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Acknowledgments

The Lake Michigan Management Plan 2000 was developed by the Lake Michigan Technical Committee with assistance from the Lake Michigan Forum and various other agencies and organizations. The LaMP benefited from the publicly and privately funded research of many institutions, results of pilots and projects and generous critiques throughout the process. This effort and incomplete list of contributors proves our goal to restore and protect the integrity of the Lake Michigan ecosystem through *collaborative*, *placed-based partnerships*.

Agency for Toxics Substances and Disease Registry
Chippewa-Ottawa Treaty Fishery Management Authority
Grand Traverse Band of Ottawa and Chippewa Indians
Illinois Environmental Protection Agency
Indiana Department of Environmental Management
Michigan Department of Environmental Quality
Oneida Tribe, Wisconsin
Wisconsin Department of Natural Resources
U.S. Army Corps of Engineers
U.S. Department of Agriculture, Natural Resource Conservation Service
U.S. Environmental Protection Agency (Region 5, Great Lakes National Program Office, Office of Research and Development)
U.S. Fish and Wildlife Service
U.S. Geological Survey

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Preface:
Lake Michigan Lakewide Management Plan

Introduction

One of the most significant environmental agreements in the history of the Great Lakes was the signing of the Great Lakes Water Quality Agreement (GLWQA) between the United States and Canada. This historic Agreement committed the U.S. and Canada (the Parties) to address the water quality issues of the Great Lakes in a coordinated, joint fashion.

Under the GLWQA as amended in 1987, the United States and Canada agreed "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." To achieve this purpose, the Parties agreed to develop and implement, in consultation with state and provincial governments, Lakewide Management Plans (LaMP) for open waters and Remedial Action Plans (RAP) for Areas of Concern (AOC). The LaMPs are intended to identify the critical pollutants that affect the beneficial uses of the lake and to develop strategies, recommendations, and policy options to restore those beneficial uses. Moreover, the Specific Objectives Supplement to Annex 1 of the GLWQA requires the development of Ecosystem Objectives for the lakes as the state of knowledge permits. Annex 2 further indicates that the RAPs and LaMPs "shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses . . . [and] are to serve as an important step toward virtual elimination of persistent toxic substances . . ."

In the case of Lake Michigan, the only Great Lake wholly within the borders of the United States, the Clean Water Act holds the U.S. Environmental Protection Agency (EPA) accountable for the LaMP. EPA has chosen a collaborative approach to the implementation of this responsibility, and a partnership of federal, state, tribal, and local governments in the basin is working with stakeholders in the Lake Michigan Forum to develop and implement the LaMP. The LaMP document serves as the guide to a continuing process of collaborative ecosystem management and partnership activities aimed at achieving the LaMP goals and restoring the 14 beneficial use impairments outlined in the GLWQA. LaMPs are to be completed in four stages: (1) when problem definition has been completed, (2) when the schedule of load reductions has been determined, (3) when remedial measures are selected, and (4) when monitoring indicates that the contribution of the critical pollutants to impairments of beneficial uses has been eliminated. These stage descriptions suggest a LaMP focused solely on the impact of critical pollutants. However, problem definition work revealed other major stressors, in addition to the critical pollutants, impacting the ecosystem. These findings indicated the need to go beyond the requirement that LaMPs address critical pollutants to integrate environmental protection and natural resource management in the process.

The LaMP process has proven to be a resource-intensive effort and has taken much longer than expected. As a result, the public has waited years for a document to review. This has created the impression that actions were delayed pending a completed document. In the interest of advancing the rehabilitation of the Great Lakes and to provide information to the public in a more timely manner, the Binational Executive Committee (BEC) resolved in 1999 to accelerate the LaMP effort (BEC 1999). Acceleration was defined as an emphasis on taking action based on the current body of knowledge and adopting a streamlined LaMP review and approval process. The LaMPs were directed to treat the stages of problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential one. Consistent with the BEC resolution, the LaMPs contain appropriate funded and proposed (non-funded) remediation, restoration, and protection actions for actual improvement of the ecosystem. The LaMP includes examples of commitments by government, tribes, and nongovernment partners.

The BEC also recommended taking an iterative approach with periodic refinements based on the lessons, successes, new information, and public input generated. This adaptive management approach applied to the LaMP process will result in adjustments over time to address the most pertinent issues facing the lake ecosystem. This process begins with LaMP 2000, with LaMP updates planned every 2 years. The LaMPs are presented in a loose-leaf format that can be inserted in a three-ringed binder, which allows for easy updates, additions of new material, and removal of outdated information. The LaMPs for Lake Erie, Lake Michigan, and Lake Superior have common chapter components, but they differ in format and their amount of detail. Some chapters are incomplete, have identified data gaps, or are presented as drafts. It is intended that comments received will fill such gaps and that draft material will be finalized for LaMP 2002. With the help of the many partners and the public, we will be able to take the best qualities from each LaMP and design more concise and user-friendly LaMPs in 2002.

A Focus on Ecosystems

According to the Federal Interagency Ecosystem Management Task Force an *ecosystem* is defined as follows:

> . . . an interconnected community of living things, including humans, and the physical environment with which they interact. As such, ecosystems form the cornerstones of sustainable economies. The goal of the ecosystem approach is to restore and maintain the health, sustainability, and biological diversity of ecosystems while supporting sustainable economies and communities. Based on a collaboratively developed vision of desired future conditions, the ecosystem approach integrates ecological, economic, and social factors that affect a management unit defined by ecological - not political - boundaries (1995).

The foundation of the ecosystem approach is relating human beings and their activities to the ecosystems that contain them.

A Focus on Partnerships

Each government, institution, organization, and individual within the Lake Michigan basin has a potential role in the stewardship of the ecosystem; however, no single government, institution, organization, or individual has the capacity to implement stewardship and achieve sustainability in the basin as a unilateral action.

The past decade has seen a profound shift from a top-down, command and control, government-dominated approach to a bottom-up, partnership-based, inclusive approach. This evolution is the manifestation of a number of changes including federal, state, and local relationships; local community empowerment; increased demands on local partners; and watershed-based institution building. In other words, if a sustainable Lake Michigan ecosystem is to be achieved, it falls to us to rearrange ourselves, our interest groups, and our governments into a new institutional framework–a framework that consists of existing organizations and governments "rafted" together as full partners in the implementation of the LaMP goals.

The idea of "rafting" originates with river rafting parties that often lash their rafts together to navigate rapids that pose a threat to single vessels. In the field of organizational management, this metaphor describes the development of partnerships of organizations brought together to solve problems too complex to be dealt with by a single organization or agency. The rafting of organizations is important at the local level because of the potential to leverage and direct local, state, and federal resources into coordinated management efforts. In addition, many issues critical to ecosystem integrity in the basin, such as nonsustainable land use, habitat loss, and nonpoint source pollution, fall into the gaps within and between existing federal, state, and local programs. Rafted organizations with diverse memberships have the expanded strength and capacities to address these gaps.

Effective place-based partnerships are the result of the rafting of **"full partners."** Full partners may be governments, organizations, interest groups, and individuals who act in collaboration with one another to achieve sustainable landscapes. Full partnership implies moving beyond the stakeholder model, wherein citizen committees (stakeholder groups) are briefed about agency plans and projects to a model based on full collaboration in the definition of sustainable landscape goals and the sharing of resources to achieve these goals. The challenge is to create the framework for participating organizations to contribute their expertise and resources, often on an uneven basis, but in a manner that allows all partners to participate in the decision-making on an even basis.

A Focus on Balance–Sustainable Landscapes

The interdependencies inherent in the ecosystem perspective require a balance between three fundamental elements: *environmental integrity, economic vitality, and sociocultural well being.* The ability of these elements to function in balance across time is a measure of *sustainability*. The ecosystem perspective requires a shift of focus from resource programs to resource systems. It places human activities and communities within an ecosystem and, consequently, within ecosystem management. It recognizes that human beings and their activities are part of the ecosystem and that they affect and are affected by its health. The goals of this LaMP are comprehensive concerns–such as the loss of critical habitats, decreasing biodiversity, nonsustainable land use, nuisance species, and threats to human health join the initial emphasis on critical pollutants.

The LaMP identifies the goals, necessary partnerships, and locations where ecosystem management must occur in order to attain sustainable landscapes in the Lake Michigan basin. Sustainable landscapes are local ecosystems that are healthy enough to provide a range of valuable benefits and services, both now and in the future. Such benefits and services to humans include the following:

- *Moderating natural events and human activities.* Healthy landscapes can make communities safer and more livable by tempering the effects of natural events and human activity. For example, wetland systems can absorb and store storm waters and thereby aid in flood control and ensure more routine flows and water levels in streams.

- *Enhancing social well-being.* Healthy landscapes provide services that make communities more enjoyable and rewarding. For example, they provide opportunities for outdoor recreation. To many, they also serve as a source of civic pride and personal and spiritual well-being.

- *Supporting local economies.* In sustainable landscapes, people meet the needs of the present without compromising the ability of future generations to meet their needs.

A Focus on Shared Information

Key to the engagement of a number of partners is the need for a common, accessible and scientific sound body of knowledge. It requires open dialogue between academia and agencies. It also necessitates a collaborative plan for monitoring in order to ensure currency in the knowledge base.

The LaMP is both a reference document and a proposal for a process to remediation of past errors and the achievement of sustainable integrity in the basin ecosystem. To this end, every effort has been made to insure that this LaMP contains clear, comprehensive goals, specific objectives, a strategic plan, and a system of indicators and monitoring for use in judging environmental status and effectiveness of current actions. It is also meant to serve as the foundation upon which can be built multi-disciplinary, place-based, public-private partnerships–the institutional arrangements required for the implementation of the plan and achievement of its goals.

A Focus on the Future

Finally, it is critically important to recognize that local partnerships cannot develop and prosper without resources. Partnerships provide capacities that extend beyond those possessed by their individual members. These capacities–the ability to conduct coordinated ecological assessments; to set shared goals, objectives, and indicators; and to align systems, plans and budgets–are recognized as necessary prerequisites for achieving the LaMP vision. This recognition must be accompanied by appropriate support and resources. Certain activities fall within the mission of governmental agencies that have a resource base of staff and funds. Other activities will be privately funded, and some may need to have diverse funds "rafted" together.

