The highest levels of PCBs are found in fish with relatively high lipid (fat) levels such as salmon, lake trout, carp, and catfish (Kleinert, 1976). Historically, carp have had the highest tissue concentrations of all species tested. Mean fillet PCB levels for carp were in excess of 38 mg/kg in 1976 and have remained above levels sufficient to trigger fish consumption advisories to the present time (Sullivan et al., 1983; WDNR, 1995d). Walleye, salmon, lake trout, and forage fish species also demonstrate elevated tissue concentrations of PCBs.

In addition to triggering fish consumption advisories, PCB contamination was sufficient to prompt closure of commercial fisheries. The large-scale commercial carp fishery in Green Bay was suspended for interstate commerce in 1975, and closed entirely in 1984 because of PCB contamination (Kleinert, 1976; Allen et al., 1987).

Data provided by the WDNR characterize the persistent nature of elevated PCB tissue levels in fish residing in the Fox River and Green Bay area. As illustrated in Figures 6-2 and 6-3, tissue concentrations in all species sampled exceeded fish consumption advisory thresholds in 1976, and remain above these thresholds in many species. Carp provide an extreme example of the extent of this contamination; whole-body PCB levels were greater than 38 mg/kg in 1978 (WDNR, 1995d). As illustrated in Figures 6-2 and 6-3, levels of PCBs in all species appear to have declined somewhat during the 1980s, but the rate of decrease has slowed and PCB concentrations remain near or above consumption advisory thresholds for most species. Consumption advisories currently are in place for most species commonly caught in the Fox River and Green Bay (WDNR, 1976-1994). Thus, the temporal extent of PCB contamination in Fox River and Green Bay fish extends for at least 19 years, beginning with the recognition in 1976 that fish tissue concentrations were dramatically elevated in all species examined.

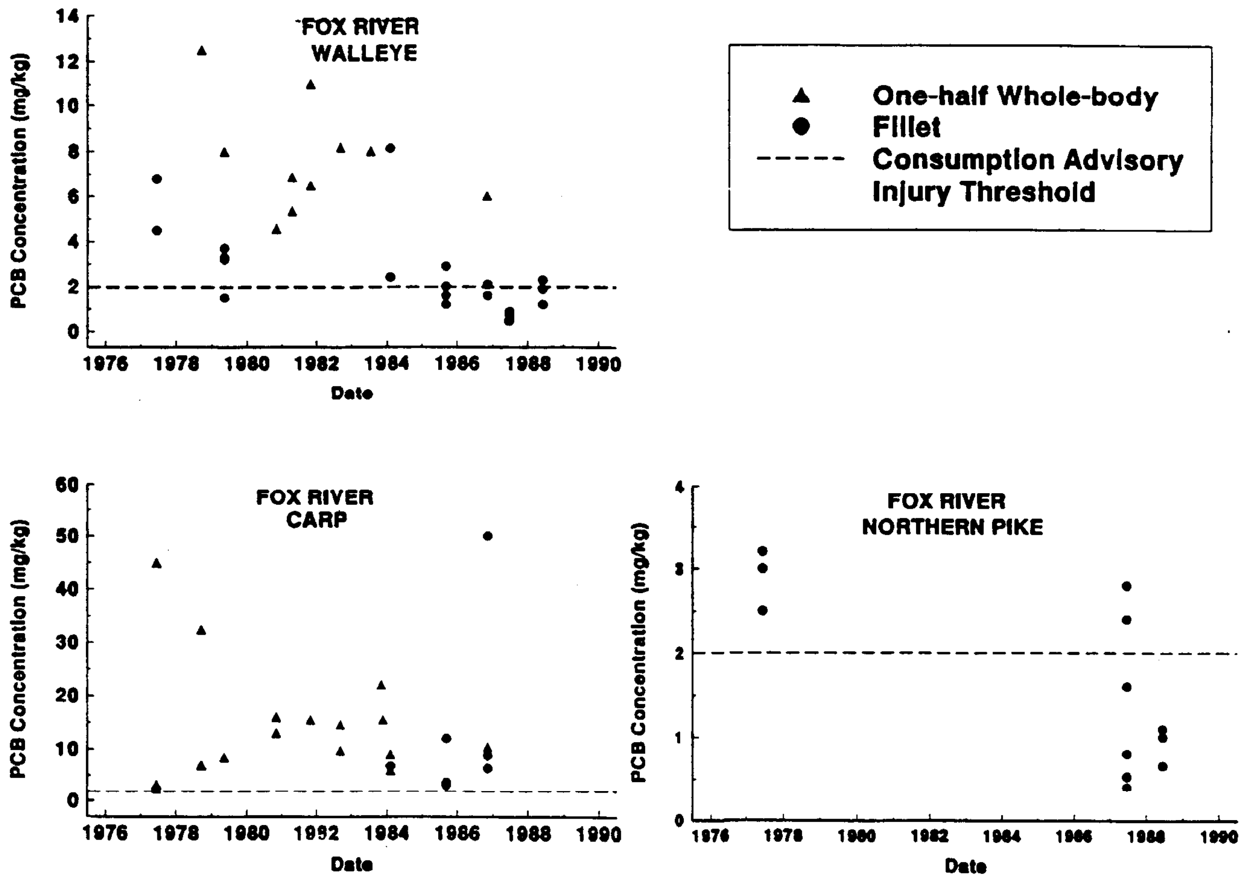
Extensive Fox River and Green Bay data were collected from Fiscal Year 1988 to Fiscal Year 1990 as part of the Green Bay/Fox River Mass Balance Study. The Mass Balance Study was coordinated by the U.S. EPA's Great Lakes National Program Office (GLNPO) and WDNR and was conducted "to test the feasibility of using a mass balance approach to assess the sources and fates of toxic pollutants spreading throughout the Great Lakes food chain" (U.S. EPA, 1992). Data collected as part of this modeling effort indicate that the Fox River is the source of PCBs accumulated by fish in Green Bay (Green Bay Mass Balance Model; electronic data provided by J. Connolly, Hydroqual, Inc.). As shown in Figure 6-4, fish PCB levels are lower in fish captured farther from the Fox River, although tissue levels in fish from outer Green Bay remain at or above consumption advisory levels for many species. This pattern also is demonstrated by salmonid PCB tissue levels measured in 1985 (Masnado, 1987) (Figure 6-5). The salmonid data demonstrate that PCB levels in fish caught outside of Green Bay (throughout northern Lake Michigan) are mostly lower than those in fish caught in Green Bay, and are near consumption advisory thresholds. The data illustrated in Figures 6-4 and 6-5 indicate that fish in outer Green Bay and Lake Michigan are also exposed to PCBs.

