7 Summary of Findings

7.1 Introduction

The RI study area includes the Lower Fox River, extending 63 km (39 mi) from the outlet of Lake Winnebago to its mouth, as well as Green Bay, from the city of Green Bay and extending 190 km (119 mi), to Michigan's Big and Little Bay de Nocs. Both the Lower Fox River, and to a lesser extent, Green Bay were historically used as general discharge points for municipal, industrial, and agricultural entities located within the watershed. Many of the historical discharge practices occurred with minimal treatment of wastes during an era of little environmental regulation and without an adequate understanding of the fate and effects the chemicals posed to the environment. As a result, numerous compounds have been detected in the sediments and water of the Lower Fox River and Green Bay, as well as in the aquatic and wildlife species living in or frequenting the system.

The data evaluated in this RI report include selected sediment and water sample analytical results collected between 1989 and 1999 along the entire 63 km (39 mi) stretch of the river as well as all of Green Bay. Sediment samples were analyzed for over 200 different chemical parameters. In addition, biological sampling data has been collected since the 1970s. Data that was used in preparing the RI report was derived from the FRDB. The FRDB was developed following quality assurance review and acceptance of data gathered during previous investigations (EcoChem, 2000). Further, the conclusions of an EPA authorized peer review included the following:

- The quantity and quality of data are good enough to support the need for cleanup action
- The data are adequate to determine the distribution of contaminants within the system and direct where cleanup actions should focus
- The data are adequate to support identification and selection of possible remedy technologies (Weston, 1999)

The FRDB was used in this RI to evaluate the distribution of select compounds in the sediment and water of both the Lower Fox River and Green Bay. Information pertaining to the distribution of chemical compounds within fish and wildlife evaluated along the Lower Fox River and Green Bay, as well as other potential risks to human health and the environment, are addressed in the SLRA (RETEC, 1998c) and the RA (RETEC, 2002), performed in conjunction with this RI.

Compounds of potential concern, representing potential risks to human and ecological health, were identified in the SLRA (RETEC, 1998c) based on conservative risk screening procedures. These compounds include the chlorinated organic compound (PCBs and dioxins/furans), the chlorinated pesticides (DDT and dieldrin), and the inorganic compounds (mercury, lead, and arsenic). Of the substances evaluated in the SLRA, PCBs are the primary compounds of concern within the Lower Fox River and Green Bay.

Between the mid 1950s and the early 1970s, PCBs were used and released to the environment through carbonless copy paper production and recycling by a number of facilities along the Lower Fox River. During this time period, PCB use was unregulated. The WDNR estimated that between about 1954 and the early 1970s the cumulative mass of PCBs discharged into the Lower Fox River was about 313,600 kg (691,370 pounds), with a possible range between 126,450 and 399,450 kg (278,775 and 880,640 pounds) (WDNR, 1999a). According to WDNR estimates, approximately 98 percent of the total PCBs were released by the end of 1971. Five point sources are estimated to have contributed over 99 percent of the PCBs detected in the river sediments (WDNR, 1999a).

Point source discharges of the compounds of potential concern (COPC) have decreased significantly since the Clean Water Act and other environmental regulations were implemented in the early 1970s. As a result, additional input of PCB into the Lower Fox River from regulated discharges has now been essentially eliminated (WDNR, 1999a). However, residual sources for PCBs and other detected compounds remain in river and bay sediments, which continue to affect water quality, fish, wildlife, and potentially humans. The RA (RETEC, 2002) identified total PCB concentrations in sediments above 250 μg/kg as a potential concern for at least 50 percent of all potential receptors. Some of the documented adverse effects associated with PCBs include altered benthic community structure and reproductive impairments in fish-eating birds (WDNR, 1996; Matteson, 1998). The WDNR issued consumption advisories for fish in both the river and the bay as early as 1976, and waterfowl advisories were issued in 1987 due to continuing elevated levels of PCBs in tissue samples. The MDNR issued a fish consumption advisory for Green Bay fish in 1977.

7.2 Physical and Ecological Characteristics

The average annual discharge rate from the Lower Fox River into Green Bay is approximately 122 m^3/s (4,300 cfs). The locations of sediment deposits are related to flow characteristics along the river channel and typically occur where water velocities decrease, such as behind dams or where the river widens. The most significant sediment accumulation in the Lower Fox River occurs downstream of

the De Pere dam, partially due to the water level and seiche effect of Green Bay where streamflow direction frequently reverses in this reach.