It is perhaps fitting that this version of the Lake Michigan LaMP will foster discussion and initial implementation during the first years of the new millennium, for just as the year 2000 serves as a symbolic point of historical demarcation, so too does this document and the process that it describes point to a new page in the management history of Lake Michigan. Because LaMP 2000 has embraced the goal of a sustainable Lake Michigan ecosystem, much of the required work will need to be accomplished by partnerships in local communities. The ability of these partnerships to achieve this goal will depend on the support of federal and state initiatives, programs, and resources as well as the committed engagement of the private sector on both the local and regional level. The extent to which this engagement provides such support for *place-based partnerships*, *ecosystem management*, and *sustainability* will determine the ability of the LaMP process to achieve its goal.

Executive Summary
Lake Michigan Lakewide Management Plan

One of the most significant environmental agreements in the history of the Great Lakes was the signing of the Great Lakes Water Quality Agreement (GLWQA) in 1972 between the United States and Canada. This historic Agreement committed the U.S. and Canada (the Parties) to address the water quality issues of the Great Lakes in a coordinated, joint fashion.

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In the case of Lake Michigan, the only Great Lake wholly within the borders of the United States, the Clean Water Act holds the U.S. Environmental Protection Agency (EPA) accountable for the LaMP. EPA has chosen a collaborative approach to the implementation of this responsibility, and a partnership of federal, state, tribal, and local governments in the basin is working with stakeholders, Lake Michigan Forum, to develop and implement the LaMP. The LaMP document serves as the guide to a continuing process of collaborative ecosystem management and partnership activities aimed at achieving the LaMP goals and restoring the 14 beneficial use impairments outlined in the GLWQA. The LaMPs are to be completed in four stages: 1) when problem definition has been completed; 2) when the schedule of load reductions has been determined; 3) when remedial measures are selected; and 4) when monitoring indicates that the contribution of the critical pollutants to impairments of beneficial uses has been eliminated. These stage descriptions suggest a LaMP focus solely on the impact of critical pollutants. However, problem definition work revealed major stressors in addition to the critical pollutants impacting the ecosystem. These findings clearly indicated the need to go beyond the requirement that LaMPs address critical pollutant to integrate environmental protection and natural resource management.

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The Lake Michigan LaMP work began in the early 1990s with a focus on critical pollutants just as monitoring showed that regulatory controls put into place in the late 1970's and 1980's were successfully reducing the levels of persistent toxic substances such as PCBs, mercury, dioxin, and pesticides. Monitoring also provided insights on system stress from nonpoint source pollution as well as aquatic nuisance species. The LaMP Committees, addressing all stressors, developed a set of ecosystem goals and objectives in 1998. The Lake Michigan LaMP states that "pathogens, fragmentation and destruction of terrestrial and aquatic habitats, exotic nuisance species, uncontrolled runoff and erosion are among the stressors contributing to ecosystem impairments."

In the 1994 SOLEC Integration Paper developed by EPA and Environment Canada it is stated:

> Governments have traditionally addressed human activities on a piecemeal basis, separating decision making on environmental quality from decision making on natural resource management or on social or economic issues … An ecosystem approach to management is a holistic approach that recognizes the interconnectedness of and addresses the linkages occurring among air, water, land, and living things.

Status of the Lake

Lake Michigan is an outstanding natural resource of global significance, under stress and in need of special attention.

Lake Michigan supports many beneficial uses: drinking water for 10 million, internationally significant habitat and natural features; food production and processing; fish for food, sport and culture; and valuable commercial and recreational uses. The quality and quantity of the Great Lakes has attracted proposals to export the water and has begun an international discussion on bulk water exports.

Despite 20 years of regulation that brought about overall reduction in conventional and toxic pollutants loads, data indicate pollutants still exert negative impacts on the chemical, physical and biological components of the Lake Michigan ecosystem. The remaining toxic challenges are significantly related to legacy contamination that results in fish consumption advisories, and impairment to aquatic organisms and wildlife. Nonpoint source pollution results in episodic beach closures, and drinking water impacts, and pesticides have been detected in the open water.

The long-range transport of both airborne pollutants and non-native species into the ecosystem pose serious environmental, as well as national and international management issues. The irreversible damage from aquatic nuisance species demands immediate attention across the basin and nation. The zebra mussel is an example of an organism that has caused physical chemical and biological damage by closing water in-take pipes, concentrating contamination, disrupting the food web of the lake, and competing for food needed by native species.

Habitat

The Lake Michigan ecosystem is a composite of a number of subecosystems and habitats: atmosphere/climate, open water, wetlands, tributaries and coastal systems. Many of these habitats rank as globally rare or imperiled due to restricted distribution, level of threat, ecological fragility, widespread damage or because they are part of the single largest source of fresh surface water in the world.

Open Lake System

The aquatic ecosystem of Lake Michigan has experienced profound changes in the past 140 years. The current status of the ecosystem is changing and heavily dependent on human management in the form of the stocking of predator fish. Any assessment of the status and trends of ecosystem health must begin with an understanding of the loss of habitat, biological diversity and subsequent establishment of non-indigenous populations.

The plankton communities (phytoplankton and zooplankton) of Lake Michigan are the base of the food web and therefore are one of the most important components of the lake's ecosystem. The abundance and types of phytoplankton are highly variable within the lake depending on time of year, area of the lake and availability of phosphorous and other nutrients. The amount of phosphorous has been the largest man-induced change to phytoplankton communities, especially in nearshore areas. Changes to plankton communities may also be occurring as a result of exotic species such as the spiny water flea (*Bythotrephes cederstroemi*) and the zebra mussel (*Dreissena polymorpha*). Many species of non-indigenous algae have also been introduced into Lake Michigan and studies indicate that increased salinity and other environmental changes are enabling introduced algae to adapt more readily to the environment of the Great Lakes. Zooplankton includes many different invertebrates and fish fry and comprises the bulk of the diet of planktivorous fish. Because most zooplankton feed on phytoplankton, their abundance and geographic occurrence are similarly dependent upon water temperature, seasonal changes and availability of food. Research conducted in the past 15 years also indicates that zooplankton populations may be experiencing changes induced by *Bythotrephes*. Dramatic declines in local *Daphnia* have coincided with increases in *Bythotrephes* populations.

Lake Michigan benthic or lake bottom communities are also under stress. Studies suggest that zebra mussels are having a significant impact on benthic community structures and plankton abundance. Zebra mussels, which can attach themselves to any hard surface in the lake, have reached densities higher than $16{,}000/m^2$ in southern Lake Michigan. Negative impacts include increased competition for plankton at the expense of fry from nearshore species (such as yellow perch), increased biomagnification of contaminants in piscivores feeding on benthivores and possible zebra mussel induced mycrocystis blooms.

Fish communities represent the highest trophic levels within the Lake Michigan aquatic ecosystem. They are also the most visible indicators of the health of the ecosystem and represent, to most people one of the most important resources of the lake. The alteration of fish communities has been the most obvious impairment to the aquatic ecosystem in Lake Michigan. The current status of the fish community is dependent upon human management by the various agencies responsible for the fisheries of Lake Michigan.

Multiple stressors continue to degrade the open lake system. Toxic chemicals contaminate water and sediment quality. Fish advisories are still in effect. Some beaches, particularly in the southern part of the lake, are closed episodically. Aquatic habitats do not naturally sustain healthy and diverse fish communities. Exotic species continue to disrupt native plant and animal communities. Unsustainable human activities, like habitat destruction resulting from urban sprawl and construction and sand mining in dune areas or other coastal regions, continue to threaten the ecosystem. Overall, ecosystem stewardship activities are currently not sufficient to overcome human-induced stressors.

Coastal and Inland Wetland System

The coastal wetland system supports the greatest diversity and biological productivity in the basin. Wetlands are important because they collect nutrients and organic materials that are washed off the land into tributaries. Tributaries carry the materials to the lake, where they are deposited on the shore by longshore currents. These materials support both the aquatic food web and habitat for bird, mammal, reptile, amphibian, and invertebrate resident and migratory species. Migratory birds use coastal wetlands as staging and feeding areas. Both lake level fluctuations and longshore sediment transport are important in maintaining this highly productive system because of their roles in bringing the materials needed to nourish and protect it.

The diverse coastal wetland is habitat for numerous species of wildlife dependent on wetlands. Many insects have an aquatic larval stage; amphibians also depend on wet conditions, at least during the larval stage. Many reptiles spend their entire lives in or near these coastal wetlands.
Most Lake Michigan fish also spend a portion of their life cycle in coastal wetlands when they move to the shallow, wetland waters to spawn. Fish have very specific spawning needs: a certain kind of substrate, current, water depth, and temperature available during a specific timeframe. Fish often return to the same places where they hatched. Similar to waterfowl, spawning fish populations become concentrated in a small area of habitat. For those spawning populations, the spawning habitats become far more important than their relative size would suggest. Although artificial reefs have been created in marine waters and in small freshwater lakes and reservoirs for decades, their effectiveness as a fishery management technique in the Great Lakes is still being evaluated. Three of eleven intentionally-placed artificial reefs in the Great Lakes are found in Lake Michigan.

The inland wetland system – wetlands away from the Lake Michigan shoreline – is the reservoir for water in the Lake Michigan drainage basin. There are many types of inland wetlands, including fens, bogs, wet meadows, and wet forests. The health of inland wetlands is dependent on the quantity and quality of groundwater and surface water. Inland wetlands help to regulate the basin's volume of water, as well as sediment and certain pollutant loads. They also store nutrients and serve as the nutrient exchange vehicle for the diversity of species which use inland wetlands as habitat and feeding areas. Both wetland and upland species breed and feed in Lake Michigan's inland wetlands.

