Approach to the Development of Delisting Targets for the Presque Isle Bay Area of Concern, Pennsylvania

Technical Report - Preliminary Draft

Prepared for:

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Prepared – *April 2005* – by:

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Chapter 1 Introduction

1.0 Study Area

Presque Isle Bay is located in northwestern Pennsylvania on the southern shore of Lake Erie (Figure 1). Overall, the drainage basin is about 66 km^2 in area, and includes much of the City of Erie as well as portions of Mill Creek, Summit, Greene, and Harbor Creek townships. The Presque Isle Bay watershed consists of the Bay itself, the Mill Creek watershed (including Garrison Run, the Cascade Creek watershed, the Scott Run watershed, and the aquatic habitats within Presque Isle Bay State Park. Mill Creek drains an area of about 34 km^2, while Cascade Creek drains an area of roughly 16 km^2.

Over time, much of the watershed draining into the Bay has become urbanized, with heavy manufacturing industries coexisting within residential and commercial neighborhoods. The pattern of multiple land use is illustrated by the percentage of the drainage basin that is classified into each of the following categories: residential (57%); open area (16%); commercial (11%); public (8%); and, industrial (7%; Potomac-Hudson 1991).

Past waste disposal practices had resulted in the discharge of industrial and domestic wastewater to the Bay or to the streams and tributaries draining into the Bay. Until changes were made to the City of Erie's wastewater treatment, collection, and conveyance system, untreated industrial, commercial, and residential wastewater escaping from combined sewer overflows was discharged to the Bay. Because approximately 80% of the watershed is a developed, urban area, the Bay received high concentrations of pollutants from stormwater runoff. While many pollutants released to the Bay from such past practices have decayed through natural biodegradation processes, substances like heavy metals and more persistent organics remain in the sediment. Additionally, the geography and geology of the Bay make it a natural "settling" basin for solids. Most of the pollutants that enter the Bay in runoff become entrapped in the sediments.

1.1 Role of Sediments in Aquatic Ecosystems

The particulate materials that lie below the water in ponds, lakes, stream, rivers, and other aquatic systems are called sediments (ASTM 2004). Sediments represent essential elements of aquatic ecosystems because they support both autotrophic and heterotrophic organisms. Autotrophic (which means self-nourishing) organisms are those that are able to synthesize food from simple inorganic substances (e.g., carbon dioxide, nitrogen, and phosphorus) and the sun's energy. Green plants, such as algae, bryophytes (e.g., mosses and liverworts), and aquatic macrophytes (e.g., sedges, reeds, and pond weed), are the main autotrophic organisms in freshwater ecosystems. In contrast, heterotrophic (which means other-nourishing) organisms utilize, transform, and decompose the materials that are synthesized by autotrophic organisms (i.e., by consuming or decomposing autotrophic and other heterotrophic organisms). Some of the important heterotrophic organisms that can be present in aquatic ecosystems include bacteria, epibenthic, and infaunal invertebrates, fish, amphibians, and reptiles. Birds and mammals can also represent important heterotrophic components of aquatic food webs (i.e., through the consumption of aquatic organisms).

Sediments support the production of food organisms in several ways. For example, hard- bottom sediments, which are characteristic of fast-flowing streams and are comprised largely of gravels, cobbles, and boulders, provide stable substrates to which periphyton (i.e., the algae that grows on rocks) can attach and grow. Soft sediments, which are common in ponds, lakes, estuaries, and slower-flowing sections of rivers and streams, are comprised largely of sand, silt, and clay. Such sediments provide substrates in which aquatic macrophytes can root and grow. The nutrients that are present in the sediments can also nourish aquatic macrophytes. By providing habitats and nutrients for aquatic plants, sediments support autotrophic production (i.e., the production of green plants) in aquatic systems. Sediments can also support prolific bacterial communities. Bacteria represent important elements of aquatic ecosystems because they decompose organic matter (e.g., the organisms that die and accumulate on the surface of the sediment) and, in so doing, release nutrients to the water column and increase bacterial biomass. Bacteria represent the primary heterotrophic producers in aquatic ecosystems. The role that sediments play in supporting primary productivity (both autotrophic and heterotrophic) is essential because green plants and bacteria represent the foundation of food webs upon which all other aquatic organisms depend (i.e., they are consumed by many other aquatic species).

In addition to their role in supporting primary productivity, sediments also provide essential habitats for many sediment-dwelling invertebrates and benthic fish. Some of these invertebrate species live on the sediments (termed epibenthic species), while others live in the sediments (termed infaunal species). Both epibenthic and infaunal invertebrate species consume plants, bacteria, and other organisms that are associated with the sediments. Invertebrates represent important elements of aquatic ecosystems because they are consumed by a wide range of wildlife species, including amphibians, reptiles, fish, birds, and mammals. For example, virtually all fish species consume aquatic invertebrates during all or a portion of their life cycle. In addition, many birds consume aquatic invertebrates during either their aquatic (e.g., dippers and sand pipers) or emergent (e.g., swallows) portions of their life cycle. Similarly, aquatic invertebrates represent important food sources for both amphibians (e.g., frogs and salamanders) and reptiles (e.g., turtles and snakes). Therefore, sediments are of critical importance to many wildlife species due to the role that they play in terms of the production of aquatic invertebrates.

Importantly, sediments can also provide habitats for many wildlife species during portions of their life cycle. For example, a variety of fish species utilize sediments for spawning and incubation of their eggs and alevins (e.g., trout, salmon, and whitefish). In addition, juvenile fish often find refuge from predators in sediments and in the aquatic vegetation that is supported by the sediments. Furthermore, many amphibian species burrow into the sediments in the fall and remain there throughout the winter months, such that sediments provide important overwintering habitats. Therefore, sediments play a variety of essential roles in terms of maintaining the structure (i.e., assemblage of organisms in the system) and function (i.e., the processes that occur in the system) of aquatic ecosystems.

1.2 Sediment Quality Issues and Concerns

Traditionally, concerns relative to the management of aquatic resources in freshwater systems have focused primarily on water quality. However, the importance of sediments in determining the harmful effects of chemical contaminants on aquatic organisms (including plants, invertebrates, amphibians, and reptiles), wildlife (amphibians, reptiles, fish, birds, and mammals), or human health has become more apparent in recent years (Long and Morgan 1991; Ingersoll *et al.* 1997). Specifically, sediment quality is important because many toxic contaminants (such as metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, chlorophenols, and pesticides), found in only trace amounts in water, can accumulate to elevated levels in sediments. As such, sediments can serve both as reservoirs and as potential sources of contaminants to the water column. In addition, sediment-associated contaminants have the potential to adversely affect sediment-dwelling organisms (e.g., by causing direct toxicity or altering benthic invertebrate community structure; Chapman 1989). Therefore, sediment quality data (i.e., information on the concentrations of chemical substances) provide essential information for evaluating ambient environmental quality conditions in freshwater systems (i.e., determining if sediments, sediment-dwelling organisms, wildlife, or human health have been injured by releases of oil or discharges of other hazardous substances into the environment).

Releases of hazardous substances from both historic and ongoing contaminant sources have resulted in the release of a variety of toxic and/or bioaccumulative substances into receiving water systems within the Presque Isle Bay watershed. Some of the substances that have been released include total organic carbon (TOC), nutrients, metals, oil and grease, polycyclic aromatic hydrocarbons (PAHs), phthalates, pesticides, and polychlorinated biphenyls (PCBs; Bright 1988; Polls *et al.* 1993; Hoke *et al.* 1993; Dorkin 1994; Ingersoll and MacDonald 1999). While some of these substances remain in the water column, many others are known to accumulate in sediments. The results of sediment quality assessments conducted over the past 20 years indicate that many of these substances occur or have occurred at elevated concentrations in sediments within Presque Isle Bay (Applied Biology Inc. 1982; Aqua Tech Environmental 1986; Rice 1991; Obert 1993; Gannett-Fleming, Inc. 1993; Cullinan and Crecelius 1995; West 1994; West *et al.* 1994; USEPA 2000a; Wellington 2002; Diz 2002; PADEP 2003). The presence of elevated concentrations of contaminants in aquatic sediments represents an environmental concern because:

- Bed sediments provide essential and productive habitats for communities of sediment-dwelling organisms, including epibenthic and infaunal organisms. These organisms include such species as scuds (amphipods), mayflies (ephemeropterans), stoneflies (plecopterans), caddisflies (trichopterans), dragonflies, damselflies (odonatans), midges (dipterans), water fleas (cladocerans), worms (oligochaetes), snails (gastropods), and clams (bivalves);
- Sediment-dwelling organisms (including epibenthic and infaunal organisms) are important elements of freshwater ecosystems, representing important sources of food for many fish and other wildlife species;
- The presence of sediment-associated contaminants in freshwater ecosystems can be harmful to sediment-dwelling organisms and wildlife species; and,
- Certain sediment-associated contaminants can bioaccumulate in the tissues of aquatic organisms and, as a result, pose a potential hazard to those species that consume aquatic organisms, including wildlife and humans.

1.3 Purpose of the Report

Under the Great Lakes Water Quality Agreement, a total of 43 areas of concern (AOCs) have been identified within the Great Lakes basin, based on the presence of conditions that impair the beneficial uses of aquatic ecosystems. The guidelines for listing geographic areas with degraded environmental conditions as AOC or delisting such AOCs once environmental conditions have improved, were established by the International Joint Commission in 1987 (IJC 1991; 1997). These 14 guidelines were used to identify 42 of the AOCs that were listed. In contrast to the other AOCs, Presque Isle Bay was designated as the 43rd Great Lakes AOC in 1991 after concerned citizens from Erie, PA petitioned for its' inclusion. Preliminary studies conducted in 1993 identified two beneficial use impairments for the Bay: 1) restrictions on dredging activities; and, 2) fish tumors or other deformities. The Bay's sediments are contaminated with low levels of PAHs and heavy metals.

Since the 1980s, Pennsylvania Department of Environmental Protection (PADEP) and its partners have collected information on sediment quality conditions within the Bay. More specifically, sediment chemistry data were collected at a number of locations in the Bay in 1982, 1986, 1990, 1994, 2000, and 2003. In addition, whole-sediment toxicity tests were conducted on samples collected within the Presque Isle Bay AOC. Ancillary data [e.g., tissue residue levels in fish, incidence of external deformities, and frequency of orocutaneous and liver neoplasms, etc.] have also been collected to provide a better understanding of environmental quality conditions within the Presque Isle Bay AOC. Based on the results of these investigations, it is apparent that sediment quality conditions have improved substantially over the past two decades and that conditions may be sufficient to facilitate delisting of one or both of the two existing beneficial use impairments. Therefore, after more than 10 years of study, PADEP, in conjunction with the AOC's Public Advisory Committee (PAC), determined that monitored natural attenuation, rather than active remediation within the AOC, would provide the most cost-effective basis for restoring beneficial uses in the study area. As a result, Presque Isle Bay was designated an AOC in the Recovery Stage in 2002.

Under the Great Lakes Water Quality Agreement, restoration of the Great Lakes AOCs has been identified as a high priority, long-term goal. However, not one of the 26 AOCs on the U.S. side of the border has been delisted, nor has any specific beneficial use impairment in these AOCs been delisted. Of the 26 American AOCs, 15 have identified restrictions on dredging as a beneficial use impairment. The International Joint Commission (IJC 1991) guidelines indicate that an impairment of the dredging beneficial use has occurred when the concentrations of contaminants in sediments exceed standards, criteria, or guidelines such that restrictions on dredging or disposal activities are imposed. In addition, the IJC (1991) established delisting criteria for the restrictions on dredging activities beneficial use impairment. The IJC (1991) guidelines indicate that the dredging beneficial use has been restored when concentrations of contaminants in sediments do not exceed the above described standards, criteria, or guidelines. While these general guidelines are useful, establishing narrative and numerical delisting targets (i.e., quantitative or measurable targets) is an AOC-specific exercise. Accordingly, there is a need to establish AOC-specific delisting targets that define, for each sediment quality indicator and metric (see Chapter 4 for more information), the conditions that need to be met in Presque Isle Bay to restore the beneficial uses of the aquatic ecosystem.

This report is intended to support petitioning for delisting of Presque Isle Bay as a Great Lakes AOC. More specifically, this document describes options for establishing delisting targets for key indicators of sediment quality conditions in Presque Isle Bay and presents the results of a preliminary assessment of sediment quality conditions in the Bay. The report focuses on sediment quality conditions because both of the identified beneficial use impairments in the Bay are associated with contaminated sediments. To provide the PAC and its partners with the information needed to establish delisting targets, the report is organized into the following sections:

- Introduction (Chapter 1);
- Background and History (Chapter 2)

- Conceptual Site Model of the Presque Isle Bay Ecosystem (Chapter 3);
- Ecosystem-Based Framework for Managing Contaminated Sediments (Chapter 4);
- Development of Ecosystem Goals, Ecosystem Objectives, and Sediment Management Objectives for Presque Isle Bay (Chapter 5);
- Selection of Ecosystem Health Indicators for Assessing the Effects of Contaminated Sediments on Beneficial Uses in Presque Isle Bay (Chapter 6);
- Identification and Evaluation of Candidate Delisting Targets for Presque Isle Bay (Chapter 7); and,
- References Cited (Chapter 8).

Definitions of many of the terms that have been used in this document are provided in the Glossary of Terms and the List of Acronyms that appear at the beginning of this report.

Chapter 2 Background and History

2.0 Introduction

This study was conducted to support the development of delisting targets for the restrictions on dredging beneficial use impairment in Presque Isle Bay. Because the establishment of delisting targets is an AOC-specific exercise, it is important to have an understanding of the site and the events that result in the listing of Presque Isle Bay as a Great Lakes AOC. Accordingly, this chapter provides a description of the study area and chronicles the events that led to its listing in 1991.

2.1 Description of Study Area

Presque Isle Bay is located in the northwestern corner of Pennsylvania on the southern shore of Lake Erie (Figure 1). It is about 4.5 miles long, 1.5 miles across at its widest point, and has an average depth of about 20 feet. A 7-mile long, re-curved sand spit named Presque Isle forms the Bay. The western end of the Bay is closed and provides access to the park. The southeastern end of the Bay connects to Lake Erie through a narrow channel that is maintained by the U.S. Army Corp of Engineers. This channel allows commercial shipping traffic and recreational boaters to enter the Bay from the lake.

Presque Isle State Park borders the northern edge of the Bay. The Isle is composed of sand and glacial sediments and has a continuous series of ponds, lagoons and lakes of which some connect directly with the Bay. The Isle contains a wide variety of animal habitats and records exist for over 320 bird species, 47 mammal species, and 30 amphibian and reptile species. Many of these are included on Pennsylvania's list of Species of Special Concern. The site is also considered one of the top birding hotspots in the country.

The bulk of the Presque Isle Bay watershed is on the other side of the Bay. It is approximately 25 square miles in area and includes much of the City of Erie, as well as portions of Mill Creek, Summit, Greene, and Harbor Creek Townships. Erie is the third largest city in Pennsylvania with a population of just over 100,000. Mill Creek Township has over 52,000 residents. Over time, much of the watershed draining into the Bay has become urbanized with heavy manufacturing industries coexisting within residential and commercial neighborhoods. The primary tributaries are Mill Creek (including Garrison Run) and Cascade Creek, which together account for about two-thirds of the water flowing into the Bay.

Past waste disposal practices had resulted in the discharge of industrial and domestic wastewater to the Bay or to the streams and tributaries draining into the Bay. Until changes were made to the City of Erie's wastewater treatment, collection, and conveyance system, untreated industrial, commercial, and residential wastewater escaping from combined sewer overflows was discharged to the Bay. Because approximately 80% of the watershed is a developed urban area, the Bay received high concentrations of pollutants from stormwater runoff. While many pollutants released to the Bay from such past practices have decayed through natural biodegradation processes, substances like heavy metals and more persistent organics (e.g., PAHs) remain in the sediment. Additionally, the geography and geology of the Bay make it a natural "settling" basin for solids. As a result, most of the pollutants that enter the Bay in runoff become entrapped in the sediments.

2.2 History

As early as 1984, the United States Fish and Wildlife Service (USFWS) began receiving reports of brown bullheads (*Ameiurus nebulosus*) with external sores and lesions being caught by fishermen from Presque Isle Bay. In January 1988, members of the Erie County Environmental Coalition (the Coalition) petitioned the Science Advisory Board of the International Joint Commission (IJC) to designate the Bay as an AOC. Formed in 1983, the Coalition included members from various local organizations such as the League of Women Voters, the Erie County Sportsman Association, the Benedictine Sisters, and the Presque Isle Audubon Society. The intent of the Coalition in seeking the designation was to focus attention on, and to secure funding for, the Bay in order to enhance the environmental and economic quality of life in the watershed.

In December 1988, Erie's City and County governments formed the Erie Harbor Improvement Council. Members were appointed and included representatives from business, industry, academia, development, government, and civic and environmental groups. The goal of the council was to clean up Presque Isle Bay by the year 2008. The objectives of the Council were to ensure that Pennsylvania met its responsibilities under the Great Lakes Water Quality Agreement (GLWQA) and to ultimately provide an action plan to clean up the Bay, restore impaired uses, and enhance economic revitalization. There motto, “A Swimmable Bay in 20 Years”, emphasized the determination and resolve of the Council.

Presque Isle Bay was designated the 43rd AOC in 1991 in response to the concerns raised by the Coalition. The Erie Harbor Improvement Council was dissolved in 1991 and its members became the PADEP PAC for the Bay. The reasons for listing the Bay were not cited in the designation so the first step for the PAC was to determine which of the IJC's 14 beneficial uses were actually or potentially impaired. Using existing data and information, a preliminary analysis identified 16 chemicals of potential concern (COPCs) in the sediment, including ten heavy metals (arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc), nutrients (phosphorus and total kjeldahl nitrogen), chemical oxygen demand, cyanide, oil and grease, and volatile organics. Polycyclic aromatic hydrocarbons were also found in the sediments (Potomac-Hudson 1991). No impairments to the water column or fish and wildlife were indicated. Based upon a limited analysis of existing data, PADEP believed that two of the 14 beneficial uses were potentially impaired: (1) fish tumors and other deformities; and, (2) restrictions on dredging.

In 1993, a Remedial Action Plan (RAP) was submitted to the IJC (PADER and PIB PAC 1992). The RAP analysis confirmed what was already known about the Bay. Available data was compared to the IJC's AOC Listing Guidelines (IJC 1991) to identify impaired beneficial uses. Analysis of data generated prior to 1990 clearly indicated impairments based upon the guidelines for fish tumors and other deformities and restrictions on dredging. Additionally, the available data, or lack of data, left questions regarding two other potential impairments: (1) degradation of phytoplankton and zooplankton populations; and, (2) beach closings.

Based upon the impaired uses evaluation, the only COPCs identified were those that were associated with sediment. No water column impairments were indicated. Fish impairments, if environmentally caused, were believed to be related to the sediment contamination; however, no correlation was made between sediment contamination and tumor rates. Sediment chemistry data were compared with readily-available benchmarks (USEPA 1977). The results of this evaluation indicated that the 16 COPCs identified in the preliminary report were present at levels of concern. In addition, although no standards for PAHs existed, the levels of these compounds in Bay sediments were thought to be elevated relative to other sides in the Great Lakes. Therefore, PAHs were included as COPCs.

