Estabrook Impoundment Sediment Remediation Pre-Design Study

Project Completion Report to USEPA

GLNPO Grant ID GL2000-082

Wisconsin Department of Natural Resources

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1. Introduction

The Milwaukee Remedial Action Plan Technical and Citizen's Advisory Committees (RAP) (WDNR, 1994a) recognized contaminated sediment as the major contributor to use impairments within the area of concern (AOC). Significant examples of the use impairment are the fish consumption advisories, in effect from Grafton to the mouth of the Milwaukee River, because of contamination from polychlorinated biphenyls (PCBs).

The contaminated sediment management strategy of the RAP identified remediation of upstream sources of contaminated sediments as a top priority. An earlier study of the site estimated that the Estabrook Impoundment on the Milwaukee River holds over 100,000 cubic yards of sediment contaminated with an estimated 5,200 Kg of PCBs (Baird and Associates, 1997). This study found that the Estabrook Impoundment contributes the greatest mass loading of PCBs to the Milwaukee River and Milwaukee Harbor. Remediation of contaminated sediment in the impoundment was expected to result in a long-term reduction in PCB mass transport in the Milwaukee River of up to 70% (Baird & Associates, 1997).

The Wisconsin DNR initiated a pre-design study of the impoundment in 2000. Funding for this study was granted by the Environmental Protection Agency's Great Lakes National Program Office (GLNPO). This report fulfills the requirements of that GLNPO grant (#GL-2000-082). This work could not have been completed without funding from the EPA, and for that the Wisconsin DNR is grateful.

2. Study Purpose and Scope

Prior to this study the data on PCB contamination in the sediment of the Estabrook Impoundment was very limited. Some high concentrations were identified by earlier sampling but the volume and extent of the contamination was not known. In addition, other important information on other potential contaminants and sediment engineering properties was lacking. The goal of this project was to better characterize sediment in the impoundment and to gather important information necessary for further design work to manage these sediments. Key objectives of this project:

1. Documents the volume of contaminated sediments within the Estabrook Impoundment;
2. Define horizontal and vertical extent of contamination;
3. Delineates the extent of PCB contamination within the Estabrook Impoundment; and
4. Confirms whether there is significant continued PCB transport from upstream areas;
5. Generates data required by NR347.

3. Site Background

Site Location

This project is located between the City of Glendale and the City of Milwaukee, in Southeast Wisconsin (Figure 1). The project encompasses Lincoln Creek downstream of Green Bay Road, the Milwaukee River downstream of the confluence with Lincoln Creek and the Milwaukee River upstream of the Estabrook Park Dam.

Figure 1. Project Location

The Estabrook impoundment contains a major contaminated sediment “hot spot” acting as a source of PCBs to the Milwaukee Estuary and Lake Michigan. Contaminated sediments are either wholly or partially responsible for most of the 11 use impairments identified in the Milwaukee Estuary RAP. In recognition of the role contaminated sediments play within the AOC and upstream, the RAP Sediment Work Group outlined a comprehensive contaminated sediment management strategy to address this complicated issue. A major component of the sediment strategy is to identify and remediate upstream sources of contaminated sediments to the Milwaukee Estuary.

The study area was divided into 5 zones for convenience (Figure 1). The zones focus on the following areas within the Estabrook Impoundment***:***

- Zone 1: Lincoln Creek from Green Bay Road to the confluence with the Milwaukee River.
- Zone 2: Entire western “oxbow” in the Milwaukee River, which contains the main sediment deposit.
- Zone 3-5: Milwaukee mainstem reaches from the confluence of the western “oxbow” downstream to Estabrook Park Dam including the Blatz Pavilion inlet.

Site History

Estabrook Impoundment is formed by the Estabrook Dam which was built in 1936. The dam backs up water approximately two and one-half miles to a point about 0.3 miles upstream of Silver Spring Road on the Milwaukee River, creating a 103 acre pool. The dam also has an impact on Lincoln Creek to a point about 0.5 miles upstream from the confluence with the Milwaukee River. The dam was built on a limestone outcrop in the river channel. The dam has a hydraulic height of 8 feet. The maximum storage is 700 acre feet.

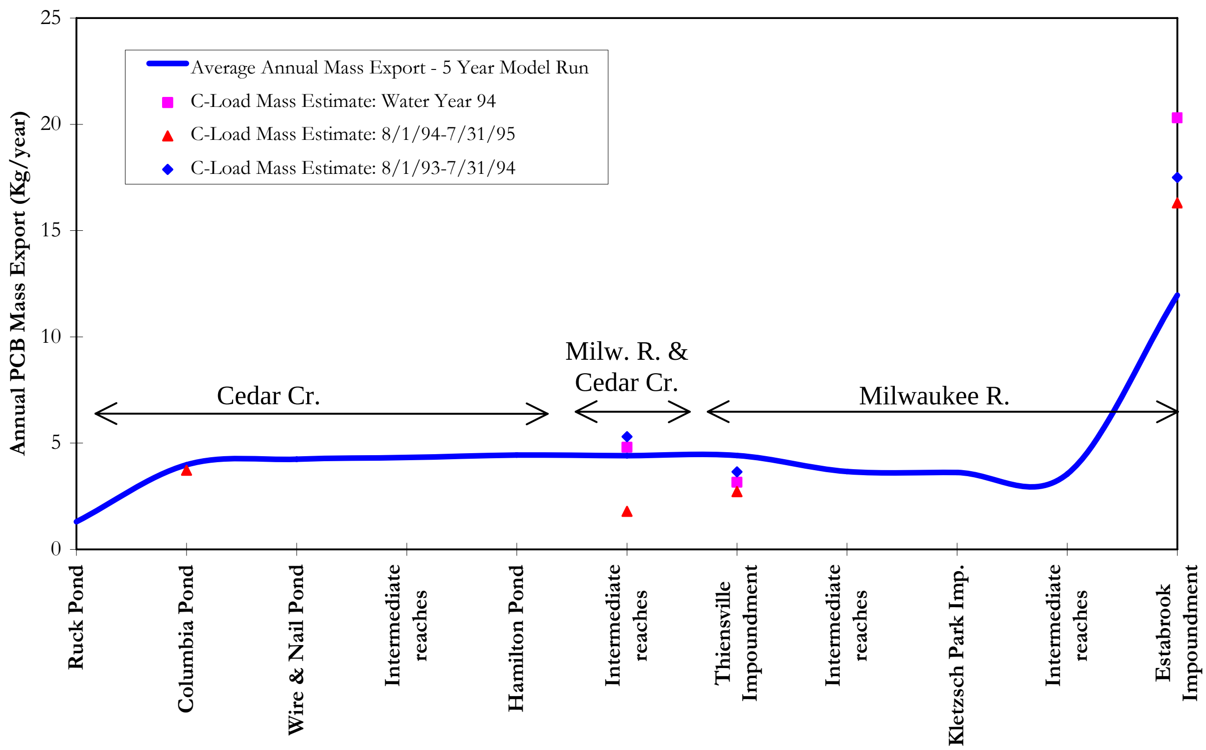
The dam has been operated to keep it open during the winter months and shut in the summer. The water pool behind the dam has also been lowered in anticipation of high flows. Periodic opening of the dam has caused the contaminated sediment to be periodically dewatered and resulted in some compaction of the sediment in the impoundment. A recent Department inspection of the dam has identified the need for significant repair work.

Past Studies

Previous work, funded by GLNPO , established the presence of an approximately 100,000 cubic yard (76,00 cu.m.) soft sediment deposit, containing about 5,200 Kg (11,500 lbs) of PCB as Aroclor 1242 (Baird & Associates, 1997). Water column monitoring for PCB, and suspended solids was conducted, and mass balance modeling was performed.

Results of work done by the United States Geological Survey (Steuer et al, 1999) shows that the Estabrook Impoundment is responsible for increasing the mass transport of PCB within the Milwaukee River system from about 5 Kg/year upstream to about 15 Kg/year downstream. Thus, this single impoundment contributes about two thirds of the total mass of PCB transported in the Milwaukee River.

Figure 1 PCB Transport in the Milwaukee River from Baird & Associates pg 74



4. Upstream Transport of PCBs

One aspect of this study was to determine if there is significant continuing transport of PCBs from upstream. There are three reference studies that indicate little continuing contribution from Lincoln Creek.

The USGS studied the distribution and transportation of PCBs in the Milwaukee River system in 1993 – 1995 (Steuer, et al, 1999). The USGS study was inconclusive in determining if Lincoln Creek was a continuing source of PCBs to the Estrabrook Impoundment. That report states " Lincoln Creek may have been or still is an additional source of PCBs to the river."

