range from non-detect to approximately 5 mg/kg (Figures 2-7 and 2-8). In sediment pockets where two samples were collected vertically, PCB concentrations either decrease with depth or are similar throughout the vertical profile (Figures 2-7 and 2-8).

Sediment SWACs were calculated for Columbia Pond, Wire and Nail Pond, the Reach Between Wire and Nail Pond and Former Hamilton Pond, and the Reach Downstream of Former Hamilton Pond for use in remedial alternatives development and evaluation. RI sediment data from 0 to 1 foot were included in the SWAC calculations. Data usage rules applied to the SWAC calculations are provided below.

- At a few sample locations, both radiochemical and PCB samples were collected at non-consecutive intervals (e.g., 0 to 0.08 feet, 0.08 to 0.16 feet, 0.58 to 0.67 feet) within the top foot. At these locations, an average PCB concentration of all available samples within the 0- to 1-foot interval was used for SWAC computations.
- If both 0- to 0.5-foot and 0- to 1-foot surface sediment samples were collected at a sediment location, only the 0- to 1-foot surface sample was used in calculations.
- If duplicate samples were collected, the PCB concentrations were averaged.
- Where present, half of the detection limit was used as the PCB concentration for non-detect values.

For both Columbia Pond and Wire and Nail Pond, SWACs were calculated by first subdividing the ponds into Thiessen polygons. The surface area of each polygon and the PCB concentration associated with the polygon were then used to compute the SWAC, as shown in Equation 1 below.

$$SWAC = \frac{\sum_{i=1}^{n}(C_i * SA_i)}{\sum_{i=1}^{n} SA_i} \quad (1)$$

where:

C_i = PCB concentration (mg/kg)

SA_i = surface area of polygon (ft^2)

n = number of samples within a specified area (e.g., pond)

Figures 2-9 and 2-10 present the polygons and assigned 0- to 1-foot PCB concentration for each polygon within Columbia Pond and Wire and Nail Pond, respectively.

Below Wire and Nail Pond, sediment is only found in limited sediment pockets; therefore, an alternative approach was used to compute SWACs, as described below.

- For sediment pockets that were sampled, the PCB concentration of the sample was applied to the area of that sediment pocket.
- For sediment pockets that were not sampled, the average PCB concentration of all 0- to 1-foot samples in that reach (e.g., between Wire and Nail Pond and Former Hamilton Pond or Downstream of Former Hamilton Pond) was applied to those pockets of sediment.
- For the area immediately above Former Hamilton Dam (where sediment was built up behind the dam), polygons were generated for each sample location and the sediment PCB concentration of that sample was applied to the area of the polygon (similar to the approach used for Columbia and Wire and Nail ponds).
- For all remaining areas (i.e., areas outside of the sediment pockets and not immediately upstream of Former Hamilton Dam), half of the average detection limit for the sediment samples (0.085 mg/kg) was applied.

Figure 2-11 illustrates the area-weighted averaging approach used for specific areas of the creek described above. Similar to Equation 1, all of the area-weighted concentrations (i.e., PCB concentration multiplied by the area component) were summed and divided by the total area within the reach to compute the SWAC. Table 2-1 provides the computed SWAC for each reach.

Table 2-1
Computed Sediment SWACs for Reaches within Cedar Creek

Reach	Sediment PCB SWAC (mg/kg)
Columbia Pond	33
Wire and Nail Pond	9.5
Between Wire and Nail Pond and Former Hamilton Pond	0.5
Downstream of Former Hamilton Pond	0.2

2.2.2 Floodplain Soil

Since 1997, a total of 331 soil samples (duplicates averaged) were collected from 164 locations within the Cedar Creek floodplain.[1] PCB concentrations in these samples ranged from non-detect to 19 mg/kg, which was found in the 0.5- to 1-foot interval of a sample collected from a low-lying area adjacent to the Ruck Pond Raceway. Floodplain soil sampling generally occurred along transects oriented perpendicular to the creek channel, and samples were generally collected in 6-inch intervals from the surface to a maximum depth of 1.5 feet. However, only 0- to 0.5-foot and 0.5- to 1-foot intervals were collected downstream of Columbia Pond. Figures 2-12 through 2-16 present the soil PCB concentrations within the Cedar Creek floodplain. The approximate 10-year floodplain shown on these figures (the outerbound of the floodplain where PCBs appear to have historically been deposited) was estimated using results from an existing one-dimensional HEC-2 model that was modified by ARCADIS to incorporate the removal of the Hamilton Dam (see Appendix C of the RI Report). On each figure, the various sample intervals are depicted using larger shapes stacked on top of one another. For example, three sample intervals at a particular location (e.g., Columbia Pond) are shown with three squares that get progressively larger for each deeper sample interval. General lateral and vertical patterns in floodplain soil PCB concentrations are described below.

- Along a given transect, PCB concentrations generally decreased with distance moving from the creek channel up into the higher elevation portions of the floodplain (which is the expected pattern given that higher elevation areas are inundated less frequently). Figure 2-17 presents the floodplain soil transect sampled directly below Wire and Nail Pond, which illustrates this trend of decreasing PCB concentration with distance from the creek, corresponding to an increase in elevation. Panel A presents the PCB concentrations in plan view along the transect, whereas Panel B plots both the elevation of each sample location and the PCB concentration (denoted by symbol color).
- PCB concentrations were generally higher at the surface (0- to 0.5-foot interval) than in the subsurface.

[1] This number excludes floodplain samples collected in 1999 in the vicinity of the Former Hamilton Pond because those floodplain sediments/soils were subsequently removed as part of the remedial action conducted in 2000.

- With the exception of one location, which had a concentration of 0.11 mg/kg, PCBs were not detected in soil samples collected outside the 10-year floodplain.

Although numerous floodplain soil samples were collected as part of the RI, there were large areas within the 10-year floodplain that were not sampled; therefore, a data interpolation approach is necessary to approximate PCB concentrations in such areas for the purpose of developing and evaluating various floodplain soil remedial alternatives. Per the proposed revisions to Wisconsin Administrative Code (WAC) Natural Resources (NR) 720, an alternative approach can be used to evaluate potential remediation areas. Working with USEPA and WDNR and based on the observed spatial patterns in PCB concentrations described above, a multi-step, screening-level approach was developed to spatially average the floodplain soil data for purposes of identifying potential areas for remediation. This approach will be formally submitted to WDNR for approval during the FS process. These potential remediation areas (on a tax parcel basis) would be targeted for future sampling during the pre-design phase of the project, and the final remediation areas would be delineated based on the results of the pre-design data.

Why? Do we need more data.

My radar is going off.

The screening-level approach was composed of the following six steps.

- Step 1 – Assign one PCB concentration to each sampling location
- Step 2 – Divide the floodplains longitudinally into reaches/subareas
- Step 3 – Divide the floodplains laterally in each reach/subarea by the 2-year flood inundation elevation
- Step 4 – Calculate the average concentration of each floodplain component (e.g., edge of creek to 2-year flood inundation elevation, 2-year to 10-year flood inundation elevations) within each reach/subarea
- Step 5 – Identify portions of the floodplain that may present difficult access and/or represent ecologically sensitive habitat (e.g., wetlands)
- Step 6 – Compute the floodplain soil SWACs for each tax parcel using an area-weighting approach, both including and excluding areas that may present difficult access and/or represent ecologically sensitive habitat (e.g., wetlands; due to the uncertainty in the extent to which such areas contribute to potential exposure to receptors)

Each of these steps is described in detail below.

First, as each floodplain soil sample location contained up to three discrete samples from different depth intervals, the maximum concentration within the core was conservatively selected as the concentration to represent the sample location.

good

Next, the floodplains were sub-divided into the following six reaches based on the presence of impoundments or former impoundments (consistent with the risk assessments) and distinct characteristics of the raceways:

- Ruck Pond Raceway
- Columbia Pond
- Wire and Nail Pond
- Between Wire and Nail Pond and Former Hamilton Pond
- Former Hamilton Pond Raceway
- Downstream of Former Hamilton Pond

Observed? Meaning that is has not been quantified?

Under Step 3, the floodplains were further divided laterally by flood inundation elevation based on the observed pattern of decreasing PCB concentrations with increasing elevation along a transect (e.g., see Figure 2-17). The hydrodynamic model developed for assessing sediment stability in the RI (see Appendix C of the RI) was used to estimate flood inundation elevations for the 2-year return interval event. The 2-year return interval event was selected as the associated flows often exceed the capacity of the creek bed (i.e., bank full event) and inundate low-lying areas, thus serving as an intermediate elevation between the creek bank and 10-year floodplain. Details relating to the development of the input parameters for the hydrodynamic modeling are provided in Appendix A.

These flood inundation elevations were then mapped into three segments: 1) the area extending from the edge of creek to the 2-year flood inundation elevation contour; 2) the area between the 2-year and 10-year flood inundation elevation contours; and 3) the area outside of the 10-year flood inundation elevation contour. The floodplain soil samples located in each of these flood inundation segments (e.g., creek to 2-year elevation) were averaged over each of the six longitudinal reaches to develop two PCB concentrations per reach (concentration for samples located between the edge of the creek and the 2-year elevation contour, and those located between the 2-year and 10-year elevation contours). Figure 2-18 provides a conceptual illustration of how the floodplains were divided by flood inundation elevation and how the average concentrations per area were assigned. Table 2-2 presents the average concentration per reach (based on the maximum concentration per sampling location) used for each flood inundation segment. Given the extensive amount of wetlands along the lower reaches of the creek, Table 2-2 also includes the average PCB concentrations of all samples inside or outside of wetlands within a particular reach for use in assessing the impact of including or excluding wetlands in the SWAC calculation.

Table 2-2
Average PCB Concentrations Applied to Flood Inundation Segments in Floodplain Soils

Reach	Flood Inundation Segment	Average PCB Concentration (mg/kg)[1]		
		Entire Reach	Inside Designated Wetland Areas	Outside Designated Wetland Areas
Ruck Pond Raceway	< 2 year	2.9	--	2.9
	2 to 10 year	0.05	--	0.05
Columbia Pond	< 2 year	1.8	--	1.8
	2 to 10 year	0.34	--	0.34
Wire and Nail Pond	< 2 year	0.83	--	0.83
	2 to 10 year	0.29	--	0.29
Between Wire and Nail Pond and Former Hamilton Pond	< 2 year	2.3	2.3	2.2
	2 to 10 year	0.05	0.03	0.05
Former Hamilton Pond Raceway	< 10 year[2]	2.5	--	2.5
Downstream of Former Hamilton Pond	< 2 year	0.97	1.7	0.68
	2 to 10 year	0.45	0.60	0.42

Notes:
1 The average PCB concentration was computed using the maximum PCB concentration of each sampling location.
2 All locations within the Former Hamilton Pond Raceway were combined into one area, and represent former sediments deposited when water pooled behind the Former Hamilton Dam was routed through the raceway.

For Step 5, wetlands, as delineated in the RI, were identified within the floodplains. There were also an historic district (Hamilton Historic District) and historic property (Concordia Mill) identified within the 10-year floodplain near Former Hamilton Pond. The proximity of these historic features will need to be considered when assessing potential remedial options during the FS. Finally, floodplain soil SWACs were computed over the portion of each individual tax parcel that lies within the 10-year floodplain, evaluating both inclusion and exclusion of the wetlands in the calculation. Figures 2-19 and 2-20 present the floodplain soil SWACs for each parcel based on including and excluding the wetlands in the calculation, respectively.

2.3 Refined Conceptual Site Model

The CSM is a qualitative representation of PCB fate, transport, and bioaccumulation in the Cedar Creek system. The CSM is used to help target areas for remediation and to identify and screen potential remedial alternatives during the FS process. This section presents a refinement of the CSM that was initially developed during the RI. This section first presents refinements of the CSM for sediments and fish based on evaluating relationships between PCBs in sediment, water, and fish (Section 2.3.1), followed by a discussion of the CSM for PCB fate and transport in floodplains (Section 2.3.2).

2.3.1 Sediments and Bioaccumulation

Because the primary objective of in-stream sediment remediation is to reduce PCB concentrations in fish tissue (see Section 3.5), the CSM described in this subsection is focused on the relationship between PCBs in fish and sediment. The refined CSM described below was based on examining spatial patterns in PCB data in the creek across multiple media (water, sediment, and biota).

PCBs can enter the creek food web from both the sediments and the water column. PCBs in the sediment bed preferentially attach to particulate organic matter (POM; e.g., sediment detritus, algae, periphyton), which forms the base of the benthic food web and is consumed by insects and other invertebrates (Figure 2-21). The POM present at the sediment bed surface is typically material that is freshly deposited from the water column and is often a preferable energy source for the food web as compared to organic matter contained deeper within the sediment bed, which is both less available and less degradable. Forage fish consume invertebrates and are in turn consumed by higher trophic-level predatory fish. In addition, PCBs in the surface sediment porewater are transported into the overlying water column by a variety of mechanisms, where they can similarly move up the food chain. The distinction between sediment- and water column-based food webs turns out to be important in many aquatic systems, including Cedar Creek, as described below. Following USEPA guidance for the evaluation of contaminated sediment sites (USEPA 2005), the refined CSM includes a representation of these processes.

Not episodic, look at any of the WC data.

A complete understanding of bioaccumulation also rests upon a realistic representation of contaminant fate and transport processes. As water flows downstream through the Site, increasing amounts of PCBs are added to the water column due to a continuous flux of dissolved PCBs from the sediment porewater (Figure 2-21) and due to episodic resuspension of PCB-containing sediments during high flow events. Porewater flux is likely more important as a source to the aquatic food web because resuspension events are not the dominant source of PCBs to the water under typical low-flow conditions, when a substantial portion of fish uptake occurs (i.e., during the growing season). Based on what?!

Thus, the CSM includes a series of linkages: between sediment and the water column; between sediment and biota; between the water column and biota; and between upstream and downstream reaches of the Site. A key line of evidence for evaluating these linkages is provided by spatial gradients in measured PCB concentrations in sediments, water, and biota.

Not good, contradicts RI

A comparison of PCB concentration gradients in surface sediment and the water column is shown on Figure 2-22. The data shown on this figure were all collected between 1998 and 2003. Surface sediment concentrations (Figure 2-22, panel a) were represented by the reach-specific SWACs presented in Table 2-1. Two sets of water column data are included in the analysis (Figure 2-22, panel b). First, the USGS collected samples monthly for approximately 1 year in 2000 and 2001 from Columbia Road (the inlet to Columbia Pond) and Highland Drive (just below Columbia Mills Dam; see Section 3.3 and Appendix A of the RI Report). In addition, as part of the RI, surface water data were collected from three laterally averaged transects each within Columbia Pond, Wire and Nail Pond, and Former Hamilton Pond over the course of 2 days in November 2003. Both sets of water column data are shown on panel b of Figure 2-22 as individual data points; the line represents the overall data average.

Average sediment PCB concentrations declined approximately two orders of magnitude from Columbia Pond to Former Hamilton Pond. In contrast, average water column PCB concentrations increased more than 10-fold from the Columbia Pond inlet to just below the

Columbia Mills Dam and then remained nearly constant from Columbia Mills Dam to Former Hamilton Pond. The USGS data show average water column total PCB concentrations that increased from approximately 1 nanogram per liter (ng/L) at the Columbia Pond inlet (Columbia Road station) to approximately 20 ng/L near the dam (Highland Drive station).[2] The 2003 RI data present a similar picture: the three Columbia Pond samples collected in 2003 were non-detect at a detection limit of 6.5 ng/L, and average concentrations for the two downstream impoundments were both approximately 20 ng/L, consistent with the 2001 to 2002 average from Highland Drive.[3]

The spatial pattern in the water data indicates that as water flows downstream, PCBs are released from the sediments into the water. Because PCB levels upstream of Columbia Pond are relatively low (approximately 1 ng/L) and sediment concentrations within the pond are relatively elevated, concentrations in the water increase substantially across the pond. Downstream of Columbia Pond, the pattern changes—water column concentrations entering these downstream reaches are already relatively elevated, and sediment concentrations are considerably lower (Figure 2-22, panel a). Thus, the additional flux of PCBs from the sediments to the water is lower in these reaches, and water column concentrations are not expected to increase as much. In fact, little to no further increase is observed in average concentrations downstream of Columbia Mills Dam (based on the limited data from 2003). A key conclusion from this evaluation is that Columbia Pond sediments are the primary source of PCBs to the water throughout the Site. This conclusion that the flux of PCBs from

Maybe

[2] The 1994 to 1995 surface water data collected by USGS in conjunction with WDNR (USGS 1999) also showed an increase in PCB concentrations between these two locations.

[3] Conclusions regarding spatial patterns in the water column are based primarily on average concentrations; in the Columbia Pond area the averages are driven by the 2001 to 2002 USGS data, which were collected in several events, over an entire year. In contrast, the 2003 surface water data were collected in a single sampling event in November, during which the flow was elevated (approximately 225 cubic feet per second [cfs] at the time of sample collection; mean annual flow in Cedar Creek is 75 cfs). Historical water column sampling data at the Site, as well as the USGS data, indicate that concentrations are more variable during colder months and higher flow periods, which further confounds the comparison of the 2003 data (from one event) with the 2000 USGS monthly data to some extent. These two programs also differed in their sampling locations: the USGS samples were collected at one location at the upstream end within each reach, and the 2003 samples were composites from three transects within each impoundment. Nonetheless, spatial variation within the impoundments downstream of Columbia Pond is not likely to have a significant effect on the key conclusions discussed above because average concentrations remained relatively constant all the way from Columbia Mills Dam down to Former Hamilton Pond and there was no noticeable trend from upstream to downstream within any impoundment (see Figure 3-11 of the RI Report).

Read to confirm

Columbia Pond sediment is much greater than that from the downstream reaches (and, hence, the reason the water data exhibit relatively little change downstream of Columbia Mills Dam) is consistent with two other historical sources of information:

1. Historical water column sampling data from 1990 to 1991 (Westenbroek 1993). These data were collected prior to the Ruck Pond remediation and, therefore, do not represent contemporary conditions. Nonetheless, they can be used to make relative comparisons regarding PCB inputs from the reaches downstream of Ruck Pond. Consistent with the more recent water column data, the 1990 to 1991 data showed that water column PCB concentrations varied according to flow conditions, but were, on average, highest within Columbia Pond and generally showed little to no further increase (or even decreases) in the downstream locations (Wire and Nail and Hamilton ponds).
2. The PCB transport model developed by Baird and Associates (1997) to support the Total Maximum Daily Load (TMDL) developed by WDNR (2008). Predictions from this model showed that total PCB flux associated with Columbia Pond sediments is much greater than the total flux from sediments within Wire and Nail and Hamilton ponds combined (see Figure 2 of WDNR 2008).

TMDL

Data from the 2003 to 2005 caged fish sampling provide additional information that can be used to evaluate relationships between PCBs in water and biota. Caged fish were suspended in the water column, above the sediment bed; therefore, they represent a food web that is associated entirely, or almost entirely, with the water column. Figure 2-23 (panel a) shows the annual average PCB concentrations in caged fish deployed for 6 weeks in 2003, 2004, and 2005. Annual average PCB concentrations in caged fish increased approximately 10-fold between Cedarburg Pond (the upstream reference location) and Columbia Pond. Concentrations then remained relatively unchanged from Columbia Pond through the Reach Downstream of Former Hamilton Pond. This pattern differs from the 100-fold decline in sediment PCB concentrations (Figure 2-22, panel a), but matches that of the water column data (Figure 2-22, panel b): average water column concentrations increased approximately 20-fold across Columbia Pond, a rise that lies within a factor of 2 of the 10-fold increase in the caged fish data. Downstream of Columbia Pond, concentrations in both water (although based on the limited data from 2003) and caged fish remained relatively constant.

The average of PCB concentrations measured in resident fish (fillet and whole body samples) collected in 2003 and 2004 are shown on panel b of Figure 2-23; individual species averages are shown as discrete data points; fillet samples are shown as filled symbols, and whole body preparations are shown as open symbols. The line represents the overall average PCB concentration in fish tissue; although concentrations are known to differ between fillet and whole body tissue preparations, the differences in average concentrations among these two sample types and individual species at a given location are relatively small, which supports use of an average as a means of summarizing the spatial gradient in the dataset as a whole. PCB levels in resident fish increased approximately by 10-fold or more between Cedarburg Pond (the upstream reference location) and Columbia Pond, and then declined from Columbia Pond to the Reach Downstream of Former Hamilton Pond, but only by less than a factor of 2 (Figure 2-23, panel b). This pattern is nearly identical to that in the caged fish data and is also generally similar to the pattern in the water column data (Figure 2-22, panel b); more importantly, it is distinctly different from that in the sediment data (Figure 2-22, panel a). These observations indicate that the water column is likely the dominant source of PCBs to the food web.

This is what we need to break.

This overall pattern in the resident fish data is also observed when considering individual species. Data throughout the Site are available for only one species—whole body white sucker collected in 2003 and 2004. PCB concentrations in white sucker increased between the Cedarburg Pond reference location and Columbia Pond, and then declined approximately 2-fold from Columbia Pond to the Reach Downstream of Former Hamilton Pond (Figure 2-24). This decline is much less than that observed in sediment concentrations, which as mentioned above is approximately a factor of 100. This difference suggests that the white sucker accumulate PCBs from a combination of water- and sediment-derived sources, but with a stronger link to the water column (the 2-fold decline is closer to the lack of gradient observed in the water column concentrations than to the 100-fold sediment decline; see Section 3.5.1 for a quantitative evaluation of these relationships). White sucker is known as a bottom feeder; therefore, its forage and habitat preferences are probably more influenced by the sediment than the other species in this ecosystem (e.g., largemouth and smallmouth bass). This provides further support to the conclusion that the primary source of PCBs to the food web is uptake from the water column. As noted above, a water column-based food web does not necessarily mean the biota all feed in the water column; rather, it means that the benthic invertebrates and bottom-feeding fish likely derive a majority of their PCBs from freshly deposited organic matter that originated from the overlying water column, rather than the PCBs contained within the deeper portions of the sediment bed.

The role of water column transfer in PCB bioaccumulation is not unique to this Site. The following are examples of other sediment sites (ranging from small streams to large lakes) where water column transfer has been identified as an important route of bioaccumulation:

- **Green Bay, Wisconsin.** The food web of Green Bay, Wisconsin, has clearly accumulated PCBs from the water column based on a combination of data analysis and modeling (Connolly et al. 1992; Quantitative Environmental Analysis [QEA] 2001).

  Referencing themselves
- **Housatonic River, Massachusetts.** An evaluation of sediment, water, and fish data from an impoundment of the Housatonic River in Massachusetts resulted in the conclusion that "the food web in Rising Pond may be tied more to dietary PCB sources based in the water than to those based in the sediments" (BBL and QEA 2003), which is a similar conclusion to that drawn here for Cedar Creek.
- **Conard's Branch and Richland Creek, Indiana.** Based on site data and a computer model, QEA (2007) concluded that in much of the Conard's Branch and Richland Creek study area, most of the PCBs in fish entered the food web from the water column. This computer model was used to develop the remedial decision at the site (USEPA 2007).

To summarize, comparisons of spatial PCB concentration gradients among sediment, water, and fish support a refined CSM in which the sediments of Columbia Pond are the dominant source of PCBs to the water column throughout the Site and the water column is the dominant source of PCBs to the food web. This CSM is supported by Site data, as well as precedents from other sites and a mechanistic understanding of PCB fate, transport, and bioaccumulation. This qualitative CSM is supported and quantified with a mathematical model in Section 3.5 and Appendix B.

2.3.2 Floodplain Soils

Unlike the complex interactions between sediments, the water column, and fish presented above, PCBs are largely transported to the floodplain soils from one source—the water column, which transports PCB-containing sediments to the floodplain during overbank conditions. The distribution of PCB concentrations in the floodplain soil reflects surface water flow and sediment deposition as the primary transport pathway. PCB data show that the highest floodplain soil PCB concentrations are predominantly present near the shoreline and in the low-lying areas where floodwater naturally accumulates (i.e., areas where inundation is most frequent). Furthermore, PCB concentrations generally decrease with distance from the water's edge, where inundation of floodwater (and associated deposition of PCB-containing sediments) is much less frequent (Figure 2-17).

As described in the RI Report, this transport mechanism occurs at a much lower rate than within the sediments due to much less frequent interaction. The low-lying floodplains along Cedar Creek become inundated during higher flow events when the creek overtops its banks. Bankfull (or overtopping) events occur to some extent nearly every year; however, the extent of floodplain inundation varies with the magnitude of the flood, with the proximal floodplains (i.e., areas closest to the creek) being flooded more frequently than distal portions of the floodplain due to the lower elevations and proximity to the creek.

3 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

3.1 Overview

This section provides a list of the ARARs and items "to be considered" (TBCs), presents the RAOs, and describes the development of PRGs.

ARARs are federal and state standards, requirements, criteria, or limitations that apply to the Site, and must be considered in the development and evaluation of the specific remedial actions. Compliance with ARARs is one of the nine criteria considered under CERCLA in the evaluation of potential remedial alternatives. ARARs are further described in Section 3.3.

RAOs are site-specific goals developed based on identified concerns related to potential human health and ecological risks, and form the basis for comparing the effectiveness of various potential remedial alternatives. The findings of the human health and ecological risk assessments are the primary basis for developing RAOs. Baseline risk assessment information is summarized in Section 3.2. A list of the RAOs is presented in Section 3.3.

PRGs represent cleanup goals for protecting human health and the environment against potential risks (described in Section 3.2) posed by exposure to chemicals of potential concern at the Site. PRGs are developed on the basis of chemical-specific ARARs, when available, or site-specific risk-related factors (i.e., the baseline risk assessment). Section 3.5 describes the development of the PRGs for the Site.

3.2 Baseline Risk Assessment

A baseline Human Health Risk Assessment (HHRA) and a Baseline Ecological Risk Assessment (BERA) were completed to evaluate potential risks to human health and the environment associated with potential exposure to PCBs in sediments, surface water, floodplain soils, and fish tissue at the Site. The study area for both the HHRA and the BERA was divided into four reaches as described in Section 1.2: 1) Columbia Pond; 2) Wire and Nail Pond; 3) the Reach Between Wire and Nail Pond and Former Hamilton Pond; and 4) Downstream of Former Hamilton Pond, which extends from the Former Hamilton Pond Dam to the Milwaukee River (Figure 1-2).

This is an opinion, delete

3.2.1 HHRA

Using conservative assumptions and data collected over several years, a number of potential exposure pathways were evaluated, including a number of recreational activities in the floodplain areas and the reaches of Cedar Creek that comprise the Site. Based on the results of the risk characterization step of the HHRA, the two primary exposure pathways posing a potentially significant human health risk were identified: 1) consumption of PCB-containing fish tissue by resident recreational child and adult anglers throughout all four reaches; and 2) direct contact with PCB-containing floodplain soils by resident children within the two most downstream reaches (i.e., Reach Between Wire and Nail Pond and Former Hamilton Pond and Reach Downstream of Former Hamilton Pond). The HHRA characterized potential excess lifetime cancer risks (ELCRs) and non-cancer hazards (using a hazard quotient [HQ] approach) under two different exposure scenarios: a reasonable maximum exposure (RME) scenario and a central tendency exposure (CTE) scenario. An RME exposure scenario is defined as the highest exposure that is reasonably expected to occur at a site but that is still within the range of possible exposures. A CTE exposure scenario attempts to estimate exposure to an average individual. In both cases, the concentration of a contaminant that an individual is exposed to in any media (e.g., fish tissue) is equal to the 95th upper confidence limit (UCL) on the mean. Other exposure parameters (e.g., ingestion rates) are different between the RME and CTE scenarios, but consistent with the overall goal of the exposure scenario (i.e., evaluating a high end compared to more average degree of exposure). The primary differences between the exposure assumptions used in the RME versus the CTE scenarios are the ingestion rates of fish tissue, incidental ingestion rates of floodplain soils, and the site use factors (i.e., the percentage of total fish in a person's diet that is assumed to come from fish caught from the Site rather than other sources, and the percentage of time a person would spend in the floodplains of the study area). For example, under the RME exposure scenario, the HHRA assumed that recreational child and adult anglers were obtaining 100 percent of their fish diet from fish caught from Cedar Creek (i.e., defined as the site use factor) and that there was no cooking-related loss of PCBs. Ingestion rates were assumed to be 37 grams per day (g/day) for adults and 12 g/day for children. Under the CTE scenario, the site use factor was assumed to range from 0.1 to 0.5 and it was assumed that there was no cooking-related loss of PCBs. Ingestion rates were assumed to be 12 g/day for adults and 4 g/day for children. Potentially significant human health risks are defined as ELCRs that exceed USEPA's target risk range of 1×10^{-4} to 1×10^{-6} and HQs that are greater than 1.0 (USEPA 2003, 1989). The results of the HHRA for the RME scenario are included in Table 3-1, and the results for the CTE scenario are included in Table 3-2. Briefly, the results for the two potentially significant pathways are summarized following the tables.

Table 3-1
Summary of HHRA Results for RME Scenario

Reach	Receptor	Exposure Media	Cancer Risk[1,3]	Non-cancer Hazard[2,3]
			RME	RME
Columbia Pond	Recreational User (Child, Park)	Soil	--	2.E-01
	Recreational User (Adult, Park)	Soil	--	3.E-02
	Recreational User (Child + Adult, Park)	Soil	1.E-06	--
	Resident, Child	Soil	--	7.E-01
	Resident, Adult	Soil	--	8.E-02
	Resident, Child + Adult	Soil	4.E-06	--
	Recreational User (Adult - Kayaker, Canoeist)	Soil, Sediment, Surface Water	6.E-06	4.E-01
	Swimmer, Adult	Sediment, Surface Water	5.E-06	3.E-01
	Angler, Adult	Fish Tissue, Sediment	--	1.E+02
	Angler, Child	Fish Tissue, Sediment	--	2.E+02
	Angler, Child + Adult	Fish Tissue, Sediment	2.E-03	--
Wire and Nail Pond	Recreational User (Adult - Kayaker, Canoeist)	Soil, Surface Water	2.E-07	5.E-02
	Resident, Child	Soil	--	1.E+00
	Resident, Adult	Soil	--	1.E-01
	Resident, Child + Adult	Soil	5.E-06	--
	Angler, Adult	Fish Tissue, Sediment	--	8.E+01
	Angler, Child	Fish Tissue, Sediment	--	1.E+02
	Angler, Child + Adult	Fish Tissue, Sediment	1.E-03	--
Reach Between Wire and Nail Pond and Former Hamilton Pond	Recreational User (Adult - Kayaker, Canoeist)	Soil, Surface Water	1.E-06	1.E-01
	Resident, Child	Soil	--	2.E+00
	Resident, Adult	Soil	--	3.E-01
	Resident, Child + Adult	Soil	1.E-05	--
	Angler, Adult	Fish Tissue, Sediment	--	1.E+02
	Angler, Child	Fish Tissue, Sediment	--	2.E+02
	Angler, Child + Adult	Fish Tissue, Sediment	3.E-03	--

Table 3-1
Summary of HHRA Results for RME Scenario

Reach	Receptor	Exposure Media	Cancer Risk[1,3] RME	Non-cancer Hazard[2,3] RME
Downstream of Former Hamilton Pond	Recreational User (Adult - Kayaker, Canoeist)	Soil	5.E-07	4.E-02
	Resident, Child	Soil	--	2.E+00
	Resident, Adult	Soil	--	2.E-01
	Resident, Child + Adult	Soil	9.E-06	--
	Angler, Adult	Fish Tissue, Sediment	--	1.E+02
	Angler, Child	Fish Tissue, Sediment	--	2.E+02
	Angler, Child + Adult	Fish Tissue, Sediment	3.E-03	--

Notes:
1 Cancer risks for the receptors that include a child and adult life stage are presented as cumulative risks (i.e., recreational park user for Columbia Pond and residents).
2 Non-cancer hazards are presented separately for adults and children.
3 Risks/hazards greater than USEPA targets are shaded.

Table 3-2
Summary of Human Health Cancer Risks and Non-cancer Hazards

Reach	Receptor	Exposure Media	Cancer Risk[1,3] CTE	Non-cancer Hazard[2,3] CTE
Columbia Pond	Recreational User (Child, Park)	Soil	NC	NC
	Recreational User (Adult, Park)	Soil	NC	NC
	Recreational User (Child + Adult, Park)	Soil	NC	NC
	Resident, Child	Soil	--	3.E-01
	Resident, Adult	Soil	--	3.E-02
	Resident, Child + Adult	Soil	1.E-06	--
	Recreational User (Adult - Kayaker, Canoeist)	Soil, Sediment, Surface Water	NC	NC
	Swimmer, Adult	Sediment, Surface Water	NC	NC
	Angler, Adult	Fish Tissue, Sediment	--	2.E+01
	Angler, Child	Fish Tissue, Sediment	--	3.E+01
	Angler, Child + Adult	Fish Tissue, Sediment	2.E-04	--

Table 3-2
Summary of Human Health Cancer Risks and Non-cancer Hazards

Reach	Receptor	Exposure Media	Cancer Risk[1,3]	Non-cancer Hazard[2,3]
			CTE	CTE
Wire and Nail Pond	Recreational User (Adult - Kayaker, Canoeist)	Soil, Surface Water	NC	NC
	Resident, Child	Soil	--	3.E-01
	Resident, Adult	Soil	--	4.E-02
	Resident, Child + Adult	Soil	1.E-06	--
	Angler, Adult	Fish Tissue, Sediment	--	2.E+00
	Angler, Child	Fish Tissue, Sediment	--	4.E+00
	Angler, Child + Adult	Fish Tissue, Sediment	3.E-05	--
Reach Between Wire and Nail Pond and Former Hamilton Pond	Recreational User (Adult - Kayaker, Canoeist)	Soil, Surface Water	NC	NC
	Resident, Child	Soil	--	8.E-01
	Resident, Adult	Soil	--	1.E-01
	Resident, Child + Adult	Soil	3.E-06	--
	Angler, Adult	Fish Tissue, Sediment	--	4.E+00
	Angler, Child	Fish Tissue, Sediment	--	7.E+00
	Angler, Child + Adult	Fish Tissue, Sediment	5.E-05	--
Downstream of Former Hamilton Pond	Recreational User (Adult - Kayaker, Canoeist)	Soil	NC	NC
	Resident, Child	Soil	--	7.E-01
	Resident, Adult	Soil	--	9.E-02
	Resident, Child + Adult	Soil	3.E-06	--
	Angler, Adult	Fish Tissue, Sediment	--	4.E+00
	Angler, Child	Fish Tissue, Sediment	--	6.E+00
	Angler, Child + Adult	Fish Tissue, Sediment	4.E-05	--

How is this the highest risk.

Notes:
NC – not calculated (this scenario was not evaluated for this receptor and pathway)
1 Cancer risks for the receptors that include a child and adult life stage are presented as cumulat
(i.e., recreational park user for Columbia Pond and residents).
2 Non-cancer hazards are presented separately for adults and children.
3 Risks/hazards greater than USEPA targets are shaded.

Resident Recreational Anglers, Fish Consumption

Under the RME scenario, ELCRs for the local angler (adult and child) catching and consuming PCB-containing fish from all four reaches ranged from 1 x 10^{-3} (Wire and Nail Pond) to 3 x 10^{-3} (Reach Between Wire and Nail Pond and Former Hamilton Pond and Reach

Downstream of Former Hamilton Pond). Non-cancer HQs for the child angler ranged from 100 (Wire and Nail Pond) to 200 (Columbia Pond, Reach Between Wire and Nail Pond and Former Hamilton Pond, and the Reach Downstream of Former Hamilton Pond). Under the CTE scenario, ELCRs for the local angler (adult + child) catching and consuming PCB-containing fish exceeded the 1×10^{-4} risk threshold only within Columbia Pond. Non-cancer HQs for the child angler ranged from 4 (Reach Between Wire and Nail Pond and Former Hamilton Pond) to 30 (Columbia Pond).

Resident Children and Adults, Soil Direct Contact

Under the RME direct contact scenario, ELCRs for resident children and adults that may be exposed to PCB-containing floodplain soils did not exceed the 1×10^{-4} risk threshold. Non-cancer HQs for the resident child were approximately equal to 2 for the Reach Between Wire and Nail Pond and Former Hamilton Pond and the Reach Downstream of Former Hamilton Pond. Under the CTE direct contact scenario, all ELCRs were less than the 1×10^{-4} risk threshold and all non-cancer HQs were less than 1.0.

Under the RME scenario, fish consumption is the primary exposure pathway with carcinogenic risks and non-carcinogenic hazards greater than USEPA risk-based targets. Non-cancer HQs for child residents exposed to surface floodplain soils in the Reach Between Wire and Nail Pond and Former Hamilton Pond and the Reach Downstream of Former Hamilton Pond are above the USEPA target of 1 (HQs = 2). Risks associated with exposure to surface soils, sediment, and/or surface water during other recreational activities are much lower, and are within or below USEPA risk-based targets.

3.2.2 BERA

The ecological risk assessment completed for the Site evaluated potential risks to aquatic-dependent wildlife resulting from exposure to PCB-contaminated sediments, surface water, and fish tissue. The results of the risk assessment indicate that the primary risk driver is consumption of PCB-contaminated fish from each of the four defined reaches in the Site. Risks also were evaluated on a Site-wide basis because aquatic-dependent wildlife are relatively wide-ranging compared to the overall size of the Site.

Assessments were completed on multiple aquatic-dependent species including great blue heron (piscivorous bird), mink (piscivorous mammal), American robin (vermivorous bird), and short-tailed shrew (vermivorous mammal). Exposure pathways included ingestion of PCB-containing forage fish from Cedar Creek and ingestion of PCB-containing floodplain soil-based invertebrates (e.g., earthworms). The risk characterization step of the BERA was based on the comparison of dietary intake of PCBs by individual receptors to toxicity reference values (TRVs) that were based on no observed adverse effect levels (NOAELs) and low observed adverse effects levels (LOAELs). HQs that represent the ratio of dietary intake of PCBs to either NOAEL-based or LOAEL-based TRVs were calculated. LOAEL-based HQs are summarized in this section because they are appropriate for the development of remedial actions that protect population and communities of ecological receptors (Efroymson et al. 1997; USEPA 1997). For the species and exposure pathways considered, the only potential incremental ecological risk identified was for mink (study area wide HQ = 6.5), due to consumption of forage fish from Cedar Creek. For specific reaches, the greatest contributors to mink risk were Columbia Pond (HQ = 9.6) and Wire and Nail Pond (HQ = 10). HQ values were lower for the Reach Between Wire and Nail Pond and Former Hamilton Pond (HQ = 2.7) and the Reach Downstream of Former Hamilton Pond (HQ = 2.5). This result is directly related to the higher forage fish (and sediment) PCB concentrations observed in these reaches.

Results of the BERA indicate that PCB concentrations in soil (for robins and short-tailed shrews) and sediment and biota (for herons) are not likely to pose significant incremental ecological risk.

3.3 Applicable or Relevant and Appropriate Requirements

Any selected remedial actions must comply with ARARs of federal and state standards, criteria, or limitations (USEPA 1988). According to the NCP (40 CFR 300.5), "applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site." A requirement may not be applicable, but nevertheless could be relevant and appropriate. Relevant and appropriate requirements address problems or situations sufficiently similar to those encountered at CERCLA sites that their use is well suited to the particular site.

In addition, some federal, state, and local environmental and public health agencies may develop criteria, advisories, guidance documents, and proposed standards that are not legally enforceable but that contain useful information for implementing a cleanup remedy or selecting cleanup levels. These fall into the category of TBCs; compliance with TBCs is not mandatory but they may complement the identified ARARs.

Occasionally, circumstances may justify a waiver of an ARAR. USEPA guidance (1988) identifies six such cases as follows:

- The remedial action selected is only a part of a total remedial action (i.e., it is an interim remedy) and the final remedy will attain the ARAR upon its completion.
- Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.
- Compliance with the ARAR is technically impracticable from an engineering perspective.
- An alternative remedial action will attain an equivalent standard of performance through the use of another method or approach.
- The ARAR is a state requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.
- For §104 Superfund-financed remedial actions, compliance with the ARAR will not provide a balance between protecting human health and the environment and the availability of Superfund money for response at other facilities.

ARARs may be categorized as chemical-specific, action-specific, or location-specific. Some ARARs fit neatly into a single category, whereas others may fall into more than one category. Each category is briefly described below.

- **Chemical-specific ARARs.** Chemical-specific ARARs are usually health or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of an acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment. These requirements provide protective site remediation levels for the contaminants in the designated media (e.g., sediment, soil, water).

- **Action-specific ARARs.** Action-specific ARARs are technology- or activity-based requirements or limitations on actions performed as part of a remedial action. For remedial actions at the Site, these requirements are not necessarily triggered by the presence of specific contaminants in sediments or floodplain soils, but rather by specific activities related to managing the impacted media.
- **Location-specific ARARs.** Location-specific ARARs apply solely to the location of the remedial action. Location-specific ARARs may restrict or preclude certain response actions or may apply only to certain portions of the site. This group of ARARs includes consideration of floodplains, wetlands, and navigation features.

The preliminary federal and state ARARs and TBCs for this Site are provided in Tables 3-3 and 3-4, respectively. Each table is divided according to chemical-, action-, or location-specific ARARs. The application of the ARARs in the evaluation of the potential remedial alternatives will be discussed further in the FS Report.

3.4 Remedial Action Objectives

As stated in USEPA guidance (USEPA 1988), RAOs are developed as medium-specific goals or objectives for the protection of human health and the environment. RAOs for the Site were developed based on the risk assessment (Section 3.2), applicable rules and regulations (Section 3.3), and discussions with and input from the USEPA and WDNR.

The following are RAOs developed for the Cedar Creek Site:

- Protect humans from exposure to PCBs in sediments that exceed protective levels
- Protect humans from exposure to PCBs in fish tissue that exceed protective levels
- Protect humans from exposure to PCBs in floodplain soils that exceed protective levels
- Protect ecological receptors from exposure to PCBs that exceed protective levels
- Reduce the transport of PCBs
- Minimize downstream movement of PCBs during implementation of the remedy

3.5 PRG Development

As described above, PRGs delineate the cleanup goals for protecting human health and the environment against potential risks posed by exposure to chemicals of potential concern at the Site. PRGs are developed on the basis of chemical-specific ARARs, when available, or site-specific, risk-related factors (i.e., the baseline risk assessment). This section describes process for defining PRGs for sediments (Section 3.5.1) and floodplain soils (Section 3.5.2).

3.5.1 Sediments

Because the HHRA indicated that the primary sediment-based exposure pathway resulting in risks exceeding the USEPA targets is fish consumption (see Section 3.2.1), the process of developing a PRG for PCBs in sediments has two major components: 1) developing a quantitative relationship between PCB concentrations in fish tissue and sediment; and 2) developing an acceptable fish tissue PCB concentration. Understanding these two factors leads to the selection of a sediment PRG.

3.5.1.1 Development of a Quantitative Relationship Between Fish Tissue and Sediment PCB Concentrations

In order to develop a PRG for sediments, it is necessary to have a means of linking PCB concentrations in the media associated with risk (i.e., fish tissue) with those in the desired media (i.e., concentrations in sediment). This section describes how such relationships were developed for the Site.

This doesn't exist

In cases where fish PCBs are derived predominately from local sediments, a commonly used means of linking fish PCB concentrations with sediments is the biota-sediment accumulation factor (BSAF). A BSAF represents a direct relationship between sediment and fish concentration. Where appropriate, it can be used to establish a sediment PRG; a unit reduction in sediment PCB concentration (e.g., 2-fold, 5-fold) is expected to yield the same unit reduction in fish PCB concentration. However, in situations where fish PCB uptake is driven by water column PCBs or by a combination of water and sediments, a 1:1 relationship between sediment and fish PCB levels is not expected. This is the case in Cedar Creek: as discussed in Section 2.3, the evaluation of spatial gradients in sediment, water, and fish PCB concentrations indicates that water column uptake is the dominant route of bioaccumulation at the Site. As an example, considering Figures 2-22 and 2-23, the relationship between fish and sediment in the Reach Downstream of Former Hamilton Pond is very different from the relationship in Columbia Pond. In Columbia Pond, the ratio between average fish concentrations (mg/kg wet weight) and average sediment concentrations (mg/kg dry weight) is approximately 1:10. In the Reach Downstream of Former Hamilton Pond, this ratio is approximately 10:1. Because this ratio changes significantly through Cedar Creek (i.e., approximately 100-fold), a BSAF relationship cannot be used for setting PRGs throughout the Site; therefore, a more sophisticated means of linking these two media is required.

In Columbia Pond, the Site data indicate that the dominant source of PCBs to the water column is the local sediments. As described in Section 2.3, in the three downstream reaches, the water column and fish PCB concentrations appear to be controlled largely by flux to the water column from the sediments of Columbia Pond and, to a lesser degree, by flux from local sediments. In these circumstances, a mathematical model that accounts for the impacts of the water column on the food web is required. Such a model was developed for the Site, as summarized below and described in detail in Appendix B.

3.5.1.1.1 Model Development

As described in Appendix B, for each reach of the Site, the model uses a mass balance equation to predict average water column concentrations based on flux from local sediments as well as transport from upstream. In Columbia Pond, the model starts with a 1 ng/L upstream water column concentration (based on the 2000 to 2001 USGS data; Figure 2-22, panel b) and calculates concentrations that increase to approximately 20 ng/L across that pond due to flux from the sediments (based on the measured sediment concentrations and standard porewater mass transfer expressions). That water concentration is then used as the upstream transport into Wire and Nail Pond. Using this same approach for each impoundment, the model predicts only slight (e.g., 2 ng/L total) increases in the water column concentration downstream of Columbia Pond, which is similar to the data as shown on panel b of Figure 2-22 (see Figure B-2 from Appendix B for a comparison of model-predicted water column concentrations with the data).

This is a conclusion, not model development

The second component of the model consists of a relationship that calculates fish PCB concentration in a given reach as a linear combination of PCBs from local sediments and PCBs from water (both expressed in terms of carbon-normalized particulate phase concentration calculated from partitioning formulations; see Appendix B). Inclusion of both water and sediment uptake pathways is consistent with the spatial gradient analyses and refined CSM presented in Section 2.3, and data- and modeling-based evaluations conducted at numerous other PCB sites, as discussed in Section 2.3. Model calibration produced a reasonable match between the model-predicted fish tissue concentrations and the measured fish concentrations throughout the Site (i.e., see Figure B-3 from Appendix B).

3.5.1.1.2 Model Evaluation of Sediment PRG

The model describes the pathways illustrated on the refined CSM diagram (Figure 2-21): the transfer of PCBs from sediments to water, the transport of PCBs from upstream to downstream with the flow of water, and the uptake of PCBs by the food web from both sediments and water. With this model, it is therefore possible to evaluate the relationship between reductions in sediment PCB concentrations and PCB concentrations in the fish. Example model results are presented in Appendix B, and results relevant to developing the PRG are summarized below.

Radar

The use of the model to evaluate a sediment PRG depends on the concentration of PCBs in the water flowing into Columbia Pond. The benefits of remediating local sediment sources of PCB within the four reaches of the Site are limited to some extent due to the fact that PCBs flow into Columbia Pond from upstream; residual fish tissue PCB concentrations will remain regardless of the extent of remediation. The 2000 to 2001 USGS data from Columbia Road, which characterize PCB transport into Columbia Pond (see Section 2.3.2), show water column PCB concentrations that ranged from non-detect (2 of 12 samples) to approximately 4 ng/L, with an average of 1 ng/L. The source of these PCBs is not known, but likely can be attributed to atmospheric inputs to the watershed as well as potential influences from Ruck Pond. As described in Appendix C, numerous studies in which sampling of precipitation and waterbodies with no known PCB sources have indicated PCB concentrations associated with atmospheric inputs are typically in the range of 0.3 to 1 ng/L (or higher). In addition, although an extensive remediation project was successfully completed in Ruck Pond, low level residual PCBs may remain in that area. Therefore, model simulations were conducted using two alternate values for the PCB concentrations in water entering Columbia Pond: 1) 1 ng/L, which is the average of the 2000 to 2001 data; and 2) 0.5 ng/L, which represents a mid-range value associated with atmospheric PCB sources.

As shown in Table B-2 of Appendix B, the model evaluated reductions in fish tissue PCB concentration associated with various levels of sediment remediation, using Columbia Pond as an example. The model predicts that when accounting for existing upstream PCB inputs (i.e., at 1 ng/L), the remediation of sediments within Columbia Pond to achieve a SWAC of 1 mg/kg results in an average fish PCB concentration in Columbia Pond of approximately 0.2 mg/kg. A more extensive remediation, involving removal of all sediments with PCB concentrations above 1 mg/kg (which would result in a SWAC less than 1 mg/kg), is predicted to reduce average fish PCB concentrations to between 0.1 mg/kg and 0.2 mg/kg. Assuming a lower upstream water column concentration of 0.5 ng/L, the resulting fish tissue concentrations are similar (between 0.1 mg/kg and 0.2 mg/kg).

At other sites, surface water PCB concentrations on the order of 1 ng/L produce fish tissue PCB concentrations similar to the risk-based targets described above. For example, a mathematical model developed by USEPA (2006) for the Housatonic River, Massachusetts, showed future concentrations anticipated upstream of the study area (approximately 1 to 2 ng/L) were sufficient to maintain fish PCB concentrations in the range of 0.1 to 0.2 mg/kg wet weight (fillet basis), even with the most extensive remedial alternative (ARCADIS, Anchor QEA, and AECOM 2010).

As discussed in Appendix B, the modeling evaluations will be expanded during the development of the FS. The extent to which reduced fish PCB levels are predicted to occur in all four reaches of the Site in response to each remedial alternative will be quantified and documented. Those alternatives include a range of remedial actions in each reach, as discussed in detail in Section 5.

3.5.1.2 Evaluation of Acceptable Fish Tissue PCB Concentrations Based on Risk Assessments

As discussed in detail in Section 3.2, the most significant contribution to potentially elevated PCB risks for both humans and ecological receptors is ingestion of PCB-containing fish tissue. Although the HHRA also considered dermal absorption as part of the resident angler scenario, and the ecological risk assessment considered incidental sediment and surface water ingestion as part of the aquatic-dependent wildlife scenario, these exposure pathways contributed very little to overall potential risks. For example, for the resident angler scenario, the dermal absorption exposure pathway typically contributed less than 0.5 percent to the total incremental risk and, in most instances, was less than 0.1 percent. Therefore, the remainder of this subsection focuses on the development of a risk-based fish tissue concentration that will be protective of human health and the environment based on consumption of fish. Reductions in sediment concentrations and associated reductions in surface water concentrations that are required to achieve an acceptable fish tissue PCB concentration will also achieve a commensurate reduction in any exposure from sediment and surface water and will add to the overall level of protection for these receptor groups, the extent of which can be calculated.

Observation: hundreds of lines of analysis are summed up into 7 words

On the basis of the results from the HHRA and the BERA, the initial focus was to develop a risk-based residual fish tissue PCB concentration that would be protective of the resident angler exposure scenario. This tissue concentration was then evaluated to assess the degree to which it also would be protective of the aquatic-dependent wildlife exposure scenario.

As noted above, within Cedar Creek, fish consumption is the primary risk driver for both humans and ecological receptors. For humans, under the RME exposure scenario, the HHRA assumed that recreational child and adult anglers were obtaining 100 percent of their fish diet from fish caught from Cedar Creek (i.e., defined as the site use factor) and that there was no cooking-related loss of PCBs. Ingestion rates were assumed to be 37 g/day for adults and 12 g/day for children. Under the CTE scenario, depending on the reach, the site use factor was assumed to range from 0.1 (Wire and Nail Pond, Reach Between Wire and Nail Pond and Former Hamilton Pond, and Reach Downstream of Former Hamilton Pond) to 0.5 (Columbia Pond) and it was assumed that there was no cooking-related loss of PCBs. Ingestion rates were assumed to be 12 g/day for adults and 4 g/day for children.

Based on these exposure assumptions, fish tissue PCB concentrations that result in a target ELCR of 1 x 10^{-4} and a non-cancer HQ=1 are as follows:

- **RME Scenario Fish Tissue Concentrations**
  - Cancer risk (target ELCR = 1 x 10^{-4}) = 0.2 mg/kg PCBs
  - Non-cancer risk (target HQ = 1.0) = 0.025 mg/kg PCBs (child) or 0.038 mg/kg PCBs (adult)
- **CTE Scenario Fish Tissue Concentrations**
  - Cancer risk (target ELCR = 1 x 10^{-4}) = 3.3 mg/kg PCBs ([illegible].7 mg/kg PCBs (Wire and Nail Pond, the Reach Between [illegible]nd Former Hamilton Pond, and the Reach Downstream of [illegible]nd), depending upon site use factor
  - Non-cancer risk (target HQ = 1.0) = ranges from 0.15 mg/kg PCBs (child; Columbia Pond) to 1.17 mg/kg PCBs (adult; Wire and Nail Pond, the Reach Between Wire and Nail Pond and Former Hamilton Pond, and the Reach Downstream of Former Hamilton Pond), depending upon child versus adult and site use factor

Why is there a lack of site specific, the has been 50 years to collect information

Due to a lack of Site-specific information for Cedar Creek, there remains uncertainty regarding the selection of values for exposure variables such as fish tissue ingestion rates, site use factors, and cooking-related losses of PCBs. Other risk assessments or risk-based approaches at sites that may be similar to Cedar Creek used a range of values for these exposure parameters to develop target fish tissue PCB concentrations that are protective of human health. Two specific examples are cited below.

First, the TMDL for Cedar Creek (WDNR 2008) used a fish tissue concentration of 0.21 mg/kg PCBs. This fish tissue concentration was based on an assumed ingestion rate of 7.4 g/day, which is equivalent to one half-pound fish meal per month. The site use factor was set equal to 1 and cooking-related loss of PCBs of 50 percent was assumed. These exposure parameters are consistent with the assumptions used in the Uniform Great Lakes Sport Fish Consumption Advisory Protocol. The target risk level for the Cedar Creek TMDL is a non-cancer HQ = 1.0. The TMDL also states that this target fish tissue concentration is consistent with an ELCR = 1 x 10^{-4}.

Second, in the Record of Decision (ROD) for the Sheboygan Harbor and River, Wisconsin site, USEPA selected a sediment cleanup goal based on a protective fish tissue concentration of 0.3 mg/kg PCBs. This target fish tissue concentration was based on an RME scenario that assumed a fish tissue ingestion rate of 54 g/day, a site use factor of 0.5, and a target ELCR risk level of 1×10^{-4}.

Given the uncertainty in the value of the exposure parameters for Cedar Creek, it is helpful to refer to the target fish tissue concentrations from the Cedar Creek TMDL and the Sheboygan Harbor and River site. These sites incorporate various assumptions about fish ingestion rates, site use factors, and cooking-related losses that likely bracket the range of values for these parameters that also apply at Cedar Creek. Also, these two sites base target fish tissue PCB targets on risk-based goals that also are consistent with the goals for Cedar Creek (i.e., a target ELCR = 1×10^{-4} and a target non-cancer HQ = 1.0). Specifically, in the Cedar Creek TMDL and the Sheboygan Harbor and River site, fish ingestion rates varied between 7.4 g/day and 54 g/day, site use factors varied between 0.5 and 1, and cooking-related losses of PCBs ranged from 0 to 50 percent. Similarly, in the Cedar Creek HHRA, considering both the RME and CTE scenarios, fish tissue ingestion rates varied between 4 g/day (CTE, child) to 37 g/day (RME, adult), site use factors varied between 0.1 and 1.0, and cooking-related losses of PCBs were assumed to be 0 percent. The target fish tissue concentrations in the Cedar Creek TMDL and the Sheboygan Harbor and River site ranged from 0.21 mg/kg PCBs to 0.3 mg/kg PCBs. These target fish tissue concentrations were developed to be consistent with target risk levels of an ELCR = 1×10^{-4} and a non-cancer HQ = 1.0. Based on the overlap in the ranges of exposure assumptions among these three sites, selecting a target fish tissue concentration of 0.2 mg/kg for Cedar Creek, which is at the conservative end of the range bracketed by the Cedar Creek TMDL and the Sheboygan ROD, and which is consistent with a target ELCR = 1×10^{-4} ELCR and a target non-cancer HQ of 1.0 at those two cases, is therefore considered protective of human health within Cedar Creek.

From an ecological risk perspective, a risk-based fish tissue goal of 0.2 mg/kg PCBs in edible tissue represents a significant reduction in fish tissue concentrations on a Site-wide basis. Specifically, exposure point concentrations used in the HHRA ranged from 2.8 to 5.1 mg/kg PCBs. A reduction in fish tissue concentrations to 0.2 mg/kg PCBs represents a reduction in edible tissue concentrations that ranges from 15- to 25-fold. This same 15- to 25-fold reduction in whole body tissue concentrations, in addition to the reduction in sediment and surface water concentrations that are necessary to achieve the fish tissue goals, is greater than the maximum 10-fold reduction required to reduce the maximum HQ for wildlife from 10 to a value of 1.

3.5.1.3 Selection of a Sediment PRG

The model simulations show that fish PCB concentrations in the range of 0.1 to 0.2 mg/kg could be achieved in Columbia Pond under various remediation scenarios that achieve at least a reduction in sediment PCB SWAC to 1 mg/kg. The model also shows that PCB inputs from upstream of Columbia Pond (atmospheric/Ruck Pond residuals), along with the role water column uptake plays at this Site, that the ability to lower fish concentrations to less than 0.1 mg/kg through sediment remediation of Columbia Pond sediments may be limited.

Several lines of evidence from the risk-based analysis indicate that a 0.2 mg/kg fish concentration would be reasonably protective as a remedial goal for the Site. Specifically, the exposure assumptions used in the RME and CTE scenarios in the Cedar Creek HHRA overlap the exposure assumptions used in the Cedar Creek TMDL and the Sheboygan Harbor and River site to develop target fish tissue concentrations that range between 0.21 mg/kg PCBs and 0.3 mg/kg PCBs and that were developed to be consistent with a target ELCR = 1×10^{-4} and a target non-cancer HQ = 1.0. Given the consistency and the overlap in the exposure assumptions used at these three sites and the general uncertainty in the actual human use patterns at Cedar Creek with respect to site use and ingestion rates of locally caught fish, a target fish tissue concentration of 0.2 mg/kg PCBs is considered to be a fish tissue target that is protective of human health and the environment.