Millions of acres of inland wetlands have been lost in the Lake Michigan basin to agriculture, industry and urban development. Over the last two centuries, wetland losses in the four states at least partially within the Lake Michigan basin have been disproportionately greater than in many other U.S. regions. Since the 1780s, Lake Michigan basin states have lost an estimated 21.9

million (62.9 percent) acres of wetlands out of their 34.8 million original wetland acres. This compares with an average loss of 52.8 percent nationwide. There are an estimated 12.9 million acres of wetland remaining in the four states, representing more than 12.3 percent of the wetlands within the lower 48 states.

Coastal Shore System: Sand Dunes

From northern Indiana and continuing northeasterly into Michigan, the most colossal shore feature in all the Great Lakes is apparent: the massive coastal dunes that flank the shore. The dunes were formed following the last glaciation and are 2,500 to 10,000 years old. They run along the entire shore to heights of 300 feet and widths of more than one mile, except when interrupted by river valleys, cities, and roads. The Lake Michigan dunes are numerous, diverse, and irreplaceable.

The dunes are subjected to residential development with summer homes and permanent residences, often very close to the shore. Ancient high lake levels formed the beach ridges, and as the lake receded, the prevailing on-shore winds continued to blow beach sand up the slopes. Lake Michigan is now home to the largest collection of freshwater sand dunes in the world.

Dune and swale or ridge and swale community complexes are found in several places through the Lake Michigan basin. They were formed as the ancestral Great Lakes receded. In the south, the dunes or ridges stretch parallel to the Lake Michigan shore and are rich in oak savanna species. The wet swales between these ridges support rich prairies and sometimes rare coastal plane marsh communities. In the north, ridges are typically dominated by red and white pine and other conifers, and the swales by white cedar swamps or sedge meadows.

On the eastern shore of Lake Michigan an invasive non-indigenous species is threatening dune ecosystems. Baby’s breath is moving into sensitive areas and out-competing native species. Control measures such as hand pulling and herbiciding are being utilized at Point Betsie and at the outskirts of Sleeping Bear Dunes National Lakeshore.

The coastal system is also home to prime waterfowl habitat. Diminished populations of top predators such as bald eagles and osprey have made a come back while some species still experience localized deformities and reproductive problems. Gulls, geese, and cormorants are now numerous in the basin, necessitating studies of possible management options.

Coastal Shore System: Global Climate Change

Global warming resulting from human activities poses the threat of increased temperatures and changing precipitation rates. Shorelines could change quickly, submerging or exposing ecosystems accustomed to harshness and variability but unable to cope with rapid change. An abrupt change in climate could prevent ecosystems that now survive in small, isolated areas from adapting.

Of particular concern are the predictions of poorer water quality and shifts in species composition. Increases in fish yields (warm water species) will be concurrent with eutrophic-like conditions and increased contaminant loading and bioavailability. While a warmer climate will provide longer seasons for agriculture and commercial shipping, changes in seasonal runoff patterns, decreases in total basin moisture and lake level decline will have negative consequences. Lake level decline will also result in significant loss, migration and changes in wetlands. Most impact assessment efforts have been concentrated on physical responses. The biological consequences of the physical responses to climate change have yet to be seriously explored.

Tributary System

Tributary streams and rivers are connected to Lake Michigan in several ways. Energy is transferred from lake to tributary and tributary to lake by way of fish movement up and downstream and material movement downstream. Diverse plant and animal habitats are found throughout the tributary system. The range of tributary habitats depends upon the size, slope, substrate, geology and land-use in the drainage basin, groundwater characteristics, climate, and the nature of the terrestrial vegetation. Many of these habitats accommodate Lake Michigan fish. Sediments and vegetative materials are sent downstream to the lake and are transported around the coastal shores and marshes of the lake to create habitats. The connectivity to the lake maximizes fish biodiversity and production.

The quality of many tributary rivers in the Lake Michigan basin has been significantly impaired due to channelization, dredging, damming, sedimentation, loss of bankside vegetation, eutrophication, increased spring flooding, and toxic contamination. Large areas of inland forests and wetlands that once served to regulate the quantity and quality of water flowing into tributaries have been lost. As a result, tributaries pass on their pollutant and sediment loads to the lakes and their suitability as spawning habitat has been seriously impaired. In urban areas, degradation has been most severe. Pollution from agriculture, industry and urban development has polluted rivers and contaminated sediments. The result is the contamination of fish and wildlife that depend on river habitats. Many rivers, particularly at the rivermouths, have been declared Areas of Concern and have many impaired beneficial uses.

Areas of Concern: Legacy Sites

Lake Michigan has 10 Areas of Concern that have documented from 5 to 14 beneficial use impairments on a local level. A number of major and hot spots removals have been successfully completed including: (1) a Superfund removal of 150,000 cubic yards of PCB-contaminated materials (containing 20,000 lbs. PCBs) from Bryant Mill Pond on the Kalamazoo River, Michigan; (2) a removal of over 12,000 cubic yards of arsenic contaminated sediments in the Menominee River, Wisconsin where arsenic levels so high the dredged material was classified as a hazardous waste; (3) a dredging demonstration in the Fox River, in Wisconsin, that removed over 10,000 cubic yards of PCB-contaminated sediments from the river that is the major source of PCBs to Lake Michigan; and (4) a Superfund action in Waukegan Harbor that removed more than approximately 453,600 kg (1 million pounds) of PCBs from the sediments.

Human Health Issues

The interaction of contaminates in the environment and impacts on human health is a complex issue since factors other than environmental exposures are also at work including genetics, lifestyle and many other factors. The major concerns are possible exposure from pathogens contaminating drinking water and beaches, and chemical contamination that bioaccumulates in fish causing the need for fish advisories. While levels of persistent toxic substances have declined in the Great Lakes the scientific understanding of the implications of exposures to these substances has increased such that there is now a broader range of concerns from effects of endocrine disruptors on human health. There is a need for the development of a methodology to assess the effects of endocrine disruptors on community health.

Air Pollution Pathway

The role of air pollution as an important contributor to water pollution has long been recognized and, in recent years, has been the subject of growing scientific study and concern. Over the past three decades, scientists have collected a large and convincing body of evidence showing that toxic chemicals released into the air can travel long distances and be deposited on land or water at locations far from their original sources. Most notably, PCBs and some persistent pollutants, including several pesticides that have not been used in significant amounts in the U.S. since the 1970's have become widely distributed in the environment and are now part of the global background.

Loadings of pesticides, canceled or restricted in the U.S., to Lake Michigan are primarily from atmospheric sources that may not be possible to regulate or control. Although there are no current commercial sources of banned pesticides in the U.S., loadings continue from remaining consumer stocks, evaporation from soils, resuspension of contaminated sediments, and airborne transport from other countries that continue to apply these substances. Further reductions must come from clean up of contaminated sites, collection and disposal of existing stockpiles (clean sweeps), and reduction in use in other countries.

Air Pollution Science

New models have been developed that combine meteorology with measured chemical compositions to locate probable air emission sources. These methods depend on estimating the movement of the air backward in time from the sampling location using wind speed and direction as well as barometric pressure. This back tracing or back-trajectory model will be applied to the southern end of Lake Michigan to help locate sources.

Pollutant Cycling

These toxic chemicals remain in the environment and continue to cycle between air, water, soil and plants and animals long after their manufacture or use has stopped. Contaminated sediments stirred up by storm or boat traffic can be ingested by fish or move to the surface where pollutants can evaporate into the air and be carried significant distances only to be redeposited again. As lake levels fall, there is the possibility of additional contaminated areas being exposed. Old pesticides may be released from agricultural lands when plowed. Pollutants can be either in the gas phase or attached to dust particles. The transport will depend on the physical state and weather patterns. This process explains pesticides used years ago in the southern United States being found in samples taken from Lake Michigan.

Nonpoint Source Pollution

While long- range transport of pollution is an important source, recent studies also point to influences of local sources, particularly nearby older urban areas. Air sampling over Lake Michigan, when the wind is carrying pollution from the Chicago area out over the lake, shows contributions of PCBs, PAHs and mercury to the lake. The relative importance of each source to the overall loadings is variable depending on season, weather and activities

Agricultural land use is found throughout the Lake Michigan basin, predominately in the southern portion. The breakdown is approximately 37 percent in the western basin with more than 99 percent of it in cropland and pasture. Small areas of orchards, groves and vineyards are located on the Door Peninsula. The second largest land use (after urban) in the southern part of the basin, approximately 37 percent , is agricultural and found mostly in the St. Joseph River basin. The eastern basin is approximately 28.5 percent agricultural, including cropland, pasture land and orchards. Parts of these areas are classified as three of the top 20 most threatened, high quality (prime farm land and/or unique soils and climatic requirements) lands under development pressure by the American Farmland Trust. The three are: Southern Wisconsin and Northern Illinois Drift Plain, Southwestern Michigan Fruit and Truck Belt, and Western Michigan Fruit and Truck Belt.

These areas are important to the overall balance and sustainability of the basin in order to achieve the LaMP vision /desired outcome of " A sustainable Lake Michigan ecosystem that ensures environmental integrity, that supports and is supported by economically viable, healthy human communities." The current management of these lands stress the Lake Michigan ecosystem by contributing sediment that carries with it pesticides and nutrients. Urban runoff also contributes sediments contaminated with not only pesticides and nutrients but also chemicals, oils, and road salt. These substances accumulate or persist in the lake because, unlike rivers that are constantly flushed with water, the lake is a sink. A drop of water entering Lake Michigan will take an average of 100 years to either evaporate or be washed into Lake Huron. For a particle of soil, the retention time is even longer and its attached contamination can be taken up into the food chain of the lake, including the human population.

Sediments also impact the habitat systems of the lake. Lake Michigan contains 40 percent of the coastal wetlands system of the entire Great Lakes system. The location of these with access to tributaries and inland systems as well as the lake provide habitat for larval stages and an abundant food supply. Too much sediment can bury submergent and emergent plants while nutrients cause too much growth and chemicals remain a long term source of contamination. Many of these chemicals are persistent and bioaccumulate in fish and aquatic organisms, resulting in limiting commercial fisheries and announcements of fish consumption advisories.