These data confirm that fish have been, and continue to be, exposed to PCBs.

Figure 6-2

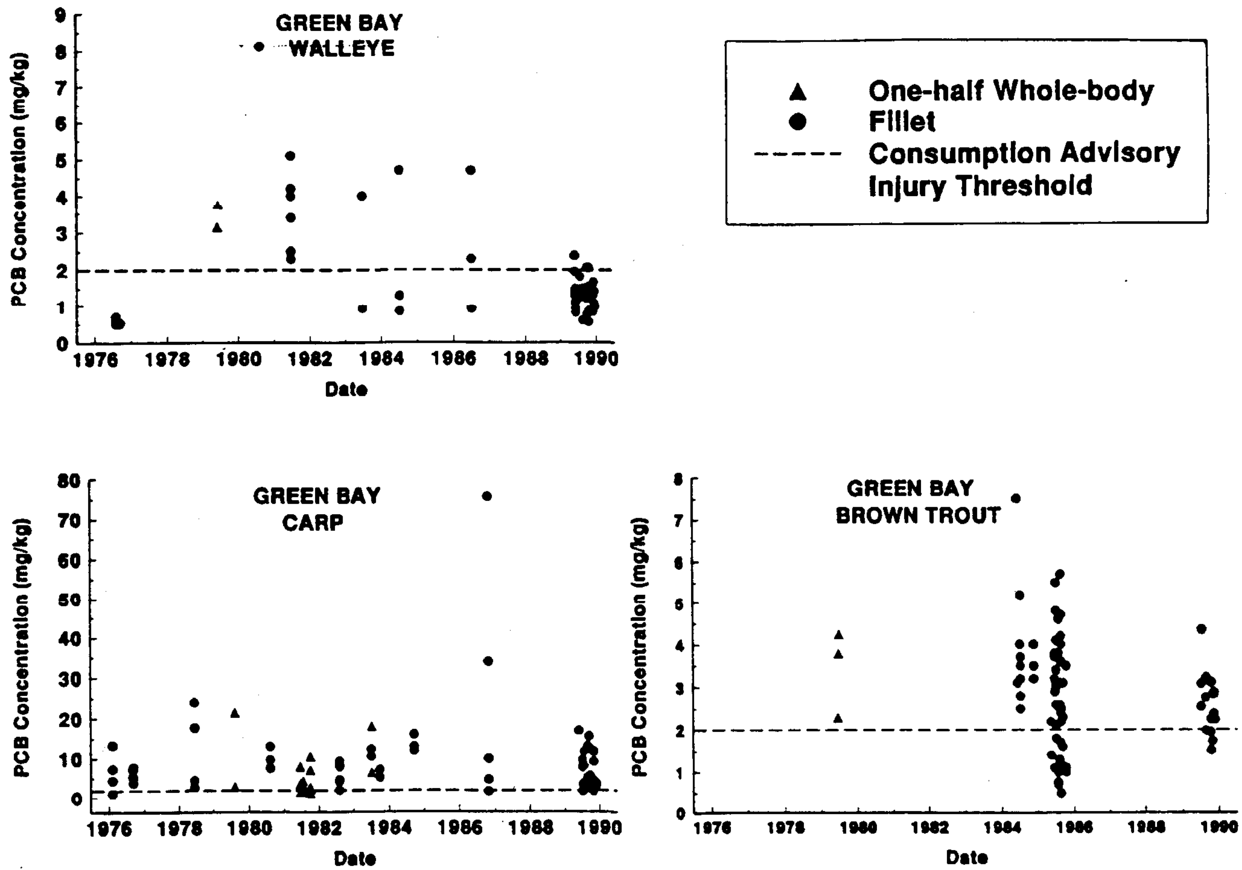
Historical Fillet PCB Concentrations for Three Fox River Fish Species.