An update to the RAP was submitted to the IJC in 1995 (PADEP 1995). The update summarized new information and data on the beneficial use impairments and responded to comments and questions received from the IJC and the United States Environmental Protection Agency (USEPA) on the RAP. Once again, studies done by PADEP, USEPA, USFWS, the Erie County Department of Health (ECDH), and others confirmed the evaluation of impaired uses in the Bay. Sediment contamination and tumors in brown bullheads were the biggest concerns. Regarding COPCs, both sediment and brown bullhead data indicated that PAHs could be of greater concern than the heavy metals. The main source for the contaminants appeared to be the in-place sediments, as no correlation was found between water and sediment contaminant concentrations (PADEP 2002).

Additional studies were conducted to answer questions regarding the two potential beneficial use impairments identified in the 1993 RAP: (1) degradation of phytoplankton and zooplankton populations; and, (2) beach closings. A seasonal study of the phytoplankton and zooplankton population of the Bay conducted by USEPA in 1992 and 1993 concluded that water samples collected from the Bay did not appear to adversely affect the populations (PADEP 2002). On the basis of this information and an analysis of conditions in the Bay, PADEP concluded that the degradation of phytoplankton and zooplankton populations beneficial use was not impaired (Obert and Wellington 1995).

The 1993 RAP cited a limited impairment for the beach closing beneficial use at the mouth of the Mill Creek Tube and possibly at other creek and stormwater inputs to the Bay. Subsequent sampling and analysis for bacterial contamination by PADEP and personnel from the Presque Isle State Park over a six-week period in 1993 did not find bacteria in concentrations above the state's water quality standard for bathing beaches. The ECDH has and continues to take monthly samples at the Water Quality Network station located in the open Bay waters between the points where Cascade and Mill creeks enter the Bay, directly in front of the public dock at Dobbins Landing. Bacterial concentrations have been consistently below the state's standard of 200 fecal coliform per 100 milliliter. While there are no designated bathing beaches in the Bay, there are no restrictions on its use for full body recreation based upon bacterial contamination. Based upon this information, the continued monitoring done by the ECDH, and the improvements to the City of Erie's combined sewer overflows, PADEP concluded that no major impairment existed for water contact recreation in the Bay and therefore, the beach closing beneficial use was no longer considered impaired.

The remaining two beneficial use impairments identified in the 1993 RAP, (1) fish tumors and other deformities; and, (2) restrictions on dredging, were still of concern following the 1995 RAP update. However, monitoring data collected thereafter (i.e., Wellington 2002; Diz 2002) indicated that sediment quality conditions were improving in the Bay. In addition, these newer data suggested that hot spots relative to sediment contamination were not readily apparent in the Bay. Rather, Bay sediments appeared to exhibit broad, low level contamination, primarily with metals and PAHs. As a result, PADEP, in conjunction with the AOC's PAC, determined that monitored natural attenuation, rather than active remediation within the AOC, would provide the most cost-effective basis for restoring beneficial uses in the study area. As a result, Presque Isle Bay was designated an AOC in the Recovery Stage in 2002.

Chapter 3 Conceptual Site Model of the Presque Isle Bay Ecosystem

3.0 Introduction

Development of a conceptual model represents an important component of ecological risk/hazard assessments because it enhances the level of understanding regarding the relationships between human activities and ecological receptors at the site under consideration. Specifically, the conceptual model describes key relationships between stressors and assessment endpoints. In so doing, the conceptual model provides a framework for predicting effects on ecological receptors and a template for generating risk questions and testable hypotheses (USEPA 1997; 1998). The conceptual model also provides a means of highlighting what is known and what is not known about a site. In this way, the conceptual model provides a basis for identifying data gaps and designing monitoring programs to acquire the information necessary to complete the assessment.

Conceptual models consist of two main elements, including: a set of hypotheses that describe predicted relationships between stressors, exposures, and assessment endpoint responses (along with a rationale for their selection); and, diagrams that illustrate the relationships presented in the risk hypotheses. The following sections of this chapter summarize information on the sources and releases of COPCs, the fate and transport of these substances, the pathways by which ecological receptors are exposed to the COPCs, and the potential effects of these substances on the ecological receptors that occur in the vicinity of Presque Isle Bay. In turn, this information is used to develop a series of hypotheses that provide predictions regarding how ecological receptors will be exposed to and respond to the COPCs.

3.1 Sources and Releases of Contaminants

There are a number of natural and anthropogenic sources of toxic and bioaccumulative substances in the Presque Isle Bay watershed. Anthropogenic sources of environmental contaminants in the watershed include industrial wastewater discharges, municipal wastewater treatment plant discharges, stormwater discharges, surface water recharge by contaminated groundwater, non-point source discharges, spills associated with production and transport activities, and deposition of substances that were originally released into the atmosphere. To support the development of a Stage I RAP for Presque Isle Bay, an evaluation of pollutant sources and transport mechanisms was conducted for the Pennsylvania Department of Environmental Resources (Potomac-Hudson 1991). The results of this evaluation indicated:

- Six significant permitted industrial point source dischargers (i.e., permitted under the National Pollutant Discharge Elimination System; NPDES) released, on average, 124 million gallons per day (MGD) of runoff, wastewater, and/or cooling water directly to Presque Isle Bay or to storm sewers or tributaries to Presque Isle Bay. These dischargers included Pennsylvania Electric Company, GAF Building Materials Corporation, Erie Forge and Steel, United-Erie, Inc., Pyramid Industries, and Urick Foundary Company;
- Three NPDES permitted municipal wastewater or water treatment plants released, on average, 1.3 MGD of treated wastewater or filter backwash water to Presque Isle Bay. These dischargers included Chestnut Street Water Treatment Plant, Presque Isle Bay State Park, and the West Filtration Plant (Sommerheim); and,
- A total of 47 combined sewer overflows released 3.1 million gallons of raw sanitary sewage and untreated industrial effluent during an average storm event to the Mill Creek/Garrison Run drainage system (i.e., 38 combined sewage outflows; CSOs), to Cascade Creek (i.e., 1 CSO), or to Presque Isle

Bay via small, unnamed tributaries, drainage ways, or outfall sewer lines (i.e., 8 CSOs).

In recent years, industrial wastewater has been largely redirected to Erie's sewer system. In 1991, roughly 18.6 MGD of industrial effluent were discharged to the sewer from 39 industrial users (Potomac-Hudson 1991. Additionally, two properties in the vicinity of Presque Isle Bay (Mill Creek Dump and Presque Isle State Park) are listed in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) as containing potentially uncontrolled hazardous wastes that require investigation (i.e., NPL listed sites) and at least one facility in the area is subject to regulation under the Resource Conservation and Recovery Act (RCRA), which means that hazardous wastes are generated, transported, treated, stored, or disposed of at the site (USEPA see USEPA Web site at http://www.epa.gov/). Although it is difficult to evaluate contributions of contaminants from other sources, surface run-off, groundwater contamination, and atmospheric deposition have all been identified as potential sources of contaminants to Presque Isle Bay (Potomac-Hudson 1991).

3.2 Identification of Chemicals of Potential Concern

Identification of COPCs represents an essential element of the risk/hazard assessment process (USEPA 1998). When used together, information on historic and current uses of the site, on regional land use patterns, on the characteristics of effluent and stormwater discharges in the vicinity of the site provides a reliable basis for identifying the preliminary COPCs at a site. However, data on the physical/chemical properties of each of those substances and historical sediment chemistry data should also be considered for further refining the preliminary list of COPCs (MacDonald and Ingersoll 2002).

In this study, the results of the review of background information (Potomac-Hudson 1991) was used as a primary basis for developing the preliminary list of COPCs in Presque Isle Bay. More specifically, COPCs that were considered to be causing or contributing to beneficial use impairments in Presque Isle Bay included metals (As, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Ni, and Zn), chemical oxygen demand, total kjeldahl nitrogen, total phosphorus, cyanide, PAHs, oil and grease, and volatile solids. However, a review of the sediment quality investigations that have been conducted since the background report was published indicates that the preliminary list of COPCs should be expanded to include several additional metals (Al, Hg, and Sb), phthalates (bis-2-ethylhexyl phthalate; BEHP), PCBs, DDT, chlordane, dieldrin, endrin, nitrosamines (NDMA and NDPA), and polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDDs/PCDFs; Table 1).

3.3 Environmental Fate of Chemicals of Potential Concern

Upon release into aquatic ecosystems, the COPCs partition into environmental media (i.e., water, sediment, soil, and/or biota) in accordance with their physical and chemical properties and the characteristics of the receiving water body. As a result of such partitioning, elevated levels of COPCs can occur in surface water (including the surface microlayer), sediments, and/or the tissues of aquatic organisms. Accordingly, information on the environmental fate can be used to classify the COPCs into three groups, including bioaccumulative substances (i.e., substances that accumulate in the tissues of aquatic organisms), toxic substances that partition into sediment, toxic substances that partition into surface waters (MacDonald *et al.* 2000).

Because this study was focused on evaluating the restrictions on dredging beneficial use impairment, an effort was made to identify the toxic COPCs that partition into sediment and bioaccumulative COPCs (toxic COPCs that partition into surface water represent the other major classification of COPCs). Information on the environmental fate and transport of the COPCs identified above provided a basis for classifying them into these two groups, as follows (Table 2):

Toxic COPCs that Partition in Sediment:

- Metals (Al, Sb, As, Ba, Cd, Cr, Cu, Fe, Hg, Pb, Mn, Ni, Sb, and Zn);
- Cyanide;
- PAHs;
- Oil and grease;
- Phthalates (BEHP);
- PCBs; and,
- Organochlorine pesticides (DDTs, chlordane, dieldrin, endrin).

Bioaccumulative COPCs:

- Metals (Cd, Hg, and Pb);
- PCBs;
- Organochlorine pesticides (DDTs, chlordane, dieldrin, endrin); and,
- PCDDs/PCDFs.

3.4 Potential Exposure Pathways

Once released to the environment, there are three pathways through which ecological receptors can be exposed to COPCs. These routes of exposure include direct contact with contaminated environmental media, ingestion of contaminated environmental media, and inhalation of contaminated air. For bioaccumulative substances, the ingestion of contaminated prey species represents the most important route of exposure for the majority of aquatic organisms and aquatic-dependent wildlife species. Direct contact with contaminated water and/or contaminated sediment and ingestion of contaminated sediment also represent a relevant, but less important exposure route for many aquatic organisms.

For toxic substances that partition into sediments, direct contact with contaminated sediments and pore water) represents the most important route of exposure for exposure for most aquatic organisms. However, ingestion of contaminated sediments can also represent an important exposure pathway for certain aquatic organisms (e.g., polychaetes that process sediments to obtain food) and aquatic-dependent wildlife species (e.g., sediment-probing birds, such as sandpipers).

For toxic substances that partition into surface water, direct contact with contaminated water represents the most important route of exposure for aquatic organisms (i.e., uptake through the gills and/or through the skin). For aquatic-dependent wildlife species, ingestion of contaminated water represents the principal route of exposure to toxic substances that partition into surface water.

3.5 Ecological Receptors Potentially at Risk

There are a wide variety of ecological receptors that could be exposed to contaminated environmental media in Presque Isle Bay. The aquatic species that occur in the Bay can be classified into six main groups, including microbiota (e.g., bacteria, fungi and protozoa), aquatic plants (including phytoplankton, periphyton, aquatic macrophytes, and riparian plants), aquatic invertebrates (including zooplankton and benthic invertebrates), fish, amphibians, and reptiles. Bird and mammals represent the principal aquatic-dependent wildlife species that occur in Presque Isle Bay.

Based on the review of the available information, Presque Isle Bay supports diverse assemblages of aquatic organisms and aquatic-dependent wildlife. For example, Diz (2002) reported that sediment-dwelling organisms included (in order of abundance):

oligochaetes, zebra mussels (*Dreissena sp.*), gastropods, amphipods, midges, isopods, leaches, nematodes, other bivalves (other than zebra mussels), caddisflies, turbellarians, mayflies, ostracods, and beatles (coleopterans). In addition, 16 fish species have been documented to spawn and rear in Presque Isle Bay (Goodyear *et al.* 1982), while another 24 are known to utilize habitats within the Bay during some portion of their life history (PFC 1988). Some of the key sportfish species that are pursued within the Bay are listed in Table 2. Although relatively little wildlife habitat exists along the south shore of Presque Isle Bay, wetland and upland habitats within Presque Isle State Park are utilized by many species of amphibians, reptiles, birds, and mammals throughout much of their life cycles, including at least 320 bird species, 47 mammalian species, and 30 amphibian species. Waterfowl and other migratory bird species also utilize these habitats seasonally.

The COPCs in the Presque Isle Bay were classified into three categories based on their predicted environmental fate (MacDonald *et al.* 2000). By considering this information, in conjunction with the exposure pathways that apply to these groups of COPCs, it is possible to identify the receptors that are potentially at risk due to exposure to contaminated environmental media. For bioaccumulative substances, the groups of aquatic organisms that are most likely to be exposed to tissue-associated contaminants include benthic invertebrates, carnivorous fish, amphibians, and reptiles. The groups of aquatic-dependent wildlife species that may be exposed to bioaccumulative substances include insectivorous birds, sediment-probing birds, carnivorous wading birds, piscivorus birds, piscivorus mammals, and omnivorous mammals.

Toxic substances that partition into sediments pose a potential risk to a variety of aquatic organisms and aquatic-dependent wildlife species. The groups of aquatic organisms that are most likely to be exposed to sediment-associated contaminants include decomposers (i.e., microbiota), aquatic plants, benthic invertebrates, benthic fish, and amphibians. Although reptiles can come in contact with contaminated sediments, it is unlikely that significant dermal uptake would occur. Sediment-probing birds are the principal group of aquatic-dependent wildlife species that are exposed to sediment-associated contaminants.

For toxic substances that partition into surface water, aquatic plants, aquatic invertebrates, fish, and amphibians represent the principal groups of exposed aquatic organisms. Although ingestion represents a potential exposure route for both birds and mammals, this pathway is likely to represent a relatively minor source of exposure for aquatic-dependent wildlife species.

3.6 Risk Questions/Testable Hypotheses

The following risk questions are intended to provide a basis for selecting indicators of sediment quality conditions in Presque Isle Bay that will provide the necessary and sufficient information to determine if beneficial uses are being protected and conserved:

1. **Survival, Growth, and Reproduction of Aquatic Invertebrates**
   - Are the levels of contaminants in whole sediments from Presque Isle Bay greater than benchmarks for the survival, growth, or reproduction of aquatic invertebrates?
   - Is the survival, growth or reproduction of aquatic invertebrates exposed to whole sediments from Presque Isle Bay significantly lower than that in reference sediments?
   - Is the structure of aquatic invertebrate communities in Presque Isle Bay sediments outside the normal range (i.e., 95th percentile) for aquatic invertebrate communities in reference areas?

2. **Survival, Growth and Reproduction of Fish**
   - Are the levels of contaminants in whole sediments from Presque Isle Bay greater than benchmarks for the survival, growth, or reproduction of fish?
   - Is the survival, growth or reproduction of fish exposed to surface water or sediments from Presque Isle Bay significantly lower than that for reference media?
   - Is the frequency of deformities, deformities, fin erosion, lesions, and tumors (DELT) abnormalities significantly higher in fish from Presque Isle Bay than in fish from reference areas?
   - Are the levels of contaminants in fish tissues from Presque Isle Bay greater than critical tissue values for the survival, growth, or reproduction of fish?

3. **Survival, Growth and Reproduction Birds**
   - Does the daily dose of contaminants received by birds from consumption of the tissues of prey species and from other media at Presque Isle Bay exceed the toxicity reference values (TRVs) for survival, growth or reproduction of birds?
   - Are the concentrations of contaminants in bird eggs from Presque Isle Bay greater than benchmarks for the survival, growth, or reproduction of birds?
   - Is the reproduction of birds utilizing the habitats in the vicinity of Presque Isle Bay significantly impaired compared to that measured for reference areas?

4. **Survival, Growth and Reproduction of Mammals**
   - Does the daily dose of contaminants received by mammals from consumption of the tissues of prey species and from other media at

Presque Isle Bay exceed the TRVs for survival, growth or reproduction of mammals?

Although microorganisms, aquatic plants, amphibians, and reptiles are important receptor groups in Presque Isle Bay, insufficient information on the toxicity of sediment-associated COPCs is available to determine the risks that Bay COPCs pose to these species.

3.7 Conceptual Model Diagram

A diagram of the conceptual site model for Presque Isle Bay that will guide the selection of measurement endpoints (i.e., indicators and metrics) for assessing the status of sediment quality conditions in the Bay is provided in Figure 2.

Chapter 4 An Ecosystem-Based Framework for Managing Contaminated Sediments

4.0 Introduction

The Great Lakes Water Quality Agreement, originally signed in 1972 and as amended in 1987, commits the governments of Canada and the United States to restoring and maintaining the physical, chemical, and biological integrity of the waters of the Great Lakes Basin. To meet this commitment, the two governments have agreed to develop and implement lake-wide management plans (LaMPs) for open waters and RAPs for specific geographic AOCs. The LaMPs are intended to identify critical pollutants that affect beneficial uses of the lakes and policy options to restore those beneficial uses. Similarly, RAPs represent the primary mechanisms for restoring the beneficial uses of aquatic ecosystems in the 43 Great Lakes AOCs that were identified by the International Joint Commission (IJC 1988). Importantly, a comprehensive ecosystem approach is to be used to address concerns related to environmental quality conditions in open waters and in the AOCs under both of these processes (i.e., LaMP and RAP). The ecosystem approach and its application in the management of contaminated sediments in Presque Isle Bay are discussed in the following sections of this chapter.

4.1 Defining the Ecosystem Approach

The ecosystem approach to planning, research, and management is the most recent phase in an historical succession of approaches to environmental management. Previously, humans had been considered to be separate from the environment in which they lived. This *egocentric approach* viewed the external environment only in terms of human uses. However, overwhelming evidence from many sources indicates that human activities can have significant and far-reaching impacts on the environment and on the humans who reside in these systems. Therefore, there was a need for a more holistic approach to environmental management, in which humans were considered as integral components of the ecosystem. The ecosystem approach provides this progressive perspective by integrating the *egocentric view* that characterized earlier management approaches, with an *ecocentric view* that considers the broader implications of human activities.

The primary distinction between the environmental and ecosystem approaches is whether the system under consideration is external to (in the environmental approach) or contains (in the ecosystem approach) the population under study (Vallentyne and Beeton 1988). The conventional concept of the environment is like that of a *house* - external and detached; in contrast, ecosystem implies *home* - something that we feel part of and see ourselves in, even when we are not there (Christie *et al.* 1986). The change from the environmental approach to the ecosystem approach necessitates a change in the view of the environment from a political or people-oriented context to an ecosystem-oriented context (Vallentyne and Beeton 1988). The essence of the ecosystem approach is that it relates *wholes* at different levels of integration (i.e., humans and the ecosystems containing humans) rather than the interdependent parts of those systems (i.e., humans and their environment; Christie *et al.* 1986).