Given: 1) the ability of the Cedar Creek system to achieve a predicted fish tissue concentration of 0.1 to 0.2 mg/kg considering an extensive sediment remediation scenario (i.e., resulting SWAC of less than 1 mg/kg); and 2) the protective nature of a 0.2 mg/kg PCB fish tissue concentration, a sediment PRG of 1 mg/kg is selected for Cedar Creek.

3.5.2 Floodplain Soils

3.5.2.1 Evaluation of Acceptable Floodplain Soil PCB Concentrations Based on ARARs and the Human Health and Ecological Risk Assessments

The purpose of this subsection is to develop a floodplain soil PCB concentration that is protective of human health and the environment. The development of this protective concentration considers an ARAR based on proposed revisions to NR 720 (discussed in Section 2.2.2), which provides guidance for the development of acceptable residual PCB levels for soils that are protective of human health. Additionally, a risk-based floodplain soil PCB concentration was computed based on the exposure assumptions employed in the human health and ecological risk assessments for the Site.

First, the calculations pertaining to a risk-based floodplain soil PCB concentration are presented as they also provide a basis for the ARAR. As described more fully in Section 3.2, the HHRA completed for the Site evaluated the direct contact exposure pathway for PCB-containing floodplain soils. This exposure pathway included incidental ingestion of PCB-containing soil and dermal absorption of PCBs through the skin. For all exposure scenarios, ELCRs were less than 1×10^{-5} (i.e., 1 in 100,000) in all reaches, and non-cancer HQs were less than 1.0 for all exposure scenarios in all four reaches, except for the resident child exposure scenario in the Reach Between Wire and Nail Pond and Former Hamilton Pond (HQ = 2.5) and in the Reach Downstream of Former Hamilton Pond (HQ = 1.7).

On the basis of these results, a risk-based residual soil PCB concentration was developed that is protective of the resident child non-cancer endpoint exposure scenario. Specifically, a soil PCB concentration was developed that would result in an HQ = 1.0 for this exposure scenario. This protective soil concentration is defined as the 95 UCL soil concentration in each of the four reaches that results in an HQ = 1 for the resident child non-cancer endpoint exposure scenario. The protective soil PCB concentration for this endpoint is 1.1 mg/kg PCBs. Although only the non-cancer endpoints are being evaluated for purposes of developing a floodplain soil PRG, soil concentrations that are protective for a cancer endpoint also were calculated. Table 3-5 presents a summary of these protective soil PCB concentrations. As can be seen from the table, a soil concentration of 1.1 mg/kg PCBs would translate into an ELCR of less than 1×10^{-5}, a conservatively protective result given that an acceptable risk range for the cancer endpoint spans two orders of magnitude, from 1 x 10^{-4} to 1 x 10^{-6}.

Table 3-5
Protective Soil PCB Concentration

Methodology	Cancer PRG (mg/kg)			Non-cancer PRG (mg/kg)
	1.E-04	**1.E-05**	**1.E-06**	**HQ=1**
Site HHRA (RME exposure scenario) and NR 720 (proposed[1])	22	2.2	0.22	1.1

Notes:
1 Proposed NR 720 uses USEPA Region 9 Residential Soil Screening Levels:
- Cancer (1.E-06) = 0.22 mg/kg
- Non-cancer (HQ=1) = 1.1 mg/kg (Aroclor 1254)

As stated previously, a state ARAR also was considered when developing a protective floodplain soil PCB concentration. Proposed revisions to NR 720 include the following acceptable residual residential soil PCB concentrations that are considered to be protective of human health:

- Cancer endpoint: 0.22 mg/kg (1 x 10^{-6} excess cancer risk)
- Non-cancer endpoint: 1.1 mg/kg (Aroclor 1254) Why not 1260

These values incorporated into the proposed revisions to NR 720 are based on USEPA Region 9 Residential Soil Screening Levels (SSLs), and are intended to be conservative. As indicated in Table 3-5 above, it is important to note that these proposed NR 720 values are the same as the values calculated using the exposure assumptions under the RME scenario in the Site HHRA and, therefore, reflect the conservative, screening-level nature of the baseline HHRA for the Site.

Proposed NR 720 directs that these protective soil PCB concentrations be applied at a site as follows:

- Cancer endpoint: For individual compounds, use the residual soil concentration that corresponds to an excess cancer risk of 1 x 10^{-6} so that the cumulative excess cancer risk will not exceed 1 x 10^{-5}.

- Non-cancer endpoint: For individual compounds, use the residual soil concentration that corresponds to an HQ = 1.0 so that the cumulative hazard index (HI) for non-carcinogens will not exceed 1.
- If toxicological indices for both carcinogenic and non-carcinogenic endpoints exist for a substance (as is the case for PCBs), both shall be evaluated and the value that generates the lowest residual contaminant level shall be used for the Site.

Recognizing each soil site has its own unique characteristics, proposed NR 720 provides two options for incorporating site-specificity when developing cleanup standards. First, proposed NR 720 (see sections NR720.05 and NR720.08) provides the option of substituting a "soil performance standard" for a "residual contaminant level" when selecting the soil cleanup standard for a site. A soil performance standard is defined in part as "existing site conditions that prevent exposure to contaminants." There are existing conditions at the Cedar Creek Site that mitigate exposure but were not incorporated in the HHRA for the Site (e.g., a large portion of the floodplain being considered for remediation is state-designated wetlands or is characterized as having thick vegetation or steep banks, all deterrents to exposure).

Secondly, proposed NR 720 (see section NR720.11(2)(3)) also indicates that "alternative assumptions specifically approved by the department in writing" can be used in lieu of the default exposure assumptions when developing a soil cleanup standard. There are Site-specific conditions (including those noted above) that were not included in the HHRA that should be taken into consideration and would result in exposure assumptions that differ from the screening-level assumptions that were used in the HHRA. Because the values incorporated into proposed NR 720 are the same as USEPA's SSLs, it is instructive to review what USEPA states about the applicability of SSLs at impacted soil sites to confirm that Site-specific assumptions are consistent with guidance provided by USEPA. Specifically, USEPA (2003) notes the following:

- "SSLs are not national cleanup standards, and exceedances of SSLs do not trigger the need for response actions at NPL sites."
- "EPA recognizes, however, that certain conservative assumptions built into the generic and simple site-specific approaches to SSL development, while appropriate for a screening analysis, may be overly conservative for setting PRGs and ultimately, site cleanup levels."

Because the proposed revisions to NR 720 allow for site-specific modifying factors and because USEPA has acknowledged that soil SSLs are very conservative in nature, it is reasonable to consider the following factors that modify the default NR 720 exposure assumptions and target risk levels:

- Apply area use factors (AUFs) developed for the CTE exposure scenario in the HHRA to account for the percentage of residential properties in the Reach Between Wire and Nail Pond and Former Hamilton Pond and the Reach Downstream of Former Hamilton Pond that are within the 10-year floodplain. These AUFs account for the fact that a child will not spend 100 percent of his or her time in the potentially PCB-containing portions of a residential property. The CTE AUFs, developed considering the fraction of each parcel that falls in the 10-year floodplain, are 0.53 and 0.62 for the Reach Between Wire and Nail Pond and Former Hamilton Pond and Downstream of Former Hamilton Pond, respectively, and result in a computed HQ of approximately 1.
- Apply other Site-specific modifying assumptions. Portions of the floodplains are characterized as having steep banks, heavy vegetation, and/or state-listed wetlands. These areas are not likely to be used by children even when they are spending time in the floodplain portions of residential properties, further reducing the AUFs developed under the CTE scenario.
- USEPA guidance defines an acceptable ELCR range as 1×10^{-4} to 1×10^{-6} (NR 720 target ELCR is 1×10^{-6}). Although proposed NR 720 limits an acceptable ELCR for any individual compound to no greater than 1×10^{-6}, it allows an ELCR of 1×10^{-5} for multiple compounds. Consideration should be given to the fact that a 1×10^{-5} ELCR is within USEPA's acceptable risk range, regardless of the fact that PCBs are the only compound of interest at the Site.

Assessing PRGs established for PCBs in soils at other sites as a benchmark for consideration, a review of floodplain soil cleanup goals presented in USEPA Region 5 decision documents since 2000 show PCB cleanup goals generally range from 1 to 5 mg/kg for residential areas (see Table 3-6).

Table 3-6
Floodplain Soils PCB Cleanup Goals at Other Sites

Site	Decision Document and Date	PCB Cleanup Goals
Allied Paper, Inc./Portage Creek/Kalamazoo River Georgia-Pacific Mill Property Kalamazoo, MI	USEPA AOC 11/06	• 10 mg/kg (Performance Standard – soil) • 1 mg/kg (Goal – soil)
Allied Paper, Inc./Portage Creek/Kalamazoo River Plainwell Impoundment TCRA Plainwell, MI	USEPA AOC and Action Memorandum 2/07	• 4 mg/kg in the floodplain or near residential properties
Allied Paper, Inc./Portage Creek/Kalamazoo River Plainwell Dam #2 TCRA Plainwell, MI	USEPA AOC and Action Memorandum 6/09	• 5 mg/kg (soils within the area and floodplain soils)
Allied Paper, Inc./Portage Creek/Kalamazoo River Portage Creek Area Kalamazoo, MI	USEPA Action Memorandum 7/11	• Performance standard for floodplain and bank soil is 10 mg/kg with a performance standard goal of 5 mg/kg
Allied Paper, Inc./Portage Creek/Kalamazoo River Willow Blvd./A-Site OU Kalamazoo, MI	USEPA ROD 9/06	• 0.33 mg/kg (soil [Willow Blvd. Drainageway, Area South of A-Site Berm, and Area East of Davis Creek] – identified as a Sediment Action Level for all areas in the ROD and chosen as a cleanup level in the Remedial Design Report) • 6.5 mg/kg (AMW-3A Area) – identified as a potential cleanup in the ROD and selected in the Remedial Design Report
Bridgestone/Firestone Noblesville, IL	Corrective Measures Proposal 3/10	• 3.8 mg/kg (surface soil) • 27 mg/kg (soil from all depths)
Fields Brook Ashtabula, OH	USEPA ROD 6/97 (Floodplain/ Wetland Area OU – OU #4) USEPA ESD 8/01 (OU #1 and OU #4)	• 1 mg/kg (residential) • 30 mg/kg (excavate – residential) • 6 mg/kg (soil cover – residential) • 6 to 8 mg/kg (industrial) • 50 mg/kg (excavate – industrial) • Human health risk based – 10^{-6}
Krejsci Dump Summit County, OH	USA Partial Consent Decree 4/02	• 0.075 mg/kg (soil)

Table 3-6
Floodplain Soils PCB Cleanup Goals at Other Sites

Site	Decision Document and Date	PCB Cleanup Goals
Little Mississinewa River Union City, IN	USEPA ROD 7/04	Action levels • 5 mg/kg (floodplain soil, residential) • 20 mg/kg (floodplain soil, recreational) Cleanup goals • 1.2 mg/kg average (floodplain soil, residential) • 20 mg/kg (floodplain soil, recreational)
Marina Cliffs/Northwestern Barrel Facility S. Milwaukee, WI	USEPA Action Memorandum 5/04	• 1 mg/kg (soil)
Rockwell International Allegan, MI	Action Memorandum 7/01	• 10 mg/kg (soil)
	USEPA ROD 9/02 (OU #2)	• 1 mg/kg (soil – top 2 feet and adjacent and/or erodible areas along River) • 10 mg/kg (soil – 2 to 12 feet) • MDEQ Part 201
Sangamo Electric Dump/Crab Orchard NWR Carterville, IL	USEPA ROD 9/02 (OU #4)	• 0.85 mg/kg (soil – ecological risk LOAEL)
Shiawassee River Howell, MI	USEPA ROD 9/01	• 10 mg/kg (floodplain soil) • 10 mg/kg (facility soil)
Solutia, Inc. Sauget, IL	USEPA Statement of Basis 7/07	• 1 mg/kg (soil – preliminary remediation goal • 10 mg/kg (soil – unrestricted area with cap) • 25 mg/kg (soil – restricted area with cap)
Westinghouse Sites Bloomington and Spencer, IN Neal's Landfill	Amendment 9/07 (OU #2 and 3)	• 5 mg/kg (floodplain soils, average)
Westinghouse Sites Bloomington and Spencer, IN Lemon Lane Landfill	USEPA ROD Amendment 5/00 (Source Control OU)	• 50 mg/kg (hot spot soil – average) • 2 mg/kg (soils – areas outside of landfill fence – high occupancy/residential) • 10 mg/kg (soils – within fence but not under cap – low occupancy/industrial) with 10-inch-thick soil cover • 20 mg/kg (soils – south side but not under cap)

3.5.2.2 Selection of a Floodplain Soil PRG

A strict interpretation of the proposed NR 720 ARAR leads to the conclusion that 0.22 mg/kg PCBs should be selected as the protective concentration because this concentration would result in a 1 x 10^{-6} ELCR for an individual compound (PCBs). However, when incorporating Site-specific considerations as allowed under proposed NR 720 (e.g., AUFs less than 1, wetlands, and steep banks), consistent with the discussion included in Section 3.5.2.1 above, and considering PRGs selected for other USEPA Region 5 sites, a soil PRG of 1.0 mg/kg PCBs is proposed for human health exposure for the Cedar Creek floodplain soils. A soil concentration of 1.0 mg/kg also would be protective of ecological receptors that may be exposed to floodplain soils either through direct contact or through ingestion of PCB-containing prey because the results of the ecological risk assessment concluded that there were no unacceptable incremental risks to terrestrial receptors at current PCB levels in floodplain soils within all four subareas of the Site.

Application of the PRG will be considered both with inclusion and exclusion of the wetlands and potentially other Site-specific modifying features (e.g., steep banks) in the determination of areas targeted for remediation. As such, floodplain soil remedial alternatives include remedial actions that achieve floodplain soil SWACs of 1 mg/kg PCBs when both including and excluding designated wetland areas, as discussed in detail in Section 5.

4 REMEDIAL TECHNOLOGY SCREENING

Prospective remedial technologies were identified, initially screened, and assembled into prospective remedial alternatives for Cedar Creek (see Section 5). Remedial alternatives for cleanup of sediments and floodplain soils include the following three components (USEPA 2005):

- General Response Actions (GRAs) – major categories of response activities such as institutional controls, monitored natural recovery (MNR), containment, removal, or treatment
- Potentially Applicable Remedial Technologies – general categories of technologies such as different in situ containment options (e.g., sediment capping/floodplain soil covering or vertical containment) or removal methods (e.g., sediment removal or floodplain soil excavation)
- Process Options – technology implementation details, such as mechanical or hydraulic dredging methods

4.1 General Response Actions

Several media-specific technology types are presented below to represent each GRA. GRAs that could be used to satisfy one or more of the RAOs are grouped into six categories.

1. **No Action:** No further remedial activities (beyond those already conducted as part of the RI/Removal Action activities) would be performed at the Site.
2. **Institutional Controls:** This category includes fish consumption advisories and access restrictions, as appropriate, to limit human contact with PCB-containing media at the Site. Monitoring tracks Site conditions and evaluates potential risks to human health and the environment associated with Site conditions over time.
3. **Source Control and MNR:** These GRAs include controlling the primary source of the contaminant of concern and allowing natural processes to reduce the bioavailability of sediment and floodplain soil over time to reduce chemical concentrations. Monitoring contaminants assess the performance of these processes against expectations.

4. **In-place Containment:** The GRA includes technologies such as capping (both natural and engineered) and vertical containment (e.g., dams) to physically and/or chemically isolate PCB-containing sediment and floodplain soil.
5. **In Situ Treatment:** This category includes in situ treatment (e.g., immobilization, biodegradation, and/or other appropriate technologies) to reduce PCB levels in Site media and/or PCB transport.
6. **Sediment/Floodplain Soil Removal and Management:** Following removal, the sediment or soil material is typically relocated to a treatment or disposal facility. Dredging often requires consideration of other unit processes such as in-water controls to minimize contaminant resuspension during removal; dewatering to reduce sediment moisture content; treatment of dredge water before discharge; and disposal and/or treatment of dredged/excavated material.

4.2 Identify and Screen Remedial Technologies

This section identifies and screens remedial technologies and process options used to develop remedial alternatives for the Site. The evaluation of technologies potentially applicable to remedial alternatives in Cedar Creek used two steps consistent with CERCLA guidance (USEPA 1988). Step 1 identified an array of possible remedial technologies and evaluated these technologies based on technical implementability. Technologies demonstrated as not effective in addressing similar conditions at other sites or that cannot be implemented due to Site-specific conditions were eliminated from further consideration. In Step 2, the remaining remedial technologies were evaluated based on overall effectiveness, technical and administrative implementability, and relative cost (USEPA 1988).

4.2.1 Step 1 – Identification and Screening of Potential Remedial Technologies

As noted above, in this initial step, technology types and process options were evaluated only on the basis of technical implementability. Technical implementability is a general, non-detailed evaluation of whether a technology type or process option is implementable with respect to site conditions and whether implementation is available and demonstrated. This initial screening step reduced the number of potential remedial technologies subjected to a more rigorous evaluation in Step 2.

Table 4-1 summarizes the identification and screening of potential remedial technologies/process options. The first two columns of the table identify GRAs with several broad technology types and associated process options. This table also provides a brief description of each process option, evaluates technical implementability, and specifies whether the technology was retained for further evaluation (Step 2).

4.2.2 Step 2 – Evaluation of Remedial Technologies and Selection of Representative Process Options

The retained process options (Table 4-1) were further evaluated based on an expanded criteria of overall effectiveness (including ability to meet RAOs), implementability (technical and administrative), and relative cost. The screening criteria used in this evaluation are described below.

- **Effectiveness.** The effectiveness criterion evaluates the technology relative to its ability to achieve RAOs in a reasonable timeframe. Both short-term and long-term effectiveness are evaluated. Short-term effectiveness encompasses potential effects to human health and environment during the construction and implementation periods, whereas long-term effectiveness encompasses the reliability and protectiveness of the technology after implementation.
- **Implementability.** The implementability criterion evaluates the technology for technical and administrative feasibility. Technical feasibility refers to the ability to construct, operate, maintain, and monitor the action during and after construction and to meet technology-specific regulations during construction. Technical feasibility also applies to the availability of necessary equipment, personnel, and services for implementation or construction. Administrative feasibility refers to the ability to obtain approvals (response actions performed pursuant to CERCLA are exempt from the procedural requirements of federal, state, and local environmental laws, though the action must nevertheless comply with the substantive requirements of such laws; see Section 3.3.
- **Cost.** The total cost of a given technology is not normally estimated during the technology screening described in this section. However, knowledge of typical technology costs obtained from vendors, cost-estimating guides, prior projects, and engineering judgment are used to evaluate the relative costs of technologies

(including overall construction, operation, maintenance, and monitoring costs) and to compare costs with those of other similar technologies. Detailed costs for each alternative are part of the comparative evaluation in the forthcoming FS.

The evaluation and subsequent screening of potentially applicable remedial technologies for each GRA is described below and summarized in Table 4-2.

4.2.2.1 No Further Action

No further action was retained as a representative process option during the initial screening step, as required by the NCP. This process option is used as a baseline against which other alternatives are evaluated.

4.2.2.2 Institutional Controls

Institutional controls are non-engineered instruments, such as administrative and legal controls, that minimize the potential for human health or ecological exposure to contamination and ensure the long-term integrity of the remedy (USEPA 2005).

Institutional controls typically are grouped into the following categories (USEPA 2005):

- Land use restrictions and maintenance requirements
- Enforcement and permit devices
- Governmental controls including permit conditions for future actions
- Informational devices including signage and fish consumption advisories that may be required until RAOs are met

For this GRA, the following two process options were considered:

- **Listing on the GIS Registry.** Listing on the RR Geographic Information System (GIS) Registry (GIS Registry; NR 726) provides notification about residential contamination and/or other continuing obligations on a property.
- **Access Restrictions.** Access restrictions are physical constraints such as fencing and notifications such as signs that would be placed along the creek to limit access.

Listing on the GIS Registry and access restrictions were retained for further consideration as a potential remedy component because they are all potentially effective at mitigating exposure to PCBs and can be implemented at relatively low cost.

4.2.2.3 Source Control and Monitored Natural Recovery

Source control is a potential representative process option. The historic source reduction at Ruck Pond and cleaning and sealing the storm sewer connection at Plant 2 in 1994 and Former Hamilton Pond in 2000 (described in the RI Report) expedited the potential achievement of the RAOs by addressing the release of additional PCBs to the creek and allowing natural recovery processes that are currently ongoing in the creek. The remnant storm drains from the Amcast facility are a potential source of contamination in the area that remains; one of the drains empties into Hamilton Pond, upstream of Green Bay Road.

Natural recovery is the process by which contaminant concentrations in sediment or floodplain soils are reduced through a combination of naturally occurring physical, chemical, and/or biological processes to the point that surface sediment concentrations are acceptable. Some natural processes (e.g., deposition of cleaner sediments onto impacted sediments, mixing and erosion) act as containment or dilution mechanisms, and others (e.g., biodegradation of contaminants by native bacteria) act as in situ treatment mechanisms. Site-wide monitoring of sediments and floodplain soils at specified intervals provides a mechanism to track natural recovery processes. Natural recovery refers to processes that act to reduce PCB concentrations in fish in the absence of, or following, active remediation.

Evidence of ongoing natural recovery is present within Cedar Creek. Sedimentation has occurred historically in Cedar Creek sediments with deposition rates in Columbia Pond and Wire and Nail Pond ranging from 0.3 to 0.9 inches per year depending on the radiodating analysis (see Section 4.2.2 of the RI Report). Long-term fish trend analyses also present strong evidence of natural recovery. As shown in a report developed by ARCADIS and Anchor QEA (2012), PCB concentrations in resident fish are declining and are expected to continue to decline. Based on the comparison of data collected in 2003, 2004, and 2010, the current rates of decline average 20 percent per year and range from 7 to 34 percent per year.

The ability of these processes to achieve PRGs with and without active remediation will be evaluated in the FS.

Enhanced Monitored Natural Recovery (EMNR) is a second process option that involves active measures, such as the placement of a thin layer of clean sand, to accelerate the natural recovery process. EMNR is often applied in areas where natural recovery may appear to be an appropriate remedy, yet the rate of sedimentation or other natural processes is insufficient to reduce risks within an acceptable timeframe (USEPA 2005). The acceleration of natural recovery most often occurs due to burial and/or incorporation and mixing of the clean material into the contaminated surface sediments through bioturbation and physical mixing processes. Other recovery processes, such as binding of contaminants to organic carbon in the clean material, can also occur, particularly if the material contains naturally occurring organic carbon. Placement of such EMNR materials is typically different than capping (discussed below) because it is not designed to provide long-term isolation of contaminants. As with MNR, EMNR includes monitoring components to verify that recovery is occurring as expected.

Both MNR and EMNR are technically implementable and effectively reducing surface PCB concentrations. MNR can be implemented at a relatively low cost and is currently occurring at the Site, whereas EMNR is a medium cost technology due to the active remediation components (e.g., equipment, materials). Both technologies will be retained for further analysis, with potential application as stand-alone technologies or they may serve to further reduce PCB concentrations in surface sediments and fish tissue following the implementation of active remediation.

4.2.2.4 In-place Containment

In-place containment involves confining chemicals in situ through placement of physical barriers or hydraulic controls. Containment technologies may be designed to prevent contact with and/or migration of the impacted material. Use of in-place containment technologies typically results in minimal short-term releases of contaminants during construction and can also provide an effective method of reducing the potential for exposure at a relatively lower cost. Containment technologies do not result in a reduction in contaminant mass, volume, or toxicity. Three remedial technologies were evaluated under the GRA of in-place containment. These remedial technologies and their respective process options are described below.

4.2.2.4.1 Soil Capping/Cover

A common method of controlling exposure to contaminated soils is to place an engineered cap over the materials. The long-term cap integrity can be maintained through scheduled maintenance and implementation of appropriate institutional controls. Where practicable, the placement of clean cap materials, as necessary to achieve adequate cap thickness, may be separated from underlying potentially contaminated materials with a marker (e.g., geotextile fabric) indicating the cap boundary.

The following are process options for soil capping:

- **Permeable Soil Cap.** Placing clean soil on the surface provides a barrier that prevents exposure to underlying soil but allows stormwater to infiltrate. Permeable soil caps would not address potential transport of PCBs from the surface soils to underlying soils; however, PCB mobility is very low in groundwater (Anderson and Pankow 1986).
- **Low-permeability Cap.** A low-permeability cap is one constructed of clay or an engineered material such as asphalt or concrete. This cap prevents exposure to underlying soils and minimizes stormwater infiltration through potentially contaminated materials, thereby reducing potential mobilization of contaminants located in the unsaturated soil zone. Engineered materials can be used in areas requiring a durable surface, such as high-traffic areas.

Both permeable and low-permeability capping are proven, effective technologies that are readily implemented; however, the permeable cap is retained and the low-permeability cap eliminated from further evaluation. A low-permeability cap is not necessary at the Site given the low mobility of PCBs in groundwater. Additionally, the low-permeability cap is less desirable because the cap is applied to floodplain soils on primarily residential properties.

4.2.2.4.2 Sediment Capping/Cover

Similar to soil capping, sediment capping is a designed system that isolates the contaminants underlying the cap. It is a common remedial technology for contaminated sediments (USEPA 2005; Palermo et al. 1998). Its effectiveness as a remedial option is demonstrated by numerous successful projects.

Sediment caps are primarily composed of sand and/or clean sediment and typically range from approximately 1 foot to several feet thick. Depending on the contaminants and environment, a cap is designed to reduce risk through the following primary functions (USEPA 2005):

- Physical isolation of the contaminated sediment sufficient to reduce exposure due to direct contact and to reduce the ability of burrowing organisms to move contaminants to the surface
- Stabilization of the contaminated sediment and erosion protection of the sediment and cap, sufficient to reduce resuspension and transport to other sites
- Contaminant isolation of the contaminated sediment sufficient to reduce exposure from dissolved and colloidally bound contaminants transported to the water column

The feasibility of sediment capping as a remedial technology is related to several factors, including underlying sediment strength, contaminant characteristics, physical and hydrological conditions at a site, and potential future uses of the waterbody. Important fate and transport properties of the contaminants in question include partitioning rates to solid materials, solubility, and biodegradation rates (in the case of organic compounds). Important physical characteristics of the Site include groundwater seepage rates (which affect the rate of contaminant advection through the cap) and surface water velocities due to currents, propeller wash, and wind- and vessel-generated wave action (which potentially affect the stability of the cap). Sediment capping may not be feasible in some areas if it negatively affects future hydraulic conditions (e.g., increases flooding) or limits habitat or potential uses of the waterway, such as navigation and recreation.

The following are two sediment capping process options:

- **Engineered Cap.** An engineered cap is composed of layered materials (e.g., sand, gravel, cobbles, geotextile) placed over in situ sediment to physically isolate and protect contaminated sediment from erosion and to mitigate transport of dissolved and colloidally bound contaminants into the water column. An engineered cap can be composed of multiple materials, each with a specific purpose (e.g., cobble for erosion protection overlying sand for chemical isolation) or the same material that can function as both erosion protection and chemical isolation. Based on USEPA (Palermo et al. 1998) and United States Army Corps of Engineers (USACE; 1998) guidance, technical research, and full-scale application of engineered caps as a remedial action at other sites, an engineered cap is a viable technology for use at the Site. Within Cedar Creek, individual areas vary in terms of erosion protection (i.e., armor) requirements to resist design flow events and other area-specific forcing conditions (e.g., ice formation potential, isolation from biota, and mitigation from chemical flux).
- **Active Cap.** An active cap is similar in design to an engineered cap (i.e., physically isolates sediments and protects from erosion); however, it reduces the flux of contaminants from underlying sediment to the water column through adsorption of contaminants onto the cap material. Reactive materials can be placed within the contaminant isolation layer of the cap (an "active" cap) to supplement this adsorption process or to provide some other physical/contaminant processes that reduce the mobility of the contaminants. Use of reactive materials may be warranted where evaluations of engineered capping show that a sufficiently thick cap cannot be created to adequately reduce the flux of contaminants over time. This condition may be due to a variety of reasons singly or in combination, such as the presence of highly mobile contaminants, high rates of groundwater advection, and/or the need to maintain certain water depths for navigation or habitat purposes. As described in USEPA (2005), examples of materials used in active caps include engineered clay aggregate materials (e.g., bentonite pellets, AquaBlok®), and reactive/adsorptive materials such as activated carbon, apatite, coke, organoclay, zero-valent iron, and zeolite. Composite geotextile mats containing one or more of these materials (i.e., reactive core mats) are available commercially. Activated carbon (including regenerated products) and more cost-effective coal materials are in place at a number of sites as a sorptive barrier, and several promising reactive cap amendments and

sediment/porewater treatment technologies were successfully demonstrated in the Anacostia River (Horne Engineering Services, LLC 2007).

Engineered caps and active caps were retained for further evaluation. Engineered caps are effective at protecting underlying materials from erosive forces within waterbodies and are a medium-range cost technology based on the cost of materials and long-term monitoring and maintenance. They are technically and administratively implementable in certain portions of the Site. Active caps provide additional protection beyond an engineered cap by adsorbing PCBs as they are transported (via diffusion and/or advection) through the cap. An active cap is a medium- to high-range cost technology due to the added cost of the amendment.

4.2.2.4.3 Vertical Containment

Vertical containment as an in-place technology was reviewed for the Site. Typically, vertical containment consists of an impermeable vertical barrier (e.g., sheetpile wall) across the groundwater flow path that impedes the horizontal transport of chemicals. In the case of Cedar Creek, the existing dams (Columbia Mills Dam and Wire and Nail Factory Dam) act as a vertical impediment to transport of PCB-containing sediment located behind the dams. The dams are currently effective at containing the sediments but would require long-term monitoring and maintenance to ensure long-term integrity. Administrative agreements between Mercury Marine and the dam owners are required to address long-term monitoring and maintenance activities. This option is considered a low to medium cost, with costs resulting from monitoring and potential maintenance/upgrade of portions of the dams. Vertical containment (i.e., dams) was retained for more detailed consideration as a potential remedy component.

4.2.2.5 Sediment/Floodplain Soil Removal and Management

Removal of contaminated soil and sediments is widely used at contaminated sites. Removed materials are treated and/or disposed of either on site or at an off-site, permitted disposal facility. The advantage of this GRA is providing removal of contaminants from the waterbody. The main disadvantages include the potential for short-term releases of contaminants during removal operations and technical limitations to removing materials below the water table and the sediment environments. Furthermore, there are several steps necessary to accomplish a complete removal scenario, and each step has several process options. Generally speaking, the steps are as follows:

1. Excavation – physically removing target material from the current location
2. Conveyance – moving material to an offloading or processing facility
3. Offloading – transporting the material from the water to the land in the case of sediments
4. Processing – preparing the material for transportation and disposal (e.g., dewatering, amendment, treatment) and treating the residual water
5. Transportation and Treatment/Disposal – moving the material to its final treatment or disposal location

Under this GRA, remedial technologies are grouped into the following five general categories for discussion of the various remedial technologies and process options:

- Removal
- Dewatering
- Water treatment
- Disposal
- Ex situ treatment

4.2.2.5.1 Removal

Removal is a technology commonly employed on contaminated soil and sediment remediation projects. For sediment sites, removal can be accomplished from the water via dredging or from the land via excavation. Excavation and dredging were two remedial technologies evaluated under the removal category; however, dredging is only applicable to sediment removal.

<u>Excavation</u>

Excavation involves the use of excavators, backhoes, and other conventional earth-moving equipment to remove contaminated soil or sediments and was retained for further evaluation. Soil excavation is effective at removing PCBs from the Site, technically implementable, especially for the shallow removal depths required at the Site (e.g., less than 1 foot), and a high cost technology.

For sediments, excavation occurs after water has been diverted or drained (i.e., "in the dry" removal). Diversion of water from the excavation area can be facilitated through the installation of temporary cofferdams, sheetpiling, or other water management structures and the lowering of the surface water elevation within the excavation area by removing stop logs from the dam structures. Following dewatering of the area, equipment can be positioned on the creek bed (or a crane mat for added stability) within an excavation area or immediately adjacent to the dewatered excavation area. Installation of sheetpile or temporary cofferdams to support dry excavation may cause unintended consequences such as erosion adjacent to the work area due to constricted river flow or other hydrodynamic forces. In addition, sheetpile installation may be inhibited by the presence of debris and/or other natural obstructions (e.g., shallow bedrock).

Excavation equipment is not likely to effectively remove all of the contaminated sediment, leaving behind a thin layer of contaminated sediment, commonly referred to as "residuals." Experience at other sites shows that excavation equipment is not effective at completely removing all contaminated sediments when operating in the wet, leaving behind a layer of residuals on the post-dredge surface. The residual sediment reduces the overall effectiveness of the remedy (NRC 2007; Bridges et al. 2010). Management of potential post-excavation residuals, either by placement of backfill/sand cover or natural recovery, is commonly considered in the evaluation of excavation as a remedial technology.

Following removal, sediments may require dewatering by passive or active draining and/or mixing with an amendment (e.g., Portland cement) prior to transport and disposal at an approved disposal facility. The degree and duration of gravity drainage and the need to mix amendments depends on the characteristics of the excavated material and the acceptance criteria at the receiving disposal facility. Different technologies to dewater the sediments are discussed in Section 4.2.2.5.2.

<u>Dredging</u>

Dredging is a method of excavation that allows the removal of sediments without water diversion or draining (i.e., "in the wet" removal). Two types of dredging were evaluated below.

- **Hydraulic Dredging.** Hydraulic dredging involves the removal of sediment slurried with surrounding water. Hydraulically dredged materials must be transported via piping directly to a staging/processing area. Booster pumps may be required to transport the materials as the distance and elevation increases between the dredge and processing areas. The solids content of hydraulically dredged slurries normally averages less than 10 percent by weight, thereby resulting in significant amounts of water requiring treatment (see discussion below for water handling constraints). Additionally, solids content can vary considerably with the specific gravity, grain size and distribution of the sediment, and depth and thickness of the dredge cut. Technical limitations associated with hydraulic dredging include inability to remove large debris and clogging of the cutterhead or pipeline with weeds, wood, rocks, and other materials.
- **Mechanical Dredging.** Mechanical dredging involves the use of a clamshell bucket on a derrick barge or mounted on a hydraulic excavator. These dredges remove sediment at approximately the same water content as the in situ material, thereby minimizing the amount of water removed (USEPA 2005). They operate in areas with limited space, and are highly maneuverable. The dredges are also able to remove large debris. Mechanically dredged sediment can be transported by barge or piped short distances. Mechanical dredges potentially cause spillage during dredging and offloading. The water contained within the bucket during removal activities must be managed. If allowed to leak out, it "generally leads to higher contaminant losses during dredging" (USEPA 2005).

Both hydraulic and mechanical dredging were retained as viable process options. As discussed in Section 5, fewer implementability concerns exist with mechanical dredging than with hydraulic, but both are carried forward into the assembly of remedial alternatives for evaluation in the FS. The specific process option to be used in implementation of a dredging alternative will be selected during remedial design, and will depend on the specific project objectives and associated constraints for the dredging operation.

4.2.2.5.2 Dewatering

Dewatering is a form of ex situ treatment that reduces the amount of water in removed materials to prepare them for further treatment or disposal. Several factors must be considered when selecting an appropriate dewatering treatment technology including physical characteristics of the soil/sediment, selected dredging method for sediments, and the required moisture content of the material to allow for the next re-handling, treatment, transport, or disposal steps in the process.

Dewatering was separated into two subcategories: passive and active dewatering. Because the moisture content of excavated soils is anticipated to be relatively low, only passive dewatering, as necessary, is anticipated for use on soils. Therefore, passive and active dewatering processes and process options are described below for use with sediment dewatering.

Passive Dewatering

Passive dewatering (also referred to as gravity dewatering) is facilitated through natural evaporation, consolidation, and drainage of sediment porewater to reduce the water content of the removed material. For dredged material, passive dewatering is facilitated through the use of an onshore temporary holding facility such as a staging area or, where sufficient space is available, a dewatering lagoon or temporary settling basin. Passive dewatering techniques can be applied to hydraulically dredged sediments where the resulting slurry is pumped into a consolidation site and is allowed to settle, clarify, and dewater by gravity. Water generated during the dewatering process is discharged after treatment. If the water content of the passively dewatered material remains above the target level, moisture-adsorbing materials such as Portland cement and fly ash are blended into the dredged material (see Section 4.2.2.5.5).

Passive dewatering is generally effective and capable of handling variable process flow rates. It is fairly simple but this method can require significant amounts of space depending on the volume of material processed, the dredging method generating the material (i.e., mechanical versus hydraulic), and the settling characteristics of the sediment. Passive dewatering is a widely implemented dewatering technology for mechanically dredged sediments. It is also amenable to hydraulic dredging at sites with limited available upland processing space when combined with the use of geotextile tubes to confine slurry and sediment during passive dewatering. Depending on the desired moisture content of the sediment, the subsequent processing or handling steps, the volume of material to be dewatered, available space, and the ability to effectively manage the dewatering effluent, passive dewatering can be a highly implementable dewatering technology option. Both process options (geotextile tubes and gravity settling) were retained for further evaluation.

Active Dewatering

Active dewatering involves the use of equipment such as centrifuges, hydrocyclones, belt presses, or plate-and-frame filter presses to separate coarse materials, or squeeze, press, or otherwise draw out water from sediment pore spaces. Active dewatering is typically used only in combination with hydraulic dredging or hydraulically rehandled dredged material to reduce the water content of the dredge slurry prior to ex situ treatment or disposal. Sufficient onshore space is needed to accommodate the selected dewatering equipment, but this space is usually less than required for settling basin-based passive dewatering. A mechanical dewatering treatment train includes treating the residual water prior to discharge.

Active dewatering has been widely implemented for a range of sediment types and is likely more effective at achieving moisture content reduction over shorter timeframes than passive dewatering. The following are active dewatering process options:

- **Plate-and-frame Filter Press.** In the plate-and-frame filter press, the sediment slurry is pumped into cavities formed by a series of plates covered by a filter cloth. Liquids are forced through the filter cloth and dewatered solids are collected in the filter.
- **Belt Filter Press.** The belt filter press involves the sediment slurry dropping onto a perforated belt where the gravity drainage takes place. Thickened solids are pressed between a series of rollers to further dewater solids.
- **Hydrocyclone.** In the hydrocyclone, the sediment slurry is fed tangentially into a funnel-shaped unit to facilitate centrifugal forces necessary to separate denser solids (e.g., sand-sized sediment particles) from liquids. Dewatered solids are collected and the overflow liquid, which contains the less dense sediment particles (e.g., silts and clays), is sent for further treatment as required.

The three active dewatering technologies are effective at reducing water content, are technically implementable, and require an equivalent cost; therefore, they were all retained as viable process options for handling hydraulically dredged sediments. These methods are not considered for application to mechanically dredged materials. The dewatering option used in implementation of an alternative will be selected during remedial design, and will depend on the specific project objectives and associated space constraints.

4.2.2.5.3 Soil and Sediment Disposal

Only off-Site disposal was considered for the Site because there is no suitable on-Site area. Off-Site disposal consists of transporting the dewatered material via truck to an off-Site, permitted disposal facility. The type of disposal facility (hazardous or non-hazardous) depends on the PCB concentration of the removed material. Materials with PCB concentrations greater than 50 mg/kg would be transported to and disposed of at an existing Toxic Substances Control Act (TSCA) permitted landfill. Conversely, materials with PCB concentrations less than 50 mg/kg would be transported to and disposed of at an existing solid waste landfill. Mercury Marine successfully implemented off-Site disposal for sediments and soils removed from Ruck Pond and the former Hamilton Pond area. Off-site disposal provides for secure, long-term containment of removed materials. Off-Site disposal is retained for further consideration as a possible remedy component.

4.2.2.5.4 Water Treatment

Water treatment is necessary following the dewatering of the removed material, particularly sediments. The following two process options were considered for the water treatment technology:

- **Activated Carbon Adsorption.** Activated carbon adsorption involves removing PCBs in the aqueous phase using granular activated carbon.
- **Filtration.** Filtration involves removing PCBs by passing water through various media, such as sand.

Both activated carbon adsorption and filtration are effective at removing PCBs. Each is technically implementable and often combined as part of the overall water treatment train. Activated carbon and filtration were successfully used by Mercury Marine to treat water containing PCBs during the Ruck Pond sediment removal action, and while doing demolition/decommissioning work at the Plant 2 facility. As such, both process options have been retained.

4.2.2.5.5 Ex Situ Treatment

Ex situ treatment technologies can be applied to soils and sediments following dewatering to immobilize, wash, extract, desorb, or destroy chemicals within the removed materials. Various process options were evaluated under these categories.

Immobilization

Solidification/stabilization was the only process option retained following the initial screening step under the remedial technology category of immobilization, as shown on Table 4-1. This technology involves adding amendments to excavated soil or sediment that immobilize and/or bind contaminants within the stabilized product. In some cases, stabilization agents are added to materials to promote a primary goal of dewatering high solids mixtures; reductions in contaminant mobility then become a secondary benefit of the process. Conversely, the presence of organic materials typically found in floodplain soils and sediments are of significant concern when applying this process. High organics content can substantially affect stabilization performance and increase costs. Because PCBs are highly hydrophobic compounds, the presence of naturally occurring organic material is a benefit in that it (organic carbon) acts to bind and further sequester the PCBs.

Given its effectiveness, ease in technical implementability, and relatively low cost as compared with other ex situ treatment technologies, solidification/stabilization was retained as a potential process option for treating and disposing of excavated soils and dredged sediment, primarily as an add-on step to further reduce the water content of the dredged material or removed soils following passive dewatering.

Soil Washing

In soil washing, soil or sediment is put in contact with an aqueous solution to remove contaminants from the soil particles. The suspension is often also used to separate fine particles from coarser particles, allowing beneficial use of the coarser fraction (if sufficiently clean) at the Site. The aqueous solution can contain surfactants or other additives to promote dissolution of contaminants. The cost of sediment washing is impacted by the percentages of fine-grained and organic constituents within the sediment matrix, as increased particle surface areas may require additional treatments. In addition, complex mixtures of contaminants and heterogeneous contaminant compositions throughout the waste stream increase the difficulties associated with designing a suitable washing solution that will consistently and reliably remove the various contaminant groups. For these cases, sequential washing, using different wash formulations and/or different sediment to wash fluid ratios, may be required. Bench-scale treatability tests would be needed to complete a Site-specific design for this technology. Soil washing is typically more expensive than most ex situ treatment options (e.g., solidification/stabilization), and its effectiveness for removing strongly hydrophobic chemicals such as PCBs, particularly from soils/sediments with a high organic content and at low PCB concentrations is limited. Although several process options for soil or sediment washing exist, very few have been developed to full-scale applications. This technology was not retaine~~d.~~

<u>Solvent Extraction</u>

Solvent extraction is a variant of soil washing in which an organic solvent (instead of an aqueous solution) is put in contact with the soil to remove contaminants. This technology is more effective than soil washing at removing hydrophobic organic compounds, but incurs substantial additional costs because the solvent must be carefully controlled, collected, treated, and recycled. The extraction process is facilitated through the use of acid or organic solvents as the extractant. For both types of solvents, post-treatment dewatering and residuals handling is required. These residuals may have increased toxicity or may require acid neutralization. In order to avoid disposal of the residuals, it is common to use chemical extraction methods in combination with other technologies, such as solidification / stabilization, incineration, or sediment washing, depending upon Site-specific conditions. This technology is not cost competitive and its effectiveness is equivalent to other methods. This technology was not retained.

<u>Thermal Destruction</u>

Thermal destruction uses high heat to remove or destroy chemicals. Incineration is a typical type of thermal destruction that destroys a range of chemicals, including PCBs, solvents, dioxin, and pesticides by thermally decomposing the contaminants via oxidation at temperatures greater than 1,600 °F. This technology can achieve high treatment efficiencies, but is also extremely expensive. The efficiency of the process depends on three main parameters: 1) temperature of the combustion chamber; 2) residence time of the sediment in the combustion chamber; 3) and turbulent mixing of the sediment. Turbulent mixing is important because the waste and fuel must contact the combustion gases if complete combustion is to occur. Sufficient oxygen must be present and is supplied as ambient air or as pure oxygen through an injection system. Process options include circulating bed combustors, fluidized beds, liquid injection, and rotary kilns.

Although incineration was successfully permitted and implemented at the Bayou Bonfouca Superfund Site in Slidell, Louisiana, the technology has been abandoned at other sites, including New Bedford Harbor in Massachusetts and Reynolds Metals in New York, due to general public perception and other community issues, including concerns over emissions to ambient air. In addition, dredged material and floodplain soils require extensive dewatering prior to incineration, adding time and expense to the process. This technology was not retained.

5 PROPOSED REMEDIAL ALTERNATIVES

5.1 Overview

Retained technologies were assembled into a range of potentially viable response action alternatives for the sediments and floodplain soils. For purposes of assembling the sediment and floodplain soils alternatives, the remedial technologies included in the alternatives are broadly defined (e.g., what type of dredging method to employ, or the type of cap to be placed). Ultimately, selection of the specific remedial technologies and/or process options depends on the context in which the technology is applied, and will be addressed during remedial design.

5.2 Sediment Remedial Alternatives

5.2.1 Assembly of Alternatives

Seven sediment remedial alternatives were assembled as presented in Table 5-1. These alternatives represent a range of options that include in situ containment and removal of contaminated sediment.

Table 5-1
Sediment Remedial Alternatives

Sediment Alternative	Description
SED-1	No action
SED-2	MNR and institutional controls
SED-3	Capping to achieve SWAC of 1 mg/kg PCBs
SED-4	(a) Removal and capping to achieve SWAC of 1 mg/kg PCBs (upper 1 foot) in Columbia Pond (b) Removal and capping to achieve SWAC of 1 mg/kg PCBs (upper 1 foot) in Columbia Pond and Wire and Nail Pond
SED-5	(a) Removal and capping in discrete areas where PCB concentrations exceed 1 mg/kg (upper 1 foot) in Columbia Pond (b) Removal and capping in discrete areas where PCB concentrations exceed 1 mg/kg (upper 1 foot) in Columbia Pond and Wire and Nail Pond
SED-6	Removal of main channel and armoring of channel banks (as necessary)
SED-7	Removal and backfill in discrete areas (all depths) where PCB concentration exceeds 1 mg/kg

5.2.2 Common Elements

Common elements shared by all or most of the sediment alternatives are described below and repeated in the applicable alternatives.

- **Removal of Ruck Pond Raceway.** Removal of all sediments (approximately 2 feet in western area and 4 feet in eastern area) in Ruck Pond Raceway, followed by backfilling with 6 inches of clean material (Figure 5-1) is a common element in the active remedial alternative (Alternatives SED-3 through SED-7). Estimated removal volumes of TSCA (i.e., PCB concentration equal to or greater than 50 mg/kg) and non-TSCA materials are 2,300 and 2,000 cubic yards (cy), respectively, for a total volume of 4,300 cy.
- Ruck Pond Raceway is a diversion conduit/channel that joins the main channel of Cedar Creek at Columbia Pond. The raceway receives storm sewer discharge from the City of Cedarburg and can also serve to divert flow from Ruck Pond, located just upstream of Columbia Pond. It is approximately 1,500 feet in length, with approximately 900 feet routed through culverts. The raceway is often dry or contains standing water; therefore, the preferred removal method is dry excavation with localized diversion of storm sewer discharge. After sediment removal, 6 inches of clean sand is placed with conventional earth-moving equipment (e.g., excavator). Based on experience at other sites, dredging/removal equipment cannot remove all contaminants (Patmont and Palermo 2007); thus, a layer of residual sediments exceeding the PRG is anticipated to remain at the base of the removal areas. For purposes of the FS, it is assumed a 6-inch backfill/sand cover layer will be placed on the removal area surface to manage anticipated residual contamination. Removed sediment will be transported via lined truck to an upland dewatering system.
- **Dewatering Area.** Staging of dewatering and water treatment, as necessary, for the active removal alternatives (Alternatives SED-4 through SED-7) is assumed to occur near the Site (e.g., Adlai Horn Park). For purposes of this AAD, the assumed process option for dewatering is a combination of gravity settling and addition of a stabilization agent, as necessary.
- **MNR below Wire and Nail Factory Dam.** Cedar Creek generally follows a riffle and pool system below Wire and Nail Factory Dam. In this area, the creek is comprised of isolated sediment deposits. These sediment pockets contain PCB concentrations

ranging from non-detect to 5.9 mg/kg and SWACs of 0.45 mg/kg and 0.24 mg/kg in the Reach Between Wire and Nail Pond and Former Hamilton Pond and the Reach Downstream of Former Hamilton Pond, respectively. As the SWACs within these reaches are currently below the sediment PRG of 1 mg/kg, these reaches meet the PRG and no active remediation is proposed. Furthermore, the sediment PCB concentrations (represented by SWACs) and fish tissue PCB concentrations within these reaches will continue to decline following remediation of upstream reaches. MNR consisting of periodic fish and sediment sampling will be performed.

5.2.3 Alternative SED-1

Alternative SED-1—no action—is the required baseline alternative for comparison of all other alternatives per USEPA guidance. Under this alternative, there would be no remediation or monitoring occurs. The Site will recover naturally over time; however, no monitoring of natural recovery is provided in this alternative to evaluate the extent of the recovery.

5.2.4 Alternative SED-2

Under Alternative SED-2—MNR and institutional controls—no active remediation is performed. Natural recovery refers to processes that act to reduce PCB concentrations in surface sediments and fish in the absence of, or following, active remediation.

This alternative consists of periodic bathymetric surveys in Columbia and Wire and Nail ponds and sediment and fish sampling throughout the creek at years 0, 5, 10, 15, and 20 after remedy implementation to track long-term trends.

5.2.5 Alternative SED-3

Alternative SED-3—capping to achieve SWAC of 1 mg/kg PCBs—contains the following components:

- Removal of sediments and backfilling with 6 inches of sand in Ruck Pond Raceway (see Section 5.2.2)

- Placement of an approximate 1-foot cap over select sediments within Columbia Pond and Wire and Nail Pond to achieve a SWAC of 1 mg/kg PCBs
- MNR for Cedar Creek below Wire and Nail Factory Dam (see Section 5.2.2)
- Long-term monitoring and maintenance of the dams and cap

The installation of a cap isolates sediments and controls chemical migration, physical erosion, and biological contact with underlying, PCB-containing sediments. The cap is placed over portions of the sediment areas of the ponds resulting in a SWAC of less than 1 mg/kg PCBs. Proposed capping areas were selected by choosing the polygons with the highest PCB concentrations and placing a cap (with an assumed PCB concentration of 0.2 mg/kg, which was the average method detection limit of the RI PCB results) over those polygons until a SWAC of 1 mg/kg PCBs was reached. For Alternative SED-3, proposed capping areas, approximately 10.3 and 1.7 acres in Columbia Pond and Wire and Nail Pond, are denoted with hatching on Figures 5-2 and 5-3, respectively. These figures also present the sediment PCB concentrations directly beneath the cap (0- to 1-foot increment where placed) or surface sediment PCB concentrations (0- to 1-foot increment where no cap is proposed). The maximum PCB concentration detected within the polygon area is also noted.

Following remedy implementation, the post-remedy sediment SWACs of approximately 0.9 mg/kg were calculated for both ponds, when assuming a PCB concentration of 0.2 mg/kg (i.e., average method detection limit of the RI PCB results) is achieved in the capped areas. Figures 5-4 and 5-5 present the post-capping surface PCB concentrations within Columbia Pond and Wire and Nail Pond, respectively.

Preliminary cap design evaluations were performed to determine the proposed cap composition and thickness. First, the cap material type necessary to resist hydrodynamic flows during a 100-year flood event was evaluated using results from the hydrodynamic modeling presented in Appendix C of the RI Report. Based on predicted velocities and shear stresses from the hydrodynamic modeling, an approximate 1-foot-thick cap with median stone diameters of approximately 1 and 2 inches is necessary for Columbia Pond and Wire and Nail Pond, respectively. As capping occurs on the existing sediment bed, hydraulic assessment is needed to determine whether cap placement proposed in Alternative SED-3 potentially affects flooding elevations. Furthermore, as PCBs are relatively immobile contaminants, a cap consisting of a well-graded material functions both as a chemical isolation layer and armor layer, thus eliminating the need for a two-layer cap.

Cap placement within the ponds occurs using either mechanical equipment (e.g., excavator or telescoping conveyor belt) operating from the shoreline and/or a shallow-draft barge. Access to the ponds likely occurs from the north shoreline where a temporary access road can be connected with Columbia Road.

As PCB-containing sediments remain in the ponds following the remedial action, this alternative relies on the dams for vertical containment of the sediments. Long-term monitoring and maintenance of both the dams and caps are components of this alternative. Long-term monitoring and maintenance of the dams consists of annual routine maintenance (e.g., brush removal) and dam safety inspections and maintenance every 5 years for 30 years. Long-term monitoring of the caps includes periodic bathymetric surveys and physical inspection of the cap, as necessary, in Columbia and Wire and Nail ponds at years 0, 5, 10, 15, and 20 after remedy implementation to assess cap stability and the need for cap maintenance.

5.2.6 Alternative SED-4a

Alternative SED-4a—removal and capping to achieve SWAC of 1 mg/kg PCBs (upper 1 foot) in Columbia Pond—contains the following components:

- Removal of sediments and backfilling with 6 inches of sand in Ruck Pond Raceway (see Section 5.2.2)
- Removal of 1 foot of sediments followed by placement of an approximate 1-foot cap over select sediments within Columbia Pond to achieve a SWAC of 1 mg/kg PCBs
- MNR for Wire and Nail Pond
- MNR for Cedar Creek below Wire and Nail Factory Dam (see Section 5.2.2)
- Long-term monitoring and maintenance of the dams and cap

As in SED-3, the installation of a cap isolates sediments and controls chemical migration, physical erosion, and biological contact with underlying, PCB-containing sediments.

However, SED-4a also includes the initial removal of sufficient sediments to allow for the maintenance of existing water depths within the ponds following placement of the cap.

This alternative involves the removal of sediments within Columbia Pond to achieve a SWAC of less than 1 mg/kg. An approximate volume of 16,700 cy of sediments (approximately 3,700 cy of TSCA and 13,000 cy of non-TSCA sediments) is targeted for removal in Columbia Pond, extending to a depth of 1 foot below the sediment surface. Following removal, a 1-foot-thick cap composed of a well-graded material is placed over the removal areas (see Section 5.2.5 for results of preliminary cap design evaluations). Removal and capping of sediments occurs over approximately 10.3 acres in Columbia Pond, as shown on Figure 5-6. Figure 5-6 presents a depiction of the PCB concentration of the upper 1 foot of sediment following removal but prior to capping, whereas Figure 5-7 depicts PCB concentrations of the upper 1 foot of sediment after capping within Columbia Pond (post-remedy conditions). Removal and capping activities result in a post-remedy sediment SWAC of approximately 0.9 mg/kg in Columbia Pond.

For purposes of this AAD, and based on sediment removals performed at other similar sites, temporary flow control measures (e.g., soldier piles and steel plates, or jersey barriers) are installed within Columbia Pond in a staged manner to allow for dry excavation. Additionally, stop logs within the Columbia Mills Dam millrace are removed to lower water surface elevations within the pond. Sediments behind the island are excavated first, followed by sediments in the main channel within the pond. Sediment removal directly upstream of the dam is performed "in the wet" using mechanical equipment (e.g., excavator) operating from a shallow-draft barge. Following removal, the sediment cap is placed using similar mechanical equipment used in the sediment removal process.

Removed sediments under dry excavation conditions are loaded directly into lined trucks for transport to nearby dewatering and water treatment systems. For wet excavation, removed sediment are placed into mini-scows or lined roll-off containers secured atop shallow draft barges that are transported to a shore side offloading area for subsequent truck transport to the dewatering system. Dewatered sediments are transported to approved, off-Site disposal facilities.

Similar to SED-3, this alternative relies on the dams for vertical containment of the sediments. Therefore, long-term monitoring and maintenance (as described in Section 5.2.5) of both the dams and caps are components of this alternative.

Under SED-4a, MNR is applied to Wire and Nail Pond as the proposed remedy. Although the PCB SWAC within Wire and Nail Pond (i.e., 9.5 mg/kg) currently exceeds the sediment PRG of 1 mg/kg, sedimentation is ongoing in Wire and Nail Pond and the Columbia Pond remedy would reduce the upstream load of PCB-containing sediments that contribute to sedimentation within Wire and Nail Pond. The time to achieve the sediment PRG within Wire and Nail Pond will be evaluated in the FS. Long-term monitoring activities to evaluate MNR include periodic bathymetry surveys within Wire and Nail Pond and sediment and fish sampling at years 0, 5, 10, 15, and 20 following the remedial action to track long-term trends.

5.2.7 Alternative SED-4b

Alternative SED-4b—removal and capping to achieve SWAC of 1 mg/kg PCBs (upper 1 foot) in Columbia Pond and Wire and Nail Pond—builds upon Alternative SED-4a by including active remediation in Wire and Nail Pond. SED-4b contains the following components:

- Removal of sediments and backfilling with 6 inches of sand in Ruck Pond Raceway (see Section 5.2.2)
- Removal of 1 foot of sediments followed by placement of an approximate 1-foot cap over select sediments within Columbia Pond and Wire and Nail Pond to achieve a SWAC of 1 mg/kg PCBs
- Remedy of MNR for Cedar Creek below Wire and Nail Factory Dam (see Section 5.2.2)
- Long-term monitoring and maintenance of the dams and cap

This alternative involves the removal of sediments within both Columbia Pond and Wire and Nail Pond to achieve a SWAC of less than 1 mg/kg in the upper 1 foot of sediment. An approximate total volume of 19,400 cy of sediments is targeted for removal in Columbia Pond and Wire and Nail Pond, extending to a depth of 1 foot below the sediment surface. The approximate removal volumes from each pond are provided in the table below.