Concentrations shown are either measured fillet concentrations or calculated as one-half measured whole-body concentrations. Also shown is 2 mg/kg consumption advisory threshold.



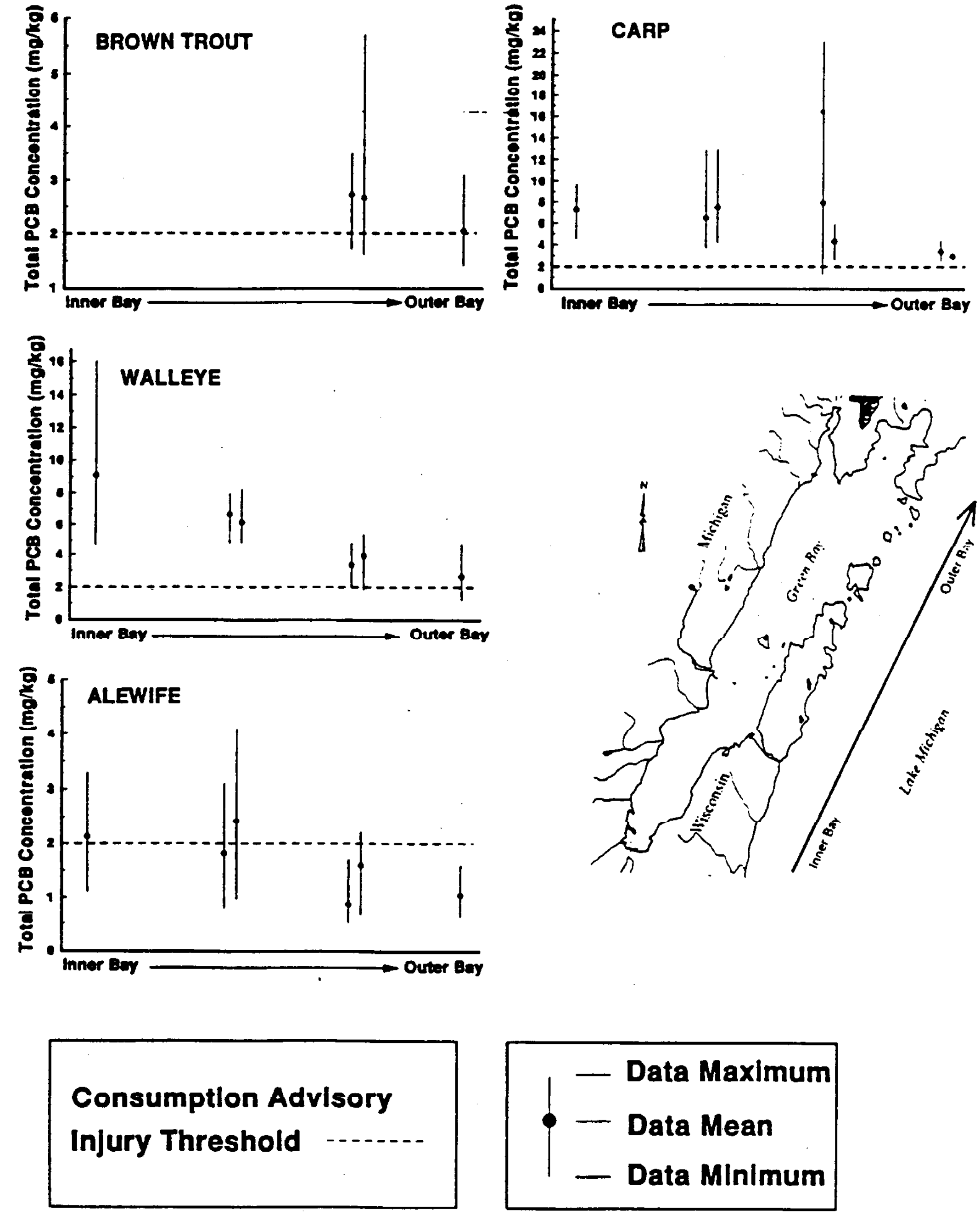
Source: WDNR, 1995d.

