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FIGURES

TABLES

ACRONYMS

AET	apparent effects threshold
AM	assessment manager
ARS	accumulation relative to sediments
AWQC	Ambient Water Quality Criteria
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COC	chain-of-custody
CFR	Code of Federal Regulations
CV	Contingent Valuation
CWA	Clean Water Act
DOI	Department of Interior
DQO	data quality objective
FCA	Fish Consumption Advisory
FDA	Food and Drug Administration
FR	Federal Register
FTL	Field Team Leader
FWPCA	Federal Water Pollution Control Act
GBMBS	Green Bay Mass Balance Study
GC/ECD	gas chromatography/electron capture detection
GC/MS	gas chromatography/mass spectrophotometry
GLFC	Great Lakes Fishery Commission
GLNPO	U.S. EPA Great Lakes National Program Office
GLWQG	Great Lakes Water Quality Guidance
HCC	human cancer criterion
IJC	International Joint Commission
kg	kilogram
l	liter
LEL	lowest effect level
LLBDM	Little Lake Butte des Morts
MDL	method detection limit
mg	milligram
MITW	Menominee Indian Tribe of Wisconsin
MS/MSD	matrix spike/matrix spike duplicate
NBS-GLSC	National Biological Survey, Great Lakes Science Center
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
ng	nanogram

NOAA	National Oceanic and Atmospheric Administration
NRDA	natural resource damage assessment
NTR	National Toxics Rule
OPA	Oil Pollution Act of 1990
OTIW	Oneida Tribe of Indians of Wisconsin
PCB	polychlorinated biphenyl
PI	Principal Investigator
pg	picogram
PM	project manager
PRP	potentially responsible party
QA/QC	quality assurance/quality control
QAPjP	Quality Assurance Project Plan
QAM	Quality Assurance Manual
%R	average percent recovery
RCDP	Restoration and Compensation Determination Plan
RI/FS	remedial investigation/feasibility study
RPD	relative percent difference
RSD	relative standard deviation
SDWA	Safe Drinking Water Act
SOP	standard operating procedure
SRM	standard reference material
SWDA	Solid Waste Disposal Act
TSA	technical system audit
TSCA	Toxic Substances Control Act
U.S. ACOE	U.S. Army Corps of Engineers
U.S. EPA	U.S. Environmental Protection Agency
U.S. FWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDHHS	Wisconsin Department of Health and Human Services
WDNR	Wisconsin Department of Natural Resources
WTP	willingness to pay

CHAPTER 1
INTRODUCTION

The U.S. Fish and Wildlife Service (U.S. FWS) of the Department of the Interior (DOI), the Menominee Indian Tribe of Wisconsin (MITW), and the Oneida Tribe of Indians of Wisconsin (OTIW) are preparing to assess damages to natural resources that have resulted from releases of hazardous substances to the Lower Fox River, Green Bay, and Lake Michigan and other areas containing natural resources potentially injured by hazardous substances released to the Lower Fox River (collectively known as the assessment area). The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) [42 U.S.C. §§ 9607], the Federal Water Pollution Control Act (CWA) [33 U.S.C. § 1321], and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) provide authority to the DOI, the MITW, and the OTIW (collectively, "the trustees") to seek such damages.

The assessment plan is designed to be in accordance with natural resource damage assessment (NRDA) regulations promulgated by the DOI at 43 CFR Part 11.

1.1 BACKGROUND

The assessment planning process represents the second phase of the NRDA process. In the preassessment phase, which was the first phase of the NRDA process, the trustees made the determination to proceed with this assessment, concluding — based on a rapid review of readily available data [43 CFR § 11.23(b)] — that there is a reasonable probability of making a successful claim for damages [43 CFR § 11.23(b)]. Specifically, the trustees made the following determinations:

1. Releases of hazardous substances to the assessment area have occurred [43 CFR § 11.23(e)(1)].

- Numerous investigators, including the U.S. FWS, the State of Wisconsin [including the Wisconsin Department of Natural Resources (WDNR)], and the U.S. Environmental Protection Agency (U.S. EPA) have demonstrated that multiple releases of polychlorinated biphenyls (PCBs), a listed hazardous substance, have occurred and continue to occur at and near the assessment area.

2. Natural resources for which trustees can assert trusteeship have been, or are likely to have been, adversely affected by the releases of hazardous substances [43 CFR § 11.23(e)(2)].

- Natural resources are likely to have been adversely affected by releases of hazardous substances include, but are not limited to, endangered species, migratory birds, surface water, sediments, plankton, benthic macroinvertebrates, fish, and wildlife.

3. The quantity and concentration of the released substances are sufficient to potentially cause injury to those natural resources [43 CFR § 11.23(e)(3)].

- Numerous investigations in the Fox River, Green Bay, and Lake Michigan have documented the presence of hazardous substances at concentrations sufficient to potentially injure natural resources in the assessment area.

4. Data sufficient to pursue an assessment are readily available or obtainable at reasonable cost [43 CFR § 11.23(e)(4)].

- Studies have been conducted in the Fox River, Green Bay, and Lake Michigan by the WDNR, U.S. EPA, and U.S. FWS which will be available at reasonable cost and will be used to the extent practicable in the NRDA. The assessment will build on these information sources to identify and evaluate potential injuries, determine exposure pathways, quantify resulting damages to the public, and develop a plan to restore injured natural resources. Additional assessment costs are likely to be reasonable, as defined by DOI regulations [43 CFR § 11.14(ee)], because preliminary estimates indicate that sediment restoration costs alone will exceed the assessment costs and the benefits of additional assessment activities outweigh the additional costs.

5. Response actions carried out or planned will not sufficiently remedy the injury to natural resources without further action [43 CFR § 11.23(e)(5)].

- Neither U.S. EPA nor WDNR has carried out or planned response actions under the CWA or CERCLA that will sufficiently remedy the injury to natural resources without further action.

1.2 PURPOSE OF THE ASSESSMENT PLAN

The purpose of an NRDA assessment plan is to ensure that the assessment is performed in a planned and systematic manner and that the methodologies selected for use in the assessment can be conducted at a reasonable cost [43 CFR § 11.30(b)]. The Assessment Plan addresses the

Trustees' overall assessment approaches and emphasizes the utilization of existing data. If determined to be necessary, the Trustees may modify the assessment plan [43 CFR § 11.32(e)].

1.3 ORGANIZATION OF THE ASSESSMENT PLAN

This Assessment Plan is organized as follows. Chapter 2 briefly presents background information on natural resources involved in the assessment, the assessment area, hazardous substances released, and the history of pulp and paper mills in the assessment area. Chapter 3 describes the authority of the trustees to proceed with the assessment. Chapter 4 identifies coordination efforts with other agencies and previous actions taken by the trustees as part of the NRDA process. Chapter 5 contains documentation of the Trustee decision to proceed with a type B assessment. Chapter 6 provides confirmation that natural resources have been exposed to hazardous substances released from the site. Chapter 7 provides a preliminary determination of the recovery period for injured natural resources. Chapters 8 and 9 provide overviews of approaches to be employed by the trustees in the injury and damage assessment process, respectively. Chapter 10 contains a quality assurance project plan for the NRDA. Chapter 11 references literature cited in the Plan.[1]

1.4 PUBLIC REVIEW AND COMMENT

This Assessment Plan is available for review and comment by potentially responsible parties (PRPs), other natural resource trustees, other affected federal or state agencies or Native American tribes, and any interested members of the public for a period of 30 days.

Comments may be submitted in writing to:

Frank J. Horvath
U.S. Fish and Wildlife Service
Region 3 (attn: ES/EC-NRDA)
B.H.W. Whipple Federal Building
1 Federal Drive
Fort Snelling, MN 55111

Comments must be received by 30 days from the date the notice of availability is published in the Federal Register.

1. Literature is cited in the text using the convention: Name (Date) or (Name, Date), where "Name" is the last name of the lead author(s) of the publication, and "Date" refers to the date of publication. For example, the citation (Smith, 1996) refers to a publication authored by Smith in 1996. Full citations are provided in Chapter 11 of the Assessment Plan.

CHAPTER 2
BACKGROUND INFORMATION ON NATURAL RESOURCES AND THE ASSESSMENT AREA

2.1 LOCATION AND DESCRIPTION OF THE ASSESSMENT AREA

The assessment area for the Lower Fox River/Green Bay NRDA includes the Lower Fox River, Green Bay, Lake Michigan, and other areas containing natural resources potentially injured by hazardous substances released to the Lower Fox River (Figure 2-1). The Lower Fox River is 39 miles long (Figure 2-2) (Bierman et al., 1992). Green Bay is 119 miles long with a maximum width of 23 miles (Figure 2-3) (Bierman et al., 1992) and an approximate surface area of 1500 square miles (Swackhamer and Armstrong, 1987). Because Green Bay empties into Lake Michigan, resources that are exposed in Green Bay may be found in Lake Michigan. In addition, trust resources may be located adjacent to or near the Fox River, Green Bay, and Lake Michigan. Finally, trust resources in Lake Michigan may be exposed to hazardous substances that were originally released into the Lower Fox River and Green Bay and then transported to Lake Michigan.[1] For example, migratory birds nesting in locations adjacent to the assessment area may be injured by releases of hazardous substances from the assessment area. Other trust resources including fish and wildlife may be exposed in the Lower Fox River or Green Bay and migrate up tributaries or travel beyond the immediate vicinity of the river and bay. If further information becomes available that suggests that the geographic scope should be modified, the extent of the assessment area will be evaluated and adjusted as appropriate.

2.2 HAZARDOUS SUBSTANCES RELEASED

Hazardous substances released into the assessment area include, but may not be limited to, PCBs (including Aroclor 1242). PCBs, including Aroclor 1242, are listed as hazardous substances at 40 CFR § 302.4, pursuant to section 102(a) of CERCLA and section 311(b)(2) of the CWA. PCB releases from area paper mills have occurred directly and indirectly as a consequence of the recycling of waste paper contaminated with PCBs. This assessment plan focuses on PCBs. However, other hazardous substances may be identified and considered by the trustees at a later date.

1. One study has indicated that the Fox River provides the greatest loading of PCBs to Green Bay (Bierman et al., 1992). In addition, a 1983 study estimated that the Fox River contributes 60% of Lake Michigan's tributary PCB load (Marti, 1984, as cited in Allen et al., 1987).

Figure 2-1
Map Showing Lower Fox River/Green Bay Assessment Area

Figure 2.1 Assessment Area

Figure 2-2
Detailed Map of Lower Fox River/Inner Green Bay and Paper Mills

Figure 2-2. Detailed Map of Lower Fox River/Inner Green Bay and Major Municipal & Industrial Discharges to the Fox River

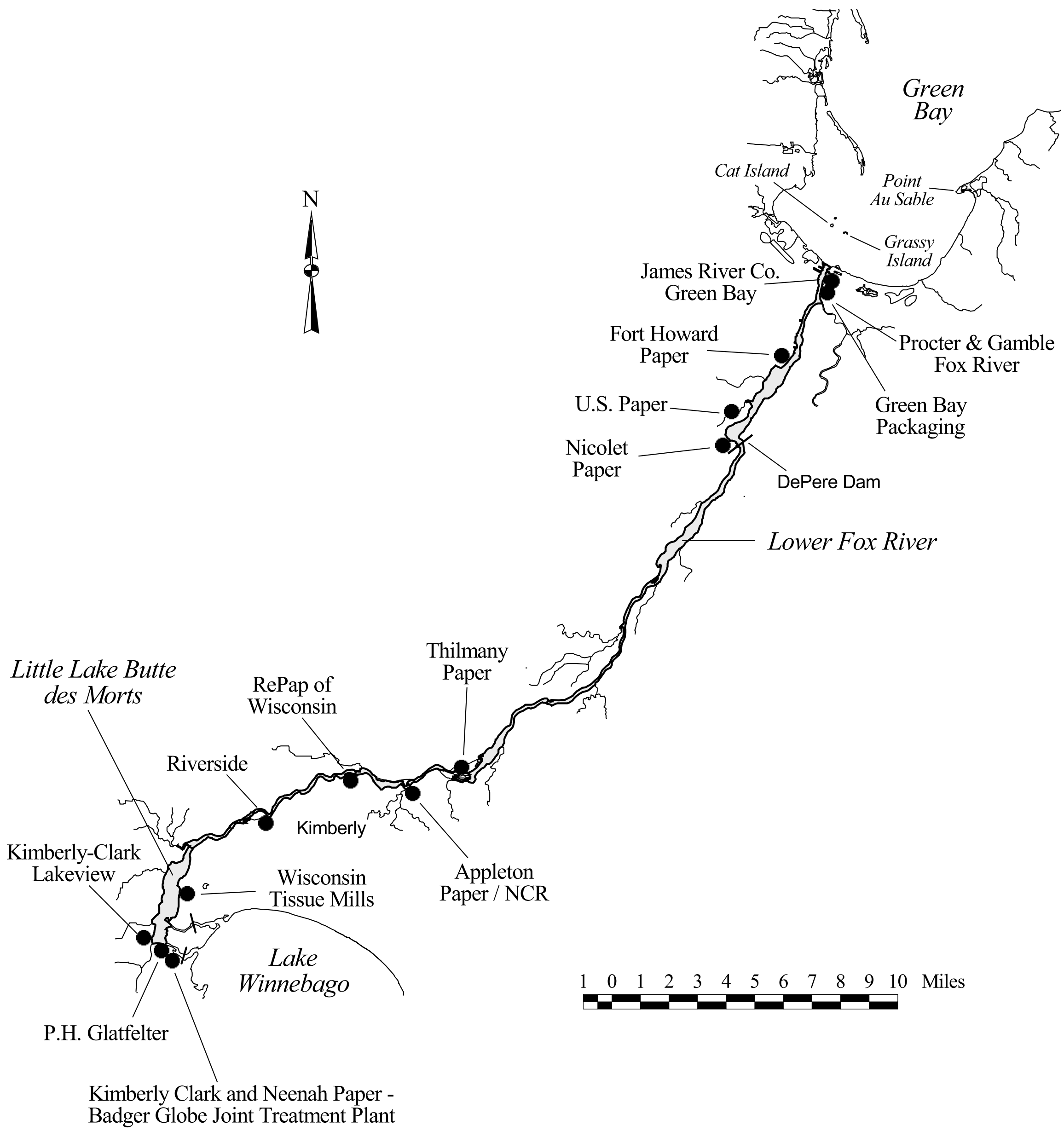
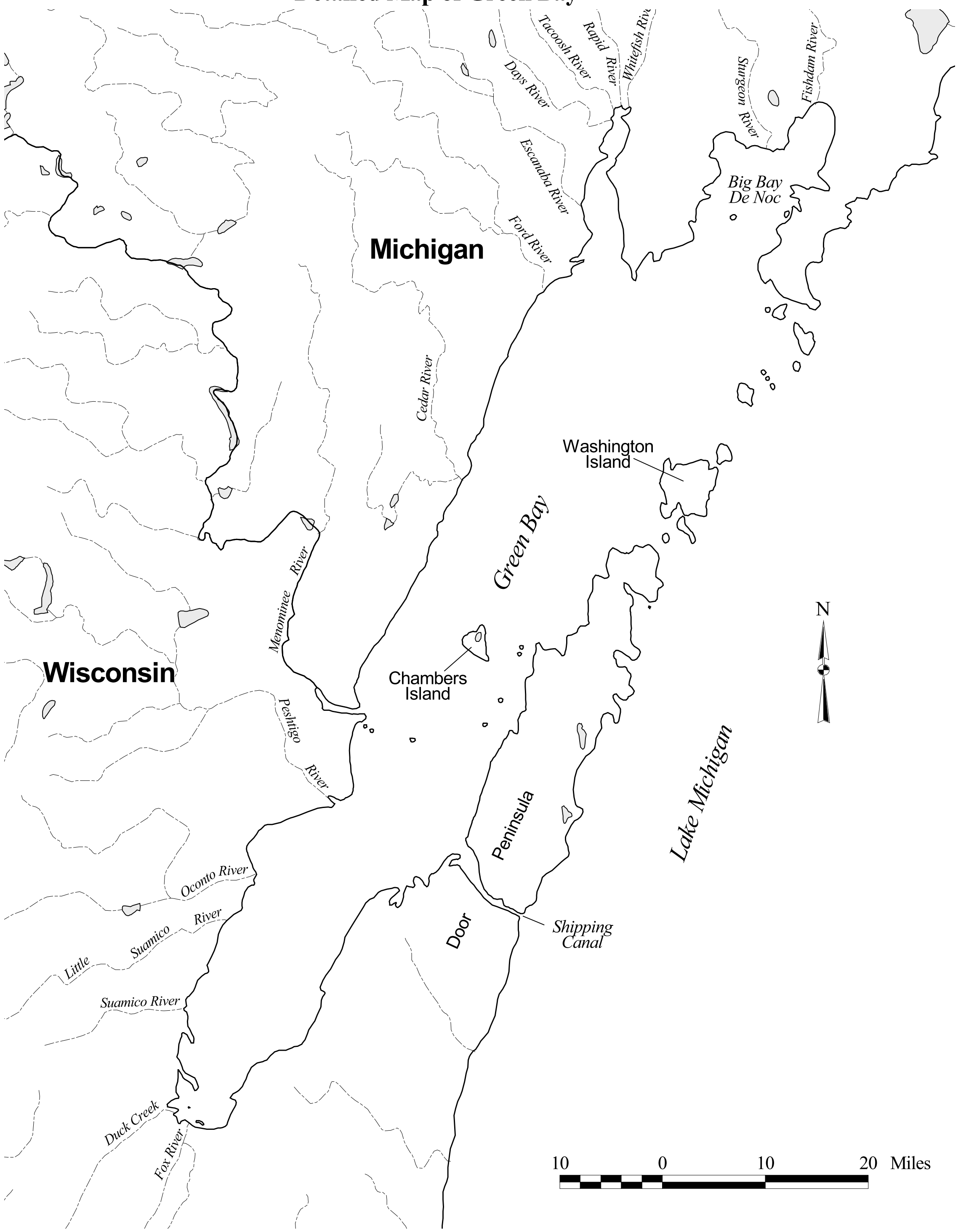


Figure 2-3
Detailed Map of Green Bay

Figure 2-3.
Detailed Map of Green Bay



2.3 HISTORY OF PULP AND PAPER MILLS AT THE ASSESSMENT AREA

Paper mills began operations along the Lower Fox River between 1850 and 1900 (Persson et al., 1988). Currently, the Lower Fox River from Lake Winnebago to Green Bay has the greatest concentration of pulp and paper mills in the world (Allen et al., 1987). In 1987, there were 14 pulp and paper mills and 5 municipal waste treatment facilities between Little Lake Butte des Morts (LLBDM) and the mouth of the Fox River at Green Bay (Allen et al., 1987). PCBs were first introduced into the paper making process in the mid-1950s (Patterson et al., 1994, cited in WDNR, 1995a). Virgin carbonless copy paper manufactured between 1957 and 1971 (the date when the use of PCBs in copy paper was discontinued) contained an average of 3.4% PCBs, in the form of Aroclor 1242 (Carr et al., 1977).

The greatest releases of PCBs into the Lower Fox River occurred during the deinking and repulping of carbonless copy paper that was manufactured with PCBs (Sullivan et al., 1983). Several paper companies along the Lower Fox River deinked and repulped carbonless copy paper between 1957 and the present, including Bergstrom Paper Corporation (currently the P.H. Glatfelter Corporation), Wisconsin Tissue Mills, Riverside Paper, and Fort Howard Paper Company (Sullivan and Delfino, 1982). Even after the 1971 discontinuation of PCB use in carbonless copy paper, PCBs remained in the effluent from paper mills. For example, concentrations of PCBs in effluent from the Bergstrom Paper Mill between 1975 and 1976 ranged from 5,500 to 75,000 ng/1 (Behrens, 1991). The PCB concentration in the effluent from Riverside Paper was measured at 3,600 ng/1 in 1976, and PCB concentrations in the effluent from Fort Howard Paper Company ranged from 1,200 to 160,000 ng/1 in 1975 and 1976 (Behrens, 1991). The highest PCB concentrations in the Fox River are found in sediment deposits in LLBDM downstream from the Bergstrom (now P.H. Glatfelter) Paper Mill (Allen et al., 1987).

Resuspension of previously contaminated sediments continues to expose natural resources to PCBs. Between LLBDM and the DePere Dam on the Lower Fox River, the estimated volume of sediments with PCB concentrations greater than 0.05 ppm exceeds 2 million m^3 (Jaeger, 1995). These sediments contain an estimated 3,886 kg of PCBs (Jaeger, 1995). Between the DePere Dam and the mouth of the Fox River, the estimated volume of contaminated sediments exceeds 5 million m^3 (Jaeger, 1995). These sediments contain an estimated 29,211 kg of PCBs (Jaeger, 1995). Contaminated sediments along the Fox River are a primary source for continuing PCB contamination of surface water and the accumulation of PCBs in the food chain in Fox River, Green Bay, and Lake Michigan environments (U.S. EPA, 1992; U.S. EPA, 1993a).

