FINAL

Focused Remedial Investigation
Lincoln Park/Milwaukee River Channel Sediments
Milwaukee, Wisconsin

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Introduction

The Lincoln Park/Milwaukee River Channel Sediments (Site) Remedial Investigation (RI) was conducted to investigate the nature and extent of sediment contamination at the Site, characterize physical conditions that may affect movement of contaminants, and assess the potential risk that the contamination poses to the environment. The RI was performed by STN JV for the Great Lakes National Program Office (GLNPO) of United States Environmental Protection Agency (U.S. EPA), under the Superfund Technical Assessment and Response Team (START) contract. The study area for the RI included the West Oxbow of the Milwaukee River and approximately one-mile stretch of the Lincoln Creek until its confluence with the primary channel of the Milwaukee River (Figure 1). In 2009, samples were collected just west of the Eastbrook Dam in the Milwaukee River.

Site Background and History

The Estabrook Impoundment located within the Cities of Glendale and Milwaukee, Wisconsin, is formed by the Estabrook Dam (Figure 1). The Estabrook Dam backs up water approximately two and one-half miles to a point approximately 0.3 miles upstream of Silver Spring Road on the Milwaukee River, creating a 103-acre pool. The dam and the impoundment influences flow within Lincoln Creek to a point approximately 0.5 miles upstream of the confluence with the Milwaukee River. The dam was historically closed soon after the spring season to flood the study area for recreational use and was opened in the beginning of the fall to drain the water. The area within Lincoln Park comprises the site that was originally occupied by an oxbow of the Milwaukee River. This area was excavated in the 1930s to create the West Oxbow, to which Lincoln Creek empties. An oxbow (East Oxbow) was also excavated to the east of the Milwaukee River. The sediments in the Lincoln Park area are comprised of sediments that were transported from Lincoln Creek and the Milwaukee River and have been deposited following the excavation of the oxbow.

Previous Investigations

PCB contamination was initially identified in the area through fish tissue samples. The first fish advisory for the site area was issued by WDNR in 1981.

Investigations by WDNR (2005) and Steuer (1999) estimated contaminated sediment volume of 64,000 cubic yards with a mass of 5,381 pounds of PCBs in the impoundment. In the West Oxbow area, there is an estimated 56,000 cubic yards of sediment contaminated with 5,000 pounds of PCBs. During the Blatz Pavilion Remedial Action from March 2008 through August 2008, approximately 4,700 cubic yards of contaminated sediment/soil was removed and backfilled through funding from WDNR.

During February 2008 and March 2009, START conducted sediment sampling activities in support of the RI. Primary focus was in the Lincoln Creek (Zone 1) and West Oxbow (Zone 2) with additional characterization activities by the Estabrook Dam (Zone 5) (Figure 2). Sediment sampling was conducted to determine sediment thickness, horizontal and vertical extent of PCB contamination, and the nature of contaminants.

During the February 2008 sampling, 33 sediment samples for PCB analysis from varying depths were collected from the in West Oxbow (Zone 2) area. Few of the samples were analyzed for bulk properties, including specific gravity, moisture content, and Atterberg limits (Table 1). In addition to sampling, sediment thickness was determined using the direct push technology equipment and manual probing techniques. Each of the sampling and probing location was surveyed. During the March 2009 sampling, sediment samples were collected from the Lincoln Creek (Zone 1), 33 samples from the West Oxbow for PCB analysis and 2 samples were collected in front of the Estabrook Dam in Zone 5 for sediment characterization. Sediment thickness surveys conducted in Zone 1 and Zone 2 was determined using manual poling at over 300 locations. The survey area extended from the north of the dam through the west oxbow and the Lincoln Creek up to the Green Bay Road to the north and up to the Milwaukee River Parkway through the primary channel on the northeast. All sampling and poling locations were surveyed to document their spatial coordinates. The horizontal control used was the WI Height Modernization monument by I43 and Hampton. The vertical control used was the chiseled cross on the bridge over the river at Hampton, just North of the Blatz Pavilion.

Physical Characteristics of the Study Areas

Sediment thickness measurements varied within each Zone of the study area. In the Lincoln Creek, fine sand and gravel was encountered below 1-foot thickness in most sections of the creek. Towards the Creek's confluence with the primary channel of the Milwaukee River, the sediment thickness increased up to 4 to 5 ft thickness.

In the West Oxbow area surrounded by the Milwaukee River Parkway and the primary channel, the sediment thickness ranged from 2.2 ft to approximately 9.5 ft. Sediments between the east side of the North Milwaukee River Parkway and the Milwaukee River indicated 6 to 7 ft thickness to the north and 3 to 5 ft to the south of the primary channel. The dominant sediment in the north was fine-grained and occurred in the upper four ft or more of the sediments while in the south, the sediment was sandy in the top 0.5 foot. The sediment thickness in the area north of the pier ranged from 5 ft to the north to about 9.5 ft by the pier. The sediments in the moderately narrow area between the primary channel and the pier, ranged in thickness from 4 ft to 7.9 ft, with the shallower areas being encountered closer to the pier. Sediments to the south are located in a narrow zone and ranged from 2.2 ft to 5.3 ft in thickness.

In general, in the area between the North Milwaukee River Parkway Bridge and the primary channel of Zone 2, the maximum sediment thickness was encountered just north of the pier (9.5 ft) and the minimum sediment thickness was encountered south of the pier (2.2 ft). Much of this area had sediment thickness between 5.5 and 7.0 ft and the sediments are dominantly fine-grained with minor, interbedded sandy intervals of generally 1 foot or less in thickness.

Sediments surrounding the small island in the impoundment between the Primary and Secondary Channels are fine grained with interbedded sandy intervals of 1.5 ft or less. Sediments had a fairly consistent thickness ranging from 5.5 ft to 6.5 ft on the east of the island while to the north and west of the island, the sediment thickness was variable ranging from 4 to 7 ft. Sediments to the south and southeast of the island varied in thickness from 6 to 8.5 ft and were sandy with a thinner fine grained interval.

Overall in the study area, the sediment thickness varied from less than 3 ft, generally adjacent to the channels, to as much as 9.5 ft in other areas. Typical sediment thickness tends to be between 5 and 7 ft although it was thinner in some areas. Sediments tend to be fine grained (silts and clays) in their upper interval, and sandy in their lower interval, although this relationship did not hold through out the study area. Thinner interbedded units of a contrasting texture occur at a number of locations. At some locations, the upper most sediments tend to be sandy and appear to represent accumulations of sandy material in small sand bars on top of the sediment flats.

Bulk characteristic profiling of sediments indicate a distinct difference between the fine-grained and coarse grained sediment intervals. The fine-grained sample intervals tend to be predominately silts (60 to

70%) with lesser portions of clay and fine sand, while the coarse grained intervals are almost exclusively fine to medium sand (greater than 90%).

Nature and Extent of Contamination

Historical information, as well as this current investigation has not identified any particular current pollution sources to Lincoln Creek/ Milwaukee River. The RI sampling and historical sampling indicates that the sediments in the study area are contaminated with PCBs from historical sources.

Lincoln Creek (Zone 1)

The focus of this RI was to investigate the historical hot spot EST5-7, with 42 milligrams per kilogram PCBs, to determine if contamination is being transported from upstream sources in to the West Oxbow. The highest PCB concentration of 5.4 mg/Kg was observed in sample LC-B-1-N in the area that was previously known to have had 41 mg/Kg PCB contamination (Figure 4). This location is closer to Green Bay Road, the upstream extent of the Lincoln Creek site. Sediment thickness in the Lincoln Creek ranged from 0 to 4.6 ft, with of fine sand and gravel below 1 foot in the northern 3/4th section of the creek. Sediment thickness was greater nearest the creek banks and towards the creek's confluence with the primary channel. Based on the RI results, no identifiable upstream migration sources were observed. However, low level PCB-contaminated sediments are present in the Lincoln Creek sediments.

West Oxbow (Zone 2)

West Oxbow investigations were conducted through 33 sediment sample analyses for PCBs (Figure 5). Sediment thickness survey through probing/polling occurred at over 300 locations, samples were collected at some locations for chemical analysis. Sediment thickness in the West Oxbow ranged from 0 to 9.5 ft in depth.

PCBs were detected in all sediment samples collected from the West Oxbow. In the top 1-foot of sediments (surface sediments), the highest PCB concentration of 143.9 mg/Kg was observed in the northern section of the primary channel at S-2 location west of the North Milwaukee River Parkway and north of the pier (Figure 3). Downstream PCB concentrations in the surface sediments were relatively low (less than 10 mg/Kg) except at sample location WO-I-2, just southwest of the Lincoln Creek's entrance in to the primary channel, where it was observed at 120 mg/Kg (Figure 8).

PCB contamination is higher sediments collected from greater than 1 foot below the sediment surface. The highest levels of contamination were seen in sediment averaging 4-6 feet below the sediment surface. The deeper depth contamination did not correlate to the locations where surface contamination was observed. PCB contamination ranged from 0.14 mg/Kg to 823 mg/Kg in the deeper sediments and was observed in sample depths up to 5.5 ft. Deeper sediment contamination was observed in two primary locations: in the pier area and in the island area of the West Oxbow. The higher PCB contamination was observed to the north, west, and southwest of the pier, with the highest concentration occurring to the southwest of the pier in location S-6. In the West Oxbow Island, the highest PCB contaminated sediment was observed in WO-I-2 location, which was situated southwest of the Lincoln Creek's confluence with the primary channel. Historical sampling to the east and south of the West Oxbow Island had PCB contamination ranging from 1 to as much as 870 mg/Kg.