The ecosystem approach is not a new concept and it does not hinge on any one program, definition, or course of action. It is a way of doing things and a way of thinking (Royal Commission on the Future of the Toronto Waterfront 1982). Adopting an ecosystem approach means viewing the basic components of an ecosystem (i.e., air, water, land, and biota) and its functions in a broad context, which effectively integrates environmental, social, and economic interests into a decision-making framework that embraces the concept of sustainability (Figure 3; CCME 1996). Importantly, the ecosystem approach recognizes that it is human activities, rather than natural resources, that need to be managed if we are to achieve our long-term goal of sustainability. The identifying characteristics of the ecosystem approach include (Vallentyne and Hamilton 1987):

- A synthesis of integrated knowledge on the ecosystem;
- A holistic perspective of interrelating systems at different levels of integration; and,
- Actions that are ecological, anticipatory, and ethical.

This expanded view then shapes the planning, research, and management decisions that are made within and pertaining to the ecosystem.

4.2 A Framework for Implementing Ecosystem-Based Management

Implementation of the ecosystem approach requires a framework in which to develop and implement management policies for the ecosystem. This framework consists of five main elements, including (Environment Canada 1996; Figure 4):

- Identification and assessment of the issues and collation of the existing ecosystem knowledge base;
- Development and articulation of ecosystem health goals and objectives;
- Selection of ecosystem health indicators to gauge progress toward ecosystem health goals and objectives;
- Conduct directed research and monitoring; and,
- Make informed decisions on the assessment, conservation, protection, and restoration of natural resources.

The first element of the framework is intended to provide all participants in the ecosystem management process with a common understanding of the key issues and the existing knowledge base. While types of information are collected, reviewed, evaluated, and collated at this stage of the process, emphasis is placed on assembling the available information on the structure, function, and status of the ecosystem, on the socioeconomic factors that influence environmental management, and on historic land and resource use patterns. Both contemporary scientific data and traditional knowledge are sought to provide as complete an understanding as possible on the ecosystem. The information that is assembled at this stage of the process should be readily accessible to all participants in the process (i.e., by completing and distributing a state of the knowledge summary report, preparing and making available a detailed technical report, and disseminating the underlying data).

In the second step of the process, participants develop a series of broad management goals (i.e., ecosystem goals) and more specific ecosystem objectives to articulate the long-term vision for the ecosystem. The ecosystem goals are based on the participants' common understanding of the ecosystem knowledge base and reflect the importance of the ecosystem to the community and to other stakeholder groups (e.g., ecosystem goals for Lake Ontario; CCME 1996; Table 3). A set of *objectives* for the various components of the ecosystem are also formulated at this stage of the process to clarify the scope and intent of the ecosystem goals (e.g., ecosystem objectives for Lake Ontario and Lake Superior; Table 4; CCME 1996). Societal values are reflected in the ecosystem goals and objectives through consultation with competing users of ecosystem resources. It is important that each of the ecosystem objectives includes a target schedule for being achieved to help keep participants prioritizing their activities. The designated uses of the aquatic ecosystem emerge from the goals and objectives that are established by stakeholders, and may include aquatic life, aquatic-dependent wildlife, human health, recreation and aesthetics, and navigation and shipping.

The third step of the ecosystem management framework involves the selection of a suite of ecosystem health indicators, which provide an effective basis for measuring the level of attainment of the ecosystem goals and objectives. Initially, a broad suite of candidate indicators of ecosystem health are identified and evaluated to determine their applicability to the site under consideration. Typically, selection criteria are identified and applied to provide a consistent basis for evaluating candidate indicators. However, local experience should also be employed to establish a suite of indicators that adequately reflects the goals and objectives that have been established. Each of the ecosystem health indicators must be supported by specific metrics and targets, which identify the acceptable range for each of the variables that will be measured to provide information on the status of the indicator (Figure 5). If all of the measured attributes or metrics fall within acceptable ranges for all of the indicators, then the ecosystem as a whole would be considered to be healthy and vital.

In the fourth step of the process, monitoring and directed research are conducted to evaluate the status of the ecosystem and to fill any data gaps that have been identified. In this application, the term monitoring is used to describe a wide range of activities that are focused on assessing the health of the ecosystem under consideration. Such monitoring could be implemented under broad environmental assessment programs (e.g., National Status and Trends Program, Environmental Monitoring and Assessment Program) or be undertaken to address site-specific concerns regarding environmental quality conditions (e.g., natural resource damage assessments, ecological risk assessments, human health risk assessments; see Chapter 2). The directed research activities should be conducted to address priority data gaps for the ecosystem under consideration. The evaluation of the adequacy of the knowledge base provides a basis for identifying data gaps, including those associated with the application of the ecosystem health indicators that were chosen (e.g., to establish baseline conditions) or with the existing knowledge base. Evaluation of the results of monitoring activities (i.e., to assess the status of each indicator) provides the information needed to determine if the ecosystem goals and objectives are being met, to revamp the metrics and targets, if appropriate, and to refine the monitoring program design.

Overall, this framework for implementing ecosystem-based management is intended to support informed decision-making. That is, the ecosystem goals and objectives establish the priorities that need to be reflected in decisions regarding the conservation of natural resources, protection of the environment, and socioeconomic development. As a final step in the process, the information on the status of the ecosystem health indicators is used by decision-makers to evaluate the efficacy of their management activities and to refine their approaches, if necessary. Successful adoption of this framework requires a strong commitment from all stakeholders and a willingness to explore new decision-making processes (Environment Canada 1996). More information on the benefits of the ecosystem approach, the implementation of ecosystem-based management, the development of management goals and objectives, and the selection of ecosystem health indicators is provided in MacDonald and Ingersoll (2002).

4.3 Application of the Ecosystem Approach to Contaminated Sediment Management

The ecosystem-based framework describes an approach to managing human activities that facilitates realization of the long-term vision that area residents have established for their ecosystem. Application of this framework to contaminated sediment management necessitates the establishment of more specific sediment management objectives (i.e., in addition to ecosystem goals and objectives) and key indicators of sediment quality conditions. Furthermore, the metrics that apply to each indicator and the corresponding targets for each metric must be selected. Chapter 5 provides background information relevant to the development of ecosystem goals, ecosystem objectives, and sediment management objectives for Presque Isle Bay. Guidance on the selection of ecosystem health indicators is provided in Chapter 6, while candidate metrics and targets for assessing the effects of contaminated sediments on beneficial uses in Presque Isle Bay are presented in Chapter 7.

Chapter 5 Development of Ecosystem Goals, Ecosystem Objectives, and Sediment Management Objectives for Presque Isle Bay

5.0 Introduction

Development of ecosystem goals, ecosystem objectives, and sediment management objectives represents an essential step toward implementation of an ecosystem-based approach to managing contaminated sediments in Presque Isle Bay. While development of such goals and objectives is an AOC-specific exercise, it is beneficial to coordinate these activities with those that are associated with the lake-wide management planning process. In this way, the goals and objectives that are established for individual AOCs will contribute to the realization of lake-wide management objectives.

This chapter provides background information on the development of ecosystem goals and objectives for Lake Erie and proposes ecosystem goals, ecosystem objectives, and sediment management objectives for Presque Isle Bay. While it is understood that the PAC will need to engage stakeholders in further discussions before more specific goals and objectives can be adopted, the information provided herein is intended to provide a basis for moving forward on the selection of indicators, metrics, and delisting targets in the near-term to support petitioning for delisting of one or more beneficial use impairments (BUIs) in Presque Isle Bay.

5.1 Development of Long-Term Vision and Ecosystem Management Objectives for Lake Erie

The Lake Erie LaMP Ecosystem Objectives Subcommittee (EOSC) is playing a lead role in the development of a long-term vision for the future and associated ecosystem management objectives for Lake Erie. Progress on the development of the LaMP for Lake Erie began in earnest with an evaluation of various ecosystem management alternatives for the lake. This approach was premised on the understanding that the Lake Erie ecosystem has been subject to extensive changes over the past two hundred years and that, in many cases, these changes appear to be irreversible. While it is not possible to return to the pre-settlement conditions of the 1700's, there is a broad interest in working toward achieving a healthier, more diverse, and less contaminated ecosystem. For this reason, the Lake Erie LaMP EOSC convened a series of public workshops to obtain input on the desired future state of the Lake Erie ecosystem. Subsequently, two experts workshops were convened to translate these vision elements into a series of ecosystem alternatives to guide the management of human activities in the Lake Erie basin, with each of the alternatives representing increasingly more progressive mitigation of agricultural, industrial, and urban land uses (Table 5). The ecosystem alternative that was ultimately selected (i.e., Ecosystem Alternative 2) was the one that was most compatible with societal values of the residents of the Basin. The selected ecosystem alternative became the Lake Erie Vision and was articulated as follows in the LaMP (2004):

Our Vision is a Lake Erie basin ecosystem where:

- *All people, recognizing the fundamental links among the health of the ecosytem, their individual actions, and their economic and physical well-being, work to minimize the human impact in the Lake Erie basin and beyond;*
- *Natural resources are protected from known, preventable threats;*
- *Native biodiversity and the health and function of natural communities are protected and restored to the greatest extent that is feasible;*

- *Natural resources are managed to ensure that the integrity of existing communities is maintained or improved;*
- *Human-modified landscapes provide functions that approximate natural ecosystem processes;*
- *Land and water are managed such that water flow regimes and the associated amount of materials transported mimic natural cycles; and,*
- *Environmental health continually improves due to virtual elimination of toxic contaminants and remedial actions at formerly degraded and/or contaminated sites.*

Following the development of the long-term vision for the future, the EOSC translated the vision into a series of ecosystem management objectives that could be used as a basis for formulating management strategies that move the ecosystem in the right direction. The ecosystem management objectives were derived to address the five major issues and concerns relative to the Lake Erie ecosystem, including: land use; nutrients; natural resource use and disturbance; chemical and biological contaminants; and, non-native invasive species. The corresponding ecosystem management objectives include:

- *Land-use activities preserve or enhance native biodiversity and ecosystem integrity. More specifically, land use activities result in gains in the quantity and quality of natural habitat in order to support the maximum amount of biodiversity and community integrity that can be achieved and be sustained for the benefit of future generations;*
- *Nutrient levels are consistent with ecosystem goals (watershed and basin-wide). More specifically, nutrient inputs from both point and non-point sources will be managed to ensure that ambient concentrations are within bounds of sustainable watershed management and are consistent with the Lake Erie Vision;*

- *Ecologically wise and sustainable use of natural resources. More specifically, natural resource uses (e.g., commercial and sport fishing, hunting, trapping, logging, water withdrawal) and disturbance by human presence or activity are managed to ensure that the integrity of healthy ecological communities are maintained and/or improved, and they provide benefits to consumers;*
- *Virtual elimination of toxic chemicals and biological contaminants. More specifically, the concentrations of toxic chemicals and biological contaminants within the basin will be virtually eliminated; and,*
- *Prevent further invasions of non-native species. Control existing non-native invasive species where possible. More specifically, non-native invasive species will be prevented from colonizing the Lake Erie ecosystem; existing non-native invasive species will be controlled and reduced where feasible and consistent with other objectives.*

As the LaMP developed its vision and ecosystem management objectives, the relationship between them and the identified BUIs were defined (Colavecchia *et al.* 2000; Table 5). Establishment of clear linkages between the ecosystem management objectives and the BUIs provided a basis for establishing a suite of indicators for Lake Erie that facilitate tracking progress towards the long-term vision for the future, including the restoration of beneficial uses of the ecosystem.

The Presque Isle Bay PAC is the principal vehicle for coordinating efforts toward beneficial use restoration in the Bay, including remedial action planning activities among the various stakeholder groups. Consistent with the terms of the GLWQA, the Presque Isle Bay PAC is coordinating with the EOSC to ensure that the RAP process fully considers the preferred ecosystem management alternative and the ecosystem vision and management objectives that describe, in narrative form, the actions needed to achieve the preferred alternative for Lake Erie. In addition, coordination among the two processes will ensure that the indicators selected for Presque Isle Bay are consistent with those that are developed to measure progress toward the desired ecosystem alternative in Lake Erie.

5.2 Development of Candidate Ecosystem Goals and Objectives for Presque Isle Bay

Ecosystem goals are broad narrative statements that define the management goals that have been established for a specific ecosystem. Definition of management goals for the aquatic ecosystem is a fundamental step towards the development of defensible management plans. The development of ecosystem goals requires input from a number of sources to ensure that societal values are adequately represented. Open consultation with the public should be considered a primary source of information for defining these goals. Government agencies, non-government agencies, and other stakeholders may also be consulted during this phase of the process.

A number of public consultation processes have already been conducted in the Lake Erie basin to support the development of a long-term vision for the future (described above). In addition, public input from this consultation process has resulted in the formulation of ecosystem management objectives to guide the development of management strategies that will support a transition toward the desired future state of the Lake Erie ecosystem. While these ecosystem management objectives could be used to develop ecosystem goals and objectives that address all of the environmental issues and concerns within the Presque Isle Bay ecosystem (i.e., Mill Creek, Cascade Creek, Scott Run, Garrison Run, Presque Isle Bay, and the nearshore waters of Lake Erie), the current investigation focused on the identification of ecosystem goals and objectives that were most closely linked to the beneficial use impairments that exist in Presque Isle Bay. More specifically, the following ecosystem goal corresponds to the existing BUIs and could be adopted for Presque Isle Bay:

To protect, sustain, and, where necessary, restore healthy, functioning aquatic ecosystems that are capable of supporting current and future uses.

While this ecosystem goal effectively articulates one element of the long-term vision for the area, it is too general to support the development of meaningful planning, research, and management initiatives for the Presque Isle Bay watershed. To be useful, ecosystem goals need to be further clarified and refined to establish ***ecosystem objectives*** that are more closely linked with ecological science (Harris *et al.* 1987). In turn, the ecosystem objectives, and more specific sediment management objectives, support the identification of indicators and metrics that provide direct information for assessing the health and integrity of the ecosystem.

Development of sediment management objectives that are consistent with the long-term vision and the ecosystem management objectives for Lake Erie requires an understanding of how contaminated sediments can adversely affect the beneficial uses of aquatic ecosystems (Table 6). Based on the summary of use impairments potentially associated with contaminated sediment, it is apparent the BUIs in Presque Isle Bay are likely to be associated with: contaminant transfer via contact with sediment or through the food web; possible metabolism to carcinogenic or more carcinogenic compounds; and/or, restrictions on disposal in open water due to contaminants and nutrients and their potential impacts on biota.

Habitats that support the production of fish and wildlife are of fundamental importance and are protected under federal and state legislation. While sediment contaminated sites typically cover a relatively small geographic area within a larger aquatic ecosystem (e.g., watershed), they have the potential to substantially influence conditions within the larger management unit. For this reason, it is essential that sediment management decisions support the long-term goals that have been established for the ecosystem, as a whole. In recognition of the importance of aquatic habitats, the following ecosystem objectives are recommended for the Presque Isle Bay ecosystem:

- *Protect and preserve recreational uses of Presque Isle Bay;*
- *Maintain and protect the benthic invertebrate community of Presque Isle Bay;*
- *Maintain an excellent quality fishery in Presque Isle Bay;*
- *Protect and improve the near-shore habitat in Presque Isle Bay;*
- *Maintain the aesthetic qualities of Presque Isle Bay (i.e., prevent algal blooms, unpleasant odors, visual impairments, etc.);*
- *Maintain and improve water quality conditions in Presque Isle Bay; and,*
- *Eliminate restrictions on dredging in Presque Isle Bay.*

These bay-wide ecosystem objectives can, then, be used to propose more specific sediment management objectives that apply directly to soft substrate habitats in Presque Isle Bay, as follows:

- *Maintain and/or restore sediment quality conditions such that benthic communities, including epibenthic and infaunal species, are protected and, where necessary, restored.*
- *Maintain and/or restore sediment quality conditions such that the health of fish populations are protected and, where necessary, restored.*
- *Maintain and/or restore sediment quality conditions such that the health of aquatic-dependent wildlife populations are protected and, where necessary, restored.*
- *Maintain and/or restore sediment quality conditions such that human health is protected and the human uses of the aquatic ecosystem (e.g., fish and wildlife consumption; navigation and shipping, etc.) are protected and, where necessary, restored.*

These sediment management objectives explicitly recognize that there are multiple uses of aquatic ecosystems that can be affected by sediment quality conditions and, hence, need to be considered in the assessment, management, and remediation of contaminated sediments. Importantly, these objectives also recognize that biotic receptors can be exposed to sediment-associated contaminants in three ways, including direct exposure to *in situ* sediments and pore water, through transfer of sediment-associated contaminants into the water column, and through the consumption of contaminated food organisms. Therefore, sediment management strategies must consider these three exposure routes, if the designated uses of aquatic ecosystems are to be protected, maintained, and restored.

It is not possible to directly measure the degree to which the recommended sediment managements have been attained. Therefore, it is necessary to establish a suite of indicators that can be used to facilitate determinations of the status of sediment quality, the benthic community, and the other valued ecosystem components. A process for establishing such key indicators (including specific metrics and delisting targets) is discussed in Chapter 6 of this document.

Chapter 6 Selection of Ecosystem Health Indicators for Assessing the Effects of Contaminated Sediments on Beneficial Uses in Presque Isle Bay

6.0 Introduction

Ecosystem goals developed cooperatively by interested stakeholder groups describe the desired state of an ecosystem (Bertram and Reynoldson 1992). Ecosystem objectives further clarify these goals by expressing them in terms of the ecological characteristics and human uses of the ecosystem. Such ecosystem goals and objectives provide a basis for establishing more specific sediment management objectives and associated ecosystem health indicators (including sediment quality indicators) that guide the assessment and management of contaminated sediments in freshwater ecosystems (MacDonald and Ingersoll 2002). Adherence to this ecosystem-based approach enhances the likelihood that any sediment management activities that are undertaken at sites with contaminated sediments will be consistent with, and support, the broader management initiatives that have been established for the ecosystem as a whole. This chapter provides guidance on the selection of ecosystem health indicators in general and more specific sediment quality indicators to support the assessment and management of contaminated sediments in Presque Isle Bay. Additional information on the selection of indicators is provided in Ingersoll and MacDonald (2002).

6.1 Identification of Candidate Ecosystem Health Indicators

In the environment, a variety of plant and animal species (i.e., receptors) can be exposed to physical, chemical, and/or biological stressors. Each of these stressors has the potential to affect the status of the ecological receptors and, in so doing, influence the structure and/or function of plant and animal communities in the ecosystem. In turn, such interactions between stressors, particularly those that are anthropogenically induced, and receptors have the potential to influence the health of the aquatic ecosystems, including the associated beneficial uses by humans.