2.4 DESCRIPTION OF NATURAL RESOURCES

The assessment area supports many plant, fish, and wildlife species, including both commercial and recreational fishing stocks. Commercial fish species in Green Bay and Lake Michigan historically have included alewife, burbot, carp, chubs, northern pike, perch, smelt, walleye, and whitefish (WDNR, 1974). Natural resources involved in the assessment include surface water, sediments, and biological resources, including aquatic biota and wildlife. Specifically, trust resources in the assessment area include, but are not limited to, threatened species (e.g., bald eagle); migratory birds (e.g., bald eagle, Forster's tern, common tern, mallard, double-crested cormorant, black-crowned night-heron, tree swallow, red-breasted merganser, herring gull, and red-winged blackbird); anadromous fish species (e.g., coho salmon, chinook salmon, pink salmon, rainbow trout, and rainbow smelt); National Wildlife Refuge lands; nationally significant interjurisdictional fish stocks in the Great Lakes (e.g., lake trout, yellow perch, lake sturgeon, walleye, forage fish, and Atlantic salmon; pursuant to the Great Lakes Fish and Wildlife Restoration Act, as amended, 16 U.S.C. 941); piscivorous mammals (e.g., otter, mink); and lake trout in Lake Michigan that were stocked from federal hatcheries.

CHAPTER 3
AUTHORITY

DOI, in conjunction with the MITW and the OTIW (collectively, the trustees), are conducting an NRDA on the Fox River, Green Bay, and Lake Michigan, pursuant to CERCLA, as amended [42 U.S.C. §§ 9607(f)(1)-(2)] and the CWA [33 U.S.C. §§ 1321(f)(4)-(5)]. The President is required under CERCLA [42 U.S.C. § 9607(f)(2)] to designate in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 CFR Part 300], the Federal officials who are authorized to act on behalf of the public as trustees for natural resources under CERCLA and the CWA. Under the NCP, the Secretary of the Interior is designated to act as a trustee for natural resources "belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the DOI," as well as the supporting ecosystems for those natural resources [40 CFR §§ 300.600(a), (b), (b)(2)].

Under the NRDA regulations, assessment plans must "include a statement of the authority for asserting trusteeship or cotrusteeship for those natural resources within the Assessment Plan" [43 CFR § 11.31(a)(2)]. Based on the authority designated to the Secretary of the Interior, DOI derives trusteeship authority over natural resources in the assessment area from its statutorily prescribed programs, including, but not limited to, the Migratory Bird Treaty Act of 1918, 16 U.S.C. §§ 703-712; the Bald and Golden Eagle Protection Act of 1940, 16 U.S.C. §§ 668-668d; the Fish and Wildlife Act of 1956, 16 U.S.C. §§ 742a-742j-1; the Anadromous Fish Conservation Act of 1965, 16 U.S.C. §§ 757a-757g; the Estuary Protection Act of 1968, 16 U.S.C. §§ 1221-1226; the Marine Mammal Protection Act of 1972, 16 U.S.C. §§ 1361-1407; the Endangered Species Act of 1973, 16 U.S.C. §§ 1531-1544; the Emergency Wetlands Resources Act of 1986, 16 U.S.C. §§ 3901-3932; the Great Lakes Coastal Barrier Act of 1988, 16 U.S.C. §§ 3501-3510; the Great Lakes Fish and Wildlife Restoration Act of 1990, 16 U.S.C. § 941; and the Great Lakes Fish and Wildlife Tissue Bank Act of 1992, 16 U.S.C. §§ 943-943c.

CERCLA also identifies Indian tribes as trustees for "natural resources belonging to, managed by, controlled by, or appertaining to such tribe, or held in trust for the benefit of such tribe, or belonging to a member of such tribe if such resources are subject to a trust restriction on alienation . . ." [42 U.S.C. § 9607(f)(1)]. Under the NCP, tribal chairmen (or heads of their governing bodies) of Indian tribes, or a person designated by the tribal officials, shall act on behalf of the Indian tribes as trustees for natural resources under tribal trusteeship [40 CFR § 300.610].

Based on the authority designating tribes as trustees for natural resources, the OTIW asserts that it is a trustee for all natural resources within its reservation as established pursuant, but not limited to, the Treaty with the Oneida, 7 Stat. 566 (1838). The MITW asserts that it is a trustee for those natural resources established pursuant, but not limited to, the Treaty of February 8, 1831, 7 Stat. 342, *supplemented*, February 17, 1831, 7 Stat. 346, *amended*, October 27, 1832, 7 Stat. 405 (Treaty of Washington); Treaty of September 3, 1836, 7 Stat. 506 (Treaty of Cedar Point); and Treaty of May 12, 1854, 10 Stat. 1064 (Treaty of Wolf River).

CHAPTER 4
COORDINATION AND PREVIOUS ACTIONS OF TRUSTEES

On December 9, 1993, the DOI invited the WDNR to act as a natural resource co-trustee for the NRDA. On February 10, 1994, the DOI invited the MITW, the OTIW, and the Stockbridge Munsee community of Wisconsin to act as natural resource co-trustees. On May 19, 1994, the WDNR declined to participate as a natural resource co-trustee. On May 26, 1994, the DOI finalized a preassessment screen and determination for the site. On June 20, 1994, the DOI identified five PRPs and transmitted notices of intent to perform an assessment and invitations to participate in the assessment [43 CFR § 11.32(a)(2)(iii)]. On August 15, 1994, the MITW decided to participate with DOI as a co-trustee at the site. On October 7, 1994, the DOI notified the MITW of its intent to develop an assessment plan. On October 20, 1994, the DOI notified the U.S. EPA, Office of Superfund, of opportunities to coordinate any future response actions with the NRDA. Neither U.S. EPA nor WDNR has carried out or planned response actions under the CWA or CERCLA. On February 5, 1996, the DOI identified two additional PRPs and transmitted notices of intent to perform an assessment and invitations to participate. Some of the PRPs notified are currently considering participation in the NRDA. In February 1996, the OTIW decided to participate with DOI as a co-trustee for natural resources. The National Oceanic and Atmospheric Administration (NOAA), has been notified of the NRDA and has elected to defer to DOI at this time.

CHAPTER 5
DECISION TO PERFORM TYPE B ASSESSMENT

This chapter documents the Trustees' decision to perform a type B assessment. Trustees may select between performing a type A or a type B NRDA [43 CFR § 11.33]. Type A procedures are "simplified procedures that require minimal field observation." [43 CFR § 11.33(a)]. A type A model has been developed for Great Lakes environments (NRDAM/GLE) [43 CFR § 11.33(a)]. Under 43 CFR § 11.34, an authorized official may use a type A assessment only if six factors are found in existence at a particular site. Several of these factors do not apply to the assessment area, including those defined in § 11.34(d) and § 11.34(f), making a type A inappropriate. NRDA regulations specify that the decision whether to use a type A model is made "by weighing the difficulty of collecting site-specific data against the suitability of the averaged data and simplifying assumptions in the type A procedure" [43 CFR § 11.35(a)].

Releases of hazardous substances in the assessment area are likely to have occurred since 1957 (Chapter 2); contamination extends over at least 39 miles of the Fox River and 1,500 square miles of Green Bay (WDNR, 1995a; Manchester, 1993) as well as Lake Michigan and other areas containing natural resources potentially injured by hazardous substances originating in the Lower Fox River. Hazardous substances have been transmitted through the food chain, affecting many different trophic levels (e.g., WDNR, 1976-1994; Masnado, 1987; Hoffman et al., 1993). Consequently, the releases cannot be considered of a short duration, minor or resulting from a single event, and therefore are not readily amenable to simplified models. Further, the spatial and temporal extent and heterogeneity of exposure conditions and potentially affected resources are not suitable for application of simplifying assumptions and averaged data and conditions inherent in type A procedures. For example, the NRDAM/GLE is designed for application to discrete spills of oil/hazardous substances "up to a few days in duration" [Vol. 1, Sec. 1.2, publication incorporated by reference at 43 CFR § 11.18(a)(5)] rather than long-term, chronic exposures; biological injuries are based on acute toxicity of substances, rather than chronic toxic effects; transport submodels are not designed to be applied to complex, heterogeneous habitats and transport parameters; and only surface water exposure pathways are considered [see publication incorporated by reference at 43 CFR § 11.18(a)(5)]. Therefore, simplified type A assessment methodologies would be inappropriate for this NRDA.

The Trustees have determined: (1) that the type A NRDAM/GLE is not appropriately applied to the long-term, spatially and temporally complex nature of releases and exposures to hazardous substances characteristic of the assessment area; (2) that substantial site-specific data already exist to support the assessment; and (3) that additional site-specific data can be collected at reasonable cost. As a result, the Trustees have concluded that the use of type B procedures is justified.

CHAPTER 6
CONFIRMATION OF EXPOSURE

A natural resource has been "exposed" to a hazardous substance if "all or part of a natural resource is, or has been, in physical contact with . . . a hazardous substance, or with media containing a . . . hazardous substance" [43 CFR § 11.14(q)]. The assessment plan should confirm that:

> . . . *at least one* of the natural resources identified as potentially injured in the preassessment screen has in fact been exposed to the released substance [43 CFR § 11.37(a)] (emphasis added).

The regulations state that "Whenever possible, exposure shall be confirmed by using existing data" from previous studies of the assessment area [43 CFR § 11.37(b)(1)].

The following sections provide confirmation of exposure for a number of the potentially injured resources within the assessment area, including the following:

- surface water resources (surface water and sediments)
- biological resources, including fish and wildlife.

It should be noted that the following discussion uses existing data to provide limited examples confirming exposure of natural resources to hazardous substances (as defined above).

6.1 SURFACE WATER

Several investigators have shown that surface water in the Lower Fox River has been exposed to PCBs, including Marti and Armstrong (1990), the U.S. Geological Survey (USGS) (House, 1990, 1995; House et al., 1993), and the WDNR (WDNR, 1995b).

6.1.1 Preliminary Evaluation of Potential Background Concentrations

PCB concentrations were measured in surface water upstream of the Fox River pulp and paper mills and in Green Bay tributaries not directly exposed to PCBs released from the Fox River (Table 6-1) (see Figures 2-2 and 2-3 for approximate locations). These locations were used as

Table 6-1
Comparison of Surface Water PCB Concentrations in the Lower Fox River with Upstream and Potential Background PCB Concentrations

Location	Year	Number of Samples	PCB Concentration (ng/l)	Reference
Upstream and Potential Background Samples				
Fox River (Menasha Dam)	1987-1988	23	max = 4.2 20 of 23 = nd[1]	House, 1995
Fox River (Neenah Dam)	1987-1988	7	nd (detection limits ranged from 1.9 to 7.0)	
Duck Creek	1987	1	nd (detection limit = 15)	House, 1990
Little Suamico River	1987-1988	3	nd (detection limits ranged from 15 to 40)	
Suamico River	1987-1988	3	nd (detection limits ranged from 15 to 40)	
Lower Fox River Downstream of Pulp/Paper Mills				
Little Lake Butte des Morts	1976	na[2]	max = 27,000	WDNR, 1995b
Appleton	1987-1988	27	max = 137 mean = 64	House, 1995
Downstream of DePere Dam	1976	na	max = 7,500	WDNR, 1995b
DePere	1989-1990	49	max = 115 mean = 45	House et al., 1993
Mouth of River	1976	na	max = 10,800	WDNR, 1995b
Mouth of River	1980-1983	8	max = 262 mean = 98	Marti and Armstrong, 1990
Mouth of River	1989-1990	110	max = 152 mean = 58	House et al., 1993

1. nd = not detected.
2. na = not available.

preliminary “background” sampling locations for this Assessment Plan. The potential background surface water samples are mostly below levels of detection for PCBs. In 1987-1988, the water draining Lake Winnebago from the Neenah and Menasha dams contained few detectable PCBs. The USGS reported total PCB concentrations from 23 samples collected at the Menasha Dam, and 7 samples collected at the Neenah Dam, in 1987-1988 (House, 1995). Twenty of 23 samples at Menasha Dam contained undetectable PCBs (detection limits ranging from 7.0 to 3.0 ng/l). The highest detectable PCB concentration was 4.2 ng/l. At the Neenah Dam, all seven samples contained no detectable PCBs, at detection limits ranging from 1.7 ng/l to 7.0 ng/l (Table 6-1).

The USGS also measured PCB concentrations in a number of Green Bay tributaries other than the Fox River in 1987-1988 (House, 1990). Table 6-1 also reports PCB concentrations from three tributaries not directly exposed to PCBs released from the Fox River: Duck Creek, the Little Suamico River, and the Suamico River. No PCBs were detectable at any of these tributaries at detection levels of 15 to 40 ng/l. In fact, no PCBs were detected in any of the 11 Green Bay tributaries sampled as part of that effort.

Thus, the only detectable PCBs from the surface water sampling described above were three samples from the Menasha Dam. These samples contained 3.8, 4.0, and 4.2 ng/l PCBs, respectively (House, 1995).

6.1.2 Fox River Concentrations

In contrast, PCB concentrations in Fox River surface water downstream of PCB releases are substantially elevated compared with potential background concentrations. In the mid-1970s, the WDNR measured PCB concentrations in Little Lake Butte des Morts as high as 27,000 ng/l and near the mouth of the Fox River as high as 10,800 ng/l (Table 6-1) (WDNR, 1995b). These concentrations are at least three to four orders of magnitude greater than background concentrations from the 1980s.

Although PCB concentrations declined from 1976 to the 1990s, investigators continued to find that Fox River surface water was exposed to elevated PCB concentrations (Table 6-1). The *average* PCB concentration of 8 water samples collected from the mouth of the Fox River between 1980 and 1983 was 98 ng/l (Marti and Armstrong, 1990). Between April 1987 and October 1988, 27 water samples were collected and analyzed from the Fox River near Appleton (House, 1995). Three of the samples exceeded 100 ng/l PCBs. The average concentration for the 27 samples was 64 ng/l (Table 6-1). In sampling conducted in the Fox River at DePere and at the mouth of the river from January 1989 through May 1990, PCB concentrations were consistently elevated (House et al., 1993). The mean concentration at DePere was 45 ng/l, and the maximum concentration was 115 ng/l (Table 6-1). At the river mouth, 110 samples were analyzed; the mean PCB concentration was 58 ng/l, clearly indicating that the Fox River has been exposed to PCBs (Table 6-1). The above data confirm that surface water has been, and continues to be, exposed to PCBs.

6.2 SEDIMENTS

The DOI regulations define “surface water resources” to include, “sediments suspended in water or lying on the bank, bed, or shoreline and sediments in or transported through . . . marine areas” [43 CFR 11.14(pp)]. This assessment plan, however, addresses sediments separately from surface water for several reasons: there is a large amount of data specific to sediments; sediments can be a principal and ongoing exposure pathway to other natural resources; and many primary restoration actions may focus on sediments.

PCB concentrations are highly elevated in sediments in the Fox River and Green Bay compared to potential background concentrations (Table 6-2). PCB concentrations in potential background sediments (upstream of the Fox River paper and pulp mills) were undetected in two samples (Blasland & Bouck, 1993; WDNR 1995c), and ranged between 0.014 and 0.044 mg/kg in four other background samples collected from the Menasha Channel (WDNR, 1993) (Figure 6-1). In contrast, PCB concentrations in LLBDM sediments just downstream of the Menasha Channel have been as high as 250 mg/kg, over four orders of magnitude greater than background concentrations (Table 6-2). Several studies have found PCB concentrations in excess of 100 mg/kg in LLBDM, including WDNR (unpublished, as cited in Lohr, 1988), Blasland & Bouck (1993), and WDNR (1995a). These PCB concentrations not only are over a thousand times greater than the potential background concentrations, but they are more than twice the 50 mg/kg threshold specified in the Toxic Substances Control Act (TSCA) regulations for hazardous chemical disposal [40 CFR § 761.60(a)(5)].

PCB concentrations are also elevated farther downstream in the Fox River (Table 6-2). For example, sediments near Kimberly contained PCB concentrations greater than 100 mg/kg during 1989 and 1990 sampling (WDNR, 1995a). In the impoundment behind the DePere Dam, PCB concentrations have been measured as high as 47.8 mg/kg (WDNR, 1995a), over 5,000 times greater than the highest background concentration (Table 6-2).

PCB concentrations are also highly elevated downstream of the DePere Dam compared to potential background levels. Table 6-2 shows data from several studies in which PCB concentrations exceed 10 mg/kg downstream of the DePere Dam; many of these data are in a PCB data summary document produced by the WDNR (Lohr, 1988). For example, PCB concentrations in the sediments near Fort Howard have been measured as high as 79 mg/kg (Table 6-2). The U.S. Army Corps of Engineers (U.S. ACOE) collected sediment samples from the Fort Howard turning basin in 1984; several samples contained PCB concentrations between 28 and 30 mg/kg (Lohr, 1988), over 3,000 times higher than background concentrations. PCB samples logged into a WDNR database (WDNR, 1995a and associated database from Jeff Steuer, USGS — Madison) show PCB concentrations in the Lower Fox River near Nicolet Paper to be as high as 75.8 mg/kg, greater than the TSCA disposal threshold (50 mg/kg) and much greater than the 0.014-0.044 mg/kg background concentrations (Table 6-2).

Table 6-2
Comparison of Maximum Sediment PCB Concentrations in the Fox River and Green Bay with Upstream and Potential Background PCB Concentrations

Location	Year	Number of Samples	Maximum PCB Concentration (mg/kg)	Reference
Upstream and Potential Background				
Menasha Channel	1990-1991	4	0.014-0.044	WDNR, 1993
Menasha Channel	1992-1993	1	<0.050	WDNR, 1995c
Lake Winnebago	1993	1	<0.061	Blasland & Bouck, 1993
Fox River Downstream of Paper Mills (Neenah to DePere)				
Little Lake Butte des Morts	1982	15	250	WDNR (unpublished), cited in Lohr, 1988
Little Lake Butte des Morts	1983	15	246	WDNR (unpublished), cited in Lohr, 1988
Deposit A, Little Lake Butte des Morts	1989-1990	≈11	223	WDNR, 1995a (and associated database from USGS)
Deposit A, Little Lake Butte des Morts	1993	33	130	Blasland & Bouck, 1993
Deposit N, near Kimberly	1989-1990	≈4	131	WDNR, 1995a (and associated database from USGS)
Deposits EE & GG, near DePere Dam	1989-1990	≈9	47.8	
Fox River Downstream of Paper Mills (DePere to mouth)				
Downstream of DePere Dam	1977	3	11.6	U.S. EPA, 1977, cited in Lohr, 1988
Downstream of DePere Dam	1983	2	40.5	WDNR (unpublished), cited in Lohr, 1988
Downstream of Nicolet Paper	1989-1990	≈10	75.8	WDNR, 1995a (and associated database from USGS)
North of Hwy 172 bridge	1989-1990	≈8	36	
Fort Howard turning basin	1984	10	30.1	U.S. ACOE, 1984, cited in Lohr, 1988
Fox River at Fort Howard	1982	27	79	WDNR (unpublished), cited in Lohr, 1988

Table 6-2 (cont.)
Comparison of Maximum Sediment PCB Concentrations in the Fox River and Green Bay with Upstream and Potential Background PCB Concentrations

Location	Year	Number of Samples	Maximum PCB Concentration (mg/kg)	Reference
Fox River at Fort Howard	1989-1990	≈7	83.7	WDNR, 1995a (and associated database per se from USGS)
Fox River mouth	1976	2	38	WDNR, 1978, cited in Lohr, 1988
Green Bay				
Near Point Au Sable	1977	12	11	WDNR, 1978, cited in Lohr, 1988
Near Grassy Island	1984	4	13	U.S. ACOE, 1985, cited in Lohr, 1988
Green Bay	1987-1990	>700	1.6	Manchester, 1993

PCB concentrations in Green Bay are lower than the concentrations in the Fox River, yet greatly elevated compared to the potential background concentrations (Table 6-2). In the 1980s, the U.S. ACOE collected samples in Green Bay near the confined disposal facility (CDF) known as Renard or Kidney Island. PCB concentrations in the sediments within the CDF were as high as 43.5 mg/kg (Lohr, 1988). In Green Bay open water sediments, PCB concentrations have been measured as high as 11 mg/kg near Au Sable Point (WDNR, 1978, cited in Lohr, 1988) and as high as 13 mg/kg near Grassy Island (U.S. ACOE, 1985, cited in Lohr, 1988). Other Green Bay sediment studies have consistently shown PCB concentrations throughout the bay to range between 1 and 2 mg/kg (Manchester, 1993; Hermanson et al., 1991), between 10 and 140 times greater than background concentrations (Table 6-2). These data confirm that sediments have been, and continue to be, exposed to PCBs.

6.3 FISH

Elevated PCB concentrations in fish from the assessment area have been documented since 1976 by the WDNR (Jensen et al., 1982; Sullivan et al., 1983; WDNR, 1995d). Since 1976, PCB fillet concentrations have been sufficiently high to trigger fish consumption advisories by the Wisconsin Department of Health and Human Services (WDHHS) for many sport and commercially exploited fish species. Fish consumption advisories are still in effect for specified sizes of most species (WDNR, 1976 to 1994) (Table 6-3).