Water currents within Green Bay are more complex than the Lower Fox River and are affected by wind speed and direction, river discharge, thermal gradients, and ice cover. These currents generally move counter-clockwise and water from the Lower Fox River moves north along the east side of the bay while water from Lake Michigan moves south along the west side. These currents also control the distribution of sediments discharged from the Lower Fox River into Green Bay. Because the mouth of the Lower Fox River is located at the southern end of Green Bay, most of the river discharge, associated sediment load, and PCBs are directed along the east shore of Green Bay.

The bay bathymetry is also influenced by water currents and, in turn, affects the distribution of sediments. Regionally, bedrock dips to the east and river tributaries to Green Bay are more prevalent along the west side of the bay. Based on current patterns, a number of spits and shallows have formed near these tributaries mouths. These spits and shallows direct the currents towards the center of the bay, thereby establishing areas within the bay where lower velocity circular currents occur. Both Long Tail Point and Little Tail Point extend at least 3.4 km (2.1 mi) into the bay. Significant sediment accumulations occur between the mouth of the Lower Fox River and a line between Long Tail Point (on the west) and Point Au Sable (on the east). Bathymetry measurements are typically less than 3.7 m (12 ft) within this area. Moving north from the mouth of the Lower Fox River, the water depth in the bay increases and the influence of the spits and shallow areas on current movement decreases.

The southern end of Green Bay is a lacustrine estuary with hypereutrophic conditions. Water quality on the south end of the bay reflects the influence of runoff and the sediment load from the Lower Fox River and other tributaries. The hypereutrophic conditions of the southern bay support a large and diverse population of fish species due to the availability of nutrients. Due to the shallow water depths, this portion of the bay warms rapidly during summer months, supporting extensive biological activity. Historically, fish dies-offs occurred during periods of extremely warm water or extended ice cover because of reduced dissolved oxygen levels from biological and chemical processes. No significant die-offs have been recorded since the 1960s or early 1970s (Lychwick, 2000c).

Water quality conditions in the northern part of the bay, especially near the passage connecting with Lake Michigan are generally oligotrophic, except in the northern portion of Big Bay de Noc or near the tributary mouths on the west side where mesotrophic or eutrophic conditions may exist.

Significant habitat areas present within the river and bay include wetlands and associated submerged SAV. Wetlands offer nesting, feeding, and refuge opportunities for birds and terrestrial animals of the region. The SAV typically associated with wetlands provide spawning, feeding and refuge habitat for a variety of forage and game fish in the river and bay. Wading birds, shorebirds, and waterfowl feed on the SAV or fish that frequent these areas, as well as nesting in these areas. Wetland habitat are preferred by mink, although these animals will also live and feed in grassland and agricultural areas, if necessary.

In addition to wetland/SAV habitat, islands offer nesting and feeding opportunities to birds and terrestrial animals, while cuts/coves offer quiet water areas where fish will congregate, birds will feed, and terrestrial animals will seek refuge or food. Eagles, double-crested cormorants, gulls/terns, and numerous other birds nest in the vicinity of the river and bay and these birds feed on the fish of the system.

Exposure of biota to PCB-impacted sediments fosters uptake of PCBs into the food chain. Therefore, the presence of PCB impacted sediments in locations near wetlands/SAV, islands, quiet water cuts/coves, and other habitat areas within or along the shores of the Lower Fox River and Green Bay are of concern and described in this report.

7.3 Nature and Extent of Sediment Impacts

7.3.1 Overview

Sediment and water samples collected from Lake Winnebago reflect relatively low background concentrations of most constituent groups compared with those observed in Lower Fox River. The sources of PCBs, and most other COPC, are located downstream of Lake Winnebago. Water samples collected from both the river and bay indicate that PCBs and the other chemical compounds are continuing to migrate through the system as particulates absorbed to river/bay sediments and in a dissolved phase.

Below Lake Winnebago and upstream of the De Pere dam, PCB impacted sediments have accumulated in specific deposit areas that reflect the dynamics of the river hydrology. Downstream of the De Pere dam and out into Green Bay, sediments and PCBs have accumulated over large continuous areas. The highest total PCB concentrations in sediments within the Lower Fox River are typically found in the vicinity of historical point source discharges, including deposits in LLBdM and SMUs 56/57. Although a number of PCB discharge points were located in LLBdM, sediment transport has since dispersed the PCBs throughout the river and over large areas downstream of the De Pere dam, especially within the bay.