Contaminant Fate and transport

PCBs found in the site sediments are most likely to adsorb to the sediments and transport with the migration of the sediments. PCBs are known to bioaccumulate in organisms and humans and bioconcentrate significantly in aquatic organisms. The fish advisory already in effect in the site area indicates the documented exposure pathway to humans. Of the 14 Beneficial Use Impairments, the Milwaukee Estuary has the following 11 impairments listed at the GLNPO website http://www.epa.gov/greatlakes/aoc/milwaukee.html#Beneficial_:

Restrictions on fish and wildlife consumption
Eutrophication or undesirable algae
Degradation of fish and wildlife populations
Beach closings
Fish tumors or other deformities
Degradation of aesthetics
Bird or animal deformities or reproduction problems
Degradation of benthos
Degradation of phytoplankton and zooplankton populations
Restriction on dredging activities
Loss of fish and wildlife habitat

Focused Ecological Hazard Evaluation

Because of documented PCB contamination in the fish tissues and the fish advisory in the site area, a focused ecological hazard evaluation for the bottom dwelling species was conducted. The consensus-based sediment quality guidelines (CBSQG) were developed to identify concentrations of chemicals that would be protective of the majority of bottom dwelling species that reside on or in the sediment and sediment port water. The guidelines establish two concentration levels: the TEC, at which no or minimal effects are predicted and the PEC at which adverse effects is highly probable (WDNR, 2003).

The limited available data for metals in the Estabrook Impoundment sediments indicated that the combined concentrations of cadmium, chromium, copper, lead, nickel and zinc in Zone 2 were high enough that adverse toxic effects on sediment dwelling species are probable. The concentrations of chromium and lead exceeded the PEC for the individual metals.

The total PAH concentration, adjusted to 1% TOC, exceeded the PEC level for only one surface sediment sample and did not exceed the PEC level in any subsurface samples. These results suggest that the concentrations of PAHs in the sediments are below the levels where adverse effects on sediment dwelling species are probable.

The data from both the 2003 sampling event (WDNR, 2005) and the 2008 START sampling event show that the total PCB concentrations in the biologically active zone exceeded the PEC in more than 50% of the samples analyzed. This suggests that adverse effect on sediment dwelling organisms due to elevated total PCB concentrations are probable in much of the surface sediment in the site area. When combined with reasonable estimates of concentrations of metals and PAHs, the overall mean PEC-Q values show an estimated average incidence of toxicity that exceeds 95% for 28% of the samples from the 2008 and 2009 START sampling event. Therefore, the probability of adverse effects to sediment dwelling species is high over large portions of the Western Oxbow in Zone 2.

Acronym List

AOC	Area of concern
ASTM	American Society for Testing and Materials
CLP	Contract Laboratory Program
Yd3	Cubic yards
DOT	Department of Transportation
EPA	Environmental Protection Agency
ft	ft
FFS	Focused Feasibility Study
FSP	Field sampling plan
GLNPO	Great Lakes National Program Office
GPS	Global positioning system
Kg	Kilogram
MCPD	Milwaukee County Parks Department
mg/Kg	milligrams per kilogram
MMSD	Milwaukee Metropolitan Sewerage District
MS	Matrix Spike
MSD	Matrix spike duplicate
msl	mean sea level
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
QA	Quality assurance
QAPP	Quality assurance project plan
QC	Quality control
RAP	Milwaukee Remedial Action Plan Technical and Citizen Advisory Committees
RI	Remedial investigation
SAP	Sampling and analysis plan
SEWRPC	Southeastern Wisconsin Regional Planning Commission
SOW	Scope of work
START	Superfund Technical Assessment and Response Team
STN	STN Environmental Joint Venture
SVOC	Semi-Volatile organic compounds
TDD	Technical Direction Document
TOC	Total organic carbon
TSCA	Toxic Substances Control Act
USCS	Unified Soil Classification System
WDNR	Wisconsin Department of Natural Resources

1.0 INTRODUCTION

STN Environmental Joint Venture (STN) has prepared this Focused Remedial Investigation (RI) for the Great Lakes National Program Office (GLNPO) of the U.S. Environmental Protection Agency (EPA). All Focused RI activities were conducted under the Superfund Technical Assessment and Response Team (START) contract, in accordance with the requirements of the U.S. Environmental Protection Agency (U.S. EPA) Technical Direction Document (TDD) Number S05-0801-002. The scope of this TDD was to conduct a focused RI for the Lincoln Park/Milwaukee River Channel Sediments Site (Site) located in Milwaukee, Milwaukee County, Wisconsin. START was tasked to prepare a health and safety plan; prepare a field sampling plan (FSP) and Quality Assurance Project Plan (QAPP), collect sediment samples and sediment thickness samples; conduct a RI to include a screening ecological risk assessment, and prepare this RI report. This Focused RI is managed by the GLNPO's Sediment Team.

1.1 Purpose of Report

The goal of this report Site project is to evaluate the extent, both vertical and lateral, to determine if remediation of contaminated sediments is necessary, within the boundaries of the Site. Previous investigations characterized Lincoln Creek and the Blatz Pavilion. The West Oxbow area, to the west of the North Milwaukee River Parkway (Parkway) Bridge and the remainder section of the primary channel south of the Parkway until its confluence with the Milwaukee River, requires additional sediment characterization to fill in data gaps. Additional investigations to evaluate/verify the transport of total PCBs (as Aroclors) in the Lincoln Creek from upstream sources are also part of the scope of this RI.

1.2 Site Background

The Milwaukee River drains approximately 850 square miles in southeastern Wisconsin (Steuer et al, 1999). PCB contamination in the river was initially identified through fish tissue sampling, and fish advisories were issued in 1981. Based on the fish sampling results, numerous studies have been completed focusing on the river or specific reaches thereof, which indicated that there were a number of locations where PCBs accumulated in river sediments. One of these areas was the Estabrook Impoundment, which is located immediately upstream of the Estabrook Dam.

The Estabrook Impoundment contributes the greatest mass loading of PCBs in the Milwaukee River Basin (Baird & Associates, 1997), and it is estimated to contain 64,000 cubic yards (yd3) of contaminated sediment with slightly more than 5,380 pounds of PCBs (WDNR, 2005). A portion of this impoundment

is the small area immediately adjacent to the Blatz Pavilion, which was originally estimated to contain approximately 3,600 yd3 of contaminated sediment and 286 pounds of PCBs. The Blatz Pavilion area is isolated from the other contaminated areas in the impoundment and has easy public access. Despite signs indicating the presence of PCBs, the public continued to risk potential exposures through swimming, wading, and fishing activities. Therefore, the Blatz Pavilion site was selected by the WDNR to be the first area to be remediated in the impoundment (WDNR RIFS Blatz Pavilion 2007). The removal of the contaminated sediments and backfilling with clean material at the Blatz Pavilion was conducted in March 2008 and was completed in August 2008. The West Oxbow, upstream from the Blatz Pavilion is the subject of this RI.

1.2.1 Site Description

West Oxbow, termed Zone 2 for the ease of project description, consists of the primary and secondary channels of the Milwaukee River (Figure 1). The primary channel is connected to the Milwaukee River at the channel's north and south ends and is located to the east of the island located in the West Oxbow. The secondary channel, located to the west of the island, begins where Lincoln Creek empties into the primary channel north of the island, and connects with the primary channel southeast of the island (Figure 1).

Lincoln and Estabrook Parks are an integral part of the county park system, and continue to serve as recreational points for local residents. Aquatic activities are an important aspect of the parks, as well as the open green space they provide. The Milwaukee County Parks Department (MCPD) allows residents to portage non-motorized watercraft across park land and to launch into the rivers controlled by the Department, including the Milwaukee River and the Estabrook Impoundment. There are three designated access sites for canoeing and kayaking in Estabrook Park and one near the Lincoln Park fishing pier, which is located on the east bank of the river, north of Hampton Avenue.

Within Lincoln Park, there are picnic areas as well as baseball and softball diamonds, football/soccer fields, a playground, a swimming pool, and walking trails. The relative location of these areas to the Blatz Pavilion affords easy access to the river, which increases the possibility of exposure by the public to PCBs in the river sediments. This is especially true in summer, when outdoor temperatures are elevated and the river provides opportunities for wading and/or (possibly) swimming as a means for cooling off at this time of year.

1.2.2 Site History

The Estabrook Impoundment is formed by the Estabrook Dam, and it is a 103-acre pool with a maximum storage of 700 acre-ft. The impoundment extends approximately 2.5 miles upstream, which is just upstream of Silver Spring Road. The dam and resulting impoundment also influences flow within Lincoln Creek to a point approximately 0.5 miles upstream of the confluence with the Milwaukee River. The Milwaukee County Park System was created on January 1, 1937, through consolidation of the Milwaukee County Park Commission and the City of Milwaukee Park Board, and both Estabrook and Lincoln Parks were incorporated into the park system at that time.

In addition to the park system, the Milwaukee County Parks Department (MCPD) controls operation of the Estabrook Dam, which includes opening and closing the dam in the fall and spring of each year, respectively, or whenever necessary, given expected flow/precipitation conditions. 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.