Figure 6-1

Maximum PCB Concentrations Measured in Lower Fox River and Green Bay Sediments. Sampling locations ordered from upstream to downstream. Note: Concentrations are plotted on a logarithmic scale.

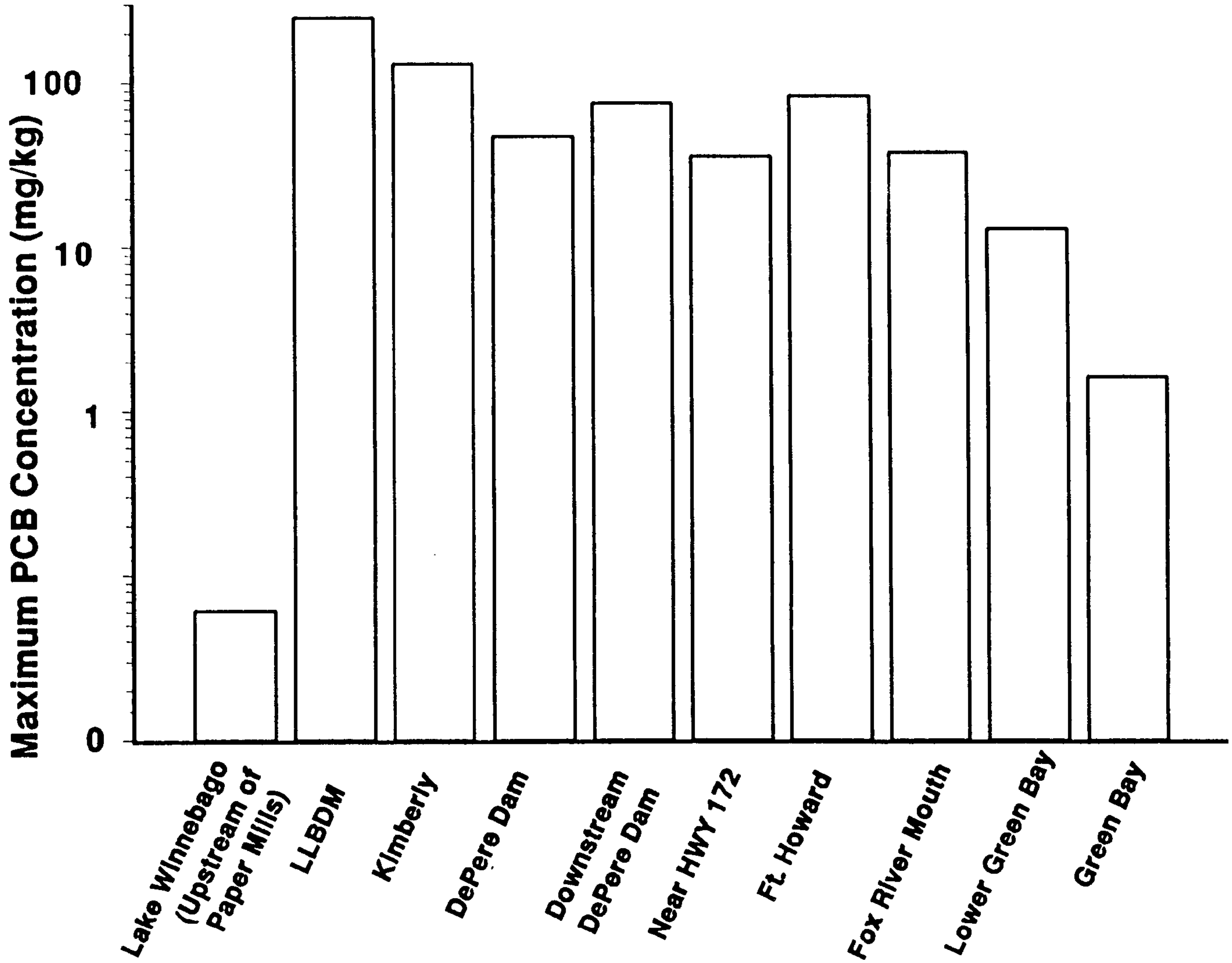


Table 6-3
1994 Wisconsin Fish Consumption Advisories Related to PCBs and Pesticides[1]

Lake Michigan

- Group 1 Advisory for lake trout (up to 20 inches), coho salmon (up to 26 inches), chinook salmon (up to 21 inches), brook trout, rainbow trout, pink salmon, smelt, and perch
- Group 2 Advisory for lake trout (20 to 23 inches), coho salmon (over 26 inches), chinook salmon (21 to 32 inches), and brown trout (up to 23 inches)
- Group 3 Advisory for lake trout (over 23 inches),[2] chinook salmon (over 32 inches), brown trout (over 23 inches), carp, and catfish

Green Bay

- Group 1 Advisory for rainbow trout (up to 22 inches), chinook salmon (up to 25 inches), brook trout (up to 15 inches), smallmouth bass, northern pike (up to 28 inches), walleye (up to 20 inches), perch, brown trout (up to 12 inches), bullhead, and white sucker
- Group 2 Advisory for splake (up to 16 inches)
- Group 3 Advisory for rainbow trout (over 22 inches), chinook salmon (over 25 inches), brown trout (over 12 inches), brook trout (over 15 inches), carp,[2] splake (over 16 inches), northern pike (over 28 inches), walleye (over 20 inches),[2] white bass, and sturgeon

Lower Fox River (from its mouth at Green Bay up to the DePere Dam)

- Group 1 Advisory for walleye (up to 15 inches)
- Group 2 Advisory for northern pike, white sucker, and walleye (15 to 18 inches)
- Group 3 Advisory for white bass,[2] walleye (over 18 inches), carp,[2] drum,[2] and channel catfish[2]

Lower Fox River (from the DePere Dam up to the Neenah-Menasha Dam)

- Group 1 Advisory for walleye (up to 15 inches), white bass, northern pike, perch, and white sucker
- Group 2 Advisory for walleye (over 15 inches), and bullheads
- Group 3 Advisory for carp (over 17 inches)

Advisory levels:
Group 1: Ninety percent or more of tested Group 1 fish meet health standards. EATING GROUP 1 FISH POSES THE LOWEST HEALTH RISK. Trim fat and skin from Group 1 fish before cooking and eating them.
Group 2: Fifty to ninety percent of test Group 2 fish meet health standards. CHILDREN UNDER 15, AND WOMEN OF CHILDBEARING AGE SHOULD NOT EAT GROUP 2 FISH. You should also limit your overall consumption of other Group 2 fish, and trim skin and fat from these fish before cooking and eating them.
Group 3: Less than fifty percent of tested Group 3 fish meet health standards. NO ONE SHOULD EAT GROUP 3 FISH.

1. A single advisory is issued for contamination with PCBs and/or pesticides. However, pesticide residues in assessment area fish do not exceed advisory levels, whereas PCB residues do exceed advisory levels.
2. Ninety percent or more of these Group 3 fish contain contaminant levels exceeding one or more advisory levels.

Source: WDNR Division of Health, 1994.

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.

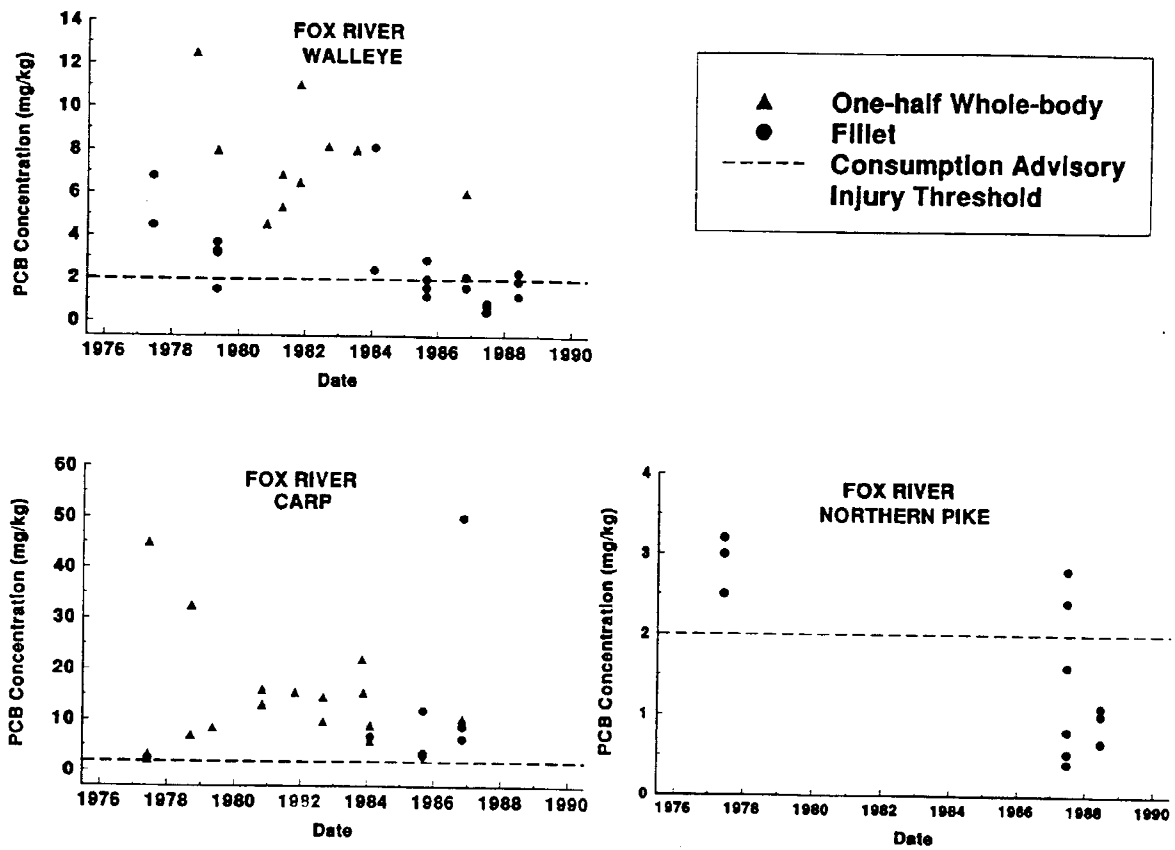
In addition to triggering fish consumption advisories, PCB contamination was sufficient to prompt closure of commercial fisheries. The large-scale commercial carp fishery in Green Bay was suspended for interstate commerce in 1975, and closed entirely in 1984 because of PCB contamination (Kleinert, 1976;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

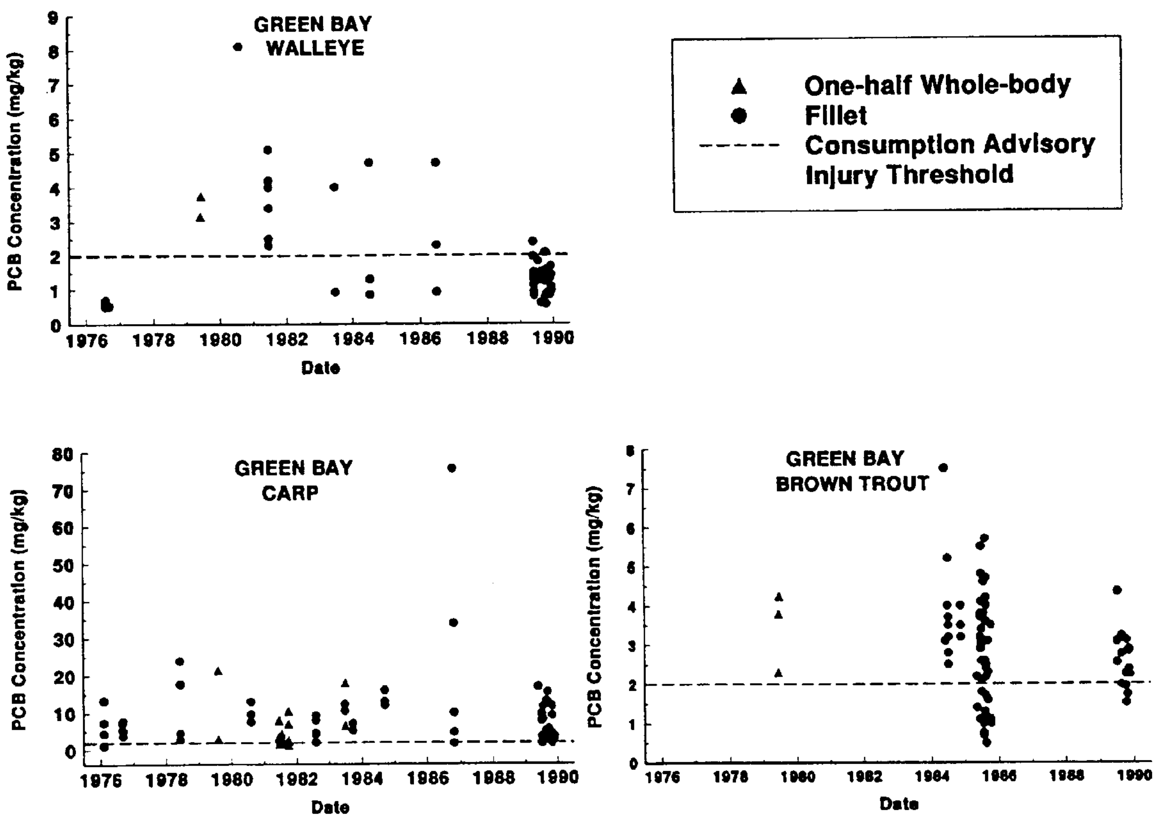
These data confirm that fish have been, and continue to be, exposed to PCBs.

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



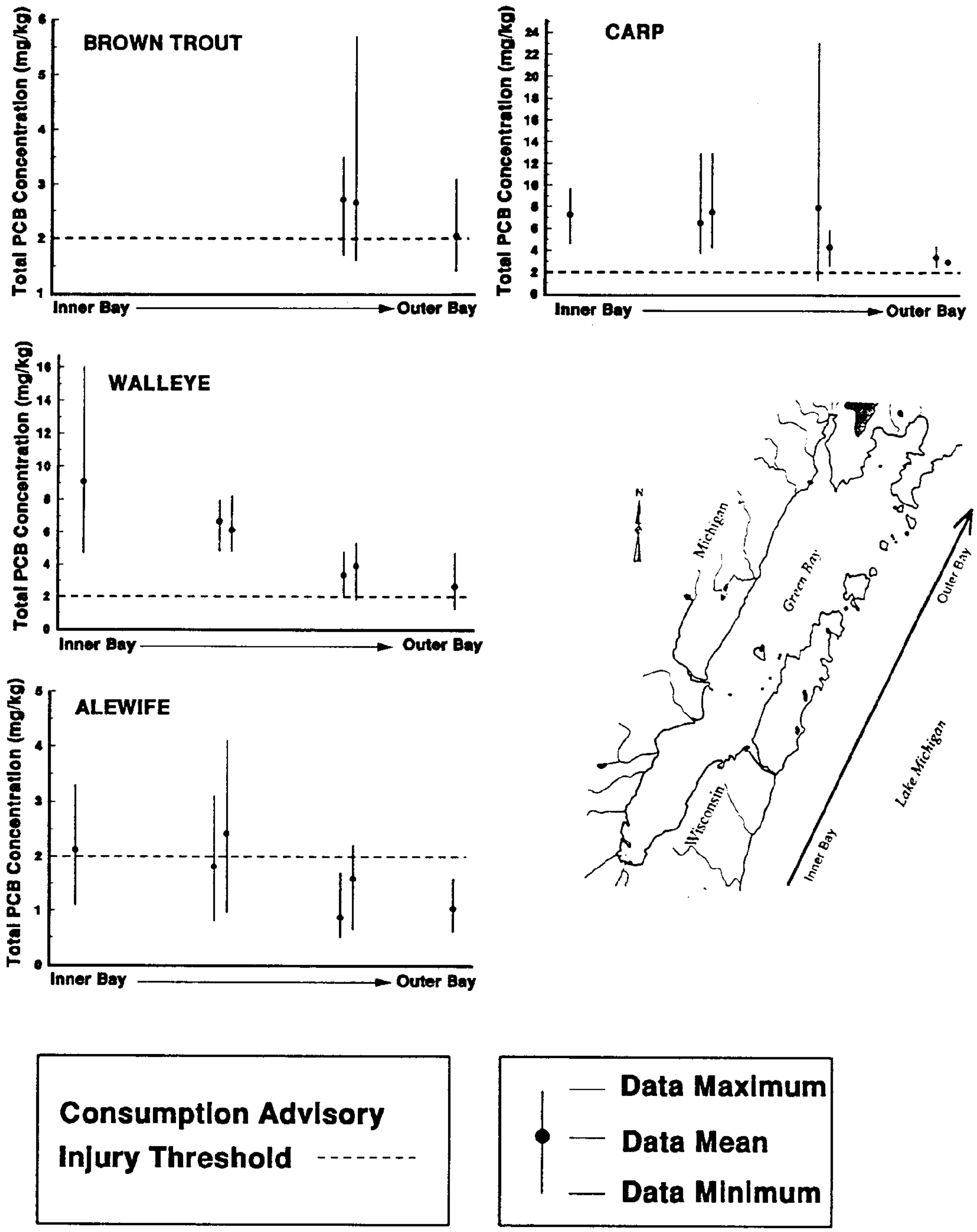
Source: WDNR, 1995d.

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.



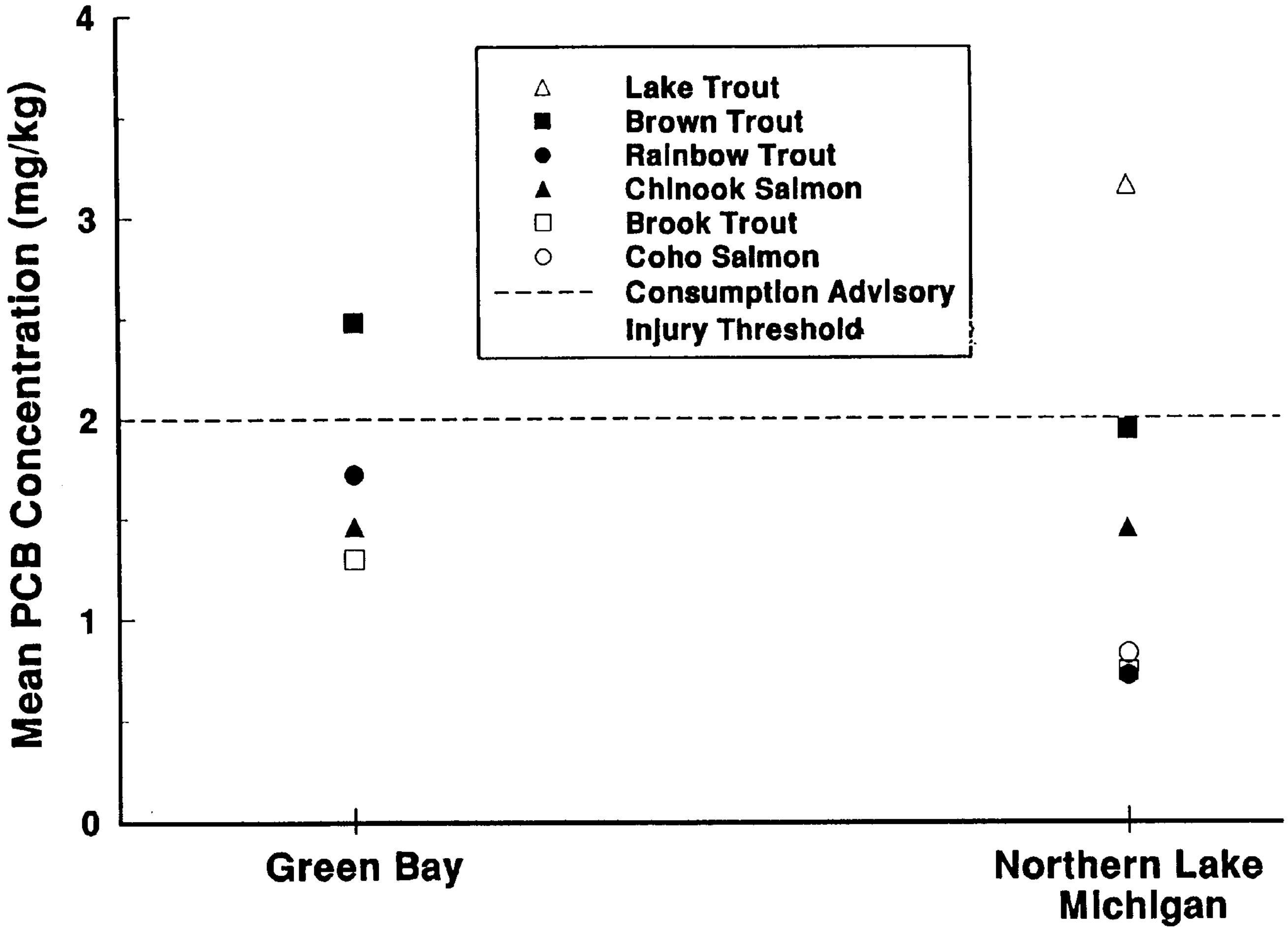
Source: WDNR, 1995d.