Figure 6-3
Historical Fillet PCB Concentrations for Three Green Bay Fish Species.
Concentrations shown are either measured fillet concentrations or calculated as one-half measured whole-body concentrations. Also shown is 2 mg/kg consumption advisory threshold.



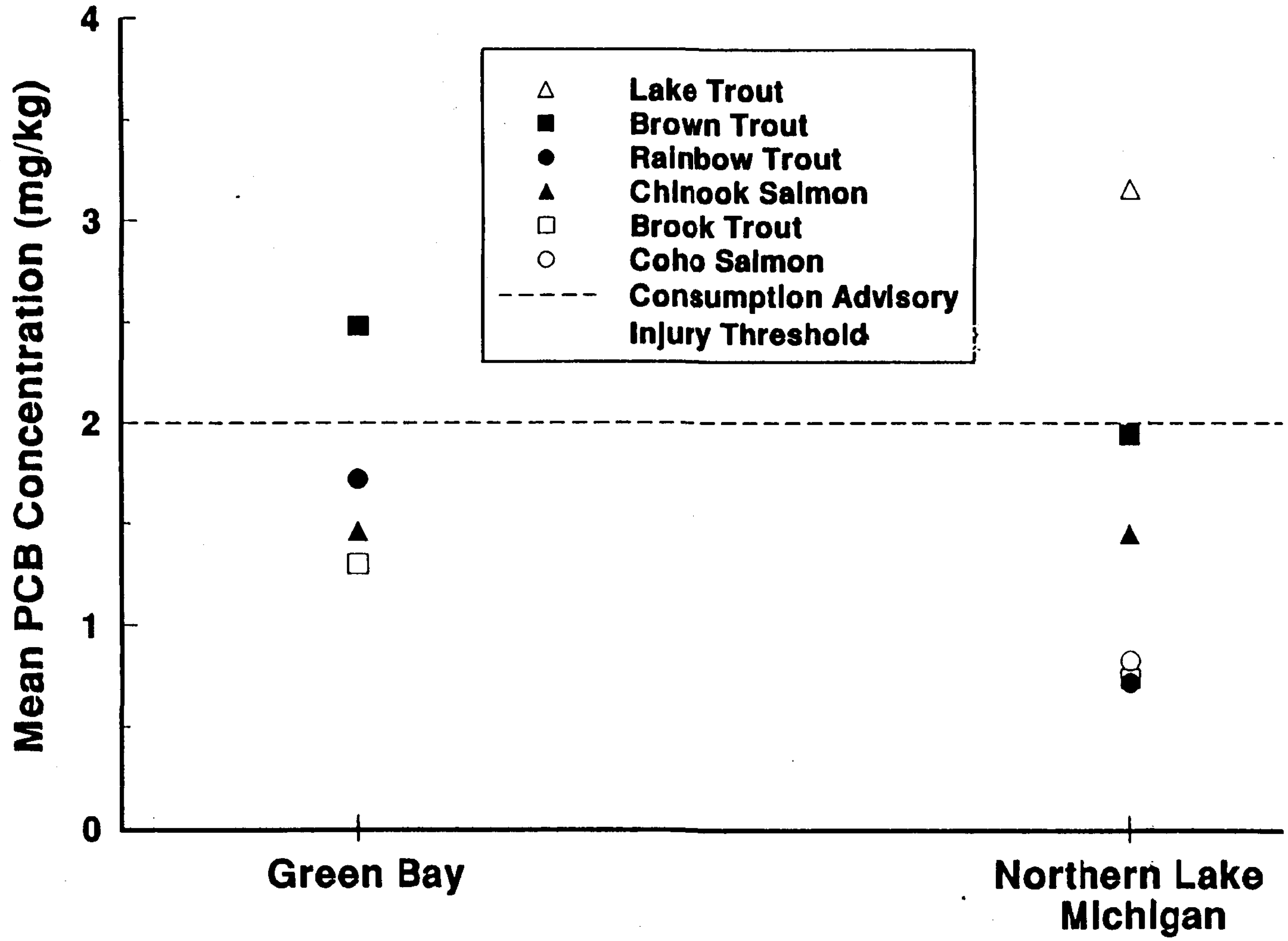
Source: WDNR, 1995d.

Figure 6-4
Fillet PCB Concentrations for Four Fish Species Collected in Four Zones in Green Bay in 1989 and 1990. Also shown is 2 mg/kg fish consumption advisory threshold.