Approximately 96,800 kg of PCBs are distributed in sediments with PCB concentrations greater than 50 ug/kg. This PCB mass is contained in about 474 million m^3 of sediment. The results are summarized below and indicate that the De Pere to Green Bay Reach and Green Bay Zone 2, combined, contain almost 60 percent of the total PCB mass in the system in less than 10 percent of the total contaminated sediment volume. The PCB mass and volume of contaminated sediment for each river reach and bay zone are listed below.

Location	PCB Mass and Percent in System*	Contaminated Sediment Volume and Percent in System*
Little Lake Butte des Morts Reach	1,540 kg (1.6%)	1.35 million m^3 (0.29%)
Appleton to Little Rapids Reach	94 kg (0.1%)	0.18 million m^3 (0.04%)
Little Rapids to De Pere Reach	980 kg (1.0%)	1.71 million m^3 (0.36%)
De Pere to Green Bay Reach	25,984 kg (26.8%)	5.52 million m^3 (1.16%)
Green Bay Zone 2	32,013 kg (33.1%)	39.5 million m^3 (8.33%)
Green Bay Zone 3	35,243 kg (36.4%)	397 million m^3 (83.72%)
Green Bay Zone 4	925 kg (1.0%)	28.9 million m^3 (6.10%)
TOTAL	**96,779 kg**	**474.16 million m^3**

* Includes sediments containing PCB concentrations greater than 50 μg/kg.

Because PCBs are no longer discharged, more recent sediment loading into the river is gradually mixing with and accumulating over PCB impacted deposits. The vertical distribution of PCB concentrations within river and bay sediments frequently increase with depth. As noted previously, the river stage and discharge rate significantly affect resuspension, mixing, transport, and redeposition of impacted sediments in the system.

PCB concentrations in surface sediments in the Lower Fox River and Green Bay are generally decreasing over time, but apparent detectable loss is limited to the top 4 inches of sediment. The rate of change in surface sediments is both reach- and deposit-specific. The change averages an annual decrease of 15 percent, but ranges from an increase of 17 percent to a decrease of 43 percent. Just below the top 4 inches, there is no distinguishable change in the sediment PCB concentrations constant. The changes in PCBs in the sediments are reflected in the significant, but slow declines in fish tissue concentrations of between 5 and 7 percent annually. Exceptions to the general overall decline were noted with walleye in Little Lake

Butte des Morts and carp in Green Bay Zone 1, where steep significant increases in PCB concentrations were observed.

7.3.2Lower Fox River PCB Impacts

7.3.2.1 Overview

Large volumes of soft sediment have accumulated at a number of locations throughout the Lower Fox River. Upstream of the De Pere dam there are 35 previously identified sediment deposits, exhibiting total PCB concentrations greater than 50 μg/kg. As indicated above, these deposits comprise approximately 2.7 percent of the total PCB mass in the system. A large majority of the PCBs in the upper three reaches of the river occur within several specific sediment deposits. Approximately 1,932 kg (4,260 pounds) of PCBs (74 percent of the total PCB mass upstream of the De Pere dam) is contained within sediment deposits A, B, POG, and EE/FF/GG/HH. The mass of PCB associated with Deposit N is not included in these estimates due to completion of the SRD project.

In the De Pere to Green Bay Reach there is one large, continuous sediment deposit between the dam and just downstream of the Fort James turning basin. Small sediment deposits are located downstream of the turning basin due to navigation channel dredging activities. Approximately 27 percent of the total estimated PCB mass in the river/bay system is located in this reach. Further, the estimated 25,984 kg (57,285 pounds) of PCB in this reach represents almost 91 percent of the total mass in the river.

The following summarizes the magnitude and extent of impacted sediments and PCBs for each reach of the river.

7.3.2.2 Little Lake Butte des Morts Reach

Deposits A through H and POG contain about 1,540 kg (3,395 pounds) of PCBs in about 1.35 million m^3 (1.77 million yd^3) of sediment with concentrations greater than 50 μg/kg PCB. RI findings for this reach include the following:

- These deposits cover about 314 hectares (775 acres) and the deposits range up to approximately 1.9 m (6.2 ft) thick.

- The highest total PCB concentration was 222,722 μg/kg.

- Upstream deposits A, B, and POG have the highest PCB mass to volume ratios in this reach. These three deposits contain 952 kg (2,100 pounds) of the PCBs in about 252,000 m^3 (329,600 yd^3) of sediment. Also, about 910

kg (2,000 pounds) of the PCBs in these three deposits is present in the upper 100 cm (3.28 ft) of sediment.

- Deposit E contains about 454 kg (1,000 pounds) of PCBs. However, the mass to sediment volume ratios for this deposit is much lower than deposits A, B, and POG.