In 1994 the Department also completed a study of impacts of storm water runoff on urban streams in Milwaukee County (WDNR 1994b). As part of that study PCB concentrations in sediment in Lincoln Creek were measured. There were no significant concentrations of PCBs found. The highest concentration was 0.88 mg/kg (mg/kg is equivalent to parts per million or ppm) found downstream of Green Bay Avenue. Additional sampling was conducted by placing 8 semipermeable polymeric membrane devices in the creek. They were left in the creek for 30 days then tested for contaminants that were concentrated in these devices. No PCBs were detected in these devices.

In 1997 Baird & Associates reported on efforts to identify the mass balance of PCBs in the Milwaukee River Basin (Baird and Associates, 1997). Thirteen sediment traps were placed in Lincoln Creek. The highest concentration of PCBs in the traps was 0.75 mg/kg from a site located at Teutonia Avenue. The report concluded "Sediment trap results performed on Lincoln Creek were inconclusive, but suggest that current PCB transport from Lincoln Creek is low."

5. Data Collection

Water and sediment samples were taken on 12 dates during the course of the project from October 2001 through September 2003. Additional data from sampling in 1993 was also incorporated in the analysis.

Sediment samples were obtained using a core sampler and a Ponar dredge sampler. Sediment core samples were obtained with a 3 inch PVC core sampler lined with lexane core liners and fitted with a upper check valve to help retain the sediments in the sampler. A total of 246 sediment samples were used by this project to map the occurrence and distribution of PCBs, PAHs and metals in the sediments of the impoundment. Details on the sampling methods are presented in the project Quality Assurance Project Plan (WDNR, 2001).

Water samples for PCB analyses were obtained by wading into the stream and compositing subsamples from various points across the stream. Subsamples are taken at the two quarter points and the midpoint of the stream transect, at minimum. Subsampling depth is approximately 6/10 of the stream depth. During high flow the subsamples are taken from bridges below each dam using a weighted sampler. Sample volumes ranged from 40 to 80 liters. PCB water samples were filtered and extracted in the field. Water samples for metals and organics were collected in appropriate containers and processed according to the QAPP. Seven water samples were taken for PCB analysis and 29 water samples were taken for total suspended solids analysis.

Water depth and sediment thickness were measured to assess the volume of soft sediment in the project area. Water depths were measured using a standard sediment sounding pole or surveyors rod. Sediment thickness, defined as the depth below the sediment surface that is penetrated by the sounding pole, was measured by subtracting the total depth of penetration of the sounding pole from the measured water depth. Measurements of water depth were made at 59 cross sections established across the channels and at spot locations throughout the study area.

6. Bathymetry

Water depths in the impoundment were measured at a time when the dam gates were closed. Depth measurements were made in cross sections spaced approximately 75 meters apart in the impoundment. The depth measurements were hand contoured between cross sections. Water depths were deepest in the Milwaukee River, ranging from 1 to 2 meters in depth, and shallowest in the oxbows which were generally below 1 meter in depth. Water depths are shown in Figure 3. Typically the dam gates are opened in the winter exposing much of the sediments in the impoundment. Operation of the gates can vary the water level approximately 2.3 meters (7.5 ft.).

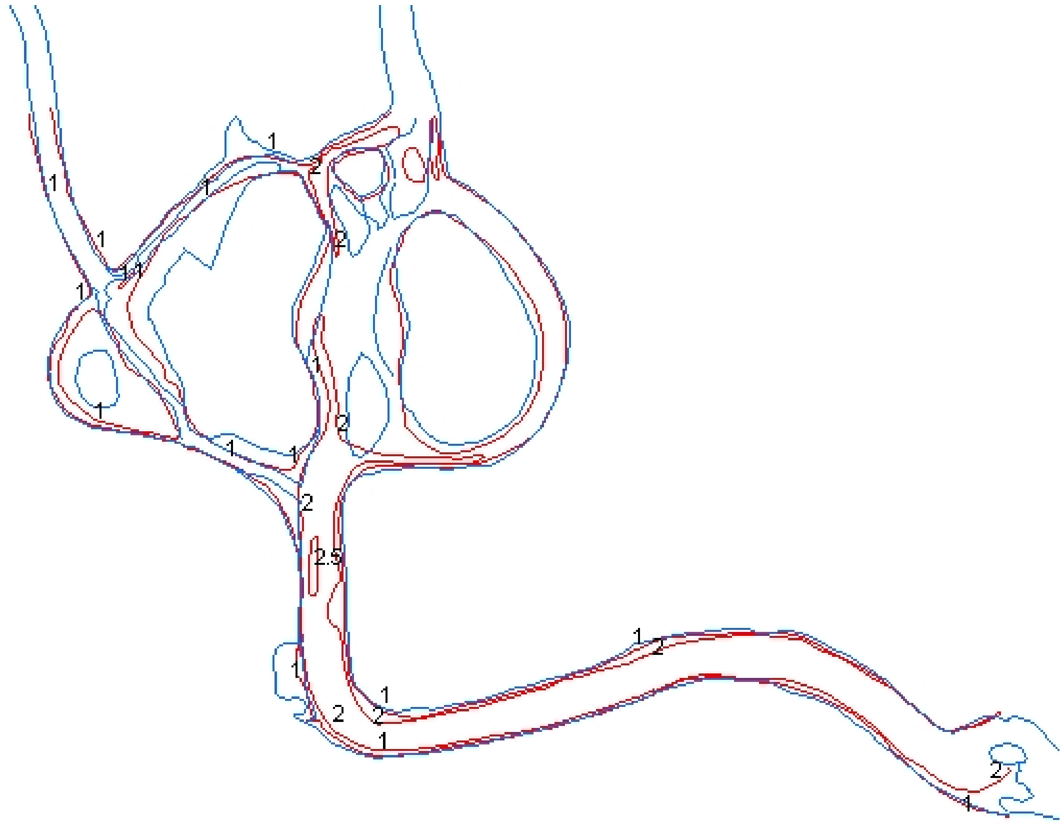
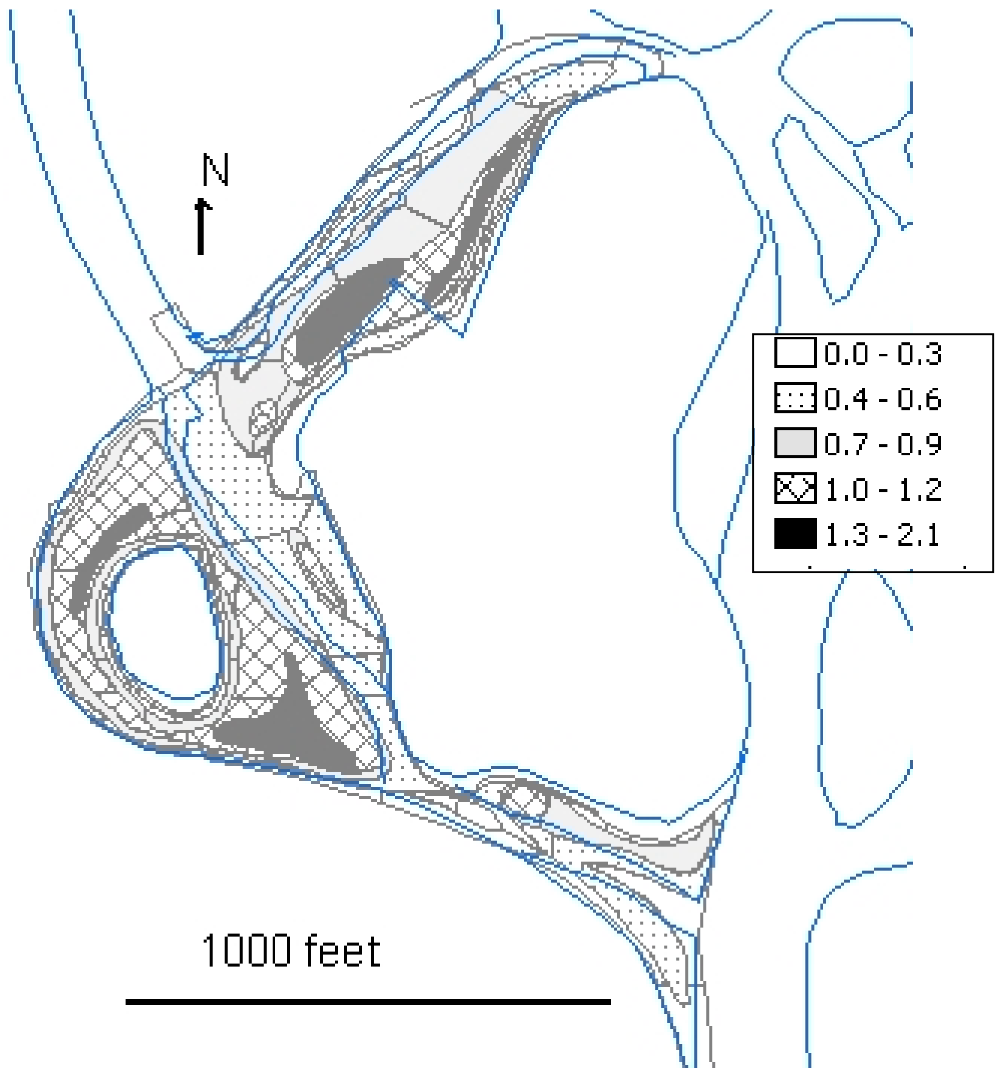