Location	TSCA Volume (cy)	Non-TSCA Volume (cy)	Total Volume (cy)
Columbia Pond	3,700	13,000	16,700
Wire and Nail Pond	0	2,700	2,700

Following removal, a 1-foot-thick cap composed of a well-graded material is placed over the removal areas (see Section 5.2.5 for results of preliminary cap design evaluations). Removal and capping activities occur over approximately 10.3 acres of Columbia Pond and 1.7 acres in Wire and Nail Pond. Figures 5-6 and 5-8 present a depiction of the PCB concentration of the upper 1 foot of sediment following removal but prior to capping in Columbia Pond and Wire and Nail Pond, respectively.

Post-remedy sediment SWACs of approximately 0.9 mg/kg were estimated for both ponds, when applying a PCB concentration of 0.2 mg/kg (i.e., average method detection limit of the RI PCB results) for capped areas. Figures 5-7 and 5-9 depict post-remedy PCB concentrations of the upper 1 foot of sediment within Columbia Pond and Wire and Nail Pond, respectively, with hatching denoting areas targeted for removal and capping.

The removal and capping process in Columbia Pond follow those presented in Alternative SED-4a (Section 5.2.6). Within Wire and Nail Pond, targeted sediment is removed "in the wet" (e.g., mechanical dredging) and cap materials are placed using conventional excavation equipment operating from a shallow draft barge. Removed sediments are loaded into mini-scows or lined roll-off containers secured atop shallow draft barges that are transported to a shore side offloading area for subsequent truck transport to the dewatering system. Sediments are transported in lined trucks to nearby dewatering and water treatment systems. Dewatered sediments are transported to approved, off-Site disposal facilities.

This alternative relies on the dams for vertical containment of the sediments; therefore, long-term monitoring and maintenance of both the dams and caps (as described in Section 5.2.5) are components of this alternative.

5.2.8 Alternative SED-5a

Alternative SED-5a—removal and capping in discrete areas where PCB concentrations exceed 1 mg/kg (upper 1 foot) in Columbia Pond—contains the following components:

- Removal of sediments and backfilling with 6 inches of sand in Ruck Pond Raceway (see Section 5.2.2)
- Removal of sediment in areas of Columbia Pond where PCB concentrations in the upper 1 foot are greater than 1 mg/kg followed by placement of a 1-foot cap in removal areas
- MNR for Wire and Nail Pond
- MNR for Cedar Creek below Wire and Nail Factory Dam (see Section 5.2.2)
- Long-term monitoring and maintenance of the dams and cap

Similar to Alternatives SED-3, SED-4a, and SED-4b, Alternative SED-5a provides isolation of PCB-containing sediments. However, in Alternative SED-5a, discrete surface sediments with PCB concentrations exceeding 1 mg/kg are targeted for removal and subsequent capping, resulting in a post-remedy sediment SWAC of approximately 0.2 mg/kg (assuming a PCB concentration of 0.2 mg/kg for capped areas) in the upper 1 foot of sediments in Columbia Pond (Figure 5-10).

An approximate total volume of 25,300 cy (approximately 3,700 cy of TSCA and 17,600 cy of non-TSCA) of sediments is targeted for removal in Columbia Pond, extending to a depth of 1 foot below the sediment surface. Following removal, a 1-foot-thick cap composed of a well-graded material is placed over the removal areas (see Section 5.2.5 for results of preliminary cap design evaluations). Removal and capping activities occur over approximately 13.2 acres of Columbia Pond. Figure 5-11 presents a depiction of the PCB concentration of the upper 1 foot of sediment following removal but prior to capping, whereas Figure 5-10 depicts PCB concentrations of the upper 1 foot of sediment after capping within Columbia Pond (post-remedy conditions).

As with the other in-place containment alternatives, Alternative SED-5a relies on the dams for vertical containment of the sediments; therefore, long-term monitoring and maintenance of both the dams and caps (as described in Section 5.2.5) are components of this alternative.

The removal and capping methodologies for Columbia Pond follow those presented in Alternative SED-4a. Similarly, natural recovery is tracked in Wire and Nail Pond with periodic bathymetry surfaces and sediment and fish sampling at years 0, 5, 10, 15, and 20 following remedy implementation.

5.2.9 Alternative SED-5b

Alternative SED-5b—removal and capping in discrete areas where PCB concentrations exceed 1 mg/kg (upper 1 foot) in Columbia Pond and Wire and Nail Pond—includes the same remedial components as Alternative SED-5a, with removal and capping in Wire and Nail Pond as opposed to MNR. Specific remedial components include the following:

- Removal of sediments and backfilling with 6 inches of sand in Ruck Pond Raceway (see Section 5.2.2)
- Removal of sediment in discrete areas of Columbia Pond and Wire and Nail Pond where PCB concentrations in the upper 1 foot are greater than 1 mg/kg followed by placement of a 1-foot cap in removal areas
- Remedy of MNR for Cedar Creek below Wire and Nail Factory Dam (see Section 5.2.2)
- Long-term monitoring and maintenance of the dams and cap

This alternative involves removal of sediments with PCB concentrations exceeding 1 mg/kg in the top foot of both Columbia Pond and Wire and Nail Pond, followed by placement of a cap in the removal areas. An approximate total volume of 25,300 cy of sediments is targeted for removal in both Columbia Pond and Wire and Nail Pond, extending to a depth of 1 foot below the sediment surface. The approximate removal volumes from each pond are provided in the table below.

Location	TSCA Volume (cy)	Non-TSCA Volume (cy)	Total Volume (cy)
Columbia Pond	3,700	17,600	21,300
Wire and Nail Pond	0	4,000	4,000

Following removal, a 1-foot-thick cap composed of a well-graded material is placed over the removal areas (see Section 5.2.5 for results of preliminary cap design evaluations). Removal and capping activities occur over approximately 13.2 acres of Columbia Pond and 2.5 acres in Wire and Nail Pond. Figures 5-11 and 5-12 present a depiction of the PCB concentration of the upper 1 foot of sediment following removal but prior to capping in Columbia Pond and Wire and Nail Pond, respectively. As with SED-5a, the post-remedy sediment SWACs of both Columbia Pond and Wire and Nail Pond are approximately 0.2 mg/kg (assuming a PCB concentration of 0.2 mg/kg for capped areas). Figures 5-10 and 5-13 depict post-remedy PCB concentrations of sediments in the upper 1 foot within Columbia Pond and Wire and Nail Pond, respectively, with hatching denoting areas targeted for removal and capping.

This alternative relies on the dams for vertical containment of the sediments; therefore, long-term monitoring and maintenance of both the dams and caps are components of this alternative, as described in Section 5.2.5.

Finally, removal and capping methodologies presented in Alternatives SED-4a and SED-4b for Columbia Pond and Wire and Nail Pond, respectively, are implemented under this alternative.

5.2.10 Alternative SED-6

Alternative SED-6—removal of sediments exceeding 1 mg/kg PCBs within main channel and armoring of channel banks in Columbia Pond and removal of sediment exceeding 1 mg/kg PCBs in Wire and Nail Pond—utilizes in-place containment and removal. This alternative includes removal of sediment at all depths with PCB concentrations exceeding 1 mg/kg in the main channel of Columbia Pond and throughout Wire and Nail Pond and, therefore, does not rely on the dams for vertical containment. Specific components of Alternative SED-6 include the following:

- Removal of sediments and backfilling with 6 inches of sand in Ruck Pond Raceway (see Section 5.2.2)
- Removal of sediments with PCB concentrations greater than 1 mg/kg in the main channel of Columbia Pond, followed by backfilling of removal areas with 6 inches of sand
- Removal of 1 foot of sediment and placement of a 1-foot-thick cap in areas outside of the main channel in Columbia Pond to achieve a SWAC of less than 1 mg/kg PCBs in the non-channel areas

- Armoring of the main channel to prevent erosion of areas outside of the main channel within Columbia Pond
- Removal of sediments with PCB concentrations greater than 1 mg/kg in Wire and Nail Pond, followed by backfilling of removal areas with 6 inches of sand
- Remedy of MNR for Cedar Creek below Wire and Nail Factory Dam (see Section 5.2.2)
- Long-term monitoring and maintenance of capped areas within Columbia Pond

Within Columbia Pond, this alternative removes sediments exceeding 1 mg/kg PCBs at any depth in the main channel. Within the main channel, a 6-inch backfill/sand cover layer is placed over the surface sediments to address potential residual contamination and the banks are armored with stone of sufficient size to resist erosion of the banks and remaining sediments outside of the main channel.

In areas outside of the main channel (i.e., area connecting Ruck Pond Raceway with Cedar Creek/Columbia Pond and area north of the island within Columbia Pond), the top foot of sediments are removed in select polygons to achieve a sediment SWAC of 1 mg/kg throughout the pond. A 1-foot-thick cap is placed over the removal areas. Figure 5-14 presents a depiction of the PCB concentration of the upper 1 foot of sediment in Columbia Pond following removal but prior to capping, on the left panel and the depth of sediment removal on the right panel. In non-channel areas, the sediment PCB concentrations are surface sediment concentrations (i.e., 0- to 1-foot increment) in uncapped areas and PCB concentrations of the upper 1 foot of sediments following removal but prior to capping, in capped areas. In the main channel, the sediment concentrations are the PCB concentrations after sediment removal, but before backfilling with sand. Polygons containing no PCB concentration designation indicate all probed sediments (as measured in 1998 during the RI) were targeted for removal.

Within Wire and Nail Pond, sediments with PCB concentrations exceeding 1 mg/kg at any depth are removed. Similar to Columbia Pond, a 6-inch backfill/sand cover is placed over removal areas to ensure a clean surface (i.e., address areas where post-removal residual PCBs are present) remains. Figure 5-15 presents the sediment concentrations remaining after sediment removal in Wire and Nail Pond on the left panel and the depth of sediment removal on the right panel. Similar to the main channel of Columbia Pond, the post-remedy sediment concentrations are the PCB concentrations after sediment removal, but before backfilling with sand.

Under this alternative, an approximate total volume of 46,000 cy of sediments is targeted for removal in both Columbia Pond and Wire and Nail Pond. The approximate removal volumes from each pond are provided in the table below.

Location	TSCA Volume (cy)	Non-TSCA Volume (cy)	Total Volume (cy)
Columbia Pond	7,300	27,400	34,700
Wire and Nail Pond	0	11,300	11,300

The post-remedy sediment SWAC of Columbia Pond is approximately 1 mg/kg (assuming a PCB concentration of 0.2 mg/kg for capped or backfilled areas), whereas the post-remedy sediment SWAC of Wire and Nail Pond is approximately 0.2 mg/kg (assuming a PCB concentration of 0.2 mg/kg for backfilled areas). Figures 5-16 and 5-17 depict post-remedy surface PCB concentrations within Columbia Pond and Wire and Nail Pond, respectively, on the left panel and the depth of sediment removal on the right panel.

As sediments with PCB concentrations greater than 1 mg/kg are removed from the portion of Columbia Pond most susceptible to mobilization during dam removal or failure, this alternative does not rely on the Columbia Mills Dam for vertical containment. The capped portions of pond requires monitoring and maintenance to ensure long-term stability of the cap.

As described in the preceding alternatives with removal, the preferred removal method in Columbia Pond is a combination of dry excavation and mechanical dredging, and the preferred removal method in Wire and Nail Pond is mechanical dredging. Removed sediment from dry excavation is loaded directly into lined trucks for transport to a nearby upland dewatering system. Removed sediments from wet excavation or mechanical dredging are placed into mini scows or lined roll-off containers secured atop shallow draft barges that are transported to a shore-side offloading area for subsequent truck transport to the dewatering system. Following dewatering, removed sediments are loaded into trucks for off-

Site transport and disposal at a suitable landfill (TSCA or solid waste) depending on PCB concentrations. The backfill sand cover or cap is placed following removal activities using conventional excavation equipment operating from shore or a shallow draft barge.

5.2.11 Alternative SED-7

Alternative SED-7—removal and backfill of sediments with PCB concentrations exceeding 1 mg/kg at any depth—is sediment removal and backfilling as described in the remedy components below.

- Removal of sediments and backfilling with 6 inches of sand in Ruck Pond Raceway (see Section 5.2.2)
- Removal of sediments with PCB concentrations greater than 1 mg/kg in Columbia Pond and Wire and Nail Pond, followed by backfilling of removal areas with 6 inches of sand
- Remedy of MNR for Cedar Creek below Wire and Nail Factory Dam (see Section 5.2.2)

This alternative removes sediments with PCB concentrations greater than 1 mg/kg in both Columbia Pond and Wire and Nail Pond. An approximate total volume of 61,800 cy of sediments is removed from both ponds. The approximate removal volumes from each pond are provided in the table below.

Location	TSCA Volume (cy)	Non-TSCA Volume (cy)	Total Volume (cy)
Columbia Pond	11,700	38,800	50,500
Wire and Nail Pond	0	11,300	11,300

The left panels of Figures 5-18 and 5-15 present the sediment concentrations remaining after sediment removal, but prior to backfilling in Columbia Pond and Wire and Nail Pond, respectively. The depth of sediment removal in Columbia Pond and Wire and Nail Pond, respectively, are presented on the right panels of Figures 5-18 and 5-15. The post-remedy sediment SWACs of both Columbia Pond and Wire and Nail Pond are approximately 0.2 mg/kg (assuming a PCB concentration of 0.2 mg/kg for backfilled areas). Figures 5-19 and 5-17 present the sediment PCB concentrations remaining post-remedy on the left panel and the depth of sediment removal on the right panel for Columbia Pond and Wire and Nail Pond, respectively. Alternative SED-7 does not rely on the dams for vertical containment because all sediments exceeding 1 mg/kg are removed from both ponds.

Removal and backfilling methodologies presented in Alternative SED-6 are implemented under this alternative.

5.3 Floodplain Soils Remedial Alternatives

5.3.1 Assembly of Alternatives

Three floodplain soil remedial alternatives were assembled as presented in Table 5-2. They represent remedies consisting of in-place containment and removal of contaminated floodplain soils.

Table 5-2
Floodplain Soils Remedial Alternatives

Floodplain Soil Alternative	Description
FP-1	No action
FP-2	(a) Topsoil/soil cover in impacted floodplains including wetlands (b) Topsoil/soil cover in impacted floodplains excluding wetlands
FP-3	(a) Removal and backfilling in impacted floodplains including wetlands (b) Removal and backfilling in impacted floodplains excluding wetlands

5.3.2 Common Elements

As described in Section 2.2.2, the proposed revisions to WAC NR 720 allow for use of an alternative approach to evaluate potential remediation areas. A preliminary, screening-level approach was developed in collaboration with USEPA and WDNR to identify potential areas for remediation. This approach will be formally submitted to WDNR for approval during the FS process.

The screening-level approach identified tax parcels that are targeted for future sampling during pre-design investigations considering both the inclusion and exclusion of wetlands from the remedial areas. These two scenarios (including and excluding wetlands) were considered given the difficulty associated with accessing wetlands (thus leading to low exposure to potentially PCB-containing soils) as well as the desire to preserve the wetlands that provide medium to high habitat value to the surrounding flora and fauna. Thus, the two scenarios balance the low exposure risk with temporary (or in some cases, potentially permanent) destruction of valuable wetland habitat.

As shown on Figure 2-19, when including wetlands in the potential removal areas, 77 of the 247 tax parcels within the 10-year floodplain contained floodplain soil SWACs exceeding the PRG of 1 mg/kg PCBs and are targeted for further investigation. Similarly, when excluding wetlands from the potential removal areas, 74 tax parcels contained floodplain soil SWACs exceeding the PRG of 1 mg/kg PCBs. Final remediation areas within the floodplains will be determined based on the results of future pre-design investigations. For purposes of this AAD, potential remedial areas are estimated by computing the portion of the 2-year floodplain remediated to reduce the SWAC within the tax parcel to less than 1 mg/kg PCBs. Table 5-3 provides the estimated remedial areas within the 2-year floodplain when considering both inclusion and exclusion of the wetlands.

Table 5-3
Estimated Remedial Areas within 2-year Floodplain

Floodplain Soil Scenario	Estimated Removal Area (acres)
Including wetlands in potential remedial areas	25
Excluding wetlands in potential remedial areas	11

5.3.3 Alternative FP-1

As with Alternative SED-1, Alternative FP-1—no action—is the required baseline alternative for comparison of all other alternatives per USEPA guidance. Under this alternative, there is no remediation or monitoring. The Site would continue to recover naturally over time.

5.3.4 Alternative FP-2

Alternative FP-2—topsoil/soil cover—places a 1-foot-thick topsoil/soil cover over select floodplain soils to achieve a floodplain soil SWAC of 1 mg/kg PCBs. This alternative requires placement of the covered areas on the GIS Registry to limit excavation and disturbance of cover areas. Alternative FP-2 is divided into two sub-alternatives to evaluate inclusion or exclusion of wetlands within the remediation footprint. As described in Section 5.3.2, the cover extends over approximately 25 and 11 acres when including and excluding the wetlands, respectively. Although the size of the remedial footprint varies, the methodology for implementing the remedy is consistent for each sub-alternative as described below.

The topsoil/soil cover is installed using typical excavation equipment (e.g., backhoe, excavator), selecting smaller equipment, when possible, to minimize the support area footprint. In ecologically sensitive areas (e.g., wetlands), innovative techniques, such as pneumatic cap placement, are used to minimize construction-related impacts. Additionally, access roads are constructed in close proximity to the remedial areas to further minimize impacts to the floodplains.

Erosion control measures (e.g., silt curtains) are placed along the creek in areas of adjacent removal to minimize transport of floodplain soils into the creek. Erosion control mats are installed on top of the cover in areas of steep banks that may be susceptible to erosive forces.

Long-term monitoring of the topsoil/soil cover includes periodic physical inspection of the cover materials at years 0, 5, 10, 15, and 20 after remedy implementation to assess sufficient vegetation (as necessary) and evidence of erosion.

Finally, because Alternative FP-2 consists of adding materials to the floodplains, a hydraulic analysis would be performed to assess whether cover placement would affect flood elevations.

5.3.5 Alternative FP-3

Alternative FP-3—removal and backfilling—removes 1 foot of floodplain soils from select areas and backfills with soil or topsoil to achieve a floodplain soil SWAC of 1 mg/kg PCBs. As with Alternative FP-2, this alternative is divided into two sub-alternatives to evaluate inclusion or exclusion of wetlands within the remediation footprint. Approximate volumes of 39,700 cy and 17,700 cy are targeted for removal when including or excluding the wetlands from the remedial areas, respectively.

As with Alternative FP-2, soil removal and backfilling are implemented using conventional excavation equipment (e.g., backhoe, excavator). If wetlands are removed and reconstructed following removal, specialized equipment (e.g., low ground pressure) may be necessary to mitigate the potential to compress the underlying soils and alter Site hydraulics. Excavated soils are placed directly into lined trucks and transported to an approved off-Site disposal facility. Additionally, access roads are constructed in close proximity to the remedial areas to further minimize impacts to the floodplains.

Erosion control measures (e.g., silt curtains) are placed along the creek in areas of adjacent removal to minimize transport of floodplain soils into the creek. Erosion control mats are installed on top of the backfill in areas of steep banks that may be susceptible to erosive forces.

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TABLES

Table 3-3
State ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
STATE CHEMICAL-SPECIFIC ARARs				
Water Quality Standards for Wisconsin Surface Waters	WAC NR 102–105	Establishes definition of water use and criteria for protection of public health and enjoyment and protection and propagation of fish, shellfish, and wildlife	TBC	Applicable only if concentrations of surface water above sediments exceed these criteria—they are TBCs
Total Maximum Daily Load	WDNR 2008	*Polychlorinated Biphenyls (PCBs) Total Maximum Daily Load for Cedar Creek & Milwaukee River (Thiensville Segment) Ozaukee County, WI.* Proposes a long-term goal of sediment PCB concentration for Cedar Creek	TBC	To be considered when developing sediment clean-up levels.
STATE ACTION-SPECIFIC ARARs				
Plans and Specifications Review of Projects and Operations	WAC NR 108	WDNR approval of any reviewable project, general operation, and control of specific water/wastewater system	ARAR	Applicable for community water systems, sewage systems, and industrial wastewater facilities
Management of PCBs and Products Containing PCBs	WAC NR 157	Establishes procedures for the storage, collection, transportation, processing, and final disposal of PCBs and materials containing PCBs at any level	ARAR	Applicable for removal, transport, and disposal of PCBs
Wisconsin Pollutant Discharge Elimination System	WAC NR 200	Technology-based effluent limits (NR 220–297): Requires compliance with permit limitations for discharge to navigable waters, including water quality effluent limits, water quality standards, national performance standards, and toxic and pretreatment effluent standards	ARAR	Applicable action-specific ARAR for remedial alternatives involving discharges

Table 3-3
State ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
Water Quality Antidegradation	WAC NR 207	Establish implementation procedures for the antidegradation policy in s. NR 102.05(1)(a)	ARAR	Applicable to proposed new or increased discharges
Water Quality Antidegradation: Waste Load Allocated, Water Quality-related Effluent Standards and Limitations	WAC NR 212–220	Establishes permit limitations for effluent discharges	ARAR	Applicable for remedial alternatives involving effluent discharges
Lining of Industrial Lagoons and Design of Storage Structures	WAC NR 213	Requires compliance with permit limitations for discharge to navigable waters from industrial treatment systems	ARAR	Potentially applicable for waste management of temporary sediment dewatering and treatment systems
Wisconsin's General Permit Program for Certain Water Regulatory Permits	WAC NR 322	Establishes minimum design standards and specifications for projects permitted under a general permit	ARAR	Potentially applicable for implementation of a given remedial alternative

Table 3-3
State ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
Dam Design and Construction	WAC NR 333	Establishes dam design protocols and dam hazard rating definitions	ARAR	Potentially applicable for implementation of a remedial alternative that leaves contamination in place and relies on long-term maintenance of Columbia Mills Dam or Wire and Nail Factory Dam
Dredging Contract Fees	WAC NR 346	Establishes procedures applicable to the removal of material from the beds of natural lakes and outlying waters for which a contract is required between the state and person desiring to remove bed material	TBC	TBC with regard to removal, transport, and disposal of sediments
Sediment Sampling and Analysis, Monitoring Protocol, and Disposal Criteria for Dredging Projects	WAC NR 347	Establishes procedures and protocols for sediment sampling and analysis, disposal criteria, and monitoring requirements for dredging projects regulated by the State of Wisconsin	TBC	TBC with regard to removal, transport, and disposal of sediments
Wisconsin State Air Pollutant Control Regulations	WAC NR 400–499	Establishes concentration levels, by chemical, for new sources; manages construction and operation permits	ARAR	Applicable action-specific ARAR for removal and disposal of PCB-contaminated sediments and soils

Table 3-3
State ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
Solid Waste Management	WAC NR 500–520	Provides definitions, submittal requirements, exemptions, and other general information relating to solid waste facilities that are subject to regulations under s. 2789.01(35) Stats.: Applicable for off-site siting processes; applicable to new and existing facilities	ARAR	Applicable for implementation of a given remedial alternative
Investigation and Remediation of Environmental Contamination	WAC NR 700	Establishes standards and procedures that allow for site-specific flexibility, pertaining to the identification, investigation, and remediation of sites and facilities that are subject to regulation under s. 144.442, 144.76, or 144.77, Stats.	ARAR	Applicable for implementation of a given remedial alternative
Notification of the Discharge of Hazardous Substances	WAC NR 706	Notification procedures and responsibilities by discharger of hazardous substances including containment, cleanup, disposal, and restoration	ARAR	Applicable for removal, transport, and disposal of contaminated sediments and soils
Great Lakes Water Quality Initiative	WAC NR 102 and 106 USEPA 1995	Sets forth guidance for any remedial action in states bordering the Great Lakes: In general, minimizes any lowering of water quality to the extent practicable	TBC	TBC with regard to remedial alternatives involving wastewater discharge
Low-hazard Solid Waste Exemption	Wisconsin Statutes Chapter 289.43	Solid waste law that allows issuance of exemption from siting requirements in NR 500–520: Dredged material may be considered "exempt" after treatment if "new" product is created	ARAR	Potentially applicable if ex situ treatment option is selected

Table 3-3
State ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
USEPA Toxic Substance Control Act Coordinated Approval	State of Wisconsin Approval Process for Dredging of Commercial Ports, WDNR 2004	USEPA Region 5 works with WDNR on review of application to waive disposal requirement in WAC NR 500 landfills and allow disposal of Toxic Substance Control Act-level sediments (greater than 50 parts per million) in a Wisconsin licensed solid waste landfill	TBC	Applicable in evaluating disposal options of soils and sediments
STATE LOCATION-SPECIFIC ARARS				
Beneficial Reuse Solid Waste Exemption	WAC NR 500.08	Establishes criteria for possible beneficial use of solid wastes after treatment: Applies to on-site reuse options only	ARAR	Applicable for disposal of treated sediments and soils meeting disposal criteria
Dredge and Fill Requirements	WDNR 1985, 1990	Report of the Technical Subcommittee on Determination of Dredge Material Suitability of In-Water Disposal	TBC	TBC for alternatives involving in-water disposal, such as confined aquatic disposal
Local Permits (building, zoning, other)		Construction in floodplain or wetland and miscellaneous construction activities	TBC	TBC for implementation of a given remedial alternative
Landfill Siting and Approval Process	Wisconsin Statutes Chapter 289	State statute for solid waste facilities: Addresses the upland disposal of solid waste along with in-river disposal options; landfill facilities are prohibited from shoreland and floodplain zone areas except by permits issued from WDNR	ARAR	Applicable for implementation of any given remedial alternative disposal option

Table 3-3
State ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
Permit in Navigable Waters	Wisconsin Statutes Chapter 30	State statute for navigable waters, harbors, and navigation: Substantive provisions that address minimizing adverse effects on navigable waterways resulting from work performed	ARAR	Applicable for work performed in navigable waterways

Notes:

ARAR	Applicable or Relevant and Appropriate Requirement
PCB	polychlorinated biphenyl
RI/FS	Remedial Investigation/Feasibility Study
TBC	to be considered
USEPA	U.S. Environmental Protection Agency
WAC NR	Wisconsin Administrative Code, Natural Resources
WDNR	Wisconsin Department of Natural Resources

Table 3-4
Federal ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
FEDERAL CHEMICAL-SPECIFIC ARARs				
CWA (as amended in the Federal Water Pollution Control Act)	40 CFR 122, 125, 129, 131; CWA 301-304, 401; 33 USC 1251-1387	Provides for federal, state, and local surface water quality guidelines (including discharge requirements to control pollutants to navigable waters [i.e., NPDES])	ARAR	Establishes relevant and appropriate water quality criteria to protect against adverse effects
FEDERAL ACTION-SPECIFIC ARARs				
NPDES Program Requirements	40 CFR 122, Subpart B; 40 CFR 125; 40 CFR 301, 303, and 307	Establishes NPDES permitting requirements for point source discharges; regulates discharge of water into navigable waters including the quantity and quality of discharge	TBC	These requirements will be considered if treated water is discharged from the site
	33 USC 1342; 40 CFR 122.26 (c)(1)(ii)(C); 40 CFR 122.44(k); 40 CFR 125.1-.3, .100-.104	BMPs to control pollutants in stormwater discharges during construction activities: Best Available Technology effluent limits for toxic and non-conventional pollutants; Best Conventional Technology limits for conventional pollutants; water-quality-based effluent limitations BMPs to prevent release of toxics to surface water from ancillary areas or spills	ARAR	BMPs for erosion and sedimentation control will be adopted to minimize the potential for rainfall or flood-induced migration of soils and sediments from disturbed areas
Clean Air Act	40 CFR 52	Air emission rates for chemical constituents: Establishes filing requirements and standards for constituent emission rates in accordance with National Ambient Air Quality Standards	TBC	To be considered for remedial alternatives that include removal of soil or treatment within the site

Table 3-4
Federal ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
National Emission Standards for Hazardous Air Pollutants	40 CFR 61, 40 CFR 63	Air standards for a range of chemicals: Establishes emission standards for hazardous air pollutants	ARAR	May apply to on-site treatment processes
Federal Criteria, Advisories, and Guidance	American Conference of Governmental Industrial Hygienists	Threshold limit value: These standards were issued as consensus standards for controlling air quality in workplace environments	TBC	Threshold limit values could be used for assessing the potential for site inhalation risks during remediation
Toxic Substance Control Act	40 CFR 761.50(a)(3)	Prohibits discharge of water containing PCBs to navigable waters unless PCB concentration is less than approximately 3 parts per billion or in accordance with discharge limits of NPDES permit	ARAR	Criteria will be considered in establishing discharge criteria for water treatment effluent
	40 CFR 761.61(c) 40 CFR 761.65	Establishes cleanup options and storage options for PCB remediation waste, including PCB-contaminated soils and sediments; options include risk-based approval by USEPA; risk-based approval option must demonstrate that cleanup or storage plan will not pose an unreasonable risk of injury to health or the environment	ARAR	Applicable to remedial actions that involve PCB-contaminated wastes
	40 CFR 761.79	Establishes decontamination standards and procedures for removing PCBs from non-porous surfaces	ARAR	Applicable to decontamination of equipment used in excavation and restoration activities

Table 3-4
Federal ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
	40 CFR 761.40	Requirements regarding the marking of PCB containers and PCB storage areas	ARAR	Applicable to remedial actions that involve PCB-contaminated wastes
	40 CFR 761, Subpart G	Policy used to determine adequacy of cleanup of spills resulting from the release of materials containing PCBs at concentration of 50 parts per million or greater	TBC	Will be considered in the event of PCB spills occurring during the work
Hazardous Materials Transportation Act, as amended	49 CFR 107, 171,179	General information, regulations, and definitions: Department of Transportation rules for transportation of hazardous materials, including procedures for the packaging, labeling, manifesting, and transporting of hazardous materials	ARAR	Applicable for material shipment off site
Rivers and Harbors Act	33 CFR 320-330	Prohibits unauthorized obstruction or alteration of any navigable water in the United States (dredging, filling, coffer dams, piers, etc.)	TBC	May be considered if piers are installed in Cedar Creek to facilitate bridge construction for material transport
USEPA Guidance – OSWER	EPA/540/R-95/052, OSWER Directive No. 9355.7-04, May 1995	*Land Use in the CERCLA Remedy Selection Process:* Presents information for considering land use in making remedy selection decisions at National Priority List sites	TBC	Guidance will be considered during evaluation of remedial alternatives

Table 3-4
Federal ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
CERCLA	42 USC 103 Section 9621(d)(4)(C)	Technical impracticability waiver	ARAR	Applicable if attainment of cleanup goals cannot be achieved due to technical impracticability from an engineering perspective
	42 USC 9601 Section 121(e)	Waives the requirement to obtain federal, state, and local permits for on-site CERCLA actions	ARAR	Applicable to CERCLA actions
USEPA Guidance - OSWER	OSWER Directive 9200.4-17P, 1997	*Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*: Provides guidance regarding the use of Monitored Natural Attenuation for the cleanup of soil and groundwater	TBC	This guidance may be considered for potential actions at the site
	OSWER 9355.7-03B-P, June 2001	*Comprehensive Five-Year Review Guidance*: Provides guidance on conducting 5-year reviews for sites at which hazardous substances, pollutants, or contaminants remain on site above levels that allow for unrestricted use and unlimited exposure	TBC	Guidance will be considered during preparation of any post remediation monitoring plans
	EPA-540-G-89-004 OSWER Directive 9355.3-01, October 1988	*Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*: Describes the general procedures for conducting a remedial investigation or feasibility study	TBC	Guidance will be considered during preparation of the feasibility study

Table 3-4
Federal ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
	EPA-540-R-05-012 OSWER 9355.0-85, December 2005	*Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*: Provides technical and policy guidance for project managers and management teams making remedy decisions for contaminated sediment sites	TBC	Guidance will be considered during preparation of remedial alternatives
USEPA Guidance	EPA-905-B-96-004, 2008	*Assessment and Remediation of Contaminated Sediments (ARCS) Program Guidance for In Situ Subaqueous Capping of Contaminated Sediments*: Provides technical guidance for subaqueous, in situ capping as a remediation technique for contaminated sediments	TBC	Guidance will be considered during preparation of remedial alternatives that consider capping
	ERDC/EL TR-08-4, February 2008	*The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk*: Provides technical guidance on assessing the effects of environmental dredging on site remedies	TBC	Guidance will be considered during preparation of remedial alternatives that consider dredging
	ERDC/EL TR-08-294, September 2008	*Technical Guidelines for Environmental Dredging of Contaminated Sediments*: Provides technical guidelines for evaluating environmental dredging as a sediment remedy component	TBC	Guidance will be considered during preparation of remedial alternatives that consider dredging
National Research Council	National Research Council 2007	*Sediment Dredging at SUPERFUND MEGASITES – Assessing the Effectiveness*: Provides a review of sediment dredging at superfund sites to assess dredging as an effective remedy component	TBC	Guidance will be considered during preparation of remedial alternatives that consider dredging

Table 3-4
Federal ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
OSHA	29 CFR 1910	General Industry Standards: These regulations specify the 8-hour, time-weighted average concentration for exposure of site workers to various organic compounds; training requirements for workers at hazardous waste operations are specified in 29 CFR 1910.120	ARAR	Applicable for on-site remedial actions
	29 CFR 1926	Safety and Health Standards: This regulation specifies the type of safety equipment to be used on site and procedures to be followed during site remediation	ARAR	These requirements apply to all site contractors and subcontractors and must be followed during all site work
	29 CFR 1904	Recordkeeping, Reporting, and Related Regulations: This regulation outlines the recordkeeping and reporting requirements for an employer under OSHA	ARAR	Applicable for on-site remedial actions performed
FEDERAL LOCATION-SPECIFIC ARARs				
CWA	40 CFR 230 ; CWA 404; 33 USC 1344	Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Materials	TBC	May be considered for remedial alternatives involving treatment and/or discharge of water to area waterways
USEPA Guidance	OSWER Directive 9355.7-04, May 1995	*Land Use in CERCLA Remedy Selection Process*: Identifies considerations for incorporating anticipated future land use in the remedy selection process	TBC	Provides guidance for consideration of future site land use in selection of a site remedy

Table 3-4
Federal ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
Endangered Species Act of 1973, as amended, 16 USC 1531-1544	16 USC 1536; 40 CFR 6.302; 50 CFR 402	Endangered and Threatened Wildlife and Plants: Federal agencies are required to verify that any action authorized, funded, or carried out by them is not likely to jeopardize the continued existence of any endangered species or threatened species, or result in the destruction or adverse modification of a critical habitat of such species, unless such agency has been granted an appropriate exemption by the Endangered Species Committee (16 USC 1536)	ARAR	May be relevant and appropriate if endangered species habitat areas would be impacted by site remediation activities
Fish and Wildlife Coordination Act, 16 USC 662	16 USC 662; 40 CFR 6.302	Federal/state coordination of changes to water bodies: Departments and agencies must first consult with the U.S. Fish and Wildlife Service, Department of the Interior, and with the appropriate agency head when proposing to impound or divert the waters of any stream, deepen a channel, or otherwise control or modify a stream or other body of water; this includes consulting with the head of the agency exercising administration over the wildlife resources of the particular state in which the action is to take place to conserve wildlife resources and to prevent the loss or damage to those resources	ARAR	Applicable to federal agencies but may be relevant and appropriate to activities in any surface water body that may be impacted by remedial activities

Table 3-4
Federal ARARs/TBCs

Regulation	Citation	Description	Applicability/ Appropriateness	Rationale
National Historic Preservation Act, 16 USC 470 et seq.	36 CFR 800, 36 CFR 65, and 40 CFR 6.301	Proposed remedial actions must take into account effect on historic properties and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment on the proposed undertaking	ARAR	Relevant and appropriate if activities will affect historic properties or landmarks at or near the site
Historic Sites, Buildings, and Antiquities Act, 16 USC 461 et seq.	36 CFR 62.6	National Landmarks: Proposed remedial actions must consider the existence of national landmarks and avoid undesirable impacts upon such landmarks	TBC	May be considered if activities will affect historical areas of the site

Notes:

ARAR	Applicable or Relevant and Appropriate Requirement
BMPs	Best management practices
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
ERDC/EL	Engineer Research and Development Center, Environmental Laboratory
NPDES	National Pollutant Discharge Elimination System
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
PCB	polychlorinated biphenyl
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
TBC	to be considered
USC	U.S. Code
USEPA	U.S. Environmental Protection Agency

Table 4-1
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 1[1,2]

General Response Action/Remedial Technology	Process Option	Description	Implementability		Screening Assessment
			Site Conditions	Available and Demonstrated	
A. No Further Action					
----	----	No further active remedial activities performed beyond the previously completed 1994 Sediment Removal in Ruck Pond and 2000 Soil Removal Action along the Former Hamilton Pond and Floodplain.	Technically Implementable	Yes	Retained. This alternative is required to be evaluated under CERCLA.
B. Institutional Controls					
I. Access Restrictions	Access Restrictions	Constraints, such as fencing and signs, would be placed along river to limit access.	Technically Implementable	Yes	Retained
II. Consumption Advisories	Consumption Advisories	Advisories to indicate how consumption of some fish should be limited.	Not legally enforceable.	Yes	Not Retained.
III. Listing on the GIS Registry	Listing on the GIS Registry	Legal restrictions that specify land use, such as limiting all excavation or disturbance of caps or other engineered controls.	Technically Implementable	Yes	Retained.
C. Source Control and Monitored Natural Recovery					
I. Source Control	Historic Source Control	Constraints/controls placed on point sources to reduce discharge of PCBs to Cedar Creek.	Technically Implementable	Yes	Retained. On-site source control activities largely completed.
II. Monitored Natural Recovery	Monitored Natural Recovery	Natural recovery from on-going process of clean sediment or floodplain soil deposition over impacted sediments or soils.	Technically Implementable	Yes	Retained. Has occurred historically in Cedar Creek sediments and is expected to continue.
	Enhanced Monitored Natural Recovery	Enhanced monitored natural recovery involves active measures, such as the placement of a thin layer of clean sand, to accelerate the natural recovery process. The acceleration of natural recovery most often occurs due to burial and/or incorporation and mixing of the clean material into the contaminated surface sediments through bioturbation and physical mixing processes.	Technically Implementable	Yes	Retained.
D. In-place Containment					
I. Soil Capping/Cover	Permeable Soil Cap	Placing clean soil on the surface provides a barrier that prevents exposure to underlying soil but allows stormwater to infiltrate.	Technically Implementable	Yes	Retained.

Table 4-1
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 1[1,2]

General Response Action/Remedial Technology	Process Option	Description	Implementability		Screening Assessment
			Site Conditions	Available and Demonstrated	
	Low Permeability Cap	Low-permeability caps may be constructed of clay or an engineered material such as asphalt or concrete. This cap would not only prevent exposure to underlying soils, but would also minimize stormwater infiltration through potentially contaminated materials, thereby reducing mobility of contaminants located in the unsaturated soil zone. Engineered materials could also be used in areas requiring a durable surface, such as high-traffic areas.	Technically Implementable	Yes	Retained.
II. Sediment Capping	Engineered Cap	Placement of a cap typically comprised of layered materials (e.g., sand, gravel, cobbles, geotextile) over in-situ sediment to physically isolate and protect contaminated sediment from erosion and mitigate transport of dissolved and colloidally bound contaminants into the water column.	Technically Implementable	Yes	Retained. Potentially implementable.
	Active Cap	Engineered cap containing specialized materials for chemical isolation. Reactive materials can be placed within the contaminant isolation layer of the cap (an “active” cap) to supplement the adsorption process or to provide some other physical/contaminant processes that reduce the mobility of the contaminants. Active cap materials include engineered clay aggregate materials (e.g., bentonite pellets, AquaBlok®), and reactive/adsorptive materials such as activated carbon, apatite, coke, organoclay, zero-valent iron, and zeolite.	Technically Implementable	Yes	Retained. Potentially implementable.
III. Vertical Containment	Existing Wire and Nail Factory and Columbia Mills Dams	The dams would serve as “vertical caps” to contain contaminated sediment.	Technically Implementable	Yes	Retained. Potentially implementable assuming long term dam stability.
E. In Situ Treatment					
I. Thermal Treatment	Thermal Treatment	The subsurface is heated to temperatures near the boiling point of water, volatilizing or destroying (by pyrolysis) volatile organic compounds. Contaminated vapors are collected using soil vapor extraction, contaminated liquids are removed by pumping from wells, and contaminants are treated. Heating can be performed by injecting steam in vertical wells, thermal conduction from vertical heated wells, or by electrical resistance when voltage is applied between subsurface electrodes.	Difficult to install in floodplains and not technically implementable for sediments.	Yes	Not retained. Not practical for floodplain soils of sediment at the Site.
II. Chemical Treatment	Chemical oxidation	In this technology, chemical oxidants are injected into the subsurface in solution form to react with and destroy organic contaminants. Common oxidants include hydrogen peroxide, potassium permanganate, ozone, and sodium persulfate, which have been shown to destroy a wide range of contaminants in soil, groundwater, and DNAPL.	Technically Implementable	Not yet demonstrated for PCBs	Not retained. Not demonstrated for PCBs in sediments.

Table 4-1
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 1[1,2]

General Response Action/Remedial Technology	Process Option	Description	Implementability		Screening Assessment
			Site Conditions	Available and Demonstrated	
III. Bioremediation	Bioremediation	Addition of nutrients (e.g., oxygen, minerals, etc.) or cultured microorganisms to the sediment to facilitate or improve the rate of natural biodegradation.	Technically Implementable	Not yet demonstrated at full-scale with PCBs	Not retained. Process has not been demonstrated at full-scale with PCBs.
IV. Stabilization/Solidification	Stabilization/ Solidification	Immobilize materials by injecting and mixing a stabilization/solidification agent (e.g., Portland cement, etc.) into the in-situ sediment or floodplain soils.	Technically Implementable	Process under development for sediments	Not retained. In-situ process not sufficiently developed for sediment and not practical for floodplain soils.
V. Electrochemical Remediation	Electrochemical remediation technology	ECRT is an innovative technology for destroying organic contaminants in situ by applying an alternating current across electrodes placed in the subsurface. In theory, the applied voltage creates redox reactions that destroy contaminants through oxidation-reduction mechanisms.	Not practical in floodplain soils	Not yet demonstrated for PCBs	Not retained. Process has not been demonstrated for PCBs. Not practical for floodplain soils.
F. Sediment/Floodplain Soil Removal and Management					
REMOVAL					
I. Dredging	Mechanical	Remove bottom sediment by directly applying mechanical force to dislodge and excavate materials (e.g., clamshell).	Technically Implementable	Yes	Retained.
	Hydraulic	Removal and transportation of bottom sediment in a liquid slurry form using hydraulic pumps (e.g., horizontal auger, cutterhead dredge).	Technically Implementable	Yes	Retained.
II. Excavation (in-the-dry)	Mechanical	Temporary structures used to create "dry" areas in the river to allow use of standard excavation equipment.	Technically Implementable	Yes, was used to remediate Ruck Pond	Retained.
DEWATERING					
I. Passive Dewatering	Gravity Settling and Drainage	Mechanically dredged materials are placed on a lined pad and allowed to drain and air dry. Hydraulic sediment slurry enters a thickener or lagoon and settles, consolidating at the bottom of the tank.	Yes, but significantly larger areas needed for handling hydraulically dredged slurries than mechanically dredged material	Yes	Retained.

Table 4-1
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 1[1,2]

General Response Action/Remedial Technology	Process Option	Description	Implementability: Site Conditions	Implementability: Available and Demonstrated	Screening Assessment
	Geotubes	Hydraulically dredged or rehandled sediments are pumped into the geotubes and excess water flows through the pores in the geotextiles, resulting in effective dewatering and volume reduction of the contaminated materials.	Technically Implementable	Yes	Retained.
II. Active Dewatering	Plate and Frame Filter Press	Sediment slurry pumped into cavities formed by a series of plates covered by a filter cloth. Liquids are forced through filter cloth and dewatered solids collected in the filter cavities.	Technically Implementable	Yes	Retained.
	Belt Filter Press	Sediment slurry drops onto a perforated belt where gravity drainage takes place. Thickened solids are pressed between a series of rollers to further dewater solids.	Technically Implementable	Yes	Retained.
	Hydrocyclone	Sediment slurry fed tangentially into a funnel-shaped unit to facilitate centrifugal forces necessary to separate solids from liquids. Dewatered solids collected and overflow liquid discharged.	Technically Implementable	Yes	Retained.
DISPOSAL					
I. On-Site Disposal	Confined Disposal Facility	Sediment/soils or residuals placed in disposal facility consisting of sheet piling and/or earthen dikes adjacent to or within a waterbody.	No. No suitable area available at the Site.	Yes	Not retained. Suitable site has not been identified in Cedar Creek.
II. Off-Site Disposal	TSCA-permitted Landfill	Disposal of solids or residuals in existing TSCA-permitted landfill.	Technically Implementable	Yes	Retained.
	Solid Waste Landfill	Disposal of solids or residuals (containing less than 50 mg/kg PCBs) in existing off-site permitted solid waste landfill.	Technically Implementable	Yes	Retained. Potentially implementable.
WATER TREATMENT					
I. Water Treatment	Activated Carbon Adsorption	PCBs in aqueous phase are removed with granular activated carbon.	Technically Implementable	Yes	Retained.

Table 4-1
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 1[1,2]

General Response Action/Remedial Technology	Process Option	Description	Implementability: Site Conditions	Implementability: Available and Demonstrated	Screening Assessment
	Distillation	PCBs separated from aqueous stream by vaporization and condensation.	No, not applicable for PCBs in aqueous stream	No	Not retained. Not applicable for PCBs in aqueous stream.
	Filtration	PCBs filtered out through various media (i.e., sand) from the liquid stream.	Technically Implementable	Yes	Retained.
EX SITU TREATMENT					
I. Immobilization	Stabilization/Solidification	Sediments are mixed ex-situ with Portland cement, fly ash, or some other stabilization agent. May be used for dewatering only, or to reduce the mobility of the chemical constituents.	Technically Implementable	Yes	Retained.
	Maectite	Process converts leachable materials into mineral crystal species within the soil matrix.	Technically Implementable	Process has not been demonstrated at full-scale with sediment.	Not retained. Process has not been demonstrated at full-scale with sediment.
II. Soil Washing	Soil Washing	In soil washing, soil or sediment is put in contact with an aqueous solution to remove contaminants from the soil particles. The suspension is often also used to separate fine particles from coarser particles, allowing beneficial use of the coarser fraction (if sufficiently clean) at the site.	Technically Implementable	Yes, but limited large-scale demonstrations for PCB-containing sediment projects	Retained.
III. Solvent Extraction	Solvent Extraction	Solvent extraction is a variant of soil washing in which an organic solvent (instead of an aqueous solution) is put in contact with the soil to remove contaminants.	Technically Implementable	Process has not been demonstrated at full scale with PCB-containing sediment	Not retained.
IV. Thermal Desorption	Thermal Desorption	Process which uses heat to increase the volatility of contaminants such that they can be removed (separated) from the solid matrix.	Technically Implementable	Process has not been demonstrated at full scale with PCB-containing sediment	Not retained.

Table 4-1
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 1[1,2]

General Response Action/Remedial Technology	Process Option	Description	Implementability: Site Conditions	Implementability: Available and Demonstrated	Screening Assessment
V. Destruction	Thermal	Process which uses high heat to remove or destroy PCBs in sediments. Incineration is a type of thermal destruction where soils/sediments are thermally treated in a fluidized bed, rotary kiln, or infrared incinerator, all of which would require permitting.	Technically Implementable	Yes	Retained.
	Chemical	Chemical Destruction - Process which degrades PCBs by adding reagents. Examples include: · Base-Catalyzed Dechlorination (BCD) - Chlorine is stripped off PCB molecules using sodium bicarbonate in a rotary reactor. · Reduction - Various chemical agents (e.g., sodium borohydride, sulfur dioxide) used to destroy PCBs through gas phase reduction. Chemical constituents are transferred to the gas phase through volatilization (thermal desorption unit). · Sodium-Based Reactions (NaPEG) - PCBs broken down into oxygenated organics, sodium chloride (salt), and biodegradable glycols.	Technically Implementable	Innovative technology that is under development	Not retained. Process still under development.
	Ultraviolet	Process which uses ultraviolet treatment to destroy contaminants in soils.	No. Not technically feasible for the site.	Innovative technology that is under development	Not retained. Process still under development and is not technically feasible for the site.

Notes:
1 Shaded process options have been retained for further analysis.
2 Preliminary assessment was completed using publically available information.
CERCLA = Comprehensive Environmental Response, Compensation, and Recovery Act
TSCA = Toxic Substances Control Act
UV = ultraviolet

Table 4-2
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 2[1,2]

General Response Action/Remedial Technology	Process Option	Description	Effectiveness	Implementability: Technically Feasible	Implementability: Administratively Feasible	Cost	Screening Assessment
A. No Further Action							
----	----	No further active remedial activities performed beyond the previously completed 1994 Sediment Removal in Ruck Pond and 2000 Soil Removal Action along the Former Hamilton Pond and Floodplain.	Yes	Yes	Yes	Low	Retained. This alternative is required to be evaluated under CERCLA.
B. Institutional Controls							
I. Access Restrictions	Access Restrictions	Constraints, such as fencing and signs, would be placed along river to limit access.	Yes	Yes	May need permits to install on properties.	Low	Retained. Potentially implementable.
II. Listing on the GIS Registry	Listing on the GIS Registry	Legal restrictions that specify land use, such as, limiting all excavation or disturbance of caps or other engineered controls.	Yes	Yes	Yes	Low	Retained. Potentially implementable.
C. Source Control and Monitored Natural Recovery							
I. Source Control	Historic Source Control	Constraints/controls placed on point sources to reduce discharge of PCBs to Cedar Creek.	Yes	Yes	Yes	Low	Retained. On-site source control activities largely completed.
II. Monitored Natural Recovery	Monitored Natural Recovery	Natural recovery from on-going process of clean sediment or floodplain soil deposition over impacted sediments or soils.	Yes	Yes	Yes	Low	Retained. Implementable; has occurred historically in Cedar Creek sediments and is expected to continue.
	Enhanced Monitored Natural Recovery	Enhanced monitored natural recovery involves active measures, such as the placement of a thin layer of clean sand, to accelerate the natural recovery process. The acceleration of natural recovery most often occurs due to burial and/or incorporation and mixing of the clean material into the contaminated surface sediments through bioturbation and physical mixing processes.	Yes	Yes	Yes	Medium	Retained. Potentially implementable.
D. In-place Containment							
I. Soil Capping/Cover	Permeable Soil Cap	Placing clean soil on the surface provides a barrier that prevents exposure to underlying soil but allows stormwater to infiltrate.	Yes	Yes	Yes	Low	Retained. Potentially implementable.

Table 4-2
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 2[1,2]

General Response Action/Remedial Technology	Process Option	Description	Effectiveness	Implementability: Technically Feasible	Implementability: Administratively Feasible	Cost	Screening Assessment
	Low Permeability Cap	Low-permeability caps may be constructed of low-permeability soil such as clay or an engineered material such as asphalt or concrete. This cap would not only prevent exposure to underlying soils, but would also minimize stormwater infiltration through potentially contaminated materials, thereby reducing mobility of contaminants located in the unsaturated soil zone. Engineered materials could also be used in areas requiring a durable surface, such as high-traffic areas.	Yes, although not necessary given limited mobility of PCBs.	Yes	Yes. Potentially undesirable on residential properties and valuable habitat areas.	Low	Not retained. Not practical for floodplain soils.
II. Sediment Capping	Engineered Cap	Placement of a cap typically composed of layered materials (e.g., sand, gravel, cobbles, geotextile) over in situ sediment to physically isolate and protect contaminated sediment from erosion and to mitigate transport of dissolved and colloidally bound contaminants into the water column.	Yes	Yes	Yes	Medium	Retained. Potentially implementable.
	Active Cap	Engineered cap containing specialized materials for chemical isolation. Reactive materials can be placed within the contaminant isolation layer of the cap (an "active" cap) to supplement the adsorption process or to provide some other physical/contaminant processes that reduce the mobility of the contaminants. Active cap materials include engineered clay aggregate materials (e.g., bentonite pellets, AquaBlok®), and reactive/adsorptive materials such as activated carbon, apatite, coke, organoclay, zero-valent iron, and zeolite.	Yes	Yes	Yes	Medium to high	Retained. Potentially implementable.
III. Vertical Containment	Existing Wire and Nail Factory and Columbia Mills Dams	The dams would serve as "vertical caps" to contain contaminated sediment.	Yes	Yes, although long term monitoring and maintenance would be necessary.	Yes	Low to medium	Retained. Potentially implementable assuming long term dam stability.
E. In Situ Treatment							
No process options retained from preliminary screening							
F. Sediment/Floodplain Soil Removal and Management							
REMOVAL							
I. Dredging	Mechanical	Remove bottom sediment by directly applying mechanical force to dislodge and excavate materials (e.g., clamshell).	Yes	Yes	Yes	High	Retained.

Table 4-2
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 2[1,2]

General Response Action/Remedial Technology	Process Option	Description	Effectiveness	Implementability: Technically Feasible	Implementability: Administratively Feasible	Cost	Screening Assessment
	Hydraulic	Removal and transportation of bottom sediment in a liquid slurry form using hydraulic pumps (e.g., horizontal auger, cutterhead dredge).	Yes	Yes, but significant amounts of water require storage and treatment.	Yes	High	Retained.
II. Excavation (in-the-dry)	Mechanical	Temporary structures used to create "dry" areas in the river to allow use of standard excavation equipment.	Yes	Yes	Yes	High	Retained.
DEWATERING							
I. Passive Dewatering	Gravity Settling and Drainage	Mechanically dredged materials are placed on a lined pad and allowed to drain and air dry. Hydraulic sediment slurry enters a thickener or lagoon and settles, consolidating at the bottom of the tank.	Yes	Yes, but significantly larger areas needed for handling hydraulically dredged slurries than mechanically dredged material.	Yes	Medium	Retained for mechanically dredged material. Insufficient space at the Site for hydraulically dredged material.
	Geotubes	Hydraulically dredged or rehandled sediments are pumped into the geotubes and excess water flows through the pores in the geotextiles, resulting in effective dewatering and volume reduction of the contaminated materials.	Yes	Yes	Yes	High	Retained as applicable to hydraulically dredged material.
II. Active Dewatering	Plate and Frame Filter Press	Sediment slurry pumped into cavities formed by a series of plates covered by a filter cloth. Liquids are forced through filter cloth and dewatered solids collected in the filter cavities.	Yes	Yes	Yes	High	Retained as applicable to hydraulically dredged material.
	Belt Filter Press	Sediment slurry drops onto a perforated belt where gravity drainage takes place. Thickened solids are pressed between a series of rollers to further dewater solids.	Yes	Yes	Yes	High	Retained as applicable to hydraulically dredged material.

Table 4-2
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 2[1,2]

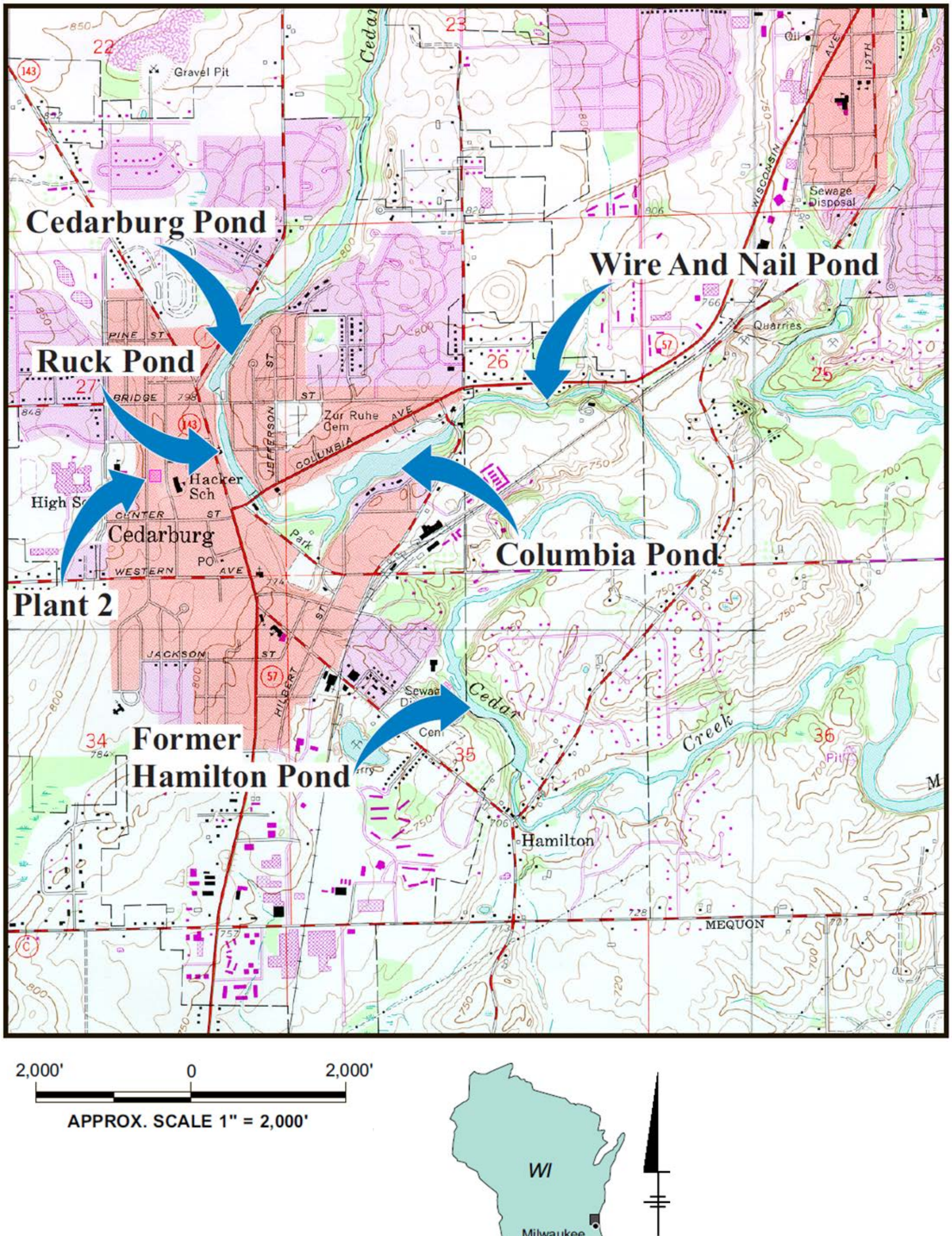
General Response Action/Remedial Technology	Process Option	Description	Effectiveness	Implementability: Technically Feasible	Implementability: Administratively Feasible	Cost	Screening Assessment
	Hydrocyclone	Sediment slurry fed tangentially into a funnel-shaped unit to facilitate centrifugal forces necessary to separate solids from liquids. Dewatered solids collected and overflow liquid discharged.	Yes	Yes	Yes	High	Retained as applicable to hydraulically dredged material.
DISPOSAL							
I. Off-Site Disposal	TSCA-permitted Landfill	Disposal of solids or residuals in existing TSCA-permitted landfill.	Yes	Yes	Yes	High	Retained.
	Solid Waste Landfill	Disposal of solids or residuals (containing less than 50 mg/kg PCBs) in existing off-site permitted solid waste landfill.	Yes	Yes	Yes	Medium to high	Retained.
WATER TREATMENT							
I. Water Treatment	Activated Carbon Adsorption	PCBs in aqueous phase are removed with granular activated carbon.	Yes	Yes	Yes	Medium to high	Retained.
	Filtration	PCBs filtered out through various media (i.e., sand) from the liquid stream.	Yes	Yes	Yes	Medium to high	Retained.
EX SITU TREATMENT							
I. Immobilization	Stabilization/Solidificatio n	Sediments are mixed ex-situ with Portland cement, fly ash, or some other stabilization agent. May be used for dewatering only, or to reduce the mobility of the chemical constituents.	Yes	Yes	Yes	Low to medium	Retained.
II. Soil Washing	Soil Washing	In soil washing, soil or sediment is put in contact with an aqueous solution to remove contaminants from the soil particles. The suspension is often also used to separate fine particles from coarser particles, allowing beneficial use of the coarser fraction (if sufficiently clean) at the site.	High fines content of sediments at the Site will limit effectiveness.	Yes	Yes	Medium to high	Not retained. Lower effectiveness at higher cost compared to other process options; questionable effectiveness with Site sediments.