Source: Green Bay Mass Balance Model; electronic data provided by J. Connolly, Hydroqual, Inc.

Figure 6-5
Fillet PCB Tissue Concentrations in Green Bay and Northern Lake Michigan for Six Salmonid Species Collected in 1985. Also shown is 2 mg/kg fish consumption advisory threshold.



Source: Masnado, 1987.

6.4 WILDLIFE

Exposure of wildlife to PCBs has been confirmed by numerous studies that have investigated contaminant levels in avian tissues. Table 6-4 presents PCB concentrations in bird eggs in studies that included control area measurements. The mean concentrations of PCBs in the eggs of birds nesting on Green Bay or the Lower Fox River ranged between 1.1 and a median of 22.2 mg/kg, whereas PCB concentrations in the eggs of birds from control areas ranged from 0.3 to 4.7 mg/kg. Overall, the concentrations of PCBs in the eggs of birds nesting on Green Bay or the Lower Fox River were generally between two and eight times higher than in their counterparts in the control populations.

Table 6-4
Comparisons of PCB Concentrations Measured in Eggs of Birds Nesting on Green Bay or the Lower Fox River with Control Areas

Species	Mean PCB Concentration (mg/kg, wet weight)		Control Site	Reference
	Green Bay	Control		
Double-Crested Cormorant	7.8	1.0	Lake Winnipegosis, Manitoba	Larson et al., 1996
Forster's Tern	22.2 (median)	4.5 (median)	Lake Poygan, Wisconsin	Kubiak et al., 1989
Common Tern	10.0	4.7	Cut River, Michigan	Hoffman et al., 1993
Bald Eagle	35	4.3	Inland Wisconsin	C. Dykstra, U.S. FWS (unpublished data)
Tree Swallow	5.05	<1	Lake Poygan, Wisconsin	NBS, 1995
Red-Winged Blackbird	1.1	0.34	Inland Wisconsin	Ankley et al., 1993

Table 6-5 presents additional selected examples of mean PCB concentrations found in the eggs of 10 species of birds nesting on Green Bay and on the Lower Fox River.

These data show that PCB contamination is widespread among bird species in the assessment area.

Table 6-5
Selected Examples of PCB Concentrations in Bird Eggs from Green Bay and the Lower Fox River

Species	Location	Year	Mean PCB Concentration (mg/kg, wet weight)[1]	Reference
Double-Crested Cormorant	Little Gull Island	1986	14.8	Tillitt et al., 1992
	Snake Island	1986	10.8	Tillitt et al., 1992
	Gravelly/ Little Gull Island	1987	12.3	Tillitt et al., 1992
	Spider Island	1988	5.3	Tillitt et al., 1992
	Fish Island	1988	9.0	U.S. FWS, 1993
Common Tern	Kidney Island	1987	10.3	U.S. FWS, 1993
Black-Crowned Night-Heron	Cat Island	1989	9.3	Rattner et al., 1994
Mallard	Hat Island	1988	1.1	U.S. FWS, 1993
	Jack Island	1988	2.9	U.S. FWS, 1993
	Spider Island	1988	3.3	U.S. FWS, 1993
Red-Breasted Merganser	Door County	1975	44.7	White & Cromartie, 1977
	Pilot Island	1988	11.5	U.S. FWS, 1993
	Spider Island	1988	6.5	U.S. FWS, 1993
	Hog Island	1988	12.1	U.S. FWS, 1993
	Door County	1989	11.1	Williams et al., 1995
	Green Bay	1990	8.5	Heinz et al., 1994
Common Merganser	Door County	1975	79.4	White & Cromartie, 1977
Bald Eagle	Fox River	1988	1 egg at 36 mg/kg	C. Dykstra (unpublished data)

Table 6-5 (cont.)
Selected Examples of PCB Concentrations in Bird Eggs from Green Bay and the Lower Fox River

Species	Location	Year	Mean PCB Concentration (mg/kg, wet weight)[1]	Reference
Herring Gull	Big Sister Island	1971	141.7[2]	Bishop et al., 1992
	Big Sister Island	1980	57[2]	Bishop et al., 1992
	Big Sister Island	1985	36.8[2]	Bishop et al., 1992
	Hat Island	1988	15.6	U.S. FWS, 1993
	Gravel Island	1988	29.5	U.S. FWS, 1993
Caspian Tern	Gravelly Island	1980	36.2	Struger and Weseloh, 1985
	Gravelly Island	1991	9.2	Ewins et al., 1994
Forster's Tern	Kidney Island	1988	7.3	Harris et al., 1993
Red-Winged Blackbird	Inner Green Bay	1988	1.1-1.2 (range)	Ankley et al., 1993

1. Values are means of studies except where otherwise indicated in table.
2. PCBs measured as Aroclor 1254:1260 1:1 mixture.