Ecosystem health, as defined by the ecosystem goals and ecosystem health objectives, cannot be measured directly (Environment Canada 1996). For this reason, establishing a suite of ecosystem health indicators to support the evaluation of the status and trends of the ecosystem as a whole is necessary. An ecosystem health indicator is any characteristic of the environment that, when measured, provides accurate and precise information on the structure and/or function of the ecosystem. By comparison, sediment quality indicators represent a subset of the entire suite of ecosystem health indicators that provide specific information on sediment quality conditions in the ecosystem under consideration. For example, sediment toxicity may be selected as an indicator of the extent to which sediments are likely to support healthy and self-sustaining populations of benthic macroinvertebrates. Such indicators can provide a basis for measuring attainment of the long-term goals and objectives for the ecosystem and for identifying any undesirable changes that have occurred or are likely to occur to the ecosystem. To be effective, however, ecosystem health indicators need to be accompanied by appropriate metrics and quantitative targets. A metric may be defined as any measurable characteristic of an ecosystem health indicator (e.g., survival of amphipods, *Hyalella azteca*, in 28-d toxicity tests), while a target defines the desirable range of a specific metric (e.g., not statistically different from the control response). The relationship between ecosystem goals, ecosystem health objectives, ecosystem health indicators, metrics, and targets, within the context of the ecosystem approach to environmental management, is illustrated in Figures 5 and 6.

Identification of candidate ecosystem health indicators represents an important step in the ecosystem-based management process. Candidate ecosystem health indicators encompass all of the ecosystem components and functions that could be used to provide information on the health of the ecosystem as a whole (i.e., to track progress toward the ecosystem goals and ecosystem health objectives). The existing knowledge base that was compiled as the first step of the process provides a summary of what is known about the structure and function of the ecosystem under investigation. As such, the existing knowledge base provides an effective basis for identifying candidate ecosystem health indicators for the system under investigation. In cases where the existing knowledge base is limited, information on similar ecosystems may be useful for identifying candidate ecosystem health indicators. The suite of indicators that are ultimately selected for assessing ecosystem health will be drawn from the candidate ecosystem health indicators that are identified at this stage of the process.

6.2 Evaluation of Candidate Ecosystem Health Indicators

While detailed information on the status of each of the physical, chemical, and biological components of the environment would provide comprehensive information on ecosystem structure and function, collecting such data on every component of the ecosystem is neither practical nor feasible. For this reason, focusing assessment activities on the candidate indicators that provide the most useful information for assessing ecosystem health is necessary. In the case on contaminated sediment assessment, it is particularly important to focus on those sediment quality indicators that have been demonstrated to provide reliable information on the effects of contaminated sediments on the structure and function of the aquatic ecosystem.

A number of approaches have been used to evaluate candidate ecosystem health indicators. For example, the International Joint Commission has developed a framework for evaluating and selecting biological indicators of ecosystem health (IJC

1991). This framework provides detailed guidance on the development of ecosystem goals, on the identification of physicochemical, biological, and sociological indicators of ecosystem health, and on the establishment of monitoring programs to assess attainment of these goals. Likewise, Environment Canada has proposed a national framework for developing biological indicators for evaluating ecosystem health, as well as specific guidance on their application (Environment Canada 1993; 1996; 1997; CCME 1996). Both of these frameworks indicate that identification of the purpose of the resultant monitoring data is a central consideration in the selection of ecosystem health indicators. The IJC (1991) recognized five distinct purposes for which environmental data are collected, including:

- **Assessment -** evaluating the current status of the environment to determine its adequacy for supporting specific uses (i.e., fish and aquatic life). That is, monitoring the attainment of the ecosystem health objectives;
- **Trends -** documenting changes in environmental conditions over time. That is, monitoring the degradation, maintenance, and/or rehabilitation of the ecosystem under consideration;
- **Early warning -** providing an early warning that hazardous conditions exist before they result in significant impacts on sensitive and/or important components of the ecosystem;
- **Diagnostic -** identifying the nature of any hazardous conditions that may exist (i.e., the specific causes of ecosystem degradation) in order to develop and implement appropriate management actions to mitigate against adverse impacts; and,
- **Linkages -** demonstrating the linkages between indicators to improve the effectiveness and efficiency of monitoring programs and to reinforce the need to make environmentally sound management decisions.

Identification of the ultimate purpose of the monitoring data is important because no single indicator will be universally applicable in every application. For this reason, selecting a suite of indicators that most directly addresses the requirements of the monitoring program is necessary. To support evaluations of the relevance of candidate ecosystem health indicators, Ryder and Edwards (1985) and the IJC (1991) identified a number of desirable characteristics of candidate indicators, including:

- **Biologically relevant** - candidate indicators must be important for maintaining a balanced community and indicative of other, unmeasured biological indicators;
- **Sensitive** - candidate indicators should exhibit graded responses to environmental stresses, should not be tolerant of environmental changes, and should not exhibit high natural variability;
- **Measurable** - candidate indicators should have operational definitions and determination of their status should be supported by procedures for which it is possible to document the accuracy and precision of the measurements (easy to measure);
- **Cost-effective** - candidate indicators should be relatively inexpensive to measure and provide the maximum amount of information per unit effort;
- **Supported by historical data** - sufficient scientific data and/or traditional knowledge should be available to support the determination of natural variability, trends, and targets for the ecosystem metrics;
- **Non-destructive** - collection of the required data on the candidate indicators should not result in changes in the structure and/or function of the ecosystem, or on the status of individual species;
- **Of the appropriate scale** - candidate indicators should be applicable for determining the status to the ecosystem as a whole, not only to limited geographic areas within the ecosystem; and,
- **Non-redundant** - candidate indicators should provide unique information on the status of the ecosystem.

- **Socially relevant** - candidate indicators should be of obvious value to, and be observable by, stakeholders or be predictive of an indicator that has these attributes;
- **Interpretable** - candidate indicators should provide information that supports evaluations of the status of the ecosystem and the associated human uses of the ecosystem (acceptable ranges or targets should be definable);
- **Anticipatory** - candidate indicators should be capable of providing an indication that environmental degradation is occurring before serious harm has occurred;
- **Timely** - candidate indicators should provide information quickly enough to support the initiation of effective management actions before significant and lasting effects on the ecosystem have occurred;
- **Broadly applicable** - candidate indicators should be responsive to many stressors and be applicable to a broad range of sites;
- **Diagnostic** - candidate indicators should facilitate the identification of the particular stressor that is causing the problem;
- **Continuity** - candidate indicators should facilitate assessments of environmental conditions over time; and,
- **Integrative** - candidate indicators should provide information on the status of many unmeasured indicators.

Application of this system for evaluating candidate indicators involves two main steps. First, the reasons for collecting monitoring data need to be explicitly identified from the five potential purposes listed above (i.e., assessment, trends, early warning, diagnostic, linkages). Next, the essential and important characteristics of ecosystem health indicators for the selected monitoring purposes need to be identified using the information in Table 7 (designated as * and 3, respectively, in Table 7; IJC 1991). Subsequently, each of the candidate ecosystem health indicators should be scored relative to the essential and important characteristics that were identified (e.g., 0 to 2 for each characteristic, depending on the degree to which they reflect the essential and important characteristics). Finally, a total evaluation score can be calculated (i.e., by summing the score for each characteristic) and used to rank the utility of each candidate ecosystem health indicator relative to the intended use of the monitoring data. A final suite of ecosystem health indicators can then be selected based on the results of this ranking process, with consideration given to the extent to which the highest ranking indicators compliment each other.

6.3 Selection of Ecosystem Health Indicators for Presque Isle Bay

Several factors need to be considered in the selection of ecosystem health indicators for assessing sediment quality conditions in Presque Isle Bay. First, the indicators that are selected must be related to the ecosystem goals and objectives that are ultimately established for the Bay by the PAC. Second, a suite of indicators should be selected to reduce the potential for errors in decisions that are made based on the results of sediment quality monitoring programs (Environment Canada 1996). Third, the selection of ecosystem health indicators should be guided by selection criteria that reflect the stated purpose of the monitoring program (as described in IJC 1991).

Relative to sediment contamination, COPCs can be classified into two general categories based on their potential effects on ecological receptors, including toxic substances and bioaccumulative substances. For toxic substances that partition into sediments, evaluation of direct effects on sediment-dwelling organisms is likely to represent the primary focus of sediment quality investigations. For bioaccumulative substances, sediment quality assessments are likely to focus on evaluating effects on aquatic-dependent wildlife (i.e., fish, amphibians, reptiles, birds, and mammals) and on human health. In this way, such investigations can provide the information needed to evaluate attainment of the sediment management objectives for the site and the ecosystem health objectives that have been recommended for soft-substrate habitats in freshwater ecosystems (see MacDonald and Ingersoll 2002 for more information).

There is a wide range of indicators that can be used to evaluate sediment quality conditions. In the past, physical and chemical indicators have been primarily used to provide a means of assessing environmental quality conditions. More recently, significant effort has also been directed at the development of biological indicators of ecosystem integrity (which are often termed biocriteria; OEPA 1988). These biological indicators may apply to one or more levels of organization and encompass a large number of metrics ranging from biochemical variables to community parameters. Ideally, environmental monitoring programs would include each of the physical, chemical, and biological variables that could, potentially, be affected by anthropogenic activities. However, limitations on human and financial resources preclude this possibility. For this reason, identifying the most relevant ecosystem health indicators for assessing sediment quality conditions is necessary.

In Presque Isle Bay, ecosystem health indicators are needed to provide the information needed to determine if sediment quality and related conditions have improved to such an extent that the two identified BUIs (i.e., restrictions on dredging activities and fish tumors and other deformities) can be delisted (i.e., the selected indicators will be used to assess the current status of the ecosystem; that is, for Assessment). The scoring system developed by the IJC (1991) provides a basis for evaluating candidate indicators relative to this use of the resultant monitoring data (Table 7). Application of the IJC (1991) criteria is dependent on identifying the most desirable characteristics of the ecosystem health indicators and subsequently evaluating the candidate indicators relative to these characteristics. Based on the information presented in Table 7, it is essential that indicators for any monitoring purpose be sensitive, measurable, cost-effective, supported by historical data, non-destructive, of appropriate scale, and non-redundant (i.e., these are the essential characteristics of ecosystem health indicators). For sediment quality evaluations that are focused on status assessment, indicators that are biologically relevant, socially relevant, and interpretable are likely to be the most relevant (i.e., these are the important characteristics of ecosystem health indicators for this monitoring application).

Application of the IJC (1991) evaluation criteria facilitates the identification of ecosystem health indicators that are the most relevant for assessing sediment quality conditions. MacDonald and Ingersoll (2000) evaluated a variety of candidate ecosystem health indicators and concluded that the following were particularly relevant for assessing sediment quality conditions in freshwater ecosystems:

Receptors of Interest	Indicator of Sediment Quality Conditions
Sediment-dwelling organisms	Chemistry of whole sediments
	Chemistry of pore water
	Toxicity of sediments to invertebrates
	Structure of benthic invertebrate communities
Wildlife resources	Toxicity of sediments to fish
	Health of fish
	Status of fish communities
	Chemistry of whole sediments
	Chemistry of fish and invertebrate tissues
Human health	Chemistry of whole sediments
	Chemistry of fish and invertebrate tissues
	Presence of fish and wildlife consumption advisories

For assessing the status of the restrictions dredging activities BUI, the key sediment quality indicator for assessing compliance with Pennsylvania's regulations is elutriate chemistry. However, several other sediment quality indicators should be considered if the guidance in the Great Lakes Material Testing and Evaluation Manual is considered, including surface-water chemistry, surface-water toxicity, whole-sediment chemistry, whole-sediment toxicity, and whole-sediment bioaccumulation (USEPA and USACE 1998). However, this additional information would be used to support decisions regarding open water disposal of dredged materials in Lake Erie, which is not permitted under policies established by PADEP. By comparison, fish health is the key indicator for determining the current status of the tumors and other deformities in fish BUI. Additional indicators would be selected if the long-term monitoring program is intended to provide the information needed to determine if the broader sediment management objectives are being met (Table 8). Tables 9 and 10 provide work sheets for scoring candidate sediment quality indicators for assessing the status of BUIs in Presque Isle Bay.

Chapter 7 Identification and Evaluation of Candidate Delisting Targets for Presque Isle Bay

7.0 Introduction

The sediment quality indicators that are selected for assessing sediment quality conditions in Presque Isle Bay are intended to support delisting of the Bay as a Great Lakes AOC. By themselves, however, the selected indicators will not provide a comprehensive basis for designing sediment quality monitoring programs, assessing the status of the existing BUIs, or determining if conditions have improved sufficiently to warrant petitioning for delisting. In addition, metrics and targets need to be established for each of the indicators that are selected for use in Presque Isle Bay. This chapter is intended to support this process by providing background information on the development of delisting targets, identifying candidate metrics and targets for selected sediment quality indicators, and recommending specific targets that would be consistent with the sediment management objectives that have been proposed for Presque Isle Bay. In addition, the procedures described in this chapter were used to select preliminary sediment quality targets that could be used to conduct an evaluation of historic and current sediment quality conditions in the Bay.

7.1 Existing Guidance on the Development of Delisting Targets

Development of delisting targets for Great Lakes AOCs is a site-specific exercise. Nevertheless, the International Joint Commission and the United States Policy Committee have provided general guidance to assist state agencies and their partners in this process. For example, the IJC (1991) established a series of listing and delisting guidelines to assist the IJC and its Boards in fulfilling its responsibilities relative to the AOCs/RAPs under the GLWQA. These guidelines were intended to be used in making recommendations regarding the listing of new AOCs and in reviewing all stages of RAPs and covered all 14 BUIs identified at Great Lakes AOCs. For the two BUIs that were identified in Presque Isle Bay, the delisting guidelines are as follows:

- When contaminants in sediments do not exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities; and,
- When the incidence rates of fish tumors or other deformities do not exceed rates at unimpacted control sites and when survey data confirm the absence of neoplastic or preneoplastic liver tumors in bullheads or suckers.

These delisting guidelines play a key role in the delisting process, as indicated in the process that IJC (1991) has established for confirming restoration of BUIs at Great Lakes AOCs (Figure 7).

In addition to the general guidance that was provided by the IJC (1991), the United States Policy Committee (2001) has established more specific guidance for developing delisting targets, including: 1) Principles for Delisting BUIs; and, 2) Criteria for Developing Delisting Targets. The principles for delisting BUIs include:

- Establish ecosystem goals and objectives for the AOC;
- Identify measurable indicators of BUI;
- Review minimum standards articulated in GLWQA and regulations of federal, state, and local jurisdictions;
- Include a temporal component in the delisting targets;
- Use the RAP process to develop delisting targets;
- Identify BUIs that cannot be fully restored due to local conditions;
- Identify BUIs that require lake-wide efforts to restore;

- Coordinate targets with Great Lakes Environmental Indicators (SOLEC); and,
- Design and implement long-term monitoring programs to assess maintenance of BUs.

In addition to the above stated principles, the U.S. Policy Committee established criteria for developing delisting targets for Great Lakes AOCs. More specifically, the U.S. Policy Committee indicated that delisting targets should:

- Be premised on local goals and ecosystem objectives;
- Be consistent with applicable federal and state regulations, objectives, guidelines, standards, and policies;
- Be consistent with the principles and objectives embodied in Annex 2 and supporting parts of the GLWQA;
- Have measurable indicators; and,
- Be developed and periodically reviewed on a site-specific basis by the respective agencies and local stakeholders.

These guidelines, principles, and criteria provide useful general guidance for developing delisting targets. Additional information that can be used in the establishment of delisting targets is provided in the following sections of this chapter.

7.2 Selection of Sediment Quality Metrics for Presque Isle Bay

Metrics may be defined as any measurable characteristic of an ecosystem health indicator (e.g., the dry weight concentration of mercury in sediments might be identified as an important metric relative to sediment chemistry). Sediment quality metrics are specific metrics that can be measured to provide information on the status of a sediment quality indicator. As such, the selected sediment quality metrics define which variables are to be measured as part of the sediment quality monitoring program. Accordingly, there is a need to identify and prioritize metrics for each of the indicators that are selected for assessing contaminated sediments.

The selection of appropriate metrics for assessing sediment quality conditions involves several steps. The first step in this process involves the identification of candidate metrics for each indicator (Table 10). Subsequently, the candidate metrics for each priority indicator need to be evaluated in terms of the utility of the information that they are likely to generate. This evaluation needs to reflect the sediment management objectives to ensure that the most appropriate metrics are selected for each ecosystem health indicator. For example, the concentrations of metals in sediment are likely to provide an appropriate metric for sediment chemistry in the vicinity of a lead-zinc smelter. However, measurement of the levels of organochlorine pesticides in sediment might be less appropriate at such a site. Therefore, the metric evaluation process provides a basis for focusing limited sediment quality assessment resources on priority sediment quality issues and concerns. Table 11 provides a listing and evaluation of candidate sediment quality metrics for Presque Isle Bay (as adapted from MacDonald and Ingersoll 2002).

7.3 Identification of Candidate Delisting Targets for Presque Isle Bay

Two types of delisting targets could be established for Presque Isle Bay, including narrative delisting targets and numerical delisting targets. Establishment of narrative delisting targets at the outset is beneficial because it enables participants in the process to establish targets that are directly linked to the sediment management objectives that were developed earlier. For example, whole-sediment toxicity might be selected as an appropriate indicator for the sediment management objective relating to the benthic invertebrate community (i.e., *Maintain and/or restore sediment quality conditions such that benthic communities, including epibenthic and infaunal species, are protected and, where necessary, restored*). In this example, the survival of the amphipod, *Hyalella azteca*, in a 10-d toxicity tests might be selected as a key metic for whole-sediment chemistry. The corresponding narrative delisting target might be:

- The survival of freshwater amphipods, *H. azteca*, exposed to sediment samples from Presque Isle Bay should be greater than or equal to the normal range of survival rates observed for appropriately selected reference sediment samples from the near-shore areas of Lake Erie.

While such a narrative target provides important information, it cannot be used alone to determine if conditions in Presque Isle Bay have improved sufficiently to warrant delisting of one or more BUIs. Numerical targets are also required for each metric to support interpretation of the data generated on each ecosystem health indicator. Such targets define the desirable or acceptable range of values for each metric. In the above example, the following numerical delisting target could be established:

- The survival of freshwater amphipods, *Hyalella azteca*, exposed to sediment samples from Presque Isle Bay should be greater than or equal 90% in 95% of the samples collected from the Bay [i.e., if 90% survival was the 95% lower confidence limit (LCL) for reference sediment samples collected from the near-shore areas of Lake Erie].

Candidate numerical delisting targets that could be considered for application in Presque Isle Bay are presented in Tables 12 to 16. For the two BUIs that have been identified in Presque Isle Bay, the following indicators, metrics, and delisting targets are proposed (Table 17):

7.4 Delisting Targets and Sediment Quality Targets for Presque Isle Bay

Beneficial Use Impairment: Restrictions on Dredging Activities.

Sediment Management Objective: Maintain and/or restore sediment quality conditions such that human health is protected and the human uses of the aquatic ecosystem (e.g., fish and wildlife consumption; navigation and shipping, etc.) are protected and, where necessary, restored.

Sediment Quality Indicator: Elutriate Chemistry.

Metrics: Concentrations of COPCs in elutriates prepared with Presque Isle Bay sediment samples (i.e., with COPC quantitation performed on elutriate samples following centrifugation and filtration).

Narrative Delisting Target: The concentrations of all major COPCs are $\leq$ 1.5 times the concentrations measured in appropriately selected reference samples from the near-shore areas of Lake Erie.

Numeric Delisting Target: To be determined.

Beneficial Use Impairment: Fish Tumors and Other Deformities.

Sediment Management Objective: Maintain and/or restore sediment quality conditions such that the health of fish populations are protected and, where necessary, restored.