Currently for the Milwaukee Estuary Area of Concern, of the 14 Beneficial Use Impairments listed, the Milwaukee Estuary has the following 11 impairments listed at the GLNPO website http://www.epa.gov/greatlakes/aoc/milwaukee.html#Beneficial_:

Restrictions on fish and wildlife consumption
Eutrophication or undesirable algae
Degradation of fish and wildlife populations
Beach closings
Fish tumors or other deformities
Degradation of aesthetics
Bird or animal deformities or reproduction problems
Degradation of benthos
Degradation of phytoplankton and zooplankton populations
Restriction on dredging activities
Loss of fish and wildlife habitat

1.2.3 Previous Investigations

The Milwaukee Remedial Action Plan Technical and Citizen's Advisory Committees (RAP) recognized contaminated sediment as the major contributor to use impairments within the area of concern (AOC). Significant examples of the use impairment cited by RAP are the fish consumption advisories, in effect

from Grafton to the mouth of the Milwaukee River because of contamination from PCBs (WDNR, 1994a).

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 GLNPO.

PCB contamination was initially identified in the area with fish tissue samples. The Milwaukee River PCB Mass Balance Study which was completed and reported in the 1997 *Milwaukee River PCB Mass Balance Project*. Additional study of the contamination in the area was conducted by the WDNR on the *Impacts of Stormwater Runoff on Urban Streams in Milwaukee County, Wisconsin* (1994). USGS published the 1999 report on the *Distribution and Transport of Polychlorinated Biphenyls and Associated Particulates in the Milwaukee River System, Wisconsin 1993-1995*.

Following the projects mentioned above, WDNR prepared the *Estabrook Impoundment Sediment Remediation Pre-Design Study* (August 2005). This study identified the volume of contaminated sediment estimated in the Estabrook Impoundment. It defined the horizontal and vertical extent of the contamination. The study also identified that there were no significant sources of PCB contamination coming from Lincoln Creek. The data gathered for the study identified the sediment handling characteristics and met WDNR Administrative Code NR347 requirements to help identify disposal options.

A remedial investigation/feasibility study was conducted for the Lincoln Park/Blatz Pavilion Site by Natural Resource Technology in March 2007.

1.3 Report Organization

The field investigations are discussed in Section 2.0 and the physical characteristics are discussed in Section 3.0. Section 4.0 discusses the nature and extent of the PCB contamination while Section 5.0

discusses the fate and transport of the PCBs. The Focused Ecological Hazard Evaluation (FEHE) is discussed in Section 6.0. The report is summarized in Section 7.0.

2.0 STUDY AREA INVESTIGATION

The study area for this RI includes the Lincoln Creek (Zone 1) and the West Oxbow (Zone 2) (Figure 1).

2.1 Results of Site Characterization

2.1.1 Surface Features

The Lincoln Park consists of approximately 312 acres of recreational property within Milwaukee County. Lincoln and Estabrook Parks are an integral part of the park system, and continue to serve as recreational points for local residents. The MCPD allows residents to portage non-motorized watercraft across park land and to launch into the rivers controlled by the Department, including the Milwaukee River and the Estabrook Impoundment. There are three designated access sites for canoeing and kayaking in Estabrook Park and one near the Lincoln Park fishing pier, which is located on the east bank of the river, north of Hampton Avenue. Within Lincoln Park there are picnic areas as well as baseball and softball diamonds, football/soccer fields, a playground, a swimming pool, and walking trails.

2.1.2 Contaminant Source Investigations

Previous investigations were conducted by WDNR and their contractors. PCB contamination was detected in the fish tissues. The Milwaukee Estuary Remedial Action Plan called for a completion of the Milwaukee River PCB Mass Balance Study, which was completed in 1997. WDNR is in the process of completing a source identification report for the project area.

2.1.3 Meteorological Investigations

The average temperature for Milwaukee, Wisconsin, is 46.1 degrees Fahrenheit (°F) (http://www.climate-zone.com/climate/united-states/wisconsin/milwaukee). The highest average temperature is in the month of July at 79.9°F, with the minimum average temperature in the month of January at 11.6°F.

Milwaukee receives an average of 32.9 inches of precipitation every year, with an average of 47.1 inches of snowfall. The months with the highest amount of precipitation is April, July and August with 3.5 inches. January has the most snowfall with an average of 13.7 inches.

The average wind speed is 11.4 miles per hour (http://www.uwex.edu/sco/milwind.html). The annual prevailing wind is west-northwest at 10.9 miles per hour.

2.1.4 Sediment Investigations

Sediment investigations occurred in two phases, first one in February 2008 and the second one in March 2009. All PCB Aroclor samples were analyzed by the U.S. EPA Contract Laboratory Program (CLP) Laboratory and the detection limits were the Contract Required Quantization Limit (CRQL). TCLP and bulk property analysis was conducted by STAT Analytical Corporation in Chicago, Illinois.

2.1.4.1 2008 Sediment Investigations

START conducted sediment investigations in February 2008 to address data gaps and define PCB contamination in the West Oxbow. START collected sediment samples from 13 locations in the West Oxbow following the *Final Field Sampling Plan* prepared for these investigations. Sampling was conducted using direct push technology (DPT) Geoprobe® equipment visual estimate of knowledge gap between 2005 based on concentrations and TSCA significance of 50 ppm. A total of 33 samples were collected from various depths for PCBs and total organic carbon (TOC) analysis (Figure 2). As part of this sampling, quality assurance/quality control (QA/QC) samples consisting of four duplicates and two matrix spike/matrix spike duplicates (MS/MSD) were collected. Of the 33 samples, four samples were also analyzed for bulk properties such as specific gravity, moisture content, and Atterberg limits (Table 1).

Sample locations were labeled S-1 through S-13 and sample identification included the area, location and depth of the sample. For example, sample collected at S-1 location in the Lincoln Park/Milwaukee River at a depth of 0 to 0.5 ft was labeled as LPMR-S-1-0-0.5. S-1 location was in the northern section of the primary channel just west of the Parkway, while S-13 was at the southernmost section of the West Oxbow area.

Of the 13 sampling locations, S-1 was the only location with PCB contamination below 1 milligram per Kilogram (mg/Kg). All other sample locations had surface (0 to 1 foot) PCB contamination over 1 mg/Kg. Sample location S-2 was located 200 ft downstream of S-1 and had 143.9 mg/Kg PCBs in the surface sediments and below 1 mg/Kg in the sample collected from over 2.5 ft (ft) depth (Figure 2). Both S-1 and S-2 were located closer to the western shores of the primary channel (Figure 3 and Table 2). Sample location S-3 was located approximately 40 ft east of S-2 on the same transect line as S-2 and represents the mid section of the channel. Here, PCB contamination was detected in all the three depths extending up to the 4-6 ft interval sample. PCB contamination was highest in the middle section of the boring sample, at 0.5 to 2 ft interval.

Sample locations S-4, S-5, and S-6 were situated surrounding the pier in the primary channel. Sample location S-4, situated to the north of the pier, had sediment deposits up to 9.5 ft. PCB contamination increased up to 5 ft depth in 2 sample intervals before falling to below 1 mg/Kg in the 7.5 to 9 ft interval sample. Sample location S-5, located to the west of the pier, had sediment deposits up to 9 ft deep. Similar to the S-4 location, PCB contamination in S-5 location also increased in the depth sample when compared to the surface sample and fell below 1 mg/Kg in the 8 to 9 ft interval sample. Sample location S-6 was situated near the southwest corner of the pier and had sediment deposits up to 6-7 ft. S-6 location had the highest PCB concentration of 823 mg/kg in the second interval sample collected from 1 to 2 ft depth. The PCB contamination in this location in the last interval sample (4 to 6 ft) was observed at 1.47 mg/Kg.

Sample locations S-7, S-8, and S-9 were situated in the West Oxbow Island between the primary and secondary channels of the Milwaukee River. Sediments depths in this area ranged from 1 to 7 ft deep. Sample location S-7, situated to the north of the island, had shallower sediment deposits (up to 3 ft) and had PCB contamination of 6.2 mg/Kg all the way down to the last interval sample. Sample location S-9, situated to the south of the island, had PCB contamination in the surface interval (6.1 mg/Kg) and in the 0.5 to 1.5 ft depth interval (8.0 mg/Kg) but was below 1 mg/Kg PCBs in the 3-foot interval sample. Sample location S-8, situated to the southwest of the island, had PCB contamination in the surface sediments (22.2 mg/Kg) as well as in the 1.5-foot interval sample (28.6 mg/Kg) but decreased to 1.17 mg/Kg PCBs in the 4 to 7-foot interval sample.

Sample locations S-10 through S-13 represent the southern end of the primary channel from the Parkway until its confluence with the Milwaukee River. Sample locations S-10 and S-11 were situated on the northern side of the channel while sample locations S-12 and S-13 were situated on the southern side of the channel. Sediment deposits ranged from 0 to 7 ft on the north side while it was in the range of 0 to 1.5 ft on the south side of the channel. Sample S-10 location, which was closer to the Parkway, had very low PCB contamination (up to 1.83 mg/Kg) in the surface and 5 to 7-foot depth interval sample. Sample location S-11, located to the south of S-10 had higher PCB contamination when compared to other locations in this area. PCB contamination ranged from 29.6 mg/Kg in the surface sample to 3.39 mg/Kg in the 1.5 to 4-foot interval sample. Sample locations S-12 and S-13 also had PCB contamination in surface and in 1.5-foot depth interval samples, with S-13 location showing higher than S-11 location contamination. The contamination ranged from 2.42 mg/kg to 4.13 mg/Kg in the surface samples and from 1.53 mg/Kg to 9.2 mg/Kg in the deeper samples.