Sediment Science

To further define this complex and important problem of understanding how nutrients, contaminants and sediments continue to recycle in the lake a number of scientific investigations are underway with the major reporting of the results expected in 2001-2002 time frame. The Episodic Events: Great Lakes Experiment (EEGLE) led by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory began in 1996. That year, a massive turbidity plume, 10 miles off shore, 200 miles long, with as much as 1 million tons of material was observed by satellite. The plume can appear as early as February or as late as May and for 5 years has been being studied by over 40 environmental scientists from federal and state agencies and universities. www.glerl.noaa.gov/eegle/

Mass Balance Science

The Lake Michigan Mass Balance Study led by U.S. EPA's Great Lakes National Program Office in 1994-95 collected data from air, water, sediment, and the open lake and from selected tributaries to improve the understanding of key environmental processes governing contaminant cycling and availability within a relatively closed ecosystem. The data will be entered into a number of models, one of which is a sediment transport model. The model will help predict how particles from near-shore locations such as tributary mouths are transported to depositional zones usually in deep water. www.epa.gov/grlakes/lmmb/sedtrans.html

In the winter of 1999 the Lake Michigan Forum held a work shop on sediment issues in the basin, followed by a summer 1999 work shop on stewardship projects. The Forum has formed an Agriculture Pollution Prevention Task Force to address specific pollution prevention projects for sediments and pesticides in the Lake Michigan Basin. www.lkmichiganforum.org

Recommendations for 2000-2010

The Lake Michigan Technical Coordinating Committee developed the following recommended management actions and activities to be completed over the next 15 years.

1. **Ballast Water Control -** The Great Lakes are not only impacted by aquatic nuisance species causing irreversible damage but also serve as a pathway to other connected ecosystems. Standards or guidelines should be developed for ballast water treatment, working toward zero discharge.

2. **Clean Legacy Sites -** The Lake Michigan Mass Balance Study has confirmed that contaminated sediment sites in the lake remain an ongoing source of contamination into the food web causing fish advisories and delaying dredging of navigable waterways, both of which affect the local economies. In order to move swiftly to clean up contaminated legacy sites, both on land and at sediment sites, we will convene federal and state Superfund, RCRA Corrective Action, Drinking Water and Surface Water programs for planning discussions focused on the Lake Michigan ecosystem. The goal is to complete almost all plans by 2005 and actions by 2010. A few of the major sediment sites may require additional time.

3. **Protect Source Water -** As the drinking water source for 10 million with globally significant features, it is important to determine if the level of protection is sufficient utilizing the state assessments that delineate source areas and assess significant potential sources of contamination. If the assessment indicates that the intake is not impacted by potential shoreline contaminants, then RAP, LaMP, and mass balance materials would be used. Consideration should also be given to the question of exporting the resource.

4. **Protect Habitat -** Determine a priority for preservation sites within the recently mapped bio-rich clusters, including connecting corridors between clusters as well as the sites identified in the North American Waterfowl Management Plan. Wetland areas, particularly those with connection to the lake that are important to many species, and restoration of coastal brownfields to greenfields ,should be highlighted. Natural areas not only provide habitat but also serve to filter sediments and nutrients runoff , as well as store flood waters and recharge ground water. Provide this information on line.

5. **Fish Collaboration -** Develop joint projects with the Great Lakes Fishery Commission that implement both the LaMP and the Joint Strategic Plan for Management of Great Lakes Fisheries. Collaborate on the development of fish spawning maps to aid protection and provide adjacent land use planners with tools and data.

6. **Match Decision Makers with Issues -** Convene and engage the appropriate level of government and other nontraditional groupings to accomplish LaMP goals and match the needed control with

the most likely control point by promoting the following:
- National dialogue for control of aquatic nuisance species and air deposition of toxics
- Academic and agency dialogue to promote sharing of data, define research needs and develop lake-related courses
- Local dialogue to provide tools and a lakewide perspective to land use planners

7. **Control Combined Sewer Overflows (CSO) and Sanitary Sewer Overflows (SSO) -** The mixed discharge of storm water and domestic waste causes beach closings and is a pathway for pathogens to enter the lake. Provide tools, training, and data to local governments to promote full compliance with CSO, SSO, and storm water regulations, and system maintenance with awareness of land use planning on a watershed basis.

8. **Develop Agriculture Pollution Prevention Strategy -** Includes and coordinates among States, NRCS, and the Lake Michigan Forum's Agriculture Task Force to promote nonpoint source pollution prevention using stream planted buffer strips, and pollution prevention for pesticides, confined animal feed operations and nutrient controls. Food web disruptions in Lake Michigan relate to sedimentation and continuing nutrient pollution.

9. **Implement Area of Concern (AOC) Remedial Action Plans (RAP) -** AOC RAPs are in various stages of completion. Many RAP and watershed groups, as well as local communities, have included the watershed in their planning and have developed a list of priorities found in Addendum 6-B. These groups need support that include tools, technical assistance and training, and some level of funding to provide the ability to leverage scarce resources.

10. **Fill Data Gaps -** Promote research with the following goals:
    - Define in-basin and out-of-basin air pollution
    - Develop technology to control aquatic nuisance species in ballast water
    - Understand pesticides, pathways, and longevity in open water
    - Reuse contaminated sediments
    - Understand endocrine disrupters and their effects, sources, and possible controls
    - Identify fish spawning site locations
    - Review and refine Lake Michigan pollutants list

11. **Clean Sweep Strategy -** Years after certain pesticides were canceled and restricted, such as DDT/DDE, dieldrin, chlordane, they are still recovered in clean sweep operations, indicating the effectiveness of the tool. However, there is no special source of funding for these activities; therefore, there is a need to develop a strategy to ensure long-term consistent funding or ownership of annual pesticide, household hazardous waste and small business PCB/mercury Clean Sweep programs for each state.

12. **Measure and Report -** Continue development of the Lake Michigan Monitoring Coordinating Council and jointly develop a Monitoring Plan for Lake Michigan that includes expanding the USGS National Water-Quality Assessment Program (NAQWA) monitoring to Michigan's eastern shore and drainage. Develop a strategy for duplicating the coordinated monitoring (simultaneous air, water, land, open water and tributary mouths) of the Lake Michigan Mass Balance Project (LMMB 1994) in 2004 to have data for a 10-year analysis. Establish a beach community monitoring network and a volunteer basin monitoring network.

13. **On-Line Information, Public Involvement Activities -** Promote sharing of public information and public involvement by providing the following: (1) on-line data site that includes public health information, (2) an on-line habitat atlas of the basin showing ecologically-rich areas, and (3) a running summary of comments and responses. Continue the Forum's public meetings, workshops and boat tour in partnership with organizations such as Grand Valley State University, which also sponsors the State of Lake Michigan Conference.

14. **TMDL Strategy -** Total Maximum Daily Loads (TMDL) must be developed when waters do not meet state-adopted water quality standards, even after the implementation of technology-based controls. TMDLs are calculated to return waters to their designated uses. States develop TMDLs for their tributaries, and a strategy for cooperative TMDL work for Lake Michigan that includes a public involvement process is needed.

15. **Stewardship Actions -** The majority of the land that drains to the lake is privately owned and managed. America's cities and towns account for 80 percent of energy use. Of that 80 percent, land use planning and urban design affect about 70 percent, or 56 percent of the nation's total energy use. Energy production and transportation are major sources of air pollution. The message from these statistics is that every basin resident is a "Lake Michigan Manager." We need to strengthen partnerships with other education and outreach efforts to promote the activities necessary to accomplish the following: (1) promote recycling efforts, energy and water conservation, and trash barrel burning awareness; (2) place special emphasis on preventing the spread of aquatic nuisance species by boat owners for the next two years; (3) communicate the importance of private efforts in habitat preservation on both public and privately owned land; and (4) develop an Areas of Stewardship program for local communities and watersheds.

Table ES-1 Lake Michigan LaMP Summary Table

CHAPTER 2	CHAPTER 3		CHAPTER 4		
Lake Michigan LaMP: Vision, Goals and Ecosystem Objectives	Indicators and Monitoring of the Health of the Lake Michigan Ecosystem		Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments and Human Health		
Endpoint Goal	Monitoring	Human Activity	Impairment	Spatial	Temporal
1. We can all eat any fish. 	• Chemical contamination in fish • Site assessments • Eagle reproduction	• Fish advisories • Congressional reports on: - Great Waters - Mercury - Dioxin	• Restrictions on fish and wildlife (F/W) consumption • Tainting of F/W flavor	Local Local	Ongoing Episodic
2. We can all drink the water. 	• Raw water quality data • Source water assessments	• Water utility notifications • Source water protection	• Restrictions on drinking water consumption or taste and odor problems	Local	Episodic
3. We can all swim in the water. 	• *E Coli* levels in recreational water	• Beach closing advisories • State 305(b) WQ reports	• Beach closings	Local	Episodic
4. All habitats are healthy, naturally diverse and sufficient to sustain viable biological communities. 	• Fish assessments • Bird counts • Wetlands inventories and assessments • Stream flows • Eco-rich area assessments	• Endangered species list • Wetlands mitigation and protection • Zoning • Fish stocking • Fish refuges • USFWS refuges • Ballast water exchange • Dune protection • Eco-rich cluster map	• Degradation of F/W populations • Fish tumors, or other deformities • Degradation of Benthos • Eutrophication or undesirable algae • Degradation of phytoplankton and zooplankton • Loss of F/W habitat • Bird or animal deformities	Regional Local Local Local Lakewide Lakewide Local	Evolving Episodic Ongoing Episodic Ongoing Ongoing Episodic
5. Public access to open space, shoreline and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem. 	• Urban density • Coastal parks acreage • Conservation easements	• Open space funding and protection statutes • Coastal zone management	• Degradation of aesthetics	Local	Evolving
6. Land use, recreation and economic activities are sustainable and support a healthy ecosystem. 	• Contaminants in recreational fish • Sustainable forests	• Superfund cleanups, dredging • CRP percent of eligible farm lands • Brownfields to greenfields redevelopment	• Restrictions on dredging • Added cost to agriculture or industry	Local Local	Evolving Evolving