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

	Mean PCB Concentration (mg/kg, wet weight)			
Species	**Green Bay**	**Control**	**Control Site**	**Reference**
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	l 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.

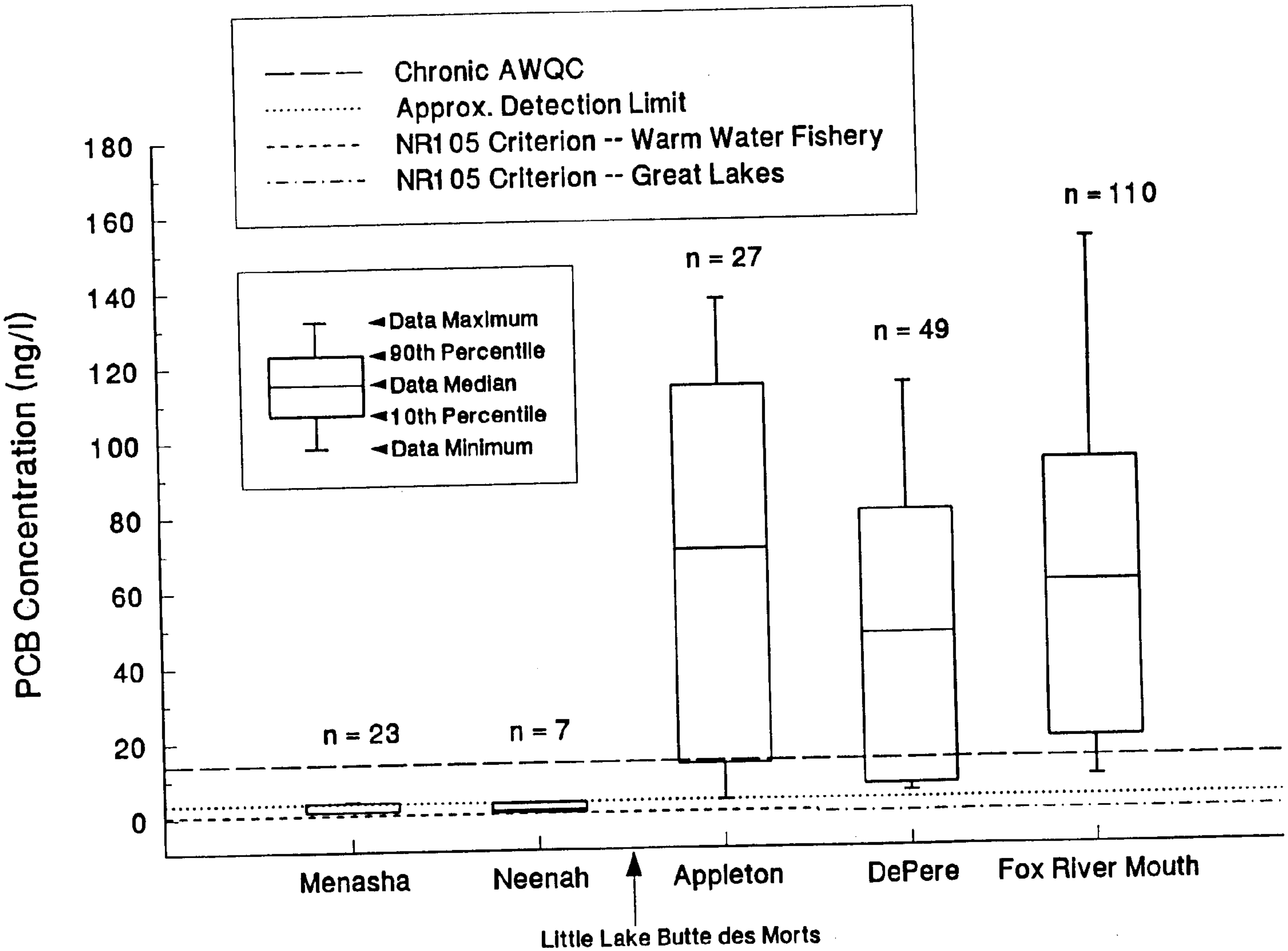
8.3.1.3 Pathway Evaluation

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

Figure 8-1

PCB Concentrations in Fox River Surface Water Showing Potential Injury Threshold Values. X-axis locations are ordered from upstream (Menasha, Neenah) to downstream of pulp/paper mills.



of 110 kg. Another model simulation estimates that over a 25 year time period, 2,000 kg of PCBs would be resuspended from sediments in the Fox River between Lake Winnebago and Green Bay (U.S. EPA, 1993a). These mass balance modeling results were based on detailed studies and simulations that included hydraulic parameters, sediment characteristics and loads, bathymetry, bottom sediment concentrations, and mobility of PCBs in the system (Bierman et al., 1992). These and other data may be utilized to evaluate pathways of hazardous substances to surface water resources. If necessary, additional studies may be undertaken to supplement existing data on pathways to exposed surface water resources in the assessment area.

8.3.1.4 Injury Quantification Approaches

Quantification of injuries to surface water resources will include evaluation of:

- the spatial extent of injuries throughout the assessment area
- the temporal extent of injuries throughout the assessment area.

For example, existing data suggest that surface water concentrations of PCBs have exceeded the NR 105 HCC of 0.49 ng/l for warm water fisheries for at least 24 years (Table 6-1; Figure 8-2). Preliminary evaluation of the spatial extent of potential injuries indicates that surface water concentrations of PCBs in the Lower Fox River from Little Lake Butte des Morts to the mouth of the Fox River have exceeded the NR 105 HCC for warm water fisheries and for Great Lakes waters (Figure 8-3). Further data analysis will be conducted in the assessment to quantify surface water injuries.

8.3.2 Sediments

8.3.2.1 Injury Definitions

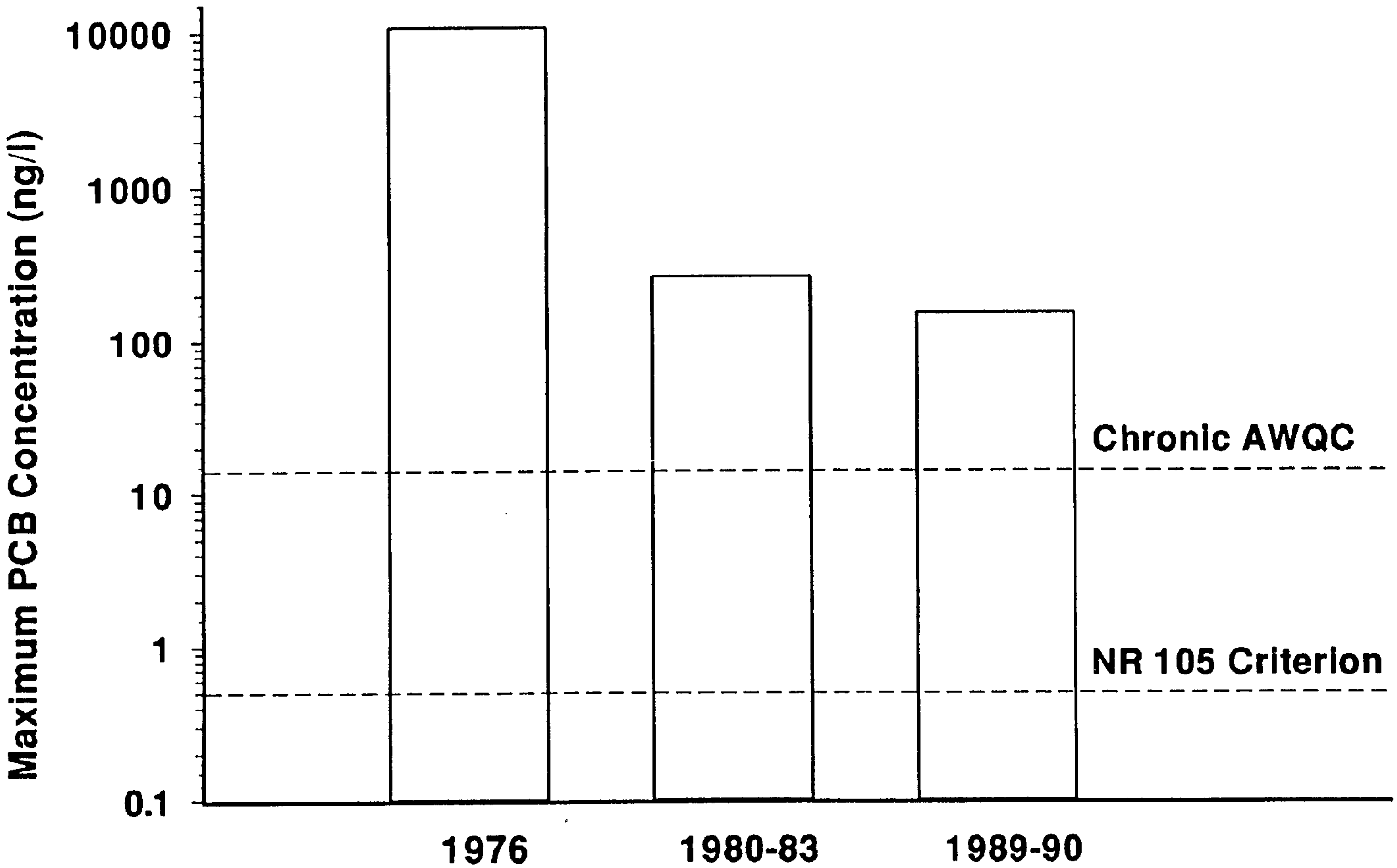
Relevant definitions of injury to sediments that may be evaluated by the trustees include:

- concentrations of PCBs sufficient to cause injury to biological or surface water resources that are exposed to sediments [43 CFR §11.62(b)(1)(v); 11.62(e)(11)].

8.3.2.2 Injury Determination Approaches

The definitions of injury presented in Section 8.3.2.1 contain several components. Table 8-4 summarizes the components of each definition and the evaluation approaches that may be used by the trustees in assessing each component.

Figure 8-2
Maximum PCB Concentrations in Surface Water at the Mouth of the Fox River, from 1976 to 1990, Compared to Potential Injury Threshold Values (concentrations plotted on a logarithmic scale)



Sources: WDNR, 1995b; Marti and Armstrong, 1990; House et al., 1993.

Figure 8-3
Map Showing Locations of 1976-1990 Surface Water Samples in the Fox River/Lower Green Bay Assessment Area that Equal or Exceed Surface Water Criteria

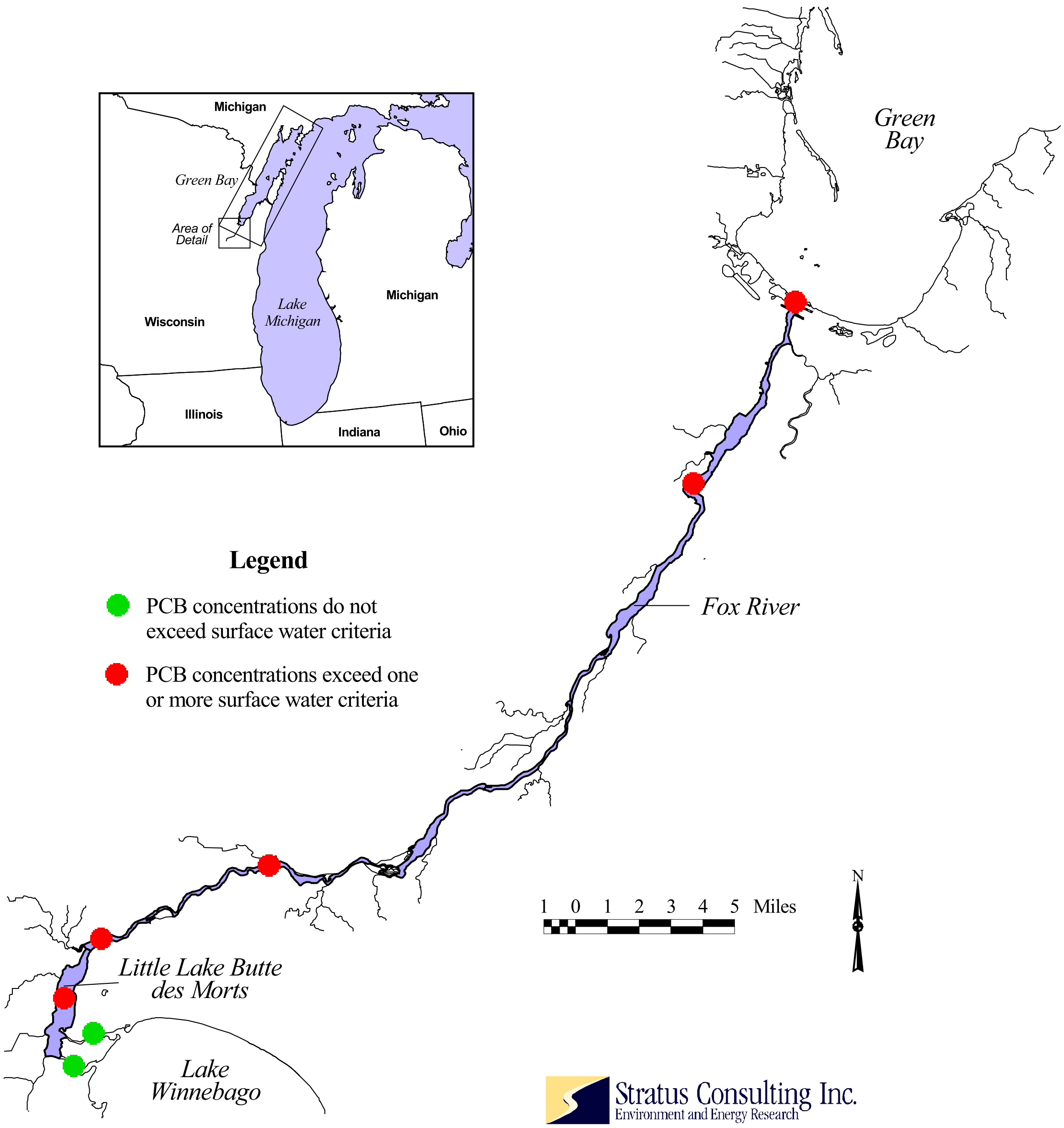


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Table 8-4
Components of Relevant Sediment Injury Definitions

Injury Definition	Definition Components	Evaluation Approach
Biological or surface water resources are injured when exposed to sediments [43 CFR §§ 11.62(b)(1)(iv)-(v)]	Biological or surface water resources are injured when exposed to sediments.	Determine whether biota or surface water have been injured as a result of exposure to sediments. Quantify concentrations of PCBs in sediments sufficient to cause injuries.

The WDNR (1993) evaluated several models for estimating the PCB concentrations in sediments that are likely to cause injury to surface water and biota. The sediment models were based on several protection endpoints, including surface water regulatory criteria, fish tissue PCB accumulation, and protection of benthic invertebrates. Table 8-5 summarizes the results of the WDNR's evaluation, which may be used for evaluation of the injury to sediment resources by the second injury test listed in Section 8.3.2.1.

The 18 threshold PCB sediment concentrations presented in Table 8-5 range from 0.0002 to 3.409 mg/kg, depending on the protection endpoint and the type of model used. Most of the threshold concentrations are substantially less than 1.0 mg/kg.

Much of the sediment PCB data collected from the Fox River/Green Bay area come from sediment cores, providing PCB concentrations at various depths. PCBs in sediments cause injury to other natural resources primarily through sediment resuspension and near-surface exposure of biota. The WDNR (1993) concluded that "the top 15 cm of bedded sediment would generally be the strata where the greatest interchange of PCBs will take place between the sediment phases and the overlying water column." Therefore, initially, PCB concentrations in the top 15 cm will be considered for sediment injury determination, although further evaluation of the active sediment zone and the potential for sediment resuspension during high flow events may be performed during the assessment phase.

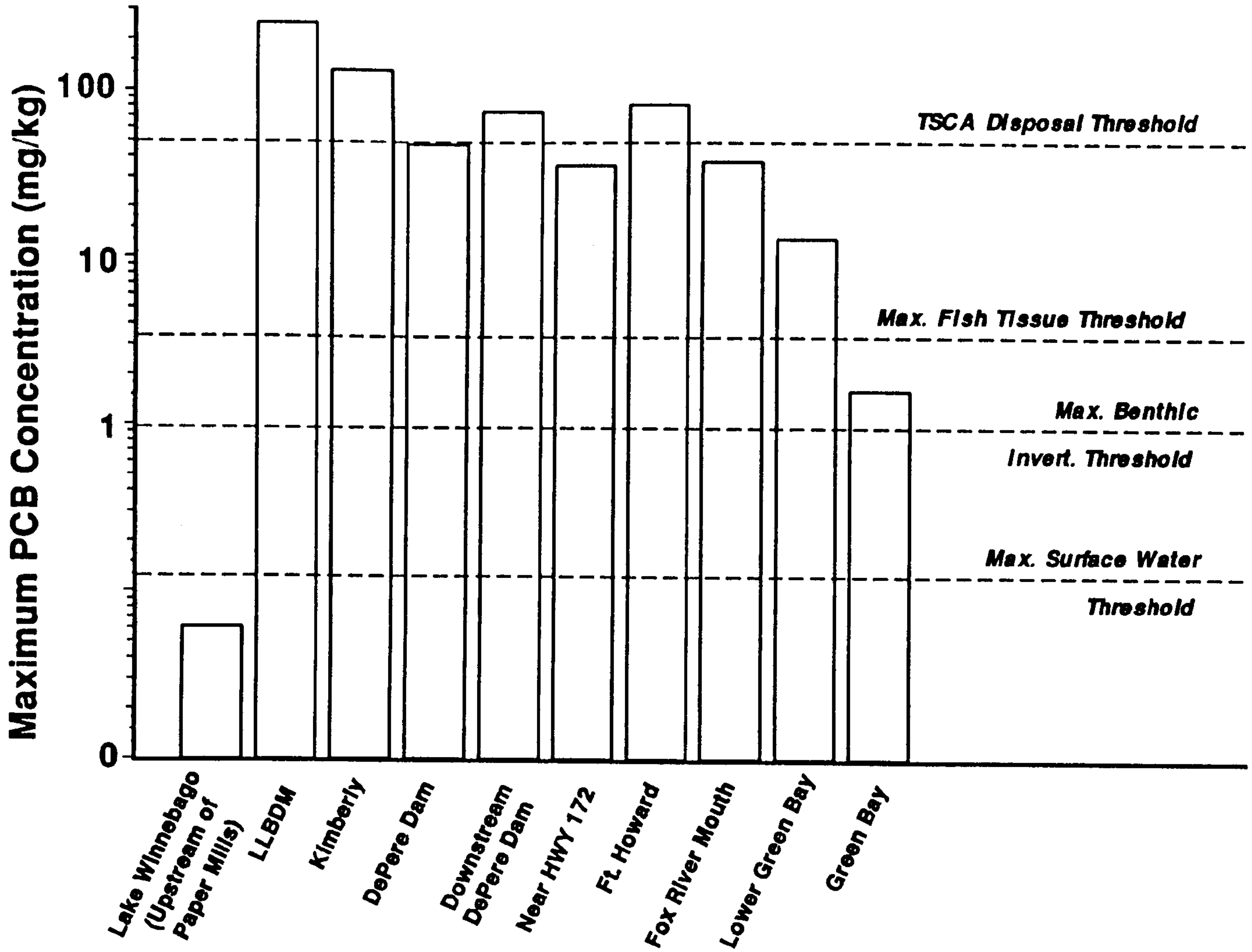
Figure 8-4 presents a preliminary example of an application of the injury determination approach. As shown in the figure, all of the sediment samples downstream of Fox River paper and pulp mills exceeded at least two injury thresholds. Four out of nine downstream sediment samples also exceeded the 50 mg/kg threshold for hazardous chemical disposal under the Toxic Substances Control Act (TSCA) [40 CFR § 761.60(a)(5)].