Table 4-2
Preliminary Screening of Potential Sediment and Floodplain Soil Remedial Technologies, Level 2[1,2]

General Response Action/Remedial Technology	Process Option	Description	Effectiveness	Implementability: Technically Feasible	Implementability: Administratively Feasible	Cost	Screening Assessment
III. Destruction	Thermal	Process which uses high heat to remove or destroy PCBs in sediments. Incineration is a type of thermal destruction where soils/sediments are thermally treated in a fluidized bed, rotary kiln, or infrared incinerator, all of which would require permitting.	Yes	Yes, but extensive dewatering pretreatment required.	Difficult to permit.	High	Not retained. Extensive pretreatment for Site materials and difficult to permit.

Notes:
1 Shaded process options have been retained for further analysis.
2 Preliminary assessment was completed using publically available information.
CERCLA = Comprehensive Environmental Response, Compensation, and Recovery Act
TSCA = Toxic Substances Control Act
UV = ultraviolet

FIGURES



Area Enlargement

REFERENCE: Base Map Source: USGS 7.5 Min. Topo. Quad., Cedarburg, Wis. (1959, Photorevised 1971 and 1976).

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Figure 1-1
Site Location Map
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

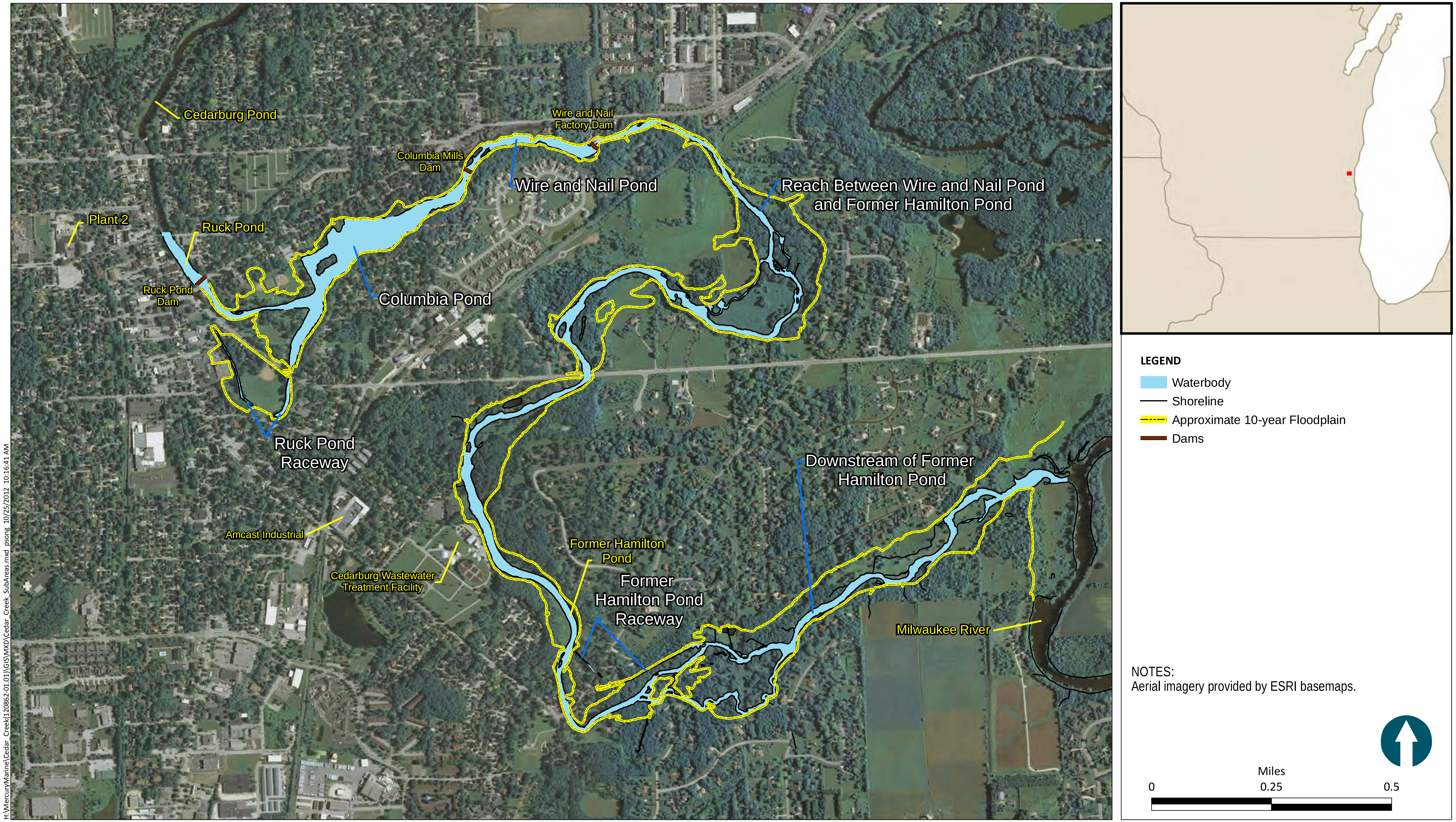

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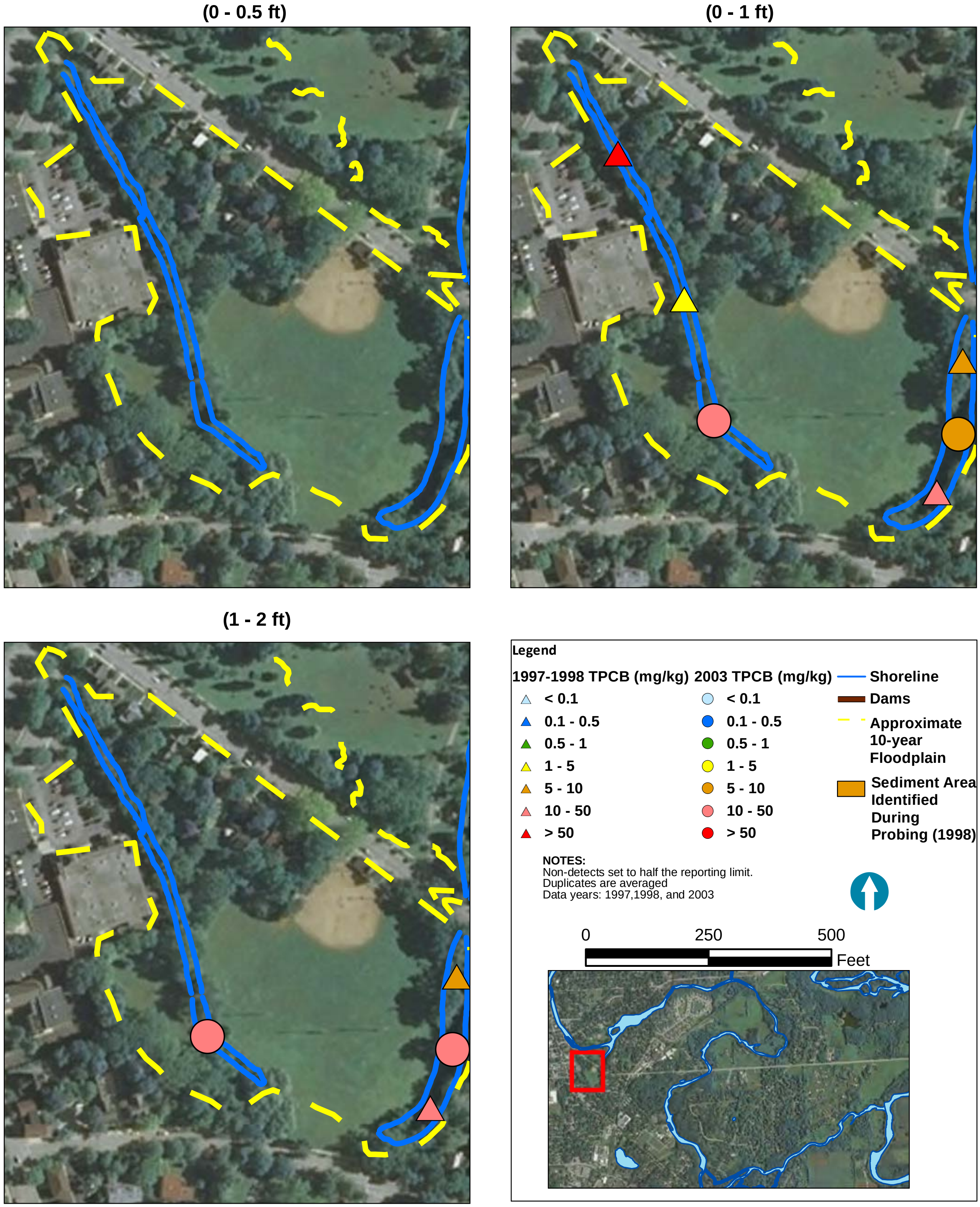
Figure 1-2
Site Reaches/Areas
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



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ANCHOR QEA

Figure 2-1a
Sediment PCB Concentrations within Ruck Pond Raceway (0 - 2 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

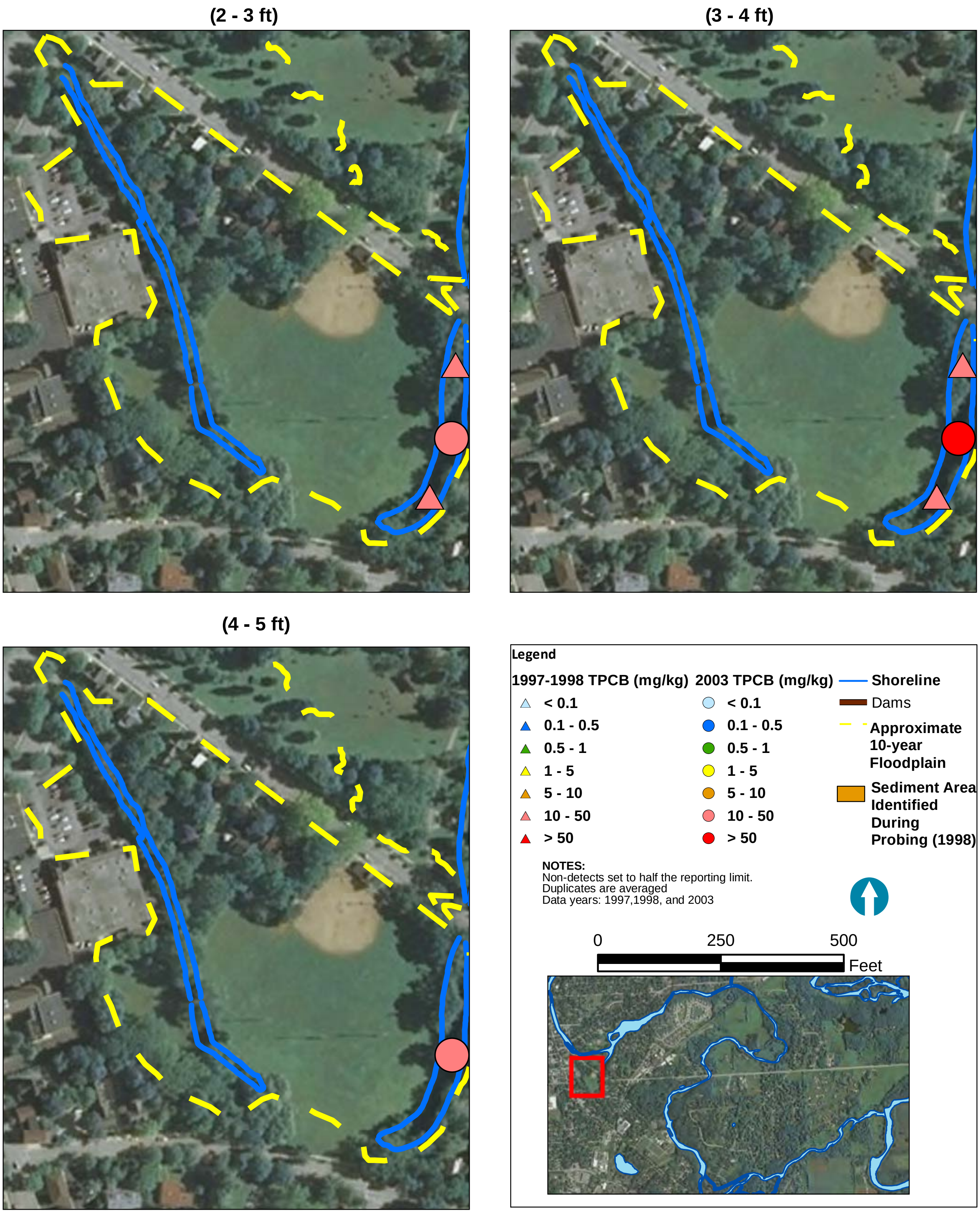

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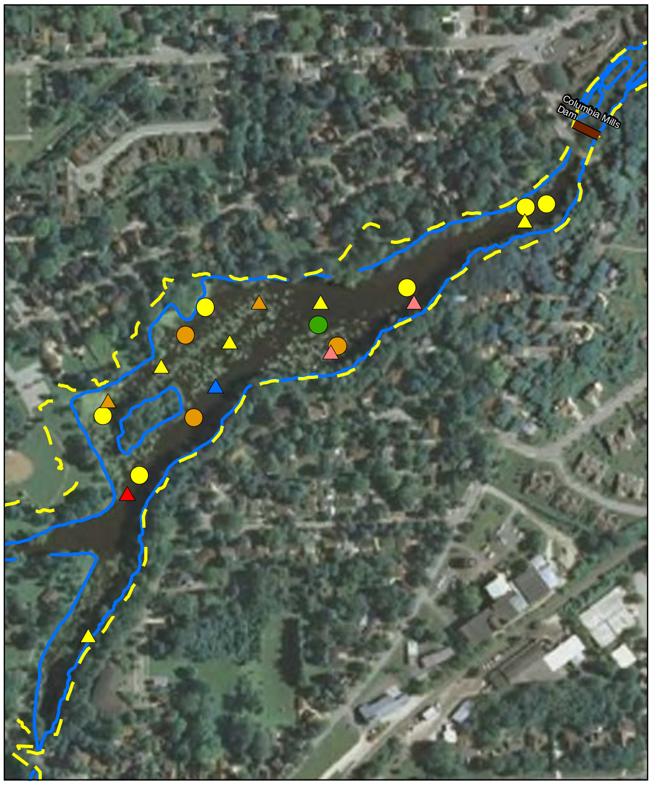
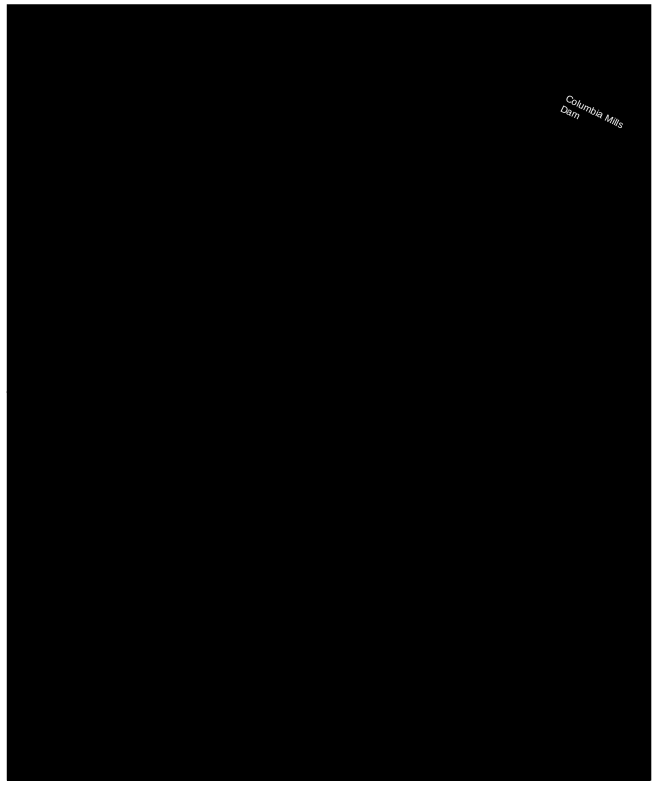
Figure 2-1b
Sediment PCB Concentrations within Ruck Pond Raceway (2 - 5 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

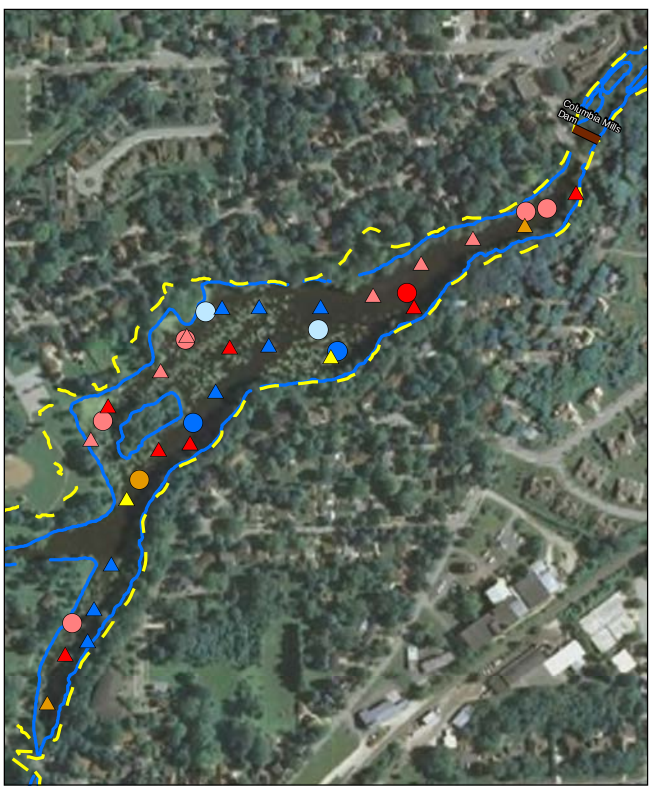
(0 - 0.5 ft)



(0 - 1 ft)



(1 - 2 ft)



Legend

1997-1998 TPCB (mg/kg)	2003 TPCB (mg/kg)	
< 0.1	< 0.1	Shoreline
0.1 - 0.5	0.1 - 0.5	Dams
0.5 - 1	0.5 - 1	Approximate 10-year Floodplain
1 - 5	1 - 5	
5 - 10	5 - 10	Sediment Area Identified During Probing (1998)
10 - 50	10 - 50	
> 50	> 50	

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged
Data years: 1997,1998, and 2003

0 500 1,000
Feet

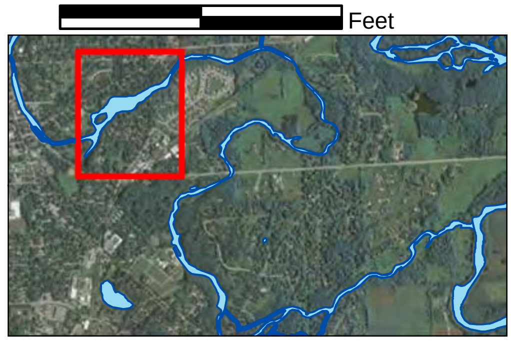


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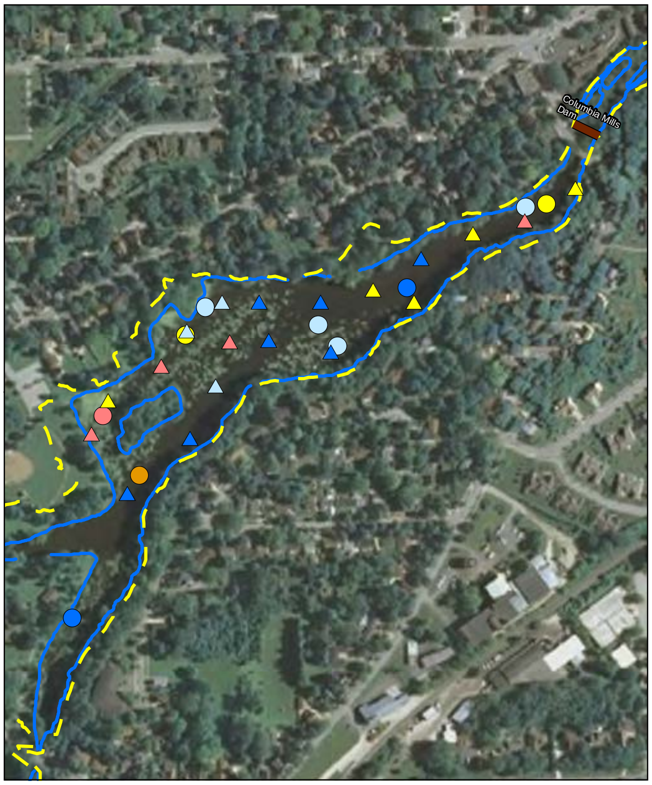
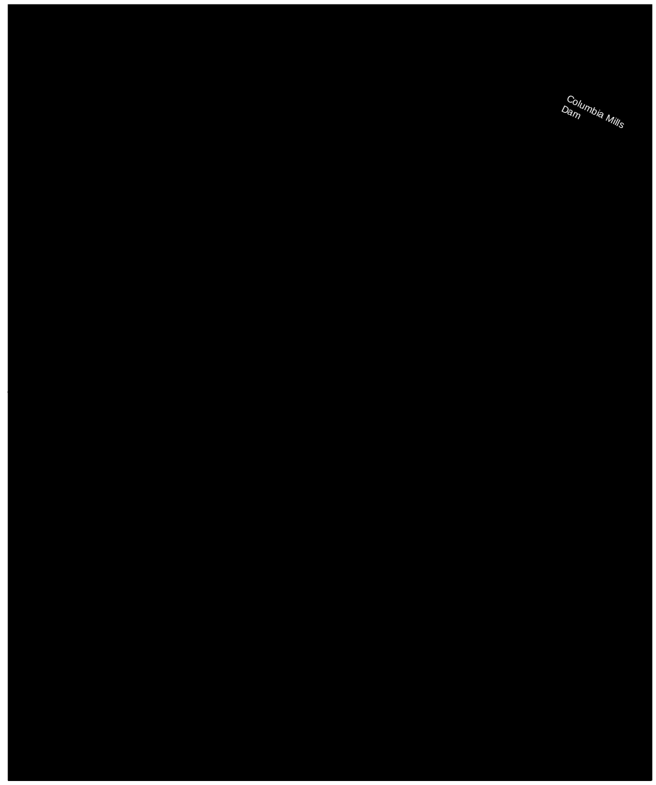
Figure 2-2a
Sediment PCB Concentrations within Columbia Pond (0 - 2 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

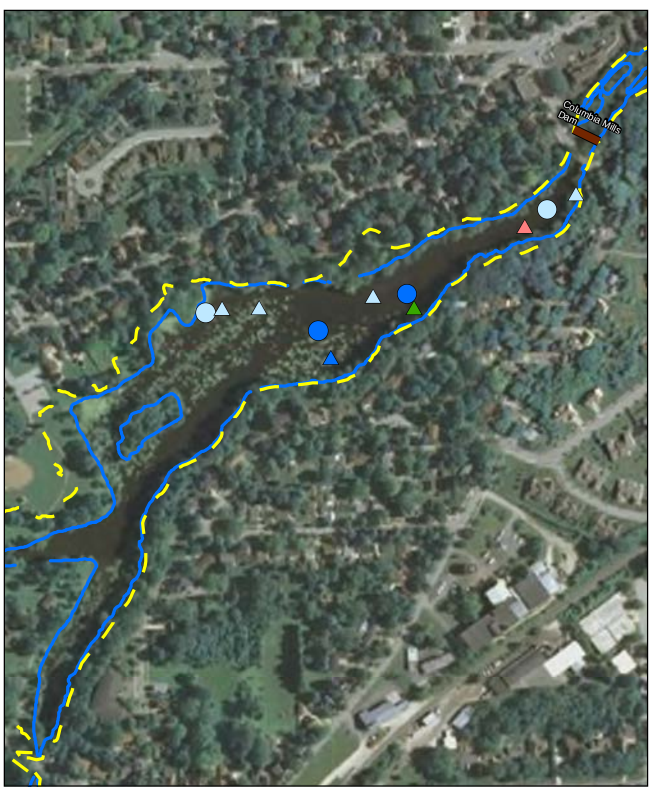
(2 - 3 ft)



(3 - 4 ft)



(4 - 5 ft)

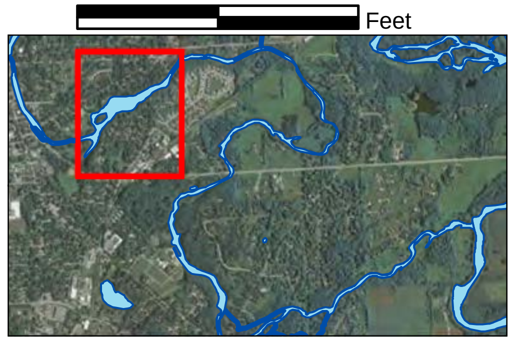


Legend

1997-1998 TPCB (mg/kg)	2003 TPCB (mg/kg)	
< 0.1	< 0.1	Shoreline
0.1 - 0.5	0.1 - 0.5	Dams
0.5 - 1	0.5 - 1	Approximate 10-year Floodplain
1 - 5	1 - 5	
5 - 10	5 - 10	Sediment Area Identified During Probing (1998)
10 - 50	10 - 50	
> 50	> 50	

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged
Data years: 1997,1998, and 2003

0 500 1,000
Feet



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ANCHOR QEA

Figure 2-2b
Sediment PCB Concentrations within Columbia Pond (2 - 5 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

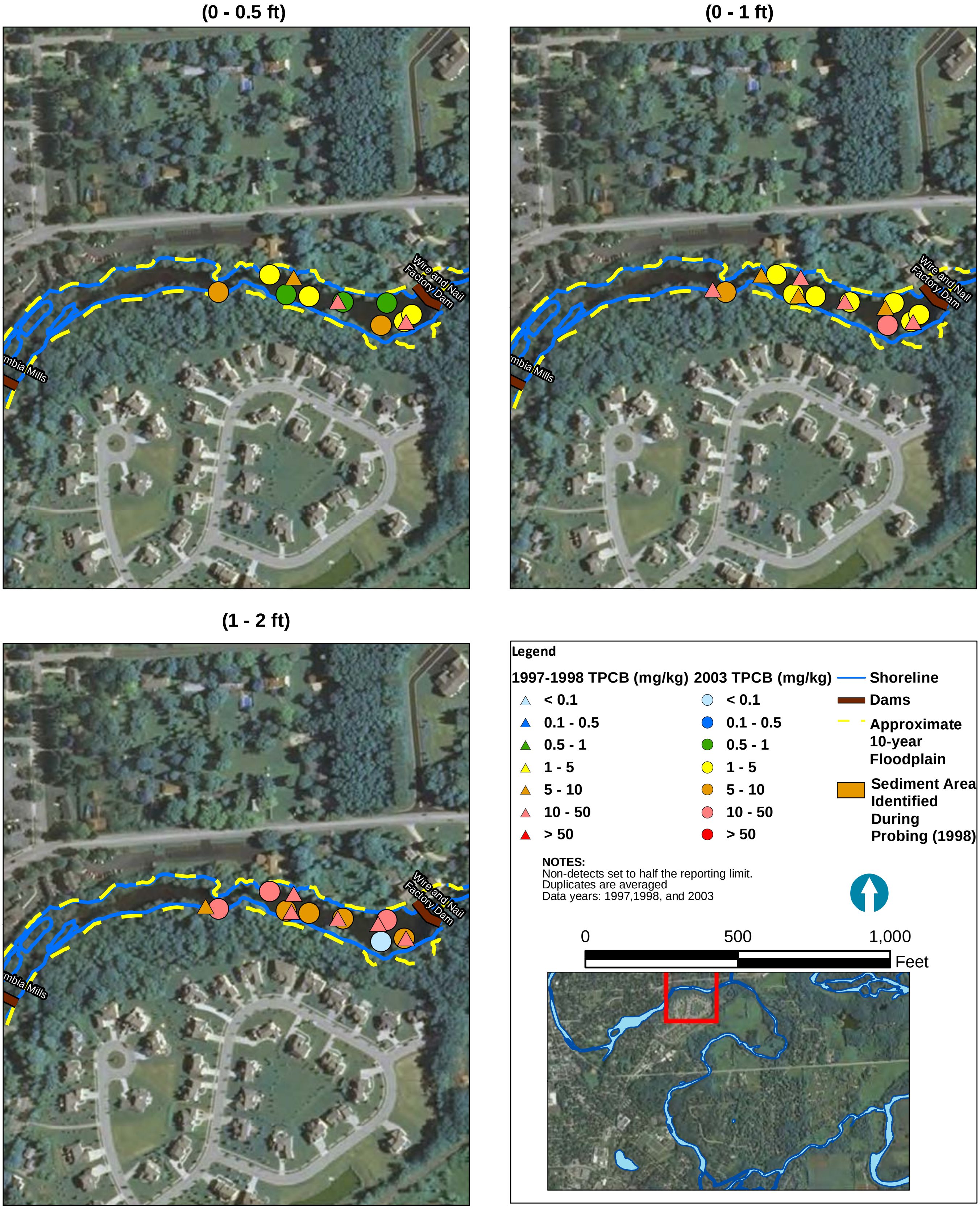

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Figure 2-3a
Sediment PCB Concentrations within Wire and Nail Pond (0 - 2 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

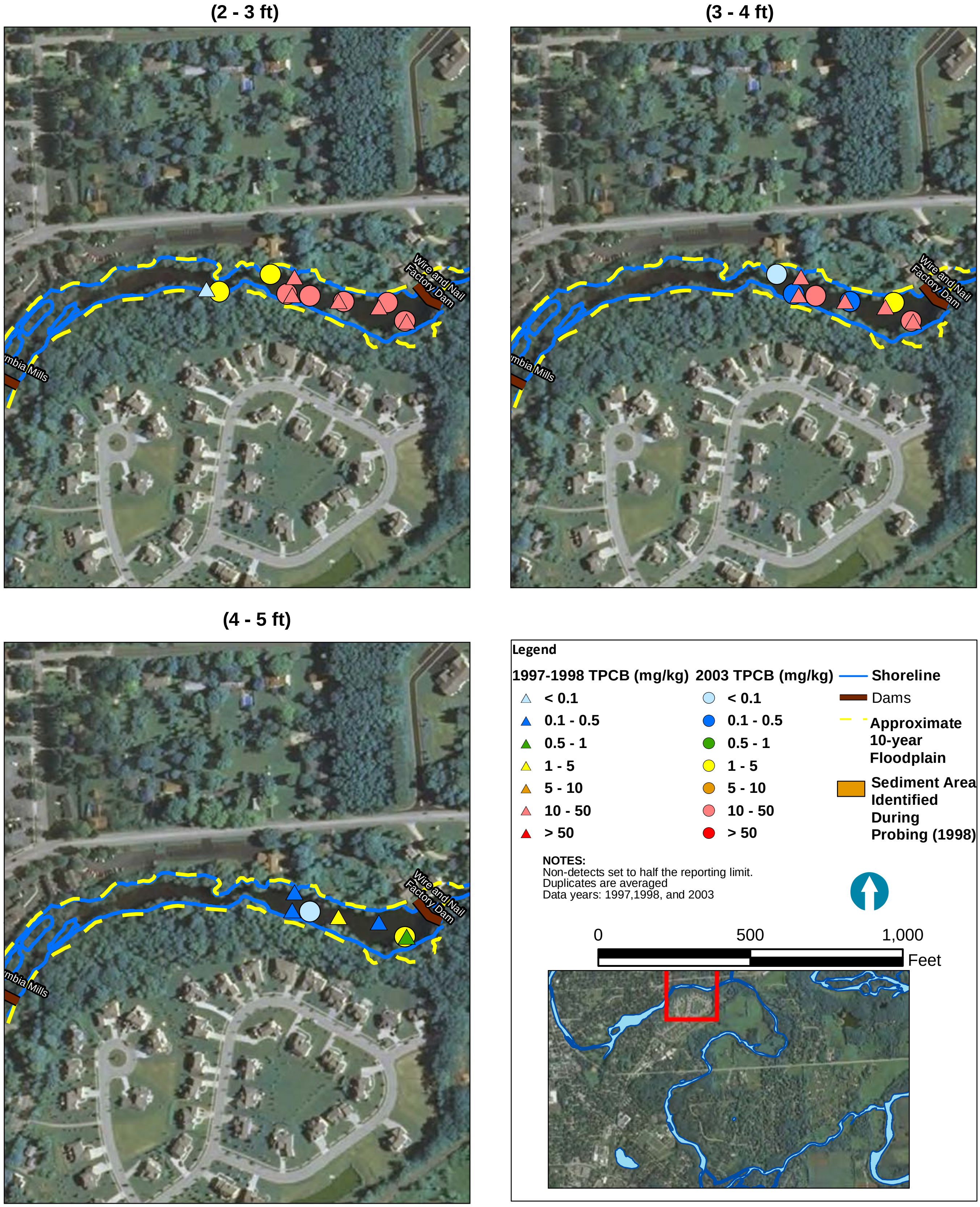

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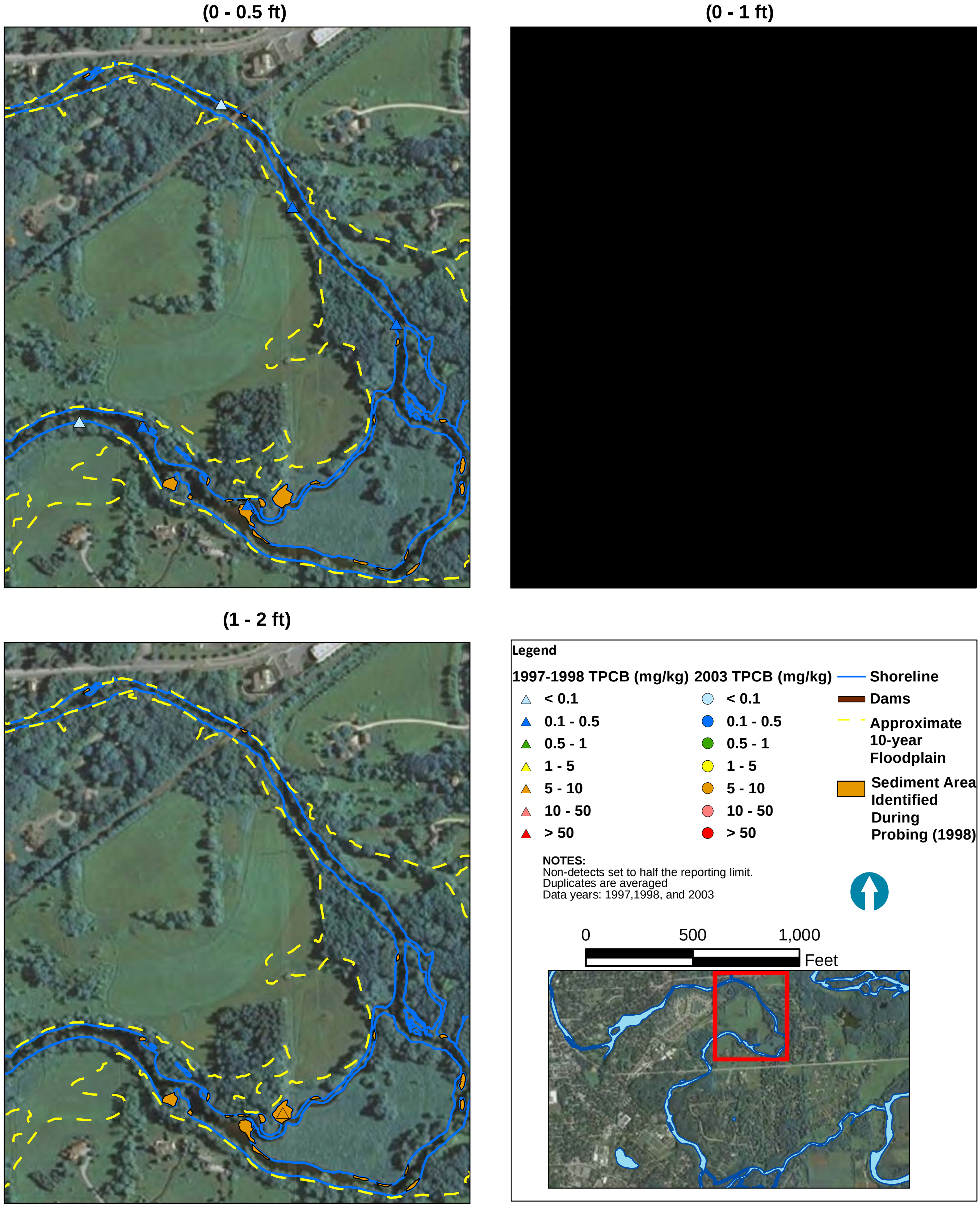
Figure 2-3b
Sediment PCB Concentrations within Wire and Nail Pond (2 - 5 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



H:\MercuryMarine\Cedar_Creek(120862-01.01)\GIS\MXD\Sediment\Measles_maps\Cedar_Creek_SED_PCBs_lt_2ft.mxd - P.Song - 24Oct2012

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Figure 2-4a

Sediment PCB Concentrations within the Upper Portion of the Reach Between Wire and Nail Pond and Former Hamilton Pond (0 - 2 feet)

Draft Alternatives Array Document

Cedar Creek Site Feasibility Study

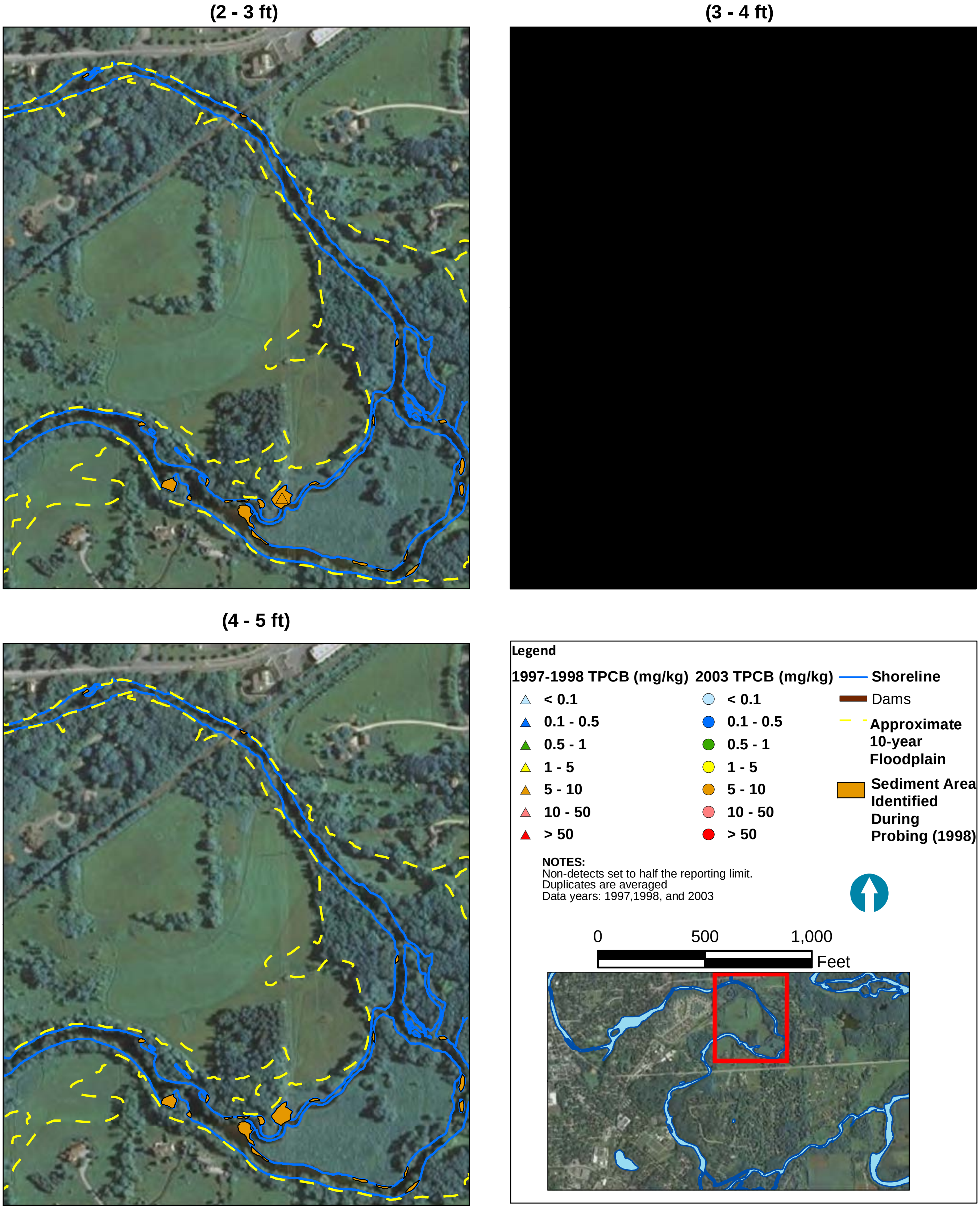

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Figure 2-4b
Sediment PCB Concentrations within the Upper Portion of the Reach Between Wire and Nail Pond and Former Hamilton Pond (2 - 5 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

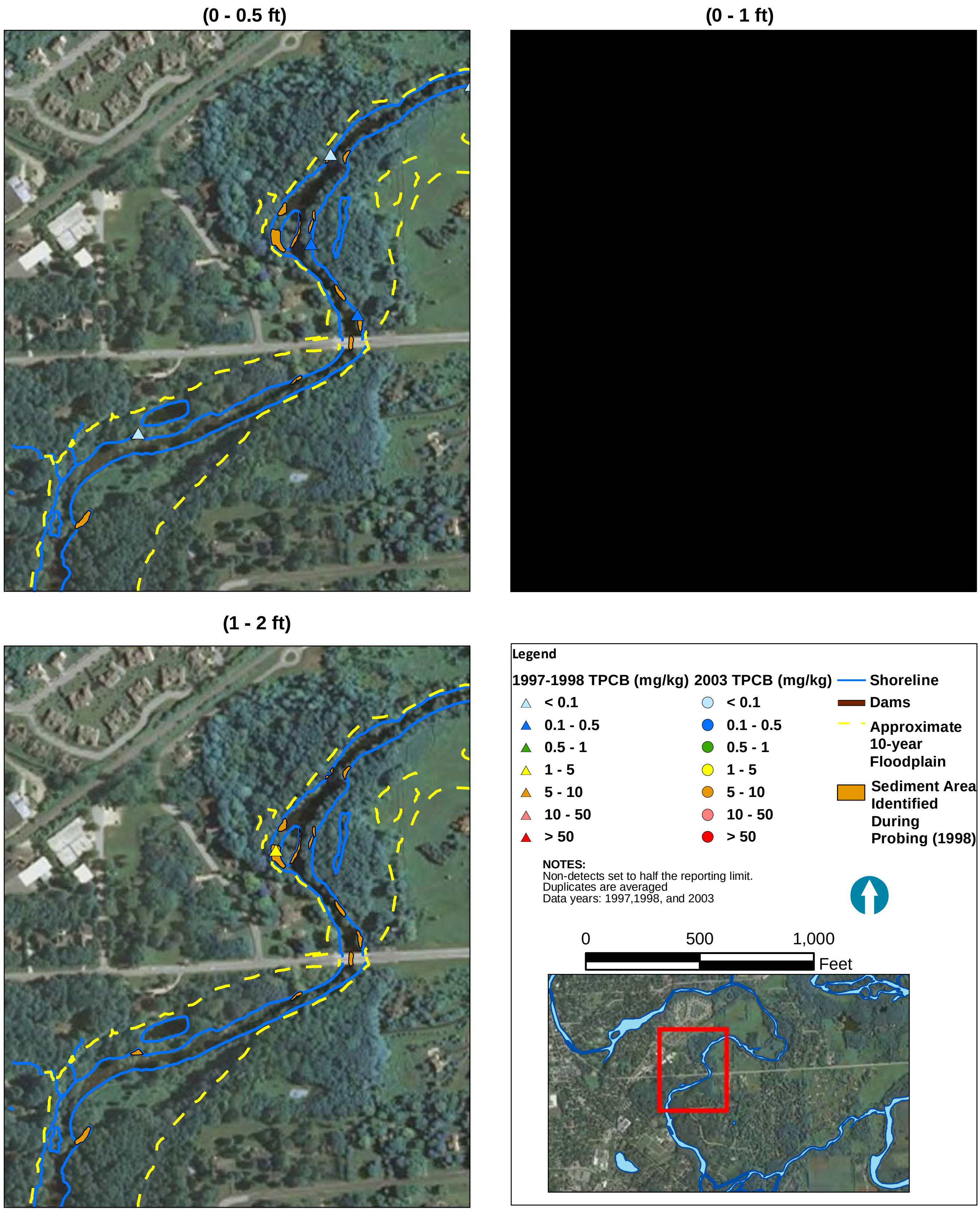

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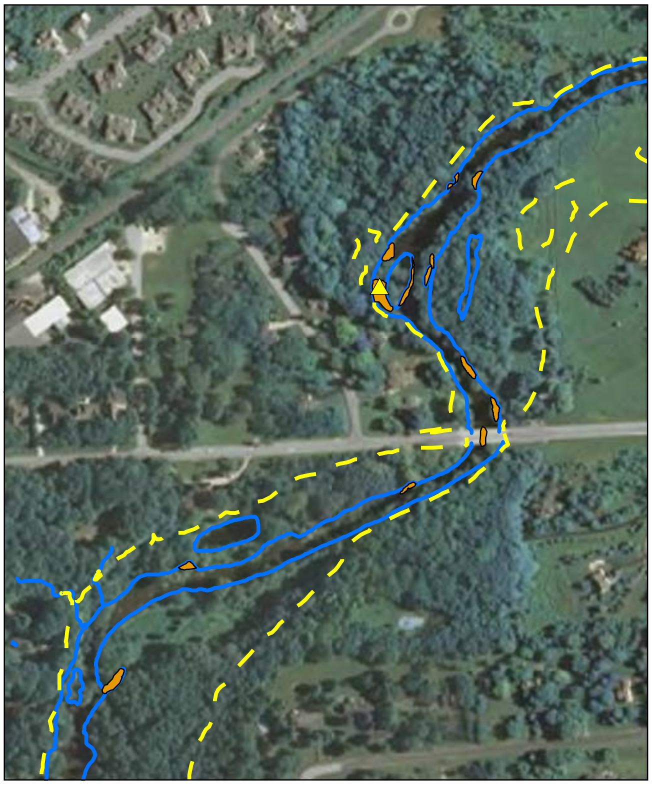
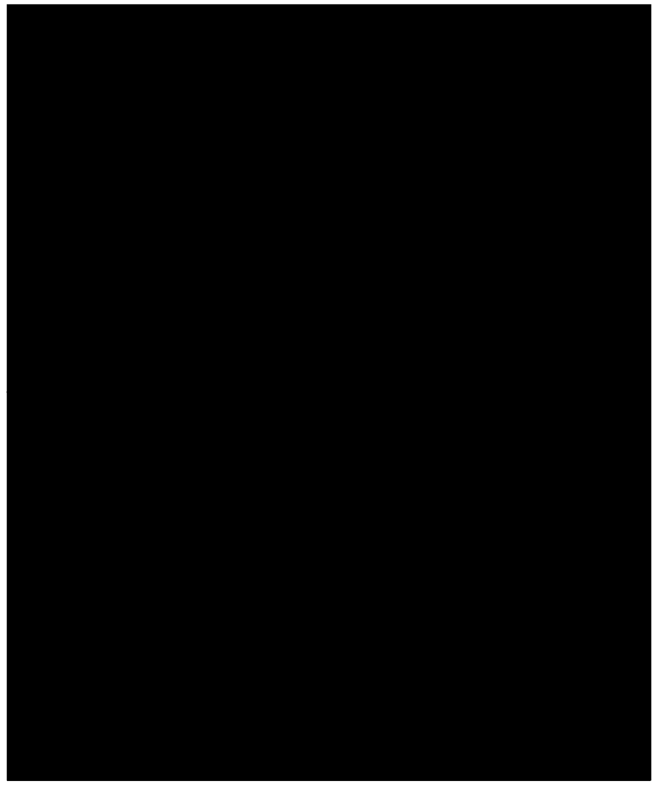
Figure 2-5a
Sediment PCB Concentrations within the Lower Portion of the Reach Between Wire and Nail Pond and Former Hamilton Pond (0 - 2 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

H:\MercuryMarine\Cedar_Creek(120862-01.01)\GIS\MXD\SedimentMeasles_maps\Cedar_Creek_SED_PCBs_gt_2ft.mxd - P.Song - 24Oct2012

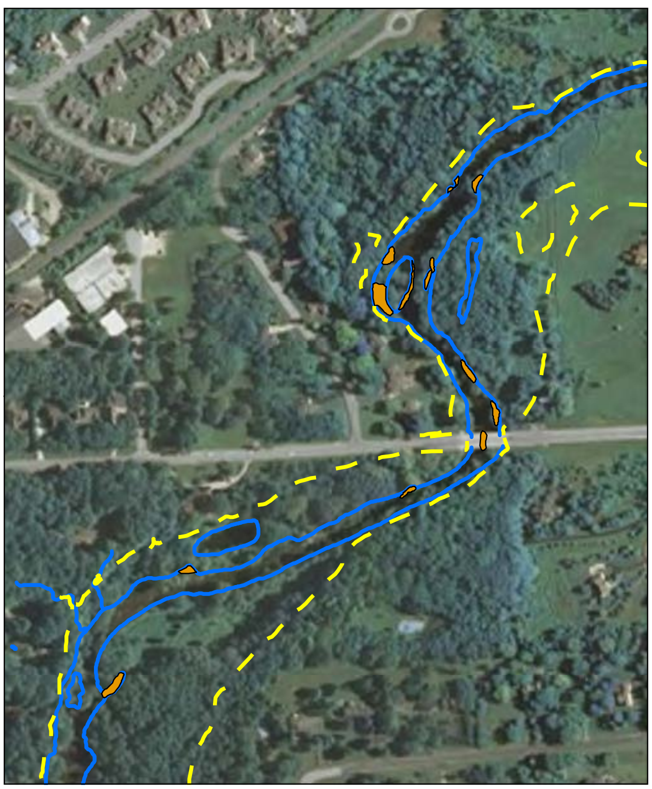
(2 - 3 ft)



(3 - 4 ft)



(4 - 5 ft)

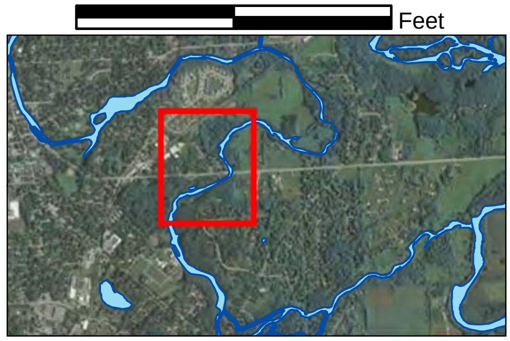


Legend

1997-1998 TPCB (mg/kg)	2003 TPCB (mg/kg)	
< 0.1	< 0.1	Shoreline
0.1 - 0.5	0.1 - 0.5	Dams
0.5 - 1	0.5 - 1	Approximate 10-year Floodplain
1 - 5	1 - 5	
5 - 10	5 - 10	Sediment Area Identified During Probing (1998)
10 - 50	10 - 50	
> 50	> 50	

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged
Data years: 1997,1998, and 2003

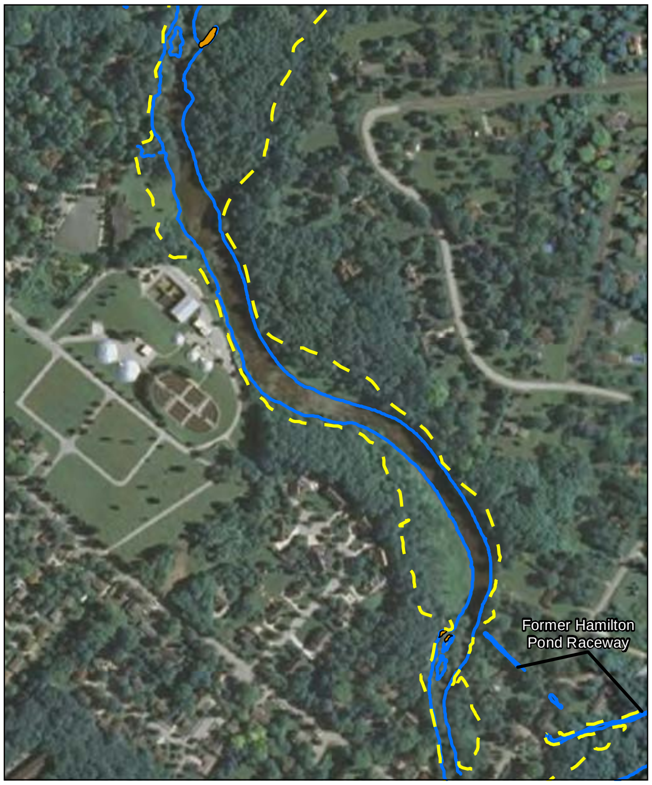
0 500 1,000
Feet



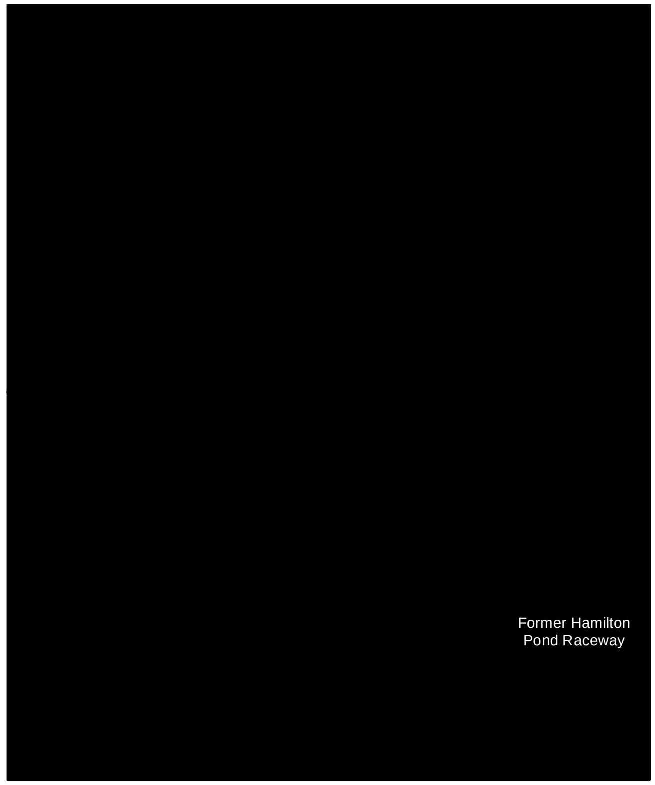
ANCHOR QEA

Figure 2-5b
Sediment PCB Concentrations within the Lower Portion of the Reach Between Wire and Nail Pond and Former Hamilton Pond (2 - 5 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