Habitat associated with this reach include Stroebe Island, located on the northeast side of Deposit E. The wetlands located between Stroebe Island and the river bank are the largest in-river wetlands in this reach. Also, an eagle nest has been observed in this area. Smaller wetland areas are located in the vicinity of deposits A, C, and POG and SAV are present in the shallow waters nearby, including near Deposit B. Two large areas of cuts/coves are present on the west side of Deposit C and just south of Deposit POG. Most of the shoreline in the LLBdM Reach is characterized as either poor or unsuitable for mink.

7.3.2.3 Appleton to Little Rapids Reach

Sediment accumulation in the Appleton to Little Rapids Reach is more localized compared with the other three reaches. Deposits I through DD contain about 94 kg (207 pounds) of PCBs in about 184,790 m^3 (241,700 yd^3) of sediment with concentrations greater than 50 μg/kg PCB. RI findings for this reach include the following:

- Deposits I through DD cover approximately 153 hectares (378 acres) and these deposits generally occur in areas of slower stream flow velocities (e.g., where the river widens, in the vicinity of dams/locks, eddy pools along the banks, etc.).

- The highest total PCB concentration was 77,444 μg/kg.

- Only deposits W, X, and DD have a volume exceeding 30,000 m^3 (39,240 yd^3) of sediment and these are located where the river widens and/or upstream of a dam.

- The average sediment volume in each of the remaining 19 deposits in this reach is about 3,780 m^3 (4,944 yd^3) and sediments range up to approximately 100 cm (3.28 ft) thick.

- Deposits T and DD contain a combined mass of about 45 kg (100 pounds) of PCBs, and these PCBs are located at depths less than 100 cm (3.28 ft).

- Approximately 32 kg (71 pounds) of PCBs remain in deposits N and O following completion of the SRD project and no future attempt to remove this mass is currently under consideration.

The Thousand-Islands Nature Conservancy, located near the city of Kaukauna and just upstream of deposits W and X, is an important habitat area in this reach. The nature conservancy is protected island habitat in which eagles nest and other birds and terrestrial animals nest and feed. The wetland and SAV habitat associated with the shores of the conservancy are the largest in the reach. Additional wetlands and SAV areas are located near the Little Rapids dam, which is in the vicinity of Deposit DD. Mink habitat in this reach varies. Between Appleton and Kaukauna the mink habitat is generally characterized as either poor or unsuitable. However, between Kaukauna and Little Rapids, the shoreline habitat is characterized as moderate to good.

7.3.2.4 Little Rapids to De Pere Reach

Sediment accumulation in this reach extends over a long distance and large area. Deposits EE through HH contain 980 kg (2,160 pounds) of PCBs in approximately 1.71 million m^3 (2.24 million yd^3) of sediment with concentrations greater than 50 μg/kg PCB. The four deposits in this reach are essentially a single sediment unit. RI findings for this reach include the following:

- These sediments cover about 266 hectares (657 acres) and are up to 2.3 m (7.5 ft) thick in select areas, especially near the De Pere dam.

- The highest total PCB concentration was 54,000 μg/kg. Further, PCB concentrations are lowest at the upstream end of Deposit EE and increase near the De Pere dam.
- Almost all of the PCB are contained in the upper 100 cm (3.28 ft) of sediments.

No significant wetland or SAV areas are located in this reach. However, this reach is generally less developed than the other three reaches and large expanses of the shoreline are characterized as marginal to good for mink habitat.

7.3.2.5 De Pere to Green Bay Reach

This reach exhibits the largest volume and areal extent of impacted sediments found in the Lower Fox River. The 96 SMUs in this reach contain 25,984 kg (57,285 pounds) of PCBs in over 5.5 million m^3 (7.2 million yd^3) of sediments with concentrations greater than 50 μg/kg PCB. RI findings for this reach include the following:

- Sediments cover about 524 hectares (1,295 acres) and range in thickness up to 4 m (13 ft).

- The highest total PCB concentration was 710,000 μg/kg.

- The mass of PCB decreases significantly with depth. Approximately 16,150 kg (35,530 pounds) of PCBs, or about 55 percent of the total PCB mass in the Lower Fox River, are located in the upper 100 cm (3.28 ft) of sediments in this reach. Approximately 10,600 kg (23,370 pounds) of PCBs (36 percent of the PCBs in the river) are buried below 100 cm (3.28 ft).

- Approximately 636 kg (1,400 pounds) of PCB and 31,000 m^3 (40,550 yd^3) of sediment were removed from SMUs 56-61 during the SMU 56/57 SRD project. Further, removal of additional sediment and PCB from SMU 56/57 started in August 2000 but the final mass and volume estimates are not expected to be known until early 2001.