Table ES-1 Lake Michigan LaMP Summary Table (continued)

CHAPTER 5		**CHAPTER 6**	
Lake Michigan Stressor Sources and Loads		**Strategic Action Agenda: Next Steps**	
Stressors	Source	Means to an End Goal	Recommendations
• Chemical - PCBs - Mercury - Dioxin - DDT - Chlordane	• Air deposition • Legacy sites • Sediments • Incinerators • Burn barrels		Implement AOC RAPs Clean Legacy Sites Clean Sweep Strategy TMDL Strategy Stewardship Actions
• Biological - Pathogens - ANS	• Land use • Point source • Nonpoint source		Protect Source Water Fill Data Gaps
• Biological - Pathogens • Physical • Chemical	• Land use • Point source • Storm water • CSO/SSO		Control CSO, SSO Develop Agricultural P2 Strategy On-Line Information, Public Involvement Activities
• Physical - Sedimentation - Habitat destruction • Biological - ANS • Chemical - Nutrients - Toxics	• Land use/sprawl • Point source • Air deposition • Ballast water • Storm water • Agriculture runoff	Control pathways Manage ANS Ecosystem stewardship Collaboration Research	Ballast Water Control Protect Habitat On-Line Information, Public Involvement Activities Stewardship Actions Fish Collaboration Fill Data Gaps Measure and Report
• Physical - Sprawl • Biological - ANS	• Land use		On-Line Information, Public Involvement Activities Stewardship Actions
• Physical • Biological • Chemical	• Land use • Point source • Legacy sites		Fill Data Gaps On-Line Information, Public Involvement Activities Stewardship Actions Match Decision Makers with Issues

Chapter 1:
Lake Michigan LaMP Overview: Program Structure, Scope, Scale, and Public Involvement

The LaMP is mandated under the Great Lakes Water Quality Agreement Amendments of 1987 and Section 118(c) of the Clean Water Act. EPA is leading a collaborative effort to develop a comprehensive, sustainable ecosystem management approach in partnership with other federal agencies; state, tribal and local governments; and the public. The LaMP is being developed through various committees and workgroups, led by the Management Committee and including the Technical Coordinating Committee, EPA staff working on the Lake Michigan Mass Balance project, and the Lake Michigan Forum. Through a series of meetings, many involving significant public input, EPA has determined that the LaMP will address all ecosystem stressors affecting the lake, critical pollutants, Areas of Concern, and contamination hot spots. As a result, this LaMP for Lake Michigan addresses habitat loss, biodiversity, and exotic species, as well as any other issues affecting the health of the lake ecosystem. The goal of this LaMP is to establish an ecosystem approach for future management of Lake Michigan in order to attain a sustainable ecosystem. The development of the Lake Michigan LaMP is an iterative process, and this document represents a foundation for 2000 to 2002 dialogue leading to LaMP 2002. This LaMP represents many years of work by many people and constitutes essentially Stages 1 to 3 of the LaMP process as required under the Great Lakes Water Quality Agreement. This document, therefore, contains the following: (1) LaMP vision, goals, and ecosystem objectives; (2) indicators of ecosystem health; (3) current status of the ecosystem, beneficial use impairments, and human health; (4) stressor sources and loads; and (5) a strategic action agenda. In addition, the LaMP contains numerous appendices and an extensive compilation of reference materials.

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Chapter 1: Lake Michigan LaMP Overview: Program Structure, Scope, Scale, and Public Involvement

1.1 About this Chapter

The purpose of this chapter is to give the reader an understanding of why the Lakewide Management Plan (LaMP) for Lake Michigan was created, who is responsible for its implementation, how it will be used to protect and manage the Lake Michigan ecosystem, and where and at what scope and scale the necessary ecosystem management must occur. The chapter will also give the reader an overview of the LaMP organization, what is presented in each of the subsequent chapters, and the plans to involve the public in LaMP updates and revisions between the years 2000 and 2002.

1.2 About the LaMP – Why

Under the Great Lakes Water Quality Agreement of 1978 (GLWQA), as amended by the Protocols of 1983 and 1987, the United States and Canada (the Parties) agreed "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem" (IJC 1993). To achieve this purpose, the Parties agreed to develop and implement LaMPs for open lake waters, in consultation with state and provincial governments.

In the case of Lake Michigan, which is the only Great Lake wholly within the borders of the United States, the LaMP development effort has been led by the United States, as called for in Section 118(c) of the Clean Water Act. The U.S. Environmental Protection Agency has taken a collaborative approach to implement this responsibility. A partnership of the federal, state, tribal and local governments in the basin is working with stakeholders in a cooperative, coordinated effort to develop and implement the Lake Michigan LaMP. As specified in Annex 2 of the GLWQA, the LaMP for Lake Michigan is designed to reduce loadings of **Critical Pollutants** in order to restore 14 designated beneficial uses (see Appendix G, Section G.2.4) and prevent increases in pollutant loadings in areas where the Specific Objectives of the Agreement are not exceeded.

Moreover, the Specific Objectives Supplement to Annex I of the GLWQA requires the development of ecosystem objectives for Lake Michigan. Pursuant to this charge, the Lake Michigan LaMP embodies a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses by seeking a balance between critical pollutant reduction and ecosystem sustainability in open lake waters and the watersheds that comprise the lake basin.

What are Critical Pollutants and Stressors?

The Great Lakes Water Quality Agreement defines *Critical Pollutants* as "substances that persist at levels that, singly or in synergistic or additive combination, are causing, or are likely to cause impairment of beneficial uses despite past application of regulatory controls due to their (1) presence in open lake waters, (2) ability to cause or contribute to a failure to meet Agreement objective through their recognized threat to human health and aquatic life, or (3) ability to bioaccumulate" (Annex 2, Section 1(b)).

Pathogens, fragmentation and destruction of terrestrial and aquatic habitats, exotic nuisance species, uncontrolled runoff, and erosion are among the *stressors* contributing to ecosystem impairments.

1.3 About the LaMP – Who

Section 118(c)(4) of the Clean Water Act is a Congressional mandate making the EPA accountable for the Lake Michigan LaMP. However, the Lake Michigan LaMP process is a collaboration aimed at achieving consensus about goals and priorities for the management of a shared resource. A process to be implemented by a broad range of governments working with diverse nongovernmental interests as equal partners.

The LaMP document serves as the guide for this continuing process of collaborative ecosystem management and partnership activities. Different participating governmental agencies and nongovernmental organizations will be expected to undertake specialized functions based on their missions and authorities, and the LaMP will serve as a focal point for work toward a common set of goals. The general public will track the progress of the LaMP by following published reports on the indicators of the health of the ecosystem components. The public also has the opportunity for direct involvement through the many LaMP education and outreach activities and stewardship projects. Each government, institution, organization, and individual has a potential role to play in the management of a precious shared resource – the Lake Michigan ecosystem.

1.4 About the LaMP- Program Structure

The structure for this basin-wide interaction includes a number of committees and workgroups. Experience has shown that progress is aided by facilitating a structure that provides the networking opportunities for a basin-wide dialogue by promoting discussion through “evolving community of interest.”

Federal, state, and tribal participants work together in committees. The structure calls for an overall Management Committee, with the following components reporting to it: a LaMP Technical Coordinating Committee, which is responsible for the document; EPA staff responsible for the Lake Michigan Mass Balance Study; and the Lake Michigan Forum, a stakeholder group funded by EPA. A more detailed discussion of the organizational structure is presented below.

1.4.1 Management Committee

The Lake Michigan Management Committee was first convened on June 20, 1991 to guide the overall development and implementation of the Lake Michigan LaMP. The original members included representatives from federal, state and tribal agencies. The current membership includes EPA (Lake Michigan Team, Great Lakes National Program Office, and Office of Research and Development; U.S. Fish and Wildlife Service; U.S. Army Corps of Engineers; U.S. Geological Survey; U.S. Department of Agriculture-Natural Resources Conservation Service; Illinois Environmental Protection Agency; Indiana Department of Environmental Management; Michigan Department of Environmental Quality; Wisconsin Department of Natural Resources; Great Lakes Fishery Commission; Chippewa-Ottawa Treaty Fishery Management Authority; and the Grand Traverse Band of Ottawa and Chippewa Indians.

The Management Committee convenes the standing Technical Coordinating Committee, Lake Michigan Forum, and other special technical committees as needed. The Management Committee directs LaMP development through approval of the document scope, specific strategies, and work plans, and it works through the committee members’ respective agencies and departments to secure adequate resources to complete the development of LaMP documents and to support and implement the LaMP strategies. Figure 1-2 at the end of this chapter illustrates the Lake Michigan LaMP organizational structure.

1.4.2 The Technical Coordinating Committees

A LaMP Technical Coordinating Committee (TCC) of cooperating agencies and governments (1) develops LaMP documents and programs and (2) recommends strategies, goals, work plans, and objectives to manage the Lake Michigan ecosystem. The current membership is the same as that of the Management Committee, with the addition of the Oneida Tribe of Wisconsin and the Agency for Toxic Substances and Disease Registry of the U.S. Centers for Disease Control and Prevention. The Steering Committee of the TCC includes a member from the EPA, the Lake Michigan Forum, and one state and tribal representative. Six subcommittees include Toxic Reduction; Human Health; Habitat; Stewardship; Partnership, Education and Outreach; and Indicators, Monitoring and Assessment. The last subcommittee is associated with two other standing committees: the Lake Michigan Mass Balance Technical Committee and the Lake Michigan Monitoring Coordinating Council (LMMCC).

1.4.3 The Lake Michigan Monitoring Coordinating Council

The Lake Michigan Monitoring Coordinating Council (LMMCC) responds to the need for enhanced coordination, communication, and data management among the many agencies and organizations that conduct or benefit from environmental monitoring efforts in the Lake Michigan basin. The LMMCC provides a forum for identifying gaps and establishing monitoring priorities; exchanging information; and forming partnerships. The LMMCC will also work in cooperation with the LaMP to develop and periodically update a monitoring plan for the Lake Michigan basin. This approach will result in cost-saving efficiencies for all involved and will provide the data needed to determine a current status of the lake ecosystem (http://wi.water.usgs.gov/lmmcc/links.html).