In summary, the PCB contamination was prevalent through out the West Oxbow showed greater concentrations at depth for most sample locations.

2.1.4.2 2009 Sediment Investigations

Sediment investigations in March 2009 were designed to gather PCB data within Lincoln Creek (Figure 4), the West Oxbow (Figure 5), the Blatz Pavilion and behind the fixed crest spillway for the Eastbrook Dam (Figure 6). In addition, sediment thickness data were collected in Lincoln Creek and the West Oxbow to supplement existing data. Sampling and sediment thickness surveys were conducted using sampling tubes along a pre-set 150 by 20 ft in the West Oxbow and 300 by 40 ft transects in Lincoln Creek. Seven sediment samples from the Lincoln Creek and eight sediment samples from the West Oxbow were collected for PCBs analysis (Table 2). Two duplicate and one MS/MSD sample was collected as part of QA/QC sampling. Sample locations were labeled WO-A through WO-S in the West Oxbow and LC-A through LC-G to represent samples collected from the Lincoln Creek.

Lincoln Creek Investigations

Seven sediment samples were collected for PCB analysis and 20 locations were surveyed for sediment thickness in the Lincoln Creek during the 2009 sampling event. Lincoln Creek study area stretched from Green Bay Road to the north to its confluence with the primary channel, approximately one mile downstream. The purpose of Lincoln Creek sampling was refine the boundaries of an area to verify and delineate historically reported PCB concentrations and to ascertain if the Lincoln Creek is currently transporting PCBs in to the West Oxbow.

Sample locations in transects A and B were situated in the northern section of the creek just south of the Green Bay Road. Sample location LC-B-N, in the vicinity of historically reported PCB area, had the maximum PCB contamination observed in the creek (0 to 1 foot at 5.4 mg/Kg PCBs). The historical PCB concentration reported in this area was at 41 mg/Kg. Sediment samples collected from 0 to 1-foot depth interval locations approximately 40 ft (LC-B-2) and 80 ft (LC-B-2-S) downstream of LC-B-N location were detected at 0.97 mg/Kg and 0.91 mg/Kg of PCBs, respectively.

Downstream location LC-C2 also showed PCB contamination at 1.3 mg/Kg in the surface (0 to 1-foot) interval sample. PCBs in the next two downstream locations were below 1 mg/Kg in the surface sediments while in LC-F-2 location, it was observed at 1.2 mg/Kg in the surface interval (Figure 7).

RI results indicate minimal PCB contamination in the creek.

West Oxbow

Eight sediment samples and three QA/QC samples were collected from the West Oxbow during the 2009 RI investigations. Two of these sample locations (WO-A and WO-C) were situated to the north of the fishing pier and represented northern section of the West Oxbow study area. The WO-A sample location was immediately west of the Parkway bridge and WO-C was midway between WO-A and the pier. Both these sample locations were closer to the banks and had surface (0 to 1-foot interval) sediment contamination of 7 and 7.9 mg/Kg PCBs, respectively. Sediment deposits in this area were shallow and did not extend below 1-foot depth. Sample location WO-F was west of the pier on the western banks of the channel and showed below 1 mg/Kg PCB contamination (Figure 8).

The sample location at the confluence of Lincoln Creek and the primary channel (WO-H) and sample location to the west of the island (WO-K) identified PCB contamination below 1 mg/Kg. A PCB concentration of 120 mg/Kg was detected in sample location WO-I in the 0 to 1.7 ft depth interval sample. WO-I location is to the southwest of Lincoln Creek and the primary channel confluence and is situated on the western bank. Sample locations WO-Q and WO-R were situated on the west and east side of the Parkway in the southern section of the primary channel. Surface sediment contamination was observed at 1.2 and 3.1 mg/Kg in WO-Q and WO-R locations, respectively. The 2009 investigation of the West Oxbow indicated one location, WO-I, contains surficial sediment contamination around the island.

Blatz Pavilion

Two samples, BP-1 and BP-2, were collected for PCB analysis from the Blatz Pavilion in the area that had been remediated during the summer of 2008 to determine if PCB contaminated sediment is being deposited from upstream. In BP-1, PCB Aroclors 1248 and 1254 were detected at 0.012J mg/Kg and 0.011J mg/Kg, respectively. PCBs were not detected in sample BP-02. The J qualifier shows that the result was detected below the reporting limit.

Milwaukee River

One sample, MRZZ-01-0-0.5, was collected for PCB analysis from behind the spillway and dam area. PCB Aroclor 1242 was detected at 41 mg/Kg (Figure 6).

2.1.5 Geological Investigations

2.1.5.1 2008 Sediment Surveys

As part of the RI, sediment thickness surveys were conducted in 2008 in areas of the West Oxbow where further delineation of PCB TSCA characterization needed to be conducted. Sediment thickness was evaluated using GeoProbe borings and manual borings spread throughout the study area. The borings were drilled until refusal and its geological information was logged along with the GPS coordinates. At every 10th boring location, a sediment core was collected for visual sediment classification. Sediment and bedrock description and classification was based upon the Unified Soil Classification System (USCS) and standard practices developed by the American Society for Testing and Materials (ASTM). The lithologic descriptions for unconsolidated materials (soils [engineering usage] or deposits) used the name of the predominant particle size (e.g. silt, fine sand, etc.). The dimensions of the predominant and secondary sizes were recorded using the metric system. The classic deposit descriptions included, as a supplement, symbols of the USCS. The color descriptions were designated by the Munsell Color System. Each sediment thickness location was also surveyed for its location information (Table 3).

2.1.5.2 2009 Sediment Surveys

Sediment thickness surveys in 2009 were conducted using manual probing equipment along a 150 ft by 40 ft grid in the Milwaukee River, 300 ft by 40 ft grid in Lincoln Creek, and 150 ft by 20 ft grid in the West Oxbow. Respective transects were labeled as LC for Lincoln Creek, MR for Milwaukee River and WO for the West Oxbow. Points along each transect were numbered from the west bank to the east bank in sequence, (i.e. 1, 2, etc). The manual probe, lined with a disposable sleeve, was pushed until refusal to determine sediment thickness. One sediment core was collected at every 3rd transect and a geologist logged in the sediment classification of the boring.

2.1.6 Human Population Surveys

The Lincoln Park area is used for recreational purposes to include canoeing, kayaking, and fishing. Other activities within Lincoln Park there are picnic areas as well as baseball and softball diamonds, football/soccer fields, a playground, a swimming pool, and walking trails. Current water supply for the Milwaukee Water Works, which supplies drinking water to the Milwaukee area, is Lake Michigan.

2.1.7 Ecological Investigations

A hazard analysis was conducted for the benthos organisms in sediment. See Section 5.0 for details on the hazard analysis.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

3.1 Regional Geology

The regional geology of the Site is dominated by the effects of multiple Wisconsinan Stage glacial advances and retreats (Schneider, 1983). In the area of the Site, coarse-grained (sand and gravel) glacial outwash deposits predominate along the Milwaukee River, which occupies the course of a former glacial outwash channel (Schneider, 2003). Numerous sand and gravel deposits adjacent to the Milwaukee River have been historically mined to the north and south of the Site. Surface and near surface deposits outside the area immediately along the Milwaukee River tend to be dominantly fine-grained (silt and clay) glacial till deposits of the Oak Creek Formation. These glacial till deposits likely underlay the outwash deposits along the Milwaukee River.

Bedrock in the Site area consists of Devonian-age dolomite and shaley dolomite of the Milwaukee and Thiensville Formations (SEWRPC, 2002). The bedrock topographic surface in the region is highly variable ranging from scattered bedrock outcrops (including just to the southeast of the Site along the Milwaukee River) to depths to bedrock of more than 150 ft. Depth to bedrock beneath the Site is mapped as being greater than 100 ft (SEWRPC, 2002).

3.1.1 Site Geology

Zone 1 – Lincoln Creek

Lincoln Creek is an originally natural stream that has been heavily impacted, either directly or indirectly, by human activity. Some stretches above Lincoln Park have been directly altered through reconstruction of the banks and channel. All of the Creek, including that in Zone 1, have been affected by urban development around Lincoln Creek. One common aspect of urban development is increased surface water runoff rates which lead to increased peak stream flows. Consequently soft sediment thicknesses in Lincoln Creek tend to be relatively thin and dominated by coarser grained sediments like sand and gravel rather than clay and silt. Sediment thicknesses and characteristics in Lincoln Creek vary depending on their relative location with respect to main channel flow and the morphology of the underlying firm substrate. For example logged borings LC-B-1N, LC-B-2, LC-B-2-S, LC-C-2, and LC-D-2 were all advanced within the same section of the stream, but encountered sediments of varying characteristics and thicknesses. Sediment thicknesses varied from approximately 0.3 foot (at LC-D-2) to 1.0 foot (at LC-B-1-N and LC-C-2). Sediment types are dominantly sandy, but varied from sand with gravel and pebbles

(LC-B-2) to sandy clay silt with organics (LC-B-1-N). Sediment thicknesses and characteristics observed in the samples from the downstream borings LC-E-2 and LC-F-2 were similar to those of the upstream borings with thicknesses ranging from 0.6 to 1.0 foot.