Sediment Quality Indicator: Fish Health.

Metrics: Incidence of intestinal, liver, and/or lip tumors and/or incidence of DELT abnormalities in benthic-dwelling fish (i.e., brown bullheads).

Narrative Delisting Target: The incidence of tumors and/or DELT abnormalities in brown bullheads from Presque Isle Bay are lower than criteria established by the IJC or similar to or lower than the rates that have been observed in fish from appropriately selected reference sites in Lake Erie.

Numeric Delisting Target: Incidence of intestinal or liver tumors in brown bullheads (i.e., considering a sample of 30 or more fish, each of which is $\geq$ 250 mm in total length) from Presque Isle Bay is < 7%. Incidence of lip tumors and overall external tumors is < 10% and < 15%, respectively, in brown bullheads from Presque Isle Bay (i.e., considering a sample of 30 or more fish, each of which is $\geq$ 250 mm in total length). DELT external anatomy index is $\leq$ 0.5% in brown bullheads from Presque Isle Bay (i.e., considering a sample of 30 or more fish, each of which is $\geq$ 250 mm in total length). These delisting targets may be refined following determination of the frequency of internal and external tumors in brown bullheads from reference sites in Lake Erie.

For the other important beneficial uses of aquatic resources in Presque Isle Bay, the following sediment quality targets are recommended (Table 17; i.e., these targets would not necessarily need to be met to proceed with the delisting process, but would provide a basis for implementing ecosystem-based management and protected key beneficial uses in Presque Isle Bay:

Beneficial Use Impairment: Not Applicable.

Ecosystem Objective: Maintain and protect the benthic invertebrate community of Presque Isle Bay.

Sediment Management Objective: Maintain and/or restore sediment quality conditions such that benthic communities, including epibenthic and infaunal species, are protected and, where necessary, restored.

Sediment Quality Indicators: Whole-sediment chemistry and whole-sediment toxicity.

Metrics: Concentrations of COPCs in whole-sediment samples.

Narrative Delisting Target: The concentrations of metals, PAHs, and PCBs are below the levels that are associated with acute or chronic toxicity in sediment-dwelling organisms; The survival of freshwater amphipods, *H.*

azteca, exposed to sediment samples from Presque Isle Bay should be greater than or equal to the normal range of survival rates observed for appropriately selected reference sediment samples from the near-shore areas of Lake Erie.

Numeric Delisting Target: Mean PEC-Q is < 1.0, PAH ESBTU is < 1.0, and SEM-AVS is < 0.0 in 90% of the whole-sediment samples collected from Presque Isle Bay. The survival of freshwater amphipods, *H. azteca*, exposed to sediment samples from Presque Isle Bay should be greater than or equal 90% in 95% of the samples collected from the Bay (i.e., if 90% survival was the 95% LCL for reference sediment samples collected from the near-shore areas of Lake Erie).

Beneficial Use Impairment: Not Applicable.

Sediment Management Objective: Maintain and/or restore sediment quality conditions such that the health of aquatic-dependent wildlife populations are protected and, where necessary, restored.

Sediment Quality Indicator: Fish and Invertebrate Tissue Chemistry.

Metrics: Concentrations of COPCs in fish and invertebrate tissues.

Narrative Delisting Target: The concentrations of bioaccumulative COPCs in fish and invertebrate tissues from Presque Isle Bay are lower than the dietary levels that are associated with adverse effects on the survival, growth, or reproduction of birds or mammals.

Numeric Delisting Target: The concentrations of bioaccumulative COPCs in fish and invertebrate tissues from Presque Isle Bay are lower than the concentrations specified in Sample *et al.* 1996)

Chapter 8 References Cited

Applied Biology, Inc. 1982. Chemical, physical and bioassay analysis of sediment samples, Erie Harbor, Erie, Pennsylvania. Prepared United States Army Corps of Engineers. Contract No. DACW49-82-C-0044. Prepared by Applied Biology, Inc. Decatur, Georgia.

Aqua Tech Environmental Consultants, Inc. 1986. The analysis of sediments from Erie Harbor; Erie Pennsylvania. Prepared for United States Army Corps of Engineers. Contract No. DACW49-86-D-0001. Technical Report No. G0176-07. Prepared by Aqua Tech Environmental Consultants, Inc. Marion, Ohio.

ASTM (American Society for Testing and Materials). 2004. Standard test methods for measuring the toxicity of sediment-associated contaminants with freshwater invertebrates. E1706-00. ASTM 2004 ASTM Annual Book of Standards Volume 11.05. West Conshohocken, Pennsylvania.

Bertram, P.E. and T.B. Reynoldson. 1992. Developing ecosystem objectives for the Great Lakes: Policy, progress and public participation. Journal of Aquatic Ecosystem Health 1:89-95.

Bright, G.R. 1988. Recent water quality in the Grand Calumet River as measured by benthic invertebrates. Proceedings of the Indiana Academy of Science 98:229-233

CCME (Canadian Council of Ministers of the Environment). 1996. A framework for developing ecosystem health goals, objectives, and indicators: Tools for ecosystem-based management. Prepared by the Water Quality Guidelines Task Group of the Canadian Council of Ministers of the Environment. Winnipeg, Manitoba. 24 pp.

Chapman, P. M. 1989. Current approaches to developing sediment quality criteria. Environmental Toxicology and Chemistry 8:589-599.

Christie, W.J., M. Becker, J.W. Cowden and J.R. Vallentyne. 1986. Managing the Great Lakes Basin as a home. Journal of Great Lakes Research 12(1):2-17.

Colavecchia, M., S. Ludsin, P. Bertram, R. Knight, S. George, H. Biberhofer, and P. Ryan. 2000. Identification of Ecosystem Alternatives for Lake Erie to Support Development of Ecosystem Objectives. Lake Erie Management Plan (LaMP) Technical Report Series. Ecosystem Objectives Subcommittee. Environment Canada and U.S. Environmental Protection Agency. (As cited in LaMP 2004).

Cullinan, V. and E. Crecelius. 1995. Evaluation of lead - 210 in Presque Isle Bay sediment cores for May 1994 study. Prepared for United States Environmental Protection Agency Region III. EPA Contract No. 68-C2-0134. Philadelphia, Pennsylvania.

Diz, H.R. 2002. An assessment of sediment quality in Presque Isle Bay Erie, Pennsylvania. Prepared for the Great Lakes National Program Office. United States Environmental Protection Agency, Region V, Chicago, Illinois. GLNPO Project No. GL97504701-01-0. 35 p.

Dorkin, J. 1994. Sediment sampling and analysis plan - West Branch Grand Calumet River: 1993 sediment chemistry data summaries. Environmental Science Division. United States Environmental Protection Agency. Region V. Chicago, Illinois. 30 pp.

Environment Canada. 1993. A proposed national framework for evaluating and reporting ecosystem health: A discussion paper. Prepared by Eco-Health Branch. Ecosystem Science and Evaluation Directorate. Environment Canada. Ottawa, Ontario.

Environment Canada. 1996. The ecosystem approach: Getting beyond the rhetoric. Prepared by the Task Force on Ecosystem Approach and Ecosystem Science at Environment Canada. Prepared for the Environment Canada Long Term Strategic Plan for Ecosystem Initiatives. Ottawa, Ontario.

Environment Canada. 1997. The Salmon River Watershed: An evaluation of the collaboration towards ecosystem objectives and a watershed vision: Summary report, February 1997. Fraser River Action Plan, Environment Canada. Ottawa, Ontario.

Gannett Fleming, Inc. 1993. Special study: Presque Isle Bay sediment quality evaluation. Prepared for U.S. Environmental Protection Agency. Region III. Harrisburg, Pennsylvania. 368 p.

Goodyear, C.S., T.A. Edsall, D.M. Ormsby Dempsey, G.D. Moss, and P.E. Polanski. 1982. Atlas of the spawning and nursery areas of Great Lakes fishes. Volume 9: Lake Erie. FWS/OBX-82/52. United States Fish and Wildlife Service. Washington, District of Columbia. (As cited in Potomac-Hudson 1997).

Harris, H.J., P.E. Sager, S. Richman, V.A. Harris and C.J. Yarbrough. 1987. Coupling ecosystem science with management: A Great Lakes perspective from Green Bay, Lake Michigan, USA. Environmental Management 11(5):619-625.

Hoke, A.R., J.P. Giesy, M. Zabik, and M. Unger. 1993. Toxicity of sediments and sediment pore waters from the Grand Calumet River - Indiana Harbor, Indiana Area of Concern. Ecotoxicology and Environmental Safety 26:86-112.

IJC (International Joint Commission). 1988. Procedures for the assessment of contaminated sediment problems in the Great Lakes. Prepared by the Sediment Subcommittee and its Assessment Work Group. Great Lakes Regional Office. Windsor, Ontario. 140 pp.

IJC (International Joint Commission). 1991. A proposed framework for developing indicators of ecosystem health for the Great Lakes region. Council of Great Lakes Research Managers. Windsor, Ontario. 47 pp.

IJC (International Joint Commission). 1997. Overcoming obstacles to sediment remediation in the Great Lakes Basin. White Paper by the Sediment Priority Action Committee. Great Lakes Water Quality Board. Windsor, Ontario

Ingersoll, C.G. and D.D. MacDonald. 1999. An assessment of sediment injury in the West Branch of the Grand Calumet River. Report prepared for the Environmental Enforcement Section, Environment and Natural Resources Division, United States Department of Justice. Washington, District of Columbia.

Ingersoll C.G. and D.D. MacDonald. 2002. A guidance manual to support the assessment of contaminated sediments in freshwater ecosystems. Volume III: Interpretation of the results of sediment quality investigations. EPA-905-B02-001-C. Prepared for the Great Lakes National Program Office. United States Environmental Protection Agency. Chicago, Illinois. Under contract to Sustainable Fisheries Foundation. Snohomish, Washington.

Ingersoll, C.G., T. Dillon, and R.G. Biddinger, editors. 1997. Ecological risk assessment of contaminated sediments. SETAC Pellston Workshop on Sediment Ecological Risk Assessment; 1995 April 23-28; Pacific Grove, California. SETAC Press. Pensacola, Florida. 390 pp.

Jarvinen, A.W. and G.T. Ankley. 1999. Linkage of effects to tissue residues: Development of a comprehensive database for aquatic organisms exposed to inorganic and organic chemicals. SETAC Press. Pensacola, Florida MacDonald et al. 2005)

LaMP (Lake Wide Management Plan). 2004. Lake Erie Lake Wide Management Plan. Prepared by the Lake Erie LaMP Working Group under direction to the Lake Erie LaMP Management Committee (Report available at http://www.epa.gov/glnpo/lakeerie/2004update/le_lamp_2004.pdf.

Long, E.R. and L.G. Morgan. 1991. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. National Oceanic and Atmospheric Administration. Seattle, Washington. 175 pp. + appendices.

MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.

NYSDEC (New York State Department of Environmental Conservation). 1999. Technical guidance for screening contaminated sediments. Division of Fish, Wildlife and Marine Resources. New York State Department of Environmental Conservation. New York, New York. 39 pp.

Obert, E.C. 1993. Presque Isle Bay Brown Bullhead tumor study, conducted from March 29, 1992 to October 7,1993. Pennsylvania Department of Environmental Protection. Bureau of Water Management. Northwest Region. Meadville, Pennsylvania.

Obert, E.C. and B. Wellington. 1995. Presque Isle Bay fish tissue results for 1995. Pennsylvania Department of Environmental Protection. Meadville, Pennsylvania.

OEPA (Ohio Environmental Protection Agency). 1988. Biological criteria for the protection of aquatic life: Volume II: Users manual for biological field assessment of Ohio surface waters. Ecological Assessment Section. Division of Water Quality Planning and Assessment. Columbus, Ohio.

PADEP (Pennsylvania Department of Environmental Protection). 1995. Presque Isle Bay Remedial Action Plan. Meadville Regional Office and the Presque Ile Bay Public Advisory Committee. Meadville, Pennsylvania. (As cited in PADEP 2002).

PADEP (Pennsylvania Department of Environmental Protection). 2002. Presque Isle Bay Remedial Action Plan. 2002 update. Meadville Regional Office and the Presque Ile Bay Public Advisory Committee. Meadville, Pennsylvania.

PADEP, USEPA, and PSG (Pennsylvania Department of Environmental Protection, United States Environmental Protection Agency, and Pennsylvania Sea Grant). 2003. Fish tumors related to Great Lakes areas of concerns conference proceedings. January 21-22, 2003. Compiled by Pennsylvania Sea Grant. Erie, Pennsylvania.

PADER and PIB PAC (Pennsylvania Department of Environmental Resources and Presque Isle Bay Public Advisory Committee). 1992. Presque Isle Bay Remediation Action Plan. Meadville Pennsylvania.

PFC. 1988. Presque Isle Bay Fisheries Assessment. Pennsylvania Fish Commission. Division of Fisheries. Fisheries Management Section. (As cited in Potomac-Hudson 1997).

Potomac-Hudson Engineering. 1991. Presque Isle Bay ecosystem study - Background report. Prepared for the Pennsylvania Department of Environmental Resources, Meadville, Pennsylvania.

Rice, C.L. 1991. Chemical analysis of sediments from Presque Isle Bay, Lake Erie, Erie Pennsylvania. Pennsylvania Field Office Special Project Report 91-2. United States Fish and Wildlife Service. Pennsylvania.

Royal Commission on the Future of the Toronto Waterfront. 1992. Regeneration. Toronto's waterfront and the sustainable city: Final report. Toronto, Ontario.

Ryder, R.A. and C.J. Edwards (Eds.). 1985. A conceptual approach for the application of biological indicators of ecosystem quality in the Great Lakes Basin. Report to the Great Lakes Science Advisory Board. International Joint Commission and The Great Lakes Fishery Commission. Windsor, Ontario.

Sample, B.E., D.M. Opresko, and G.W. Suter II. 1996. Toxicological benchmarks for wildlife: 1996 Revision. ES/ER/TM-95/R3. Office of Environmental Management. United States Department of Energy. Oak Ridge, Tennessee. 217 pp.

United States Policy Committee. 2001. Restoring United States Great Lakes Areas of Concern. Delisting principles and guidelines. Prepared by the Great Lakes Commission. Ann Arbor, Michigan.

USEPA (United States Environmental Protection Agency). 1977. Guidelines for pollutional classification of Great Lakes Harbor Sediment. Region V. Chicago, Illinois.

USEPA (United States Environmental Protection Agency). 1997. Ecological risk assessment guidance for Superfund: Process for designing and conducting ecological risk assessments. Environmental Response Team. Edison, New Jersey.

USEPA (United States Environmental Protection Agency). 1998. Guidelines for ecological risk assessment. Risk Assessment Forum. EPA/630/R-95/002F. Washington, District of Columbia.

USEPA (United States Environmental Protection Agency). 2000a. Dioxin/furan levels in the surficial sediments of Presque Isle Bay.

USEPA (United States Environmental Protection Agency). 2000b. Prediction of sediment toxicity using consensus-based freshwater sediment quality guidelines. EPA 905/R-00/007. Great Lakes Program Office. Chicago, Illinois.

USEPA (United States Environmental Protection Agency). 2003. Predicting amphipod toxicity from sediment chemistry. EPA/600/R-02/056. Prepared by National Oceanic and Atmospheric Administration. Office of Response and Restoration. Coastal Protection and Restoration Division. Seattle, Washington.

USEPA and USACE (United States Environmental Protection Agency and United States Army Corps of Engineers). 1998. Evaluation of dredged material proposed for discharge in water of the US. Testing Manual. EPA 823-B-98-004. United States Environmental Protection Agency. Washington, District of Columbia.

USFDA (United States Food and Drug Administration). 2001. Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed. Washington, District of Columbia.

Vallentyne, J.R. and A.L. Hamilton. 1987. Managing the human uses and abuses of aquatic resources in the Canadian ecosystem. *In:* M.C. Healey and R.R. Wallace (Eds.). Canadian Aquatic Resources. Canadian Fisheries and Aquatic Sciences Bulletin 215:513-533. (As cited in Vallentyne and Beeton 1988).

Vallentyne, J.R. and A.M. Beeton. 1988. The "ecosystem" approach to managing human uses and abuses of natural resources in the Great Lakes Basin. Environmental Conservation 15(1):58-62.

Wellington, R.J. 2002. Surficial sediment sampling Presque Isle Bay - Erie, Pennsylvania. 2000-2001 sampling survey. Erie County Department of Health. Erie, Pennsylvania.

West, D. E., H. Tulli, and J. Neff. 1994. Presque Isle Bay sediment quality evaluation report for May 1994 study. Final. Prepared for United States Environmental Protection Agency. Region III. Water Quality Planning Section. Prepared by Battelle Ocean Sciences. Duxbury, Massachusetts.

West, D.E. 1994. Evaluation of polycyclic aromatic hydrocarbons in Presque Isle Bay sediment cores for May 1994 study. Prepared for United States Environmental Protection Agency. Region III. Contract No. 68-C2-0134. Prepared by Battelle Ocean Sciences. Duxbury, Massachusetts.

Tables

Table 1. Identification of chemicals of potential concern in the Presque Isle Bay Area of Concern.

Chemical of Potential Concern (COPC)	Toxic COPCs in Whole Sediments	Bioaccumulative COPCs in Whole Sediments	Reference
Metals (mg/kg DW)			
Aluminum	Y		Obert (1993)
Antimony	Y		Wellington (2002)
Arsenic	Y		Potomac-Hudson (1991)
Barium	Y		Potomac-Hudson (1991)
Cadmium	Y	Y	Potomac-Hudson (1991)
Chromium	Y		Potomac-Hudson (1991)
Copper	Y		Potomac-Hudson (1991)
Iron	Y		Potomac-Hudson (1991)
Lead	Y	Y	Potomac-Hudson (1991)
Manganese	Y		Potomac-Hudson (1991)
Mercury (Methyl mercury)	Y	Y	Gannett Fleming Inc. (1993)
Nickel	Y		Potomac-Hudson (1991)
Silver	Y		Potomac-Hudson (1991)
Zinc	Y		Potomac-Hudson (1991)
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg DW)			
Acenaphthene			
Acenaphthylene	Y		Potomac-Hudson (1991)
Anthracene	Y		Potomac-Hudson (1991)
Benz(a)anthracene	Y		Potomac-Hudson (1991)
Benzo(a)pyrene	Y		Potomac-Hudson (1991)
Chrysene	Y		Potomac-Hudson (1991)
Dibenz(a,h)anthracene	Y		Potomac-Hudson (1991)
Fluoranthene	Y		Potomac-Hudson (1991)
Fluorene	Y		Potomac-Hudson (1991)
2-Methylnaphthalene	Y		Potomac-Hudson (1991)
Naphthalene	Y		Potomac-Hudson (1991)
Phenanthrene	Y		Potomac-Hudson (1991)
Pyrene	Y		Potomac-Hudson (1991)
Total PAHs	Y		Potomac-Hudson (1991)
Polychlorinated Biphenyls (PCBs; µg/kg DW)			
Total PCBs	Y	Y	Rice (1991)
Total PCBs		Y	
Aroclor 1016		Y	
Aroclor 1242		Y	
Aroclor 1248	Y	Y	
Aroclor 1254	Y	Y	West *et al.* (1994)
Aroclor 1260		Y	West *et al.* (1994)
Aroclor 1268		Y	

Table 1. Identification of chemicals of potential concern in the Presque Isle Bay Area of Concern.