The Lake Michigan research dialogue provided by the LMMCC has roots in the Lake Michigan Mass Balance Project and many of the meetings held with its principal investigators. It is critical to build on this interaction and formalize the exchange of information and networking to maintain and link monitoring and research.

1.4.4 The Lake Michigan Forum

The LaMP process also involves a comprehensive approach to public involvement. This approach provides opportunities for public involvement and input across all levels of interest, ranging from the establishment of the Lake Michigan Forum to working with EPA to develop the LaMP, to broad public outreach and education efforts designed to ensure the involvement of all who wish to participate in the process. The Forum, facilitated by EPA, has leveraged its EPA funding for many projects. As the LaMP has evolved so has the Forum, and it is now taking on the role of partner in highly visible pollution prevention, land use, and outreach projects. The Forum developed the current LaMP outline, and Forum members checker the Monitoring and Assessment Committee and lead the Stewardship, the Partnership and Education, and Outreach Committees. The Lake Michigan Forum cochairs also attend and present status reports at all meetings of the Management Committee.

1.5 About the LaMP- How

This section discusses how the LaMP is used to document the current status of the lake and as a reporting mechanism for a wide variety of public and private stakeholders. It also describes the use of science and sophisticated modeling to aid policy decisions.

1.5.1 The Document and Reporting

Under the GLWQA, LaMPs and Remedial Action Plans (RAP) for designated Areas of Concern (AOC) are to be submitted to the International Joint Commission (IJC) when a key stage of work is completed. For LaMPs, there are four reporting stages:

Stage 1: When the definition of the problem has been completed

Stage 2: When the schedule of load reductions is determined

Stage 3: When remedial measures are selected

Stage 4: When monitoring indicates that the contribution of **Critical Pollutants** to impairment of the identified beneficial uses has been eliminated

In practice, these stages often overlap. In 1999, the Senior Management of EPA Region 5, in consultation with managers from the affected states, determined that the present edition of the Lake Michigan LaMP would constitute a LaMP that has combined attributes of Stages 1 through 3. The LaMP is part of an ongoing, iterative process – one that reflects the current states of environmental knowledge, planning, and action. The success of this LaMP will ultimately be measured by the degree to which it has guided public and private efforts toward achieving the Lake Michigan LaMP goals of a sustainable ecosystem and the restoration and protection of all beneficial uses.

Much of the required work will occur through partnership activities in local communities. Effective partnerships between governments, nongovernmental organizations, and concerned citizens will help to ensure that the LaMP process is successful in restoring the Lake Michigan ecosystem to one that is healthy and sustainable.

1.5.2 Science and Models: The Lake Michigan Mass Balance Project

The LMMB Project is an enhanced monitoring and modeling project that is working to develop a sound, scientific base of information to inform LaMP policy decisions. The LMMB Project's specific objectives are as follows:

1. To identify relative loading rates of four different categories of pollutants entering Lake Michigan: PCBs, mercury, transnonachlor, and atrazine

2. To evaluate relative loading rates by media (such as tributaries, atmospheric deposition, and contaminated sediments) to better target future load reduction efforts and to establish baseline loading estimates against which to gauge future progress (all samples for the mass balance study were taken in 1994 and 1995)

3. To develop the predictive ability to determine the environmental benefits of specific load reduction scenarios for toxic substances and the time required to realize those benefits through the use of models

4. To improve our understanding of key environmental processes and how they combine to govern the movement of pollutants through the lake (cycling) and fish and plant life (bioavailability)

State agencies in Illinois, Indiana, Michigan, and Wisconsin; the National Oceanic and Atmospheric Administration; and the Universities of Minnesota, Michigan, Wisconsin (Madison and Milwaukee), Maryland, and Indiana; Rutgers University and State University of New York at Buffalo are collaborating on the LMMB project. Additional information about the LMMB project is presented in Chapter 3.

Data from this project will be used to develop the final LaMP load reduction schedule.

1.6 About the LaMP-Scope

> **What is the Ecosystem Approach?**
>
> The goal of an ecosystem approach is to restore and maintain the health, sustainability, and biological diversity of the ecosystems while supporting sustainable economies and communities. Based on a collaboratively developed vision of desired future conditions, the ecosystem approach integrates ecological, economic, and social factors that affect a management unit defined by ecological - not political - boundaries. (The Ecosystem Approach: Healthy Ecosystems and Sustainable Economies, Vol. II. November 1995, page 1.)

This Lake Michigan LaMP has evolved beyond the 1993 toxic reduction plan, which focused on critical pollutants, specific areas of concern, and contamination hot spots. This LaMP also addresses all known stressors on the ecosystem. Concerns such as the loss of critical habitats, biodiversity, and the introduction of nuisance species, and other issues believed to affect ecosystem health, including human health and performance, have been added to the earlier focus on critical pollutant in an effort to establish an **ecosystem approach** for future lake management. Public comments have advocated this approach, and the current state of research has provided mounting evidence that physical and biological stressors are significantly degrading the Lake Michigan basin ecosystem.

The need to expand the scope of the LaMP document to include an ecosystem approach became clear as the Lake Michigan LaMP process matured. The following is a brief chronology of the evolution of the scope of this document:

- As early as November 1989, at a Chicago workshop, the proposed Framework for Lakewide Management Plans for Critical Pollutants raised the issue of scope.

  As originally envisioned in the GLWQA, the scope of LaMPs was restricted to chemical integrity or critical pollutants–especially toxic chemicals. However, a group of experts representing fishery and environmental managers, academia, and nongovernmental organizations concluded that the Lake Michigan LaMP should enlarge its scope of activities to encompass a true ecosystem approach (Eschenroder and others 1991). Also, Donahue and others (1991) reviewed six other remediation initiatives that predated the 1987 Protocol and concluded that the LaMP process should be used as a planning framework where many activities are pursued–including, but not limited to, control of critical pollutants.

- Following the 1995 public comment period on the second draft of the Lake Michigan LaMP, reorganization initiatives within EPA Region 5 placed responsibility for the management of the LaMP with the multiprogram Lake Michigan Team. This team engaged the LaMP Technical Coordinating Committee and the Lake Michigan Forum stakeholders in a discussion of the scope of the LaMP. They recommended an outline for a LaMP and ecosystem plan that was approved by the Lake Michigan Management Committee in 1997.

- The LaMP ecosystem goals were adopted by the Lake Michigan Management Committee on August 18, 1998.

- In July 1999, the Binational Executive Committee (BEC) of the GLWQA parties directed the LaMPs for 2000 to pursue the following:

  "Treat problem identification, selection of remedial and regulatory measures, and implementation as a concurrent, integrated process rather than a sequential one. The LaMPs should embody an ecosystem approach, recognizing the interconnectedness of critical pollutants and the ecosystem. BEC endorses application of the concept of adaptive management to the LaMP process. By that, we adapt an iterative process with periodic refining of the LaMPs which build upon the lessons, successes, information, and public input generated pursuant to previous versions. LaMPs will adjust over time to address the most pertinent issues facing the Lake ecosystems. Each LaMP should be based on the current body of knowledge and should clearly state what we can do based on current data and information. The LaMPs should identify gaps that still exist with respect to research and information and actions to close those gaps."

1.7 About the LaMP-Where

In order to play a meaningful role in helping to attain a sustainable ecosystem, the LaMP must identify those pollution problems throughout the basin ecosystem that contribute to, or have the potential to contribute to, beneficial use impairments and nonattainment of LaMP goals. In determining their potential impact on the ecosystem, the extent of environmental problems and the frequency of their occurrence are both important considerations. For the Lake Michigan LaMP, it is proposed that beneficial use impairments be classified as follows:

Spatial

- Local – An AOC as designated by the Parties of the Agreement or other areas affecting the lake as designated by the Lake Michigan Management Committee

- Regional – An AOC cluster or multijurisdiction watershed

- Open water or lakewide – Concerning pervasive impairment of the lake as a whole

Temporal

- Ongoing – A continuing situation of impairment
- Episodic – An impairment that was documented but is not continuous
- Evolving – Unrelated episodic events that suggest a trend but are not yet continuous

Lake Michigan has 10 designated AOCs: the Manistique River, Menominee River, Fox River/Green Bay, Sheboygan River, Milwaukee Estuary, Waukegan Harbor, Grand Calumet River/Indiana Harbor, Kalamazoo River, Muskegon Lake, and White Lake. Figure 1-1 indicates the locations of the 10 AOCs. The gray area in the figure defines the Lake Michigan drainage basin. A discussion of each of these 10 AOCs, including their current status, can be found in Chapter 4 and Appendix F.

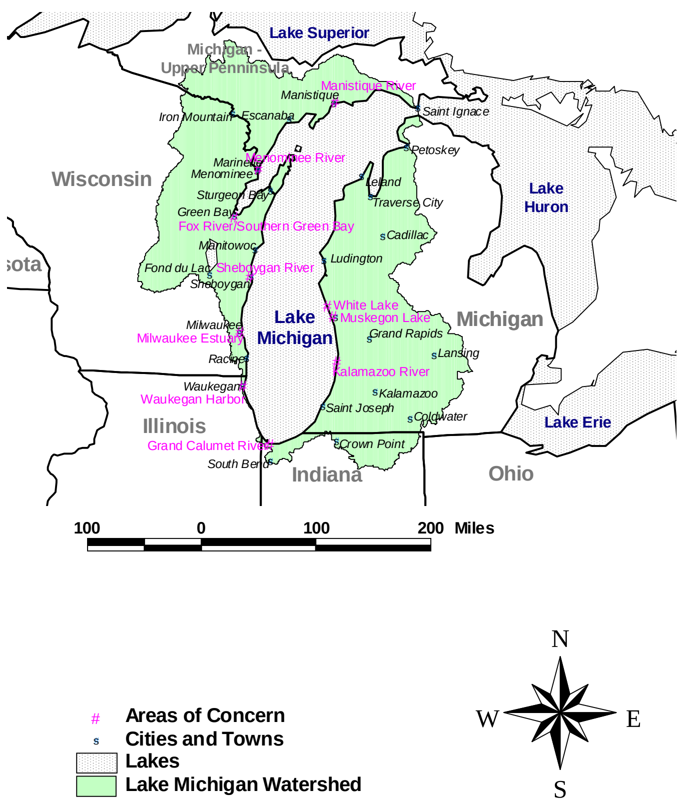


Figure 1-1. Lake Michigan Areas of Concern

The state LaMP coordinators work with each AOC, and representatives of the local RAP committees are invited to participate in the Lake Michigan Forum in order to enhance communication and coordination of plans and activities on the local AOC and basin-wide LaMP level.