Sediment thicknesses in Zone 1 based on probe resistance vary more than those observed from the sampled and logged borings. Probe-derived thicknesses vary from less than 1 foot (primarily along the western side of the lower stretch of Zone 1) to as much as 5 ft (in an area near the middle of the channel in the central part of Zone 1). However this 5 ft measured thickness is based on a single probe measurement and may simply reflect filling of a local depression in the more resistant streambed substrate. Sediment thicknesses were measured at approximately 4 ft at two locations near the mouth of Lincoln Creek. However, most measured sediment thicknesses within Zone 1 ranged from less than 1 foot to approximately 2 ft.

In general, sediments tend to be thinner and coarser grained where stream flows are the highest (near the creek middle in straight stretches and along the eastern section outside of the creek where creek curves) and thicker and finer grained in other areas. Unusually thick sediment thicknesses (from 2 to 5 ft) may be encountered, but may represent areas of limited extent given how few measured thicknesses exceeded 2 ft depth.

Zone 2- West Oxbow

The shallow local geology of the Lincoln Park West Oxbow or Zone 2 has been heavily changed by man-made alterations. This area appears to have originally been occupied by an oxbow lake or filled oxbow lake that was once the main channel for the Milwaukee River. The area of the West Oxbow from Lincoln Creek downstream to the Milwaukee River (Zone 2B) was originally occupied by the lower stretch of Lincoln Creek. All of Zone 2 was excavated in the 1930's. Consequently the natural stratigraphy underlying Zone 2 has been disrupted. The investigated sediments comprise sediments transported from Lincoln Creek and the Milwaukee River that were deposited from the excavation of the impoundment.

The deposition of these sediments has been controlled by a combination of natural fluvial processes and artificial control of the Milwaukee River. Historically, the downstream dam which was constructed on the River in the 1930's, has been closed in the spring following spring runoff to raise the water level in the oxbows and nearby areas for recreational purposes. In the fall, the dam is opened allowing most of the water in the oxbows to drain away leaving many areas of the oxbows exposed or submerged below shallow water through the winter. Until the dam is closed again in the spring, most of this area only

experiences significant submersion and relatively rapid flow velocities during high water flow events associated with snow melt runoff and heavy regional precipitation events.

While Zone 2 has been subject to gradual aggradation (depositional buildup) of sediments since the 1930's excavation activities, it is still a naturally ephemeral geological system subject to alterations of at least the upper sediment stratigraphy by unusually high river flow events. Such events can erode previously stable layers or areas of sediments and replace them with completely different sequences. Such an event may have occurred in June 2008 between the March 2008 and March 2009 sediment investigation field events. During the June 2008 heavy flow event, parts of Southeastern Wisconsin experienced 100-year flood events. While it is not clear that Zone 2 was subject to a flood event of that magnitude, it can be concluded that it did experience a higher than normal annual peak flow event in June 2008. The March 2009 appearance of some areas of the sediment flats, particularly on the east side of the primary channel where Lincoln Creek joins it, was markedly changed from how it looked in March 2008. The surface topography of the exposed sediments in this area had changed with some areas being higher and other being lower than was observed in March 2008. Therefore, it is likely that sediment sequences present in the Lincoln Park impoundment in March 2009 investigation were at least somewhat altered from those present during the March 2008 investigation.

The investigated sediments are located in different areas of sediment accumulations called either sediment flats or flats for the purpose of this report or channels. The flats border shorelines and are separated from one another by two channels. The primary channel of the West Oxbow is connected to the Milwaukee River at the channel's north and south ends and is located to the east of the island located in the impoundment. The secondary channel, located to the west of the island, begins where Lincoln Creek empties into the primary channel north of the island, and connects with the primary channel southeast of the island.

Sediment thicknesses and characteristics vary somewhat from area to area. Detailed sediment descriptions are provided in sediment boring logs provided in Appendix A for those collected in 2008 and Appendix B for those collected in 2009. Overall sediment thickness was defined as the interval between the top of sediment and a point where a distinct increase in coring resistance was encountered. Materials below the point of distinct sediment resistance tended to consist of dense sand and occasionally sand and gravel, and to be distinctly denser than the overlying sediments. The top of this more dense material is interpreted as representing the top of the original impoundment surface following excavation. This

underlying denser material likely represents older sediments, fluvial materials, or glacial deposits exposed during impoundment excavation and should therefore represent relatively uncontaminated material.

Sediment thicknesses within the flats of Zone 2 vary from less than 3 ft, generally adjacent to the channels, to as much as 9.5 ft. Typical sediment thicknesses in the flats tend to be between 5 and 7 ft although some flats have thinner average sediment thicknesses. Sediments tend to be fine grained (silts and clays) in their upper interval, and sandy in their lower interval, although this relationship does not hold everywhere. Thinner interbedded units of a contrasting texture occur at a number of locations. At some locations, the uppermost sediments tend to be sandy and appear to represent accumulations of sandy material in small sand bars on top of the sediment flats. A more detailed description of sediment characteristics by different areas is provided below. It should be noted that two 2009 logged borings in flat areas had 0.5-foot thick sandy silt intervals at the top of the sediment sequence. This may reflect deposition during the high flow event of June 2008.

Sediment thicknesses within the channels of Zone 2 vary from less than 1-foot to up to 5 ft. Average sediment thicknesses in the channels in Zone 2A tend to be somewhat greater than those in the channels of Zone 2B. This may reflect higher river flow velocities in Zone 2B than Zone 2A due to the additional flow contribution from Lincoln Creek. Furthermore, sediments in the primary channel of Zone 2B are thinner than those in the secondary channel. Again this is likely because the primary channel experiences higher flow velocities than the secondary channel. Sediments in the channels tend to be sandy with some silt and little or no clay. The uppermost sediment layer (approximately 0.5-foot or less) in the channels tends to be dominantly sandy, which probably reflects the effects of the July 2008 high flow event.

Four 2008 samples were collected from texturally homogenous depth intervals from four select borings for bulk characteristic profiling, which included grain-size analyses (Table 4).

Some of the percentages in Table 4 have been corrected to match the reported raw sieve size results and do not match the final reported percentages of sand or fines reported in the laboratory report. The results of the sieve size analyses indicate a distinct difference between the fine-grained and coarse grained sediment intervals. According to the results the fine grained sample intervals tend to be predominately silts (60 to 70%) with lesser portions of clay and fine sand, while the coarse grained intervals are almost exclusively fine to medium sand (greater than 90%).

For convenience, the sediment flats are subdivided into different areas to facilitate description of sediment variability across Zone 2 (Figure 9 and Table 5).

North Flat: on north side of primary channel (Zone 2A)

This area is a very narrow zone of sediment accumulation along the northwest shore of the primary channel. The overall sediment thickness encountered at the two borings in this area is approximately 8 ft. However, encountered sediment profiles at each boring are distinctly different precluding generalization about sediment types in this area. Sediments at boring S-1 are predominantly sandy, while those at boring S-2 are predominantly fine grained. The sediment base has a consistent elevation of 606 ft above msl.

East Flat: east of primary channel and north of pier (Zone 2A)

This area is a broad zone of sediment accumulation along the east shore of the primary channel to the north of the pier. Sediment thicknesses vary from approximately 5 ft at the northern end of this area to approximately 9.5 ft at the southern end, but are dominantly between 5.5 and 7.0 ft. Encountered sediment types in this area are dominantly fine-grained with minor, interbedded sandy intervals of generally 1-foot or less in thickness. The sediment base at most boring locations has an elevation of 608.8 to 610.8 ft above msl. The sediment base at three locations in the southern portion of this area is lower with elevations ranging from 606.7 to 607.6 ft above msl.

East Flat: east of primary channel and west of pier (Zone 2A)

This area is a moderately narrow zone of sediment accumulation along the east shore of the primary channel to the west of the pier and the shoreline. Sediment thicknesses are between 6.3 and 7.9 ft. The sediment thickness at one location near the shore (boring S-6) is only 4 ft. Encountered sediment types in this area are dominantly fine-grained with minor, interbedded sandy intervals of 1-foot or less in thickness. The sediment base at all boring locations, except S-6, has an elevation ranging from 608.1 to 608.9 ft above msl. The sediment base elevation at S-6 is considerably higher (612.4 ft above msl), which is likely due to its close location to the shore.

East Flat: east of primary channel and south of pier (Zone 2B)

This area is a variably narrow zone of sediment accumulation along the east shore of the primary channel to the south of the pier. Sediment thicknesses in this area are generally thinner than those further north ranging from 2.2 to 5.3 ft. No sediment profiles were collected from borings in this area. The sediment

base in this area is highly variable ranging from 609.9 to 613.6 ft above msl. This variability is likely due to the near shore locations of these borings.

West Flat: west of secondary channel (Zone 2B)

This area is represented by a single boring (ST-22), which was the only boring that could be obtained from the west shore of the secondary channel. This shore is a cutbank due to relatively high flow velocities, and fine-grained sediment accumulation along most it is likely to be limited. This boring location was only probed and no sediment descriptions were obtained. The observed sediment thickness was 6 ft with a sediment base elevation of 608.4 ft above msl.