Figure 3, Approximate Water Depth in Meters (Dam Closed)

7. Sediment Mapping

The thickness of soft sediment was measured at cross sections used for the bathymetry, at sediment coring locations and at spot measurement locations. The thickness of the sediment was hand contoured to generate an isopach (contour lines showing equal thickness of sediment) map (Figure 4). Accumulated soft sediment is thickest in the two side oxbows ranging up to 1.65 meters. Sediment in the main channel tended to be below 0.5 meters with some thicker deposits located near the dam. Sediment mapping was confined to the areas of the impoundment where there is known sediment contamination. Mapped area were the west oxbow (Zone 2) and the Milwaukee River below the oxbows (Zones 3-5). The computed volume of soft sediment is 98,800 cubic yards (75,500 cubic meters) for Zones 2-5.



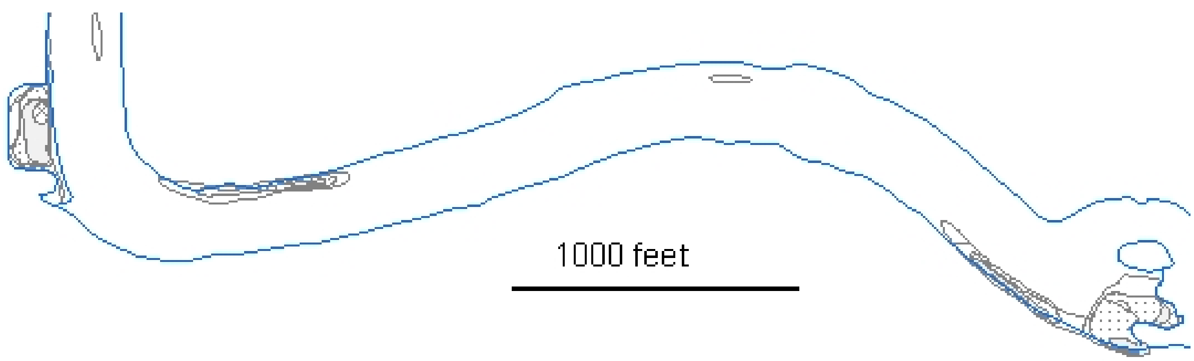


Figure 4, Sediment isopach map, thickness in meters

8. Sediment Assessment

Geotechnical

Twenty two sediment samples were analyzed for physical characteristics (Table 1). The organic content of the sediment ranged from 1.7 to 16.6 percent. Atterberg limits were determined for five samples. The plasticity index ranged from 7 to 13, the liquid limit (%) ranged from 32% to 50% and the plastic limit ranged from 26 to 37.

The sediments were primarily fine grained dominated by silt sized particles. Sand and gravels were seen in the delta areas of Lincoln Creek and in the lower portion of the west oxbow where it joins the Milwaukee River. The sediments generally have a high moisture content and corresponding low dry bulk density. Sediments with higher levels of sand and gravel (> 70%) have higher bulk densities in the range of 60 to over 100 pounds per cubic foot. Sediments with elevated percent fines (silts and clays) above 60% tend to have bulk densities below 60 pounds per cubic foot.

The total organic carbon (TOC) content in the sediment correlates positively with the percent fines. The overall range of TOC is from approximately 2 to 17 %. TOC is negatively correlated with bulk density.

Table 1. Sediment physical characteristics

Sample Id	% Gravel	% Sand	% Silt	% Clay	% fines	% TOC	m%	Gs	Db #/cu.ft.
1X1		12.60	47.60	39.80	87.40	11.6	75.8		55
1X2(G)	47.70	40.60	7.60	4.10	11.70	4.8	48.7		72
1X3		0.80	71.10	28.10	99.20	16.6	246.5		22
2X1	7.40	68.20	16.40	8.00	24.40	4.1	54.4		68
3X1	1.20	89.20	3.20	6.40	9.60	3.1	33.9		87
3X2		89.20	5.30	5.50	10.80	1.7	29		94
3X3		23.40	41.30	35.30	76.60	9.6	54.3	2.64	68
4XX1		6.10	56.00	37.90	93.90	6.5	43.9		76
4X2(top)		5.90	70.10	24.00	94.10	10.5	76.9		54
4X2(mid)		3.50	67.70	28.80	96.50	10.14	59.2		64
4X3		5.30	69.90	24.80	94.70	9.9	69.6		58
4X4A		5.00	52.20	42.80	95.00	8.1	55	2.57	67
4X4B	0.20	74.60	11.30	13.90	25.20	2.9	31.6		90
4X5A		4.40	60.60	35.00	95.60	10.7	63	2.53	62
4X5B	0.60	7.90	55.20	36.30	91.50	9.1	62.9		62
4X6		10.10	61.30	28.60	89.90	14.2	79.8		53
4X7		33.90	44.00	22.10	66.10	8.7	58.1	2.59	65
4X8		3.30	53.80	42.90	96.70	11.6	69.5		58
4X9		5.70	59.60	34.70	94.30	9.1	71.3	2.71	57
4X10		24.20	42.90	32.90	75.80	10.2	59.8		64
5x1	14.80	82.80	0.70	1.70	2.40	3.5	23.4		102
5x2	4.10	92.30	1.30	2.30	3.60	2.6	35.7		85

% TOC = percent total organic carbon
%m = percent moisture, weight of water/ weight of total sample
Gs = specific gravity of the solids
Db = dry bulk density in pounds per cubic foot

Chemical

PCB results from sediment samples were similar to results obtained in previous sampling events. Concentration sampled in the period 2001-2003 ranged from no detection up to 460 ppm sampled in the 0-1ft interval of core EST 4-11 in the upper west oxbow (Figure 5). The highest concentrations were observed in sediments from the western lagoon (Zone 2) and near shore deposits at the Blatz Pavilion inlet and on the west bank of the Milwaukee River below the oxbow (Zone 3). Data from earlier samples from 1995 ranged as high as 870 ppm PCBs in the lower west oxbow at 30-40 cm (1-1.3 ft.) beneath the sediment surface. The analytical laboratory identified the PCBs in the sediment as a mixture of the Aroclors 1242, 1248, and 1254. Past studies of the Milwaukee River system above this study site reported an Aroclor 1254 and 1260 mixture (Steuer, 1999) and an Aroclor 1260, 1242, and 1248 mixture (Westenbrook, 1993).