Chemical of Potential Concern (COPC)	Toxic COPCs in Whole Sediments	Bioaccumulative COPCs in Whole Sediments	Reference
Pesticides/Herbicides (µg/kg DW)			
Chlordane	Y	Y	West *et al.* (1994)
Sum DDD	Y	Y	West *et al.* (1994)
Sum DDE	Y	Y	West *et al.* (1994)
Sum DDT	Y	Y	West *et al.* (1994)
Total DDT	Y	Y	West *et al.* (1994)
Dieldrin	Y	Y	Rice (1991)
Endrin	Y	Y	West *et al.* (1994)
Phthalates (µg/kg DW)			
Bis(2-ethylhexyl)phthalate	Y		Gannett Fleming Inc. (1993)
PCDDs and PCDFs (ng/kg DW)			
2,3,7,8-TCDD Toxic Equivalents (TEQs)[1]		Y	USEPA (2000)
Other COPCs (µg/kg DW)			
Chemical Oxygen Demand	Y		Potomac-Hudson (1991)
Cyanide	Y		Potomac-Hudson (1991)
Nitrosamines	Y		Obert (1993)
NDMA	Y		Obert (1993)
NPMA	Y		Obert (1993)
Oil and Grease	Y		Potomac-Hudson (1991)
Total Kjeldahl Nitrogen	Y		Potomac-Hudson (1991)
Total Phosphorus	Y		Potomac-Hudson (1991)
Total Volatile Solids	Y		Potomac-Hudson (1991)

Note: Reference identifies the first study to have identified a substance as a COPC in Presque Isle Bay; other studies may have confirmed the COPC.

Table 2. List of fish species know to utilize habitats in Presque Isle Bay (Potomac-Hudson 1991).

Common Name	Species Name (to come)
Black bullhead	
Black crappie	
Bluegill	
Bowfin	
Brown bullhead	
Brown trout	
Bullhead spp.	
Carp	
Channel catfish	
Chinook salmon	
Coho salmon	
Crappie spp.	
Freshwater drum	
Gizzard shad	
Grass pickerel	
Lake trout	
Largmouth bass	
Longnose gar	
Muskellunge	
Northern pike	
Pumpkinseed	
Rock bass	
Smallmouth bass	
Spottail shiner	
Spotted gar	
Steelhead trout	
Walleye	
Warmouth	
White bass	
White crappie	
White perch	
Yellow bullhead	
Yellow perch	

Table 3. Ecosystem goals and objectives for Lake Ontario (as developed by the Ecosystem Objectives Work Group; CCME 1996).

Ecosystem Goals	Ecosystem Objectives
* The Lake Ontario ecosystem should be maintained and as necessary restored or enhanced to support self-reproducing diverse biological communities	* The waters of Lake Ontario shall support diverse, healthy, reproducing and self-sustaining communities in dynamic equilibrium with an emphasis on native species.
* The presence of contaminants shall not limit the use of fish, wildlife and waters of the Lake Ontario basin by humans and shall not cause adverse health effects in plants and animals.	* The perpetuation of a healthy, diverse and self-sustaining wildlife community that utilizes the lake for habitat and/or food shall be ensured by attaining and sustaining the waters, coastal wetlands and upland habitats of the Lake Ontario basin in sufficient quality and quantity.
* We as a society shall recognize our capacity to cause great changes in the ecosystem and we shall conduct our activities with responsible stewardship for the Lake Ontario basin.	* The waters, plants and animals of Lake Ontario shall be free from contaminants and organisms resulting from human activities at levels that affect human health or aesthetic factors such as tainting, odor and turbidity.
	* Lake Ontario offshore and nearshore zones and surrounding tributary, wetland and upland habitats shall be of sufficient quality and quantity to support ecosystem objectives for health, productivity and distribution of plants and animals in and adjacent to Lake Ontario.
	* Human activities and decisions shall embrace environmental ethics and a commitment to responsible stewardship.

Table 4. Ecosystem objectives for Lake Superior (as developed by the Superior Work Group; CCME 1996).

Objective Category	Objective Narrative
General	Human activity in the Lake Superior basin should be consistent with "A Vision for Lake Superior"…Future development of the basin should protect and restore the 14 uses identified in Annex 2 of the Great Lakes Water Quality Agreement.
Aquatic Communities	Lake Superior should sustain diverse, healthy, reproducing and self-regulating aquatic communities closely representative of historical conditions.
Terrestrial Wildlife Objective	The Lake Superior ecosystem should support a diverse, healthy, reproducing and self-regulating wildlife community closely representative of historical (i.e., pre-1885) conditions.
Habitat Objective	Extensive natural environments such as forests, wetlands, lakes and watercourses are necessary to sustain healthy native animal and plant populations in the Lake Superior ecosystem and have inherent spiritual, aesthetic and educational value. Land and water uses should be designed and located in harmony with the protective and productive ecosystem functions provided by these natural landscape features. Degraded features should be rehabilitated or restored where this is beneficial to the Lake Superior ecosystem.
Human Health Objective	The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin. The appearance, taste and odour of water and food supplied by the Lake Superior ecosystem should not be degraded by human activity.
Developing Sustainability	Human use of the Lake Superior ecosystem should be consistent with the highest ethical and scientific standards for sustainable use. Land, water and air use in the Lake Superior ecosystem should not degrade it nor any adjacent ecosystems. Use of the basin's natural resources should not impair the natural capability of the basin ecosystem to sustain its natural identity and ecological functions, nor should it deny current and future generations the benefits of a healthy, natural Lake Superior ecosystem. Technologies and development plans that preserve natural ecosystems and their biodiversity should be encouraged.

Table 5. Linking ecosystem management objectives to Lake Erie's beneficial use impairments (LaMP 2004).

Ecosystem Management Objective	Beneficial Use Impairment
Land Use	Degraded Fish and Wildlife Populations Restrictions on Fish and Wildlife Consumption Bird or Animal Deformities or Reproductive Problems Restrictions on Dredging Degradation of Benthos Eutrophication or Undesirable Algae Beach Closings Loss of Fish and Wildlife Habitat
Nutrients	Degraded Fish and Wildlife Populations Degradation of Benthos Eutrophication or Undesirable Algae Degradation of Aesthetics Degradation of Phytoplankton and Zooplankton Populations
Chemical and Biological Contaminants	Restrictions on Fish and Wildlife Consumption Bird or Animal Deformities or Reproductive Problems Fish Tumors and Other Deformities Degraded Fish and Wildlife Populations Restrictions on Dredging Activities (quality) Beach Closings Degradation of Benthos
Natural Resource Use and Disturbance	Degraded Fish and Wildlife Populations Loss of Fish and Wildlife Habitat
Non-native Invasive Species	Degraded Fish and Wildlife Populations Degradation of Benthos Degradation of Aesthetics Loss of Fish and Wildlife Habitat Eutrophication or Undesirable Algae Degradation of Phytoplankton and Zooplankton Populations

Table 6. A summary of use impairments potentially associated with contaminated sediment and the numbers of Great Lakes areas of concern with such use impairments (from IJC 1997).

Use impairment	How contaminated sediment may affect use impairment	*Number of Areas of Concern with the impaired use (%)
Restrictions on fish and wildlife consumption	* Contaminant uptake via contact with sediment or through the food web	36 (86%)
Degradation of fish and wildlife populations	* Contaminant degradation of habitat * Contaminant impacts through direct sediment contact * Food web uptake	30 (71%)
Fish tumors or other deformities	* Contaminant transfer via contact with sediment or through the food web * Possible metabolism to carcinogenic or more carcinogenic compounds	20 (48%)
Bird or animal deformities or reproduction problems	* Contaminant degradation of habitat * Contaminant impacts through direct sediment contact * Food web uptake	14 (33%)
Degradation of benthos	* Contact * Ingestion of toxic contaminants * Nutrient enrichment leading to a shift in species composition and structure due to oxygen depletion	35 (83%)
Restrictions on dredging activities	* Restrictions on disposal in open water due to contaminants and nutrients and their potential impacts on biota	36 (86%)

Table 6. **A summary of use impairments potentially associated with contaminated sediment and the numbers of Great Lakes areas of concern with such use impairments (from IJC 1997).**

Use impairment	How contaminated sediment may affect use impairment	*Number of Areas of Concern with the impaired use (%)
Eutrophication or undesirable algae	* Nutrient recycling from temporary sediment sink	21 (50%)
Degradation of aesthetics	* Resuspension of solids and increased turbidity * Odors associated with anoxia	25 (60%)
Added costs to agriculture or industry	* Resuspended solids * Presence of toxic substances and nutrients	7 (17%)
Degradation of phytoplankton or zooplankton populations	* Toxic contaminant release * Resuspension of solids and absorbed contaminants and subsequent ingestion	10 (24%)
Loss of fish and wildlife habitat	* Toxicity to critical life history stages * Degradation of spawning and nursery grounds due to siltation	34 (81%)

Table 7. Desirable characteristics of indicators for different purposes (from IJC 1991).

Characteristic of Indicator	Purpose of Indicator				
	Assessment	Trends	Early Warning	Diagnostic	Linkages
Biologically relevant	3	3	2	2	2
Socially Relevant	3	3	2	2	2
Sensitive	*	*	*	*	*
Broadly applicable	2	2	2	1	1
Diagnostic	1	1	1	3	1
Measurable	*	*	*	*	*
Interpretable	3	3	2	1	1
Cost-effective	*	*	*	*	*
Integrative	2	2	1	1	2
Historical data	*	*	*	*	*
Anticipatory	1	1	3	1	2
Nondestructive	*	*	*	*	*
Continuity	2	3	1	1	1
Appropriate scale	*	*	*	*	*
Lack of redundance	*	*	*	*	*
Timeliness	2	2	3	3	2

Table entries are on a scale of importance from one to three, where one indicates lower importance and three indicates an essential attribute. Characteristics that are universally desirable and do not differ between purposes are marked with an asterisk (*).

Table 8. Candidate sediment quality indicators for assessing restoration of beneficial uses potentially affected by contaminated sediments.

Use Impairment	Candidate Sediment Quality Indicator													
	Whole-Sediment Chemistry	Whole-Sediment Toxicity	Benthic Community Structure	Bioaccumulation	Tissue Chemistry	Surface Water Chemistry	Surface Water Toxicity	Physical Variables	Elutriate Chemistry	Elutriate Toxicity	Fish Health	Fish Community Structure	Wildlife Community Structure	Wildlife Health
Restrictions on fish and wildlife consumption	1	NA	NA	1	1	2	NA	NA	NA	NA	NA	NA	NA	NA
Degradation of fish & wildlife populations	1	1	2	2	2	1	1	1	2	2	1	1	1	1
Fish tumors or other deformities	2	NA	NA	2	2	NA	NA	NA	NA	NA	1	2	NA	NA
Bird or animal deformities or reproduction problems	2	NA	NA	2	2	NA	NA	NA	NA	NA	NA	NA	2	1
Degradation of benthos	1	1	2	2	2	2	2	1	2	2	NA	NA	NA	NA
Restrictions on dredging activities	1	1	NA	1	1	1	NA	NA	1	1	NA	NA	NA	NA
Eutrophication or undesirable algae	2	NA	NA	NA	NA	1	1	NA	2	NA	NA	NA	NA	NA
Degradation of aesthetics	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	NA	NA	NA	NA
Added costs to agriculture or industry	NA	NA	NA	NA	NA	1	NA	1	NA	NA	NA	NA	NA	NA
Degradation of phytoplankton or zooplankton populations	NA	NA	NA	NA	NA	1	1	NA	2	2	NA	NA	NA	NA
Loss of fish and wildlife habitat	1	1	2	1	1	1	1	1	2	2	1	1	1	1

1 = Primary Indicator; 2 = Secondary Indicator; NA = not applicable.

Table 9. Candidate sediment quality indicators for assessing restoration of beneficial uses potentially affected by contaminated sediments.

Use Impairment	Candidate Sediment Quality Indicator													
	Whole-Sediment Chemistry	Whole-Sediment Toxicity	Benthic Community Structure	Bioaccumulation	Tissue Chemistry	Surface Water Chemistry	Surface Water Toxicity	Physical Variables	Elutriate Chemistry	Elutriate Toxicity	Fish Health	Fish Community Structure	Wildlife Community Structure	Wildlife Health
Restrictions on fish and wildlife consumption														
Degradation of fish & wildlife populations														
Fish tumors or other deformities														
Bird or animal deformities or reproduction problems														
Degradation of benthos														
Restrictions on dredging activities														
Eutrophication or undesirable algae														
Degradation of aesthetics														
Added costs to agriculture or industry														
Degradation of phytoplankton or zooplankton populations														
Loss of fish and wildlife habitat														

1 = Primary Indicator; 2 = Secondary Indicator; NA = not applicable.

Table 10. Worksheet for scoring candidate sediment quality indicators relative to essential and important characteristics for assessing the current status of beneficial use impairments in Presque Isle Bay.

Desirable Characteristics of Sediment Quality Indicators	Candidate Sediment Quality Indicator														
	Whole-Sediment Chemistry	Whole-Sediment Toxicity	Benthic Community Strucutre	Bioaccumulation	Tissue Chemistry	Surface Water Chemistry	Surface Water Toxicity	Physical Variables	Elutriate Chemistry	Elutriate Toxicity	Fish Health	Fish Community Strucutre	Wildlife Community Strucutre	Wildlife Health	TOTAL SCORE
Biological Relevance															
Social Relevance															
Sensitivity															
Measurability															
Interpretability															
Cost Effectiveness															
Availability of Historical Data															
Non-Destructiveness															
Appropriateness of Scale															
Lack of Redundancy															

Each attribute should be scored form 0 to 2, depending on the degree to which the indicator meets the essential and important characteristics.

Table 11. Recommended metrics for various indicators of sediment quality conditions for freshwater environments (Ingersoll and MacDonald 2002).

Ecosystem Health Indicators	Candidate Metrics	Relative Priority
Whole-Sediment Chemistry	Concentration of COPCs	High
	Mean probable effect concentration-quotient	High
	Total organic carbon	High
	SEM minus AVS	Moderate*
	PAH ESBTUs	High
	Pore-water chemistry	Moderate
Whole-Sediment Toxicity	10-day *Hyalella azteca* survival and growth	Moderate
	10-day *Chironomus tentans* survival and growth	Moderate
	28-day *Hyalella azteca* survival and growth	High
	Life-cycle Chironomid test	Moderate*
	In situ toxicity tests	Low
	Microtox®/Mutatox®	Low
Benthic Invertebrate Community Structure	Total abundance	Moderate
	Abundance of key taxa/groups	High
	Diversity	High
	Evenness	Moderate
	Presence/absence of indicator species	Moderate
	Biomass	Moderate*
	Macroinvertebrate index of biotic integrity	High
Pore-Water Chemistry	Concentrations of COPCs	High
	Ammonia	High
	Hydrogen sulfide	High
	BOD	Low
	Dissolved Oxygen	Low
Pore-Water Toxicity	48-hour *Daphnia magna* survival	Low
	7-day *Ceriodaphnia dubia* survival and reproduction	Moderate
	7-day fathead minnow (larval) survival and growth	Low
	Microtox®	Low
Physical Characteristics	Particle size	High
	Sedimentation rate	Moderate
	% Depositional area	Moderate
Elutriate Chemistry	Concentrations of COPCs	High
Elutriate Toxicity	48-h *Daphnia magna* survival	Moderate*
	7-d *Ceriodaphnia dubia* survival and reproduction	Moderate*
	7-d fathead minnow (larval) survival and growth	Moderate*

Table 11. Recommended metrics for various indicators of sediment quality conditions for freshwater environments (Ingersoll and MacDonald 2002).

Ecosystem Health Indicators	Candidate Metrics	Relative Priority
Surface-Water Chemistry	Predicted COPC concentrations (Addams Model)	Moderate*
	Concentrations of COPCs	Moderate*
Water Column Toxicity	96-hr *Selenastrum capricorntum* cell yield and cell density	Moderate*
	48-hr *Daphnia magna* survival	Moderate*
	7-d *Ceriodaphnia dubia* survival and reproduction	Moderate*
	7-d fathead minnow (larval) survival and growth	Moderate*
	96-hr rainbow trout (juvenile) or fathead minnow (juvenile) survival	Moderate*
Water-Sediment Bioaccumulation	Concentrations of COPCs in whole sediment	High
	Concentrations of COPC in *Lumbriculus variegatus* following 28-d exposures	High
	Theoretical bioaccumulation potential	Moderate*
	Concentrations of COPCs in *in situ* macroinvertebrates	High
Fish-Tissue Chemistry	Concentrations of COPCs in whole fish	High
	Concentrations of COPCs in selected fish tissues	High
	Presence of fish consumption advisories	High
Fish Health	Number of preneoplastic and neoplastic lesions in fish livers	High
	Frequency of DELT abnormalities	High
	Frequency of external tumors	High
	Presence of external tumors	High
	P450 activity	Low
	Internal parasite loads in fish	Low
	External parasite loads in fish	Low
Wildlife-Tissue Chemistry	Concentrations of COPCs in bird eggs	High
	Concentrations of COPCs in edible tissues	Moderate*

*represents mofifications from MacDonald and Ingersoll (2002)

COPCs = chemicals of potential concern; SEM = simultaneously extracted metals; AVS = acid volatile sulfides; PAH = polycyclic aromatic hydrocarbons; ESBTU = equilibrium-partitioning sediment benchmark toxic units; BOD = biological oxygen demand; DELT = deformities, fin erosion, lesions, and tumors.

Table 12. Selected toxicity thresholds for whole sediment for evaluating the effects of chemicals of potential concern on the benthic invertebrate community.

Chemical of Potential Concern (COPC)	Selected Toxicity Thresholds	Type	Source
Metals (mg/kg DW)			
Aluminum	58000	ERM	Ingersoll et al. 1996
Antimony	25.0	SEL	NYSDEC 1994
Arsenic	33.0	PEC	MacDonald *et al.* 2000
Barium	60	HTP	USEPA 1977
Cadmium	4.98	PEC	MacDonald *et al.* 2000
Chromium	111	PEC	MacDonald *et al.* 2000
Copper	149	PEC	MacDonald *et al.* 2000
Iron	250000	PEL	Ingersoll et al. 1996
Lead	128	PEC	MacDonald *et al.* 2000
Manganese	1200	PEL	Ingersoll et al. 1996
Mercury	1.06	PEC	MacDonald *et al.* 2000
Nickel	48.6	PEC	MacDonald *et al.* 2000
Silver	2.2	SEL	NYSDEC 1994
Zinc	459	PEC	MacDonald *et al.* 2000
SEM-AVS	0.0		Ankley *et al.* 1996
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg DW)			
Acenaphthene	88.9	PEL	CCME 1999
Acenaphthylene	128	PEL	CCME 1999
Anthracene	845	PEC	MacDonald *et al.* 2000
Benz(a)anthracene	1050	PEC	MacDonald *et al.* 2000
Benzo(a)pyrene	1450	PEC	MacDonald *et al.* 2000
Chrysene	1290	PEC	MacDonald *et al.* 2000
Dibenz(a,h)anthracene	135	PEL	CCME 1999
Fluoranthene	2230	PEC	MacDonald *et al.* 2000
Fluorene	536	PEC	MacDonald *et al.* 2000
2-Methylnaphthalene	201	PEL	CCME 1999
Naphthalene	561	PEC	MacDonald *et al.* 2000
Phenanthrene	1170	PEC	MacDonald *et al.* 2000
Pyrene	1520	PEC	MacDonald *et al.* 2000
Total PAHs	22800	PEC	MacDonald *et al.* 2000
ESBTUs[1]	1.0	FCV	USEPA 2003
Polychlorinated Biphenyls (PCBs; µg/kg DW)			
Total PCBs	676	PEC	MacDonald *et al.* 2000
Aroclor 1248	2400	TET (@ 4% OC)	MEQ/EC 1992
Aroclor 1254	340	PEL	CCME 1999

Table 12. Selected toxicity thresholds for whole sediment for evaluating the effects of chemicals of potential concern on the benthic invertebrate community.