PCBs have also been detected in the tissues of chicks and adult birds on Green Bay. PCB concentrations of 0.253 mg/kg have been measured in the plasma of nestling bald eagles (C. Dykstra, U.S. FWS, unpublished data); a mean of 4 mg/kg was measured in Forster's tern chick carcasses (Harris et al., 1993); a mean of 3.3 mg/kg was measured in the plasma of adult Caspian terns (Mora et al., 1993); and up to 84.8 mg/kg were measured in the carcasses of incubating adult double-crested cormorants in 1988 (U.S. FWS, 1993). These data confirm that birds have been, and continue to be, exposed to PCBs.

In addition, PCBs have been detected in mink trapped in Door and Brown counties, adjacent to Green Bay. In one animal, the whole body concentration (excluding pelt) of PCBs was 0.56 mg/kg. In the other animal, 16 PCB congeners were above detection limits, but total PCBs was not quantitated. These data confirm that mink have been exposed to PCBs (WDNR, 1996).

CHAPTER 7
RECOVERY PERIOD

This section provides a preliminary determination of the recovery period for the exposed natural resources of the assessment area [43 CFR § 11.31 (a)(2)]. This preliminary determination can "serve as a means of evaluating whether the approach used for assessing the damage is likely to be cost-effective . . ." [43 CFR § 11.31 (a)(2)]. This preliminary determination is based on existing literature and data. It is not based on studies specifically designed to estimate a recovery period for the assessment area.

A recovery period is defined as "either the longest length of time required to return the services of the injured resource to their baseline condition, or a lesser period of time selected by the authorized official and documented in the Assessment Plan" [43 CFR § 11.14 (gg)]. Services are defined as "the physical and biological functions performed by the resource including the human uses of those functions. These services are the result of the physical, chemical, or biological quality of the resource" [43 CFR § 11.14 (nn)]. The following factors may be considered in estimating recovery times:

- ecological succession patterns in the area
- growth or reproductive patterns, life cycles, and ecological requirements of biological species involved, including their reaction or tolerance to the . . . hazardous substance involved
- bioaccumulation and extent of . . . hazardous substances in the food chain
- chemical, physical, and biological removal rates of the . . . hazardous substance from the media involved . . . [43 CFR § 11.73 (c)(2)].

Recovery of natural resources to baseline conditions requires recovery of currently contaminated *media* because biotic resources will continue to be injured as long as environmental media such as soils, sediments, and water remain contaminated and continue to operate as exposure pathways. As shown in Sections 6.1 and 6.2, surface water and sediments of the Lower Fox River and Green Bay have been exposed to PCBs and other hazardous substances. Natural and human induced resuspension of contaminated sediments results in contamination of surface water. Biota are exposed to contaminants through direct contact with sediments and surface water as well as through food chain pathways (WDNR, 1995a).

Current estimates of natural recovery periods for the contaminated resources and media of the Lower Fox River and Green Bay are very long. Approximately 25,000-30,000 kg of PCBs exist in sediment deposits below the DePere Dam, and an additional 3,000-4,000 kg of PCBs exist in sediment deposits between Little Lake Butte des Morts and the DePere Dam (Jaeger, 1995). PCBs are highly persistent compounds with very low potential for natural degradation. Natural recovery can occur if contaminated sediments are buried with clean sediments to below the depths where the contaminated sediments could be disturbed by benthic organisms or physical processes (Allen et al., 1987). Projections from the Green Bay Mass Balance model indicate that surface water concentrations in inner Green Bay "would continue in the 5 to 10 ng/l range for 75 or more years" if no remediation actions are taken (Patterson, 1993). Also, high flow events that disturb contaminated sediments can result in periodic large increases in PCB concentrations in Green Bay (Allen et al., 1987).

CHAPTER 8
INJURY ASSESSMENT APPROACHES

8.1 INTRODUCTION

Chapter 6 provided data confirming that natural resources in the assessment area have been exposed to multiple and continuing releases of PCBs. It is likely that natural resources have been and will continue to be injured as a result of this exposure. To confirm the existence and extent of injuries, the trustees will need to conduct an injury assessment. The purpose of the injury assessment phase is to determine whether natural resources have been injured [43 CFR § 11.61], to identify the environmental pathways through which injured resources have been exposed to hazardous substances [43 CFR § 11.63], and to quantify the degree and extent (spatial and temporal) of injury [43 CFR § 11.71].

DOI regulations define "injury" as a

> . . . measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a . . . release of a hazardous substance, or exposure to a product of reactions resulting from the . . . release of a hazardous substance. As used in this part, injury encompasses the phrases "injury," "destruction," or "loss" [43 CFR § 11.14(v)].