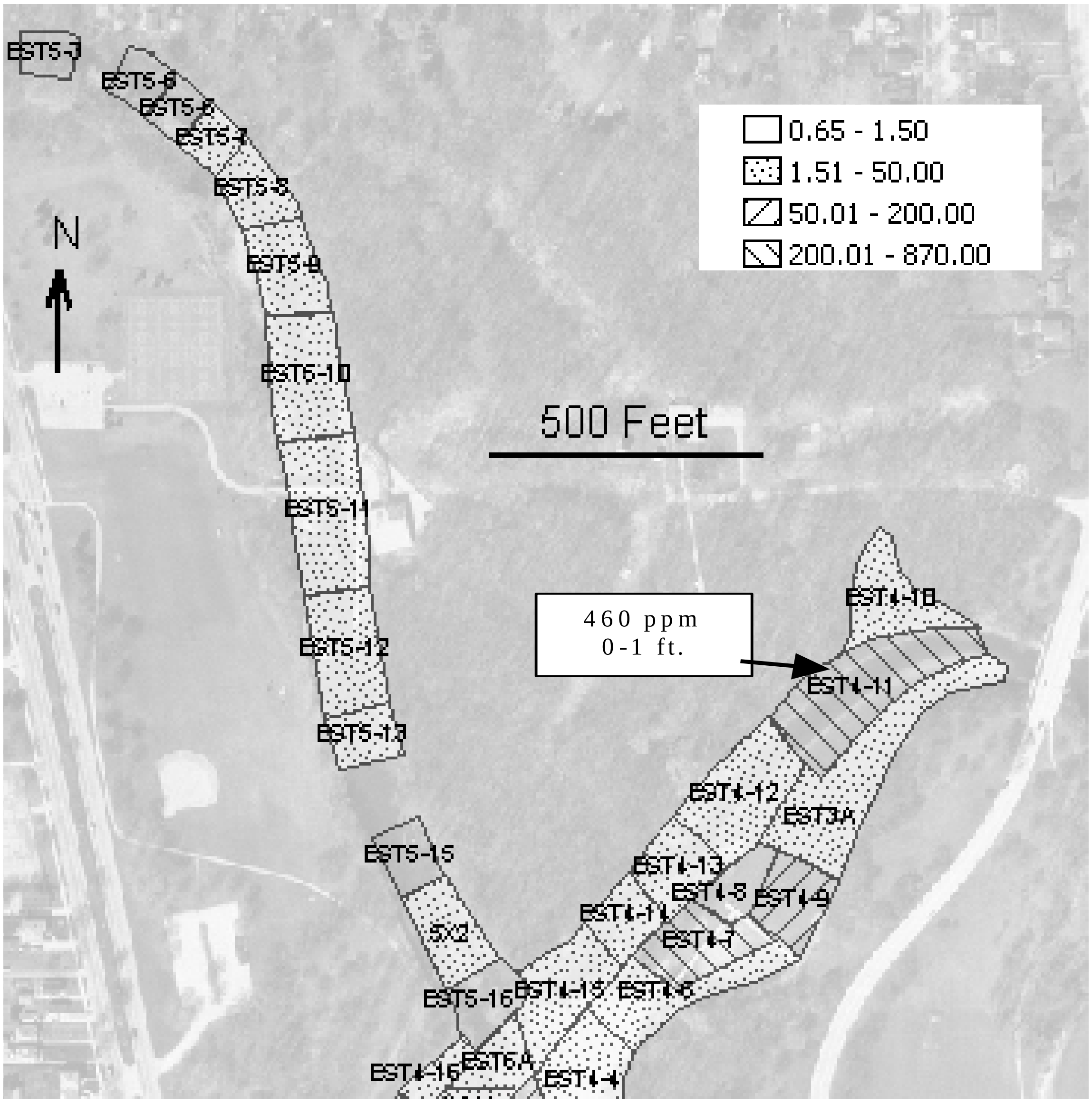


Figure 5a PCB concentrations milligrams per kilogram, Lincoln Creek & Upper West Oxbow, Zones 1& 2.

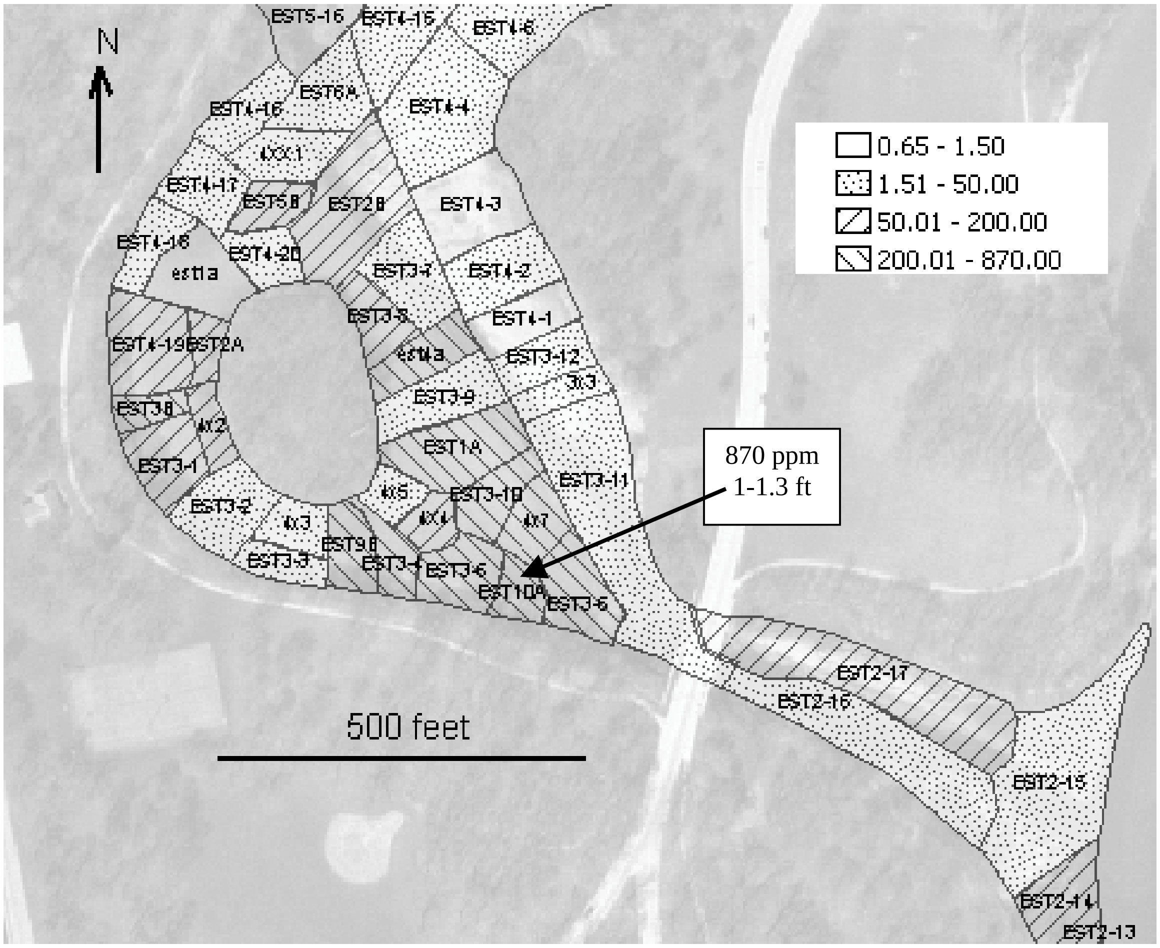


Figure 5b PCB concentrations milligrams per kilogram, West Oxbow, Zones 2 & 3.