Chemical of Potential Concern (COPC)	Selected Toxicity Thresholds	Type	Source
Organochlorine Pesticides (μg/kg DW)			
Chlordane (total)	17.6	PEC	MacDonald *et al.* 2000
Sum DDD	28.0	PEC	MacDonald *et al.* 2000
Sum DDE	31.3	PEC	MacDonald *et al.* 2000
Sum DDT	62.9	PEC	MacDonald *et al.* 2000
DDT (total)[2]	572	PEC	MacDonald *et al.* 2000
Dieldrin	61.8	PEC	MacDonald *et al.* 2000
Endrin (total)[3]	207	PEC	MacDonald *et al.* 2000
Phthalates (μg/kg DW)			
Bis(2-ethylhexyl)phthalate	4788	SC (@ 4% OC)	Newell 1989
Other COPCS (μg/kg DW)			
Cyanide	0.25	HTP	USEPA 1977
PEC-Q			
20% probability of toxicity	0.22	PEC	MacDonald *et al.* 2000
50% probability of toxicity	0.63	PEC	MacDonald *et al.* 2000

DW = dry weight; NB = no benchmark available; ERM = effects range median;
SEL = severe effect level; PEC = probable effect concentration; HPT = heavily polluted threshold;
PEL = probable effect level; FCV = final chronic value; OC = organic carbon; TET = toxic effect threshold;
SQAL = sediment quality advisory level; FTT = freshwater toxicity threshold; SC = sediment criterion.

SEM-AVS = Simultaneously Extracted Metals minus Acid Volatile Sulphides
ESBTU = Equilibrium Partitioning Sediment Benchmark Toxic Units; BHC = Benzene hexachloride;
DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane.
PEC-Q = Probable Effect Concentration Quotient

NYSDEC = New York State Department of Environmental Conservation; USEPA = United States Environmental Protection Agency
CCME = Canadian Council of Ministers of the Environment; MEQ/EC = Ministere de l'Environnement du Quebec/Environment Canada

[1]For a list of substances that should be used to calculate ESBTUs see Table xx. In this study, ESBTUs were calculated using data on 13 parent PAHs.

[2]Total DDT is the sum of 6 isomers.

[3]Total endrin is the sum of endrin aldehyde and ketone.

Table 13. Selected toxicity thresholds for whole sediment for evaluating the effects of chemicals of potential concern on the fish community.

Chemicals of Potential Concern (COPCs)	Selected Benchmarks	Type	Source
Metals (mg/kg DW)			
Aluminum	NB		
Antimony	25	ERM	Long and Morgan 1991
Arsenic	70	ERM	Long *et al.* 1995
Barium	NB		
Cadmium	9.6	ERM	Long *et al.* 1995
Chromium	370	ERM	Long *et al.* 1995
Copper	270	ERM	Long *et al.* 1995
Iron	NB		
Lead	218	ERM	Long *et al.* 1995
Manganese	NB		
Mercury	0.71	ERM	Long *et al.* 1995
Nickel	51.6	ERM	Long *et al.* 1995
Silver	3.7	ERM	Long *et al.* 1995
Zinc	410	ERM	Long *et al.* 1995
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg DW)			
Acenaphthene	500	ERM	Long *et al.* 1995
Acenaphthylene	640	ERM	Long *et al.* 1995
Anthracene	1100	ERM	Long *et al.* 1995
Benz(a)anthracene	1600	ERM	Long *et al.* 1995
Benzo(a)pyrene	1600	ERM	Long *et al.* 1995
Chrysene	2800	ERM	Long *et al.* 1995
Dibenz(a,h)anthracene	260	ERM	Long *et al.* 1995
Fluoranthene	5100	ERM	Long *et al.* 1995
Fluorene	540	ERM	Long *et al.* 1995
2-Methylnaphthalene	670	ERM	Long *et al.* 1995
Naphthalene	2100	ERM	Long *et al.* 1995
Phenanthrene	1500	ERM	Long *et al.* 1995
Pyrene	2600	ERM	Long *et al.* 1995
Total PAHs	44792	ERM	Long *et al.* 1995
ESBTUs[1]	1.0		USEPA 2003
Polychlorinated Biphenyls (PCBs; µg/kg DW)			
Total PCBs	180	ERM	Long *et al.* 1995
Aroclor 1248	NB		
Aroclor 1254	340	PEL	CCME 1999
Organochlorine Pesticides (µg/kg DW)			
Chlordane (total)	6	ERM	Long and Morgan 1991
Sum DDD	20	ERM	Long and Morgan 1991
Sum DDE	15	ERM	Long and Morgan 1991

Table 13. Selected toxicity thresholds for whole sediment for evaluating the effects of chemicals of potential concern on the fish community.

Chemicals of Potential Concern (COPCs)	Selected Benchmarks	Type	Source
Organochlorine Pesticides (µg/kg DW; cont.)			
Sum DDT	7	ERM	Long and Morgan 1991
DDT (total)[2]	46.1	ERM	Long *et al.* 1995
Dieldrin	8	ERM	Long and Morgan 1991
Endrin (total)[3]	45	ERM	Long and Morgan 1991
Phthalates (µg/kg DW)			
Bis(2-ethylhexyl)phthalate	NB		
Other COPCS (µg/kg DW)			
Cyanide	NB		

DW = dry weight; NB = no benchmark available; ERM = effects range median;
PEL = probable effects level; SQAL = sediment quality advisory level; OC = organic carbon.

SEM-AVS = Simultaneously Extracted Metals - Acid Volatile Sulfides
ESBTU = Equilibrium Partitioning Sediment Benchmark Toxic Units; BHC = Benzene hexachloride;
DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane.
PEC-Q = Probable Effect Concentration Quotient

[1]For a list of substances that should be used to calculate ESBTUs see Table xx. In this study, ESBTUs were calculated using data on 13 parent PAHs.

[2]Total DDT is the sum of 6 isomers.

[3]Total endrin is the sum of endrin aldehyde and ketone.

Table 14. Summary of critical body burdens of selected COPCs in fish tissues. These toxicity thresholds identify concentrations of COPCs that are associated with adverse effects in freshwater, estuarine, or marine fish species.

Chemical of Potential Concern (COPC)	Lowest Observed Adverse Effect Level in Fish Muscle Tissue	Source
Metals (mg/kg WW)		
Cadmium	0.13 [1]	Westernhagen *et al.* 1980
Lead	NB	
Mercury (methyl mercury)	0.7	Niimi and Kissoon 1994
Polychlorinated Biphenyls (PCBs; µg/kg WW)		
Total PCBs	1100 [2]	Orn *et al.* 1998
Aroclor 1016	NB	
Aroclor 1242	NB	
Aroclor 1248	NB	
Aroclor 1254	1530 [3]	Berlin *et al.* 1981
Aroclor 1260	NB	
Aroclor 1268	NB	
Organochlorine Pesticides (µg/kg WW)		
Aldrin + Dieldrin	NB	
Chlordane (total)	NB	
Sum DDD	NB	
Sum DDE	NB	
Sum DDT	NB	
DDT (total) [4]	165 [5]	Pandian and Bhaskaran 1983
Dieldrin	NB	
Endrin (total) [6]	120	Bennett and Day 1970
PCDDs and PCDFs (ng/kg WW)		
2,3,7,8-TCDD Toxic Equivalents (TEQs)	116 [3]	Walker *et al.* 1994

WW = wet weight; NB = no benchmark available.

DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene;
DDT = Dichlorodiphenyltrichloroethane; PCDD = Polychlorinated dibenzo-*p*-dioxin;
PCDF = Polychorinated dibenzofuran; TCDD = Tetrachlorodibenzo-*p*-dioxin.

[1]Converted from dry weight to wet weight (0.2 factor; Stephen *et al.* 1985).
[2]Benchmark was for whole body, but was applied to muscle tissue (resulted in signficantly reduced ovary weight).
[3]Benchmark was for whole body, but was applied to muscle tissue.
[4]Total DDT is the sum of 6 isomers.
[5]The LOEL for Total DDT is the arithmetic mean of the range of values provided.
[6]Total endrin is the sum of endrin aldehyde and ketone.

Table 15. Selected bioaccumulation-based sediment quality criteria (SQC) for the protection of aquatic-dependent wildlife (from NYSDEC 1999).

Chemical of Potential Concern (COPC)	Selected SQCs	Water Type
Metals (mg/kg OC)		
Cadmium	NB	
Lead	NB	
Mercury (Methyl mercury)	NB	
Polychlorinated Biphenyls (PCBs; µg/kg OC)		
Total PCBs	1400	FW/SW
Aroclor 1016	NB	
Aroclor 1242	NB	
Aroclor 1248	NB	
Aroclor 1254	NB	
Aroclor 1260	NB	
Aroclor 1268	NB	
Organochlorine Pesticides (µg/kg OC)		
Aldrin + dieldrin	770	FW/SW
Chlordane (total)	6	FW/SW
Sum DDD	NB	
Sum DDE	NB	
Sum DDT	NB	
DDT (total)[1]	1000	FW/SW
Dieldrin	NB	
Endrin (total)[2]	800	FW
PCDDs and PCDFs (ng/kg OC) [3]		
2,3,7,8-TCDD Toxic Equivalents (TEQs) - mammalian	833	FW/SW
2,3,7,8-TCDD Toxic Equivalents (TEQs) - avian	7000	FW/SW

OC = organic carbon; NB = no benchmark available; FW = freshwater; SW = saltwater.

DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene;
DDT = Dichlorodiphenyltrichloroethane; PCDD = Polychlorinated dibenzo-*p*-dioxin;
PCDF = Polychorinated dibenzofuran; TCDD = Tetrachlorodibenzo-*p*-dioxin.

[1]Total DDT is the sum of 6 isomers.

[2]Total endrin is the sum of endrin aldehyde and ketone.

[3]The selected benchmarks are the high risk thresholds from USEPA 1993 (high risk concentrations were derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species).

Table 16. Summary of toxicity thresholds for aquatic-dependent wildlife for chemicals of potential concern in Presque Isle Bay. Toxicity thresholds identify the concentrations of COPCs in fish that represent lowest observed adverse effect levels (LOAELs) for various groups of wildlife receptors (with focal species in parentheses; from Sample *et al.* 1996).

Chemical of Potential Concern (COPC)	Avian Receptor Groups	Mammalian Receptor Groups
	Piscivorous *(Kingfisher)*	Piscivorus Mammals *(Otter)*
Metals (mg/kg WW)		
Cadmium	39	39
Lead	NB	NB
Mercury (Methyl mercury)	0.13	0.13
Polychlorinated Biphenyls (PCBs; µg/kg WW)		
Total PCBs	NB	720
Aroclor 1016	NB	18000
Aroclor 1242	NB	1400[A]
Aroclor 1248	NB	600[A]
Aroclor 1254	3600	600[A]
Aroclor 1260	NB	NB
Aroclor 1268	NB	NB
Organochlorine Pesticides (µg/kg WW)		
Aldrin + Dieldrin	NB	NB
Chlordane (total)	21000	20000
Sum DDD	NB	NB
Sum DDE	NB	NB
Sum DDT	NB	NB
DDT (total)[1]	55	16000
Dieldrin	NB	810
Endrin (total)[2]	200	2000
PCDDs and PCDFs (ng/kg WW)		
2,3,7,8-TCDD Toxic Equivalents (TEQs)	60[B]	12.6[C]

WW = wet weight.

DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene;
DDT = Dichlorodiphenyltrichloroethane; PCDD = Polychlorinated dibenzo-*p* -dioxin;
PCDF = Polychorinated dibenzofuran; TCDD = Tetrachlorodibenzo-*p* -dioxin.

[A]This benchmark is from (Chapman 2003).

[B]This benchmark is the high risk thresholds from USEPA (1993; high risk concentrations were derived from TCDD doses expected to cause 50 to 100% mortality in embryos and young of sensitive species).

[C]This benchmark is from Tillitt *et al. (* 1996).

[1]Total DDT is the sum of 6 isomers.

[2]Total endrin is the sum of endrin aldehyde and ketone.

Table 17. Candidate sediment quality targets for Presque Isle Bay Area of Concern.

Sediment Management Objective	Key Sediment Quality Indicators	Candidate Metrics	Candidate Delisting Target
Protection of Benthic Invertebrate Community	Whole-Sediment Chemistry (surficial)	Mean PEC-Q	< 1.0 (USEPA 2000b)
		PAH ESBTU	< 1.0 (USEPA 2003)
		SEM-AVS	< 0.0
	Whole-Sediment Toxicity (surficial)	28-d *Hyalella azteca* survival	>90% (CAS; USEPA 2000)
Protection of Fish Community	Whole-Sediment Chemistry (surficial)	COPC concentration	> SQGs for < 5 COPCs (MacDonald *et al.* 2005)
	Fish-Tissue Chemistry	COPC concentration	< TRGs (background; Jarvinen and Ankley 1999)
	Fish Health	External Tumor Freqency in BB	~5% of fish with external tumors
Protection of Wildlife Community	Whole-Sediment Chemistry (surficial)	COPC concentration	< SQGs (NYSDEC 1999)
	Fish-Tissue Chemistry	COPC concentration	< TRGs (background; Sample *et al.* 1996)
Protection of Human Health and Human Uses	Fish-Tissue Chemistry	COPC concentration	< TRGs (USFDA 2000)
Eliminate Restrictions on Dredging	Elutriate Chemistry (dredging depth)	COPC concentration	< 1.5X of Lake Erie Background < PA WQSs

COPC = chemical of potential concern; SEM = simultaneously extracted metals; AVS = acid volatile sulfides; SQGs = sediment quality guidelines;
PAH = polycyclic aromatic hydrocarbons; ESBTU = equilibrium-partitioning sediment benchmark toxic units; TRGs = tissue residue guidelines;
PEC-Q = probable effect concentration-quotient; BB = ???

Figures

Figure 1. Map of the Presque Isle Bay Area of Concern (AOC).

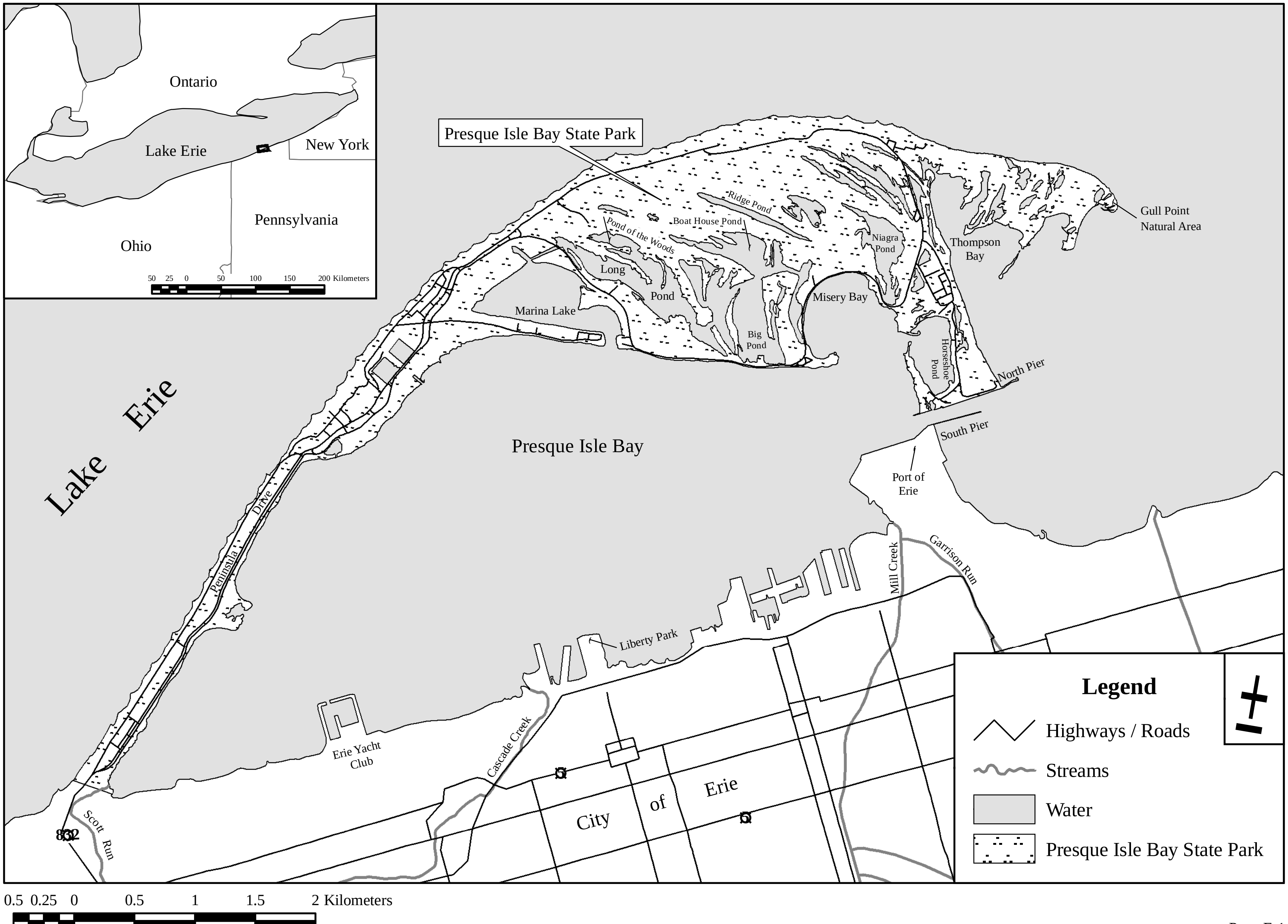


Figure 2. Conceptual model diagram illustrating exposure pathways and potential effects for all categories of COPCs.