Island Flat, east, west and north of the island (Zone 2B)

This area consists of the zone of sediment accumulation to the east, north, and west of the small island in the impoundment. Sediment thicknesses in this area to the east of the island are fairly consistent ranging from 5.5 to 6.5 ft. Sediment thicknesses in this area to the north and west of the island are more variable ranging from 4 to 7 ft, although all locations but one (ST-25) have thicknesses between 5.5 and 7 ft. Collected sediment profiles appear to indicate that sediments in this area tend to be fine grained with interbedded sandy intervals of 1.5 ft or less. The sediment base at boring locations between the primary channel and the island has an elevation of 609.2.to 610.5 ft above msl. The sediment base at boring locations between the secondary channel and the island generally has an elevation of 607.9 to 609.5 ft above msl. One boring location (ST-25) west of the island has a higher elevation of 611.7 ft above msl.

Island Flat, south and southeast of the island (Zone 2B)

This area consists of the zone of sediment accumulation to the south and southeast of the small island in the impoundment. Sediment thicknesses in this area range from 6 to 8.5 ft. Collected sediment profiles appear to indicate that sediments in this area tend to be sandy with a thinner fine grained interval. Boring ST-30 is located on a small sand bar at the southeast end of the island. The sediment base at boring locations between the primary channel and the island has an elevation of 607.2 ft above msl near the island to 609.9 ft above msl at the far southeast end of the flat.

Northern Southeast Flat, north of primary channel and east of bridge (Zone 2B)

This area consists of the zone of sediment accumulation to the north of the primary channel between the Milwaukee River Parkway bridge and the Milwaukee River. Sediment thicknesses in this area are fairly consistent ranging from 6 to 7 ft. Collected sediment profiles indicate variable sediment types, although

dominantly fine-grained in the upper four ft or more. The sediment base elevation ranges from 609.0 to 610.3 ft above msl.

Southern Southeast Flat, south of primary channel and east of bridge (Zone 2B)

This area consists of the zone of sediment accumulation to the south of the primary channel between the Parkway bridge and the Milwaukee River. Sediment thicknesses in this area are thinner, and a little more variable then those north of the channel ranging from 3 to 5 ft. Collected sediment profiles indicate variable sediment types, although dominantly sandy in the uppermost approximately 0.5-foot. The sediment base elevation ranges from 609.3 to 611.3 ft above msl.

Primary Channel, just west of bridge (Zone 2B)

This portion of the primary channel is located just downstream from the confluence of the primary and secondary channels. The measured sediment thickness in this area was only 1.2 ft. It consisted of 0.4 foot of sand overlying 0.8-foot of sandy silt.

Primary Channel, between the bridge and the Milwaukee River (Zone 2B)

This portion of the primary channel is located between the bridge and the confluence of the primary channel and the Milwaukee River. The measured sediment thickness in this area was only 1.5 ft. It consisted of 0.5-foot of sand overlying 1.5 ft of sandy silt.

Summary

The sediment flats were created over time as periodic spring high-water flows flooded these areas and deposited sediments. Most of the deposition on the flats is likely due to uncommon high-flow events. Individual sandy units in particular are likely due to single high-flow events, such as those sandy units observed at the tops of the 2009 boring samples. Contamination would likely be relatively consistent in layers of consistent sediment type since those layers would represent single depositional events. The variability in soil profiles between nearby borings indicates that depositional units are likely limited in horizontal extent. Sediments were likely deposited as lense-like bodies. It appears unlikely that single depositional beds of more than a few inches in thickness exist across wide areas.

Channel deposits tend to be thinner than those in the sediment flats varying from less than 1-foot to locally as much as 5 ft. However, they appear to average less than 3 ft. This is due to the higher stream flow velocities in the channels, which would tend to carry most fine grained sediment downstream before

it can be deposited. Therefore, contamination would be expected to be less common or widespread in the channel sediments than in the sediment flats.

4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 Result of Site Characterization

The following section discusses the nature and extent of the PCB contamination within the Lincoln Creek and the West Oxbow of the Milwaukee River area.

4.1.1 Sources

Historical information, as well as current investigations have not identified any sources of PCBs in the Lincoln Park/Milwaukee River.

4.1.2 Sediments

Lincoln Creek (Zone 1)

The Lincoln Creek study area extended from Green Bay Road on the north to its confluence with the primary channel of the Milwaukee River in the south. Of the seven sediment samples collected from this region, PCB contamination was observed above 1 mg/Kg in four locations. The highest concentration of 5.4 mg/Kg PCBs was observed in sample LC-B-1-N, in the area that was previously known to have had 41 mg/Kg PCB contamination. This location is closer to the Green Bay Road. PCB contamination was observed at 1.2 mg/Kg in LC-F-2 location, approximately 0.75 mile downstream of Green Bay Road. Sediment thickness in the Lincoln Creek ranged from 0 to 4.6 ft, with the encounter of fine sand and gravel below 1-foot in the northern 3/4th section of the creek. Sediment thickness was deeper in the shores of the creek. Based on the RI results, no identifiable upstream migration sources were observed. However, low level PCB-contaminated sediments are present in the Lincoln Creek Sediments.

West Oxbow (Zone 2)

The West Oxbow sediment investigation was accomplished through 44 samples collected from various depths and analyzed for PCBs (Figure 8). Aroclors were detected in every sample location in the West Oxbow. PCB contamination is higher in greater than 1-foot depth sediments when compared to the surface sediment contamination. Majority of the contamination was encountered up to an average 4-6 foot depth interval. The maximum PCB concentration of 143.9 mg/Kg in the top 1-foot layer of sediments was observed in the northern section of the primary channel at S-2 location west of the Parkway. Downstream PCB concentrations in the surface sediments were relatively low (less than 10 mg/Kg) except at sample

location WO-I-2, just southwest of the Lincoln Creek's entrance in to the primary channel, where it was observed at 120 mg/Kg.

The deeper interval contamination did not correlate to the locations where surface contamination was observed. PCB contamination ranged from 0.14 mg/Kg to 823 mg/Kg in the deeper sediments and was observed in sample depths up to 5.5 ft. Deeper sediment contamination was observed in 2 primary locations: in the pier area and in the island area of the West Oxbow. The higher PCB contamination was observed to the north, west, and southwest of the pier, with the highest concentration occurring to the southwest of the pier in location S-6. In the West Oxbow Island, the highest PCB contaminated sediment was observed in WO-I-2 location which was situated southwest of the Lincoln Creek's confluence with the primary channel. Historical sampling to the east and south of the West Oxbow Island had PCB contamination ranging from 1 to as much as 870 mg/Kg. Sample results in the channel between the Parkway and its confluence with the Milwaukee River on the south also indicated PCB contamination in depths up to 5-7 ft.

In general, the vertical extent of contamination varies in the West Oxbow, with contamination extending to over 6 ft depth in the pier area, to about 4 ft in the West Oxbow Island area, and up to 5-7 ft to the southeast of the Parkway. Five sediment samples collected at locations S-2, S-4, S-5, S-6, and WO-I-3 exceeded the Toxic Substance Control Act (TSCA) limit of 50 mg/Kg for disposal at the subtitle D landfill and thus require disposal at a subtitle C landfill. Samples S-4, S-5 and S-6 are located around the fishing pier for the largest area of TSCA-level contaminated sediment and goes down to a depth of 5.5 feet. There are several other small hot spot areas that exceed TSCA. Sample S-2 is located on the north near where the previous Lincoln Creek emptied into the West Oxbow, and is surficial at a depth of 0.5 feet. The other sample, WO-I-3, exceeds the TSCA limit is located near where the current Lincoln Creek empties into the West Oxbow, and was found at a depth of 1.7 feet.

Two disposal samples were also collected in the West Oxbow, WO-K-3 and WO-H-3. See Table 6 for disposal results. Samples were analyzed for PCBs by Method 8082, TCLP Metals by Method 1311/6020 and TCLP Mercury by Method 1311/7470A, TCLP SVOCs by Method 1311/8270C, TCLP VOCs by Method 1311/8260B, Specific Gravity, Reactive Cyanide by Method 3.3.2, Reactive Sulfide by Method 3.4.2, Flash Point by Method 1010, pH by Method 9045C and Phenolics by Method 9066. None of the results showed that the sediment was hazardous or TSCA-related waste.

Blatz Pavilion (Zone 3)

Two samples, BP-1 and BP-2, were collected from the top ½ foot for PCB analysis from the Blatz Pavilion in the area that had been remediated during the summer of 2008 (Figure 6). This sampling was conducted to verify any transport of PCBs from upstream locations in to the remediated Blatz Pavilion areas. Aroclors 1248 and 1254 were detected at 0.012J mg/Kg and 0.011J mg/Kg, respectively, in one sample (BP-01). The J flag designates a positive detection below the CLP contract required detection limit.

Milwaukee River (Zone 5)

One sediment sample (MRZZ-01-0-0.5) was collected behind the spillway next to the Estabrook Dam to depositional area behind the fixed crest spillway (Figure 6). Sediment thickness in the spillway ranged from an estimated 5.0 ft within the debris area on the south end to no measureable sediment along the northern section of the dam. The sample was collected from a depth of 0 to 0.5 ft and had Aroclor 1242 at 41 mg/Kg.

5.0 CONTAMINANT FATE AND TRANSPORT

The contaminant of concern for this focused RI is PCBs. The following section discusses the fate and transport of PCBs.