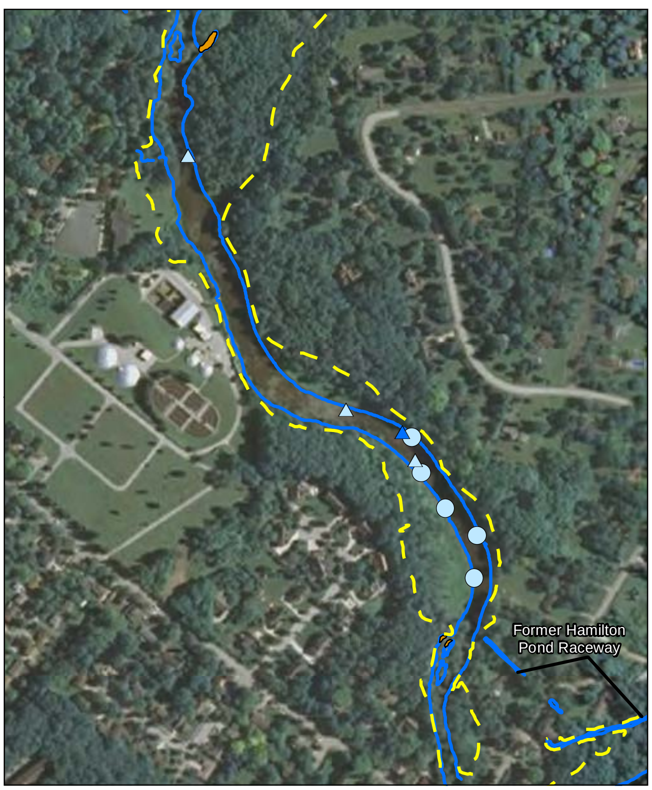
(0 - 0.5 ft)



(0 - 1 ft)



(1 - 2 ft)



Legend

1997-1998 TPCB (mg/kg)	2003 TPCB (mg/kg)	
< 0.1	< 0.1	Shoreline
0.1 - 0.5	0.1 - 0.5	Dams
0.5 - 1	0.5 - 1	Approximate 10-year Floodplain
1 - 5	1 - 5	
5 - 10	5 - 10	Sediment Area Identified During Probing (1998)
10 - 50	10 - 50	
> 50	> 50	

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged
Data years: 1997,1998, and 2003

0 500 1,000
Feet

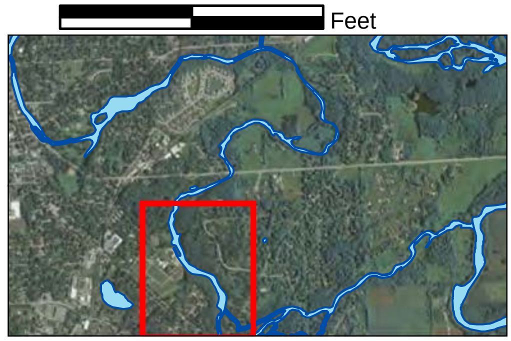


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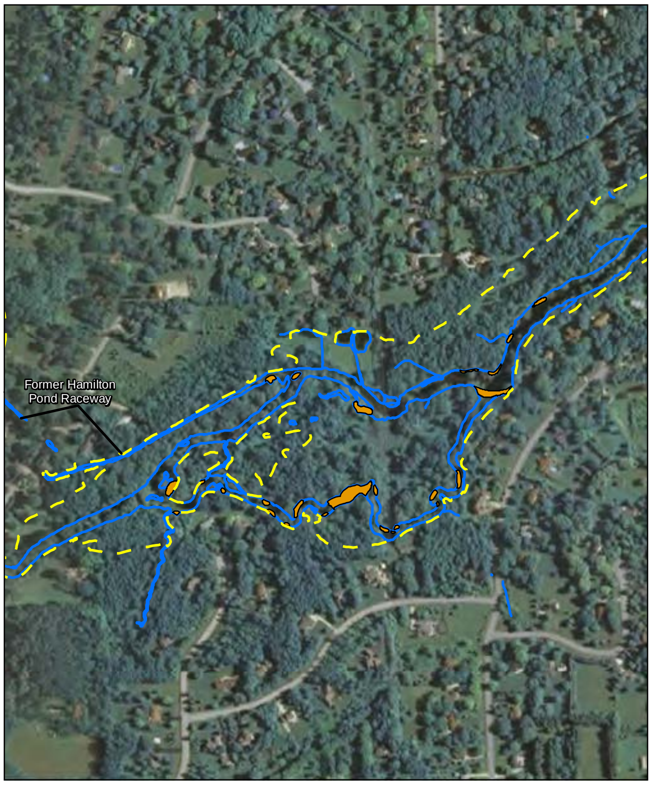
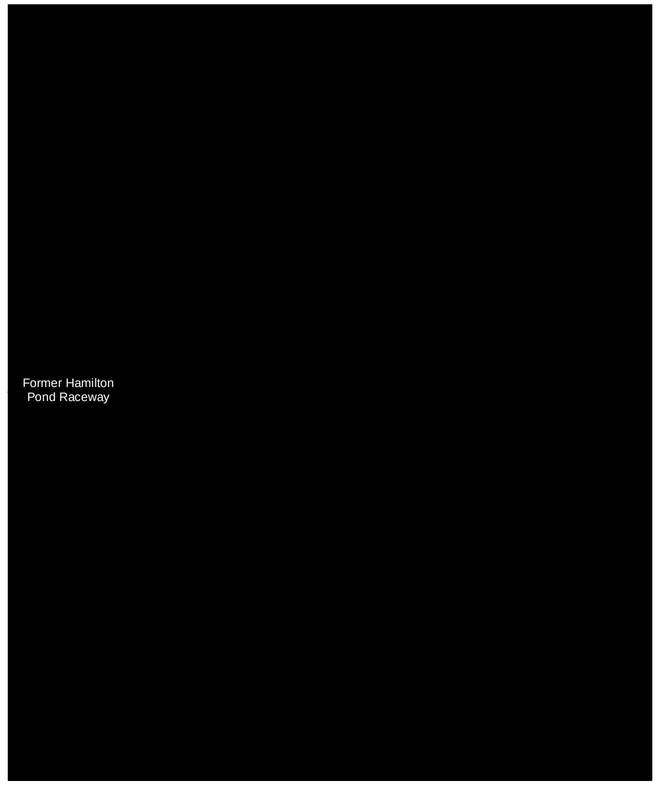
Figure 2-6
Sediment PCB Concentrations within Former Hamilton Pond (0 - 2 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

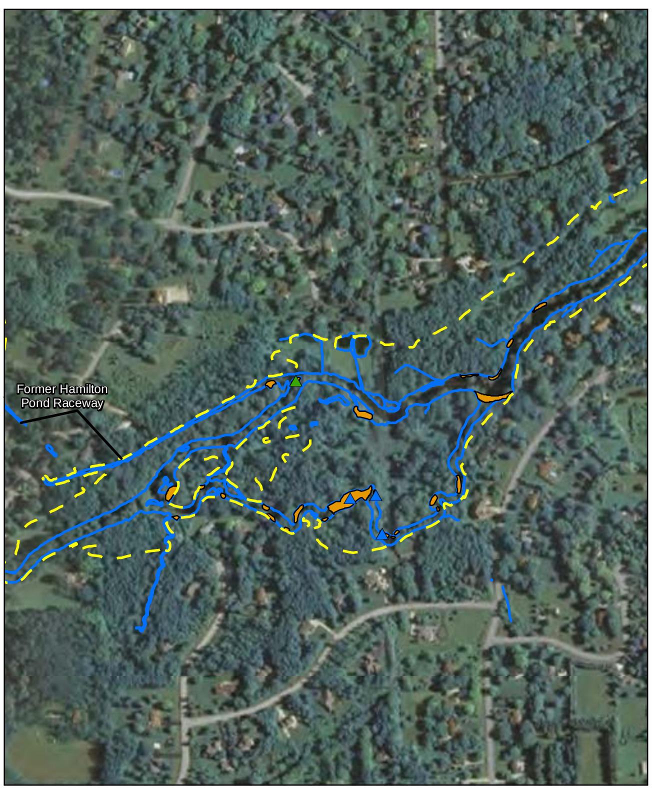
(0 - 0.5 ft)



(0 - 1 ft)



(1 - 2 ft)

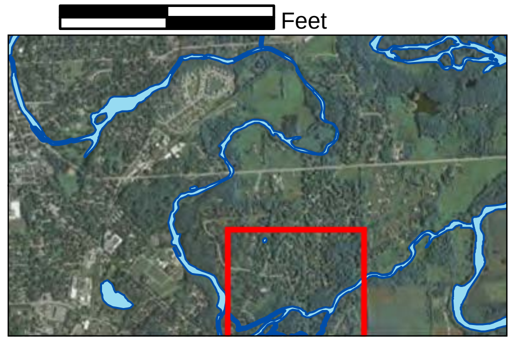


Legend

1997-1998 TPCB (mg/kg)	2003 TPCB (mg/kg)	
< 0.1	< 0.1	Shoreline
0.1 - 0.5	0.1 - 0.5	Dams
0.5 - 1	0.5 - 1	Approximate 10-year Floodplain
1 - 5	1 - 5	
5 - 10	5 - 10	Sediment Area Identified During Probing (1998)
10 - 50	10 - 50	
> 50	> 50	

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged
Data years: 1997,1998, and 2003

0 500 1,000
Feet



H:\MercuryMarine\Cedar_Creek(120862-01.01)\GIS\MXD\SedimentMeasles_maps\Cedar_Creek_SED_PCBs_lt_2ft.mxd - P.Song - 17Oct2012

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Figure 2-7
Sediment PCB Concentrations Downstream of Former Hamilton Pond (0 - 2 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

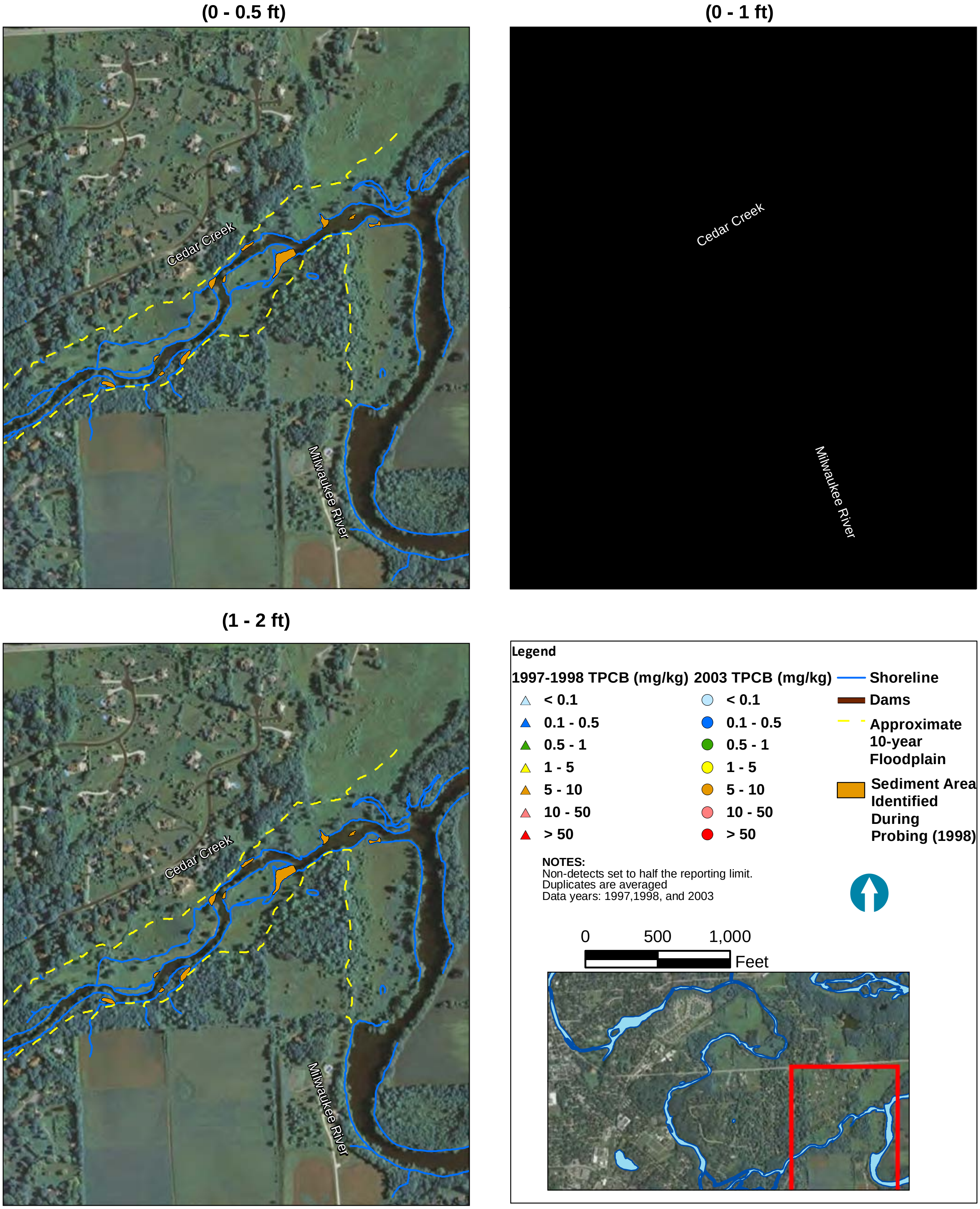

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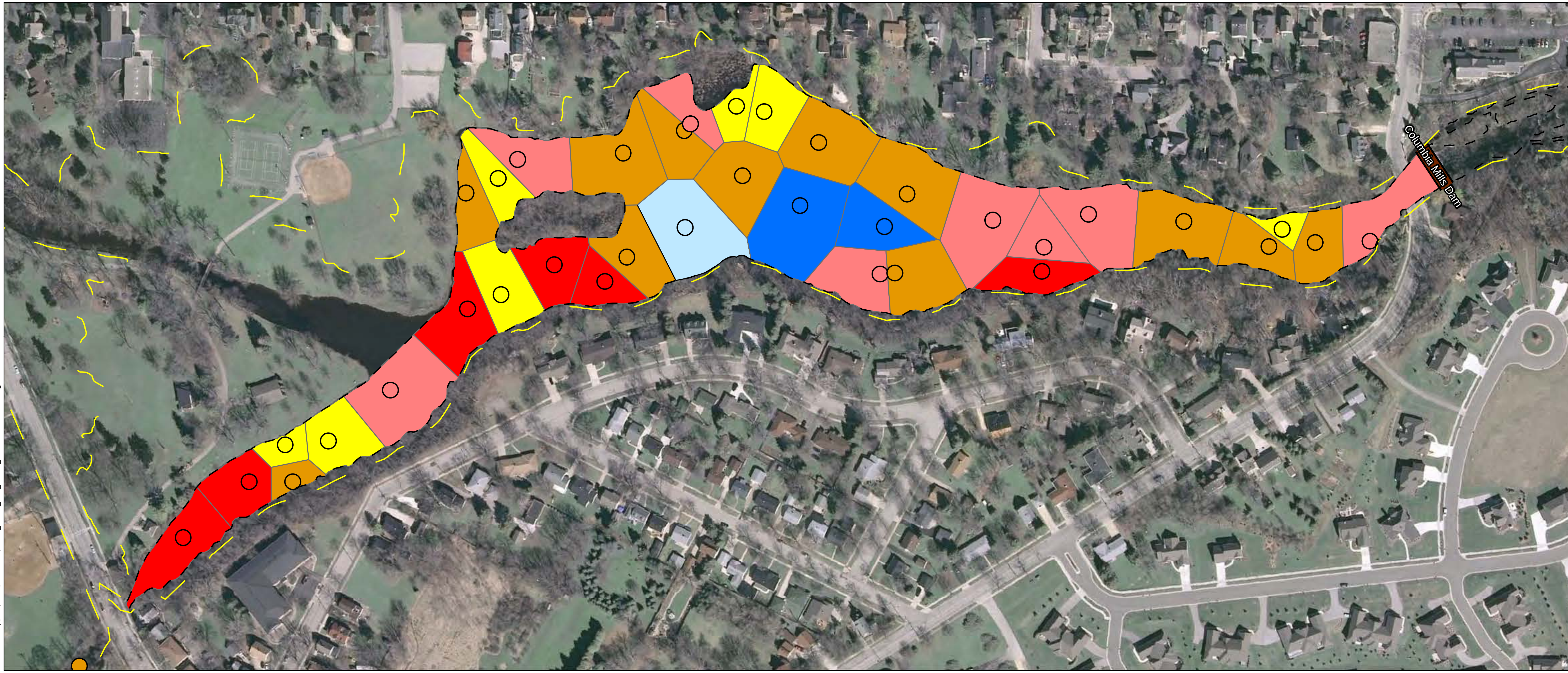
Figure 2-8
Sediment PCB Concentrations Downstream of Former Hamilton Pond Near the Confluence with Milwaukee River (0 - 2 feet)
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



Legend

Thiessen Polygon TPCB (mg/kg)

- **< 0.11**
- **0.11 - 0.32**
- **0.32 - 1**
- **1 - 5**
- **5 - 10**
- **10 - 50**
- **> 50**

Approximate 10-year Floodplain

Dams

Core Locations

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.
Data years: 1998 and 2003.
Data Depths: (0 - 1 ft), one sample from depth (0 - 1.6 ft)
Aerial imagery provided by ESRI basemaps.

0 500 1,000 Feet

\\HELIOS\aq\D_Drive\Projects\MercuryMarine\Cedar_Creek(120862-01.01)\GIS\MXD\Sediment\Cedar_Creek_SED_PCBs2_thiessen.mxd - P.Song - 26Oct2012

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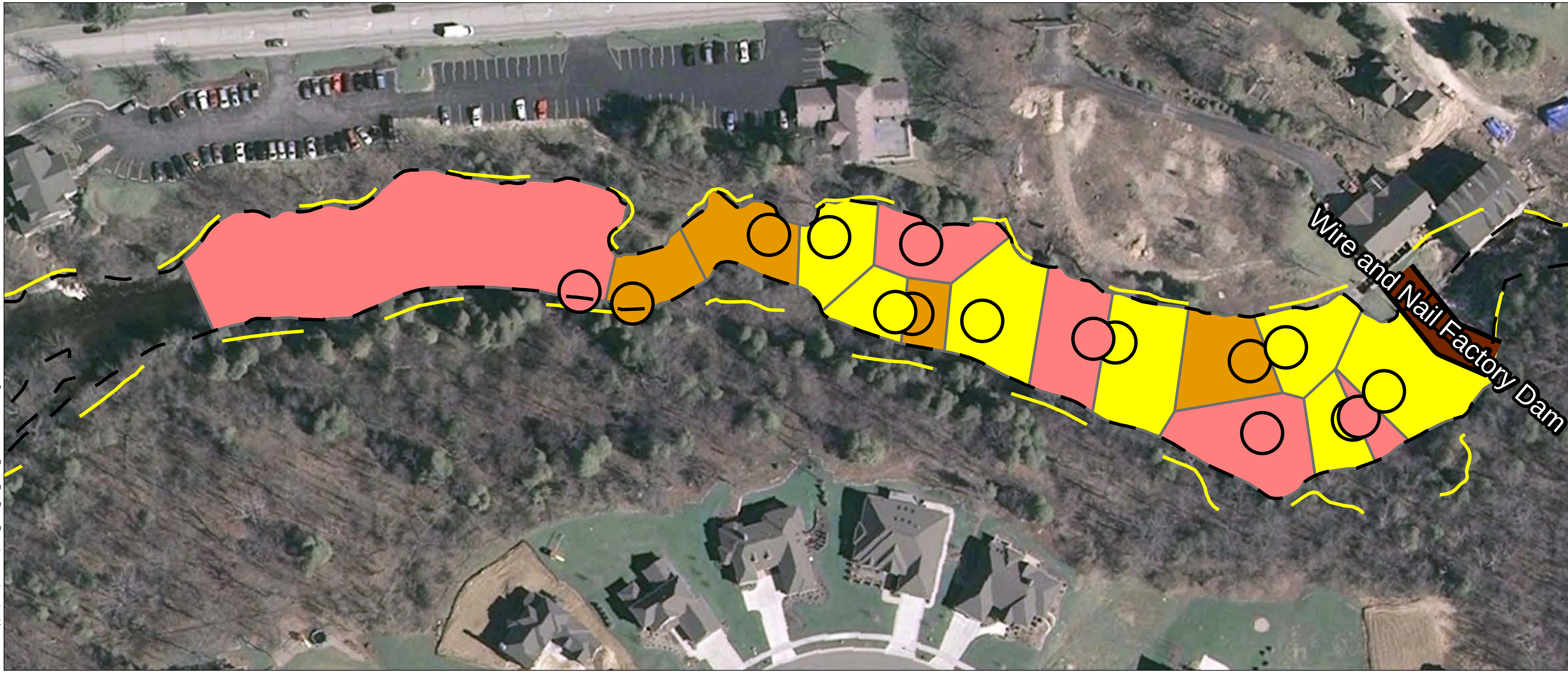
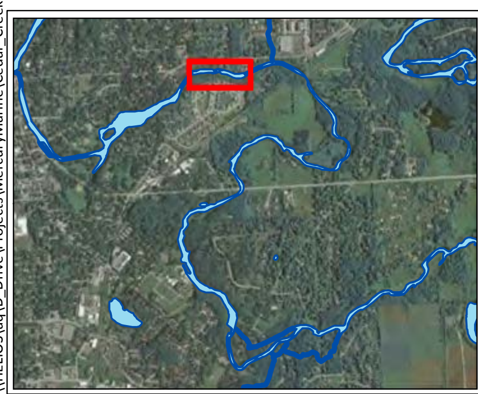
Figure 2-9
Sediment PCB SWACs within Columbia Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study





Legend

Thiessen Polygon TPCB (mg/kg)
- **< 0.11**
- **0.11 - 0.32**
- **0.32 - 1**
- **1 - 5**
- **5 - 10**
- **10 - 50**
- **> 50**

Approximate 10-year Floodplain

Dams

Core Locations

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.
Data years: 1998 and 2003.
Data Depths: (0 - 1 ft), one sample from depth (0 - 1.6 ft)
Aerial imagery provided by ESRI basemaps.

0 250 500
Feet

\\HELIOS\aq\D_Drive\Projects\MercuryMarine\Cedar_Creek(120862-01.01)\GIS\MXD\Sediment\Cedar_Creek_SED_PCBs2_thiessen.mxd - P.Song - 26Oct2012

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Figure 2-10
Sediment PCB SWACs within Wire and Nail Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

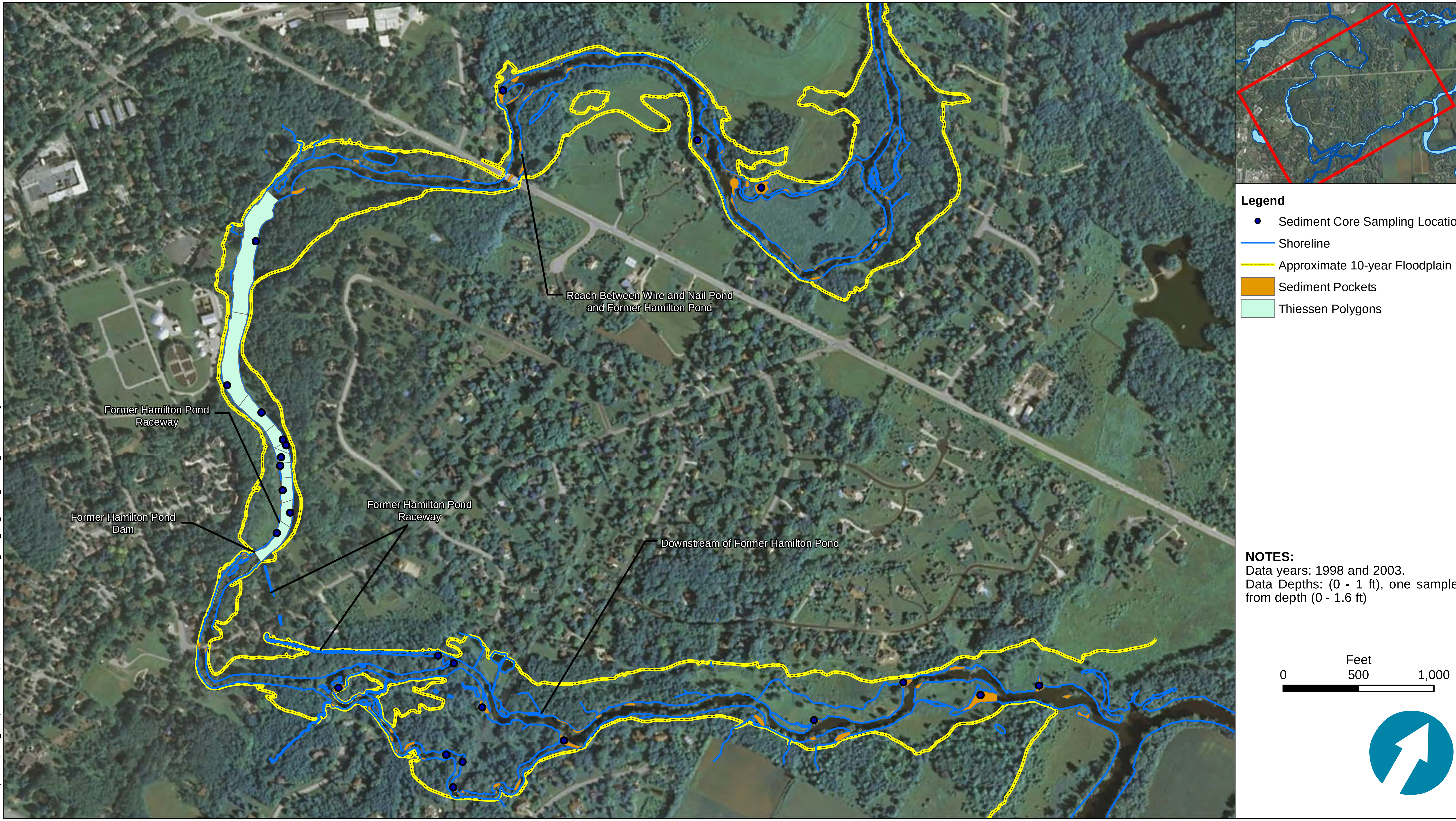

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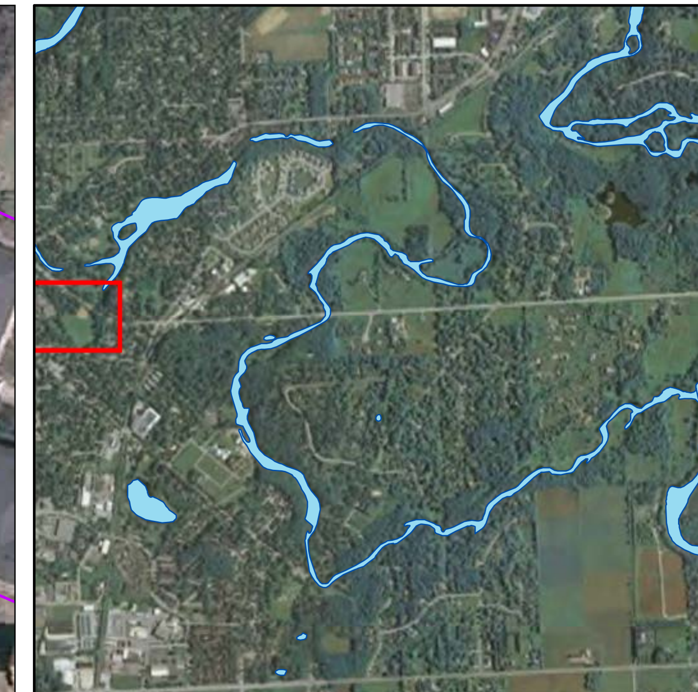
Figure 2-11
Floodplain Soil Area-Weighting Approach for Calculating SWACs
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



LEGEND

- Waterbody
- Shoreline
- Dams
- Approximate 10-Year Floodplain
- Tax Parcels

Wetland Classification

- RI Identified Cover Types
  - B - Emergent Aquatic Wetlands
- WDNR Mapped Wetland Class Descriptors
  - E1H - Persistent Emergent/Wet Meadow
  - E2K - Narrow Leaved, Persistent Emergent/Wet Meadow
  - T3K - Deciduous, Broad-Leaved, Forested

Total PCB (mg/kg)	Sample Locations
< 0.2	0 - 6 in
0.2 - 1	6 - 12 in
1 - 5	12 - 18 in
5 - 10	
> 10	

NOTES:
Wetland delineations are approximate.

Feet
0 125 250

H:\MercuryMarine\Cedar_Creek(120862-01.01)\GIS\MXD\Floodplain\Archive_for_SH\Cedar_Creek_Floodplain_Habitat_Concentrations_20120906.mxd aq_user 10/17/2012 1:53:32 PM

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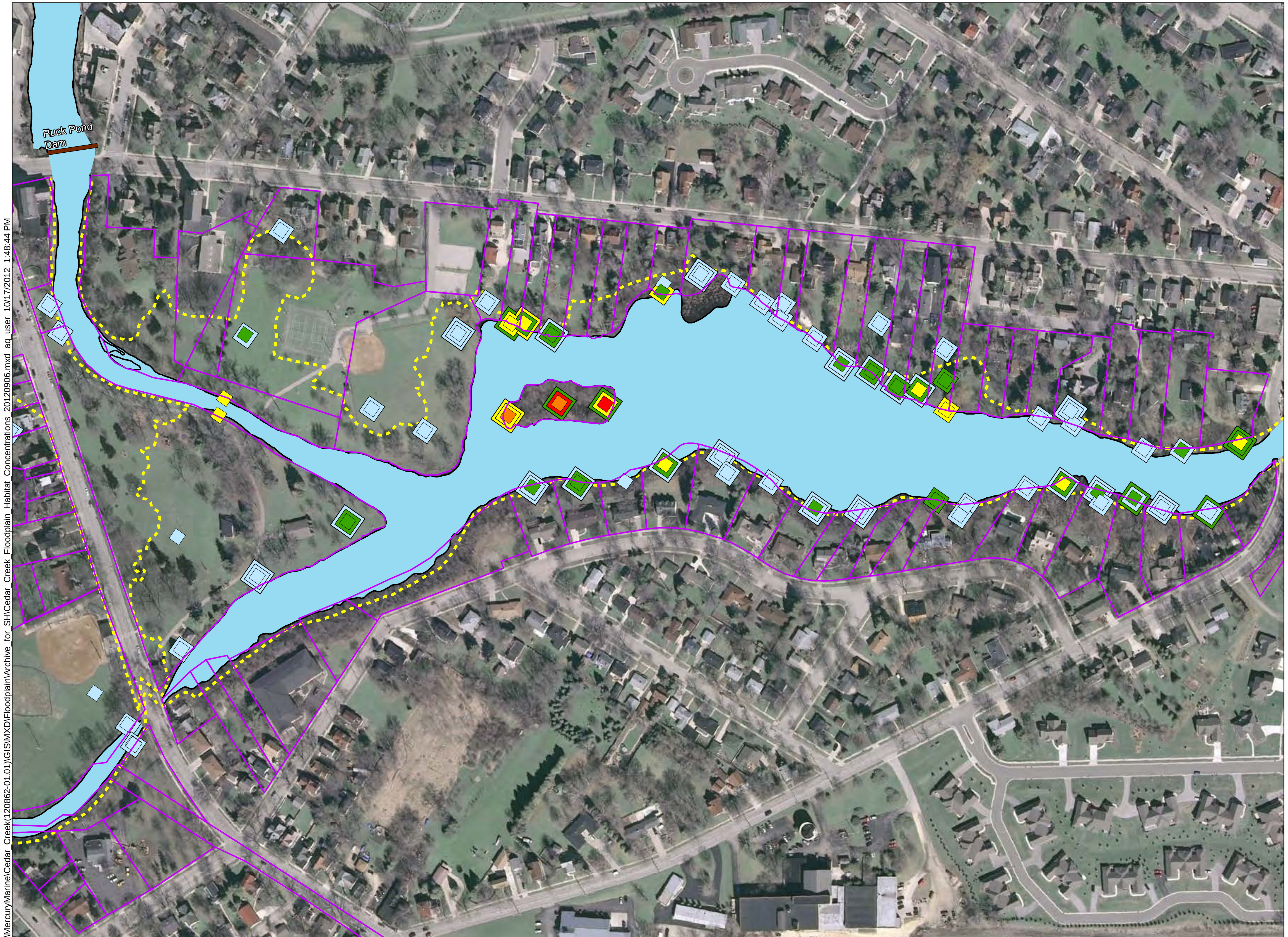
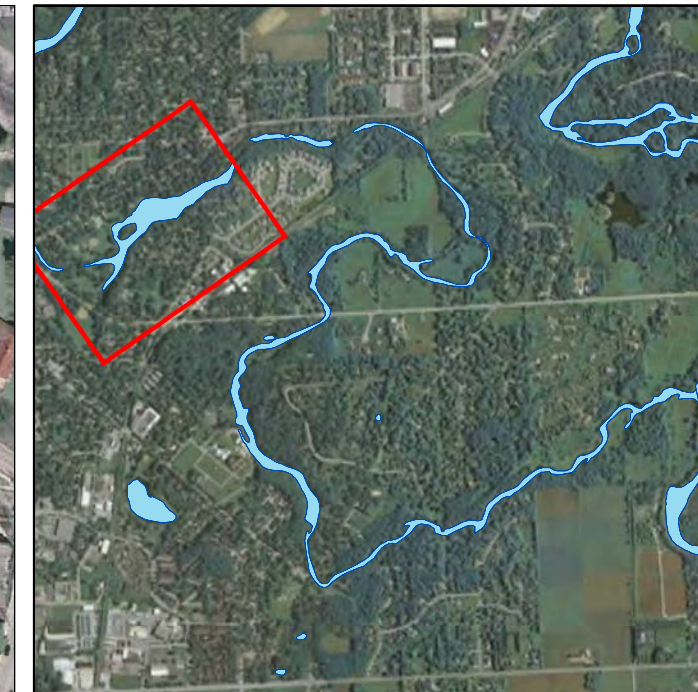
Figure 2-12
Floodplain Soil PCB Concentrations within Ruck Pond Raceway
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study





LEGEND

- Waterbody
- Shoreline
- Dams
- Approximate 10-Year Floodplain
- Tax Parcels

Wetland Classification

- RI Identified Cover Types
  - B - Emergent Aquatic Wetlands
- WDNR Mapped Wetland Class Descriptors
  - E1H - Persistent Emergent/Wet Meadow
  - E2K - Narrow Leaved, Persistent Emergent/Wet Meadow
  - T3K - Deciduous, Broad-Leaved, Forested

Total PCB (mg/kg)

- < 0.2
- 0.2 - 1
- 1 - 5
- 5 - 10
- > 10

Sample Locations

- 0 - 6 in
- 6 - 12 in
- 12 - 18 in

NOTES:
Wetland delineations are approximate.

Feet
0 250 500

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Figure 2-13
Floodplain Soil PCB Concentrations within Columbia Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

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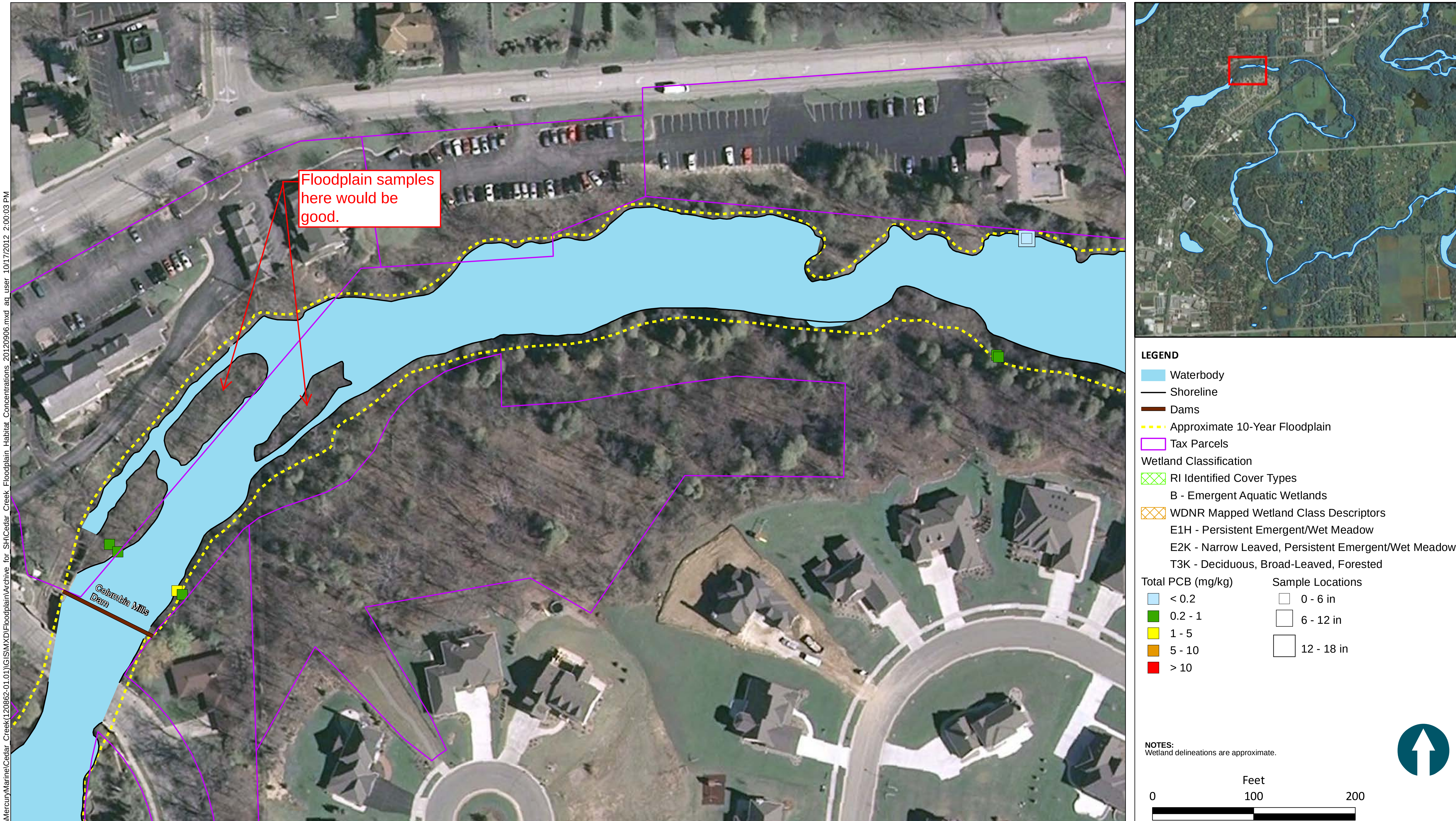

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Figure 2-14
Floodplain Soil PCB Concentrations within Wire and Nail Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

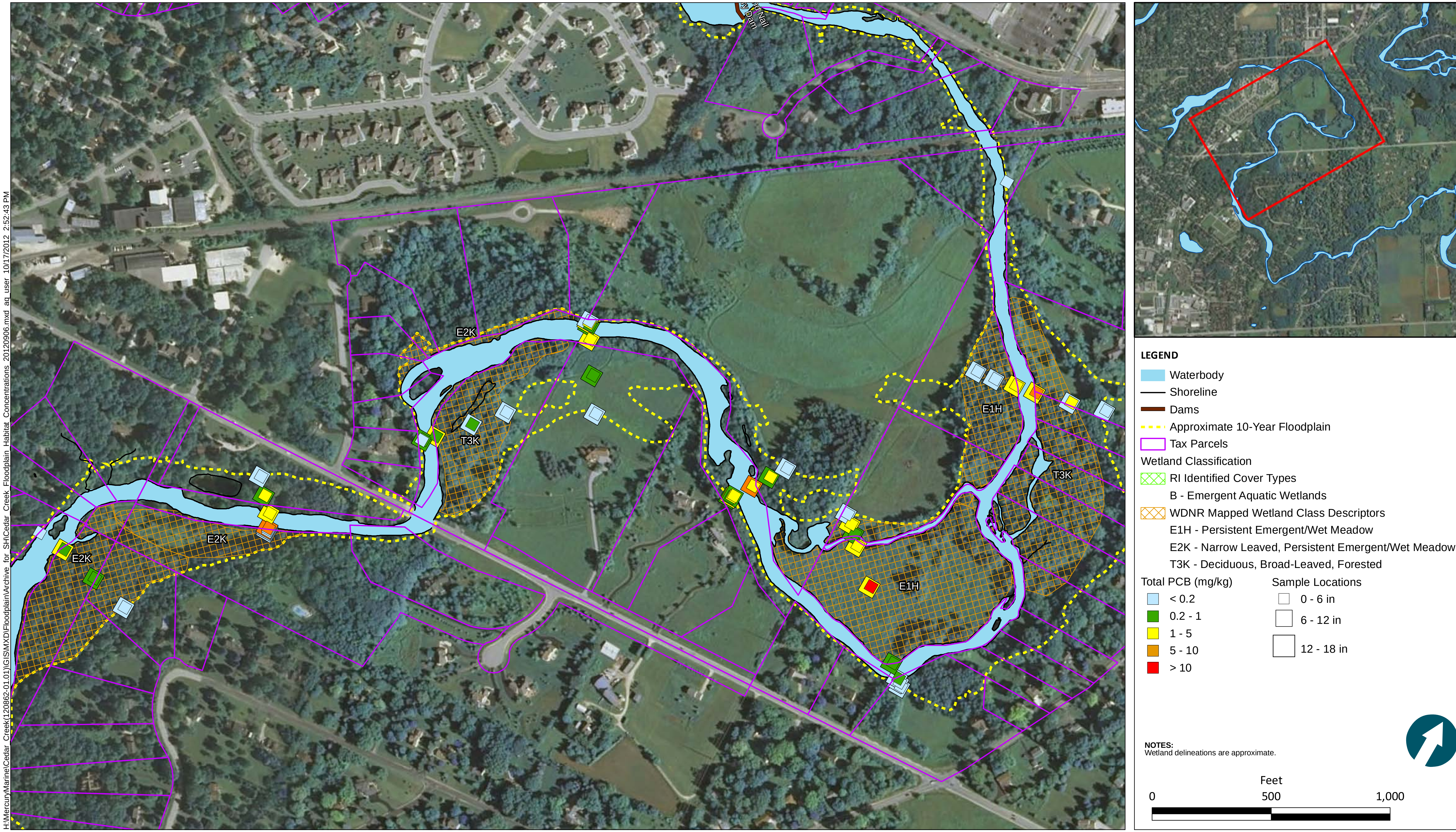

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Figure 2-15
Floodplain Soil PCB Concentrations between Wire and Nail Pond and Former Hamilton Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

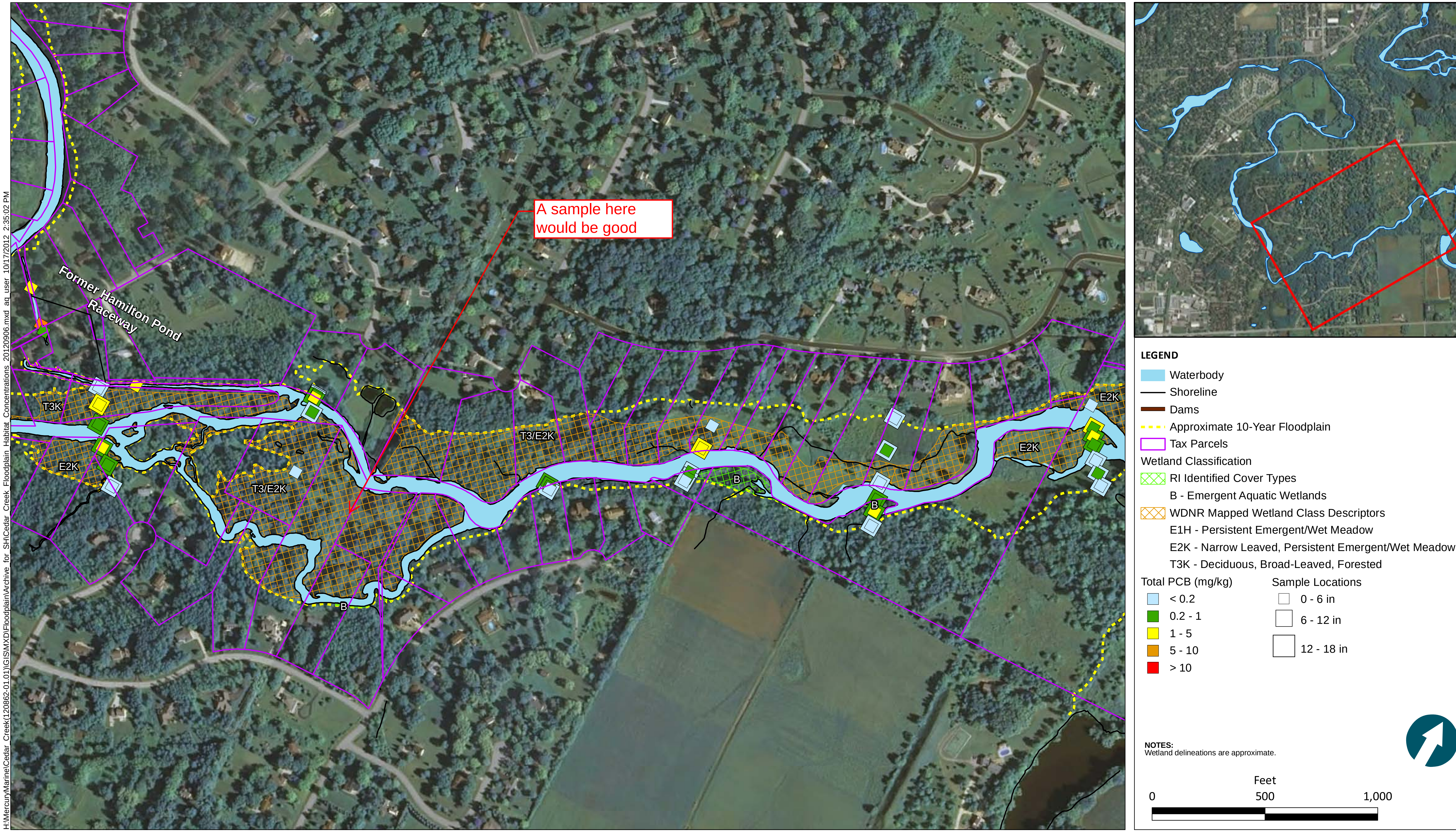

Figure 2-16
Floodplain Soil PCB Concentrations Downstream of Former Hamilton Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

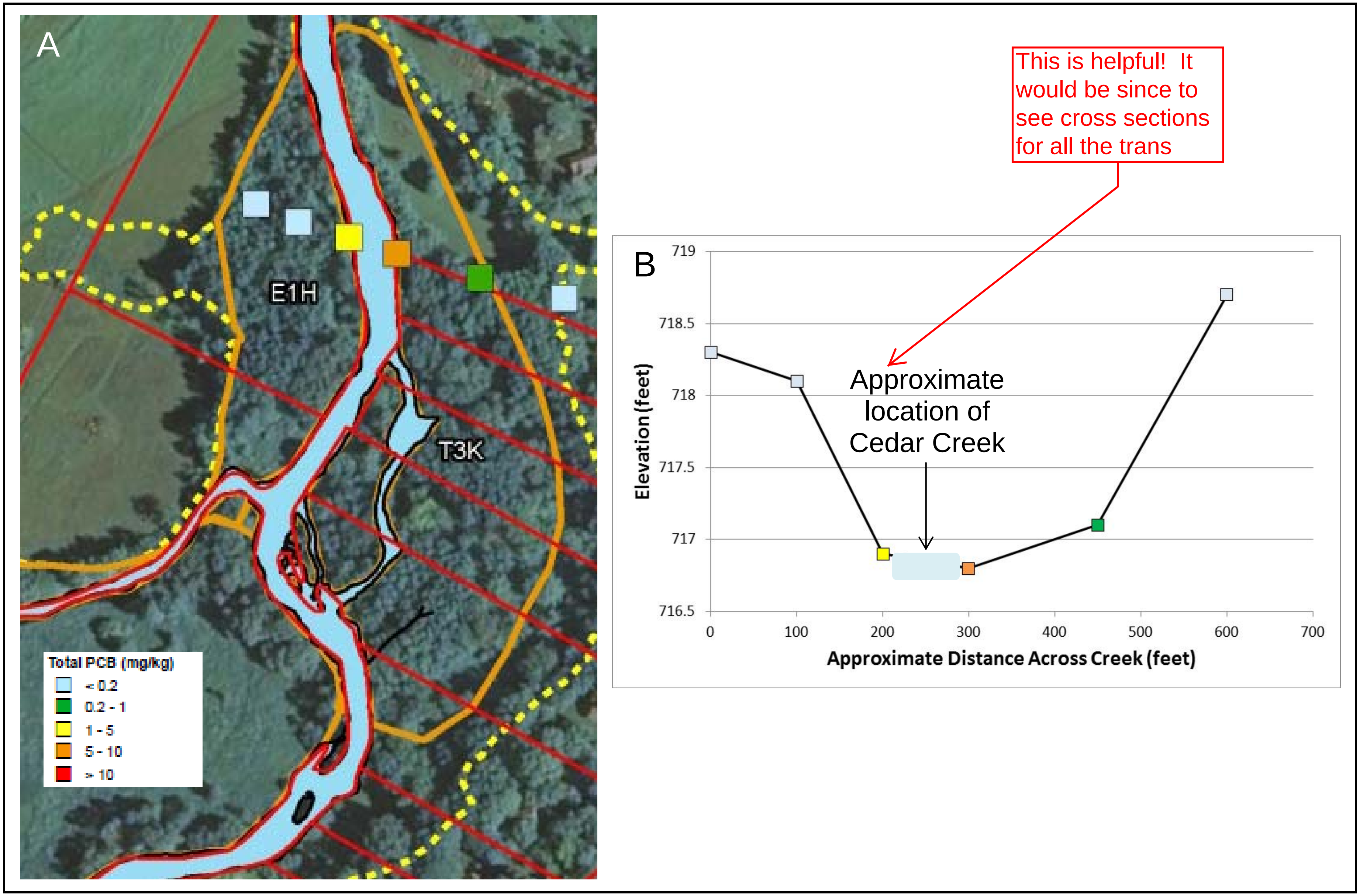

Figure 2-17
PCB Concentrations in Floodplain Soils along Transect Below Wire and Nail Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

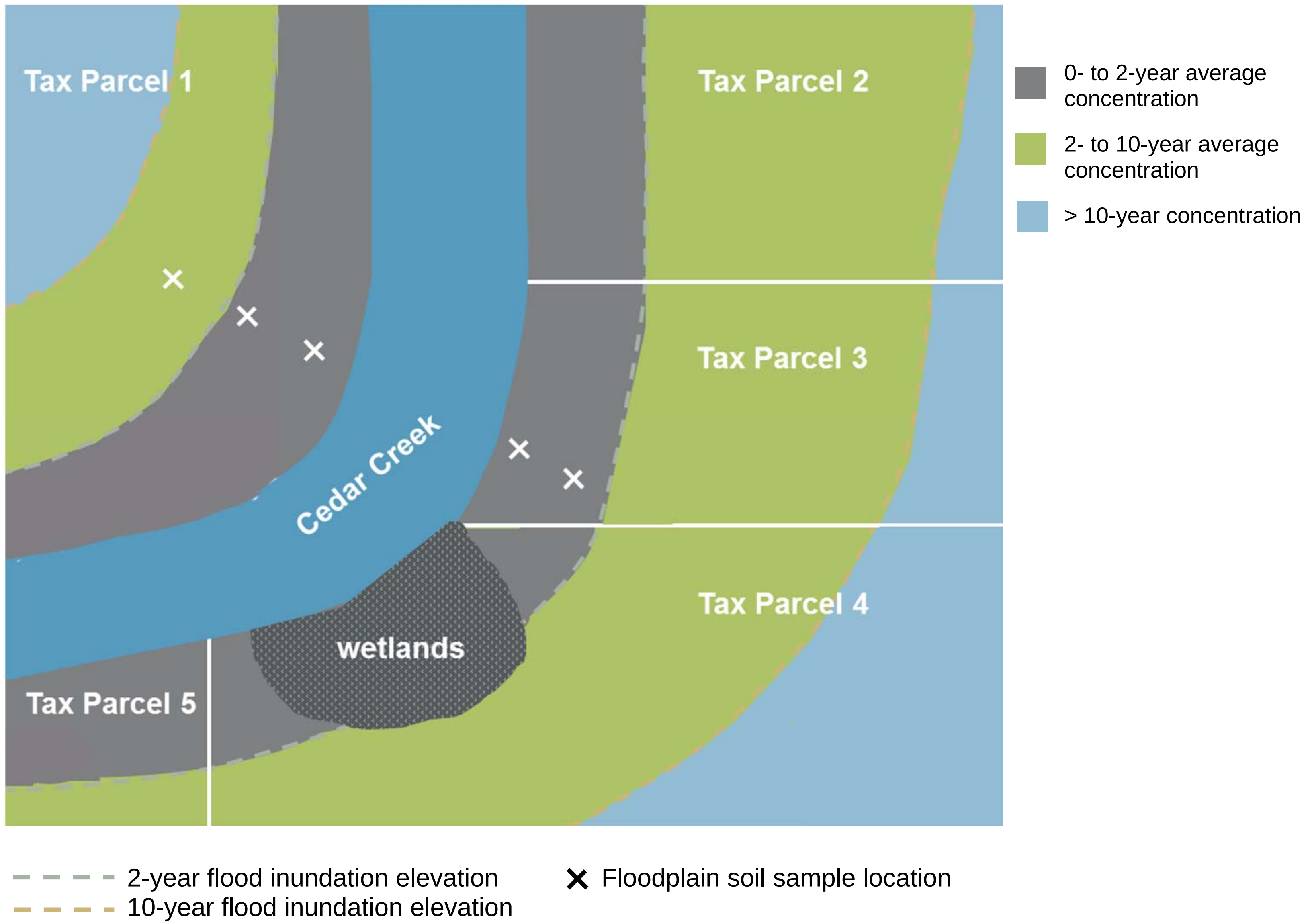

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Figure 2-18
Conceptual Illustration of Approach Used to Assign PCB Concentrations to Floodplain Soils
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

H:\MercuryMarine\Cedar_Creek\Cedar_Creek(120862-01.01)\GIS\MXD\Floodplain\SWAC_over_10yr\Cedar_Creek_Floodplain_PCBs_0-10yr_SWACs.mxd ldesantis 10/26/2012 3:32:40 PM

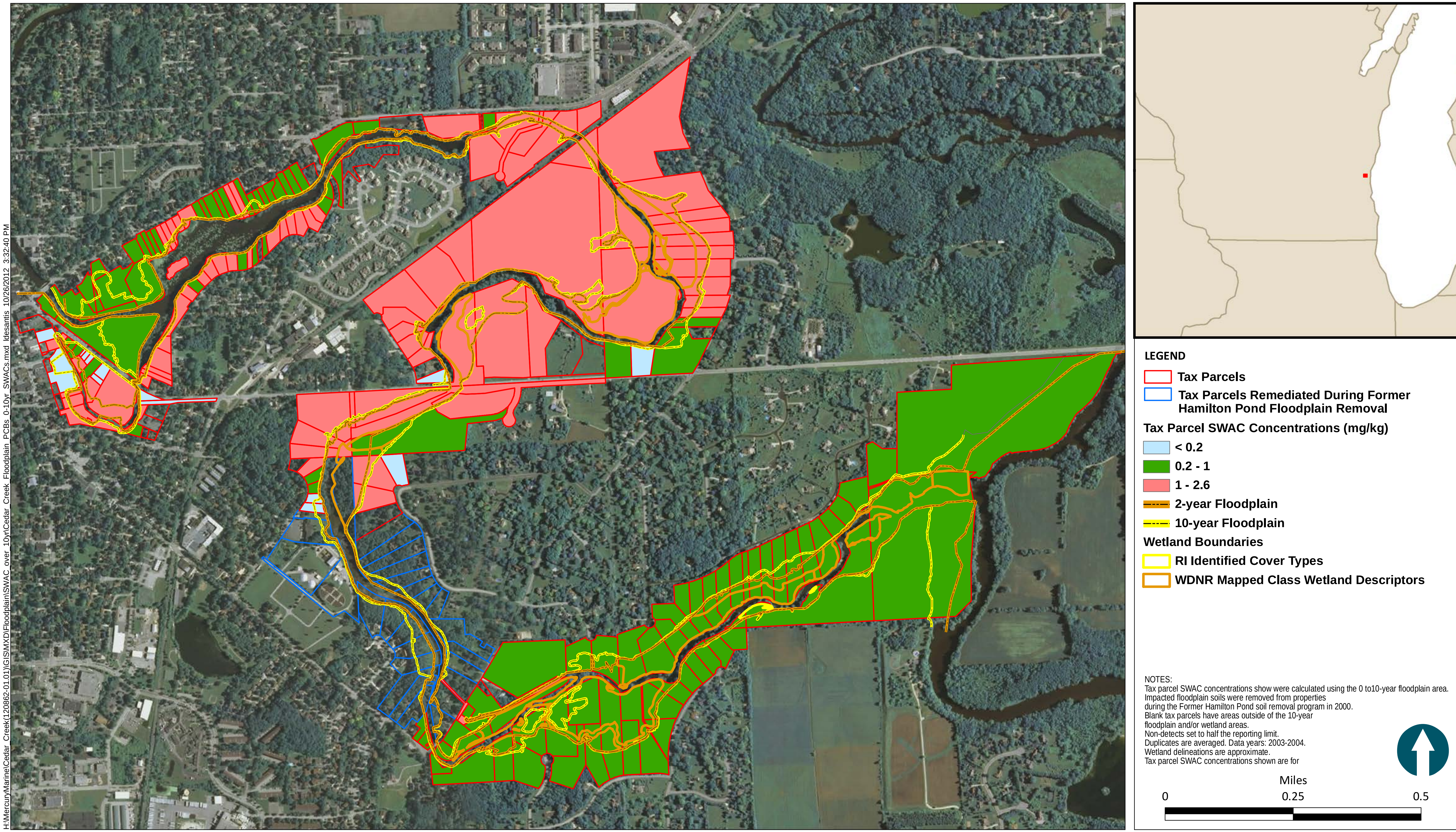

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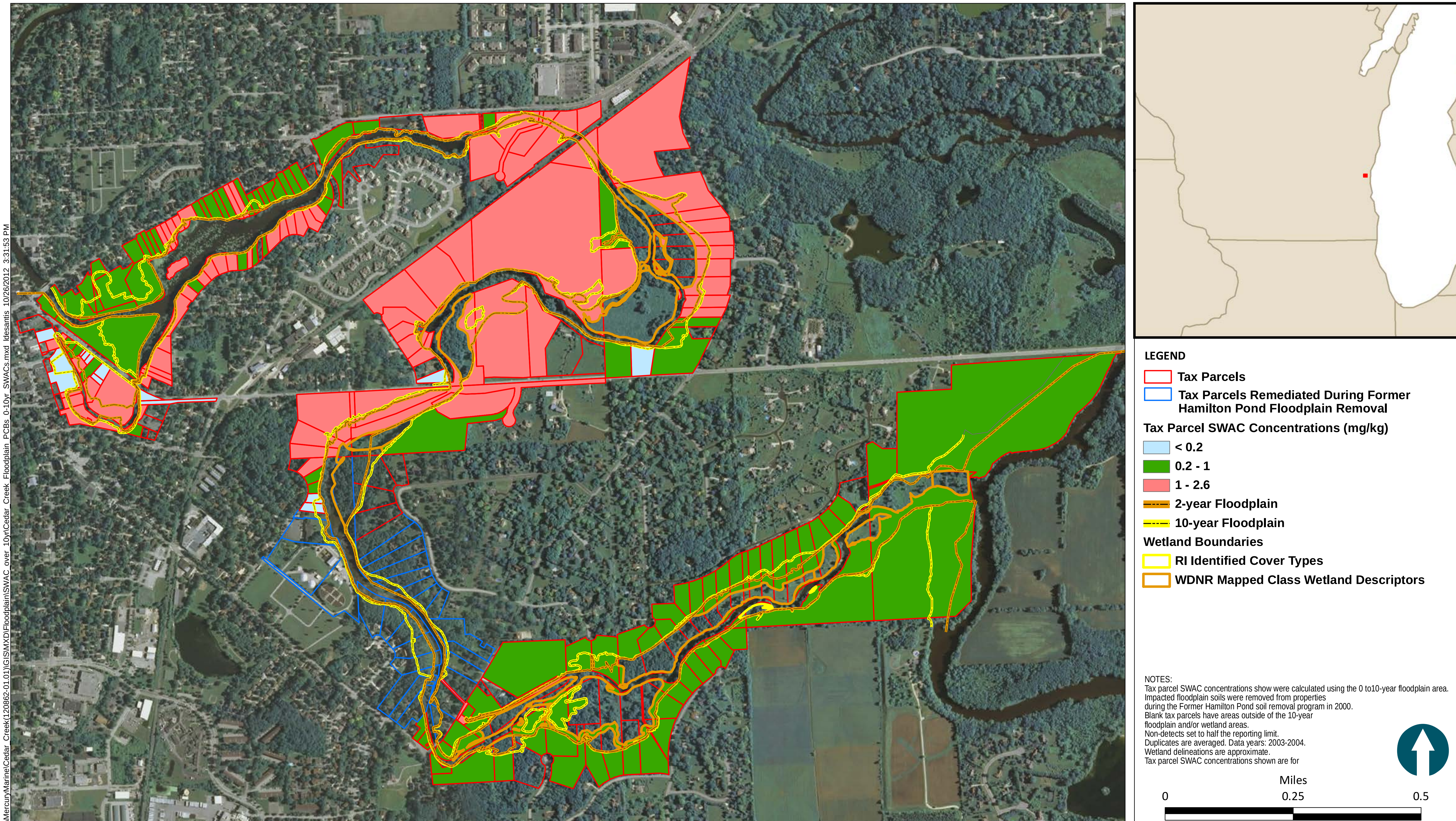
Figure 2-19
Floodplain Soil PCB SWACs Including Wetlands
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



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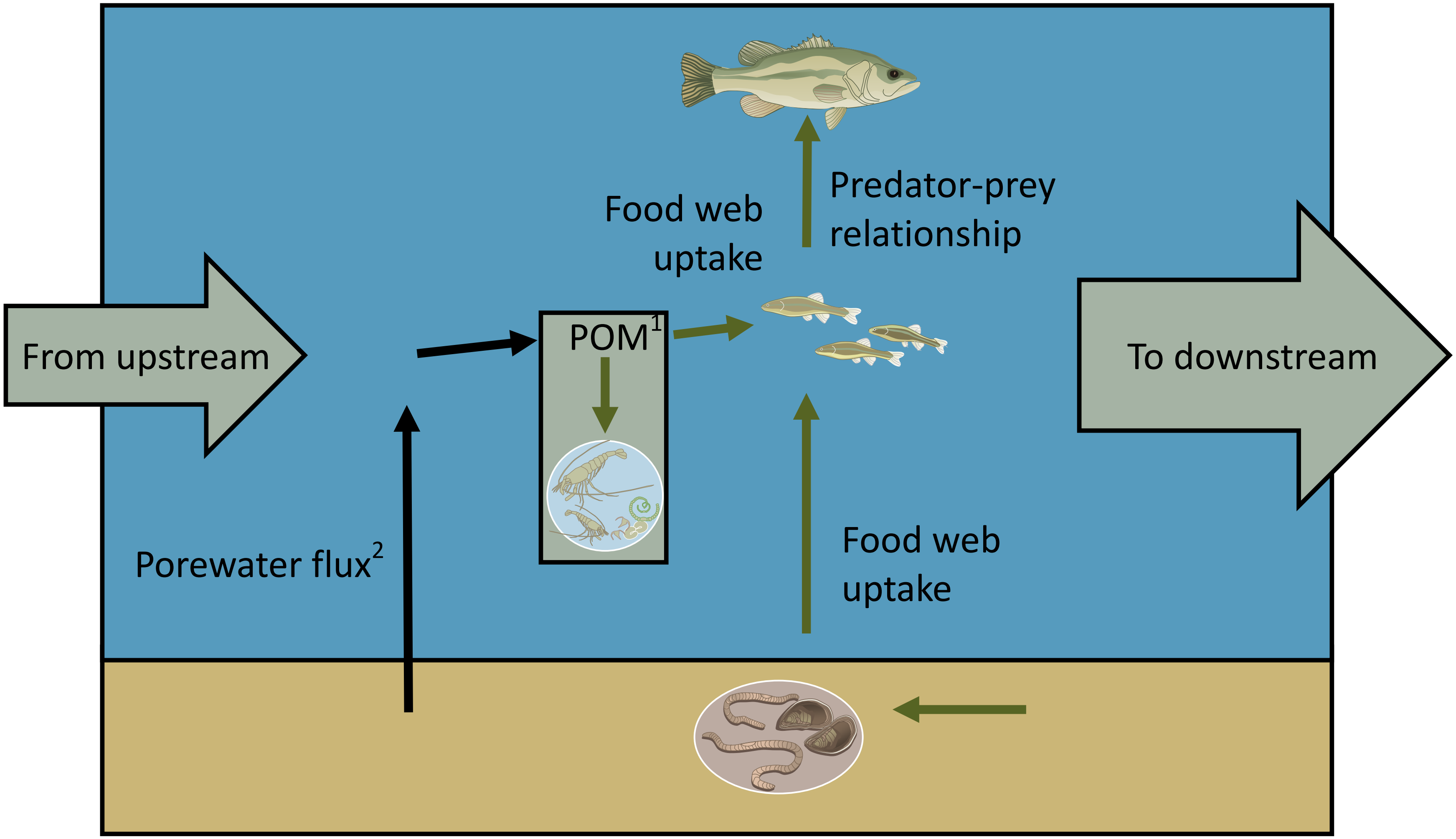
ANCHOR QEA

Figure 2-20
Floodplain Soil PCB SWACs Excluding Wetlands
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



This is a simplified representation of polychlorinated biphenyl (PCB) fate and transport and bioaccumulation, including only the most important pathways for decision-making in Cedar Creek.