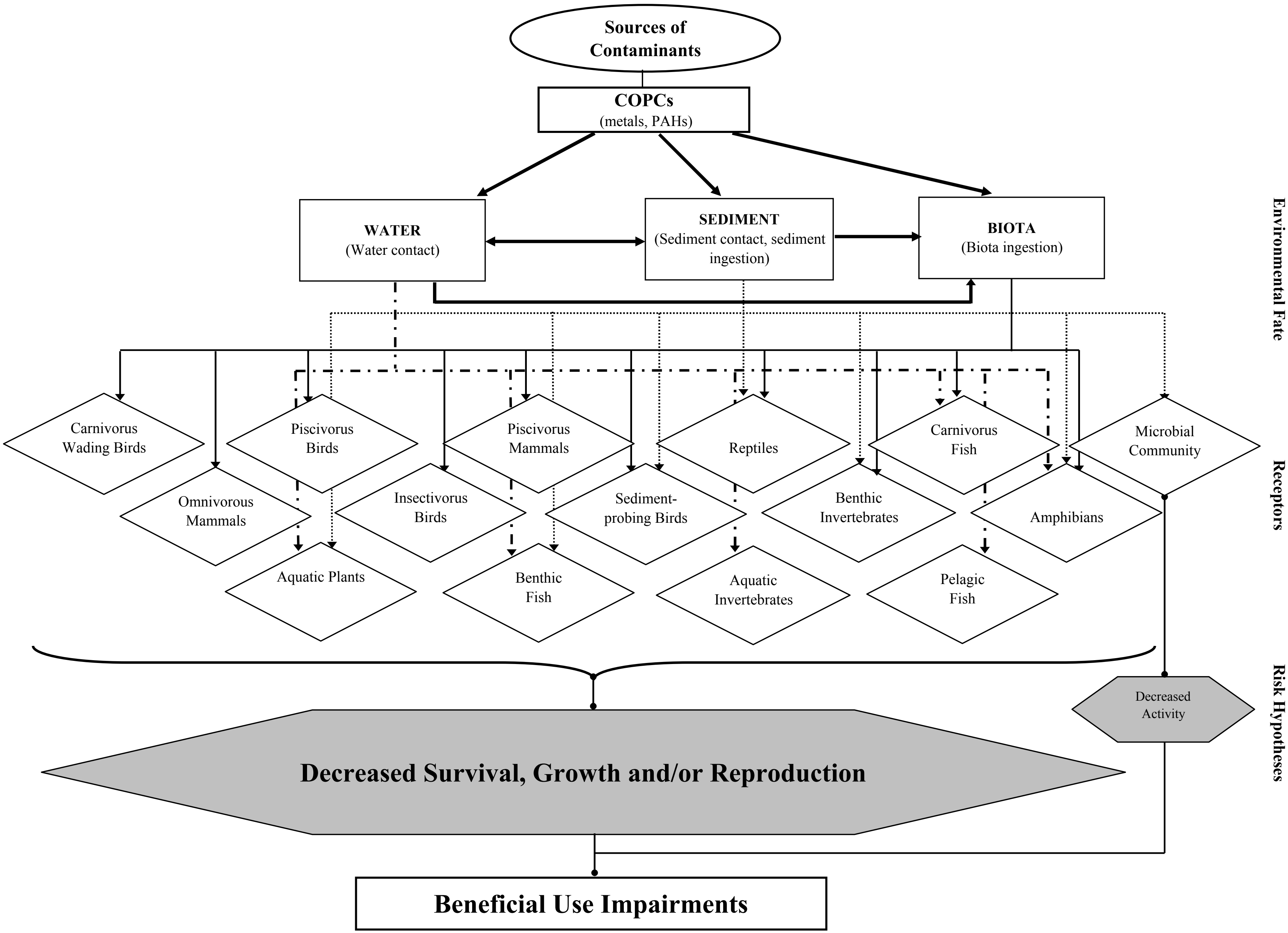
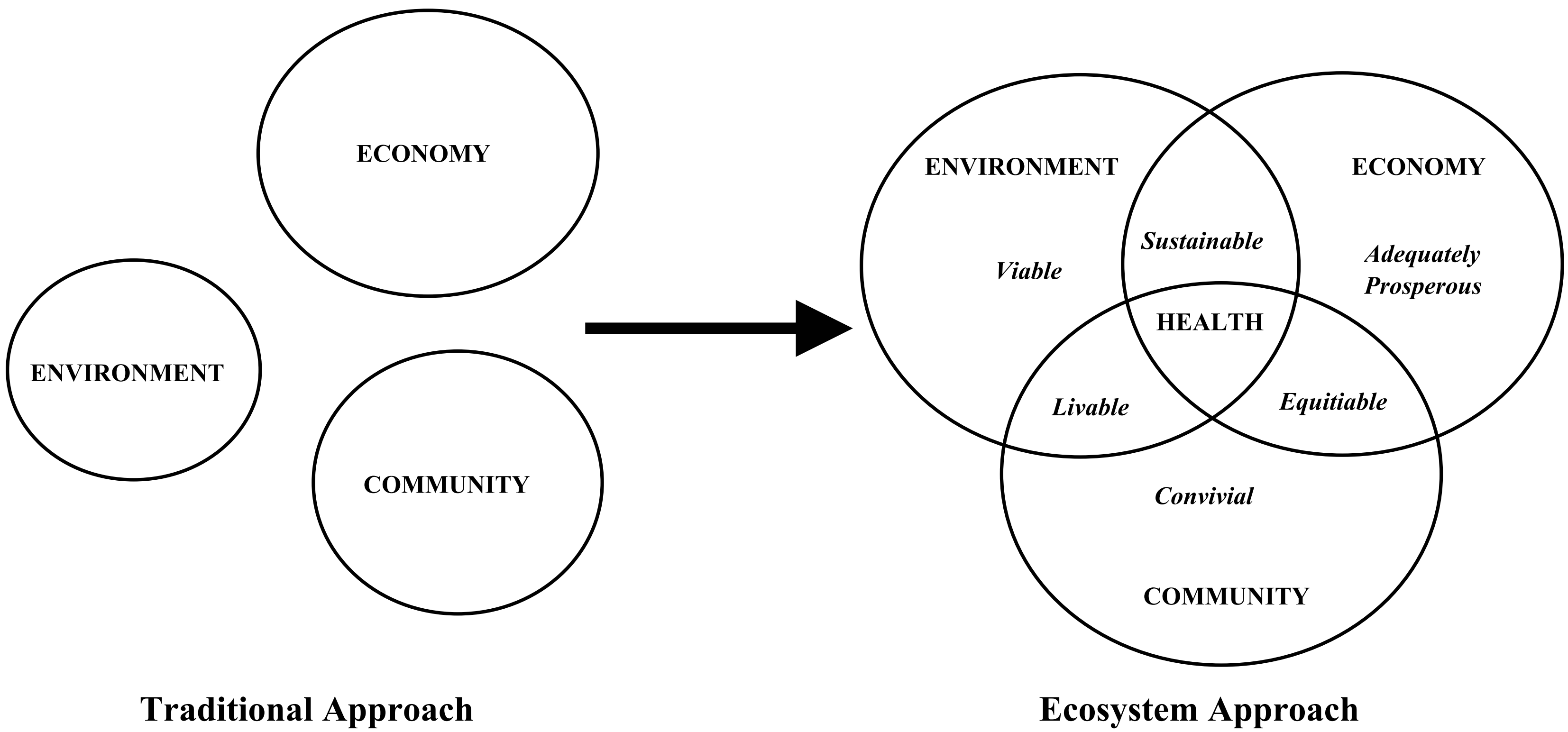


Figure 3. The shift from traditional to ecosystem-based decision making (from CCME 1996).



Relationships within ecosystems can best be visualized as three interlocking circles: environment, economy, and community. Traditionally most decision making separates these three components, with little understanding (or even heed), for example, of the effects of economic decisions on community needs or the environment. The challenge now is two-fold: to understand the links between these components and to redress the balance among them. The ecosystem approach requires an equal and integrated consideration of these elements.

Figure 4. A framework for ecosystem-based management (from CCME 1996).

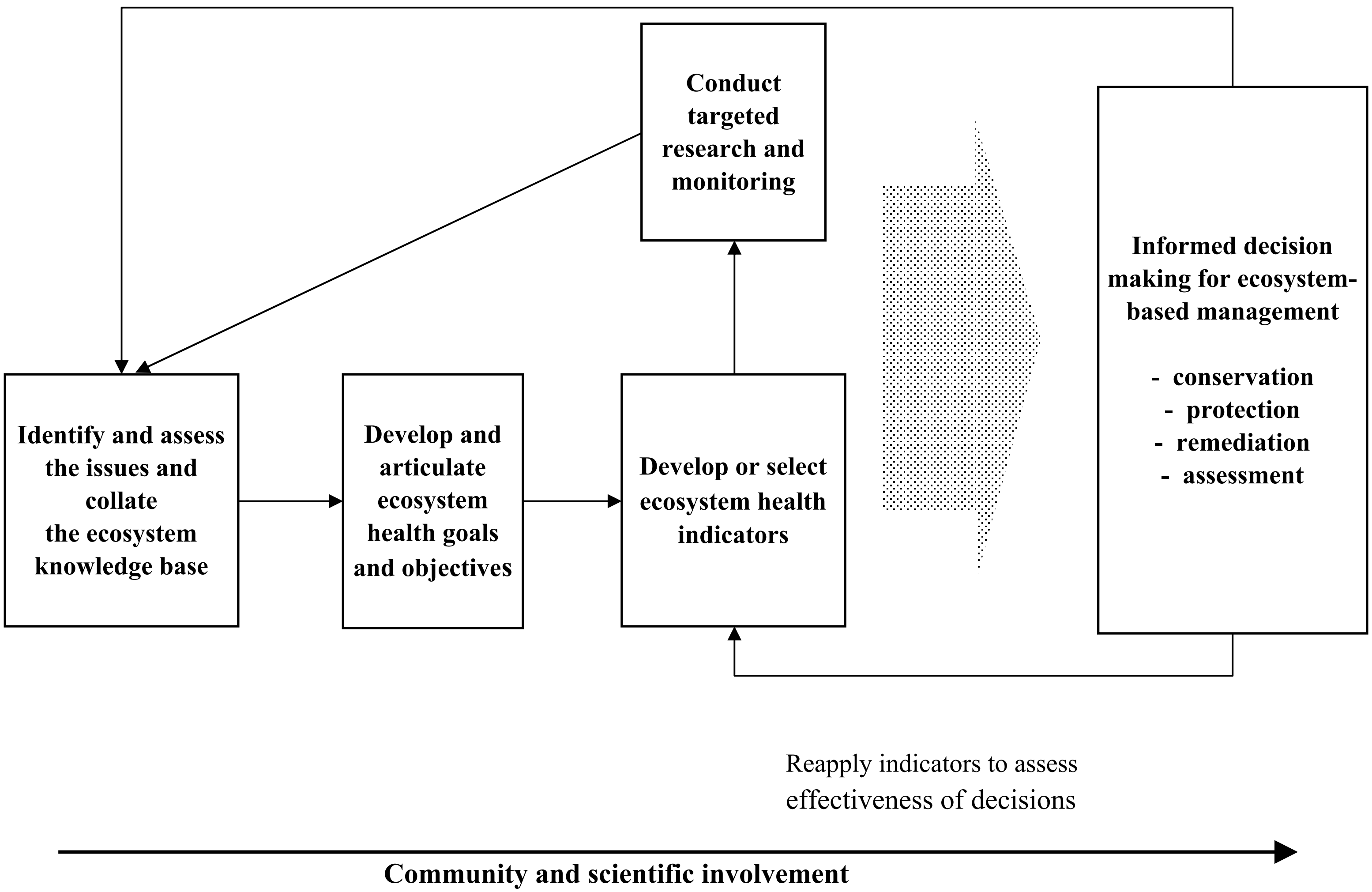


Figure 5. Relationship between ecosystem goals, objectives, indicators, metrics, and targets.

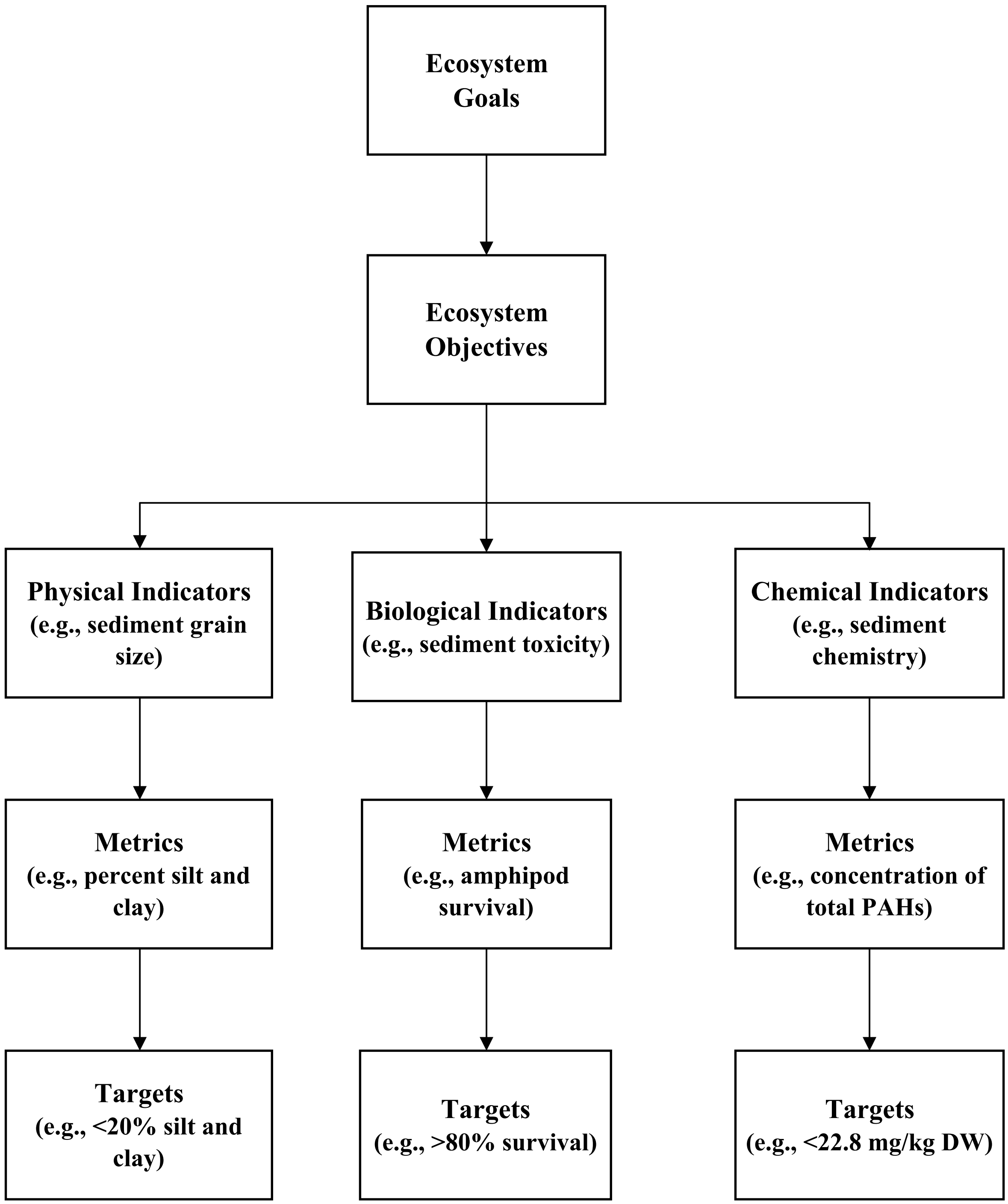


Figure 6. An overview of the implementation process for the ecosystem approach to environmental management.

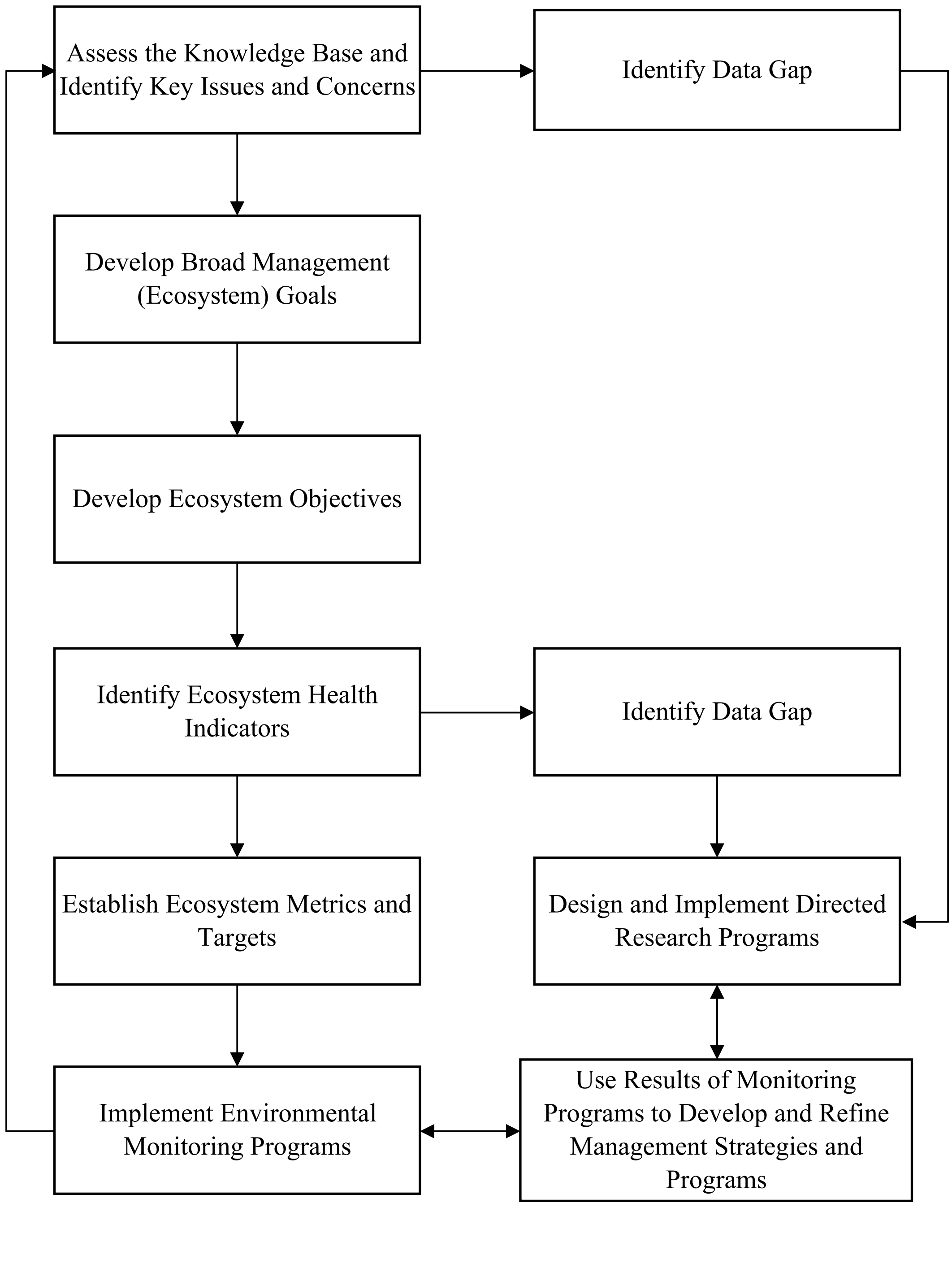


Figure 7. Process for confirming restoration of beneficial use impairments (IJC 1991).