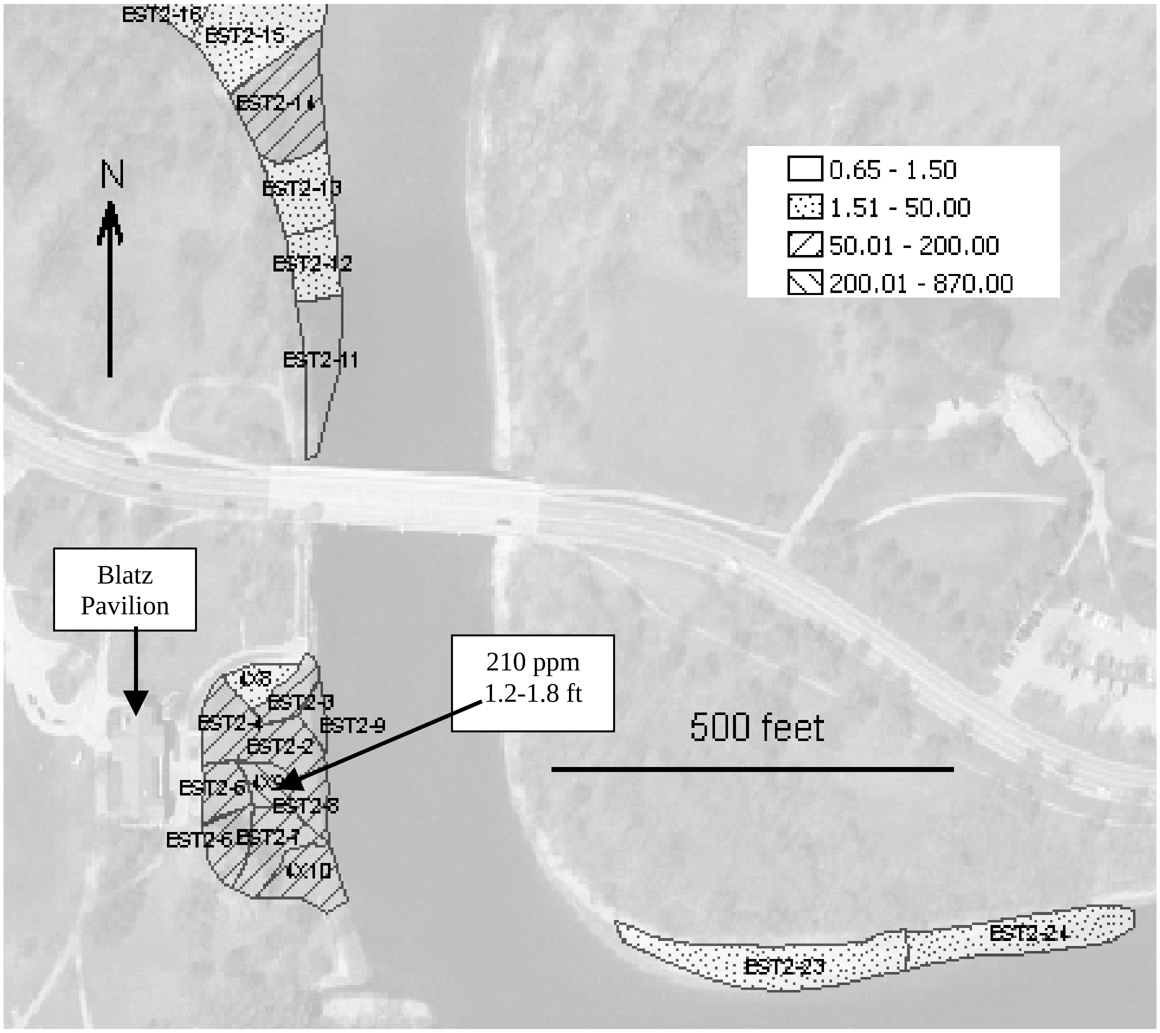


Figure 5c PCB concentrations milligrams per kilogram, Milwaukee River below the oxbows, Zone 3.

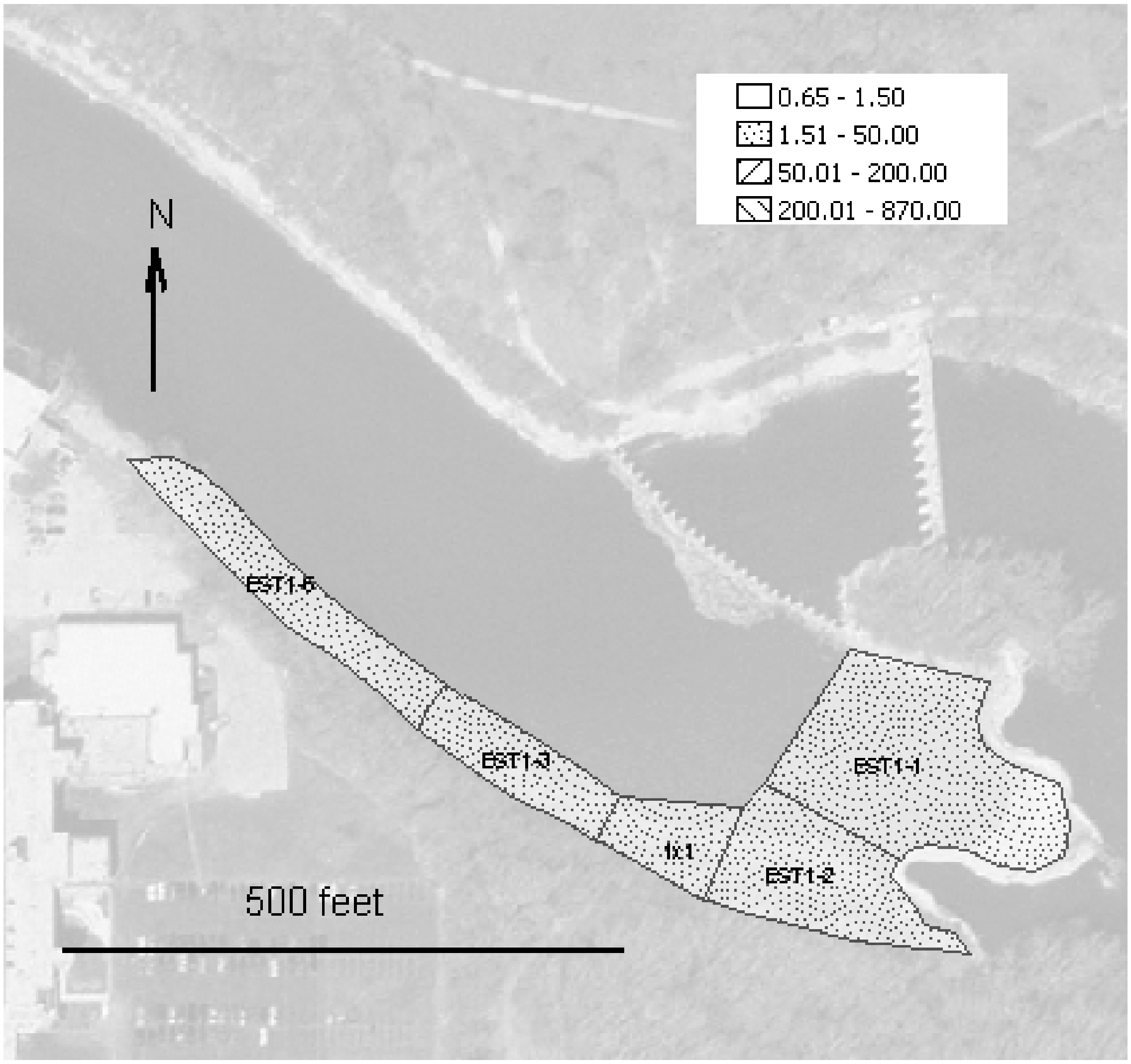


Figure 5d PCB concentrations milligrams per kilogram, Milwaukee River at Estabrook Dam, Zone 5.

PCB values are high in the sediment of the impoundment. Typical urban values for PCBs are usually in the range of less than 1 ppm. Background concentrations at this site as measured in the sediments in Lincoln Creek above Estabrook are in the range of 0.2 to 2ppm. Threshold impairment of the aquatic habitat is typically seen at levels as low as a range of 0.06 to 0.6ppm PCBs (assumed TOC range of 1% to 10%) (WDNR, 2003).

Metals and nutrient results from composited sediment samples from the various zones of the site are presented in Table 2.   Literature reference values are presented in Table 2 to lend perspective on the significance of these data to aquatic effects (WDNR, 2003). Consensus-Based Sediment Quality Guidelines (CBSQG) values derived from an extensive analysis of aquatic effects data on a wide range of aquatic organisms contained in the literature, are shown in this table. These values provide for a screening level evaluation of the potential for effects on aquatic organisms. The CBSQG defined four levels of classification based on three concentration breakpoints for a wide range of pollutants. The levels of concern were defined as follows:

A concentration below the threshold effects concentration (TEC) is defined as Level 1;
Above the TEC and below the midpoint effects concentration (MEC) is defined as Level 2;
Above the MEC and below the upper effects concentration (PEC) is defined as Level 3;
Above the PEC is defined as Level 4.

Table 2. Metals and nutrients in sediment composited by zones.

					CBSQG Values		
	Zone 2	Zone 3	Zone 4	Zone 5	TEC	MEC	PEC
Oil & Grease	5030	6870	4630	2350	N/a	N/a	N/a
Nitrogen NH3-N	29.1	35.8	25.2	2.5	N/a	N/a	N/a
Nitrogen Kjedahl Total	1910	2020	1630	1340	N/a	N/a	N/a
Phosphorus	1018	1120	965	512	N/a	N/a	N/a
Arsenic		ND(< 5)	ND(< 5)		9.8	21.4	33
Barium	89.7	160	88.8	61.6			
Cadmium	1.5	3.9	1.6	1.2	0.99	3.0	5.0
Chromium	38.5	140	76	37.3	43	76.5	110
Copper		106			32	91	150
Lead	88	322	199	104	36	83	130
Manganese	449	428	314	394	460	780	1,100
Nickel	20	45	23	19	23	36	49
Iron ICP	14,200	18,300	11,300	11700	20,000	30,000	40,000
Cyanide		ND (<2)					
Zinc	207	444	222	166	120	290	460
Solids Percent	55.1	56.1	56.4	71.7			
Mercury	0.148		0.167	0.072	0.18	0.64	1.1
Nitrogen NO3+NO2	0.5	0.69	1.7	1.1	N/a	N/a	N/a

Most sample results for metals tend to be relatively low and within level 1. Parameters above the TEC are cadmium, chromium, lead and zinc, which are common urban contaminants. Concentrations of these four metals range up to Level 4, indicating likely impairment of the aquatic habitat.