- Excluding SMUs 56-61, six SMU groups (SMUs 20-25, 32-37, 38-43, 62-67, 68-73, and 80-85) contain almost 11,000 kg (24,250 pounds) of PCB, or about 37 percent of the total mass in the Lower Fox River. These SMU groups also exhibit the highest PCB concentrations or greatest PCB mass to sediment volume ratios in the river.

Both banks of the river in this reach are extensively developed. Therefore, significant habitat locations within this reach are largely confined to submerged wetland areas associated with the mouth of the river. Only 16 hectares (40 acres) of wetlands and SAV were identified in this reach. Additionally, two large areas of cuts/coves are located in SMUs 20-25, just downstream of the De Pere dam, and in SMUs 44-49. These are both areas with elevated PCB concentrations in surface sediments. Mink habitat in this reach is generally characterized as unsuitable.

7.3.3Green Bay PCB Impacts

7.3.3.1 Overview

The PCB mass and impacted sediment volume in Green Bay are much larger than in the Lower Fox River. Considering sediments with concentrations greater than 50 μg/kg PCB, the estimated mass in Green Bay exceeds 68,180 kg (150,310 pounds) and the volume exceeds 465 million m^3 (608 million yd^3). This represents almost 71 percent of the PCB mass and over 98 percent of the contaminated sediment volume in the system.

Estimates of the PCB load transported from the Lower Fox River into Green Bay were completed using data from 1994/95 and 1998. Approximately 220 kg (485 pounds) of PCBs were transported from the river into the bay during 1994/95. Based on water samples collected during 1998, this load decreased to about 125 kg (275 pounds). The PCB load from the river into the bay is affected by the seasonal and yearly changes in stream flow as well as the declining finite source of PCBs located within the river.

Total PCB concentrations in sediment are highest, and the mass/volume ratios greatest, near the mouth of the Lower Fox River and decrease with distance. The presence and distribution of PCBs within Green Bay reflect the influence of discharge from the Lower Fox River as well as the predominantly counter-clockwise current patterns in Green Bay. Sediments with the highest PCB concentrations are located in the immediate vicinity of the river mouth or along the east shore of the bay.

7.3.3.2 Green Bay Zone 2

This zone contains approximately 32,000 kg (70,550 pounds) of PCBs in 39.5 million m^3 (51.6 million yd^3) of sediment. Sediments with the highest PCB concentrations have accumulated adjacent to the navigation channel and between the mouth of the river and Point Au Sable. The PCB distribution reflects the influence of Green Bay current patterns, as higher concentrations are located along the east side of the bay. RI findings for this zone include the following:

- Sediments in Zone 2A cover about 5,930 hectares (14,650 acres) and have an average thickness of about 0.34 m (1.1 ft). In Zone 2B the sediments cover about 5,150 hectares (12,725 acres) and have an average thickness of about 0.38 m (1.25 ft).

- The highest total PCB concentration was 17,000 μg/kg.

- Considering only sediments with PCB concentrations greater than 1,000 μg/kg reduces the mass and volume estimates to 28,100 kg (61,950 pounds) and 17.8 million m^3 (23.3 million yd^3), respectively. This represents slightly more than 29 percent of the PCBs in the system but less than 5 percent of the total estimated contaminated sediment volume.

- Considering only the upper 30 cm (1 ft) of sediments, approximately 14,5000 kg (31,900 pounds) of PCBs are contained within about 29.8 million m^3 (39 million yd^3) of sediment. This represents about 15

percent of the total PCB mass and 6 percent of the contaminated sediment volume in the system.

The most significant habitat types within Green Bay are wetlands and islands. A number of wetland areas are located within Zone 2. The Point Au Sable and Whitney Slough wetland areas are located along the east shore of Green Bay (Zone 2B). Atkinson Marsh, Long Tail Point, Dead Horse Bay, and portions of the Little Tail Point wetland areas are all located along the west shore of the bay (Zone 2A).

Fish spawn and feed throughout Zone 2 due to the shallow water depths and abundant nutrients available in this hypereutrophic environment. Although sediment impacts are greater in Zone 2B than in Zone 2A, the discharge of the Lower Fox River and the seiche effect both contribute to the dispersal of PCB-impacted sediments throughout this entire zone.