Notes:

1 POM = particulate organic matter

2 Porewater flux refers to a range of mechanisms that result in the movement of PCBs in dissolved form from the sediment bed into the overlying water.

Legend

Physical/chemical processes

Biological processes

Figure 2-21

Routes of PCB Uptake by Fish in Cedar Creek

Draft Alternatives Array Document

Cedar Creek Site Feasibility Study

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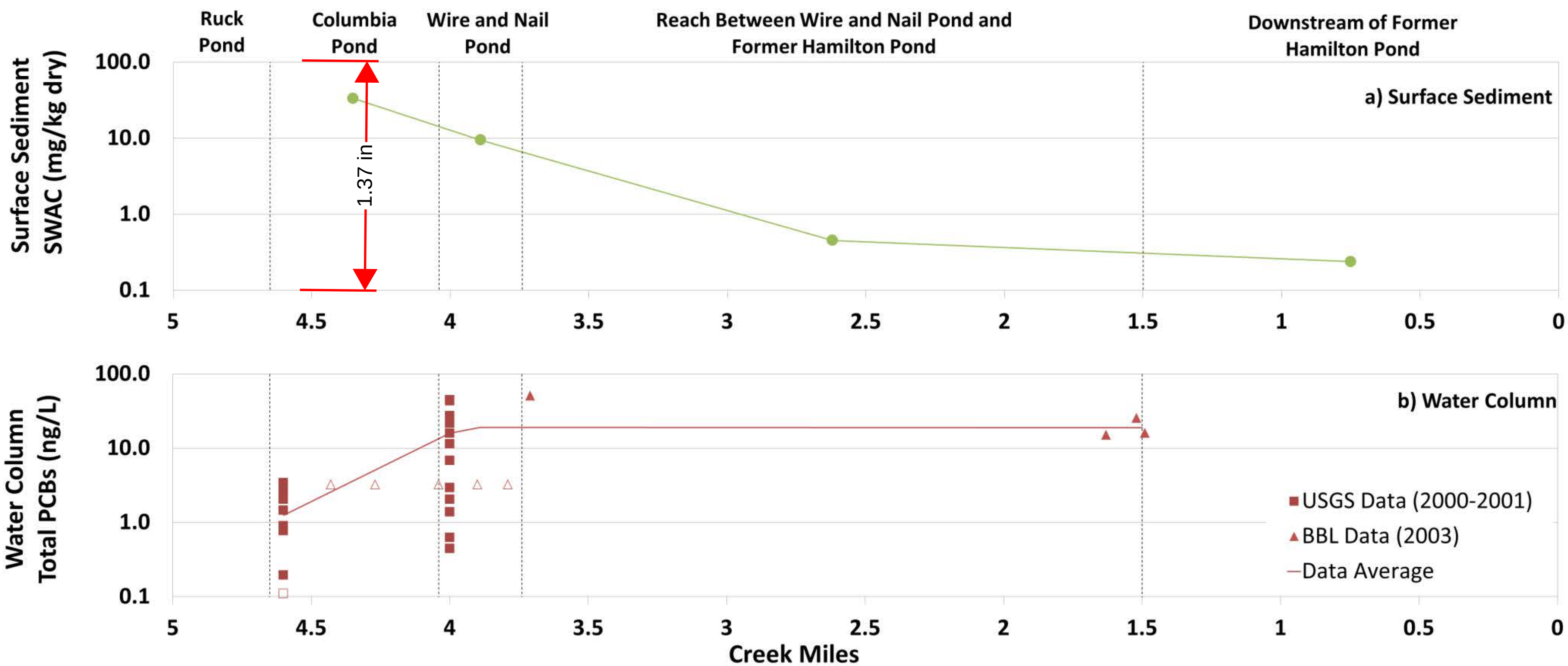
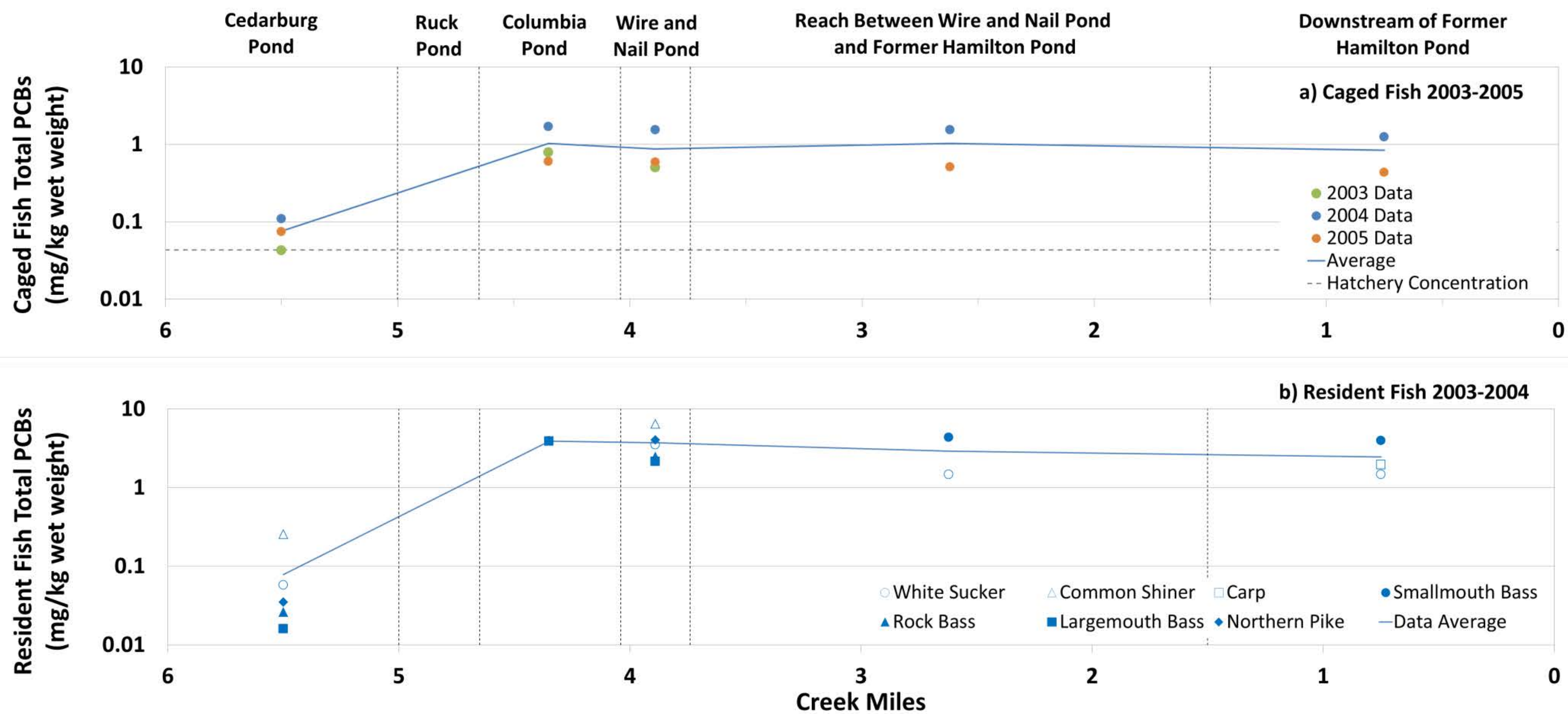


Note: Duplicates averaged for water column and non-detects shown at 1/2 MDL; non-detects shown as open symbols.

Figure 2-22
Comparison of Spatial Gradients in Surface Sediment and Water Column
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



Notes: Duplicates averaged; resident fish fillet samples shown as filled symbols, resident fish whole body samples shown as open symbols.

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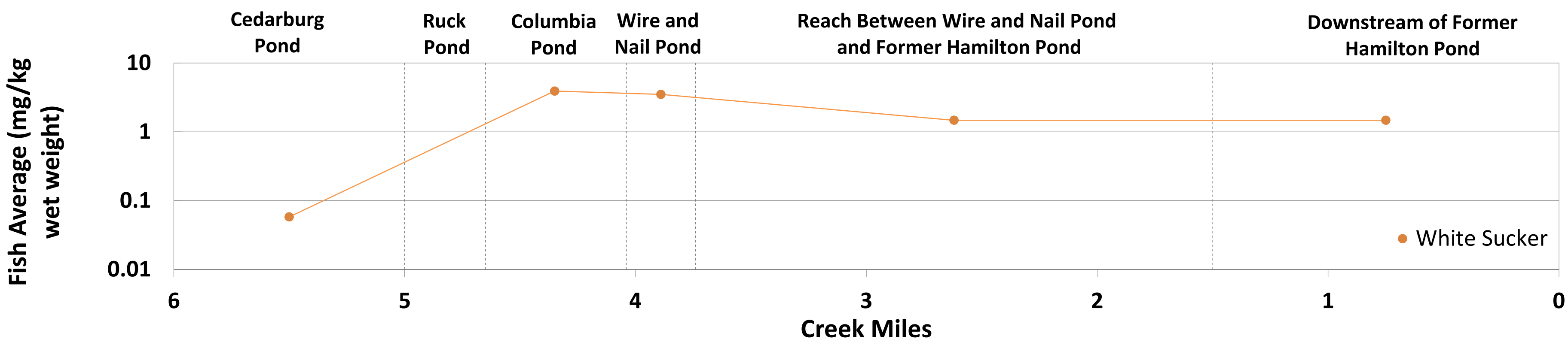
Figure 2-23
Comparison of Spatial Gradients in Caged Fish and Resident Fish Tissue PCB Concentrations



Notes: Whole body samples; duplicates averaged.

Figure 2-24
Spatial Gradient in White Sucker Fish Tissue PCB Concentrations
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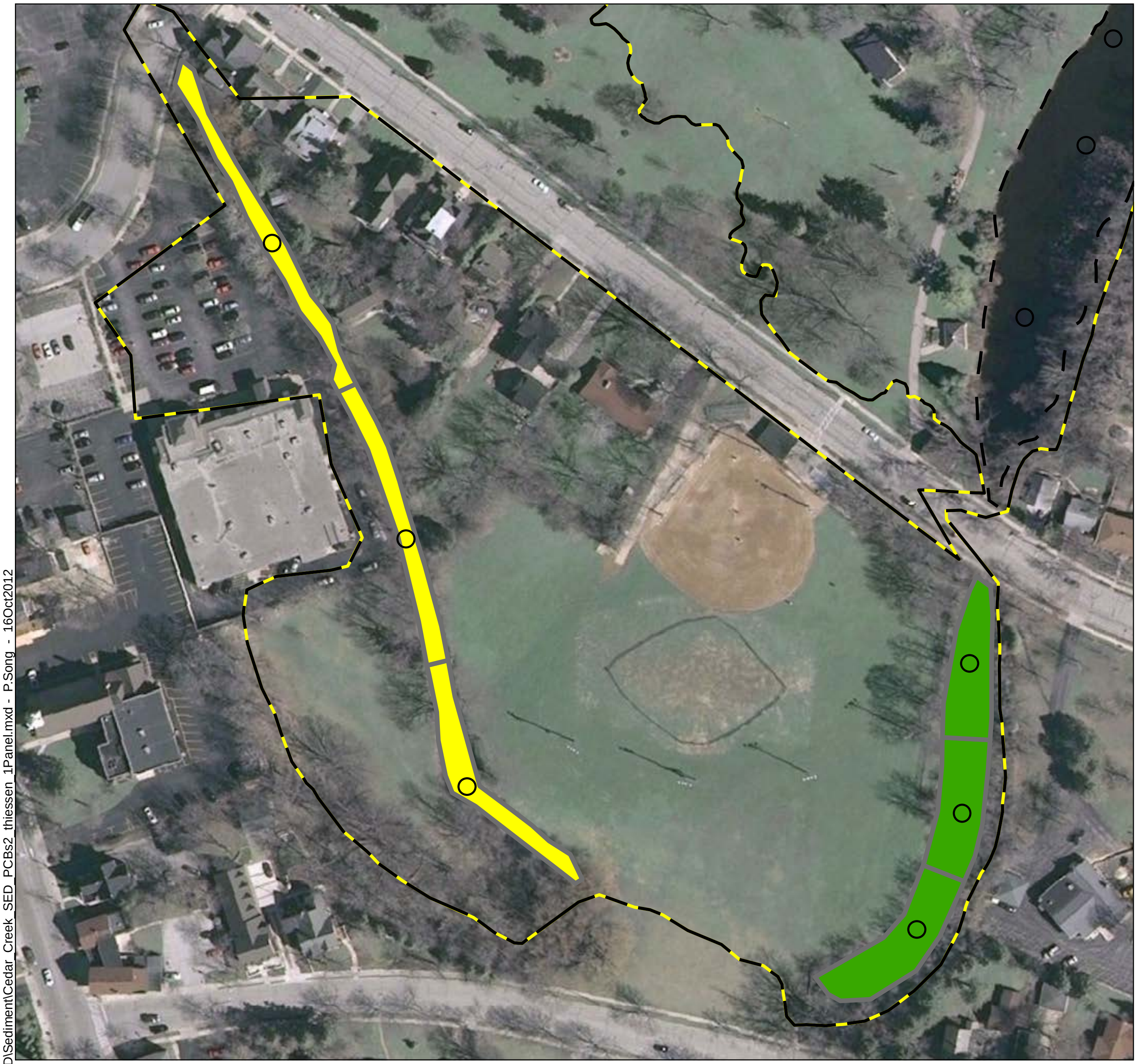

Legend

Core Locations

Approximate 10-yr Floodplain

Depth of Sediment Removed (ft)

2

4

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.
Data years: 1998 and 2003.
Data Depths: (0 - 1 ft), one sample from depth (0 - 1.6 ft)
Aerial imagery provided by ESRI basemaps.

Feet
0 100 200

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Figure 5-1
Proposed Remedial Areas at Ruck Pond Raceway
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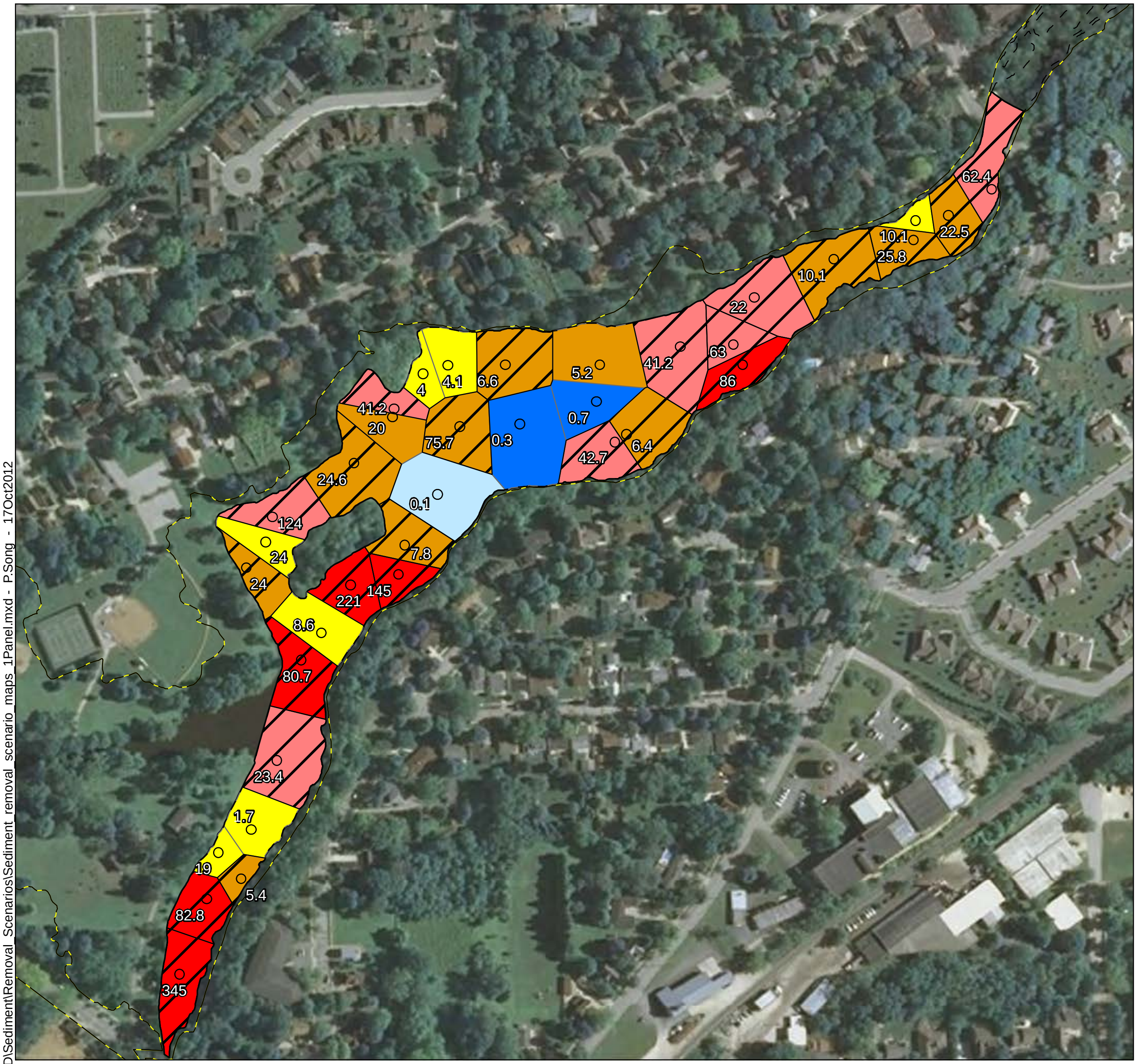

Legend

Pre-Capping TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Maximum remaining TPCB concentrations shown.
The pre-capping TPCB concentrations present the sediment PCB concentration directly beneath the cap (0- to 1-foot increment where cap is placed [see capping area hatching]) or surface sediment PCB concentrations (0- to 1-foot increment where no cap is proposed).
Non-detects set to half the reporting limit.
Duplicates are averaged.

Feet
0 250 500

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Figure 5-2
Sediment PCB Concentrations below Cap within Columbia Pond for Alternative SED-3
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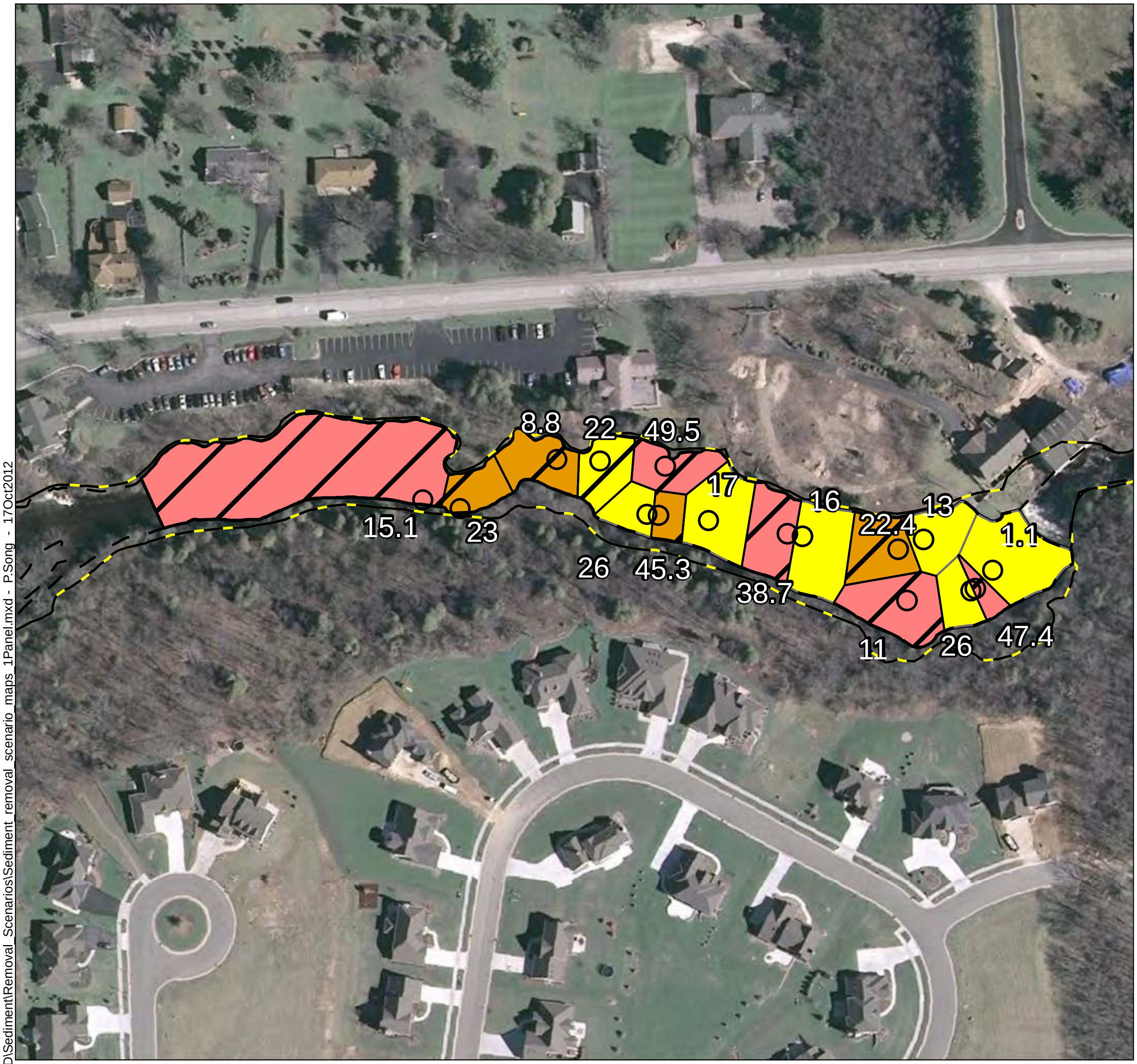

Legend

Pre-Capping TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Maximum remaining TPCB concentrations shown.
The pre-capping TPCB concentrations present the sediment PCB concentration directly beneath the cap (0- to 1-foot increment where cap is placed [see capping area hatching]) or surface sediment PCB concentrations (0- to 1-foot increment where no cap is proposed).
Non-detects set to half the reporting limit.
Duplicates are averaged.

Feet
0 250 500

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Figure 5-3
Sediment PCB Concentrations below Cap within Wire and Nail Pond for Alternative SED-3
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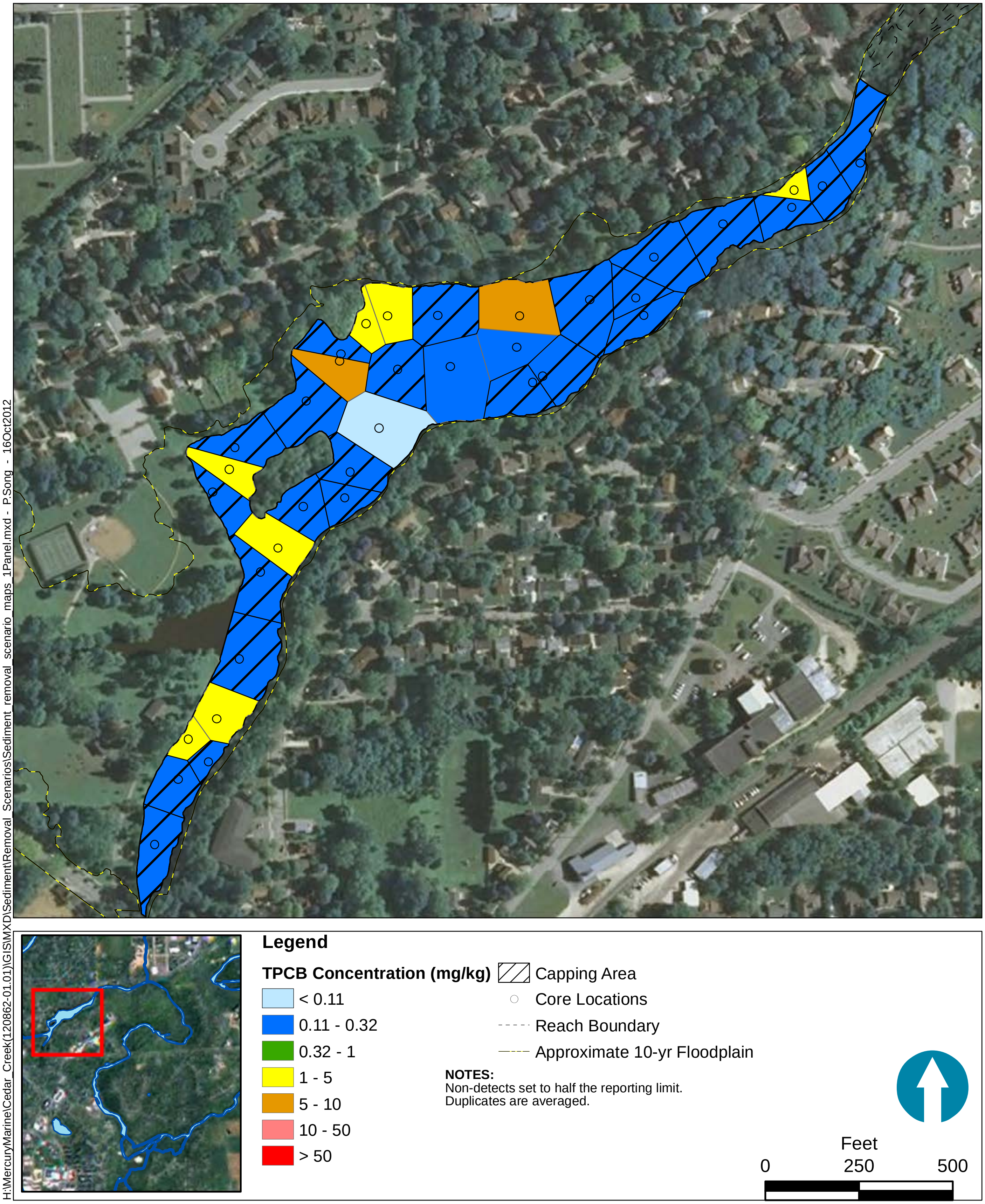

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Figure 5-4
Post-remedy Surface PCB Concentrations for Alternative SED-3 at Columbia Pond
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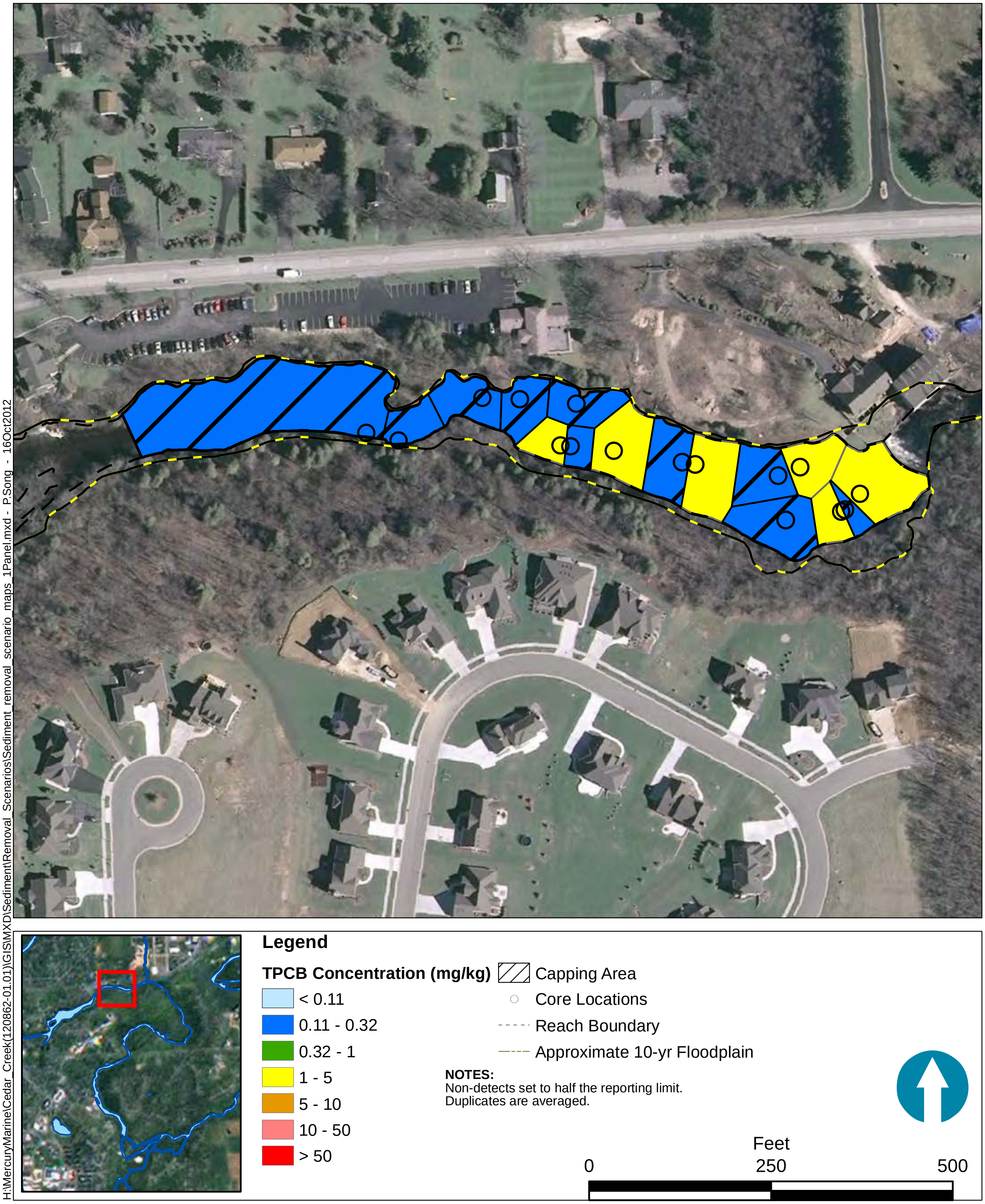

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Figure 5-5
Post-remedy Surface PCB Concentrations for Alternative SED-3 at Wire and Nail Pond
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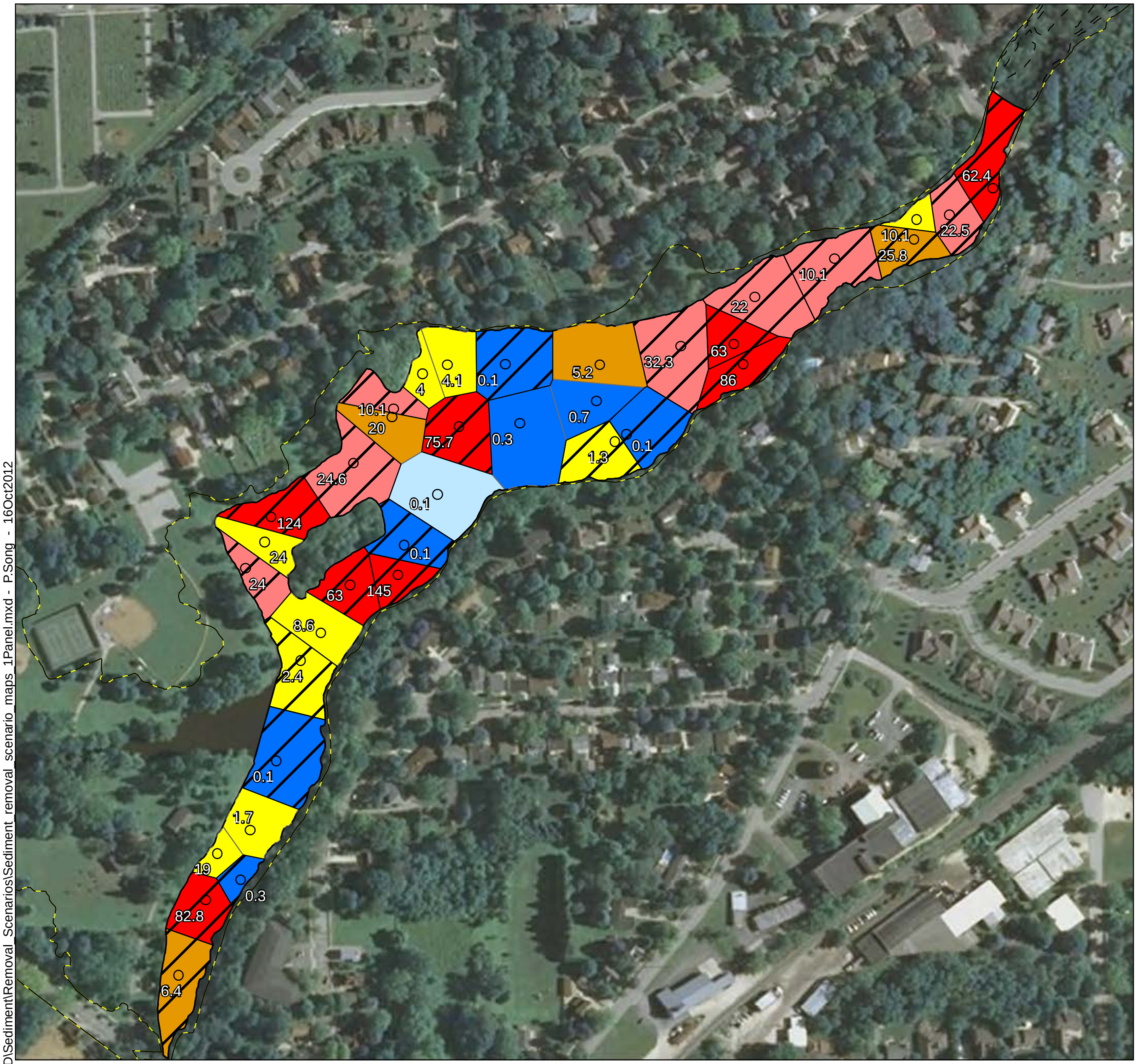

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Legend

Pre-Capping TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Maximum remaining TPCB concentrations shown.
The pre-capping TPCB concentrations present: 1) sediment PCB concentrations of the upper 1 foot of sediment following removal and prior to capping (see capping area hatching); or 2) surface sediment PCB concentrations (0- to 1-foot increment) where no cap is proposed.
Non-detects set to half the reporting limit.
Duplicates are averaged.

Feet
0 250 500

Figure 5-6
Sediment PCB Concentrations below Cap within Columbia Pond for Alternatives SED-4a and SED-4b
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

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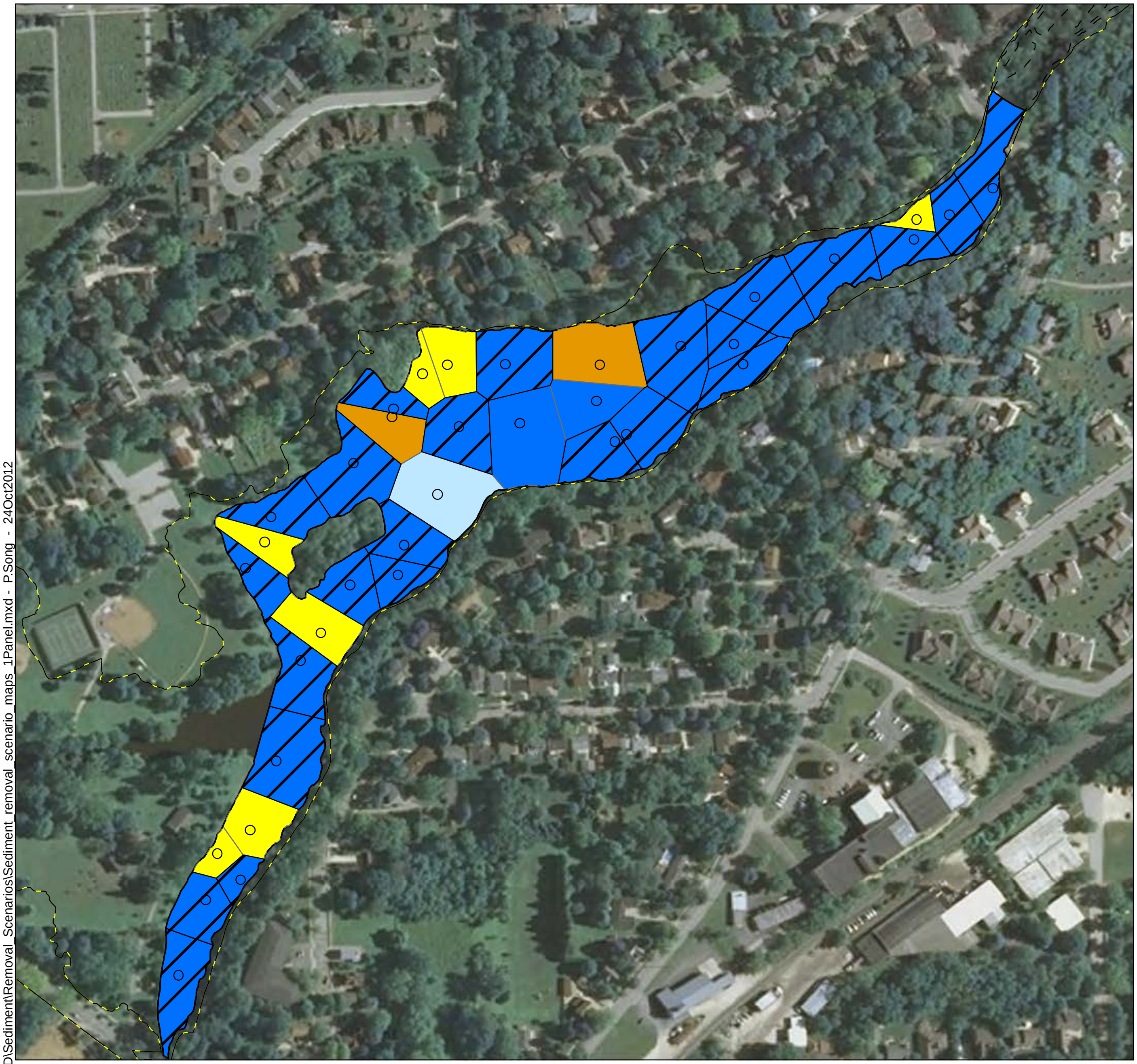

Legend

TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.

Feet
0 250 500

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Figure 5-7
Post-remedy Surface PCB Concentrations for Alternatives SED-4a and SED-4b at Columbia Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

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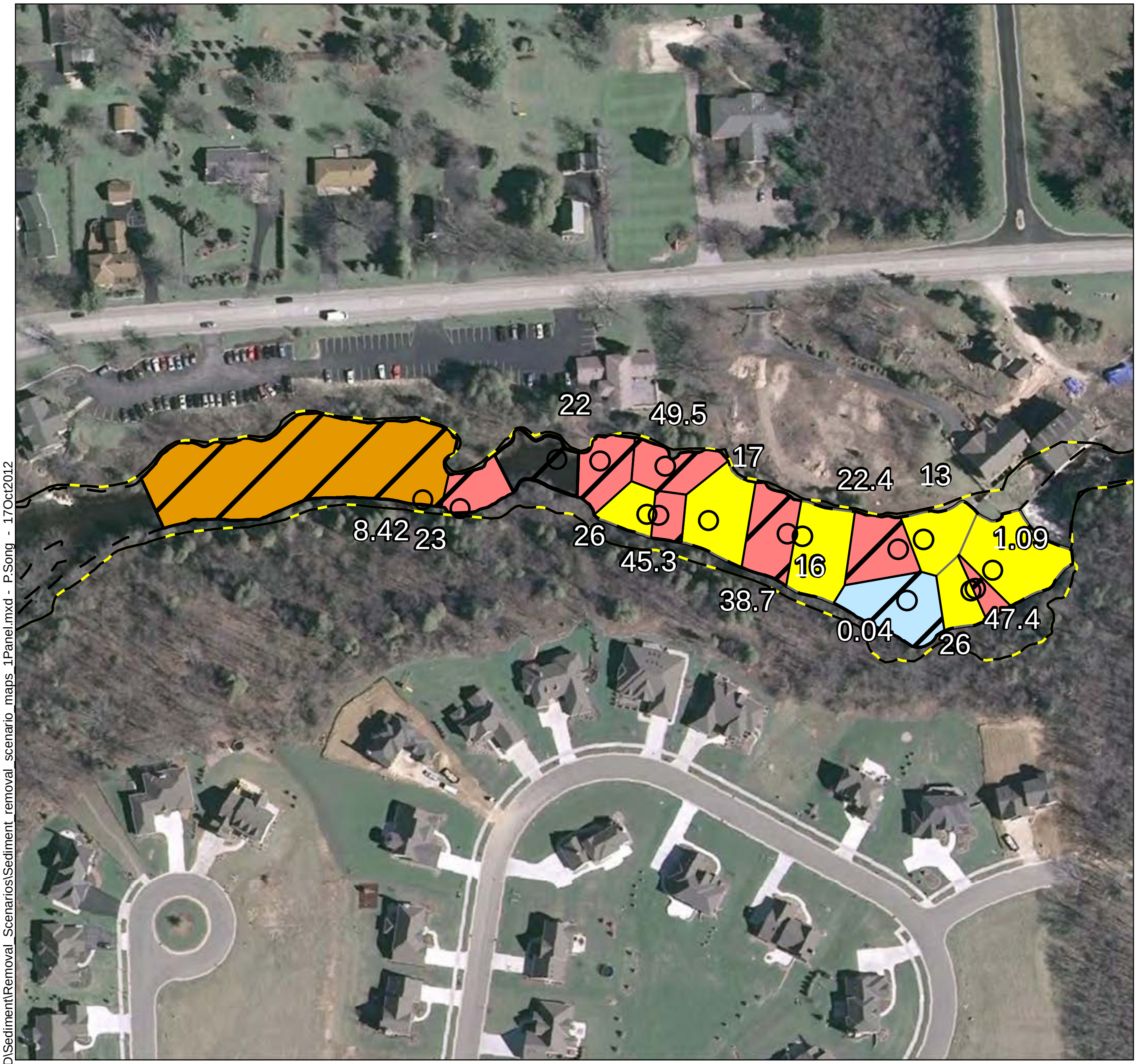

Legend

Pre-Capping TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Maximum remaining TPCB concentrations shown.
The pre-capping TPCB concentrations present: 1) sediment PCB concentrations of the upper 1 foot of sediment following removal and prior to capping (see capping area hatching); or 2) surface sediment PCB concentrations (0- to 1-foot increment) where no cap is proposed.
Non-detects set to half the reporting limit. Duplicates are averaged.
Empty polygons indicate no remaining sediment following removal.

Feet
0 250 500

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Figure 5-8
Sediment PCB Concentrations below Cap within Wire and Nail Pond for Alternative SED-4b
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

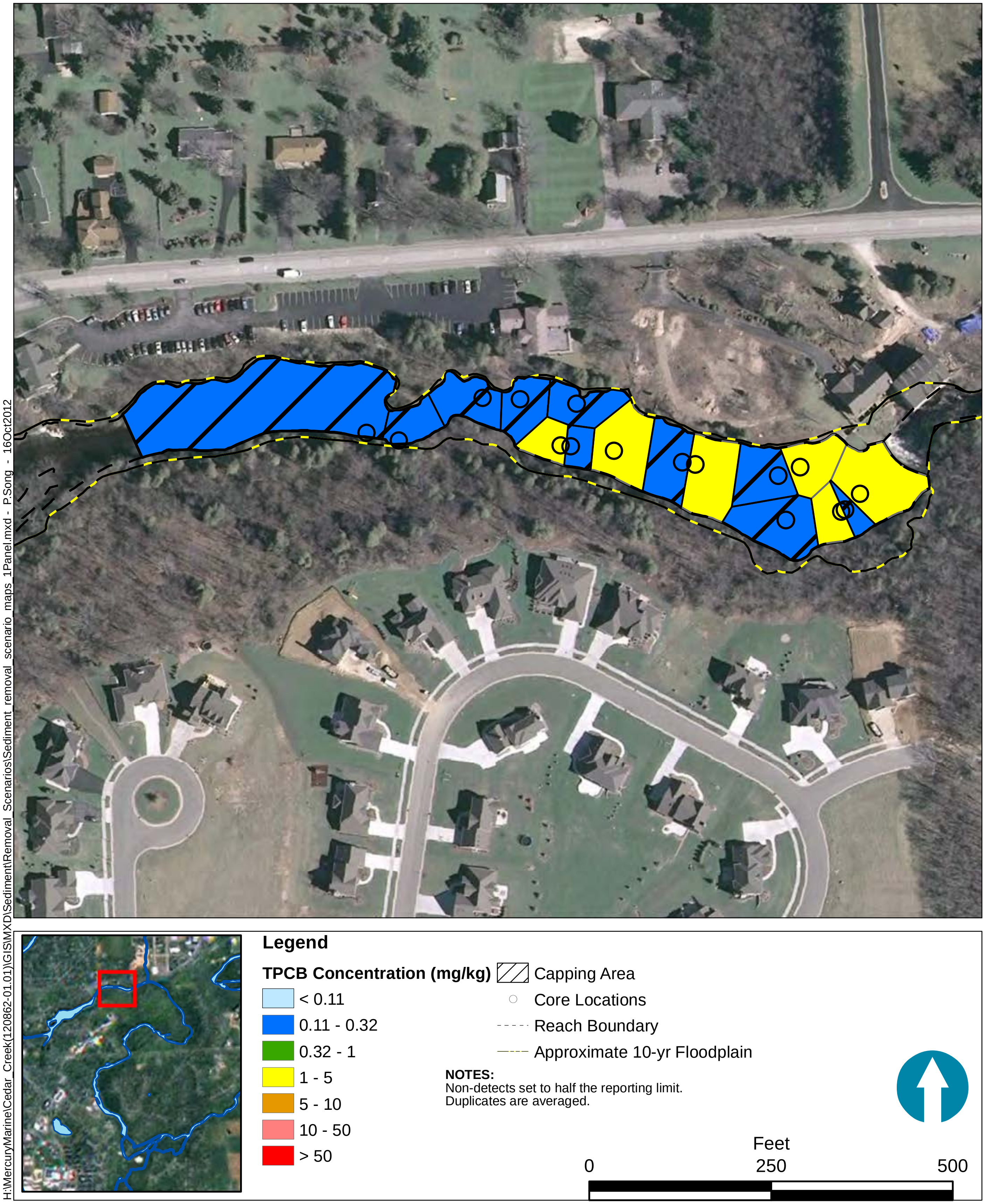

Figure 5-9
Post-remedy Surface PCB Concentrations for Alternative SED-4b at Wire and Nail Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

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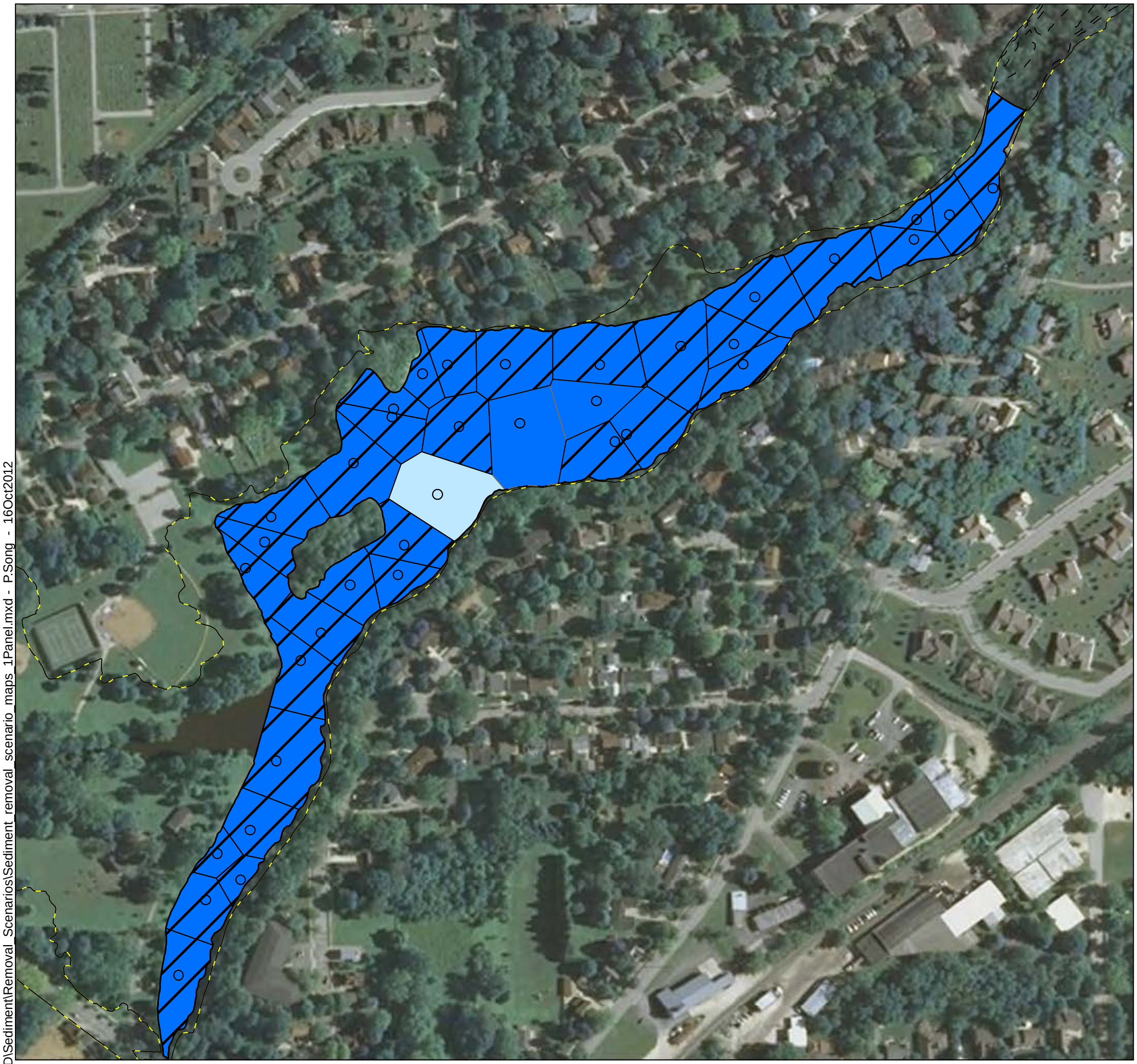

Legend

TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.