5.1 Potential Routes of Migration

PCBs were detected in the sediments of the Lincoln Creek and in the area where the Lincoln Creek converges with the Milwaukee River. PCBs are mixtures of different congeners of chlorobiphenyls and the relative importance of the environmental fate mechanisms generally depends on the degree of chlorination. In river areas, PCBs tend to absorb to sediment particles and do not tend to dissolve into the water. PCBs can to volatize rapidly from water, when the water temperature is warm enough.

5.2 Contaminant Persistence

PCBs do not readily break down and may remain in the environment for long periods of time. The persistence of PCBs increases with the degree of chlorination. The persistence of PCBs increases with an increase in the degree of chlorination. Mono-, di- and trichlorinated biphenyls biodegrade relatively rapidly, tetrachlorinated biphenyls biodegrade slowly, and higher chlorinated biphenyls are resistant to biodegradation. The PCBs in water tend to adsorb to suspended matter. PCBs are also known to bioaccumulate in organisms and humans. PCBs have shown to bioconcentrate significantly in aquatic organisms through the food chain, increasing in concentration as they move up the chain. The main exposure route to humans is through fish ingestion of contaminated fish and drinking contaminated water. The current BUIs and the restrictions for the Milwaukee Estuary are in place by taking these exposure routes into consideration for the human exposure at the Lincoln Park.

5.3 Contaminant Migration

In sediment environments, PCBs tend to attach to sediment particles. The migration of the PCBs in sediment will tend to depend on the migration of the sediment particles themselves. The water solubility is greater for the lower chlorinated PCBs, the higher chlorinated PCBs tends to remain adsorbed to sediment particles. Due to Estabrook Dam opening and closing every year, sediment transportation to downstream locations is very likely. With sediment transportation, contaminant migration is also very likely to occur.

6.0 FOCUSED ECOLOGICAL HAZARD EVALUATION

6.1 Ecological Evaluation

The Wisconsin Water Program staff developed and published a set of consensus-based sediment quality guidelines [(CBSQG)(WDNR, 2003)]. The CBSQG numbers are the geometric means from several sets of sediment quality guidelines (SQG) that had been previously developed independently by several states, Canadian provinces, U.S. EPA, the National Oceanic and Atmospheric Agency (NOAA) and several researchers (Persaud et al. 1993; Long and Morgan, 1991; Ingersoll et al. 1996a, 1996b; MacDonald et al. 2000a, 2000b; Swartz, 1999). These SQG were generally developed using empirical approaches based on databases which related a range of observed effects (e.g. reduced survival, growth or reproduction of benthic macroinvertebrate organisms) to a range of increasing concentration of individual sediment-associated contaminants. The guidelines establish two concentration levels based on effects–a lower threshold effect concentration (TEC) at which no or minimal effects are predicted and a probable effect concentration (PEC) at which adverse effects are highly probable or will frequently be seen. The focus of the CBSQG was primarily on developing concentrations of chemicals that would be protective of the majority of bottom dwelling species that reside on or in the sediment and sediment port water.

6.1.1 Uses of Sediment Quality Guidelines

The effects-based CBSQG are intended as screening level concentrations for commonly found contaminants that will help identify the need for further actions. They are used to assess the quality of prospectively dredged materials (NR 347 dredging projects); to screen site concentrations for evaluation of the relative potential risks to sediment dwelling species; to evaluate the need to collect additional sediment chemistry data; as toxicity benchmarks in a screening level ecological risk assessment; and as one line of evidence among multiple lines of evidence used to support decision-making. The CBSQG should not be used on a stand-alone basis to establish cleanup levels or for sediment management decision making.

6.2 Ecological Evaluation

6.2.1 Calculation of PEC-Q and estimated mean PEC-Q values

During 2008, START collected a number of sediment core samples from the West Oxbow area. The samples were analyzed only for PCB Aroclor mixtures. Following the WDNR (2003) guidelines on Consensus-Based Sediment Quality Guidelines (CBSQG), the results are compared to probable effects

concentration (PEC) for PCBs. The observed PCB concentrations were first adjusted to a 1% total organic carbon (TOC) basis and then were divided by the CBSQG PEC value for total PCBs (676 µg/kg) to determine the PEC-Quotient (PEC-Q). The WDNR (2003) guidelines also indicates that a mean overall PEC-Q for metals, total PAHs, and total PCBs combined, can be calculated which gives additional confidence in the evaluation of the probability of adverse effects on benthic macroinvertebrate communities. Because analyses for metals and PAHs were not performed during the 2008 samples, historical data from a 2003 sampling event as described in WDNR (2005) were used to provide an estimate of the PEC-Q values for metals and PAHs.

6.2.2 Details of 2003 Sampling Event; Definition of Zones

The samples analyzed for metals from the 2003 sampling event (WDNR, 2005) were composite samples from five zones sized according to the amount of soft sediment found in a 1993 survey as defined in the QAPP for this sampling event (WDNR, 2001). Zone 5 included Lincoln Creek up to its confluence with the west oxbow and Zone 1 extended down to Estabrook Dam. Samples for NR347 (i.e. metals, pesticides) were composite samples prepared for each zone. A uniformly-sized portion of each surficial core was set aside and blended with samples from other cores taken in each zone (WDNR, 2001).

The zones as defined in the QAPP (WDNR, 2001) were different from the zones defined in the final report from the 2003 sampling event (WDNR, 2005). Due to the composite samples analyzed for metal concentrations were collected based on the zones as defined in the QAPP, that definition of the borders and numbering of the zones was retained during the evaluation of the 2008 sampling event. The PCB results from the 2008 sampling event were grouped by these zones for calculation of overall mean PEC-Q values that combine the PEC-Q values for metals, total PAHs, and total PCBs.

6.2.3 Historical Data Evaluation

Data for the TOC percent and PAHs are not available for the surface horizons (0 to 0.6 ft and 0.6 to 1.2 ft) for several of the core samples collected in the 2003 sampling event (WDNR, 2005). However, results for PCB analysis for these samples were listed in the Data Appendix to WDNR (2005). Therefore, these samples are listed in Table 7 of this evaluation, but the cells for TOC and PAH results in this table have the entry "nd" for no data, but the PCB results are presented for completeness. Because the TOC data are not available for these samples, the PCB values could not be adjusted to 1%TOC to be comparable to the basis for the CBSQG PEC value for PCBs. Therefore, PEC-Q values for PCBs in the surface horizons were not calculated. Because of the limited number of PAHs data points for the top 40 centimeters (cm)

of sediment, the highest PEC-Q for total PAHs in each of the zones (as defined in the QAPP, 2001) was selected for combination with the metals and PCB data to calculate the mean overall PEC-Q.

6.2.4 Biologically Active Zone

The CBSQG numerical values apply to the biologically active zone associated with deposited sediments in flowing (streams and rivers) and static (lakes and ponds) water bodies (WDNR, 2003). The biologically active zone typically encompasses the top 20 to 40 cm of sediment in freshwater environments (Clarke et al. 2001). The majority of benthic organisms are usually associated with the top 15 cm, although certain invertebrate and/or amphibian species can use sediment down to 100 cm below the surface during certain portions of their life history. For the purposes of this evaluation, the biologically active zone was defined as the first 40 cm (1.3 ft) of sediment, and any horizon sampled with a starting depth of 40 cm or less was included in the analysis. This limitation to the upper 40 cm was based on the fact that the available metals data were limited only to surficial layers.

6.2.5 PCB Non-detects, 2008 sampling event

The PCB data from the 2008 sampling event were reported as concentrations of individual Aroclor mixtures. The Aroclor mixtures 1242, 1248, and 1254 were positively detected and identified in at least one of the samples. Other Aroclor mixtures that were not positively detected in any of the samples were not carried through the evaluation. For those samples where Aroclor mixtures 1242, 1248, or 1254 were not detected, the detection limit was carried through the analysis, because these Aroclor mixtures could have been present at or below the detection limit.

6.3 Results

6.3.1 Metals

The mean PEC-Q_{metals} values ranged from a low of 0.4 for the Zone 2 and Zone 5 surface sediment samples to 1.2 for Zone 3 (Table 8). There were no samples taken from Zone 5 in the 2008 sampling event, therefore Zone 5 was not considered further. The highest mean PEC-Q_{metals} of 1.2 was for Zone 3, which includes the sediments in the western oxbow of the Estabrook Impoundment from just north of the island in the oxbow south to the Parkway Bridge.

6.3.2 PAHs

The PEC-Q_{PAH} values ranged from a low of 0.1 in Zone 1, (Lincoln Creek before the confluence with Estabrook Impoundment) to 1.4 at sampling point 4X5 (located just south of the island in the western oxbow) in Zone 3. The PAH concentration, adjusted to 1% TOC of 1,478 is below the threshold effects concentration for total PAHs of 1,670 (WDNR, 2003). Therefore, no adverse effects on benthic macroinvertebrate communities would be expected. The PEC-Q_{PAH} of 1.4, however, indicates that the PAH concentration adjusted to 1% TOC is above the concentration where adverse affects are probable. A PEC-Q_{PAH} value in excess of 1.0 was only observed at one sampling point. Because of the limited number of surface sediment sampling points with complete PAH and TOC data, the highest PEC-Q_{PAH} value observed in each zone was selected to carry forward in the overall mean PEC-Q calculation for the 2008 sampling event. The selected PEC-Q_{PAH} values are presented in Table 9.