Areas of Concern

In 1978 and 1987 the Great Lakes Water Quality Agreement between the US and Canada was expanded to address critical stressors affecting the basin's ecosystem. The intersections of major tributaries and the Lakes are areas where human activity by-products and collected river deposits concentrate. "The Parties recognize that there are areas in the boundary waters of the Great Lakes system where, due to human activity, one or more of the General or Specific Objectives of the Agreement are not being met. Pending virtual elimination of the persistent toxic substances in the Great Lakes system, the Parties, in cooperation with the State and Provincial Governments and the Commission, shall identify and work toward restoring and protecting beneficial uses in Areas of Concern or in open waters."

For each AOC a stakeholder group was convened to work with federal and state agencies to develop remedial action plans that defined the problem and suggested remedial actions. This program has been very successful in capturing the energy and creativity of the communities. Unfortunately, agency funding and resources have been uneven and have never approached the scale needed for remediation of large-scale legacy sites. The U.S. Army Corps of Engineers, acting under Superfund, Resource Conservation and Recovery Act (RCRA) Corrective Action Program, and the Clean Water Act authorities have successfully completed large-scale actions. The Superfund program ranks sites using the hazard ranking system (HRS), which is based upon specific criteria. This ranking serves as a "pattern" used in allocating resources and setting priorities among the AOCs.

Government and AOC communities want to move ahead and "delist" the AOCs as they are cleaned up, but there are complications as site remediation does not deliver complete or immediate removal of impairments. While remediation removes legacy pollution sources, the watershed and/or long range transport may be contributing to on-going pollution problems.

Many AOCs have evolved to incorporate a watershed focus, looking at nonpoint source pollution and pollution prevention to not only restore the area but also to focus on the health of the basin. The challenge for 2000 to 2002 is determining how AOC areas move to delisting and which agency has the lead for that part of the process. An AOC priority list of activities is presented in Addendum 6-B.

To attain sustainable ecosystem integrity, the LaMP must identify those goals, necessary partnerships, and locations where ecosystem management must occur. The 10 AOCs have been designated as top priority areas. The assessment of the current status of the lake has uncovered other sources of contaminants and stressors. Due to the rerouting of the Chicago River into the Mississippi River system, Chicago appears not to be in the basin; however, groundwater from the Chicago area has not been diverted, and the city's large airshed has been shown to be a source of pollutants that affect the lake. In addition, data from the LMMB project monitoring has shown that the St. Joseph River contributes pesticides from its large agricultural watershed. The LaMP process is working with both of these areas.

The Grand Traverse Bay is an example of an area that retains biological integrity and has created a broad-based coalition of local organizations and interests to engage in various initiatives to promote the preservation of environmental quality in the region. Building on this experience and noting the necessity of these efforts throughout the basin, the Lake Michigan Forum introduced a concept of self-designation,

Areas of Stewardship. This designation would help target agency technical assistance to those watersheds in the basin in which local partnerships are engaged in developing visions, identifying environmental concerns, setting priorities, and designing and implementing comprehensive plans for sustainable landscapes. This program would encompass AOCs and focus planning efforts on watersheds, crossing political boundaries. A prototype of this effort is underway in the Kalamazoo area.

Areas of Stewardship

An area of stewardship is defined as an area, most often a watershed, for which a level of ecosystem integrity has been established as a goal and where an integrated, multi-organizational initiative or partnership is actively working to achieve that goal. There are places around the Lake Michigan basin where such efforts are already in place such as in most AOC areas. In addition, Chicago Wilderness, the Kalamazoo Multi-Jurisdictional Watershed Agreement, and ongoing work in Grand Traverse Bay and Door County also fit the vision of stewardship.

1.8 The LaMP Document - Organization

This LaMP 2000 serves several purposes. First, it provides introduction and general background to the LaMP program and process. Second, it presents a framework and road map for presenting the current understanding of the lake and additional data to be added in later years. Third, it summarizes the technical research and scientific study of many Lake Michigan Partners. Fourth, it presents actual pollution prevention, restoration and other actions that governments, tribes, and industries can take to achieve the overall goals and vision of the LaMP.

The LaMP was written with many different audiences in mind, including managers of federal, state, and local programs; researchers; educators; and the general public. It attempts to address a complex issue: understanding, protecting, and managing the Lake Michigan ecosystem. The following is an overview of the organization of the LaMP.

Chapter 2: Lake Michigan LaMP – Vision, Goals, and Ecosystem Objectives, presents a holistic view of the ecosystem, a broad vision of restoration and protection goals, and authorities that will motivate all who might have an impact on the ecosystem health and sustainability of the lake. The LaMP ecosystem goals that resulted from this collaborative and evolutionary process are also presented and are placed within the context of the many international and national goals that have been established for all the Great Lakes, including the reduction of critical pollutants.

Chapter 3: Indicators and Monitoring of the Health of the Lake Michigan Ecosystem, proposes a number of indicators that will provide a consistent measure to report on key ecosystem components in order to assess progress toward ecosystem integrity, and describes numerous monitoring effects underway around the basin.

Chapter 4: Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments, and Human Health, provides a detailed description of the ecosystem and its current status, including impairments of beneficial uses.

Chapter 5: Lake Michigan Stressor Sources and Loads, describes the current state of the science regarding chemical, physical, and biological causes and sources of the impairments.

Chapter 6: Strategic Action Agenda: Next Steps, presents the overall objectives needed to guide management of the ecosystem, and a list of recommendations to help achieve these objectives. A matrix format that presents examples of strategic actions for 2000 to 2002 is also presented for public comment.

Appendices: The Lake Michigan LaMP also includes an extensive compilation of supporting and reference materials.

- Appendices A, B, and C provide information on stressor management programs, physical properties of the chemical stressors, and the human health impacts of the chemical stressors, respectively.

- Appendix D contains the Lake Michigan Stakeholder Directory, which provides information about the numerous stakeholders throughout the Lake Michigan basin.

- Appendix E includes the draft Lake Michigan total maximum daily load (TMDL) strategy.

- Appendix F contains more detailed information on each of the 10 AOCs.

- Appendix G includes additional information describing the Lake Michigan ecosystem.

- Appendix H contains the EPA reference, "Region 5 Guide for Developing Environmental Goals, Milestones, and Indicators."

Finally, the reader will find a Lake Michigan LaMP Summary Table (provided at the end of Chapter 2 and each subsequent chapter) that provides a brief summary of the LaMP chapters presented previously.

1.9 The LaMP Document – Public Involvement

A major tenet of ecosystem management is the continuous involvement of the public that is "inclusive and respectful of all viewpoints and stakeholders," Keystone National Policy Dialogue on Ecosystem Management 1996. Because there are many public groups and community perspectives, with varying levels of interest and need for information, a public involvement effort for the Lake Michigan ecosystem is no less complex then the scientific data collected and analyzed.

The development of goals and subgoals for the LaMP took this complexity into consideration under subgoal 11 " we have enough information/data/understanding/indicators to inform the decision-making process." Achievements of that subgoal will hopefully motivate the public so subgoal 9 can be achieved: ecosystem stewardship activities are common and undertaken by public and private organizations in communities around the basin."

The LaMP Partnership, Education, and Outreach Committee developed public involvement tools. These tools, used over the last few years, have proven successful in reaching the public and providing ways to continue involvement if desired. They include employing current technology in developing web pages and decimating compact discs (CD) along with unique basin resources, such as a university research vessel. Plans include (1) updating the 10 Lake Michigan AOC fact sheets and keeping them on line and (2) making The Lake Michigan Explorer educational CD and a Cd version of the LaMP available for distribution. The Lake Michigan Forum has committed to continue its publicly distributed newsletter and web site that features not only Forum activities, but also articles on the AOCs, LaMP projects, and pollution prevention efforts. The Forum is again seeking funding for use of the Grand Valley State W.G.

Jackson research vessel for the third educational tour around the lake for Summer 2000. The Forum will also continue to sponsor public meetings in conjunction with their meetings held four times per year around the basin. The Environmental Youth Award Program with basin scout groups has been launched and was well received. This model needs to be marketed to all areas of the basin for maximum participation.

A variety of public meetings are planned between the LaMP 2000 release of this document and the development of the LaMP 2002 report. Many of these meetings will focus on a particular aspect of the LaMP with the goal of engaging the public in a discussion on a more specific level, for example, long-range transport of air pollution. The following are among the meetings and reports currently planned:

<u>Spring/Summer</u>

No date	–	Tribal Meetings
April 27, 2000	–	Chicago Kent Law School

<u>Summer</u>

No date	–	Planning Commissions Summer Boat Tour with public meeting at each Port of Call, including Chicago and other locations
August 2, 2000	–	Sustainable Agriculture Task Force, Sheboygan,WI
September 2000	–	Great Lakes National Beach Conference Chicago, IL

<u>Fall</u>

No date	–	Teachers Conference, Roosevelt University, Chicago, IL
October 17-19, 2000	–	State of the Lakes Conference, Hamilton, Ontario
November 8-9, 2000	–	Long Range Transport of Air Pollution, St. Joseph, MI
May 2001	–	Lake Michigan Monitoring Coordinating Council
November, 2001	–	State of Lake Michigan Conference, Grand Valley State University, Muskegon, MI

This list is incomplete and subject to change; current information can be found at www.epa.gov/lakemich or www.lakemichiganforum.org.