In addition to the wetland areas, both Bay Port and Kidney Island CDFs are located in this zone. Both CDFs have received PCB impacted sediments removed during navigation channel dredging activities and gulls/terns nest on Kidney Island while waterfowl and other birds nest and feed in the vicinity of Bay Port. Mink habitat associated with the two CDFs are generally marginal. Mink habitat in Zone 2B is generally poor to unsuitable, although moderate to good habitat is present with increasing distance from the mouth of the Lower Fox River. Zone 2A mink habitat is generally marginal or better north of the mouth of Duck Creek.

7.3.3.3 Green Bay Zone 3

This zone contains approximately 35,240 kg (77,700 pounds) of PCBs in approximately 397 million m^3 (519 million yd^3) of sediment. PCB distribution results show that sediments with the highest concentrations have accumulated along the east shore of Green Bay, extending from Dyckesville to Egg Harbor, reflecting the influence of Green Bay current patterns. RI findings for this zone include the following:

- Sediments in Zone 3A cover about 85,890 hectares (212,240 acres) and have an average thickness of just 0.21 m (0.7 ft). In Zone 3B, the sediments cover about 69,340 hectares (171,340 acres) and have an average thickness of about 0.31 m (1 ft).

- The highest total PCB concentration was 1,320 μg/kg.

- Considering only sediments with concentrations greater than 1,000 μg/kg PCB reduces the mass and volume estimates to 1.65 kg (3.64 pounds) and 8,800 m^3 (11,510 yd^3), respectively. This zone represents

very small percentages of the estimated total PCB mass and contaminated sediment volume in the system.

- Considering only the upper 30 cm (1 ft) of sediments, approximately 30,000 kg (66,000 pounds) of PCBs are contained within about 355.9 million m^3 (465.5 million yd^3) of sediment. However, a large majority of this mass is located in sediments which have less than 1,000 μg/kg PCBs.

Similar to Zone 2, wetlands and islands are the main habitat located along or within the bay. Extensive wetland areas are located along the west shore of Green Bay and fish spawn and feed throughout this area. However, sediments with the highest PCB concentrations in Zone 3 are located along the east shore of Green Bay. Only two large wetland areas, the Little Sturgeon Bay and Sand Bay wetlands, are located along the east shore. Also, on the east side of the bay, fish spawn and feed within a very narrow band of shallow water located near the shore as well as in the vicinity of Little Sturgeon Bay and the islands located in this area. In addition to the wetlands, a number of small islands are located along the east shore of Green Bay, extending from Little Sturgeon Bay to the tip of the Door Peninsula. These islands offer secure nesting locations for numerous types of birds.

Mink habitat was only characterized only as far north as the city of Marinette on the west side of the bay and just north of the city of Sturgeon Bay on the east side. The Zone 3 shoreline is generally characterized as marginal to good, except in areas where development has occurred, such as the cities of Dyckesville and Sturgeon Bay.

7.3.3.4 Green Bay Zone 4

Based on the estimates of the PCB mass and sediment volume, Zone 4 is relatively unaffected compared to zones 2 and 3. Zone 4 contains less than 925 kg (2,040 pounds) of PCBs, or only about one percent of the total mass in the system. Total PCB concentrations in sediment within Zone 4 are all less than 500 μg/kg except for one sample which had a concentration of 751 μg/kg.

Habitat present in this zone includes wetlands, SAV, islands, and other areas which support fish, birds, and wildlife. Based on the small mass of PCBs and the low concentrations (compared with the other river reaches and bay zones), habitat within this zone is relatively unimpacted.

7.3.4Other Chemical Compounds

Elevated concentrations of the other six COPCs are typically widespread in river and bay sediments with little or no spatial relation to specific discharge sources.

The distribution of these chemicals reflects the dynamic nature of the river and bay environments, the effect of downstream transport of sediments in the system, and/or non-point pollution sources.

The RI findings with respect to other chemical parameters in sediments include the following:

- Mercury was used in a number of pulp and paper production activities to reduce organic slime (Konrad, 1971). The SLRA identified mercury concentrations exceeding 0.15 mg/kg as a potential concern. Mercury concentrations in Lake Winnebago sediments averaged 0.14 mg/kg while average concentrations in each reach of the Lower Fox River ranged from 1.26 to 2.42 mg/kg. The elevated mercury concentrations are widespread in the Lower Fox River sediments and are not associated with any specific deposit or point source discharge. Mercury concentrations in Green Bay are much lower than levels in the river. The average concentration in Zone 2 was 0.593 mg/kg but averages in zones 3 and 4 range only up to 0.19 mg/kg, which is just above the Lake Winnebago background concentration.

- Except for PCB and mercury, no specific existing or historical discharge sources were identified for the other COPCs.