Feet
0 250 500

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Figure 5-10
Post-remedy Surface PCB Concentrations for Alternatives SED-5a and SED-5b at Columbia Pond
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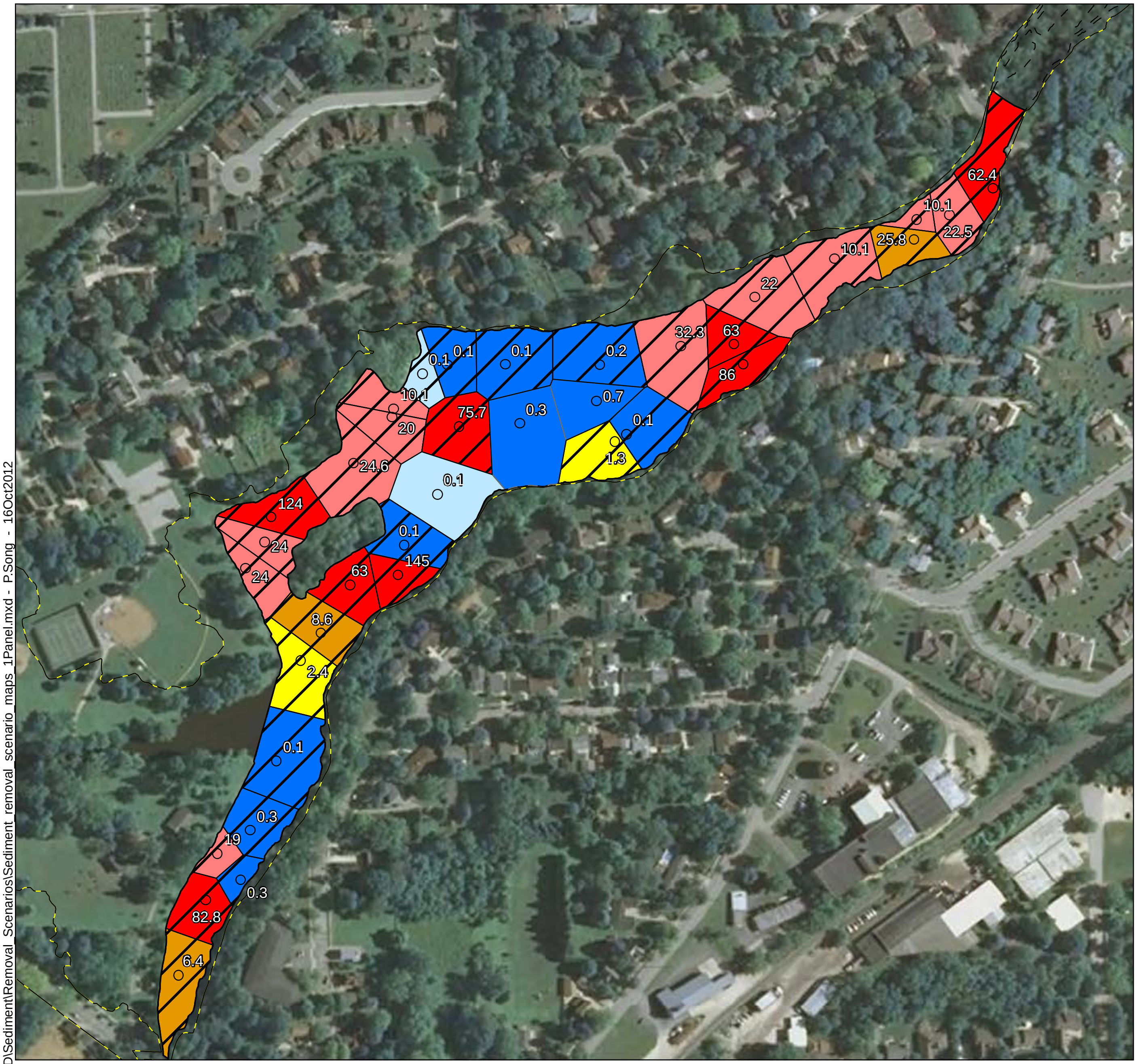

Legend

Pre-Capping TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Maximum remaining TPCB concentrations shown.
The pre-capping TPCB concentrations present: 1) sediment PCB concentrations of the upper 1 foot of sediment following removal and prior to capping (see capping area hatching); or 2) surface sediment PCB concentrations (0- to 1-foot increment) where no cap is proposed.
Non-detects set to half the reporting limit.
Duplicates are averaged.

Feet
0 250 500

Figure 5-11
Sediment PCB Concentrations below Cap within Columbia Pond for Alternatives SED-5a and SED-5b
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Cedar Creek Site Feasibility Study

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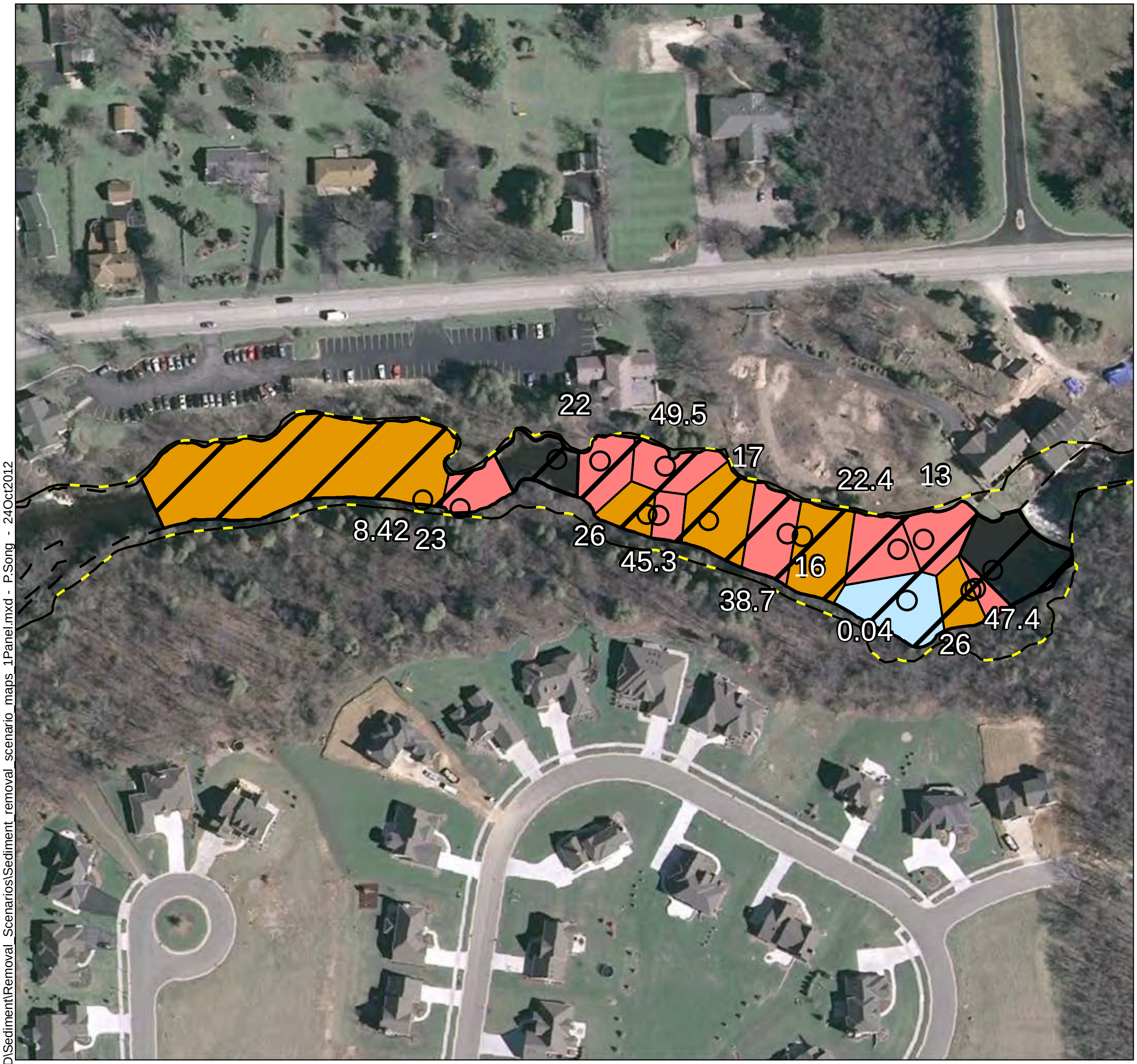

Legend

Pre-Capping TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Maximum remaining TPCB concentrations shown.
The pre-capping TPCB concentrations present: 1) sediment PCB concentrations of the upper 1 foot of sediment following removal and prior to capping (see capping area hatching); or 2) surface sediment PCB concentrations (0- to 1-foot increment) where no cap is proposed.
Non-detects set to half the reporting limit. Duplicates are averaged.
Empty polygons indicate no remaining sediment following removal.

Feet
0 250 500

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Figure 5-12
Sediment PCB Concentrations below Cap within Wire and Nail Pond for Alternative SED-5b
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

Legend

TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.

Feet
0 250 500

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Figure 5-13
Post-remedy Surface PCB Concentrations for Alternative SED-5b at Wire and Nail Pond
Draft Alternatives Array Document
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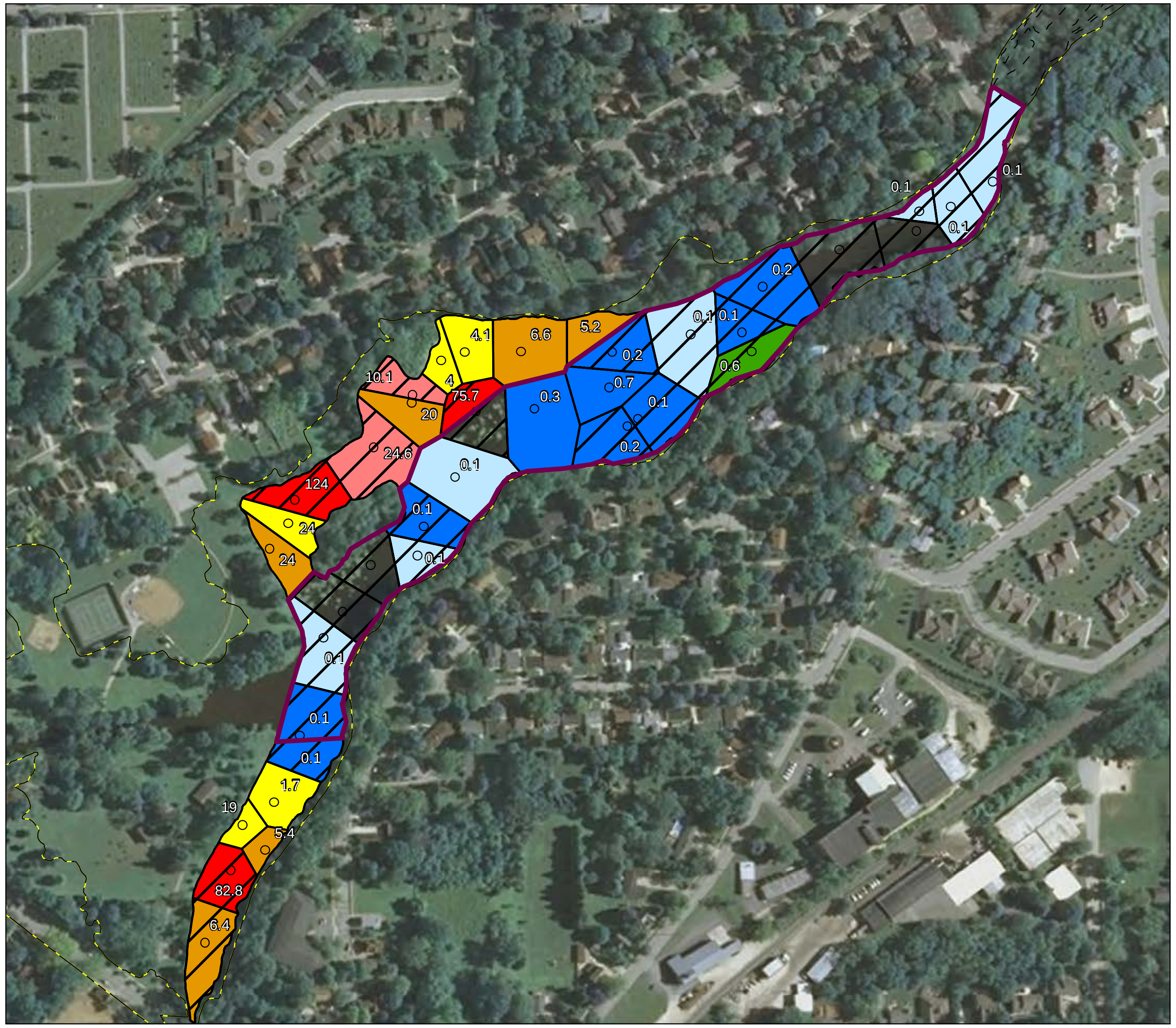
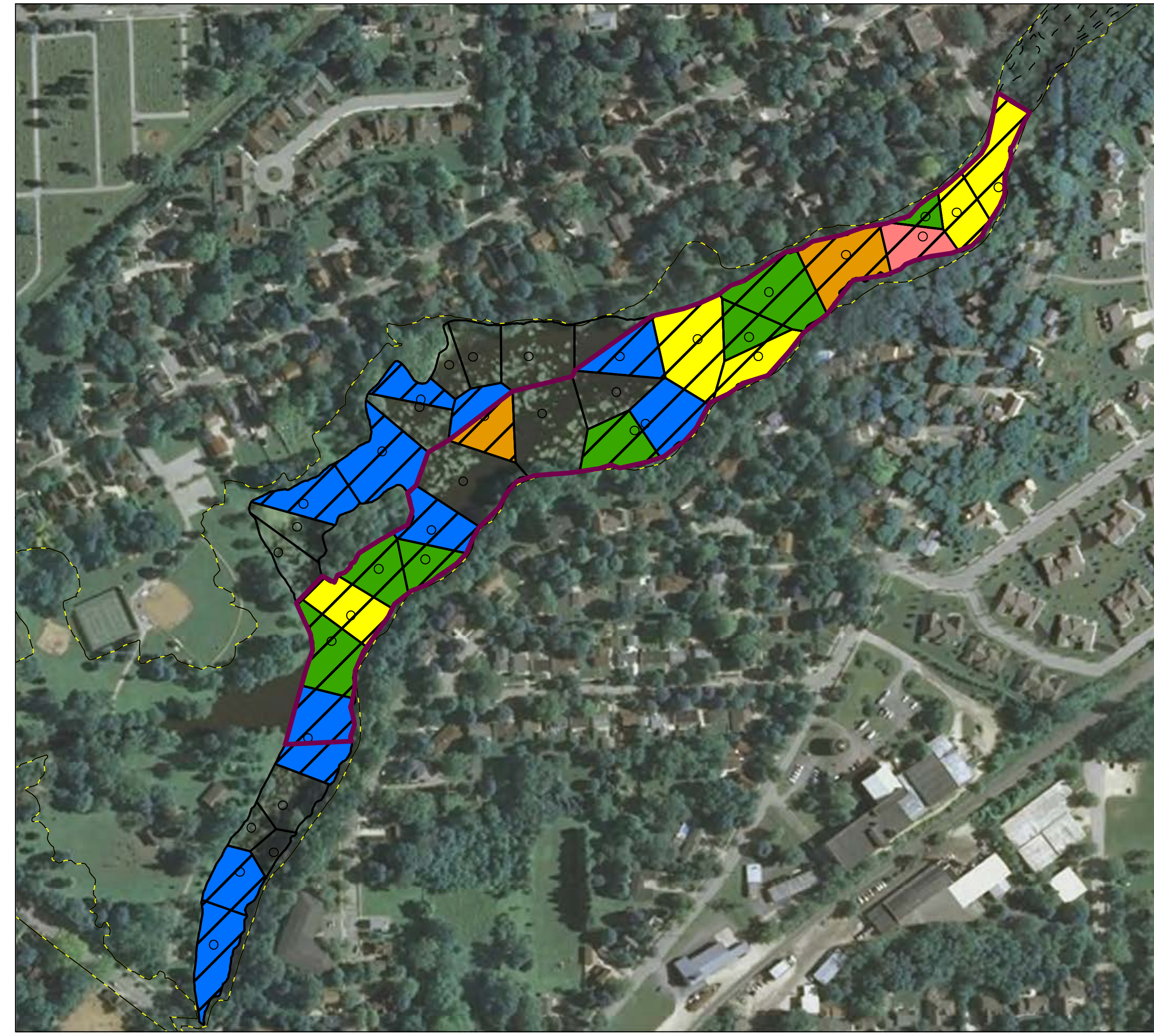
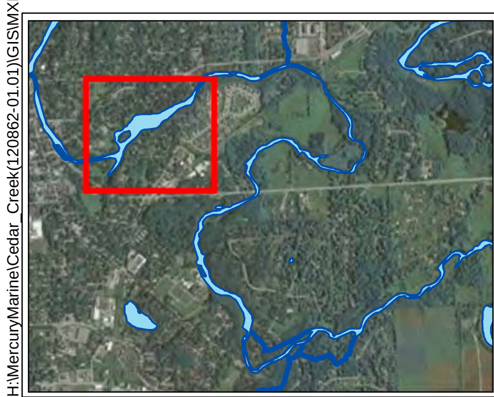
Sediment Concentrations Remaining Post-Removal (mg/kg)



Depth of Sediment Removed (ft)





Legend

Pre-Capping TPCB Concentration (mg/kg)
- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Dredging/Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain
- Main Channel Delineation

Depth (ft)
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- > 6

NOTES:
Maximum remaining concentrations shown.
The pre-capping TPCB concentrations present: 1) sediment PCB concentrations of the upper 1 foot of sediment following removal and prior to capping (see capping area hatching); or 2) surface sediment PCB concentrations (0- to 1-foot increment) where no cap is proposed.
Non-detects set to half the reporting limit. Duplicates are averaged.
Empty polygons indicate no remaining sediment following removal.

0 500 1,000
Feet

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Figure 5-14
Sediment PCB Concentrations below Cap within Columbia Pond for Alternative SED-6
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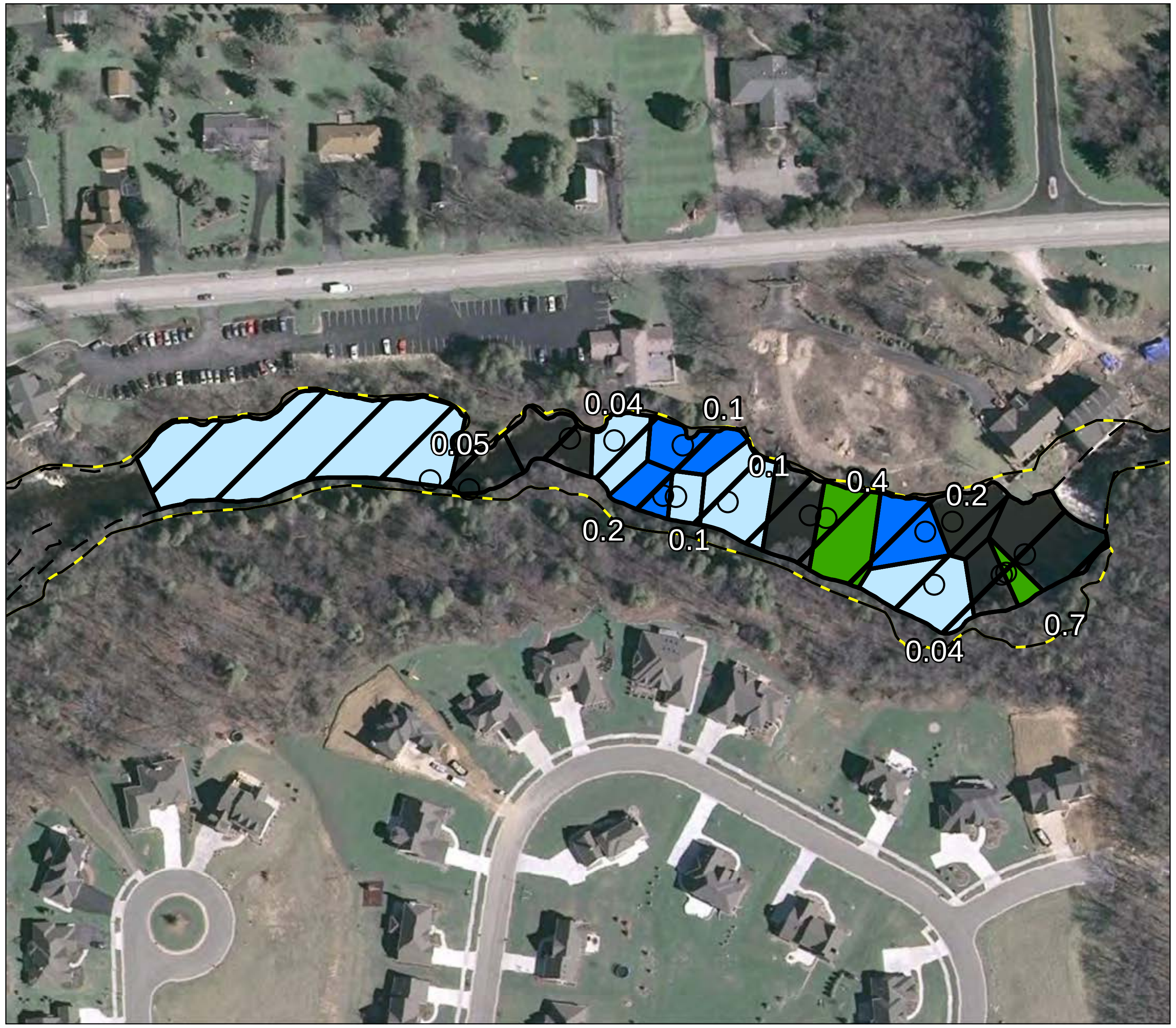
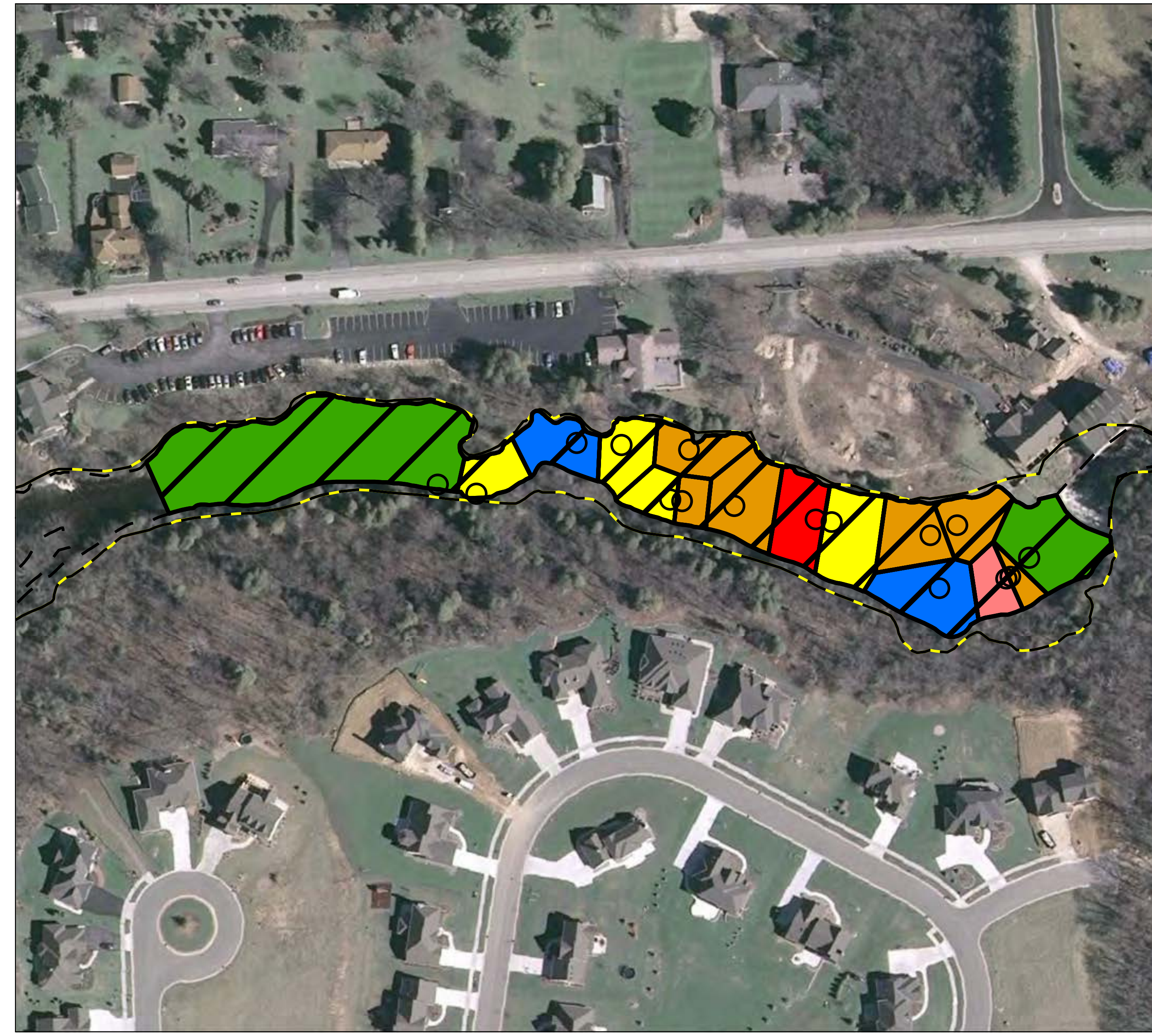
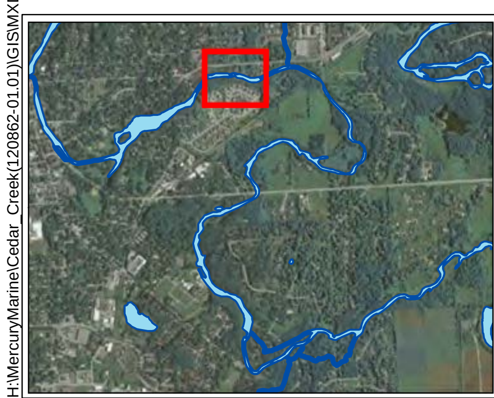
Sediment Concentrations Remaining Post-Removal (mg/kg)



Depth of Sediment Removed (ft)





Legend

Pre-Capping TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Dredging/Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

Depth (ft)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- > 6

NOTES:
Maximum remaining concentrations shown.
The pre-capping TPCB concentrations present: 1) sediment PCB concentrations of the upper 1 foot of sediment following removal and prior to capping (see capping area hatching); or 2) surface sediment PCB concentrations (0- to 1-foot increment) where no cap is proposed.
Non-detects set to half the reporting limit. Duplicates are averaged.
Empty polygons indicate no remaining sediment following removal.

0 250 500
Feet

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Figure 5-15
Sediment PCB Concentrations below Cap within Wire and Nail Pond for Alternatives SED-6 and SED-7
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

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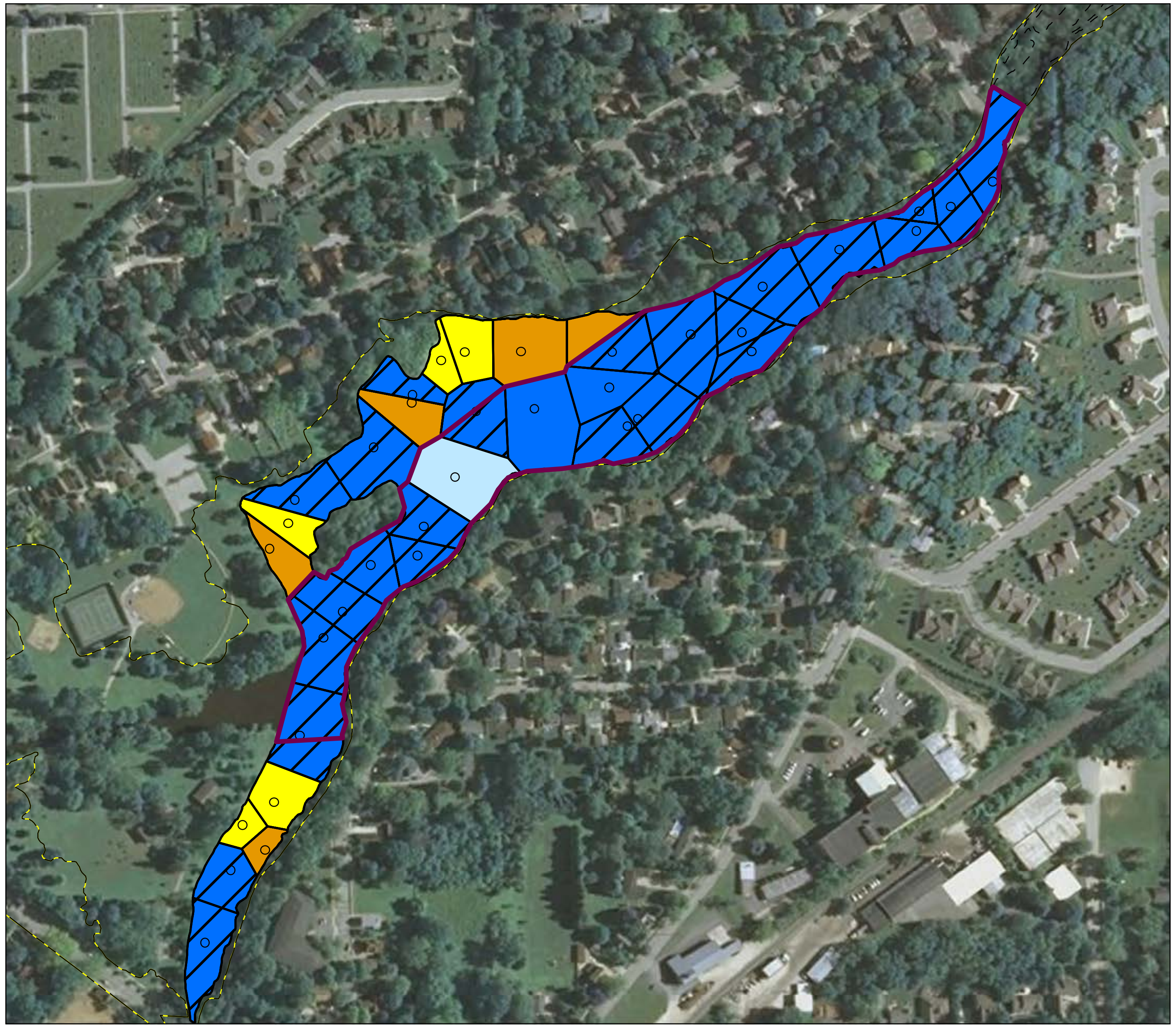
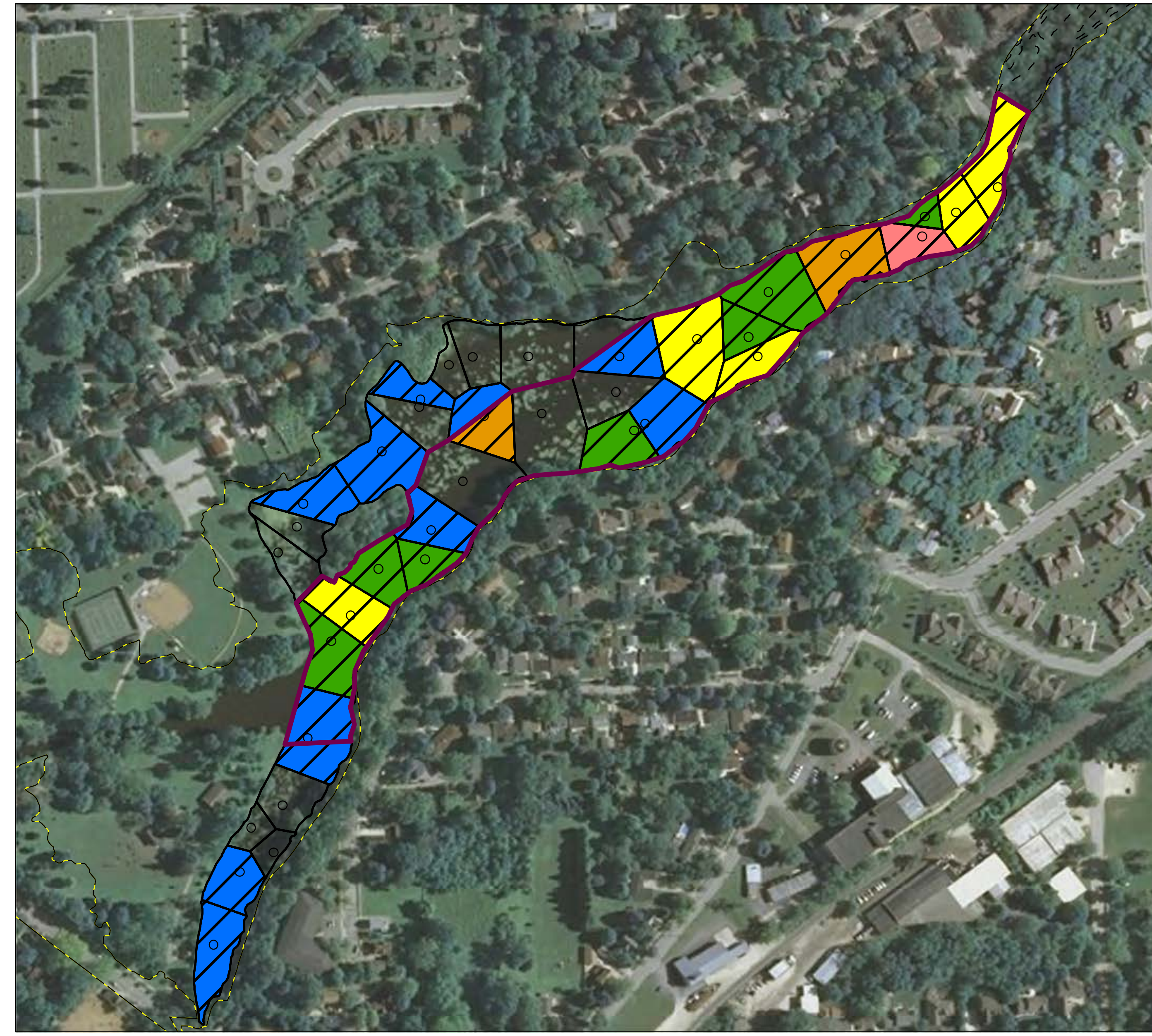
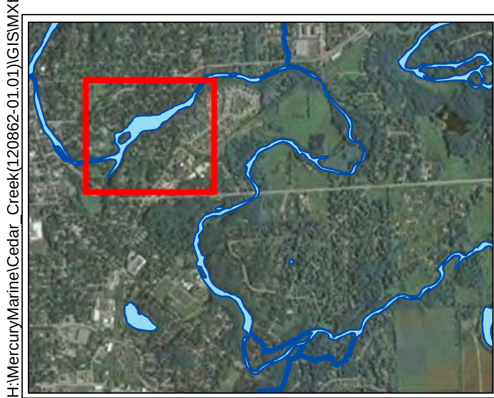
Sediment Concentrations Remaining Post-Removal (mg/kg)



Depth of Sediment Removed (ft)





Legend

TPCB Concentration (mg/kg)
- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Dredging/Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain
- Main Channel Delineation

Depth (ft)
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- > 6

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.
Empty polygons indicate no remaining sediment following removal.

0 500 1,000
Feet

Figure 5-16
Post-remedy Surface PCB Concentrations for Alternative SED-6 at Columbia Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

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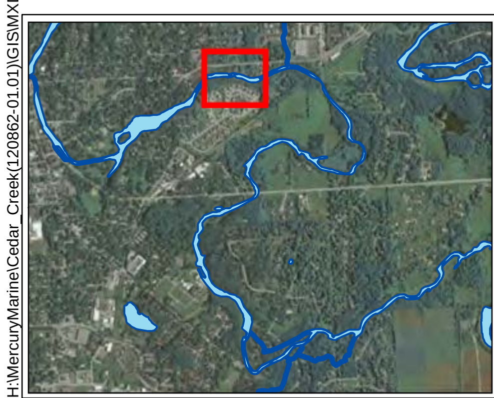
Sediment Concentrations Remaining Post-Removal (mg/kg)

Depth of Sediment Removed (ft)



Legend

TPCB Concentration (mg/kg)
- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Dredging/Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

Depth (ft)
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- > 6

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.
Empty polygons indicate no remaining sediment following removal.

0 250 500 Feet

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Figure 5-17
Post-remedy Surface PCB Concentrations for Alternatives SED-6 and SED-7 at Wire and Nail Pond
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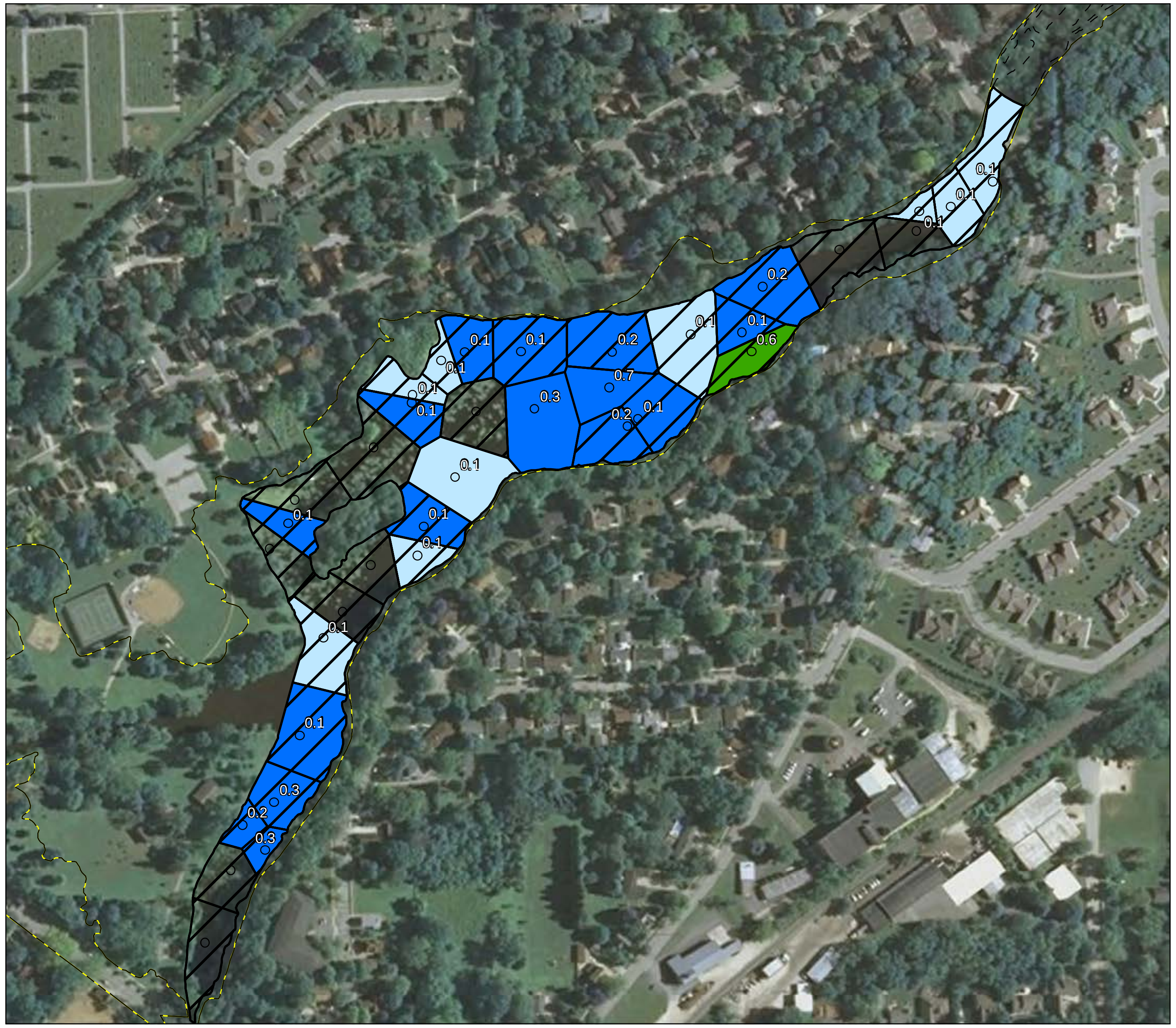
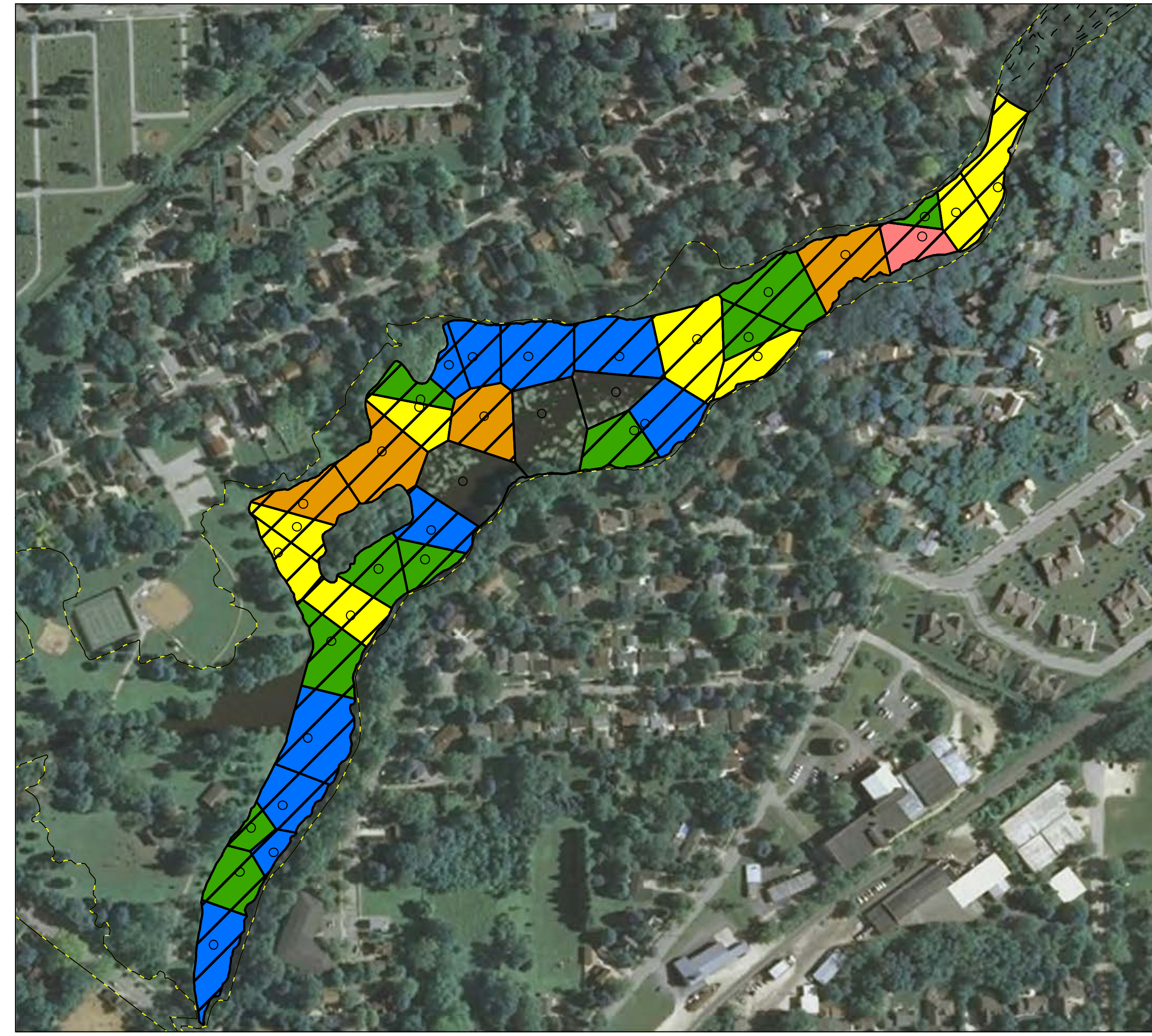
Sediment Concentrations Remaining Post-Removal (mg/kg)



Depth of Sediment Removed (ft)



Legend

Pre-Capping TPCB Concentration (mg/kg)
- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Dredging/Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

Depth (ft)
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- > 6

NOTES:
Maximum remaining concentrations shown.
The pre-capping TPCB concentrations present: 1) sediment PCB concentrations of the upper 1 foot of sediment following removal and prior to capping (see capping area hatching); or 2) surface sediment PCB concentrations (0- to 1-foot increment) where no cap is proposed.
Non-detects set to half the reporting limit. Duplicates are averaged.
Empty polygons indicate no remaining sediment following removal.

0 500 1,000
Feet

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Figure 5-18
Sediment PCB Concentrations below Cap within Columbia Pond for Alternative SED-7
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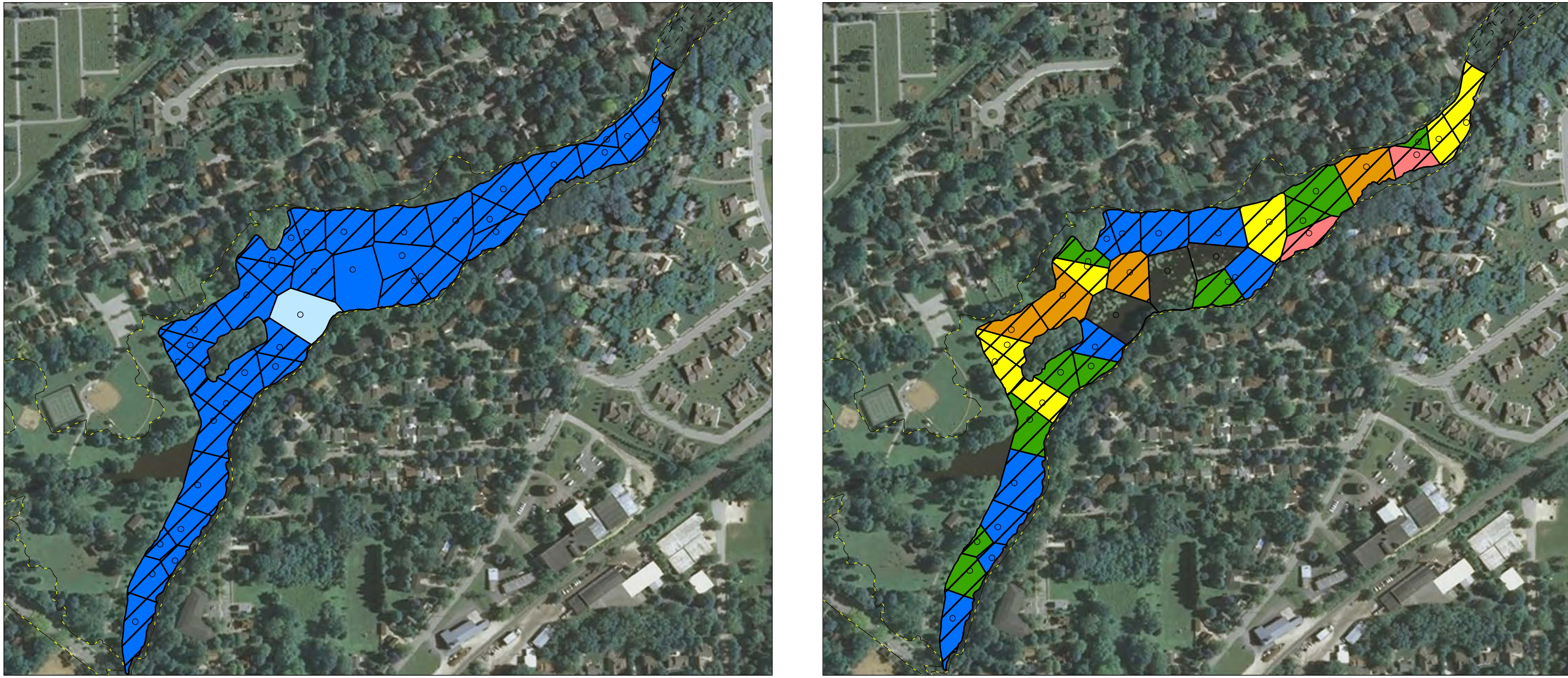
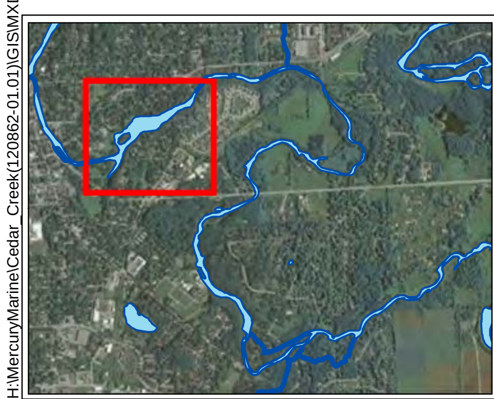
Sediment Concentrations Remaining Post-Removal (mg/kg) | Depth of Sediment Removed (ft)





Legend

TPCB Concentration (mg/kg)

- < 0.11
- 0.11 - 0.32
- 0.32 - 1
- 1 - 5
- 5 - 10
- 10 - 50
- > 50

- Dredging/Capping Area
- Core Locations
- Reach Boundary
- Approximate 10-yr Floodplain

Depth (ft)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- > 6

NOTES:
Non-detects set to half the reporting limit.
Duplicates are averaged.
Empty polygons indicate no remaining sediment following removal.

0 500 1,000
Feet

H:\MercuryMarine\Cedar_Creek(120862-01.01)\GIS\MXD\SedimentRemoval_Scenarios\Sediment_removal_scenario_maps_2Panel_20120815.mxd - P.Song - 17Oct2012

ANCHOR QEA

Figure 5-19
Post-remedy Surface PCB Concentrations for Alternative SED-7 at Columbia Pond
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

APPENDIX A
HYDRODYNAMIC MODELING TO SUPPORT FLOODPLAIN SOILS ASSESSMENT

DRAFT ALTERNATIVES ARRAY DOCUMENT

APPENDIX A: HYDRODYNAMIC MODELING TO SUPPORT FLOODPLAIN SOILS ASSESSMENT

CEDAR CREEK SITE FEASIBILITY STUDY

Prepared for

Mercury Marine

Prepared by

Anchor QEA, LLC

October 2012

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LIST OF ACRONYMS AND ABBREVIATIONS

AAD	Alternatives Array Document
cfs	cubic feet per second
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
NAVD88	North American Vertical Datum of 1988
RI	Remedial Investigation
Site	Cedar Creek Site
SMS	Surface Water Modeling System
USACE	U.S. Army Corps of Engineers
USACE-WES	USACE Waterways Experiment Station
USGS	U.S. Geological Survey

1 INTRODUCTION

A screening-level approach was developed to spatially average the floodplain soil data for use in remedial alternative development and evaluation for the Cedar Creek Site (Site). As described in Section 2.2 of the main text of the Draft Alternatives Array Document (AAD), Step 3 of this process was to laterally divide the 10-year floodplain, which is the approximate extent of PCB-containing floodplain soils as described in the Remedial Investigation (RI) Report (ARCADIS 2012), by flood inundation elevations. This appendix provides a summary of the hydrodynamic modeling activities performed to compute flood inundation elevations for the 2-year and 5-year flood events, which were assessed for laterally dividing the 10-year floodplain into smaller sections.

2 HYDRODYNAMIC MODEL OVERVIEW

The two-dimensional, Site-specific hydrodynamic models developed for use in assessing sediment stability during extreme events in the RI Report were also used to predict flood inundation elevations for the 2-year and 5-year return interval events. As described in Appendix C of the RI Report, the Site-specific models were developed using the RMA2 hydrodynamic model. The RMA2 model is a two-dimensional, depth-averaged (i.e., the model computes lateral, not vertical, variations in flows), finite element, hydrodynamic numerical model routinely used by the U.S. Army Corps of Engineers (USACE) for hydrodynamic studies, sediment stability assessments, and sediment transport studies (USACE 2006). It is currently part of the USACE TABS-MD modeling package, which is supported by the USACE Waterways Experiment Station (USACE-WES) in Vicksburg, Mississippi. The RMA2 model was used in conjunction with the Surface Water Modeling System (SMS) for RMA2, which is a pre- and post-processor that includes a graphical interface for display of inputs and results.

3 MODEL INPUT

The RMA2 model has three main components:

1. Model grid (developed based on the Site bathymetry and topography)
2. Boundary conditions (upstream flow and downstream stage)
3. Additional hydrodynamic parameters (e.g., bed roughness represented by Manning's n value and turbulent exchange coefficient represented by the Peclet number)

The model grids and additional hydrodynamic parameters used in the model simulations presented in the RI Report were also used for the 2-year and 5-year return interval flow events. These components are briefly described below and are presented in more detail in the RI Report. A detailed description of the development of the boundary conditions for the 2-year and 5-year return interval events is described below (see Boundary Conditions).

3.1 Model Grid

As described in the RI Report, the Site was divided into the following three models at the two impoundments:

- Columbia Pond Model: Extends from Ruck Pond Dam to Columbia Mills Dam
- Wire and Nail Pond Model: Extends from Columbia Mills Dam to Wire and Nail Factory Dam
- Former Hamilton Pond Model: Extends from Wire and Nail Factory Dam to the end of the Site (i.e., confluence with the Milwaukee River)

The model grids contained the main creek channel extending to the 100-year floodplain, as shown in the Ozaukee County Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) mapping (FEMA 2007).

3.2 Additional Hydrodynamic Parameters

Bed roughness and turbulent exchange coefficient are also model input parameters included in the Site-specific models. Values for both parameters used in the RI Report were also used in the flood inundation modeling.

3.2.1 Bed Roughness

The Manning's n value is used to represent the bed roughness in the hydrodynamic model. Visual observations of the creek bed and bank materials, as well as grain-size analysis of surficial sediments were used to assign bed roughness in the model grids (ARCADIS 2012). The following values were assigned to the respective bed materials in the models:

- Areas primarily covered with fine sands, silts, and clays = 0.025
- Areas primarily covered with cobble/gravel = 0.043
- Vegetated land areas = 0.060
- Open land areas (parks) = 0.050

3.2.2 Turbulent Exchange Coefficient

Turbulence may be generally defined as the effect of temporal variations in velocity and the momentum exchange associated with their spatial gradients. In particular, turbulence is viewed as the temporal effects occurring at time scales smaller than the model time step. Turbulence is accounted for in RMA2 by allowing the model to automatically adjust the turbulence exchange coefficient (E), after each solution iteration, based on a provided Peclet number. A Peclet number of 20 was utilized in the modeling.

3.3 Boundary Conditions

3.3.1 Upstream Boundary Condition – Return Interval Flow Rate

The computed return interval flow rates were used as the upstream boundary condition for Columbia Pond, Wire and Nail Pond, and Former Hamilton Pond hydrodynamic model simulations. The return interval flow rates were estimated for the 2-year and 5-year events using a statistical analysis of historical stream flow measurements from U.S. Geological Survey (USGS) Cedar Creek near Cedarburg gage (USGS #04086500), located approximately 2 miles north of Cedarburg, Wisconsin. The daily stream-flow data, which were available from 1930 through 2011, were analyzed using the USGS flood frequency analysis PeakFQ program (Flynn et al. 2006). Figure A-1 presents the daily stream flow and computed 2-year and 5-year return interval flow rates.

There are no major flow contributions from tributaries or outfalls between the Cedar Creek flow gage and the confluence of Cedar Creek with the Milwaukee River; therefore, the return interval flow rates estimated from the gage data were used in all three models, and no additional flows were incorporated into the model's upstream boundary conditions.

3.3.2 Downstream Boundary Condition – Water Surface Elevation

The downstream boundary condition for the hydrodynamic models is the return interval event water surface elevations (i.e., stage). Similar to the 10-year and 100-year hydrodynamic model runs presented in Appendix C of the RI Report, the 2-year and 5-year stages for the Columbia and Wire and Nail ponds were estimated using rating curves at the Columbia Mills Dam and Wire and Nail Factory Dam developed from HEC-2 modeling (with the Former Hamilton Pond Dam removed from the simulation) that was performed by ARCADIS.

The downstream boundary condition for the Former Hamilton Pond hydrodynamic model is the return interval stage at the confluence of Cedar Creek with the Milwaukee River. To estimate the return interval stage at this location, flow data from the USGS Cedar Creek near Cedarburg gage (USGS #04086500) were related to flow and water surface elevation data from the Milwaukee River near Cedarburg USGS gage (USGS #04086600) in the Milwaukee River (located approximately 1 mile downstream of the confluence) using a three-step process:

1. PeakFQ software was used to compute the return interval flow rates at the Milwaukee River near Cedarburg USGS gage (USGS #04086600). Daily flow rate data were available from 1982 through 2011.
2. A rating curve was developed at the Milwaukee River near Cedarburg USGS gage (USGS #04086600) using flow data and water surface elevation data that were available from 1990 through 2012. This rating curve was used to approximate the water surface elevation at the USGS gage (Figure A-2).
3. The water surface elevation at the confluence of Cedar Creek with the Milwaukee River was then estimated by accounting for the change in slope of the hydraulic grade line between the confluence and the USGS gage. The slope of the hydraulic grade

line of the Milwaukee River was estimated using the return interval flood events presented in the FEMA FIS (FEMA 2007).

3.4 Model Input Summary

The hydrodynamic model boundary conditions for the return interval simulations and the method used to estimate each value are presented in Table A-1.

Table A-1
Model Inputs for the 2-year Return Interval Event

Model	Upstream Flow Rate (cfs)		Upstream Flow Rate Method	Downstream Water Surface Elevation (feet, NAVD88)		Downstream Water Surface Elevation Method
	2-year	5-year		2-year	5-year	
Columbia Pond	916	1,691	PeakFQ[1]	768.1	768.5	HEC-2[2]
Wire and Nail Pond	916	1,691	PeakFQ[1]	757.0	757.4	HEC-2[2]
Former Hamilton Pond	916	1,691	PeakFQ[1]	675.1	675.6	Data Comparison[3]

Notes:
cfs – cubic feet per second
NAVD88 – North American Vertical Datum of 1988
1. A flood frequency analysis program developed by USGS (Flynn et. al. 2006).
2. One-dimensional HEC-2 river modeling was performed by ARCADIS.
3. Return interval flow rates and a rating curve were developed at a nearby gage in the Milwaukee River. The stage was then estimated at the confluence of Cedar Creek with the Milwaukee River based on the slope of the hydraulic grade line of the Milwaukee River during return interval flood events.