A screening of the sediments for organics and pesticides was performed on sediments from two locations (Table 3). Chlordane and DDD were the only results returned above the levels of detection. Contaminant levels for chlordane were in the Level 1 category below the threshold effects concentration. DDD was elevated in the Level 2 category above the threshold effects but below the midpoint effects concentration.

Table 3. Organics and Pesticides

	Zone 3	EST. ZONE
BHC GAMMA	ND	ND
CHLORDANE-CIS	0.017	0.01
CHLORDANE-TRANS	0.012	ND
DDT P P	*I <0.020	*I <0.020
DDD P P	0.15	0.068
DDE P P	*I <0.035	*I <0.020
DIELDRIN	ND	ND
ENDRIN	ND	ND
HEXACHLOROBENZENE	ND	ND
METHOXYCHLOR	ND	ND
NONACHLOR-TRANS	ND	ND
NONACHLOR CIS	ND	ND

Polycyclic Aromatic Hydrocarbons (PAH) are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. This study samples for 20 PAHs commonly associated with ecological effects. The results show concentrations that are elevated at levels typically seen in urban waterways (Table 4). Most samples had individual PAH concentration that tended to range in the Level 2 and Level 3 categories (normalized to TOC). Three samples had individual results in the Level 4 category for a few selected PAHs. Areas with the highest levels of PAHs tended to be from the Lincoln Creek sediments. Full results for PAH chemistry and an analysis of the results relative to sediment quality guidelines are presented in the data appendix at the end of this report.

Organic carbon in sediment has a counteracting effect on PAHs with respect to effects on aquatic organisms. Therefore CBSQG effects levels values for PAHs should be normalized to the organic carbon content of the sediment prior to comparison with sediment quality guidelines. Table 4 presents the summed results of the measured PAH concentration not normalized to TOC. Normalized values can be seen in the tables of the data appendix.

Table 4. PAH results

	Total PAH concentrations in micrograms per kilogram dry weight						
	Horizon						
FIELD Name	Surface	A	B	C	D	E	F
1X1		55,410	76,660				
1X3	26,320						
2X4	1,470						
3X3				70,500	44,470	58,400	
4X10				59,210	38,210	44,290	
4X2		48,680		61,860	65,330	45,030	91,890
4X3			92,098	72,600	127,300		
4X4		61,000	67,700	49,810	82,100	2,148	811
4X5		333,800	68,090	37,170	80,400	318	318
4X7		66,430		83,090	118,800		
4X8				58,680	29,380		
4X9				80,480	66,280	25,540	
4XX1		36,220					
5X1	49,360						
5X2		13,700	20,500				
Note: Horizon depths vary at different sample points. Depth ranges 0 -3.5 feet							

NR 347 Parameters

Sediment samples were collected and analyzed for parameters required by NR 347 Wisconsin Administrative Code, *Sediment Sampling and Analysis, Monitoring Protocol and Disposal Criteria for Dredging Projects*. The sampling parameters and techniques of NR 347 were incorporated in this study to aid in future permitting for possible remedial action on the site. The purpose of the code is to obtain characterization data necessary for state and federal permit review including determining the types and degree of contaminants present, environmental controls that may be required, the proper handling and disposition of material removed from the site, and risk screening. NR 347 provides a standardized data collection process and general list of parameters. State and federal regulators can modify the list or procedures as appropriate to a given project site. The code does not have specific numerical criteria for approval or modifications to a project; the intent is to provide regulatory reviewers with sufficient information for permit decision-making.

Modeling of PCB Mass

The distribution and mass of PCBs in the sediments of the project area were modeled using the isopach sediment maps and data from the sediment core samples. The model approach was to divide the surface area of the project area into polygons centered on the core locations. Polygons were hand drawn allowing the various areas of the impoundment to be apportioned to a given core location based on the similarity of the depositional environment.

The mass of PCBs in each polygon was computed based on the area of the polygon, the PCB concentration measured or computed for each 10 cm layer in the polygon multiplied by the thickness of the interval (10 cm.) and the dry bulk density of the sediment. PCB mass was only computed for layers that had measured PCBs obtained in the core samples. PCB concentrations were not extrapolated beneath the sampled depth of the core samples. Therefore the computed mass of PCBs for the overall site and in most of the polygons is biased low compared with what may be computed if all core samples were driven to depths were PCBs were not present. In addition, the modeling of PCB mass used a simplified computation of the mass present in the 10 cm intervals. The interval volume was computed by multiplying the thickness of the interval by the area of the polygon. This technique is likely to bias the PCB mass high compared to modeling the mass based on a contour-volume computation where sediment thickness or isopach contours are used to extrapolate changes in a polygon's interval surface area with depth. Overall the mass modeling developed in this study greatly benefited from the high density of data points for sediment thickness, the number of sample locations, and the distribution of the data points in the various depositional areas of the impoundment. A total of 88 polygons were modeled to assess the mass of PCBs and the quantity of contaminated sediment.

The modeling focused on the primary areas of elevated PCB contamination. Polygons with little sediment thickness or PCB concentrations below 2ppm were generally not modeled. Some low-concentration polygons adjacent to areas of higher concentration, such as the Lincoln Cr. Channel in the west oxbow, were modeled to provide a better understanding of the distribution of sediments in the principal areas of contamination.

Figure 5 is a map of the model polygons showing the maximum concentration of PCBs measured in each polygon. In this figure it can be seen that the principal areas of highest contamination are outside of the Milwaukee River and Lincoln Cr. Channels and are in the west oxbow and the small bay near the Blatz Pavilion. A summary of the model results is presented in Table 5 . Table 9 at the end of this report shows the model input data and individual results for each polygon including PCB concentration, mass, density, and sediment volumes.

Table 5. Summary Statistics, PCB Sediment Modeling (rounded values)

Total soft sediment	98,800 cu. yd. (75,500 cu. m.)
Modeled polygons > 1.5 ppm PCBs, volume	64,000 cu. yd. (49,000 cu. m.)
Modeled polygons > 50 ppm PCBs, volume	24,000 cu. yd. (18,400 cu. m.)
Modeled polygons > 100 ppm PCBs, volume	22,000 cu. yd. (16,600 cu. m.)
PCB mass in sediment > 1.5 ppm PCBs	5,400 lbs. (2,400 kg.)
Maximum PCB concentration	870 ppm
Maximum PCB concentration on surface	460 ppm

9. PCB Transport

PCB transport from Lincoln Creek was measured on seven dates during the project.   Samples were collected from the creek water column and analyzed for PCBs to assess the potential loading to the impoundment. A goal of this study was to obtain samples when the highest concentrations of suspended solids and the associated PCBs would be expected; during high flow periods. The mean flow in Lincoln Creek is 4.1cfs (Steuer, 1999) in Table 6 it can be seen that water samples were obtained on high flow days with flows approximately 10 to 140 times the mean flow.

Channel modification work for flood control in the Lincoln Creek Channel was implemented during the project. As a result of this work the USGS flow gaging and monitoring station was removed. Lincoln Creek flow monitoring data was available for limited periods from June 1, 2003, to September 30, 2003 while this study was underway.   Since USGS data was not available for the entire the study period a model hydrograph was used to determine the flow during the sample times.

Table 6. Lincoln Creek Water Column Sample Results

Date	PCB Dissolved (ng/l)	PCB Particulate (ng/l)	PCB Particulate (ug/g)	Total PCBs (ng/l)	TSS (mg/l)	Flow mean (cfs)	loading g/day
06/03/2002	1.61	11.13	0.10	12.74	113	558	0.017
08/13/2002	1.72	40.75	0.19	42.47	213	579	0.060
09/29/2002	0.94	24.27	0.38	25.21	179	89	0.005
10/02/2002	0.54	13.79	0.10	14.33	69	60	0.002
04/30/2003	0.72	48.19	0.45	48.91		37	0.004
05/09/2003	0.59	21.01	0.36	21.6	127	92	0.005
07/05/2003	2.31	21.5		23.81		45	0.003
Mean	1.20	25.81	0.26	27.01	140	209	0.014
Median	0.94	21.50	0.28	23.81	127	89	0.005

PCB transport in Lincoln Creek averaged 0.014 g/day with a median value of 0.005 g/day. This is a relatively small quantity compared with the values measured at other sites in the Milwaukee River system (Table 7). Theinsville, above the Estabrook Impoundment, had a measured load of 9.6 g/day and the outlet of the impoundment at the Estabrook Dam had a load of 26.1 g/day. These data indicate that Lincoln Creek is not a significant source of PCBs to the impoundment. However, the loading data do show that the impoundment itself is a very significant source of PCBs to the Milwaukee River downstream of the Estabrook Dam.