Table 8-5
Summary of Potential Sediment PCB Injury Thresholds
(numerical thresholds from WDNR, 1993)

Injury Endpoint	Type of Model	Threshold Sediment PCB Concentration (mg/kg)
Causes surface water concentrations to exceed 0.49 ng/l (NR 105 HCC — warm water fisheries)	Equilibrium partitioning	0.004-0.020
Causes surface water concentrations to exceed 3.0 ng/l (NR 105 Wild and Domestic Animal criterion)	Equilibrium partitioning	0.022-0.123
Causes PCB concentrations in edible fish fillets to exceed 2 mg/kg FDA action level for protection of human health	Accumulation Relative to Sediments (ARS)	0.20-1
	Thermodynamic Equilibrium Model	0.188-1.038
	Bioconcentration Model	0.616-3.409
	Food Chain Multiplier Model	0.035-0.104
Causes whole fish PCB concentrations to exceed 0.100 mg/kg International Joint Commission (IJC) objective for protection of piscivorous birds and mammals	ARS	0.010-0.050
	Thermodynamic Equilibrium Model	0.0045-0.026
	Bioconcentration Model	0.015-0.082
	Food Chain Multiplier Model	0.0009-0.0026
Causes PCB concentrations in whole fish to exceed 0.023 mg/kg GLWQG for protection of piscivorous wildlife	ARS	0.002-0.012
	Thermodynamic Equilibrium Model	0.001-0.006
	Bioconcentration Model	0.004-0.020
	Food Chain Multiplier Model	0.0002-0.0006
Causes surface water PCB concentrations to exceed 14 ng/l U.S. EPA chronic AWQC for protection of aquatic life	Equilibrium Partitioning Model	0.070-0.554
Exceeds lowest effect level (LEL) for protecting 95% of benthic invertebrate species from Aroclor 1248 — Ontario Ministry of the Environment	Organic Carbon- and Aroclor-Dependent Model	0.030-0.240
Exceeds apparent effects threshold (AET) for protecting marine invertebrates — State of Washington sediment standards	Organic Carbon-Dependent; based on lab bioassays	0.120-0.960
Exceeds AET for protecting marine invertebrates — NOAA (National Oceanic and Atmospheric Administration)	Data from Equilibrium Partitioning models and spiked-sediment toxicity tests	0.370

Figure 8-4

Maximum PCB Concentrations Measured in Lower Fox River and Green Bay Sediments Compared to Potential Injury Threshold Values and the TSCA Disposal Threshold Value. Sampling locations ordered from upstream to downstream. Note: Concentrations are plotted on a logarithmic scale.



Sediment PCB concentrations in Green Bay are also elevated. In 1977, the WDNR (1978, in Lohr, 1988) collected 12 sediment samples from the bay. The highest concentration found was 11 mg/kg, over three times higher than the highest threshold shown in Table 8-5. Four of the 12 samples reported in Lohr (1988) exceed 3.4 mg/kg, the highest threshold concentration in Table 8-5, including samples from Green Bay Harbor and one sample from southeast of Point Au Sable. In 1984, the U.S. ACOE (1985, in Lohr, 1988) collected four sediment samples from Green Bay near Grassy Island. One of these samples contained 13 mg/kg PCBs.

Data on Green Bay sediment PCB concentrations were summarized by Manchester (1993). Based on these data, it appears that the PCB concentrations averaged over all sampled depths ranged approximately between 0.1 and 1 mg/kg. Concentrations of PCBs at 1 mg/kg exceed the high range of 12 of the 18 potential injury thresholds shown in Table 8-5. Further data analysis will be conducted in the assessment to evaluate sediment injuries.

8.3.2.3 Pathway Evaluation

Once released into the environment, the low water solubility of PCBs dominates their environmental fate and transport. In the environment, PCBs are strongly adsorbed onto soils, sediments, and particulates; the highest environmental concentrations typically accumulate in aquatic sediments containing microparticulates and high organic or clay content (Eisler, 1986). In aquatic systems, sediments are a primary transport mechanism and sink for PCBs (Thomann and Connolly, 1984; Ram and Gillett, 1993). Consequently, important pathways to injured sediments include the settling of PCBs from contaminated surface water and resuspension of contaminated sediments. Data on sediment concentrations and distributions, coupled with physical transport data and models, will be used to evaluate pathways. If necessary, additional studies may be undertaken to supplement existing data on pathways to exposed sediment resources in the assessment area.

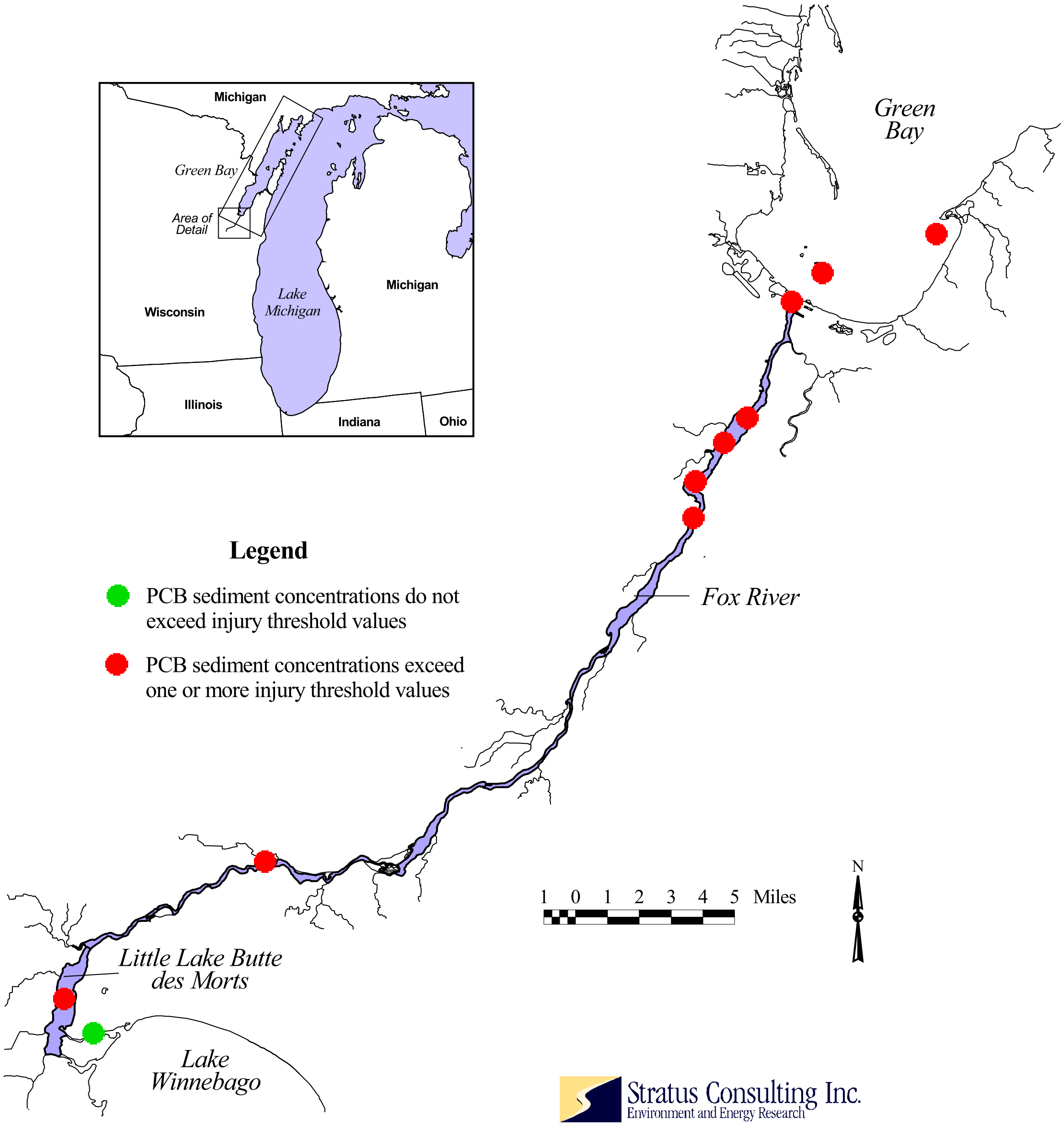
8.3.2.4 Injury Quantification Approaches

Quantification of injuries to sediment resources will include an evaluation of:

- the spatial extent of injuries throughout the assessment area
- the temporal extent of injuries throughout the assessment area.

For example, existing data indicate that sediment concentrations of PCBs in the Lower Fox River and Green Bay have exceeded sediment PCB injury thresholds (Tables 8-4, 8-5) for at least 16 years (Table 6-2). Preliminary evaluation of the spatial extent of potential injuries indicates that concentrations of PCBs in sediment deposits from Little Lake Butte des Morts to mid-Green Bay have exceeded PCB injury thresholds (Figures 8-4, 8-5). Further data analysis will be performed in the assessment to quantify injuries.

Figure 8-5
Map Showing Locations of 1977-1993 Sediment Samples in the Fox River/Lower Green Bay Assessment Area that Meet or Exceed Potential Sediment PCB Injury Thresholds



8.4 AQUATIC BIOTA RESOURCES

8.4.1 Injury Definitions

Relevant biological injuries defined by DOI regulations [43 CFR § 11.62(f)(1)] may include the following:

- concentrations of a hazardous substance sufficient to exceed action or tolerance levels established under section 402 of the Food, Drug and Cosmetic Act, 21 U.S.C. 342, in edible portions of organisms [43 CFR § 11.62(f)(1)(ii)]

- concentrations of a hazardous substance sufficient to exceed levels for which an appropriate State health agency has issued directives to limit or ban consumption of such organism [43 CFR § 11.62(f)(1)(iii)]

- concentrations of a hazardous substance sufficient to cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

8.4.2 Injury Determination Approaches

The injury definitions in Section 8.4.1 contain several components. Table 8-6 summarizes the components of each definition and the approaches that may be used by the trustees in assessing each component.

As shown in Figures 6-2 to 6-5, PCB fillet concentrations in fish from the Fox River and Green Bay have been sufficiently high since 1976 to trigger fish consumption advisories by the WDHHS for many sport and commercially exploited fish species. Fish consumption advisories are still in effect for specified sizes of most species (WDNR, 1976 to 1994) (Table 6-3). PCB contamination has been sufficient to prompt closure of commercial fisheries. The large-scale commercial carp fishery in Green Bay was suspended from interstate commerce in 1975, and closed entirely in 1984 because of PCB contamination (Kleinert, 1976; Allen et al., 1987). Further data analysis of consumption advisories will be performed in the assessment to evaluate these potential injuries.

PCBs also can adversely affect fish viability by causing mortality, decreased reproductive success (Table 8-7), and increased incidence of fry deformities (Eisler, 1986). Other documented effects of PCBs on fish include edema; hemorrhages; arrested growth and development; liver enlargement; calcium, magnesium, and cholesterol metabolism disruption; decreased coordination; anemia; and hyperglycemia (Eisler, 1986; Peterson et al., 1993). In addition, PCBs can also cause inhibition of immune functions, tumor formation, and neurotoxicity (Safe, 1994).

Table 8-6
Components of Relevant Biological Resources Injury Definitions

Injury Definition	Definition Components	Evaluation Approach
Food, Drug, and Cosmetic Act exceedences [43 CFR § 11.62 (f)(1)(ii)]	Tissue concentrations of a hazardous substance in edible portions of organisms exceed applicable standards.	Compare organism tissue concentrations to applicable Food and Drug Administration (FDA) standards.
Consumption advisory exceedences [43 CFR § 11.62 (f)(1)(iii)]	Tissue concentrations of a hazardous substance exceed levels for which a state has issued directives to limit or ban consumption.	Compare organism tissue concentrations to consumption advisories.
Adverse changes in viability [43 CFR § 11.62 (f)(1)(i)]	The biological resource or its offspring has undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations.	Determine whether the measured biological response satisfies the criteria for indicating an adverse change in viability.

Table 8-7
Egg-Concentration Values for Reproductive Effects from Existing Literature

Species	Egg PCB Concentration (mg/kg)	Effect	Reference
Rainbow Trout	2.7	75% mortality by day 30 post-hatch	Hogan and Brauhn, 1975
Atlantic Salmon	0.6 to 1.9	46 to 100% mortality of eggs and fry	Johansson, 1970 (cited in Niimi, 1983)
Lake Trout	2.0 (estimated)	decreased hatching success	Mac and Schwartz, 1992
Chinook Salmon	3.0	decreased hatching success	Ankley et al., 1991

Early life stages in fish are more sensitive to PCB toxicity than are adult fish (Eisler, 1986). Adverse effects such as reduced egg hatchability, fry mortality, and developmental deformities occur at PCB concentrations orders of magnitude less than concentrations causing adult mortality (Nebeker et al., 1974; Eisler, 1986). Fish embryos can acquire PCB burdens both by uptake from water and via maternal transfer during oogenesis (Broyles and Noveck, 1979; Niimi, 1983; Ankley et al., 1989; Noguchi and Hesselberg, 1991; Spitsbergen, 1991, as cited in Walker and Peterson, 1991). In the embryo, PCBs accumulate in the lipid-rich yolk to concentrations that are typically much greater than those in the surrounding water (Broyles and Noveck, 1979) and may be greater than those in the maternal fish (Niimi, 1983). Many of the adverse effects of PCBs on fry generally occur during yolk sac absorption, suggesting that the toxicity of PCBs to early life stages is associated with uptake of PCBs from the yolk sac by the developing embryo (Mac, 1988; Harris et al., 1994).

PCBs in Great Lakes fish have been implicated as a causal factor in the low reproductive success of fish throughout the region (Willford et al., 1981). Some studies have investigated the possibility that PCBs are responsible for the limited natural reproduction of lake trout and salmon in Lake Michigan, and for the occasionally high mortality in eggs collected from feral Great Lakes fish and incubated in fish hatcheries (e.g., Stauffer, 1979; Willford et al., 1981; Mac, 1988; Walker and Peterson, 1991). Several investigators have posited a relationship between PCB concentrations in feral lake trout eggs and mortality (Ankley et al., 1991; Mac and Schwartz, 1992).

Adverse changes in viability may be assessed through further data analysis and by evaluating potential toxicological effects of PCBs on assessment area fish, such as described below in Section 8.6.

8.4.3 Pathway Determination

Exposure pathways to biological resources in the assessment area include direct exposure through physical contact with hazardous substances in surface water and sediments as well as indirect exposure through food chain processes. Data on PCB concentrations in surface water, sediments, and fish prey will be used to evaluate exposure pathways. If necessary, additional studies may be undertaken to supplement existing data on pathways to exposed aquatic biota resources in the assessment area.

8.4.4 Injury Quantification Approaches

Quantification of injuries to aquatic biota resources will include evaluation of:

- the spatial extent of injuries throughout the assessment area
- the temporal extent of injuries throughout the assessment area.

For example, existing data suggest that elevated concentrations of PCBs in aquatic biota have resulted in a restriction on the commercial carp fishery since 1975 (Kleinert, 1976), and in consumption advisories for sport fish since 1976 (WDNR, 1976-1994). Preliminary evaluation of the spatial extent of injury indicates that PCB concentrations in fish collected from inner to outer Green Bay exceed consumption advisory thresholds (Figure 6-4). Further data analysis will be performed to quantify injuries to aquatic biota.

8.5 TERRESTRIAL BIOTA RESOURCES

8.5.1 Injury Definitions

Relevant biological injuries defined by DOI regulations may include:

- concentrations of a hazardous substance sufficient to exceed action or tolerance levels established under section 402 of the Food, Drug and Cosmetic Act, 21 U.S.C. 342, in edible portions of organisms [43 CFR § 11.62(f)(1)(ii)]

- concentrations of a hazardous substance sufficient to exceed levels for which an appropriate State health agency has issued directives to limit or ban consumption of such organism [43 CFR § 11.62(f)(1)(iii)]

- concentrations of a hazardous substance sufficient to cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

8.5.2 Injury Determination Approaches

The injury definitions in Section 8.5.1 contain several components. Table 8-8 summarizes the components of each definition and the approaches that may be used by the trustees in assessing each component.

Laboratory studies have shown that concentrations of PCBs in bird eggs in the range of 5-10 mg/kg may be associated with embryotoxicity (e.g., Britton and Huston, 1973; Brunstrom and Reutergardh, 1986; Kubiak et al., 1989; Peakall et al., 1972; Wiemeyer et al., 1984; Yamashita et al., 1993). Table 6-5 shows that PCBs in eggs of numerous bird species throughout the assessment area greatly exceed that concentration.

As shown in Tables 8-9 and 8-10, studies of birds nesting on Green Bay or the Lower Fox River demonstrate a pattern of adverse effects, including the following:

Table 8-8
Components of Relevant Biological Resources Injury Definitions

Injury Definition	Definition Components	Evaluation
Food, Drug, and Cosmetic Act exceedences [43 CFR § 11.62 (f)(1)(ii)]	Tissue concentrations of a hazardous substance in edible portions of organisms exceed applicable standards.	Compare organism tissue concentrations to applicable FDA standards.
Consumption advisory exceedences [43 CFR § 11.62 (f)(1)(iii)]	Tissue concentrations of a hazardous substance exceed levels for which a state has issued directives to limit or ban consumption.	Compare organism tissue concentrations to consumption advisories.
Adverse changes in viability [43 CFR § 11.62 (f)(1)(i)]	The biological resource or its offspring has undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations.	Determine whether the measured biological response satisfies the criteria for indicating an adverse change in viability.

- reduced reproductive success, including reduced hatching success in Forster's terns (Kubiak et al., 1989), common terns (Hoffman et al., 1993), double-crested cormorants (Tillitt et al., 1992; Larson et al., 1996), and bald eagles (C. Dykstra, unpublished data)

- physical deformations, including head and neck edema, and bill and leg deformities in double-crested cormorants (Larson et al., 1996), black-crowned night-herons (Hoffman et al., 1993), common terns (Hoffman et al., 1993), and Forster's terns (Kubiak et al., 1989)

- "wasting" of Forster's tern chicks, i.e., failure to put on weight during nestling development usually followed by death prior to fledgling (Harris et al., 1993)

- reduced Forster's tern parental attentiveness during incubation (Kubiak et al., 1989)

- reduced colony tenacity in Caspian terns (Mora et al., 1993).

Further data analysis will be performed to evaluate injuries to terrestrial biota.

Table 8-9
Comparisons of Hatching Success/Productivity and Embryo & Nestling Deformity Rates among Birds Nesting on Green Bay/Lower Fox River (impact area) and Control Areas

Species	Hatching Success/Productivity		Deformity Rate		Reference
	Impact	Control	Impact	Control	
Forster's Tern	37% hs[1]	75% hs	33%	12%	Kubiak et al., 1989
Common Tern	71% hs	85% hs	11%	0%	Hoffman et al., 1993
Double-Crested Cormorant	55-65% hs	64-76% hs	0.76%	0.06%	Larson et al., 1996
Bald Eagle	0.39 young/pair	1.09 young/pair	—	—	C. Dykstra unpublished data

1. hs = hatching success.

8.5.3 Pathway Determination

Exposure pathways to biological resources in the assessment area include direct exposure through physical contact with hazardous substances in surface water and sediments as well as indirect exposure through food chain processes. For example, PCB residue data from bottom- and sediment-dwelling organisms exposed directly to PCBs in water and sediments can be used to determine areal dispersion of PCBs. PCB residue data from indicator species can be used to represent the exposure of a particular trophic level in a food chain. If necessary, additional studies may be undertaken to supplement existing data on pathways to exposed wildlife resources in the assessment area.

8.5.4 Injury Quantification Approaches

Quantification of injuries to terrestrial biota resources will include evaluation of:

- the spatial extent of injuries throughout the assessment area
- the temporal extent of injuries throughout the assessment area.

For example, existing data indicate that elevated concentrations of PCBs in eggs of numerous bird species throughout the assessment area have exceeded since the early 1970s concentrations demonstrated in laboratory exposure and field studies to cause injuries. Preliminary evaluation of the spatial extent of potential injuries indicates that bird injuries have been observed at several

Table 8-10
Adverse Morphological, Physiological, and Behavioral Effects Observed in Green Bay and the Lower Fox River Wildlife Species

		Overt External Malformations					Behavioral Abnormality	
Species	**Reduced Reproduction**	**Edema**	**Beak**	**Leg**	**Chick “Wastin g”**	**Internal Malformations**	**Reduced Parental Attentiveness**	**Reduced Colony Tenacity**
Double-Crested Cormorant	X	[1]	X[1]					
Black-Crowned Night-Heron		X	[2]			X[2]		
Common Tern	X	X[2]		X[2]				
Forster’s Tern	X	X[3]	X[4]	X[4]	X[5]	X[3,4]	X[3]	
Caspian Tern								X [6]
Bald Eagle	X	[7]						

1. Larson et al., 1996.
2. Hoffman et al., 1993.
3. Kubiak et al., 1989.
4. Hoffman et al., 1987.
5. Harris et al., 1993.
6. Mora et al., 1993.
7. Dykstra unpublished data.

locations in inner Green Bay and outer Green Bay (Figure 8-6). Further data analysis will be performed to quantify injuries to birds and other wildlife species.

8.6 SUMMARY OF PRESENT AND ONGOING STUDIES

The following studies have, or are soon to be, initiated by the Trustees to supplement existing data.