4 MODEL OUTPUT

The interval event flow rates and downstream water surface elevations were used as inputs to the Site-specific hydrodynamic models to predict flood inundation elevations. The flood inundation elevations were then extracted from the models along the center of Columbia Pond, Wire and Nail Pond, and Former Hamilton Pond to the confluence with the Milwaukee River using post-processing software. Next, the 2-year and 5-year model-predicted flood inundation elevations (and the 10-year floodplain computed as part of the sediment stability assessment from the RI Report) were plotted with the elevations of the floodplain soil samples collected along transects (see Section 2.1 of the main text of the Draft AAD for a description of the sample collection methods). Figure A-3 presents the flood inundation elevations and chemistry sample elevations from Wire and Nail Factory Dam to the confluence of Cedar Creek with the Milwaukee River. As shown on Figure A-3, a majority of the floodplain soil samples are located within the 2-year floodplain, with few samples located between the 2-year and 5-year floodplain and 5-year and 10-year floodplain. Therefore, in an effort to use a reasonable number of samples when computing average PCB concentrations described in Section 2.2 of the main text of the Draft AAD, the floodplain was laterally divided into only two segments: edge of creek to 2-year flood inundation elevation and 2-year to 10-year flood inundation elevation (see Figure 2-18 of the main text of the Draft AAD).

5 REFERENCES

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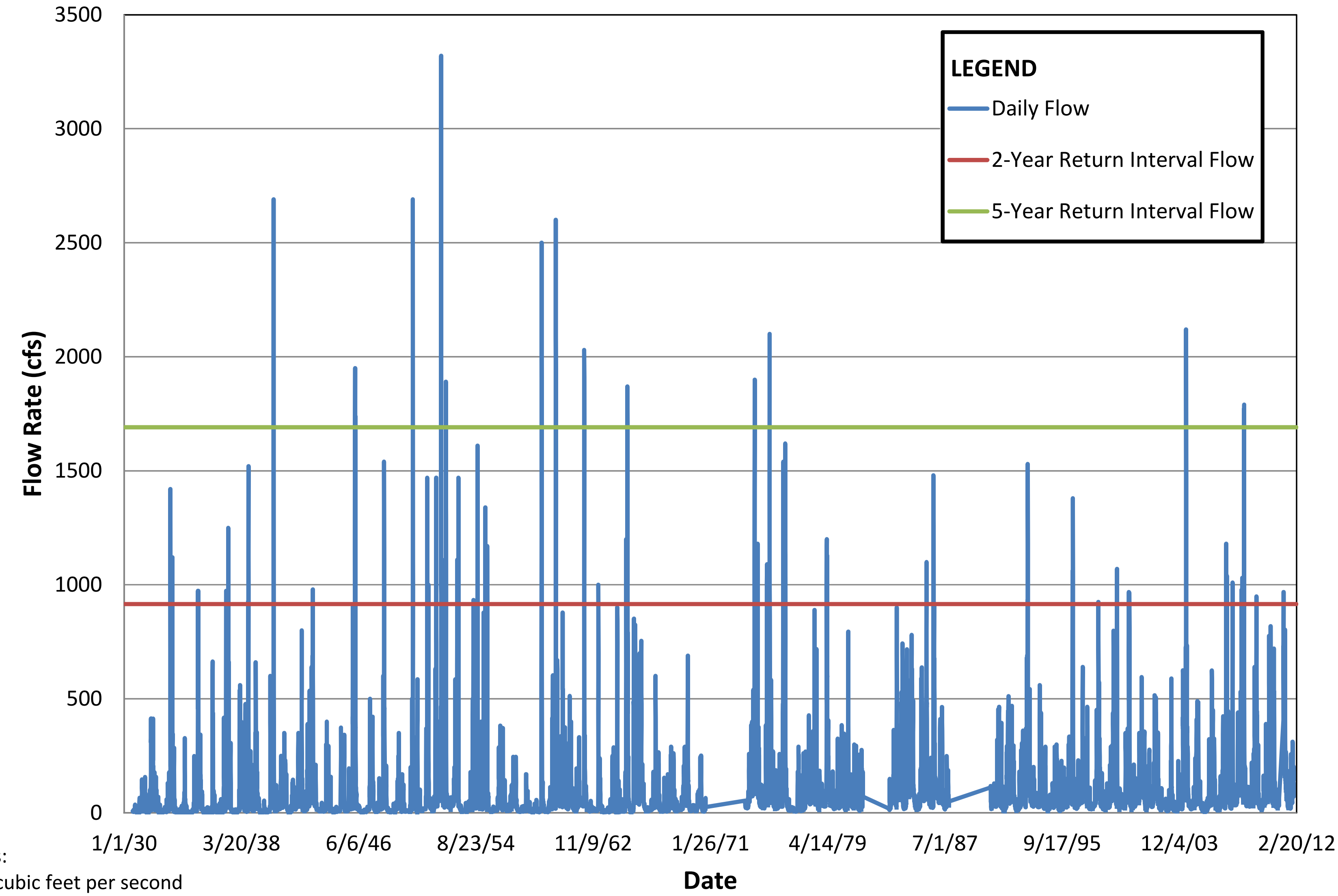
Flynn, K.M., W.H. Kirby, and P.R. Hummel, 2006. *User's Manual for Program PeakFQ Annual Flood-Frequency Analysis Using Bulletin 17B Guidelines*: U.S. Geological Survey, Techniques and methods Book 4, Chapter B4; 42 pgs.

U.S. Army Corps of Engineers (USACE), 2006. *Users Guide to RMA2 Version 4.5*. U.S. Army Corps of Engineers – Waterways Experiment Station Coastal and Hydraulics Laboratory. July 2006.

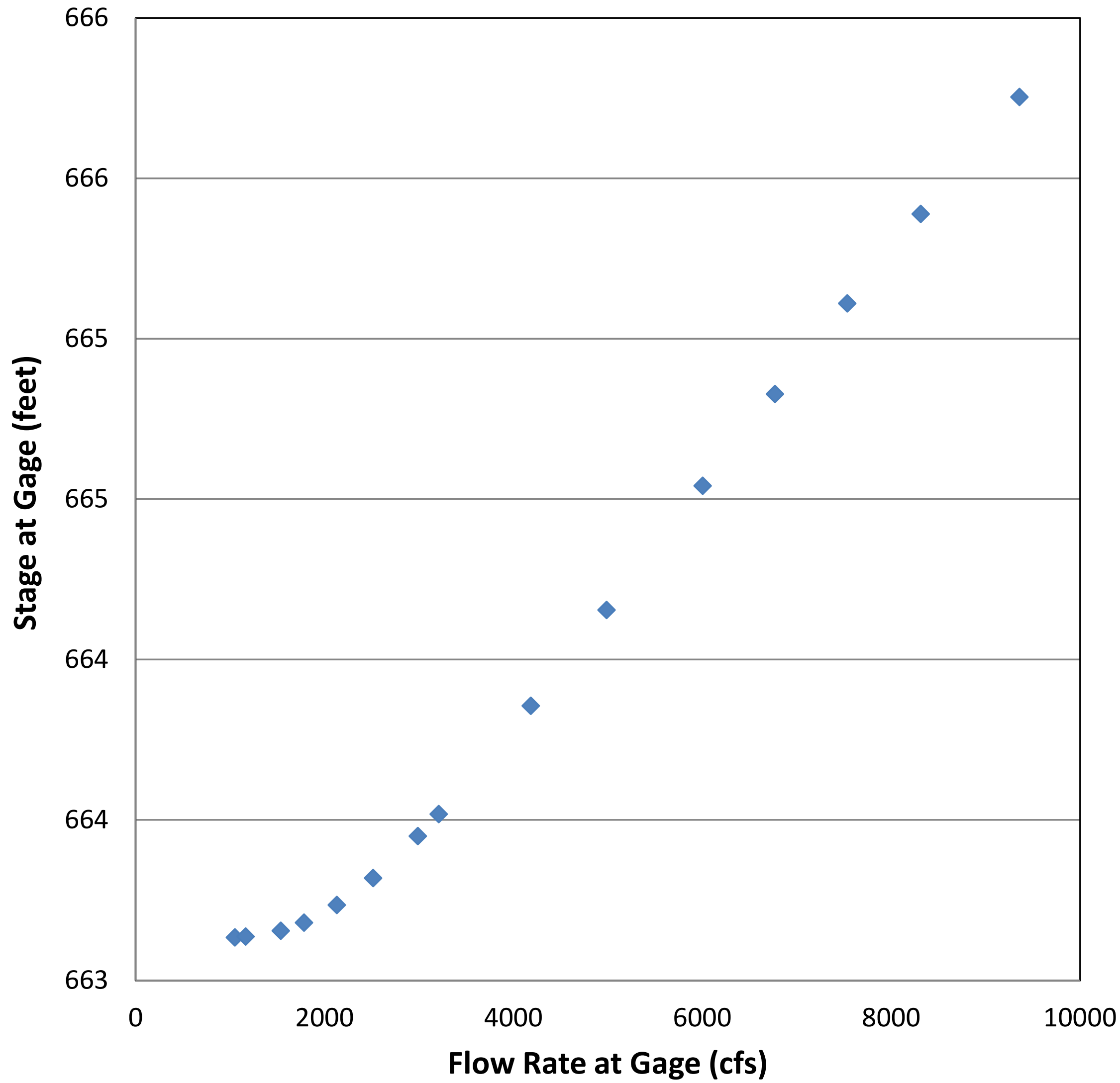
FIGURES



Notes:
cfs – cubic feet per second
Data obtained from USGS Gage Station 04086500

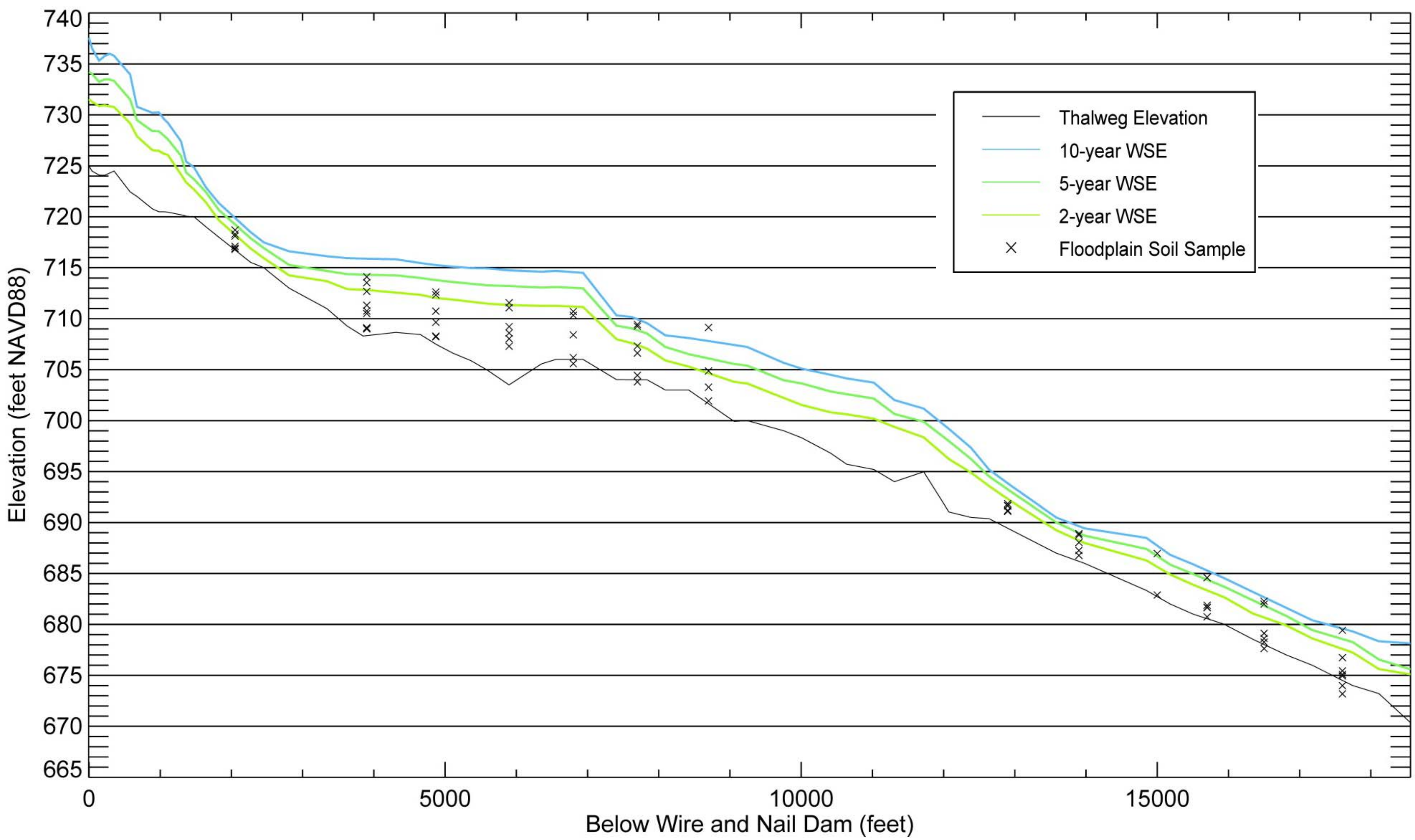
ANCHOR QEA

Figure A-1
Streamflow in Cedar Creek near Cedarburg, Wisconsin
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



Notes:
cfs – cubic feet per second
Data obtained from USGS Gage Station Milwaukee River Near Cedarburg, WI (Station ID 04086600)

Figure A-2
Rating Curve for Milwaukee River near Cedarburg, Wisconsin
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



Notes:
NAVD88 – North American Vertical Datum of 1988
WSE – water surface elevation

Figure A-3
Return Interval Elevations and Floodplain Soil Sample Elevations
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

APPENDIX B
PCB FLUX AND BIOACCUMULATION MODEL

DRAFT ALTERNATIVES ARRAY DOCUMENT

APPENDIX B: PCB FLUX AND BIOACCUMULATION MODEL

CEDAR CREEK SITE FEASIBILITY STUDY

Prepared for

Mercury Marine

Prepared by

Anchor QEA, LLC

October 2012

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
AAD	Alternatives Array Document
BSAF	biota-sediment accumulation factor
CSM	conceptual site model
DOC	dissolved organic carbon
FS	Feasibility Study
mg/kg	milligram per kilogram
ng	nanogram per liter
OC	organic carbon
PCB	polychlorinated biphenyl
POM	particulate organic matter
PRG	preliminary remediation goal
RI	Remedial Investigation
Site	Cedar Creek Operable Unit of the Cedar Creek Superfund Alternative Site
SWAC	surface-weighted average concentration
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WDNR	Wisconsin Department of Natural Resources

1 INTRODUCTION

This appendix describes a mathematical model that was developed to simulate the relationships between polychlorinated biphenyls (PCBs) in the sediment, water, and fish in Cedar Creek. This model was developed to support the Cedar Creek Site Feasibility Study (FS) and the associated Alternatives Array Document (AAD). The primary objective of the model is to provide a quantitative tool that can be used to evaluate the effectiveness of potential sediment remediation options, and to thereby evaluate remedial alternatives during the FS. This appendix describes the model development and calibration and presents initial applications of the model that were used to support the development of sediment preliminary remediation goals (PRGs) for the Cedar Creek Operable Unit of the Cedar Creek Superfund Alternative Site (Site).

2 MODEL DEVELOPMENT

2.1 Model Processes

As described in Section 2.3 of the AAD main text, the conceptual site model (CSM) for Cedar Creek was refined based on analysis of spatial gradients in Site data. The refined CSM indicates that: 1) sediments in Columbia Pond are the dominant source of PCBs to the water column at the Site; and 2) the water column is the dominant source of PCBs to the food web. The processes associated with this refined CSM are illustrated on Figure B-1, and include the following:

- Sorption of PCBs to particulate organic matter (POM) in the sediment and water column (i.e., partitioning between the dissolved and particulate phases)
- Flux of PCBs from the surface sediment porewater into the overlying water column (by a variety of mechanisms)
- Transport of PCBs to downstream reaches via the water column
- Consumption of PCBs associated with POM (in both the water column and surface sediments) by insects and other invertebrates and subsequent transfer to higher levels of the food web (i.e., forage fish consume invertebrates and are in turn consumed by higher trophic-level predatory fish)

The mathematical model described herein provides a quantitative representation of these processes, and contains two components: a sediment/water component and a fish bioaccumulation component. Details on the model framework and governing equations for these two components are provided in the following subsections.

2.2 Spatial and Temporal Scale

The model was developed on a reach-averaged basis, and is used to relate PCB concentrations in water, sediment, and fish for each of the following four reaches (see Figure 1-2 of the AAD):

- Columbia Pond
- Wire and Nail Pond
- Reach Between Wire and Nail Pond and Former Hamilton Pond
- Reach Downstream of Former Hamilton Pond

The model performs calculations for steady-state conditions, which means it predicts average fish concentrations based on average concentrations in water and surface sediment. Its calculations are meant to provide estimates over relatively long time-scales (e.g., averages over several years). Such a temporal scale is appropriate for the goal of evaluating long-term differences in sediment and fish PCB concentrations between current conditions and potential post-remediation conditions.

2.3 Model Governing Equations

2.3.1 Sediment/Water Component

The sediment and water column component of the model uses a mass balance approach for each reach. The following processes are included in this mass balance and are illustrated on Figure B-1: 1) transport of PCBs into the reach at its upstream end; 2) flux of PCBs from surface sediment porewater into the overlying water column[1]; and 3) transport of PCBs out of the reach at its downstream end. Each reach is treated as a single, completely mixed segment; the governing equation for this mass balance is:

$$QC_{up} + k_f AC_{pw} = QC \qquad (1)$$

where:

Q	=	flow rate [L^3/T]
C_{up}	=	water column PCB concentration entering the reach from upstream [M/L^3]
k_f	=	porewater mass transfer coefficient [L/T]
A	=	surface area of the reach [L^2]
C_{pw}	=	surface sediment porewater PCB concentration [M/L^3]
C	=	average water column PCB concentration of the reach [M/L^3]

Provide reference

[1] Although PCBs are exchanged between the sediment bed and water column by deposition and erosion during high flow events, these processes were not represented in the model because, as discussed in Section 2.3 of the AAD main text, these processes are episodic in nature and, therefore, likely have limited contribution to fish uptake, which occurs mostly during the growing season, when flows are generally low.

The mass balance is calculated separately for each individual reach, and the reaches are linked together by the transport terms. Specifically, the incoming PCB load for a given reach is equal to the outgoing load for the reach immediately upstream (i.e., from Equation 1, C_{up} for a given reach is equal to C from the reach upstream). Therefore, the mass balance shown by Equation 1 can be solved for the water column concentration in the reach of interest as follows:

$$C = C_{up} + \frac{k_f A C_{pw}}{Q} \tag{2}$$

Solution of Equation 2 is performed in a sequential manner (i.e., from upstream to downstream), starting with Columbia Pond. For Columbia Pond, there is no upstream reach included in the model; therefore, C_{up} for that reach is a boundary condition, which is specified as a model input.

The porewater concentration (C_{pw} in Equation 2) is related to the PCB concentration of the sediments using equilibrium partitioning formulations (e.g., Karickhoff 1984; Chapra 1997). Because PCBs are highly hydrophobic, three-phase organic carbon (OC) partitioning was used. The three phases are: 1) freely dissolved; 2) bound to dissolved organic carbon (DOC); and 3) sorbed to particulate OC. The equation for calculating the porewater concentration based on three-phase partitioning is as follows:

$$C_{pw} = \frac{C_{sed}}{f_{OC} K_{OC}} (1 + m_{doc} K_{doc}) \tag{3}$$

where:

C_{sed} = dry weight sediment PCB concentration [M/M]

f_{OC} = organic carbon fraction of sediment [M/M]

K_{oc} = organic carbon partition coefficient [L^3/M]

m_{doc} = concentration of DOC in the porewater [M/L^3]

K_{doc} = porewater DOC partition coefficient [L^3/M]

The model also uses partitioning formulations to calculate the phase distribution within the water column; this is necessary because the bioaccumulation component of the model (described in the next subsection) calculates fish uptake from the water based on the concentration of PCBs sorbed to POM in the water column. The concentration of PCBs in the water column particulate phase, expressed on a sorbed phase OC-normalized basis, is calculated as follows (e.g., Chapra 1997):

$$C_{wc,POM} = C\left(\frac{K_{OC}}{1 + f_{OC,wc}K_{OC}\,TSS + m_{doc,wc}K_{doc,wc}}\right) \tag{4}$$

where:

$C_{wc,POM}$	=	water column POM sorbed phase PCB concentration [M/M]
$f_{OC,wc}$	=	organic carbon fraction of water column particulate matter [M/M]
TSS	=	total suspended solids concentration in the water column [M/L^3]
$m_{doc,wc}$	=	water column DOC concentration [M/L^3]
$K_{doc,wc}$	=	water column DOC partition coefficient [L^3/M]

As discussed in the following subsection, the sediment and water column PCB concentrations described in the equations presented above (both expressed on a POM sorbed phase basis) are used as inputs in the bioaccumulation component of the model to calculate fish tissue PCB concentrations.

2.3.2 Fish Bioaccumulation Component

The bioaccumulation component of the model computes fish PCB concentrations as the sum of accumulation from sediment and from the water column. The model represents food web bioaccumulation using a trophic transfer factor that is the ratio of concentrations in the fish (milligram per kilogram [mg/kg] lipid) to concentrations in particulate matter (mg/kg OC). (Note that for a purely benthic food web, this trophic transfer factor is equivalent to the biota-sediment accumulation factor [BSAF].) Specifically, uptake from sediment is calculated as the product of the trophic transfer factor times the PCB concentration sorbed to sediment organic matter times the fractional contribution of sediment organic matter to the food web. Similarly, uptake from the water is calculated as the product of the trophic transfer factor times the PCB concentration sorbed to POM in the water column times the fractional contribution of water column organic matter to the food web:

$$C_{fish} = af_{sed}\frac{C_{sed}}{foc} + af_{wat}C_{wc,POM} \quad (5)$$

where:

C_{fish}	=	lipid-normalized fish PCB concentration [M/M]
a	=	trophic transfer factor [M/M]
f_{sed}	=	fraction of fish PCB uptake from sediment POM [fraction]
f_{wat}	=	fraction of fish PCB uptake from water column POM [fraction]

Note that $f_{sed} + f_{wat} = 1$.

2.4 Model Parameters

Values for the model input parameters used in the equations presented in the preceding section were developed based on Site-specific data, literature, experience from models developed at other sediment PCB sites, and through calibration. The following subsections describe how the parameters were developed and present the values used in the model.

2.4.1 Sediment/Water Component

The numerical values used for each input to the sediment and water component of the model (i.e., the equations presented in Section 2.3.1), as well as the sources from which they were obtained, are listed in Table B-1 below. A description of how these parameters were developed is as follows:

- **Flow rate**: Because the model is steady state, the average flow rate in the creek based on data from the U.S. Geological Survey (USGS) gauge at Columbia Avenue was used in the model. This value was used for all reaches because there are no significant tributaries that enter the stretch of the creek simulated in the model.
- **Sediment PCB concentrations**: For each reach, a surface-weighted average concentration (SWAC) was calculated for OC-normalized PCBs based on the 1998 and 2003 Remedial Investigation (RI) datasets using the approach described in Section 2.2.1 of the AAD main text.
- **Upstream water column PCB concentrations**: As discussed in Section 2.3.1, the model requires as a boundary condition a specification of the PCB concentration in the water flowing into Columbia Pond. This value was based on the average

concentration measured at Columbia Avenue during the 2000 to 2001 USGS sampling (U.S. Environmental Protection Agency [USEPA] 2002a, 2002b).

- **Partition coefficients**:
  - K_{OC}: The 1994 to 1995 surface water data collected by WDNR and USGS (Steuer et al. 1999) included measurements of particulate and dissolved phase PCBs as well as particulate and DOC. These data were used to develop a Site-specific estimate of K_{OC}. The average K_{OC} value calculated from the samples collected from within Cedar Creek was consistent with: 1) literature values for the PCB composition (i.e., Aroclor 1260) present in Cedar Creek (e.g., Mackay et al. 1992); 2) values calculated by Westenbroek (1993) based on 1990 to 1991 surface water data; and 3) values calculated by USGS (Steuer et al. 1999).
  - K_{doc}: The DOC partition coefficient was estimated using the common approach in which K_{doc} is assumed to equal K_{OC} times a proportionality constant (e.g., Bierman et al. 1992; Burkhard 2000). Because the nature of DOC in porewater tends to be different than that in surface water, with the latter being mostly refractory carbon, and the former containing larger amounts of labile carbon, a higher proportionality constant was used for porewater than for surface water. The values used in the model were based on values calculated from sediment and surface water partitioning studies performed at another site (Housatonic River, Massachusetts; USEPA 2006) that has a similar PCB composition to that in Cedar Creek. Based on these values, porewater K_{doc} was calculated as 10 percent of K_{OC}, and K_{doc} in surface water was calculated as 1 percent of K_{OC}. These values are also consistent with the differences in K_{doc} between surface water and sediment porewater noted by Burkhard (2000), and the water column value is the same as that used by USGS (Steuer et al. 1999).

- **OC concentrations**: The model equations require specification of OC content in the particulate and dissolved phases for both the surface water and sediment/porewater. These values were estimated based on Site-specific data, as follows:
  - Values for water column f_{OC} and DOC were specified based on representative averages from the 1994 to 1995 Wisconsin Department of Natural Resources (WDNR)/USGS sampling data from Columbia Avenue and Highland Drive (Steuer et al. 1999). The selected values were similar to those reported from the 1990 to

1991 data (Westenbroek 1993) and the 2003 RI data (ARCADIS 2012). The same values were used for each reach because no significant spatial variations were observed in the available data.

- Sediment f_{OC} values were not explicitly used in the model because the sediment PCB concentration used to calculate porewater PCB concentrations (i.e., Equation 3) is expressed on an OC-normalized basis, as discussed above. The porewater DOC concentration was assumed to equal that in the surface water. That value is generally consistent with porewater DOC values measured at other sites (e.g., USEPA 2006). Nonetheless, the sensitivity of the model to this assumption evaluated during calibration.

What does similar mean? Quantify that

- **Water column total suspended solids (TSS)**: Data from Cedar Creek show that TSS varies with flow rate; an average value was developed to represent the steady-state conditions simulated by the model. Data from surface water sampling conducted in 1990 to 1991 (Westenbroek 1993), 1994 to 1995 (Steuer et al. 1999), and 2000 to 2001 (USEPA 2002a, 2002b) were reviewed, and averages by location were calculated for each dataset. When taken as a whole, the resulting averages were found to be similar by location, so a single representative average was used in the model for all reaches. This value was found to be generally consistent with the average from the single sampling event conducted in 2003 as part of the RI (ARCADIS 2012).
- **Porewater mass transfer coefficient**: As shown in Equation 1, the model employs a surface porewater exchange coefficient (k_f) to calculate the flux of PCBs from the sediment to the overlying water column. This parameter represents the combined effects of a number of processes occurring at the sediment surface that result in a dissolved-phase mass transfer to the water column (e.g., diffusion, bioturbation, gas ebullition, hyporheic exchange). Because these processes act in unison and are difficult to measure independently, k_f is a site-specific parameter. As such, the value used in the model was determined through calibration, as discussed in Section 3.1.1 below. The final calibrated value was consistent with values from the literature (e.g., Thibodeaux et al. 2001; Thibodeaux and Bierman 2003) and with those measured at and used to model porewater PCB flux at other sites (e.g., USEPA 2000; Alcoa 2002; Erickson et al. 2005; Anchor QEA, LLC 2012).

Table B-1
Input Parameters for Sediment/Water Component of the Model

Model Parameter	Symbol	Value	Units	Data Source
Flow rate	Q	80	cubic feet/second	Average from USGS gauge 04086525
Surface sediment PCB concentration (organic carbon normalized)	C_{sed}/f_{OC}	Reach-specific	milligrams/ kilogram organic carbon	Surface sediment (0 to 12 inches) SWAC calculated for each reach from 1998 and 2003 RI data
Columbia Pond:		486		
Wire and Nail Pond:		88		
Reach Between Wire and Nail Pond and Former Hamilton Pond:		13		
Below Former Hamilton Pond:		4.9		
Surface area	A	Reach-specific	acres	Calculated using GIS software
Columbia Pond:		15		
Wire and Nail Pond:		2.5		
Reach Between Wire and Nail Pond and Former Hamilton Pond:		21		
Below Former Hamilton Pond:		16		
Upstream water column PCB concentration (Columbia Pond)	C_{up}	1	nanograms/ liter	Average fro[illegible] data at [illegible]
Organic carbon partition coefficient (log)	log K_{OC}	6.8	log liters/kilogram	Calculated from 1994 to 1995 WDNR/USGS data
Porewater DOC partition coefficient (log)	log K_{doc}	5.8	log liters/kilogram	Calculated as 0.1 times K_{OC}
Water column DOC partition coefficient (log)	log $K_{doc,wc}$	4.8	log liters/kilogram	Calculated as 0.01 times K_{OC}
Porewater DOC concentration	m_{doc}	10	milligrams/ liter	Assumed value based on surface water value and range of data from other sites
Water column particulate matter organic carbon fraction	$f_{OC,wc}$	10%	fraction	Representative average based on 1994 to 1995 WDNR/USGS data and 2003 RI data
Water column DOC concentration	$m_{doc,wc}$	10	milligrams/ liter	Representative average based on 1994 to 1995 WDNR/USGS data
Water column TSS concentration	TSS	15	milligrams/ liter	Representative average based on 1990 to 1991 WDNR data, 1994 to 1995 USGS/WDNR data, and 2000 to 2001 USGS data
Porewater mass transfer coefficient	k_f	10	centimeters/ day	Calibrated value

Where does this come from, source is vague, bs radar is on.

2.4.2 Fish Bioaccumulation Component

Two parameters were included in the fish bioaccumulation component of the model: the organic matter to biota trophic transfer factor (*a* in Equation 5) and the fractions of uptake from water and sediment (f_{wat} and f_{sed} from Equation 5, where $f_{sed} + f_{wat} = 1$). The same trophic transfer factor was applied to both media and was held constant throughout the four reaches. This value was determined through calibration, and was found to be consistent with literature, as discussed in Section 3.1.2 below. The fractions of uptake from water and sediment characterize the proportion of PCBs taken up by fish that comes from the water column POM and sediment POM, respectively. Like the trophic transfer factor, these values were determined through calibration and held constant throughout the four reaches. The final calibrated values for f_{wat} and f_{sed} were consistent with the refined CSM, in that the fraction of uptake from the water was much larger than that from sediment.

As discussed in Section 2.3.2, Equation 5 computes fish concentrations on a lipid-normalized basis. Therefore, the average fish lipid content for a given reach was used to convert the model-calculated, lipid-based values into wet-weight values for comparison to the remediation targets[2]. These values were based on the average percent lipid measured in fish collected during the 2003 to 2004 fish program (which were the same data used for model calibration, as discussed below), and are as follows:

- Columbia Pond:
- Wire and Nail Pond
- Reach Between Wire and Nail Pond and Former Hamilton P
- Reach Downstream of Former Hamilton Pond

So there isn't much different how fat the fish are. Ok. That doesn't mean that lipid content should be used to normal for every species, if at all.

[2] Though lipid content is known to vary among different fish species, the individual species sampled from Cedar Creek fish showed little variation in lipid content. The average lipid content of individual fish species analyzed for PCBs on a whole-body basis ranged from 1 to 6 percent and the average lipid content in fish fillet samples from individual species ranged from 0.5 to 2.5 percent. This relatively small variation in lipid content is consistent with the small differences observed in average PCB concentrations among the species (see Section 2.3 of the AAD main text) and supports the use of an overall average lipid content as a means of converting model-calculated, lipid-based values into wet-weight values for comparison to target concentrations.

3 MODEL RESULTS

3.1 Model Calibration

The model was calibrated to represent conditions in the early 2000s because this represents the most recent period during which measurements of PCB concentrations in all three media (i.e., surface sediments, water column, and fish) were collected[3]. Calibration was performed by adjusting model parameters until the resulting model predictions of PCB concentrations matched the data. The sediment/water and bioaccumulation components were calibrated separately, as discussed in the subsections that follow.

3.1.1 Sediment/Water Component

For the sediment/water component of the model, the porewater mass transfer coefficient (k_f) was calibrated to match the spatial pattern observed in the water column data collected in 2000 to 2001 and 2003 (see section 2.3 of the AAD main text for a description of these data and spatial gradients). The k_f value selected, 10 centimeters per day, is consistent with values used to model porewater exchange flux at many other sites (as discussed above in Section 2.3.1), and resulted in model-predicted water column concentrations that matched the Site data[4].

The results from the calibrated sediment/water component of the model are shown on Figure B-2. The model-predicted water column concentrations were within the range of data for each reach, and matched the average values by reach very closely. The model results capture the large increase in concentration observed in the average water column concentrations across Columbia Pond, as well as the lack of a spatial gradient observed in the reaches downstream of Columbia Pond (i.e., from Wire and Nail Pond to Former Hamilton Pond).

[3] There are more recent fish data from 2010, but data on sediments and surface water were not collected at that time.

[4] As discussed in Section 2.3.1, the value used for porewater DOC was uncertain and was also evaluated during calibration. However, it was found that adjusting porewater DOC had the same effect on model results as adjusting k_f (i.e., increasing or decreasing either could be used to produce similar unit changes in predicted concentrations). Thus, use of a different porewater DOC value in the model would simply require an adjustment of the k_f value so that calibration was still achieved; such adjustment would not make k_f inconsistent with the literature. Therefore the selected porewater DOC value was not varied and the calibration was achieved through adjusting only k_f.

3.1.2 Fish Bioaccumulation Component

RI warns 5x that spatial concentrations of fish are not ok to compare.

The parameters in the fish bioaccumulation component of the model (i.e., the sediment/water uptake fractions and the trophic transfer factor) were calibrated by selecting values that resulted in model-predicted, lipid-normalized fish concentrations that best matched the spatial patterns observed in the 2003 and 2004 average fish PCB concentrations from within each reach. The final value calibrated for the trophic transfer factor was 14 kg OC/kg lipid. This value is consistent with values observed in other water column-based food webs. For example, in Green Bay, Wisconsin, PCB concentrations in predator fish (measured on a lipid basis) are approximately 10 to 30 times higher than in phytoplankton (measured on an OC basis; HydroQual 1995). The value for f_{sed} that best represented the spatial gradient in fish PCB concentrations was 2 percent; therefore, f_{wat} was set to equal 98 percent. Setting f_{sed} to a value higher than 2 percent resulted in the model predicting a spatial decline in fish PCB concentrations that was greater than that exhibited by the data.

The results from the calibrated bioaccumulation component of the model are shown on Figure B-3. The predicted fish PCB concentrations match the slight decline in average concentrations observed from Columbia Pond to Wire and Nail Pond and also match the general lack of spatial gradient downstream of Wire and Nail Pond. The resulting model-predicted fish PCB concentrations were well within the range of the individual fish species averages for a given reach.

The relative PCB contributions from sediments and water to the fish can be calculated by multiplying, for each source, the dietary fraction (i.e., f_{sed} or f_{wat} from Equation 5) by the PCB concentration in the POM and the trophic transfer factor. Based on the calibrated model, approximately 53 percent of the PCBs in the fish from Columbia Pond originated from the sediments and 47 percent from the water column. The contribution of local sediments declined downstream—17 percent in Wire and Nail Pond, 3 percent in the Reach Between Wire and Nail Pond and Former Hamilton Pond, and 1 percent in the Reach Downstream of Former Hamilton Pond—due to the large decrease in sediment PCB concentrations with downstream distance. Note that in Columbia Pond and Wire and Nail Pond these PCB doses from local sediment organic matter are considerably greater than the fractional contribution of sediment organic matter (i.e., f_{sed} = 2 percent) to the diet. This is because PCB concentrations on the sediment organic matter are much greater than PCB concentrations on the water column POM (e.g., OC-normalized PCB concentrations of Columbia Pond surface sediment are approximately 50 times higher than the concentrations calculated for the water column POM sorbed phase in that reach).

Finally, as discussed previously, the majority of the PCBs in the water column (in all four reaches) are derived from sediment flux in Columbia Pond. Thus, even though the food web's consumption of organic matter is dominated by water column uptake within each reach, the PCBs in the sediments, especially within Columbia Pond, are the ultimate source to the water and thus drive the overall bioaccumulation of PCBs under current conditions in all four reaches.

3.2 Initial Model Applications

The calibrated model was used to evaluate the effects of sediment remediation in Columbia Pond and the role of the upstream boundary condition on fish PCB concentrations by performing a series of initial simulations. The inputs for these simulations were based on the following:

- Two sediment PCB concentrations in Columbia Pond (expressed as a SWAC) were evaluated: 1 mg/kg (dry weight) and 0.2 mg/kg. These hypothetical post-remediation concentrations were used to support the development of PRGs for the Site, as discussed in Section 3.5.1 of the AAD main text. These two levels span a range of PCB concentrations that might be achieved through varying extents of remediation in the pond. Section 5 of the AAD main text presents sediment remedial alternatives that would achieve SWACs of 1 mg/kg (e.g., SED-3, SED-4) and 0.2 mg/kg (e.g., SED-5, SED-7), when assuming a PCB concentration of 0.2 mg/kg (i.e., average method detection limit of the RI PCB results) would be achieved in the capped areas.
- In addition to the base value used in the calibrated model of 1 nanogram per liter (ng/L), an alternate value of 0.5 ng/L for the water column PCB concentration upstream of Columbia Pond was evaluated. This lower concentration was used to represent potential reductions that may have occurred since the data were collected in 2000.

The results of these initial model applications are presented in Table B-2.

Table B-2
Model-predicted Fish Concentrations for Initial Model Applications

Scenario	Surface Sediment Concentration in Columbia Pond (SWAC)		Upstream Water Concentration (µg/L)	Average Fish Tissue Concentration in Columbia Pond (mg/kg wet weight)
	(mg/kg dry weight)	(mg/kg OC)		
Values in calibrated model (based on data from early 2000s)	33.4	486	1	4.2
Remediation to achieve approximately 1 mg/kg SWAC in Columbia Pond (based on polygon removal analysis)	1	12	1	0.23
	1	12	0.5	0.16
More extensive remediation in Columbia Pond	0.2	2	1	0.14
	0.2	2	0.5	0.08

Notes:
µg/L – micrograms per liter
mg/kg – milligrams per kilogram
OC – organic carbon
SWAC – surface-weighted average concentration

A different organic content was used for this calculation.

The model predicts that when using existing upstream conditions (i.e., 1 ng/L), remediation of sediments within Columbia Pond to achieve a SWAC of 1 mg/kg would result in an average fish PCB concentration in Columbia Pond of approximately 0.2 mg/kg. A more extensive remediation that would result in a SWAC of 0.2 mg/kg is predicted to reduce average fish PCB concentrations to between 0.1 mg/kg and 0.2 mg/kg. Assuming an upstream water column concentration of 0.5 ng/L, and a remedy that achieves a SWAC of 1 mg/kg in Columbia Pond, the resulting fish tissue concentrations are between 0.1 mg/kg and 0.2 mg/kg. Finally, the more extensive remediation coupled with an upstream water concentration of 0.5 ng/L resulted in predicted fish PCB concentrations of approximately 0.1 mg/kg in Columbia Pond.

4 SUMMARY AND NEXT STEPS

A site-specific mathematical model that is consistent with the Cedar Creek refined CSM has been developed. It is based on well-established principles of PCB fate, transport, and bioaccumulation modeling, including a mass balance for PCB transport in the water column and exchange with the sediments, equilibrium partitioning, and linear trophic transfer to calculate fish PCB concentrations based on the concentrations of PCBs sorbed to POM in the water column and surface sediment. The model's input parameters were developed based on available site-specific data, literature, and experience from other sites. By adjusting a limited number of parameters, the model was calibrated and is able to reproduce the observed spatial gradients in the Cedar Creek water column and fish tissue PCB concentrations. The model was used to develop preliminary predictions of achievable fish PCB concentrations in Columbia Pond based on two sediment remediation scenarios (SWAC of 1 mg/kg and 0.2 mg/kg) and two input values for the upstream water column PCB concentration (1 ng/L and 0.5 ng/L) to support PRG development.

This model will be used in the FS to evaluate the full range of alternatives developed for the Site (i.e., as described in Section 5 of the AAD main text). These evaluations will support the effectiveness assessment of each alternative. The FS modeling evaluations will be performed by developing estimates of the post-remediation sediment PCB concentrations in each reach (based on remedial footprint), and using the model to predict fish PCB concentrations that would be achieved in each reach, for each alternative evaluated in the FS. These modeling evaluations will likely include sensitivity analyses surrounding certain inputs/assumptions (such as that included herein for the upstream water column PCB concentration). These model-based analyses will be documented in an appendix to the FS.

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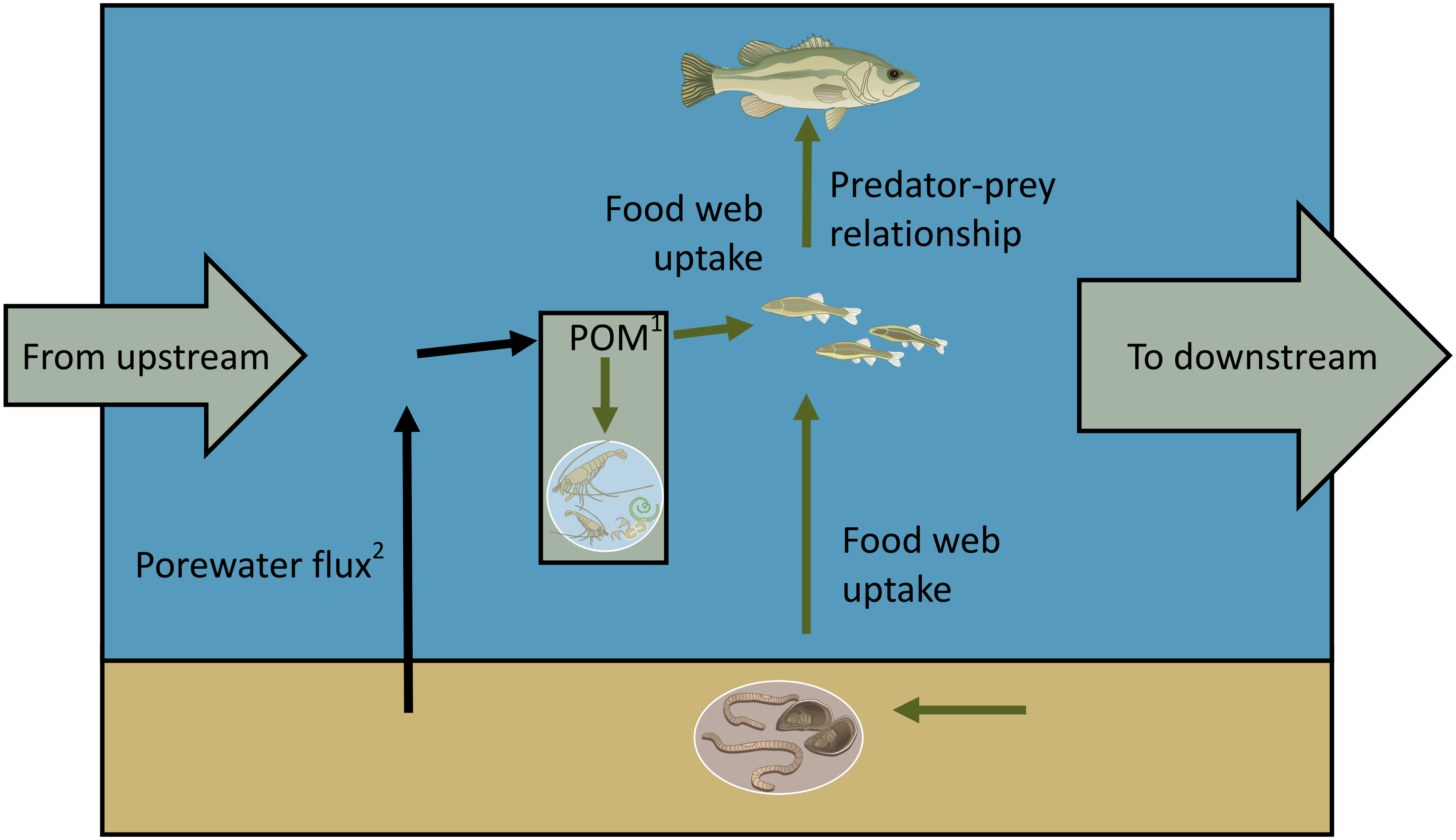
FIGURES



This is a simplified representation of polychlorinated biphenyl (PCB) fate and transport and bioaccumulation, including only the most important pathways for decision-making in Cedar Creek.

Notes:

1 POM = particulate organic matter

2 Porewater flux refers to a range of mechanisms that result in the movement of PCBs in dissolved form from the sediment bed into the overlying water.

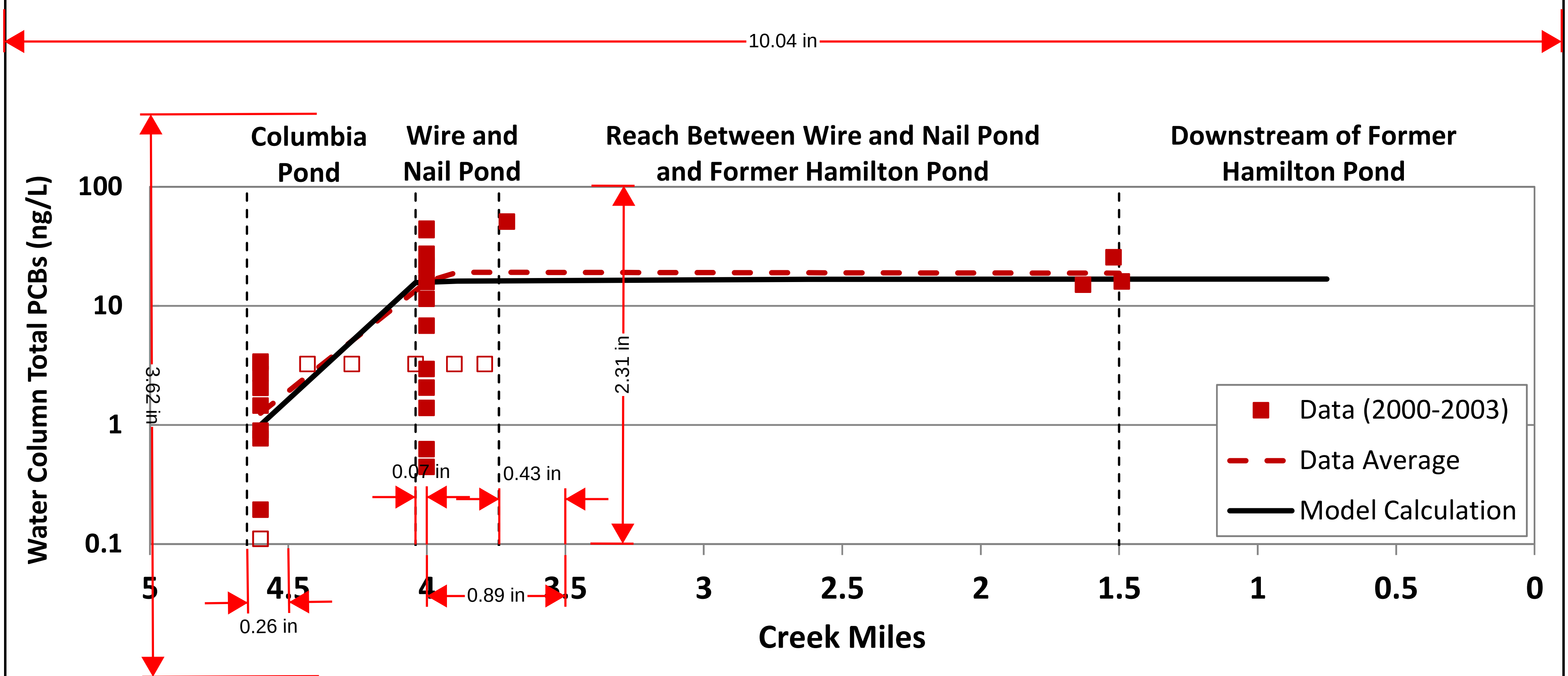
Legend

Physical/chemical processes

Biological processes

ANCHOR QEA

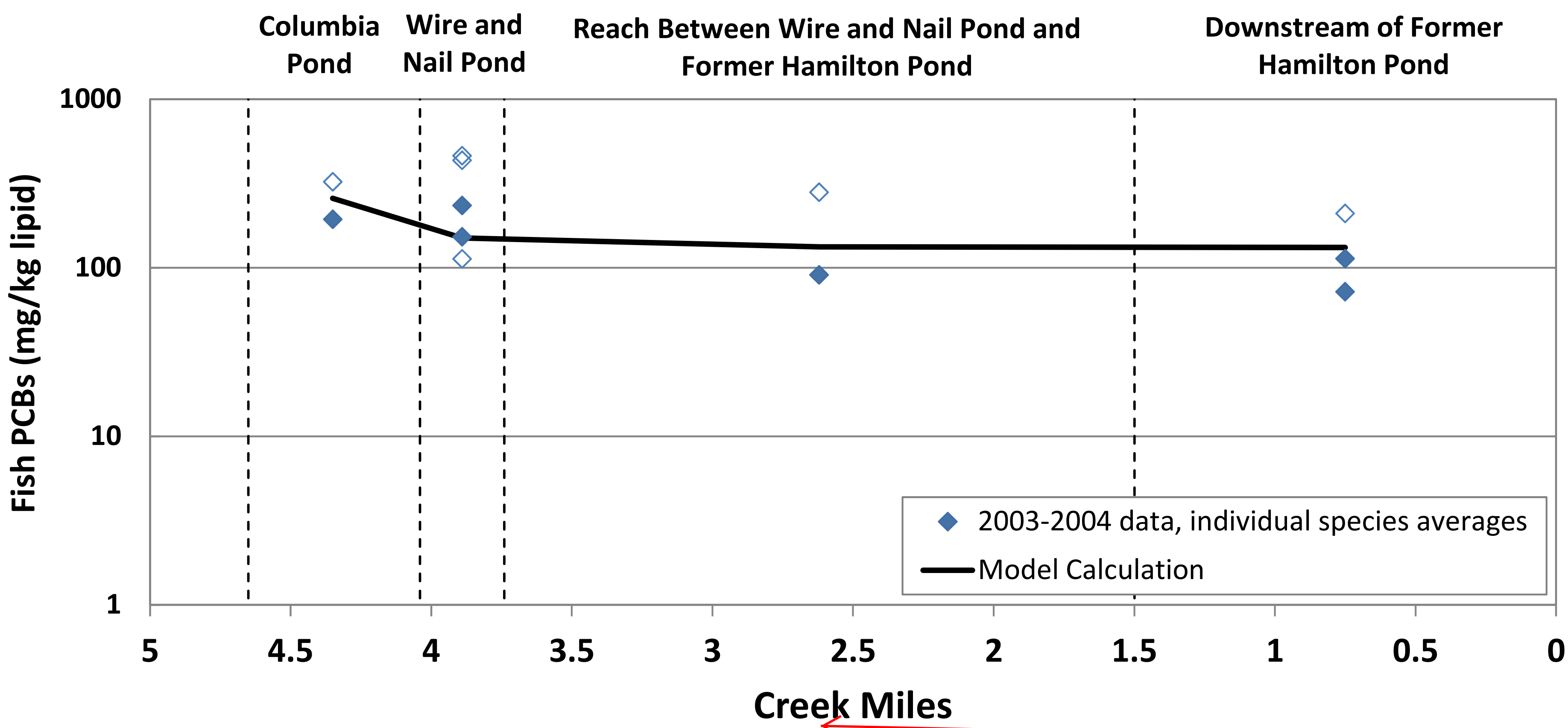
Figure B-1
Routes of PCB Uptake by Fish in Cedar Creek
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



Note:
Non-detects set to half the MDL and shown as open symbols.

ANCHOR QEA

Figure B-2
Comparison of Model-predicted and Observed Water Column PCB Concentrations
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study



Creek Miles is not part of the conceptual site model. Why is it being shown.

Note:
Whole-body fish preparations are shown as open symbols.

ANCHOR QEA

Figure B-3
Comparison of Model-predicted and Observed Fish PCB Concentrations
Draft Alternatives Array Document
Cedar Creek Site Feasibility Study

APPENDIX C
PCB CONCENTRATIONS IN PRECIPITATION AND SURFACE WATERS IMPACTED BY ATMOSPHERIC INPUTS

DRAFT ALTERNATIVES ARRAY DOCUMENT

APPENDIX C: PCB CONCENTRATIONS IN PRECIPITATION AND SURFACE WATERS IMPACTED BY ATMOSPHERIC INPUTS

CEDAR CREEK SITE FEASIBILITY STUDY

Prepared for

Mercury Marine

Prepared by

Anchor QEA, LLC

October 2012

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LIST OF ACRONYMS AND ABBREVIATIONS

AAD	Alternatives Array Document
ICPRB	Interstate Commission on the Potomac River Basin
ng/L	nanograms per liter
PCB	polychlorinated biphenyl

1 INTRODUCTION

The model used to quantify the relationship between sediment, water, and fish polychlorinated biphenyl (PCB) concentrations in Cedar Creek (documented in Appendix B) requires, as a boundary condition, an estimate of the water column PCB concentration entering Columbia Pond. For Columbia Pond, the incoming water column PCBs are derived from a combination of atmospheric inputs to the watershed above Columbia Pond, as well as potential post-remediation residual PCBs associated with Ruck Pond. No specific measurements exist of the potential contribution from Ruck Pond. However, a literature review was conducted on PCB concentrations measured in precipitation and surface water bodies having no known PCB sources other than atmospheric deposition.

PCBs are present throughout the biosphere. Sampling of surface water bodies having no sources other than atmospheric deposition and sampling of precipitation commonly indicate average PCB concentrations in the range of approximately 0.1 to 1.5 nanograms per liter (ng/L) (Table C-1). For example, Glaser et al. (2006) reported PCB concentrations in rainwater sampled from a rural watershed in the southeastern U.S. averaging 0.3 ng/L and ranging from 0.07 to 1.3 ng/L. The Interstate Commission on the Potomac River Basin (ICPRB; 2007) reported PCB concentrations in small streams within the Potomac River Basin that averaged between 0.1 and 0.4 ng/L. More local to Cedar Creek, in the Great Lakes Basin, PCB concentrations in precipitation reported by Salamova and Hites (2010) and Sun et al. (2006) generally averaged 1 to 1.5 ng/L in non-urban areas. In surface water from Grand River, Michigan, PCB concentrations in 2005 were reported to range from approximately 1 to 3 ng/L (Westenbroek 2010).

The data listed in Table C-1 show surface water PCB concentrations attributable to atmospheric sources are expected to range from 0.3 to more than 1 ng/L.

Table C-1
Summary of Literature-reported PCB Background Concentrations in Surface Water and Precipitation

Location	Collection Dates	Waterbody: Mean and Range of PCB Concentration (ng/L)	Waterbody: Sample Size	Precipitation: Mean and Range of PCB Concentration (ng/L)	Precipitation: Sample Size	Citation
Lake Tahoe	1995	0.375[1]	2	4.95 (4.8 - 5.1)[2]	2	Datta et al. 1998
Marlette Lake		0.68[1]	1	-	-	
Chester, NJ (light suburban)	1998-2001	-	-	0.52 (0.10)[3]	12	Van Ry et al. 2002
Pinelands, NJ (background forest)		-	-	0.38 (0.076)[3]	27	
Tuckerton, NJ (coastal, light residential)		-	-	0.35 (0.11)[3]	13	
Chicago, IL	1997-2003	-	-	7.1±0.9 (1.5-35)	7	Sun et al. 2006
Sleeping Bear Dunes, MI	1997-2003	-	-	1.1±0.10 (0.1-6.1)	7	
Etowah River	2003	0.29	-	-	-	USEPA 2004
Oostanaula River		0.28	-	-	-	
Savannah River	2004-2005	0.083 (0.021 - 0.15)	2	0.29	12	Glaser et al. 2006
Oconee River		0.17 (0.10-0.24)	2	-	-	
Ocmulgee River		0.38 (0.25 - 0.50)	2	-	-	
Grand River, MI	2005	1.66 (1.0-2.88)	11	-	-	Westenbroek 2010
Aquia Creek	2005-2006	0.16 (0.05 - 0.26)	2	-	-	ICPRB 2007
Chopawamsic Creek		0.31 (0.06 - 0.64)	3	-	-	
Coan Mill Stream		0.27 (0.19 - 0.34)	2	-	-	
Monroe Creek		0.37 (0.35 - 0.39)	2	-	-	
Nomini Creek		0.16 (0.13 - 0.19)	2	-	-	
Occoquan River		0.18	1	-	-	
Pohick Creek		0.12 (0.08 - 0.16)	2	-	-	
Potamac Creek		0.12 (0.08 - 0.16)	2	-	-	
Powel Creek		0.24 (0.17 - 0.32)	2	-	-	

Table C-1
Summary of Literature-reported PCB Background Concentrations in Surface Water and Precipitation

Location	Collection Dates	Waterbody: Mean and Range of PCB Concentration (ng/L)	Waterbody: Sample Size	Precipitation: Mean and Range of PCB Concentration (ng/L)	Precipitation: Sample Size	Citation
Quantico Creek	2005-2006	0.16 (0.04 - 0.37)	3	-	-	ICPRB 2007
Upper Machodoc Creek		0.045 (0.04 - 0.05)	2	-	-	
Williams Creek		0.19 (0.18 - 0.20)	2	-	-	
Eagle Harbor, MI	2003-2007	-	-	0.98±0.13	45	Salamova and Hites 2010
Chicago, IL	2003-2007	-	-	6.8±0.76	45	
Sleeping Bear Dunes, MI	2003-2007	-	-	1.50±0.25	43	
Cleveland, OH	2003-2007	-	-	2.8±0.30	54	
Sturgeon Point, NY	2003-2007	-	-	1.3±0.40	41	

Notes:
1. Mean dissolved
2. Snow
3. ∑PCB volume weighted mean (standard error) ng/L

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