This chapter provides an overview of approaches that will be used by the trustees to assess injuries in the assessment area. The trustees will use existing literature and data, where available, to determine and quantify injuries. Where these data are insufficient, additional studies may be performed.

This chapter is organized as follows. Section 8.2 describes the injury assessment process. Section 8.3 addresses injuries to surface water resources. Section 8.4 addresses injuries to aquatic biota resources. Section 8.5 addresses injuries to terrestrial biota resources. Section 8.6 presents a summary of present and ongoing studies. Section 8.7 discusses procedures for sharing data.

8.2 INJURY ASSESSMENT PROCESS

The injury assessment process includes the following phases:

1. **Injury Determination Phase.** The injury determination phase serves to determine whether an injury to one or more natural resources has occurred and that the injury resulted from release of a hazardous substance. This phase includes the following two steps:

    a. **Determination That Injury Has Occurred**. In the first step, trustees determine whether injuries that meet the definitions of injury in 43 CFR § 11.62 for surface water, ground water, air, geologic, and biological resources have occurred.

    b. **Pathway Determination**. In the next step, or pathway determination step, exposure pathways for transport of hazardous substances to injured natural resources are identified [43 CFR § 11.63]. The preamble to the August 1, 1986, DOI regulations note that pathway determination may be accomplished by the "demonstration of sufficient concentrations in the pathway for it to have carried the substance to the injured resources" [51 FR 27684, August 1, 1986].

2. **Injury Quantification Phase.** The effects of the releases of hazardous substances are quantified in terms of changes from "baseline conditions" [43 CFR § 11.71(b)(2)]. Specific steps in the quantification phase include measuring the degree to which the condition of the natural resource differs from baseline conditions[1] and quantifying the extent of the injury [43 CFR § 11.71(b)(2), § 11.71(b)(1), and § 11.71(c)(1)].

8.3 SURFACE WATER RESOURCES

Surface water resources are defined as including both surface water and sediments suspended in water or lying on the bank, bed, or shoreline [43 CFR §11.14(pp)]. The assessment of injuries to surface water resources will consider both surface water and sediment resources.

8.3.1 Surface Water

8.3.1.1 Injury Definitions

Relevant definitions of injury to surface water resources that may be evaluated by the trustees include the following:

1. Baseline conditions are the conditions that "would have existed at the assessment area had the . . . release of the hazardous substance . . . not occurred" [43 CFR § 11.14(e)] and are the conditions to which injured natural resources should be restored [43 CFR § 11.14(ll)].

- Concentrations and duration of substances in excess of applicable water quality criteria established by Section 304(a)(1) of the Clean Water Act (CWA), or by other Federal or State laws or regulations that establish such criteria, in surface water that before the . . . release met the criteria and is a committed use as habitat for aquatic life, water supply, or recreation. The most stringent criterion shall apply when surface water is used for more than one of these purposes [43 CFR § 11.62(b)(1)(iii)].

- Concentrations and duration of substances in excess of drinking water standards as established by Sections 1411-1416 of the Safe Drinking Water Act (SDWA), or by other Federal or State laws or regulations that establish such standards for drinking water, in surface water that was potable before the release [43 CFR § 11.62(b)(1)(i)].

- Concentrations and duration of substances sufficient to have caused injury to biological resources when exposed to surface water, suspended sediments, or bed, bank, or shoreline sediments [43 CFR § 11.62(b)(1)(v)].

Table 8-1 lists specific regulatory criteria and concentration thresholds that may be used to evaluate injury to surface waters as defined in 43 CFR § 11.62 (b)(1)(iii) and (v). Established criteria include PCB concentrations intended to protect aquatic life, wild and domestic animals, and humans. Pursuant to Section 304 of the Clean Water Act, the U.S. EPA has established ambient water quality criteria (AWQC) for the protection of aquatic life. For PCBs, the AWQC is 14 ng/l for chronic exposure. The National Toxics Rule (NTR), which was promulgated by the U.S. EPA pursuant to CWA, established numeric criteria for 92 priority pollutants including PCBs [57 FR 60848 *et seq.*]. The NTR adopted the U.S. EPA chronic AWQC for PCBs of 14 ng/l. The State of Wisconsin established risk-based human cancer criteria (HCC) of 0.49 ng/l in warm water fisheries and 0.15 ng/l in the Great Lakes (NR 105 — WI State Code). The most restrictive criterion for PCBs is the Great Lakes Water Quality Guidance (GLWQG) promulgated by the U.S. EPA in 1995 under 40 CFR § 132. The GLWQG recommends surface water PCB criteria that are two orders of magnitude lower than the NR 105 criteria.