- The spatial distribution of dioxin/furan compounds cannot be evaluated because only 22 samples were collected from deposits D/E/POG, deposits EE/HH, and SMUs 56/57. Concentrations of 2,3,7,8 TCDD/F detected in sediments ranged from 0.23 to 170 ng/kg (ppt). The SLRA identified furan concentrations above 2,000 ng/kg as a potential concern.

- Sixteen chlorinated pesticides, which are generally associated with agricultural non-point source activities, were detected in river sediments at concentrations up to 67 μg/kg. Additional non-point pesticide sources may include atmospheric deposition and stormwater run-off from pesticides used at parks, golf courses, and other institutional facilities; however, these sources are likely to be small compared with agricultural activities. Only seven compounds were detected in more than four sediment samples. These included DDT, and its derivatives DDD and DDE, endrin aldehyde, endrin ketone, gamma-BHC (lindane), and heptachlor. Distribution of these compounds was generally sporadic. Only DDT and dieldrin were identified by the SLRA as being COPCs. The SLRA identified DDT (total)

concentrations above 1.6 μg/kg as a potential concern. DDT was detected at 10 widely distributed locations within the Lower Fox River above this concentration. There is no established concentration of concern for dieldrin, which was detected in only one sample from LLBdM, suggesting that dieldrin distribution is very limited. Neither DDT nor dieldrin were detected within Green Bay.

- Lead is a naturally occurring element in soil and sediment. Background lead concentrations in Lake Winnebago sediments averaged 35 mg/kg while average concentrations in each reach of the Lower Fox River ranged from 75.6 to 167.8 mg/kg. However, a disproportionately large number of samples for these two compounds were collected in the De Pere to Green Bay Reach. The SLRA identified lead concentrations above 47 mg/kg as a potential concern. While some deposits exhibit concentrations as high as 1,400 mg/kg, lead occurrence is widespread in the Lower Fox River sediments and cannot be related to any specific point source discharge. In Green Bay, the average lead concentration ranged from 1.5 to 29.9 mg/kg, which is lower than the Lake Winnebago background concentration.

- Arsenic is also naturally occurring and background concentrations in Lake Winnebago sediments averaged 5.33 mg/kg. The SLRA identified arsenic concentrations above 8.2 mg/kg as a potential concern. An elevated arsenic concentration was detected in only one location (SMU 38) at 385 mg/kg. Excluding this arsenic detection, average concentrations in both the river and the bay were below either the Lake Winnebago background concentration or the SLRA level of 8.2 mg/kg.

- SVOCs, which result from both point and non-point sources in urban and rural areas, were detected throughout the Lower Fox River at concentrations exceeding the background levels observed in Lake Winnebago. The SVOCs detected at higher concentrations included PAHs and also occurred in widespread areas of the river. Total PAH concentrations below 4,000 μg/kg typically do not warrant further assessment. Total PAH concentrations along the Lower Fox River ranged from non-detectable to 60,000 μg/kg. A number of locations from LLBdM to the mouth of the river exceeded 4,000 μg/kg with the highest values frequently observed downstream of more urbanized areas. None of the sediment samples collected within Green Bay Zone 2 exceeded 4,000 μg/kg, and PAHs were not detected in zones 3 or 4.

7.4 Chemical Transport and Fate

The organic COPCs, including PCBs, dioxin/furan, pesticides, and PAHs, exhibit strong affinities for organic material in the sediments. The suspension and transport of these compounds absorbed onto the sediments is largely controlled by moving water in the Lower Fox River and Green Bay. Greater volumes of sediments become suspended and are transported during high flow events (such as storms and spring snow melt). The Lower Fox River has an average discharge of 122 m^3/s (4,300 cfs). Data from Water Years 1989-99 indicate that river discharge exceeds both 272 m^3/s (9,605 cfs) 10 percent of the time. Previous investigators have estimated that these high flow events transport more than 50 to 60 percent of the PCB mass which moves over the De Pere dam and into Green Bay (Velleux and Endicott, 1994; WDNR, 1995).

Water samples collected during 1994/95, confirm these results as well as the estimate of the PCB mass transported into Green Bay. Particulate PCB concentrations suspended in the water column increase moving downstream. Also, downstream of LLBdM, the particulate PCB concentration is approximately three times greater than the dissolved PCB concentration. Particulate PCB concentrations are related to water temperatures and flow whereas the dissolved PCB concentrations are generally constant and never exceeded 33 μg/kg. Particulate PCB concentrations decline dramatically during the winter months, when water temperatures are below 4°C (40°F), and increase in response to high flow events during the summer. WDNR (1995) concluded that this seasonal variation is related to the amount of algae present in the water, which appear to facilitate suspension and transport of PCB in the water column. Similar results were found for mercury in samples collected at the mouth of the river.