8.6.1 Field Collection of Walleye and Salmonids

8.6.1.1 Objectives

The objectives of this effort include:

- collection of walleye, brown trout, and lake trout (as available) for determination of whole-fish contaminant concentrations

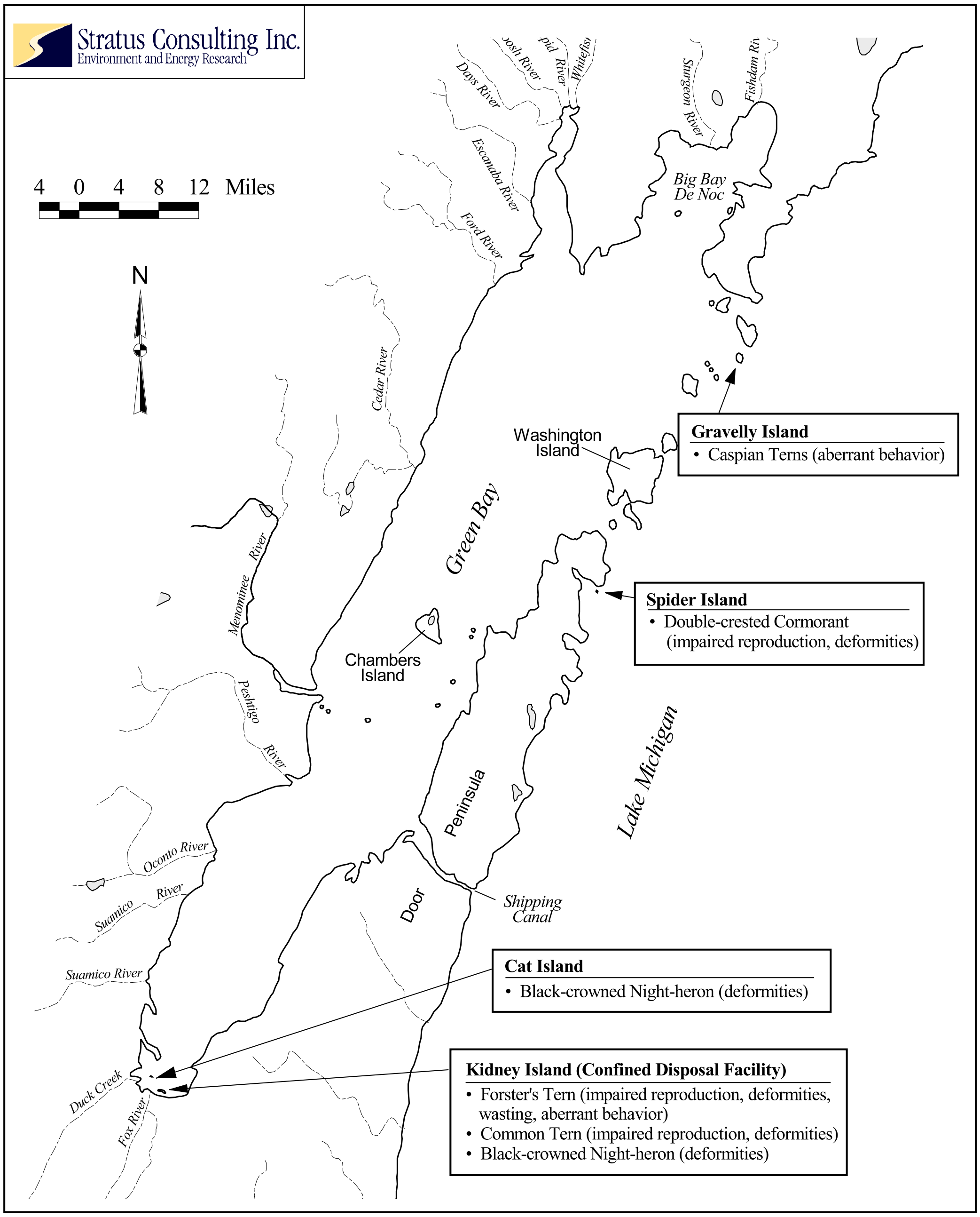
- collection of walleye, brown trout, and lake trout (as available) for determination of contaminant concentrations to be used in pathway analyses and to evaluate predictions of the Green Bay Mass Balance model

- evaluation of potential physiological and deformative injuries in fish collected from the assessment area.

8.6.1.2 Approach

Approximately 100-150 walleye may be collected from the Fox River, Lower Green Bay, Middle Green Bay, and Upper Green Bay, approximately 40-60 brown trout may be collected from Middle Green Bay and Upper Green Bay, and approximately 30-50 lake trout may be collected from Upper Green Bay and from two other locations near Green Bay in western Lake Michigan. Fish collection may be by electroshocking, gill netting, and/or trap-netting, as necessary. Whole fish will be processed and archived for contaminant analyses. Walleye will also be processed for liver histopathological analyses. Trout may be collected by electroshocking, gill netting, trap-netting, and/or angling, as necessary. Whole fish will be processed and archived for contaminant analyses. Additional live-caught fish will be processed for bioindicator analyses (e.g., immunotoxicological, histopathological, and biochemical analyses). For reference purposes, 10 brown trout and 13 lake trout will be obtained from local (Wisconsin/Michigan) fish hatcheries and processed for bioindicator analyses. Fillets of fish collected for bioindicator analyses will be analyzed for total PCB concentrations.

Figure 8-6
Location of Observed Adverse Effects on Birds: Green Bay



8.6.2 Lake Trout PCB/Thiamine Reproductive Study

8.6.2.1 Objectives

The objectives of this study include:

- evaluating potential adverse effects thresholds for Green Bay PCB effects on embryo/larval viability of lake trout

- evaluating potential interactions between thiamine deficiency and PCB effects on embryo/larval viability of lake trout.

8.6.2.2 Approach

This task will involve characterizing and quantifying the relative and interactive effects of egg thiamine deficiencies and Green Bay PCBs on the hatching success and survival of salmonid embryos and larvae. Thiamine deficient eggs may be obtained from females collected from a population known to be affected by low thiamine levels and free of contaminants. Thiamine deficient eggs may also be produced in hatchery fish by feeding adult females with chemicals that block thiamine uptake. PCBs may be obtained by extraction from walleye captured in inner Green Bay. Deficient eggs may be treated with thiamine (either injected or in an egg-soaking bath) and PCBs (by injection) in a block design.

Completion of this study may involve the following subtasks:

- field collection of thiamine deficient lake trout eggs
- hatchery production and collection of thiamine deficient lake trout eggs
- augmentation of thiamine levels by soaking or injection
- injection of PCBs extracted from Green Bay walleyes into eggs
- monitoring of embryo/larval viability from time of injection to time of first feeding
- evaluation of viability data to estimate thresholds for thiamine deficiency and PCB effects.

8.6.3 Determination of Contaminant Concentrations in Tern Eggs

8.6.3.1 Objectives

The objective of this study is to:

- collect common and Forster's tern eggs from colonies in vicinity of the Lower Fox River/Green Bay for PCB residue analysis.

8.6.3.2 Approach

Eggs from approximately 10 nests will be collected for each species. The total number of nests containing eggs in the study colonies will be determined and this figure used to ensure that the study nests are spread throughout the colony. If, for example, the colony contains 60 nests with eggs, the colony will be walked through and an egg will be collected from every 6th (60/10) nest.

8.7 OBTAINING AND SHARING DATA

Under 43 CFR § 11.31(a)(2) and § 11.31(c)(3) of the NRDA regulations, a type B assessment plan is required to include objectives for any testing and sampling, sampling locations, sample and survey design, numbers and types of samples to be collected, and analyses to be performed on assessment studies. At this time, it is not feasible to provide this information because it is still under development by the trustees. However, the trustees intend to make this information available for public review and comment once it has been developed. Similarly, procedures for sharing data pursuant to 43 CFR § 11.31(a)(4) will be made available for public review and comment as soon as they have been developed.

CHAPTER 9
DAMAGE DETERMINATION

9.1 INTRODUCTION

This chapter provides an overview of the restoration planning and economic valuation approaches to be used in the damage determination assessment phase. These approaches are explained in the context of the DOI regulations promulgated under CERCLA (43 Part 11, as amended).

The purpose of the damage determination phase is to establish the amount of money to be sought in compensation for injuries to natural resources resulting from a discharge of oil or release of a hazardous substance. The measure of damages is the *cost of restoration*, rehabilitation, replacement, and/or acquisition of the equivalent of the injured natural resources and the services those resources provide.[1] (Hereafter, for brevity, the terms restore and restoration are used to refer to all actions that restore, rehabilitate, replace, and/or acquire equivalent natural resources and natural resource service flows.) Damages may also include, at the discretion of the authorized official, the *compensable value* of all or a portion of the services lost to the public for the time period from the discharge or release until the resources and their services are returned to baseline conditions [43 CFR § 11.80(a)(2)(b)]. In short, damages include restoration costs and may include compensable values.

Baseline is defined as the condition of the injured resource had the release of hazardous substances not occurred [43 CFR § 11.14(e)]. Restoration actions are undertaken to return injured natural resources to their baseline conditions. Actions that achieve baseline at an earlier date will restore the ability of natural resources to provide services sooner than if baseline were achieved at a later date. In this way, the restoration actions that achieve baseline at the earlier date reduce total interim compensable values. Therefore, restoration actions and compensable values are jointly determined.

The term *interim damages* refers to all damages from the time of release to when resources are returned to baseline and encompasses past damages up to the present, ongoing damages during restoration actions, and future residual damages after restoration actions have ceased if the restoration actions do not fully restore natural resources to baseline levels.

1. The exact requirements in terms of restoration of resources and/or services is subject to review and revision based on *U.S. DOI v. Kennecott Utah Copper Corporation* [93-1700 (D.C. Cir. 1996)]. This review and revisions, if any, will be reflected in the Restoration Compensation and Determination Plan.

The remainder of this chapter is divided into two sections that discuss approaches to restoration planning and costing (Section 9.2) and compensable value determination (Section 9.3). This discussion will guide the trustees in developing a Restoration and Compensation Determination Plan (RCDP) that will list a reasonable number of possible restoration alternatives [43 CFR § 11.81]. The RCDP is intended to provide sufficient information to enable the trustees to select the appropriate restoration alternative to be used to determine restoration costs and compensable values.

At the time that this assessment plan is being made available for public comment and review, the existing information is insufficient to develop the RCDP. Consistent with the DOI regulations, the RCDP will be developed and issued after the completion of the Injury Determination and Quantification phases and will be made available for public review and comment [43 CFR § 11.81(d)(1-2)].

9.2 RESTORATION PLANNING APPROACHES

The restoration planning will develop and evaluate restoration alternatives necessary to restore injured natural resources to baseline conditions and to address additional restoration of natural resources and services at the site or at other sites to which compensable damages may be applied. Because no response actions are currently planned for implementation at any portion of the entire assessment area, the restoration analysis will be based on the assumption that no response will be undertaken.

The information reviewed for the restoration cost analysis will be used to:

- characterize the current natural resource injuries and their relationship to alternative restoration actions [43 CFR § 11.81(a)(1)]
- identify and evaluate restoration actions required to partially or fully restore resources and services to baseline conditions [43 CFR § 11.82(a)]
- identify and evaluate additional resource restoration or enhancement actions to which compensable damages may be applied [43 CFR § 11.93(a)].

The trustees will identify a range of possible restoration actions that will include [43 CFR § 11.73, 11.82(b) and (e)]:

- intensive efforts to achieve complete restoration, or, if complete restoration is infeasible to achieve intermediate levels of restoration

- replacement or acquisition of equivalent resources that provide the same or substantially similar services

- "no-action" natural recovery with minimal management actions, including an evaluation of how long such natural recovery can be expected to occur, if ever.

When selecting the appropriate restoration alternative to be used to determine restoration costs and compensable values, the trustees will evaluate each proposed actions using all relevant considerations, including the following factors identified by DOI [43 CFR § 11.82(d)]:

- technical feasibility
- the relationship between the expected restoration costs and expected restoration benefits
- cost-effectiveness
- results of any actual or planned response actions
- potential for additional natural resource injury resulting from the proposed alternative
- natural recovery time period
- ability of resource to recover with or without alternative actions
- potential effects of the proposed action on human health and safety
- consistency with relevant Federal, State, and tribal policies
- compliance with applicable Federal, State, and tribal laws.

For the application of compensable values to additional resource restoration and enhancement actions, other factors also may be considered such as trustee objectives for regional resource management, timing of restoration, the types and location of restoration.

The application of a strict cost-benefit test to each proposed alternative is not required under the DOI regulations and is therefore not envisioned by the trustees. The trustees will, however, consider the likely costs and benefits of each proposed action in light of the other relevant considerations. A detailed economic study of the proposed alternatives is not considered.

The methodologies to be used to establish the cost of restoration alternatives will be consistent with the DOI regulations [43 CFR § 11.83], with emphasis on comparison and unit cost methods [43 CFR § 11.83(b)(2)(i) and (ii)]. Other methods may also include probability methodologies, factor methodology, standard time data methodology, cost- and time-estimating relationships, and other cost estimating methodologies where they are consistent with the regulations [43 CFR § 11.83(b)(2)].

The trustees will consider all potential restoration costs when evaluating proposed alternatives. These costs typically include many of the following components:

- planning costs

  - restoration plan development
  - public review, public meetings, response to comments, and community relations
  - human health and safety, and quality assurance plans
  - chemical, physical, and biological surveys
  - feasibility and pilot studies
  - National Environmental Policy Act (NEPA) [42 U.S.C.A. § 4321 et al.] compliance, and other regulatory compliance requirements

- implementation costs

  - physical, chemical, and biological containment removal, treatment, and containment
  - habitat creation and enhancement
  - wildlife restocking and protection
  - land and water rights acquisition
  - contributions to existing mitigation banking programs or regional response plans
  - trustee oversight of actions undertaken by responsible parties
  - community relations
  - contracting costs

- program evaluation and monitoring costs

  - monitoring progress of restoration actions
  - evaluating restoration results
  - follow-up studies or actions, as required
  - on-going management.

9.3 COMPENSABLE VALUES

9.3.1 Damage Assessment Concepts and Measures

Compensable values include "the value of lost public use of the services provided by the injured resources, plus lost nonuse values such as existence and bequest values" [43 CFR § 11.83(c)(1)]. These terms are defined in the regulations as follows:

- *use value* is the value of the resources to the public attribution to the direct use of the resources provided by the natural resources [43 CFR 11.83(c)(1)(I)]

- *nonuse value* is the difference between compensable value and use value [43 CFR 11.83(c)(1)(ii)].

We also use the following terms and definitions of the concepts, which are consistent with DOI regulations:[2]

- *Direct use values* are generally associated with well-identified active, and often on-site, resource uses such as recreational and commercial activities.

- *Nonuse values (or passive use values)* arise from the values individuals place on resources apart from their own readily identified and measured direct use. Nonuse values may include bequest values for the availability of resources for use by others now and in the future, and existence values for the protection of the resources even if they are never used [56 FR 19760].

Additionally, option values to preserve the site for one's own *potential* future use and casual or indirect uses of natural resources, such as enjoying the site while driving or walking by or working near the site; and enjoying hearing about, reading about, or seeing photographs of the site may also be included in direct uses or passive uses depending on the study design.

Damage assessments may place dollar values on direct use and passive use impacts that result from natural resource and service flow injuries. The primary measure of value is based on *Willingness to pay (WTP)*, which is how much an individual would be willing to pay to have no injuries, or to clean up the injuries in the assessment area. WTP is also a measure of damages from having incurred the injuries, or an estimate of what individuals would pay to clean up the injuries in the assessment area. WTP measures are consistent with choices made everyday in purchasing goods and services and through voting choices that entail costs to support changes in environmental quality and other public goods.

2. Some authors use different terms to refer to these concepts, or define the terms slightly differently. These differences generally have little substantive impact on the computation of total compensable damages.

9.3.2 Service Flow Losses and Selection of Economic Assessment Methods

Economic methods are used to identify, characterize, quantify, and value human use service flow losses. Identified in Table 9-1 are examples of potential services flow losses in the assessment area for which economic assessment methods may be required. The economic assessment methods, and the final detailed specification of study designs, are contingent upon further progress on the injury assessment activities so that the economic assessments are consistent with the injury determination. Based on the potential service flow losses at the site, at least three groups of methods are anticipated in the compensable value assessment, including:

Table 9-1
Potentially Affected Service Flows
Associated with Potential Injuries to Natural Resources
in the Lower Fox River/Green Bay/Lake Michigan Assessment Area

Potentially Injured Resource	Examples of Service Flows
Fish	▸ Recreational fishing use ▸ Subsistence fishing use ▸ Commercial fishing (e.g., carp) use ▸ Ecological services nonuse ▸ Tribal values use and/or nonuse
Wildlife	▸ Recreational and subsistence hunting use ▸ Nonconsumptive recreation use (e.g., bird watching: bald eagles, cormorants, herons) ▸ Ecological services nonuse ▸ Tribal values use and/or nonuse
Surface water	▸ Swimming use ▸ Boating use ▸ Aquatic habitat use and/or nonuse ▸ Assimilative capacity use and/or nonuse[1] ▸ Ecological services use and/or nonuse (e.g., habitat) ▸ Tribal values use and/or nonuse
Sediments	▸ Habitat use and/or nonuse ▸ Recreation use (hiking, picnicking) ▸ Assimilative capacity use and or nonuse[1] ▸ Tribal values use and/or nonuse

1. The ability of a resource to "absorb low levels of [contaminants] without exceeding standards or without effects" [51 FR 27716 Aug. 1, 1986].

1. **Valuation methodologies for recreational uses.** Assessments of recreational use values will be used to assess direct use impacts and values for interim injuries, and for evaluating restoration alternatives, for recreational fishing, wildlife hunting and viewing, and other recreational activities.

2. **Market price methods.** Market prices, including factor pricing and other market based methods, can be used to estimate damages related to commercial fishing, and potentially for damages related to subsistence fishing and other resource impacts still to be addressed.

3. **Total compensable value methods.** Methods such as contingent valuation and revealed preference methods can be used to establish use values, nonuse values, or total compensable values in WTP measures.

9.3.3 Assessments of Recreational Uses

Recreational use of natural resources in the assessment area may be among the most important direct uses affected by PCB contamination at the site. The following categories of recreational use services may be addressed:

- recreational fishing
- recreational hunting
- other recreation, including nonconsumptive recreational use such as wildlife viewing, boating, swimming, hiking, and picnicking.

Recreational Fishing

Recreational fishery service flow losses may be associated with (1) changes in the quantity, quality, and location of fishery stocks for species such as lake trout, and (2) fish consumption advisories. The accumulation of PCBs in sportfish in the assessment area has resulted in the establishment of fish consumption advisories (FCAs). These FCAs have varied through time and by location (Table 9-2). FCAs for fish caught in Lake Michigan have been established by all the states surrounding Lake Michigan and by Wisconsin tribes. Discovery of PCBs and other contaminants in sportfish species led to the establishment of an FCA in 1976 for the Wisconsin waters of Green Bay and Lake Michigan, and for the Fox River below Lake Winnebago. The initial FCAs were relatively general. As more information about the contamination of sportfish species became available, FCAs were increasingly refined to focus on location, species, and size.

Generally, the FCAs reflect two levels of consumption restrictions. At the more restrictive level, the FCAs advise that some fish, primarily larger fish, as well as fish from locations with higher levels of PCBs, should not be eaten at all. At the less restrictive level, the FCAs advise that women of childbearing years and children should not eat the fish and all others should restrict

Table 9-2
Fish Consumption Advisories for the Wisconsin Waters of Lower Fox River, Green Bay, and Lake Michigan, 1990-1995

Species	Location		
	Lower Fox River, Green Bay to De Pere	Green Bay	Lake Michigan[1] (for PCBs and pesticides)
Carp	●	●	●
Catfish	●		●
Drum	●		
Lake Trout 20-23”			○
Lake Trout > 23”			●
Walleye < 18”	○		
Walleye > 18”[2]	●	●	
Northern Pike	○		
White Sucker	○		
White Bass	●	●	
Coho Salmon > 26”			○
Chinook Salmon 21-32”			○
Chinook Salmon > 32”			●
Splake < 16”		○	
Splake > 16”		●	
Rainbow > 22”		●	
Chinook > 25”		●	●
Brown Trout > 12”		●	
Brook Trout > 15”		●	
Brown Trout < 23”			○
Brown Trout > 23”			●
Northern Pike > 28”		●	
Sturgeon[3]		●	

○ = Limit consumption to 1 meal per week for general population, no consumption by children or women of childbearing years.
● = No consumption.

1. Based on State of Wisconsin advisories. Lake Michigan advisories for other states are the same or similar.
2. Greater than 20” in Green Bay.
3. 1993-1995 only.

Sources: WDNR Division of Health, 1990-1995.

consumption of these fish to one meal a week. The Wisconsin fish consumption advisories for fish contaminated with PCBs and pesticides are accompanied by advice regarding the preparation of these fish. The preparation advice includes removal of skin and fat, cooking by baking or broiling, and discarding any drippings.

The current Lake Michigan FCAs for Illinois and Indiana are identical to those issued by Wisconsin. The State of Michigan FCAs for Lake Michigan differ slightly from Wisconsin's for larger lake trout and chinook salmon: these larger fish from northern Lake Michigan are subject only to a restricted consumption advisory. Furthermore, in Michigan waters of Lake Michigan, walleye over 22" are subject to a restricted consumption advisory, and larger whitefish from southern Lake Michigan should not be consumed at all.