Table 8-1
Surface Water PCB Criteria (in ng/l) for State of Wisconsin

Source	Protection Endpoint		
	Aquatic Life (chronic)	Wild and Domestic Animals	Human Cancer Criterion
WDNR Criteria (NR 105 — State code)		3.0	0.15 (Great Lakes) 0.49 (warm water fishery)
U.S. EPA CWA § 304 (45 FR 79339)	14		0.08
National Toxics Rule (57 FR 60915)	14		0.45
GLWQG (40 CFR § 132)		0.075	0.0039

8.3.1.2 Injury Determination Approaches

Each of the injury definitions identified in Section 8.3.1.1 consists of several components. Table 8-2 summarizes the components of each definition and the approaches that may be taken in assessing each component.

Table 8-2
Components of Relevant Surface Water Injury Definitions

Injury Definition	Definition Components	Evaluation Approach
Water quality exceedences [43 CFR § 11.62(b)(1)(iii)]	Surface waters are a committed use as aquatic life habitat, water supply, or recreation.	Determine whether assessment area water bodies have committed uses.
	Concentrations and duration of hazardous substances are in excess of applicable water quality criteria.	Temporal and spatial comparisons of surface water concentrations to state, federal, and tribal water quality criteria.
	Criteria were not exceeded prior to release.	Compare baseline conditions to state, federal, and tribal water quality criteria.
Drinking water standards exceedences [43 CFR § 11.62 (b)(1)(i)]	Concentrations and duration of hazardous substances are in excess of applicable drinking water standards.	Temporal and spatial comparisons of surface water concentrations to state, federal, and tribal standards.
	Water was potable prior to release.	Compare baseline conditions to drinking water standards.
Biological resources injured when exposed to surface water/sediments [43 CFR § 11.62(b)(1)(v)]	Biological resources are injured when exposed to surface water/sediments.	Determine whether fish and benthic macroinvertebrates have been injured as a result of exposure to surface water/sediments.

A preliminary review of existing data suggests injuries to surface water, according to the injury definitions presented in Table 8-2. For example, Table 8-3 and Figure 8-1 present summaries of existing surface water data relative to injury threshold concentrations.

These data indicate that the U.S. EPA chronic AWQC for protection of aquatic life was exceeded in 168 of 186 (90%) samples collected in the Fox River; the Wisconsin NR 105 criterion for the protection of wild and domestic animals was exceeded in 100% of the water samples collected from the Fox River; the Wisconsin NR 105 criterion for protection against human carcinogenicity was exceeded in 100% of the water samples collected in the Fox River; and the GLWQG was exceeded in 100% of the water samples collected from the Fox River. Further data analysis will be conducted in the assessment to evaluate surface water injuries.

Table 8-3
Summary of PCB Concentrations in Fox River Surface Water, Using USGS Data

Year	Number of Samples	PCB Concentration (ng/l)	Percent of Samples Exceeding NR 105 HCC (0.49 ng/l or 0.15 ng/l)	Percent of Samples Exceeding Chronic AWQC (14 ng/l)
Neenah Dam (upstream of pulp and paper mill releases)				
1987-1988[1]	7	nd[2] (detection limit between 1.9 and 7.0)	0%	0%
Menasha Dam (upstream of pulp and paper mill releases)				
1987-1988[1]	23	max = 4.2 20 of 23 = nd[2]	13%	0%
Appleton (downstream of Little Lake Butte des Morts)				
1987-1988[1]	27	max = 137 mean = 64	100%	89%
DePere				
1989-1990[3]	49	max = 115 mean = 45	100%	78%
Mouth of Fox River				
1989-1990[3]	110	max = 152 mean = 58	100%	96%

1. House, 1995.
2. nd = not detected.
3. House et al., 1993.

8.3.1.3 Pathway Evaluation

Pathways from discharge sources to surface water resources in the assessment area include direct discharges of hazardous substances to surface water, resuspension of contaminated sediments, and aerial transport (Bierman et al., 1992). For example, effluent concentrations of PCBs directly discharged from the Bergstrom Paper Mill (now called P.H. Glatfelter Company) between 1975 and 1976 ranged from 5,500 to 75,000 ng/l. PCB concentration in the effluent from Riverside Paper was measured at 3,600 ng/l in 1976. PCB concentrations in the effluent from Fort Howard Paper Company ranged from 1,200 to 160,000 ng/l in 1975 and 1976 (Behrens, 1991).

Substantial resuspension of contaminated sediments continues to expose surface water resources to PCBs. For example, the Green Bay and Lower Fox River mass balance models estimate that in 1989 alone, 230 kg of PCBs were resuspended from the stretch of the Fox River below the DePere Dam (Bierman et al., 1992; WDNR, 1995a). The model also estimates that 120 kg of PCBs would settle out of the surface water back into sediments, yielding a net PCB resuspension