The overall PCB flux through the Lower Fox River and Green Bay system is estimated to be as follows:

- Approximately 125 kg (275 pounds) to 220 kg (485 pounds) of PCB are annually transported from the Lower Fox River into Green Bay as part of the suspended sediment load. According to some estimates, this load may have ranged as high 550 kg (1,210 pounds) annually in the past.

- The estimated annual PCB load into Green Bay from tributaries other than the Lower Fox River is estimated to be approximately 10 kg (22 pounds).

- The estimated annual stormwater runoff from non-point sources into the Lower Fox River is estimated to be 1 kg (2.2 pounds).

- Estimates for annual atmospheric deposition of PCB into the Lower Fox River range from 3 kg (6.6 pounds) to 5 kg (11 pounds) while deposition into Green Bay ranges from 2 kg (4.4 pounds) to 35 kg (77 pounds).

- Estimates for annual volatilization of PCBs from surface waters into the atmosphere range up to 5 kg (11 pounds) for the Lower Fox River while volatilization from Green Bay ranges from 130 kg (287 pounds) to 500 kg (1,100 pounds).

- Approximately 122 kg (270 pounds) of PCB are transported annually from Green Bay into Lake Michigan.

At present, roughly 0.4 percent to 1 percent of the PCB mass within the river was discharged into the bay annually. Atmospheric contributions and losses of PCBs are minimal compared to the mass in the river and bay and the amount of PCB transported in dissolved or particulate phase.

7.5 Investigative Assumptions/Uncertainties

Due to the heterogeneity and dynamic nature of the river and bay sediments, various assumptions are necessary in evaluating and interpreting the data and results. These assumptions are discussed below:

- The data used in this RI includes results from numerous investigations performed over an extended period of time. Sediment data were collected over a 10 year period while tissue samples date from 1971. In sediments, temporal changes in the magnitude and extent of the compounds of concern will occur over this time period, particularly at the sediment/water interface. In general, however, sediment mobility decreases with depth and the occurrence and mass of the compounds of concern as described herein is not likely to have appreciably changed over the period of these investigations. Although surface sediment concentrations decrease over time, once sediments are buried, the PCBs tend to remain in place and increase concentrations with depth (The Mountain-Whisper-Light, 2001). The PCB mass exported from the river into Green Bay (estimated to be 1 percent or less annually) is far less than the amount that remains in place. Although shallower PCB sediment concentrations may vary more significantly over the short term, declining PCB concentrations in the sediment and water column on a large scale are a long-term phenomena. Temporal variability in PCB occurrence and mass is believed to be less significant than its

spatial heterogeneity. Therefore, the Fox River Database considered all usable analytical results over the period of these investigations, subject to the specified acceptance criteria. In tissue samples, decreasing concentration trends have been observed but the rate of decrease has slowed significantly since the 1980s. Also, some fish species show stable or increasing tissue concentration trends. Therefore, the analyses completed as part of this effort are not suitable for predicting future trends.

- The density of sediment sampling points in the river and bay affects the accuracy of the interpolated distribution of PCBs and the general distribution of the other COPCs described in this report. Some sediment locations (deposits/SMUs/zones) have been sampled extensively while others have been characterized by relatively few samples. However, it is believed that sufficient sampling has been conducted to characterize the compounds present and areas of the Lower Fox River and Green Bay of greatest concern.

- The precision and accuracy of laboratory analytical results for specific sediment samples can be affected by factors such as sampling methods, the representativeness of the sample at a specific location, matrix interferences and analytical protocols. Total PCBs were either analyzed and reported by the laboratory or were calculated from Aroclor or PCB congener results for a given sample. However, the analytical results in the FRDB are assumed to reasonably reflect sediment and water quality, based on the independent quality assurance review and acceptance criteria.

- Sediment bed properties (grain size, cohesion, water content, etc.) generally change more rapidly with depth than horizontally over a large area. It is possible that there is compaction of the sediments when sediment cores are collected. Sample core lengths and the corresponding analytical results have not been adjusted to correct for possible sediment compaction or the percentage of core length recovered, which may tend to underestimate PCB distribution and mass at depth.

Based on the data contained within the FRDB, sufficient sampling and analysis has been conducted to characterize the magnitude and distribution of COPCs in the Lower Fox River and Green Bay as well as allow development of the Baseline Risk Assessment and Feasibility Study.