The presence of FCAs and potential presence of PCB-related injuries could affect the quality of recreational fishing in many ways. Evidence regarding the magnitude of the behavioral responses of anglers to FCAs can be found in several recent studies (e.g., Fiore et al., 1989; Knuth and Connelly, 1992; Knuth et al., 1993; Silverman, 1990; Vena, 1992; West et al., 1993). These studies consistently report that the public respond to advisories by reducing trips to the affected site, targeting alternative species, changing fish consumption behavior, and changing fish consumption preparation methods. Each of these behavioral responses results in injuries and damages to the public. Others who are active at the injured sites but who make no behavioral change, may also be damaged because they simply enjoy the experience less than if there were no advisories.

Supplemental evidence is also found in a Wisconsin study. Anglers who were fishing inland waters only were asked about the relative importance of various factors that played a part in choosing not to fish in the Great Lakes (Bishop et al., 1994). "PCB and other contamination in the fish" was identified as a "somewhat important" or "very important" factor by 55% of the respondents. No other single factor was cited by a higher proportion of respondents. Many of the FCAs apply to large fish, and the possibility of catching large fish is often a primary reason why anglers fish (Bishop et al., 1990; Morey et al., 1995).

The objectives of the recreational fishery damage assessment are three-fold. The first objective is to quantify the impacts of fish injuries on recreational anglers. Potential impacts to be examined include changes in the rates of participation in fishing; number of trips and location of trips; the species and size of fish targeted on a fishing trip; impacts on decisions regarding keeping, preparing, and consuming fish; and impacts on the quality of the experience. The second objective is to quantify economic values associated with the recreational fishing impacts, which when combined with quantification of use impacts can be used to compute compensable use value damages. The third objective is to obtain information useful to evaluate potential restoration actions to which compensable damage awards may be applied.

Recreational Hunting and Other Recreational Impacts

Since 1987 the State of Wisconsin has issued a waterfowl consumption advisory for waterfowl taken from the Lower Fox River/Green Bay (WDNR, 1987), and there is no evidence that this advisory will be lifted in the near future. This advisory suggests that all skin and visible fat be removed before cooking mallard ducks using these waters and that drippings or stuffing should be discarded because they may retain fat that contains PCBs. Just as FCAs result in recreational fishing service flow losses, so too do waterfowl consumption advisories. Other recreation service flow losses may also occur because of the fish and waterfowl advisories and because of other contamination at the site. Waterfowl and wildlife observation, shoreline use, and boating are examples of recreational activities that may be directly or indirectly affected.

9.3.4 Commercial Fishing

Releases of PCBs may have caused impacts to commercial fisheries in the assessment area, which results in damages to the commercial operators and to the public. The assessment will address public losses.

The carp fishery may be of particular relevance because carp tend to accumulate PCBs and because nearly all of the commercially harvested Lake Michigan carp were caught in Green Bay. Annual harvest exceeded 3 million pounds in 1973 and 1974 [data provided by Eva Moore, National Biological Survey, Great Lakes Science Center (NBS-GLSC)], and dropped to 700,000 pounds in 1975. This drop coincided with concerns expressed by the U.S. FDA and the Wisconsin Department of Agriculture regarding the safety of carp caught in Green Bay (Kleinert, 1976). A summary of the 1974 commercial fishery in Wisconsin (WDNR, 1976) noted, “With PCB contamination a serious problem in larger and older carp, the future harvest, which takes place primarily in the winter months, is not very bright.” In 1984, the carp fishery in Green Bay was closed entirely because of PCB contamination, and thus, the carp fishery on Lake Michigan was effectively ended. After 1984, the entire annual Lake Michigan commercial harvest of carp was typically less than 1,000 pounds.

The alewife fishery is also relevant because these fish also accumulate PCBs. Alewife harvest in Lake Michigan began in the late 1950s (WDNR, 1974). By the 1970s, commercial alewife harvest ranged from 30 million to 40 million pounds annually. During the 1980s, the annual commercial harvest ranged from about 10 million pounds to 23 million pounds [data provided by Randy Eshenroder, Great Lakes Fishery Commission (GLFC), 1995]. Substantial decreases in Lake Michigan alewife populations led to dramatic reductions in alewife harvest beginning in 1991. In that year, harvest dropped to about one million pounds (Eva Moore, NBS-GLSC, 1995). By 1993, the Lake Michigan commercial alewife fishery had nearly disappeared.

The Lake Michigan commercial alewife fishery was not centered in Green Bay; however, commercial harvests in Green Bay were significant. Annual alewife harvests in Green Bay averaged about 4.5 million pounds for 1978 through 1983 (Randy Eshenroder, GLFC, 1995). The fishery in the Michigan waters of Green Bay ended in 1984. Commercial alewife harvest in the Wisconsin waters of Green Bay decreased dramatically after 1984. From 1978 to 1983, commercial alewife harvests in the Wisconsin waters of Green Bay averaged about 2.6 million pounds annually, and from 1985 through 1990, the annual average was about 0.6 million pounds, a decrease of about 77% (Randy Eshenroder, GLFC, 1995). If both the Wisconsin and Michigan waters of Green Bay are considered, the overall reduction in Green Bay alewife harvest was about 87%. For the same two time periods, the reduction in alewife harvest in the waters of Lake Michigan outside of Green Bay was about 39%.

At least part of the reduction in the Green Bay alewife fishery can be attributed to concerns about PCBs. By 1982, a publication from the University of Wisconsin Sea Grant Institute noted:

> Sea Grant is also maintaining its longstanding role in the forefront of research on the movement of PCBs and other microcontaminants through aquatic ecosystems. The presence of these toxic substances in carp and alewife is currently limiting the harvest of these fish (Kraft, 1982).

9.3.5 Subsistence Fishing

Given the large geographic area over which FCAs exist as a result of PCB contamination from the Lower Fox River, it is likely that many subsistence anglers have been affected. The damage determination will further investigate the significance of potential subsistence fishing losses and may quantify damages for these losses.

9.3.6 Additional Tribal Damages

Tribal resources and resource services may have been injured by PCB contamination from the Lower Fox River/Green Bay assessment area. Such injuries may have resulted in cultural, recreational, and commercial injuries and damages. Additional tribal injuries and damages may be assessed. Assessment tasks may include:

- identify potentially injured natural resources and natural resources service flows (e.g., cultural, historic, recreational, commercial)
- address, qualitatively and quantitatively, the characteristics and magnitude of service flow injuries

- compute, qualitatively and quantitatively, resource, service, and monetary measures of total compensable values.

9.3.7 Nonuse and Total Compensable Value Studies

The identified direct use value studies, such as recreation use and market price studies, may only be able to address a subset of compensable values. For example, separate tribal use value studies may not be possible and therefore may require consideration of other studies addressing nonuse values. Nonuse values and total compensable values (use and nonuse), may be estimated using the contingent valuation method [43 CFR § 11.83(c)(2)(vii)], and by other valuation methods that are cost-effective, feasible, and reliable [43 CFR § 11.83(c)(3)].

Contingent valuation and revealed preference approaches are anticipated to be used to address nonuse values and total values. These studies may measure WTP in monetary units or in units of other resources and services that individuals would forgo to prevent injuries or require to accept continued injuries. The first objective of these studies is to complete the computation of all compensable values. This includes identifying the impacts, understanding their absolute and relative importance to the public, and valuing the impacts. A second objective is to assist trustees in evaluating how differences in restoration options affect compensable damages. A third objective is to assist trustees by evaluating additional resource restoration and enhancement actions to which any compensable value awards may be applied.

9.3.8 Double Counting, Uncertainty, and Discounting

The DOI regulations state that "double counting of damages should be avoided" [43 CFR § 11.84(c)]. Compensable value estimates, by definition, are separate from restoration costs and do not amount to double counting. When estimating compensable values, recreational use value, market value studies and other methods will be used, where possible, to estimate use values. Where use values cannot be separately estimated, contingent valuation and other methods may be used to estimate nonuse values or total values. Any potential overlap between total value estimates and use value estimates will be explicitly addressed so that no double counting occurs.

Compounding of past interim damages and discounting of future interim damages will use discount rates as identified in the DOI regulations [43 CFR § 11.84(e)].

Uncertainty will be addressed by analyzing how the damages vary in response to key analytic variables and assumptions [43 CFR § 11.84(d)], and reasonable alternative assumptions will be examined, including alternative discount rates.

CHAPTER 10
QUALITY ASSURANCE PROJECT PLAN

10.1 INTRODUCTION

This Quality Assurance Project Plan (QAPjP) has been developed to support studies that may be performed as part of the Lower Fox River/Green Bay NRDA. Under the NRDA regulations [43 CFR § 11.31] the QAPjP is required to develop procedures to ensure data quality and reliability. This QAPjP is intended to provide quality assurance/quality control (QA/QC) procedures, guidance, and targets for use in future studies conducted for the NRDA. It is not intended to provide a rigid set of predetermined steps with which all studies must conform or against which data quality is measured, nor is it intended that existing data available for use in the Lower Fox River/Green Bay NRDA must adhere to each of the elements presented in this QAPjP. Ultimately, the quality and useability of data is based on methods employed in conducting studies, the expertise of study investigators, and the intended uses of the data. The QAPjP has been designed to be consistent with the NCP and U.S. EPA's Guidelines and Specifications for Preparing Quality Assurance Project Plans (U.S. EPA, 1983).

The elements outlined in this plan are designed to:

- provide procedures and criteria for maintaining and documenting custody and traceability of environmental samples

- provide procedures and outline QA/QC practices for the sampling, collection, and transporting of samples

- outline data quality objectives (DQOs) and data quality indicators

- provide a consistent and documented set of QA/QC procedures for the preparation and analysis of samples

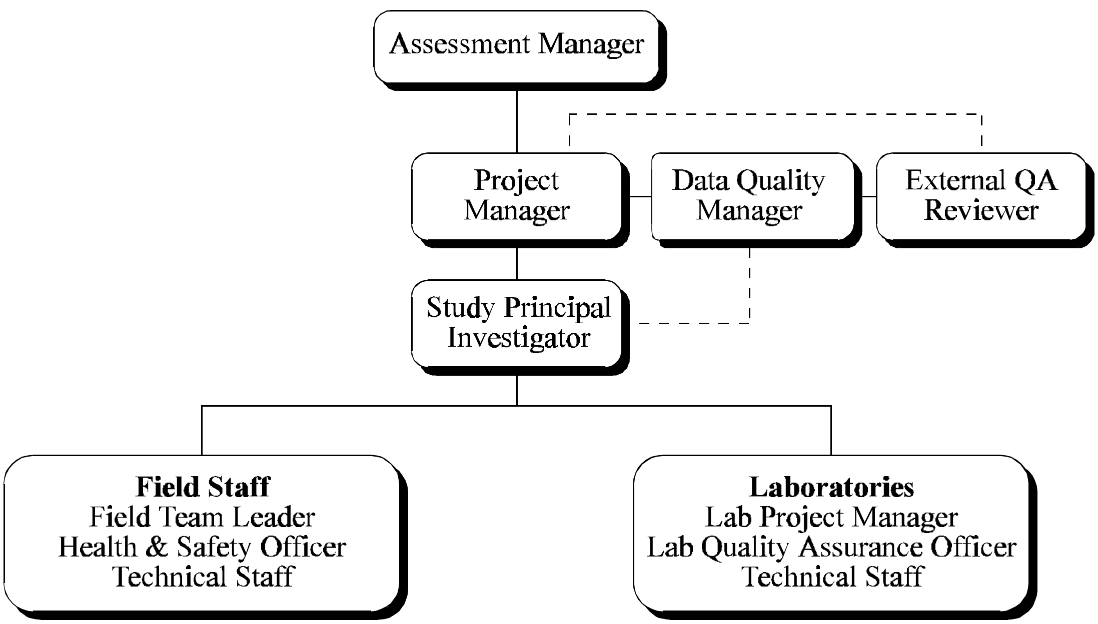
- help to ensure that data are sufficiently complete, comparable, representative, unbiased, and precise so as to be suitable for their intended uses.

Prior to the implementation of NRDA studies, Standard Operating Procedures (SOPs) providing descriptions of procedures typically will be developed. These SOPs will be appended to this QAPjP, as developed, to provide an ongoing record of methods and procedures employed in the assessment. SOPs will be developed and updated as methods and procedures are reviewed and accepted for use.

10.2 PROJECT ORGANIZATION AND RESPONSIBILITY

Definition of project organization, roles, and responsibilities helps ensure that individuals are aware of specific areas of responsibility that help ensure data quality. However, fixed organizational roles and responsibilities are not necessary and may vary by study or task. An example of project quality assurance organization, including positions with responsibility for supervising or implementing quality assurance activities, is shown in Figure 10-1. Key positions along with lines of communication and coordination are indicated. Descriptions of specific quality assurance responsibilities of key project staff are included below. Only the project positions related directly to quality assurance and quality control are described; other positions may be described in associated project plans. Specific individuals and laboratories selected to work on this investigation will be summarized and appended to this QAPjP or included in study-specific SOPs when they are established.

Figure 10-1
Project Organization



10.2.1 Assessment Manager and Project Manager

The Assessment Manager (AM) is responsible for all technical, financial, and administrative aspects of the project. The Project Manager (PM) supports the AM and is responsible for producing quality data and work products for this project within allotted schedules and budgets.

Duties include executing all phases of the project and efficiently applying the full resources of the project team in accordance with the project plans. Specific QA-related duties of the AM and the PM can include:

- coordinating the development of a project scope, project plans, and data quality objectives
- ensuring that written instructions in the form of SOPs and/or associated project plans are available for activities that affect data quality
- monitoring investigative tasks for their compliance with plans, written procedures, and QC criteria
- monitoring the performance of subcontractors in regard to technical performance and specifications, administrative requirements, and budgetary controls
- participating in performance and/or systems audits and monitoring the implementation of corrective actions
- reviewing, evaluating and interpreting data collected as part of this investigation
- supervising the preparation of project documents, deliverables, and reports
- verifying that all key conclusions, recommendations, and project documents are subjected to independent technical review, as scheduled in project plans.

10.2.2 Data Quality Manager

A Data Quality Manager can be assigned who is responsible for overall implementation of the QAPjP. Duties include conducting activities to ensure compliance with the QAPjP, reviewing final QA reports, preparing and submitting QA project reports to the AM and PM, providing technical QA assistance, conducting and approving corrective actions, training of field staff in QA procedures, and conducting audits, as necessary. Specific tasks may include:

- assisting the project team with the development of data quality objectives
- managing preparation of and reviewing data validation reports
- submitting quality assurance reports and corrective actions to the PM
- ensuring that data quality, data validation, and QA information are complete and are reported in the required deliverable format

- communicating and documenting corrective actions
- maintaining a copy of the QAPjP
- supervising laboratory audits and surveillance
- ensuring that written instructions in the form of SOPs and/or associated project plans are available for activities that affect data quality
- monitoring investigative tasks for their compliance with plans, written procedures, and QC criteria
- monitoring the performance of subcontractors in regard to technical performance and specifications, administrative requirements, and budgetary controls
- reviewing, evaluating and interpreting data collected as part of this investigation.

10.2.3 External QA Reviewer

External QA Reviewers can serve as outside reviewers of QA documentation and procedures, perform data validation, and may perform field and/or laboratory audits.

10.2.4 Principal Investigator

Study-specific Principal Investigators (PIs) ensure that QA guidance and requirements are followed. The PI or the designee will note significant deviations from the QAPjP for the study. Significant deviations will be recorded and promptly reported to the PM and Data Quality Manager. In addition, the PI typically is responsible for reviewing and interpreting study data and preparing reports.

10.2.5 Field Team Leader

The Field Team Leader (FTL) supervises day-to-day field investigations, including sample collection, field observations, and field measurements. The FTL generally is responsible for all field quality assurance procedures defined in the QAPjP, and in associated project plans and SOPs. Specific responsibilities may include:

- implementing the field investigation in accordance with project plans
- supervising field staff and subcontractors to monitor that appropriate sampling, testing, measurement, and record keeping procedures are followed
- ensuring the proper use of SOPs associated with data collection and equipment operation
- monitoring the collection, transport, handling, and custody of all field samples, including field QA/QC samples
- coordinating the transfer of field data, including field sampling records, chain-of-custody records, and field logbooks
- informing the PI and Data Quality Manager when problems occur, and communicating and documenting any corrective actions that are taken.

10.2.6 Laboratory Project Manager

A Laboratory Project Manager can be responsible for monitoring and documenting the quality of laboratory work. Duties may include the following:

- ensuring staff and resources to produce quality results in a timely manner are committed to the project
- ensuring that the staff are adequately trained in the procedures that they are using so that they are capable of producing high quality results and detecting situations that are not within the QA limits of this project
- ensuring that the stated analytical methods and laboratory procedures are followed, and documenting the laboratory's compliance
- maintaining a laboratory Quality Assurance Manual, and documenting that its procedures are followed
- ensuring that laboratory reports are complete and reported in the required deliverable format
- communicating, managing, and documenting all corrective actions initiated at the laboratory

- notifying the Data Quality Manager, within one working day of discovery at the laboratory, of any situations that will potentially result in qualification of analytical data.

10.2.7 Technical Staff

Project technical staff represent a variety of technical disciplines and expertise. Technical staff should have adequate education, training, and specific experience to perform individual tasks, as assigned. They are required to read and understand any documents describing the technical procedures and plans that they are responsible for implementing.

10.3 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

10.3.1 Overview

The overall quality assurance objectives for this project are to help ensure that the data collected are of known and acceptable quality for their intended uses. Quality assurance objectives are qualitative and quantitative statements that aid in specifying the overall quality of data required to support various data uses. These objectives often are expressed in terms of precision, accuracy, completeness, comparability, representativeness, and sensitivity. Laboratories involved with the analysis of samples collected in support of this NRDA will make use of various QC samples such as standard reference materials (SRMs), matrix spikes, and replicates to assess adherence to the quality assurance objectives discussed in the following sections. Field and laboratory QC targets for chemical analyses, frequency, applicable matrices, and acceptance criteria are listed in Table 10-1.

Because numeric QC criteria are study, method, and laboratory specific, criteria are not included in this QAPjP. When appropriate, criteria can be established when study and method procedures are approved; such criteria will be appended to this QAPjP or included in study-specific SOPs. Criteria will be determined based on factors that may include:

- specific analytical methods and accepted industry standards of practice
- laboratory historical performance of selected analytical methods
- intended uses of the data.

Where statistically generated or accepted industry standards of practice are not available, QC criteria may be defined by the Data Quality Manager working with the Laboratory QA Officer and Principal Investigators.

Table 10-1
Field and Laboratory QC Sample Targets for Chemical Analyses

QC Element	Target Frequency	Applicable Matrices	Target Acceptance Criteria
Field Duplicate	1 in 20 samples	S, SW, T	Study dependent
Laboratory Duplicate	1 in 20 samples or 1 per analysis batch	S, SW, T	Method dependent
Standard Reference Material	1 per analysis batch	S, SW, T	Method dependent
Equipment Blank	1 in 20 samples	SW	Study dependent
Matrix Spike	1 in 20 samples or 1 per analysis batch	S, SW, T	Method dependent
Surrogates	All samples for organics analysis	S, SW, T	Method dependent
Laboratory Control Sample	1 per analysis batch	S, SW, T	Method dependent

S = Sediment; SW = Surface Water; T = Tissue.

10.3.2 Quality Control Metrics

Accuracy

Accuracy is a quantitative measure of how close a measured value lies to the actual or "known" value. Sampling accuracy is partially evaluated by analyzing field QC samples such as field blanks, trip blanks, and rinsates (or equipment blanks). In these cases, the "true" concentration is assumed to be not detectable, and any detected analytes may indicate a positive bias in associated environmental sample data.

Laboratory accuracy is assessed through the use of sample (matrix) spikes and other QC samples. For example, a sample (or blank) may be spiked with an inorganic compound of known concentration and the average percent recovery (%R) calculated as a measurement of accuracy. A second procedure is to analyze a standard (e.g., SRMs or other certified reference materials) and calculate the %R for that known standard. As an additional, independent check on laboratory accuracy, blind SRMs submitted as field samples may be used.

Accuracy criteria are established statistically from historical performance data, and often are based on confidence intervals set about the mean. Where historical data are not adequate for statistical calculations, criteria may be set by the Laboratory Project Manager, Data Quality Manager, and Principal Investigators. Accuracy criteria will be appended to this QAPjP or included in study-specific SOPs, when established. Accuracy may be assessed during the data validation or data quality assessment stage of these investigations.

Precision

Precision is a measure of the reproducibility of analytical results under a given set of conditions. The overall precision of a set of measurements is determined by both sampling and laboratory variables. Reproducibility is affected by sample collection procedures, matrix variations, the extraction procedure, and the analytical method.

Field precision typically is evaluated using sample replicates, which are usually duplicate or triplicate samples. Sample replicates may be generated by homogenizing the sample, splitting the sample into several containers, and initiating a blind submittal to the laboratory with unique sample numbers. For a duplicate sample, precision of the measurement process (sampling and analysis) is expressed as:

$$\text{Relative Percent Difference (RPD)} = \frac{(\text{Duplicate Sample Results} - \text{Sample Result})}{(\text{Duplicate Sample Results} + \text{Sample Result})} \times 200.$$

For a triplicate analysis, precision of the sampling and analysis process is expressed as:

$$\text{Percent Relative Standard Deviation (\%RSD)} = \frac{\sigma_{n-1}}{\text{Mean}} \times 100,$$

where "σ_{n-1}" is the standard deviation of the three measurements.