Table 7. PCB loading in the Milwaukee River System 1994-1995 (USGS, 1999)

Location	Median Load (g/day)
Cedar Creek @ Columbia Avenue	1.5
Cedar Creek @ Highland Road	6.5
Milwaukee River @ Highway T	0.8
Milwaukee River @ Pioneer Rd.	4.8
Milwaukee River @ Thiensville	9.6
Milwaukee River @ Estabrook Dam	26.1

Following the collection of this data it should be noted a major fire occurred in an old industrial facility (the Kaiser Property) located at 34th and Hampton. There were several PCB filled transformers reported to be on that site. The fate of the PCBs in that facility following the fire has not been determined.

10. Remediation and Risk Management

PCB contamination in the Estabrook Impoundment is well above background concentrations and does presents an elevated level of risk to humans and wildlife. In addition, these sediments are a significant source of PCBs to the Milwaukee River below the study site. Sediment concentrations in many places are some of the highest measured in the state and exceed the concentration threshold of the federal Toxic Substances Control Act (TSCA) of 50 ppm for classification as a toxic waste. At these levels any effort to remove the contamination or to manage it in place will require additional efforts and expense.

The risk presented by the presence of PCB contaminated sediment in the Estabrook Impoundment has not been precisely quantified. However, the concentrations and the extent of the contamination strongly indicate that the PCB pose a risk to humans and wildlife, locally and downstream. Management of the risk may include a reduction of human contact with the sediments of the site, avoidance of the consumption of fish and wildlife that may have bioaccumulated the PCBs, or removal of the contamination.

Approaches to manage PCB contaminated sediment can include institutional controls (e.g., `advisories to the public, access restrictions, prohibited activities), removal and disposal of the contamination, and in-place disposal/containment such as capping. These approaches can be used in combination or individually to manage the risk of a site. A common approach at sites in Wisconsin with high levels of PCBs has been to institute advisories to the public to avoid contact with the sediment and to avoid the consumption of fish and wildlife that may have bioaccumulated the PCBs. Remedial actions may include the removal of the highest levels of contamination and either capping the residuals in place or allowing natural processes to either disperse, dilute, or bury the remaining contamination.

The cost of remediating PCB contaminated sediment can vary depending on characteristics of the site, the levels of contamination, and the selected remedy. Overall project costs for the 1997-98 Fox River Deposit N PCB cleanup project were reported at $525 per cu. yd. (Foth & Van Dyke, 2000). This was a relatively small 8190 cu. yd. project designed as a demonstration project and performed under challenging site and weather conditions and with significant expenses for design and public outreach. The design consultants for the project believed that a similar project implemented at a larger scale (100,000 cu. yd.) may be achievable for costs on the order of $200 per cu. yd.

Based on experience with PCB sediment remediation and other site cleanups the Department has used a fairly wide cost range for projecting concept-level potential costs for PCB sediment site remediation of from $300/ cu. yd. to $600/ cu. yd. This cost range is used as a rough estimate at the early stage of examining a site with the intent that more precise estimates will be developed over time with further investigations, an engineering feasibility study, and/or remedial design. In addition, the cost for action on the site will also vary with the level of effort and with decision-making related to the timing of action, how much of the site is addressed, and approach selected. Conceptual remediation costs are presented in Table 8.

Table 8. Conceptual Remediation Costs

Areas	area acres	volume cu. yd.	average thickness ft.	cost range low ($300/cu.yd)*	cost range high ($600/cu.yd.)*
Blatz Pavilion Bay					
all sediment	1	3,596	2.2	$1,100,000	$2,200,000
Lagoon & River					
PCB > 1.5 ppm < 50 ppm	17	35,703	1.3	$10,700,000	$21,400,000
PCB > 50 ppm	7	20,828	2.0	$6,200,000	$12,500,000
Total					
All areas > 1.5 ppm				$18,000,000	$36,100,000

*cost values rounded

11. Conclusions

The Department of Natural Resources in cooperation with other agencies has monitored the presence and transport of PCBs in the Milwaukee River and Cedar Creek. These PCBs have been shown to be a significant risk to humans and the environment. This study has shown that the Estabrook Impoundment has significant PCB contamination. Relatively high levels have been measured at the sediment surface and at depth. This project has mapped the distribution of the sediment and PCB concentrations in the impoundment and found that the contamination is principally confined to the west oxbow, the Blatz Pavilion inlet, and the Milwaukee River Channel below the oxbows. The study has assessed the site for other contaminants and the data indicate that levels of metals, PAHs, and other organics are elevated. However, the levels of these contaminants are within the range seen at other urban waterways and below the environmental risk levels posed by PCBs at this site.

Monitoring data have shown that Lincoln Creek is currently not a significant source of PCBs to the impoundment. However, the impoundment is a significant source of PCBs to downstream areas of the Milwaukee River below the Estabrook Dam.

Concept-level remediation costs for the impoundment could be in the range of $18 million to $36 million depending on the quantity of contamination addressed and the management approach selected. It is possible that new information developed as part of a design study could increase or decrease remediation costs significantly.

12. References

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Table 9a. Sediment > 50 ppm; layer concentration, volume and PCB mass (excludes Blatz Pavilion)

		PCB Concentration by Sediment Layer (0.1 cm intervals)																
Zone	**Polygon**	1	2	3	4	5	6	7	8	9	10	11	Maximum PCB ppm	Area sq.m.	Dry Bulk Density lbs/cu.ft.	Volume cu.m.	Volume Cu. Yd.	PCB Mass lbs.
3	EST2-14	23	23	23.00	60.13	62.00	62.00	0	0	0	0	0	62	1135	91	681	891	92
2	4X4	79	79	35.84	19.00	19.00	9.81	1.10	4.56	4.60	1.56	0.05	79	443	68	488	638	27
2	EST2A	3	49	100	2.5	1.5	0.4	0	0	0	0	0	100	368	68	221	289	14
2	EST3-8	100	100	100	13	13	13	0	0	0	0	0	100	663	68	398	520	54
2	EST2B	3	22	120	0.9	0	0	0	0	0	0	0	120	2027	68	811	1060	71
2	EST5B	100	120	1.20	0.00	0.00	0.00	0.00	0	0	0	0	120	540	68	162	212	29
2	EST4-19	0	12	12.00	124.34	130.00	130.00	13.38	1.00	0	0	0	130	1342	68	1074	1404	136
2	4X2	9	9	88.32	150.00	132.52	6.74	1.23	0.45	0.62	0	0	150	443	68	399	522	42
2	EST3-1	150	150	150	2.8	2.8	2.8	0	0	0	0	0	150	955	68	573	749	105
2	EST4-9	1	1	0.84	180.92	190.00	190.00	190.00	0	0	0	0	190	1575	68	1103	1442	285
3	EST2-17	4	4	3.6	200	200	200	17	0	0	0	0	200	3162	91	2214	2895	634
2	EST4-7	240	240	240.00	144.80	140.00	0	0	0	0	0	0	240	2068	68	1034	1353	500
2	EST3-5	4	4	4.1	250	250	250	3.7	0	0	0	0	250	871	68	609	797	160
2	EST3-10	3	3	3.1	260	260	260	0	0	0	0	0	260	720	68	432	565	137
2	EST3-4	270	270	270	31	31	31	0	0	0	0	0	270	526	68	316	413	114
2	EST3-6	9	9	9.4	270	270	270	3.5	0	0	0	0	270	1018	68	713	932	206
2	EST6B	4	9	300.00	7.80	0.75	0	0	0	0	0	0	300	677	68	338	442	52
2	est4a	3	2	180	360	6.5	0	0	0	0	0	0	360	771	68	385	504	102
2	4X7	9	20	72.00	177.46	380.00	193.56	17.00	17.00	0	0	0	380	703	68	563	736	150
2	EST1A	3	3	380	0	0	0	0	0	0	0	0	380	1402	68	421	550	130
2	EST4-11	460	460	460.00	34.46	13.00	13.00	0	0	0	0	0	460	4245	68	2547	3331	1470
2	EST3B	0	0	470.00	0	0	0	0	0	0	0	0	470	382	68	114	150	43
2	EST10A	2	2	100	870	70	7.7	1.8	0	0	0	0	870	473	68	331	433	120

Summary	volume cu yd	pcb lbs	area m2	acres	average thickness ft
total	20,828	4,676	26,509	6.5	2.0