6.3.3 PCBs

The PEC-Q_{PCB} values for the 2003 sampling event (WDNR, 2005) ranged from a low of 0.1 to a high of 34.1 for samples that had a starting depth of 40 cm or less (Table 9). Out of the 16 samples, 50% had PEC-Q_{PCB} values that exceeded 1, which indicates that adverse effects on benthic macroinvertebrates are probable.

The PEC-Q_{PCB} values for the 2008 sampling event (Table 7) ranged from a low of 0.2 to a high of 121.7 for samples that had a starting depth of 40 cm or less. Out of the 23 samples that met these criteria, 65% had PEC-Q_{PCB} values that exceeded 1, which indicates that adverse effects on benthic macroinvertebrates are probable.

6.3.4 Overall Mean PEC-Q

Overall mean PEC-Q values were calculated for the results of the 2008 sampling event. Overall mean PEC-Q values were calculated by summing the PEC-Q values for metals, total PAHs, and total PCBs, and dividing by three. The metals PEC-Q for each composite sample from the zone was used for all STN 2008 sampling points within a given zone. The highest PAH PEC-Q from each zone was also used in order to be conservative. Dividing by the number of PEC-Q values included in the overall mean normalizes the value to provide comparable indices of contamination among samples for which different numbers of contaminants were analyzed (WDNR, 2003). The equation [$Y= 101.48(1-0.36^{X})$] presented in Appendix A (WDNR, 2003) was used to estimate the probability of observing sediment toxicity at a given overall mean PEC-Q based on the results of MacDonald et al. (2000a). The overall mean PEC-Q

values ranged from a low of 0.4 to a high of 40.9. The estimated average incidence of toxicity exceeded 95% for 28% of the samples for which data were available (Table 7).

6.4 Discussion of Ecological Hazard Evaluation

The CBSQG were developed to identify concentrations of chemicals that would be protective of the majority of bottom dwelling species that reside on or in the sediment and sediment port water. The guidelines establish two concentration levels: the TEC, at which no or minimal effects are predicted and the PEC at which adverse effects are highly probable (WDNR, 2003).

The limited available data for metals in the Estabrook Impoundment sediments indicated that the combined concentrations of cadmium, chromium, copper, lead, nickel and zinc in Zone 2 were high enough that adverse toxic effects on sediment dwelling species are probable. The concentrations of chromium and lead exceeded the PEC for the individual metals. The concentration of lead also exceeded its PEC in Zone 3 but the mean PEC-Q for all metals combined did not exceed 1 for Zone 3. Due to the sediment samples analyzed for metals were composite samples collected only from the surface layers, it is not possible to identify hot spots of contamination that could be remediated to reduce the risk to benthic macroinvertebrates. It is also not possible to evaluate the depth of sediment that would need to be treated or removed to reduce the risks.

The data for PAHs are more extensive than for metals, however, the data for total PAH concentrations for several surface sediment samples are missing from the WDNR (2005) report and the data appendices. The total PAH concentration, adjusted to 1% TOC, exceeded the PEC level for only one surface, sediment sample. None of the total PAH concentrations found in subsurface sediment samples exceeded the PEC level. These results suggest that the concentrations of PAHs in the Estabrook Impoundment sediments are below the levels where adverse effects on sediment dwelling species are probable.

The data from both the 2003 sampling event (WDNR, 2005) and the 2008 sampling event described in this report show that the total PCB concentrations in the biologically active zone exceeded the PEC in more than 50% of the samples analyzed. This suggests that adverse effect on sediment dwelling organisms due to elevated total PCB concentrations are probable in much of the surface sediment in the Estabrook Impoundment. When combined with reasonable estimates of concentrations of metals and PAHs, the overall mean PEC-Q values show an estimated average incidence of toxicity that exceeds 95% for 28% of the samples from the 2008 sampling event. Therefore, the probability of adverse effects to

sediment dwelling species is high over large portions of the western oxbow of the Estabrook Impoundment.

Note that the CBSQG generally do not consider the food chain aspects of such bioaccumulative compounds as methyl mercury and the nonpolar organic compounds (e.g. PCBs) in terms of effects to humans or wildlife (WDNR, 2003). Where necessary, other approaches such as food chain modeling and back calculating from acceptable fish tissue levels should be used to establish protective levels of bioaccumulative contaminants in sediments for ecological receptors and humans.

7.0 SUMMARY AND CONCLUSIONS

7.1 Summary

7.1.1 Nature and extent of Contamination

Historical information, as well as current investigation has not identified any discrete sources in Lincoln Creek/West Oxbow of the Milwaukee River. The RI sampling and historical sampling indicates that the sediments in the study area are contaminated with PCBs at levels that present a significant ecological risk. The fish consumption advisory issued by the Wisconsin Division of Public Health is evidence of significant human health risk.

Lincoln Creek (Zone 1)

The RI activities in the creek included investigating the historical hot spot, EST5-7, with 41 mg/Kg PCBs, and determining if contamination is being transported to the West Oxbow. The highest PCB concentration of 5.4 mg/Kg PCBs was observed in sample LC-B-1-N in the area that was previously known to have had 41 mg/Kg PCB contamination. This location is closer to the Green Bay Road. Sediment thickness in Lincoln Creek ranged from 0 to 4.6 ft, with of fine sand and gravel below 1-foot in the northern 3/4th section of the creek. Sediment thickness was deeper in the shores of the creek and towards the creek's confluence with the primary channel. Low level PCB-contaminated sediments are present in the Lincoln Creek.

West Oxbow (Zone 2)

West Oxbow investigations were conducted through 44 sediment sample analyses for PCBs. Sediment thickness survey through probing/polling occurred at over 300 locations, with some of these locations being collocated with chemical sample locations. Sediment thickness in the West Oxbow ranged from 0 to 9.5 ft in depth.

PCBs were detected in all sediment samples collected from the West Oxbow. The highest PCB concentration in the top 1-foot section of the sediments (surface sediments), was observed in the northern section of the primary channel, in S-2 location (143.9 mg/Kg) west of the Parkway and north of the pier. Downstream PCB concentrations in the surface sediments were relatively low (less than 10 mg/Kg)

except at sample location WO-I-2, just southwest of the Lincoln Creek's entrance in to the primary channel, where it was observed at 120 mg/Kg.

PCB concentrations in deep sediments (i.e. greater than 1 foot) are higher than surficial concentrations, with the majority of the contamination at an average 4 to 6-foot depth interval. The deeper contamination did not correlate to the locations where surface contamination was observed. PCB contamination ranged from 0.14 mg/Kg to 823 mg/Kg in the deeper sediments and was observed in sample depths up to 5.5 ft. Deeper sediment contamination was observed in 2 primary locations: in the pier area and in the island area of the West Oxbow. The higher PCB contamination was observed to the north, west, and southwest of the pier, with the highest concentration occurring to the southwest of the pier in location S-6. In the West Oxbow Island, the highest PCB contaminated sediment was observed in WO-I-2 location, which was situated southwest of the Lincoln Creek's confluence with the primary channel. Historical sampling to the east and south of the West Oxbow Island had PCB contamination ranging from 1 to as much as 870 mg/Kg in sediment depths up to 5 ft.

7.1.2 Fate and Transport

PCBs found in the Site sediments are most likely to adsorb to the sediments and transport with the migration of the sediments. PCBs are known to bioaccumulate in organisms and humans and bioconcentrate significantly in aquatic organisms. The fish advisory already in effect in the Site area indicates the documented exposure pathway to humans.

7.1.3 Hazard Evaluation

Because of the fish consumption advisory in the Site area, a focused ecological hazard evaluation for the bottom dwelling species was conducted. The CBSQG were developed to identify concentrations of chemicals that would be protective of the majority of bottom dwelling species that reside on or in the sediment and sediment pore water. The guidelines establish two concentration levels: the TEC, below which no or minimal effects are predicted and the PEC above which adverse effects are highly probable (WDNR, 2003).

The limited available data for metals in the Estabrook Impoundment sediments indicated that the combined concentrations of cadmium, chromium, copper, lead, nickel and zinc in Zone 2 were high enough that adverse toxic effects on sediment dwelling species are probable. The concentrations of chromium and lead exceeded the PEC for the individual metals.

The total PAH concentration, adjusted to 1% TOC, exceeded the PEC level for only one surface sediment sample and did not exceed the PEC level in any subsurface samples. These results suggest that the concentrations of PAHs in the sediments are below the levels where adverse effects on sediment dwelling species are probable.

The data from both the 2003 sampling event (WDNR, 2005) and the 2008 START sampling event show that the total PCB concentrations in the biologically active zone exceeded the PEC in more than 50% of the samples analyzed. This suggests that adverse effect on sediment dwelling organisms due to elevated total PCB concentrations are probable in much of the surface sediment in the Site area. When combined with reasonable estimates of concentrations of metals and PAHs, the overall mean PEC-Q values show an estimated average incidence of toxicity that exceeds 95% for 28% of the samples from the 2008 START sampling event. Therefore, the probability of adverse effects to sediment dwelling species is high over large portions of the West Oxbow in Zone 2.

7.2 Conclusions

7.2.1 Data Limitations

The Estabrook Dam influences the flow conditions in the study area. The opening and closing of the dam greatly influences the transport of contaminated sediments in the study area. The sediment survey data collected during this RI is subject to these influences in the study area.

7.2.2 Recommended Remedial Action Objectives

Based on the scope of work assigned under this RI, no formal risk assessment was conducted for the Site and hence, no remedial action objectives (RAOs) were developed.

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