Laboratory precision typically is evaluated using laboratory duplicates, matrix spike duplicates, or laboratory control sample or SRM duplicate sample analysis. Duplicates prepared in the laboratory are generated before sample digestion occurs. Laboratory precision is also expressed as the RPD between a sample and its duplicate, or as the %RSD for three values.

Precision criteria are established statistically from historical performance data, and are usually based on the upper confidence interval set at two standard deviations above the mean. Where historical data are not adequate for statistical calculations, criteria may be set by the Laboratory Project Manager, Data Quality Manager, and Principal Investigators. Precision criteria will be appended to this QAPjP or included in study-specific SOPs, when established.

Completeness

Completeness is defined as the percentage of measurement data that remain valid after discarding any invalid data during the field or laboratory QC review process. A completeness check may be performed following a data validation process. Analytical completeness goals may vary depending on study type, methods, and intended uses of the data.

Analytical data completeness will be calculated by analyte. The percent of valid data is 100 times the number of sample results not qualified as unusable (R), divided by the total number of samples analyzed. Data qualified as estimated (J) due to minor QC deviations (e.g., laboratory duplicate RPD exceeded) will be considered valid.

Comparability

Comparability is a qualitative parameter expressing the confidence with which one dataset can be compared to another. Comparability is facilitated by use of consistent sampling procedures, standardized analytical methods, and consistent reporting limits and units. Data comparability is evaluated using professional judgment.

Representativeness

Representativeness expresses the degree to which data accurately and precisely represent a defined or particular characteristic of a population, parameter variations at a sampling point, a processed condition, or an environmental condition. Representativeness is a qualitative parameter which is dependent upon the proper design of the sampling program and proper laboratory protocol. Sampling designs for this investigation will be intended to provide data representative of sampled conditions. During development of sampling plans and SOPs, consideration will be given to existing analytical data, environmental setting, and potential industrial sources. Representativeness will be satisfied by ensuring that the sampling plan is followed.

Sensitivity

Detection limit targets for each analyte and matrix will be appended to this QAPjP or included in study-specific SOPs, as they are established.

10.4 SAMPLING PROCEDURES

10.4.1 Sample Collection

Samples are collected and handled in accordance with the procedures contained in SOPs or associated project plans. These documents typically describe sample collection, handling, and documentation procedures to be used during field activities. SOPs and work plans/protocols may cover the following topics, as appropriate:

- procedures for selecting sample locations and frequency of collection
- sample site selection, positioning, and navigation procedures
- sampling equipment operation, decontamination, and maintenance
- sample collection and processing, which includes sample collection order and homogenization procedures, sample containers, and volume required
- field QC sample and frequency criteria
- sample documentation, including chain-of-custody (COC) and field documentation forms and procedures
- sample packaging, tracking, storage, and shipment procedures.

10.4.2 Sample Containers, Preservation, and Holding Times

Containers will be prepared using EPA-specified or other professionally accepted cleaning procedures. Analysis statements for containers prepared by third-party vendors will be included in the project file. Since the investigations involved with this NRDA may involve samples not amenable to typical environmental sample containers (such as whole body tissue samples), multiple types of containers may be required. For example, sample containers may include aluminum foil and watertight plastic bags for tissue samples and whole body samples.

Target size and type of sample containers needed for potential analyses are listed in Tables 10-2 through 10-4. These tables also include the recommended preservatives and holding times.

When appropriate, sample coolers will contain refrigerant in sufficient quantity to maintain samples at the required temperatures until receipt at the laboratories.

Table 10-2
Recommended Sample Containers, Preservation, and Holding Times — Sediment Samples

Parameter	Container [a]	Preservation	Holding Time [b]
PCBs	8 ounce glass jar w/ Teflon lined lid	4°C or -18°C	14 days/40 days 1 year/40 days
PCB congeners and co-planars	8 ounce glass jar w/ Teflon lined lid	4°C or -18°C	14 days/40 days 1 year/40 days
Total organic carbon	4 ounce glass jar	4°C	28 days
Particle size	4 ounce glass jar	4°C	6 months

Notes:
a. Provide an additional two volumes if Matrix Spike/Matrix Spike Duplicate (MS/MSD) is desired.
b. 14 days/40 days = time from sampling to extraction/time from extraction to analysis. Holding times serve as recommended targets, but do not, of themselves, determine or limit data quality or useability.

Table 10-3
Recommended Sample Containers, Preservation, and Holding Times — Tissue Samples

Parameter	Container [a]	Preservation	Holding Time [b]
PCBs, lipids	Wrapped in aluminum foil or placed in watertight plastic bags or glass jars	-18°C	1 year (extraction) 40 days (analysis)

Notes:
a. Provide an additional two volumes if MS/MSD is desired.
b. See Table 10-2, Note (b).

10.4.3 Sample Identification and Labeling Procedures

Prior to transportation, samples should be properly identified with labels, tags, or markings. Identification and labeling typically includes, but need not be limited, to the following information:

- project identification
- place of collection
- sample identification

Table 10-4
Recommended Sample Containers, Preservation, and Holding Times — Surface Water Samples

Parameter	Container[a]	Preservation	Holding Time[b]
PCBs	1 liter amber glass bottle with Teflon lined lid	4° C	7 days (extraction) 40 days (analysis)

Notes:
a. Provide an additional two volumes if MS/MSD is desired.
b. See Table 10-2, Note (b).

- analysis request
- preservative
- date and time of collection
- name of sampler (initials)
- number of containers associated with the sample.

Items may be preprinted by computer using indelible ink, may be prepared by hand prior to sampling, or may be prepared in the field. Prelabeling of bottles can significantly reduce field time and confusion. After sample collection, the following tasks typically will be performed:

- wipe the outside of the container with a paper towel; the outside of the container must be clean when received by the laboratory

- complete the label with time, date, and sampler initials

- seal the label with clear sealing tape to further protect the sample label, and place a custody seal over the top of the container so that the container can not be opened without breaking the seal.

10.4.4 Field Sampling Forms

Field sampling forms should be described in the appropriate SOP or associated project plans. Forms typically must be completed in the field at the same time as the sample label. As with the sample label, much of the information can be preprinted, but date, time, sampler's initials, and other specific field observations should be completed at the time of sampling.

10.4.5 Sample, Storage, and Tracking

In the field, samples may be stored temporarily in coolers with wet or dry ice (as appropriate). Security should be maintained and documentation of proper storage should be provided in the project field note book. Samples stored temporarily in coolers should be transported to a storage facility as soon as logistically possible. When possible, samples will be shipped directly to the appropriate laboratories from the field.

Prior to analysis, samples will be stored under appropriate conditions at the storage facility or laboratory (refrigerator or freezer). Security should be maintained at all times. A log book or inventory record typically is maintained for each sample storage facility refrigerator or freezer. The log books or inventory records are used to document sample movement in and out of the facility. In general, samples will be placed into a freezer and information regarding sample identification, matrix, and study will be recorded. Additional information in the record for each sample may include: (1) the date of the initial storage, (2) subsequent removal/return events with associated dates, and (3) initials of person(s) handling the samples. Additional information may include study name and special comments.

Documentation should allow for unambiguous tracking of the samples from the time of collection until shipment to the laboratory. The tracking system should include a record of all sample movement and provide identification and verification (initials) of the individuals responsible for the movement.

10.5 SAMPLE CUSTODY

Chain-of-custody (COC) procedures are adopted for samples throughout the field collection, handling, storage, and shipment process. Each individual sample will be assigned a unique identification label and have a separate entry on a COC record. A COC record should accompany every sample and every shipment to document sample possession from the time of collection through final disposal.

10.5.1 Definition of Custody

A sample is defined as being in a person’s custody if one of the following conditions applies:

- The sample is in the person’s actual possession or view.
- The sample was in the person’s possession and then was locked in a secure area with restricted access.

- The person placed it in a container and sealed the container with a custody seal in such a way that it cannot be opened without breaking the seal.

10.5.2 Procedures

The following information typically will be included on COC forms:

- place of collection
- laboratory name and address
- sample receipt information (total number of containers; whether COC seals are intact; whether sample containers are intact; and whether the samples are cold when received)
- signature block with sufficient room for "relinquished by" and "received by" signatures for at least three groups (field sampler, intermediate handler, and lab)
- sample information (field sample identifier, date, time, matrix, lab sample identifier, and number of containers for that sample identifier)
- the name of the sampler
- airbill number of overnight carrier (if applicable)
- disposal information (to track sample from "cradle to grave")
- a block for special instructions
- analysis request information.

The sample identification, date and time of collection, and request for analysis on the sample label should correspond to the entries on the chain-of-custody form and in associated field log books or sampling forms.

The data quality manager or designated representative is responsible for reviewing the completed COC forms. Any inconsistencies, inaccuracies, or incompleteness in completing the forms must be brought to the attention of the field staff completing the form. If the problem is significant, corrective action should be taken and documented. Depending on the problem, this may involve informing the lab that a sample ID or analysis request needs to be changed, or notifying the Field Team Leader that retraining of field staff in COC procedures is indicated. The corrective action and its outcome should be documented.

10.6 ANALYTICAL PROCEDURES

A number of analytical methods or procedures may be used, including: quantification of Aroclors using Method 8081; quantification of Total PCBs using Method 8081; or quantification of PCB congeners and co-planars using gas chromatography with electron capture detection (GC/ECD) and/or gas chromatography with mass spectrophotometry (GC/MS). Co-planar PCB congeners may be analyzed and reported with the PCB congener analysis. Preconcentration steps (e.g., carbon column cleanup) may be required to obtain adequate detection limits for these compounds. General QC considerations and targets for analyses are described below, along with considerations for biological testing.

Laboratory method detection limit (MDL) studies should be conducted for each matrix per analytical method, according to specifications described in 40 CFR Part 136 or other comparable professionally accepted standards. The MDLs for each target analyte should be less than or equal to the required screening levels. The MDL is a statistically-derived, empirical value that may vary.

Laboratory QC samples, which include a method blank, replicate (matrix spike or duplicate) analyses, laboratory control sample, and a standard reference material (SRM), will be performed at a target frequency of one per twenty samples per matrix per analytical batch. Method blanks should be free of contamination of target analytes at concentrations greater than or equal to the MDL; or associated sample concentrations should be greater than 10 times the method blank values. The matrix spike/matrix spike duplicate and laboratory control sample analyses should meet accuracy and precision goals.

10.7 CALIBRATION PROCEDURES AND FREQUENCY

This section provides information on general calibration guidelines for laboratory and field methods.

10.7.1 Laboratory Equipment

All equipment and instruments used for laboratory analyses will be operated and maintained according to the manufacturer's recommendations, as well as by criteria defined in the laboratory's SOPs. Operation, maintenance, and calibration should be performed by personnel properly trained in these procedures. Documentation of all routine and special maintenance and calibration information should be recorded in appropriate log books and reference files.

Calibration curve requirements for all analytes and surrogate compounds should be met prior to sample analysis. Calibration verification standards, which should include the analytes that are expected to be in the samples and the surrogate compounds, should be analyzed at a specified frequency and be within a percent difference or percent drift criterion.

10.7.2 Field Equipment

All equipment and instruments used to collect field measurements will be operated, maintained, and calibrated according to the manufacturer's recommendations, as well as by criteria defined in individual SOPs. Operation, calibration, and maintenance should be performed by personnel properly trained in these procedures. Documentation of all routine and special maintenance and calibration information should be recorded in appropriate log books or reference files. Field instruments that may be used include thermometers/ temperature probes, scales, pH meters, dissolved oxygen meters, and global positioning system units.

10.8 DATA REDUCTION, VALIDATION, AND REPORTING

10.8.1 General Approach

Data generated by the laboratory and during field measurements may undergo data review and validation by an External QA Reviewer. Laboratory data may be evaluated for compliance with data quality objectives, with functional guidelines for data validation, and with procedural requirements contained in this QAPjP.

10.8.2 Data Reporting

Laboratories should provide sufficient information to allow for independent validation of the sample identity and integrity, the laboratory measurement system, the resulting quantitative and qualitative raw data and all information relating to standards and sample preparation.

10.8.3 Data Review and Validation of Chemistry Data

Data review is an internal laboratory process in which data are reviewed and evaluated by laboratory supervisory or QA personnel. Data validation is an independent review process conducted by personnel not associated with data collection and generation activities. External and independent data validation may be performed for selected sample sets as determined by the PM and Data Quality Manager. Each data package chosen for review will be assessed to determine whether the required documentation is of known and documented quality. This includes evaluating whether:

- field chain-of-custody or project catalog records are present, complete, signed and dated
- the laboratory data report contains required deliverables to document procedures.

Two levels of data validation may be performed: full or cursory validation. Initial data packages received for each sample matrix may receive full validation. This consists of a review of the entire data package for compliance with documentation and quality control criteria for the following items:

- analytical holding times
- data package completeness
- preparation and calibration blank contamination
- initial and continuing calibration verifications
- internal standards
- instrument tuning standards
- analytical accuracy (matrix spike recoveries, laboratory control sample recoveries)
- analytical precision (comparison of replicate sample results)
- reported detection limits and compound quantitation
- review of raw data and other aspects of instrument performance
- review of preparation and analysis bench sheets and run logs.

Cursory validation may be performed on a subset of the data packages, at the discretion of the PM and Data Quality Manager. Cursory review includes the comparison of laboratory summarized QC and instrument performance standard results to the required control limits, including:

- analytical holding times
- data package completeness
- preparation and calibration blank contamination
- analytical accuracy (matrix spike recoveries, laboratory control sample recoveries)
- analytical precision (comparison of replicate sample results).

The full or cursory validation will follow documented quality control and review procedures as outlined in guidelines for data validation (U.S. EPA, 1993b) and documented in validation and method SOPs. Various qualifiers and/or comments or narratives may be applied to data during the validation process. These qualifier codes may be assigned to individual data points to explain deviations from quality control criteria and will not replace qualifiers or footnotes provided by the laboratory. Data validation reports summarizing findings will be submitted to the Data Quality Manager for review and approval.

Laboratory data will be evaluated for compliance with data quality objectives. Data useability, from an analytical standpoint, may be evaluated during the data evaluation. The data users (the Principal Investigator, PM, AM) will determine the ultimate useability of the data.

10.9 PERFORMANCE AND SYSTEM AUDITS

A Data Quality Manager or designee will be responsible for coordinating and implementing any QA audits that may be performed. Checklists may be prepared that reflect the system or components being audited, with references to source of questions or items on the checklist. Records of all audits and corrective actions should be maintained in the project files.

10.9.1 Technical System Audits

Technical System Audits (TSAs) are qualitative evaluations of components of field and laboratory measurement systems, including quality control procedures, technical personnel, and QA management. TSAs determine if the measurement systems are being used appropriately. TSAs are normally performed before or shortly after measurement systems are operational, and during the program on a regularly scheduled basis. TSAs involve a comparison of the activities described in the study plan and SOPs with those actually scheduled or performed. Coordination and implementation of any TSAs will be the responsibility of a Data Quality Manager or designee.

Analytical Data Generation (Laboratory Audit)

Laboratory audits may be performed to determine whether the laboratory is generating data according to all processes and procedures documented in associated project plans, QAPjP, SOPs, and analytical methods. Laboratory audits can be performed by an External QA Reviewer, a Data Quality Manager, or their designee.

Field Audits

Field Audits may be performed to determine whether field operations and sample collection is being performed according to processes and procedures documented in the study plan, QAPjP, and SOPs.

10.9.2 Performance Evaluation Audits

Performance Evaluation Audits are quantitative evaluations of the measurement systems of a program. Performance Evaluation Audits involve testing measurement systems with samples of known composition or behavior to evaluate precision and accuracy typically through the analysis of standard reference materials.

10.10 PREVENTATIVE MAINTENANCE PROCEDURES AND SCHEDULES

Preventative maintenance typically is implemented on a scheduled basis to minimize equipment failure and poor performance. In addition to scheduled calibration procedures described above, the following procedures may be followed:

- Thoroughly clean field equipment before returning to the office. The equipment generally should be stored clean and dry.

- Replaceable components, such as pH electrodes and dissolved oxygen membranes, should be inspected after and before each use, and replaced as needed to maintain acceptable performance.

- Equipment that is identified to be malfunctioning or out-of-calibration will be removed from operation until repaired or re-calibrated.

10.11 PROCEDURES USED TO ASSESS DATA USEABILITY

Data useability ultimately is a function of study methods, investigator expertise and competence, and intended uses. QA/QC procedures are designed to help ensure data useability but, in themselves, neither assure data useability nor — if not implemented — indicate that data are not useable or valid. Data validity and useability will ultimately be determined by the Principal Investigator, PM, and AM using best professional judgment. Independent data validation, consultations with Data Quality Managers, and review of project-wide databases for data compatibility and consistency can be used to support useability evaluations. The useability and validity of existing and historical data, which were not collected pursuant to the QAPjP presented in this Assessment Plan, will be determined by the AM, PM, Principal Investigators, and Trustee technical staff using best professional judgment.

10.12 CORRECTIVE ACTIONS

10.12.1 Definition

Corrective actions consist of the procedures and processes necessary to correct and/or document situations where data quality and or QA procedures fall outside of acceptance criteria or targets. (These criteria/targets may be numeric goals such as those discussed in Section 10.3, or procedural requirements such as those presented throughout the QAPjP and other project documents (e.g., SOPs)).

The goal of corrective action is to identify as early as possible a data quality problem and to eliminate or limit its impact on data quality. The corrective action information typically is provided to a Data Quality Manager for use in data assessment and long term quality management. Corrective action typically involves the following steps:

1. discovery of a nonconformance or deviations from data quality objectives or this plan
2. identification of the party with authority to correct the problem
3. planning and scheduling of appropriate corrective action
4. confirming that the corrective action produced the desired result
5. documenting the corrective action.

10.12.2 Discovery of Nonconformance

The initial responsibility of identifying nonconformance with procedures and QC criteria lies with the field personnel and bench-level analysts. Performance and system audits are also designed to detect these problems. However, anyone who identifies a problem or potential problem should initiate the corrective action process by, at least, notifying a Principal Investigator or Data Quality Manager of his/her concern.

Deviations from QAPjP or SOP procedures are sometimes required and appropriate due to field or sample conditions. Such deviations should be noted in field or laboratory logbooks and their effect on data quality evaluated by a Principal Investigator and Data Quality Manager. Occasionally, procedural changes are made during the course of an investigation because method improvements are identified and implemented. Even though these procedural improvements are not initiated due to nonconformance, they are procedural deviations and typically should be documented.

10.12.3 Planning, Scheduling, and Implementing Corrective Action

Appropriate corrective actions for routine problems depend on the situation and may range from documentation of the problem, to resampling and reanalysis, to the development of new methods. When the corrective action is within the scope of these potential actions, the bench-level analyst or the field staff can identify the appropriate corrective action and implement it. Otherwise, the corrective action should be identified and selected by the PM, the Field Team Leader, the Laboratory Manager, or the Data Quality Manager.

10.12.4 Confirmation of the Result

While a corrective action is being implemented, additional work dependent on the nonconforming data should not be performed. When the corrective action is complete, the situation should be evaluated to determine if the problem was corrected. If not, new corrective actions should be taken until no further action is warranted, either because the problem is now corrected or because no successful corrective action has been found.

10.12.5 Documentation and Reporting

Corrective action documentation may consist of the following reports or forms:

- Corrective action forms initiated by project staff. These forms will be collected, evaluated, and filed by the Data Quality Manager.
- Corrective action log maintained by the Data Quality Manager in order to track the types of nonconformance problems encountered and to track successful completion of corrective actions.
- Corrective action plans, if needed to address major nonconformance issues.
- Performance and systems audit reports, if such audits are performed.
- Corrective action narratives included as part of data reports from independent laboratories.
- Corrective action forms initiated by laboratory staff and summarized in the report narrative.

10.12.6 Laboratory-Specific Corrective Action

The need for corrective action in the analytical laboratory may come from several sources: equipment malfunction, failure of internal QA/QC checks, method blank contamination, or failure of performance or system audits; and/or noncompliance with QA requirements.

When measurement equipment or analytical methods fail QA/QC checks, the problem should immediately be brought to the attention of the appropriate laboratory supervisor in accordance with the laboratory's SOP or Quality Assurance Manual. If failure is due to equipment malfunction, the equipment should be repaired, precision and accuracy be reassessed, and the analysis rerun.

All incidents of QA failure and the corrective action tasks should be documented, and reports should be placed in the appropriate project file. Corrective action should also be taken promptly for deficiencies noted during spot-checks of raw data. As soon as sufficient time has elapsed for corrective action to be implemented, evidence of correction of deficiencies should be presented to a Data Quality Manager or PI.

Laboratory corrective actions may include, but are not limited to:

- reanalyzing the samples, if holding time criteria permits and sample volume is available
- resampling and analyzing
- evaluating and amending sampling analytical procedures
- accepting data and acknowledging the level of uncertainty.

CHAPTER 11
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