Table 9b. Sediment >1.5 ppm and < 50 ppm; layer concentration, volume and PCB mass (excludes Blatz Pavilion)

		PCB Concentration by Sediment Layer (0.1 cm intervals)																
Zone	**Polygon**	1	2	3	4	5	6	7	8	9	10	11	Maximum PCB ppm	Area sq.m.	Dry Bulk Density lbs/cu.ft.	Volume cu.m.	Volume Cu. Yd.	PCB Mass lbs.
3	EST2-11	1.5	1.5	1.50	1.50	0	0	0	0	0	0	0	1.50	665	91	266	348	1
1	EST5-10	1.6	1.6	1.60	0	0	0	0	0	0	0	0	1.60	2,760	94	828	1,083	4
5	EST1-1	1.7	0	0	0	0	0	0	0	0	0	0	1.70	2,926	64	878	1,148	1
3	EST2-13	1.8	1.8	0	0	0	0	0	0	0	0	0	1.80	637	91	127	167	1
1	EST5-9	1.8	1.8	1.80	0	0	0	0	0	0	0	0	1.80	1,835	94	551	720	3
1	EST5-12	1.9	1.9	0	0	0	0	0	0	0	0	0	1.90	2,486	94	746	975	3
1	EST5-8	1.9	1.9	1.90	0	0	0	0	0	0	0	0	1.90	1,366	94	410	536	3
1	EST5-11	2.1	2.1	2.10	2.10	0	0	0	0	0	0	0	2.10	3,435	94	1,374	1,797	10
1	5X2	2.2	0	0	0	0	0	0	0	0	0	0	2.20	1,723	94	172	225	1
2	EST4-15	2.2	2.2	2.20	0.72	0.65	0.65	0.65	0	0	0	0	2.20	2,372	68	1,661	2,172	5
4	EST2-23	2.4	2.4	2.40	2.40	0	0	0	0	0	0	0	2.40	1,488	45	595	778	2
2	EST4-6	1.9	1.9	1.90	2.38	2.40	0	0	0	0	0	0	2.40	2,358	68	1,179	1,542	6
1	EST5-13	2.5	2.5	2.50	0	0	0	0	0	0	0	0	2.50	1,100	94	330	431	3
2	EST4-17	2.8	2.8	2.80	2.80	0	0	0	0	0	0	0	2.80	881	68	352	461	2
3	EST2-15	2.9	2.9	2.90	2.90	0	0	0	0	0	0	0	2.90	3,398	91	1,359	1,778	13
3	EST2-12	3	3	3.00	0.92	0.81	0	0	0	0	0	0	3.00	473	91	237	310	2
2	EST3-12	1.4	1.4	1.4	3.1	3.1	3.1	0	0	0	0	0	3.10	728	68	437	571	2
2	EST4-10	3.1	3.1	3.10	0.39	0.25	0	0	0	0	0	0	3.10	2,058	68	1,029	1,346	5
2	EST4-4	3.2	3.2	3.20	0	0	0	0	0	0	0	0	3.20	2,259	68	678	886	5
2	EST6A	3.2	0.7	0.90	0.38	0.00	0.00	0	0	0	0	0	3.20	1,059	68	424	554	1
2	EST4-16	3.6	3.6	3.60	0.46	0.30	0	0	0	0	0	0	3.60	716	68	358	468	2
2	EST4-2	3.8	3.8	3.80	3.80	0	0	0	0	0	0	0	3.80	1,128	68	451	590	4
2	EST3-11	1.1	1.1	1.1	4	0	0	0	0	0	0	0	4.00	3,484	68	1,393	1,822	6
2	EST4-13	4.4	4.4	0	0	0	0	0	0	0	0	0	4.40	1,612	68	322	422	3
2	3X3	2.2	2.58	4.40	5.02	6.20	4.40	2.03	0.43	0	0	0	6.20	495	68	396	518	3
2	EST4-12	6.4	6.4	6.40	0	0	0	0	0	0	0	0	6.40	2,975	68	893	1,167	14
5	EST1-2	1.7	1.7	1.70	6.27	6.50	6.50	6.50	0	0	0	0	6.50	1,587	64	1,111	1,453	11
5	1X1	6.7	6.7	6.70	6.70	6.70	0	0	0	0	0	0	6.70	655	64	327	428	5

)

Table 9b continued. Sediment >1.5 ppm and < 50 ppm; layer concentration, volume and PCB mass (excludes Blatz Pavilion

Zone	**Polygon**	PCB Concentration by Sediment Layer (0.1 cm intervals) 1	2	3	4	5	6	7	8	9	10	11	Maximum PCB ppm	Area sq.m.	Dry Bulk Density lbs/cu.ft.	Volume cu.m.	Volume Cu. Yd.	PCB Mass lbs.
5	EST1-5	9.8	9.8	9.80	2.01	0	0	0	0	0	0	0	9.80	1,317	64	527	689	9
3	EST2-16	11	11	11.00	1.39	0	0	0	0	0	0	0	11.00	2,554	91	1,021	1,336	28
2	EST3-3	11	11	11	2	2	0	0	0	0	0	0	11.00	483	68	242	316	4
5	EST1-3	14	14	14.00	3.43	2.90	0	0	0	0	0	0	14.00	859	64	430	562	9
4	EST2-24	14	14	0	0	0	0	0	0	0	0	0	14.00	1,128	45	226	295	5
2	EST3-9	16	16	16	7.9	7.9	7.9	0	0	0	0	0	16.00	1,049	68	630	824	18
2	EST3-7	20	20	20	0	0	0	0	0	0	0	0	20.00	1,112	68	334	436	16
2	4XX1	22	22	16.47	0.45	0.45	0	0	0	0	0	0	22.00	810	68	405	530	12
2	EST4-20	23	23	23.00	1.68	0.60	0.60	1.14	1.20	0	0	0	23.00	606	68	485	634	11
2	EST3-2	30	30	30	1.8	1.8	0	0	0	0	0	0	30.00	1,089	68	544	712	25
2	EST4-18	32	32	32.00	11.06	10.00	0	0	0	0	0	0	32.00	637	68	318	417	18
2	EST3A	0.58	1.7	36	0	0	0	0	0	0	0	0	36.00	4,250	68	1,275	1,668	39
2	EST4-14	38	38	38.00	5.35	3.70	0	0	0	0	0	0	38.00	1,203	68	602	787	36
2	4X5	4	4	18.84	42.00	42.00	20.63	0.40	0.62	0.89	1.20	0.19	42.00	427	68	469	614	14
1	EST5-7	0.77	0.77	0.77	41.92	44.00	44.00	0	0	0	0	0	44.00	790	94	474	620	34
2	4X3	46	46	46.00	26.58	14.24	1.70	1.28	0.29	0	0	0	46.00	542	68	434	568	24

Summary	vol cu yd	pcb lbs	area m2	acres	average thickness ft.
total	35,703	425	67,515	16.7	1.3

Table 9c. Blatz Pavilion Sediment; layer concentration, volume and PCB mass

Polygon	PCB Concentration by Sediment Layer (0.1 cm intervals)																
	1	2	3	4	5	6	7	8	9	10	11	Maximum PCB ppm	Area sq.m.	Dry Bulk Density lbs/cu.ft.	Volume cu.m.	Volume Cu. Yd.	PCB Mass lbs.
EST2-9	1	1	1	0	0	0	0	0	0	0	0	1	153	59.7	46	60	0.1
4X8	3	9	42	28	1	1	0	0	0	0	0	42	266	59.7	160	209	4.7
EST2-3	55	55	55	4	1	1	0	0	0	0	0	55	305	59.7	183	240	11.0
EST2-4	56	56	56	22	20	0	0	0	0	0	0	56	506	59.7	253	331	22.4
EST2-8	56	56	56	5	3	3	1	0	0	0	0	56	273	59.7	191	250	10.4
EST2-6	3	3	3	105	110	110	0	0	0	0	0	110	389	59.7	233	305	27.4
EST2-5	3	3	3	143	150	0	0	0	0	0	0	150	334	59.7	167	219	21.3
EST2-2	2	2	2	152	160	160	0	0	0	0	0	160	466	59.7	280	366	46.8
4X10	3	5	16	69	170	86	6	3	1	0	0	170	536	59.7	482	631	40.4
EST2-7	3	3	3	162	170	170	18	2	0	0	0	170	556	59.7	445	582	62.2
4X9	2	2	2	73	210	105	5	2	1	1	0	210	257	59.7	257	336	21.8

Summary	volume cu yd	pcb lbs	area m2	acres	ave thickness ft
Total	3,527	269	4,041	1.0	2.2