<u>Summer 2000</u>
Two reports will be published, the first is the final report of the LaMP/Great Lakes Commission Tributary Monitoring Project. The second is the Lake Michigan Forum's status report on Agriculture Pollution Prevention in the Lake Michigan basin.

1.9.1 Public Comments

1995 LaMP

In the early 1990s, two early drafts of the Lake Michigan LaMP were presented for public comment. The comment period for the second LaMP draft closed in September 1995. The comments fell into four categories: (1) document format, (2) document and program scope, (3) data attribution, and (4) use of risk-based analysis.

In order to be responsive to the comments and concerns expressed, the decision was made to (1) expand the program and the document by taking an ecosystem approach, as outlined in this chapter; (2) coordinate document production with the Lake Michigan Mass Balance (LMMB) Project findings to provide the most current additional data, as well as use modeling to help determine risk; and (3) provide clearly referenced material.

Many of the comments that dealt with language and presentation were considered in production of LaMP 2000 but are now moot because wording from the 1995 document was not utilized.

LaMP 2000

This document is presented as a working document, not as a "draft not yet complete." It was the goal of the Binational Executive Committee to provide a *current* foundation for discussion–not necessarily a *complete one.* The LaMP will be modified every 2 years based on new findings and public discussion. This is a necessary step if we are to institute **adaptive management** on an ecosystem scale.

Comments

Comments are welcome and can be provided on-line at the website below or in writing to U.S. EPA, Attention Lake Michigan Team, 77 West Jackson Boulevard, Chicago, Illinois, 60604.

On-Line Response

To provide current and open access to all comments and response actions to the draft released in April 2000, comments and responses will be summarized and posted at www.epa.gov/lakemich. The Lake Michigan Forum will feature some of the comments and responses in the Forum's Newsletter, at the November 2001 State of Lake Michigan Conference, and in the 2002 LaMP report.

> "Adaptive management encourages active participation by all stakeholders in the planning, implementation, monitoring, and redirection of ecosystem management initiatives. Social and economic values and expectations are routinely considered, along with ecological objectives, in continually correcting the course of management. Results from the monitoring of ecological, economic, and social variables are used to track management outcomes" (Keystone Report, 1996).

1.9.2 Next Steps

The public involvement process outlined above is not intended to just inform the public about the LaMP, but also to engage the public in discussions about the findings and suggested activities. There are many aspects of this plan that are incomplete, and the public dialogue process is intended to gain input and move the decision-making process forward.

In particular, comments are needed on the following:

Chapter 1. The concept of Area of Stewardship

Chapter 3. Priorities for the indicator list

A list of indicators cross walked with the LaMP subgoals is presented for public comment. The LaMP will be working with the Lake Michigan Monitoring Coordinating Council to develop a monitoring plan that will provide clear monitoring commitments and the data to measure an indicator.

Chapters 4 and 5. Efforts needed to continue to fill in data gaps

The LMMB models will be completed within the 2000-2002 time frame as will the EEGLE Project lead by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory www.glerl.noaa.gov/eegle/. EEGLE will incorporate currents, temperature, wave and ice along with sediment transport and food simulations to determine the impact of the massive spring turbidity plume along 200 miles of southern Lake Michigan shoreline. EEGLE and LMMB models will presented to ecosystem managers and the public in 2002.

Additional monitoring is needed to fill in the gaps in our data. We need to plan now to sample some of the same locations on the 10 year anniversary of the LMMB in 2004 to document trends and gather data for the TMDL efforts in the basin.

Chapter 6. Actions, priorities, and other actions needed such as the follow:

♦ Eco-rich Areas and habitat identification placed on-line in GIS Mapping

Identification of eco-rich areas where protection activities should be a priority are underway. The Great Lakes Commission has been funded by EPA to gather Lake Michigan data for production of an on-line atlas that would provide a basin-wide land use planning and protection tool. USFWS is mapping the threatened and endangered species in the basin by county. The EPA Region 5 Ecosystem Team, in partnership with Region 5 States, is preparing ecologically rich area maps. EPA Office of Research and Development is preparing "greenness contrast" maps for all the Great Lakes beginning with Lake Michigan in spring 2000. The purpose of this map is to present a large scale overview of the amount of green cover that has been lost to development in the last few decades.

♦ TMDL Strategy

There are many efforts underway that provide an opportunity to use the LaMP and LMMB data and models. We are requesting comments on the TMDL Strategy in the appendix as soon as possible as work on developing the strategy and gathering data need to begin soon.

♦ Quantified Targets for Pollution Reduction

Reduction targets presented have been pulled from national EPA commitments and from other initiatives like the Binational Strategy and are therefore funded through EPA Regional Office and State grants. They are presented as interim or working targets. The public and multi-agency discussion on specific reduction targets is pending the results of the LMMB model runs. Specific targets and commitments will be part of the 2002 report.


Lake Michigan Lakewide Management Plan
Organization Structure
Adopted August 18, 1998
US Policy Committee
Management Committee
Federal Agencies
State Agencies
Tribal Agencies
EPA Mass Balance Technical Coordinating Committee
Management Plan Technical Coordinating Committee
Lake Michigan Forum
Steering Subcommittee
Human Health Subcommittee
Education and Outreach Subcommittee
Toxic Reduction Subcommittee
Stewardship Subcommittee
Habitat Subcommittee
Indicators, Monitoring, and Assessment Subcommittee
Research Science Advisors
Lake Michigan Monitoring Coordinating Council

Chapter 2:
Lake Michigan Lakewide Management Plan: Vision, Goals, and Ecosystem Objectives

Chapter 2 of the Lake Michigan Lakewide Management Plan defines the vision, goals, and ecosystem objectives of the Lake Michigan LaMP. The ecosystem goals were adopted in August 1998, expanding the focus of the LaMP from chemical stressors and beneficial use impairments to include physical and biological stressors and human health issues. The vision, goals, and subgoals are based on three principles: (1) remediation, (2) integrity and sustainability, and (3) partnership frameworks. LaMP goals must be linked to beneficial use impairments, development of indicators, monitoring and reporting on indicators, effective implementation strategies, and stakeholders. Subgoals describe either endpoints or means to achieving those endpoints. While all 14 beneficial uses are impaired in at least one location in the basin, the impairment is not necessarily uniform across the basin. Therefore, beneficial use impairments are classified spatially as follows: (1) local, (2) regional, or (3) open lake or lakewide. In addition, the LaMP will promote stewardship and preservation activities in areas where no use impairments exist. The Technical Coordinating Committee and Lake Michigan Forum have developed draft ecosystem indicators to identify simple values that reflect the condition of an ecosystem component. The LaMP committees, regional federal agencies, and the Great Lakes Commission have established the Lake Michigan Monitoring Coordinating Council (LMMCC) to coordinate and support monitoring activities in the Lake Michigan basin, as well as to disseminate the information available. Implementation strategies will require cross-jurisdictional and cross-program coordination. However, many of the tools necessary to restore and maintain the Lake Michigan ecosystem already exist, and careful coordination among the diverse stakeholders can integrate diverse resources and regulatory authorities to ensure the attainment of the Lake Michigan LaMP vision, goals, and ecosystem objectives.

CONTENTS

Tables

Chapter 2: Lake Michigan Lakewide Management Plan: Vision, Goals, and Ecosystem Objectives

2.1 About This Chapter

The purpose of this chapter is to present and discuss the vision and goals for the Lake Michigan LaMP process. The chapter introduces and defines a suite of **ecosystem** management **goals** developed in accordance with the purpose of the Great Lakes Water Quality Agreement. The chapter also describes the role that various statutes and ordinances, agencies, partner organizations, stakeholder communities, and the general public play in the achievement of the LaMP goals. These goals provide a blueprint for the implementation of the LaMP, and they provide a set of "finish lines" against which progress in achieving lakewide management can be monitored and measured.

ECOSYSTEM GOALS

Ecosystem goals are holistic and integrative. They are designed to achieve a balance between the environmental, economic, and social elements upon which the ecosystem approach is based. For the purposes of the Lake Michigan LaMP, ecosystem goals have been organized into two classes: those that specify endpoints and those that specify the appropriate means to those ends.

The suite of goals presented in this chapter provides the context for the integration of the programs and projects that make up ecosystem management on a basin-wide scale. Because agency policies, missions, and program objectives are necessarily specific and sometimes narrowly focused, any single ecosystem goal may address multiple media and disciplines. In addition, care has been taken to develop a suite of goals that integrate remediation in the context of the restoration and protection required for long-term sustainability in the basin ecosystem. Finally, the goals provide a basis for specifying the levels of ecosystem integrity required to restore beneficial uses and provide for healthy human and natural communities in the Lake Michigan basin, as well as the basis for LaMP objectives and LaMP indicators, elements necessary for the measurement of progress toward the LaMP vision. A glossary of terms defined by the organizations working with these concepts is provided at the end of this chapter.

2.2 The Goal Development Process

In 1998, the Lake Michigan Technical Coordinating Committee (TCC) and the Lake Michigan Forum worked with the Green Mountain Institute for Environmental Democracy to develop goals and objectives for the LaMP using comparative risk methods. The goals build on and amplify the purpose of the GLWQA, which was amended in 1987 to endorse a coordinated, cooperative effort to protect and restore the Great Lakes ecosystem. In 1997, the Lake Michigan Management Committee approved an ecosystem scope for the Stage 1 Lake Michigan LaMP, and in August 1998, the Management Committee adopted the ecosystem goals presented below.

These decisions and actions result in not only continued work on chemical stressors, a focus of the previous two LaMP drafts, but also a definition and framework for the LaMP ecosystem scope. This expanded scope encourages work on physical and biological stressors, human health, the continuation of activities to address beneficial use impairments, and the development of a set of LaMP objectives. The challenge of the LaMP is to coordinate the ecosystem goals and objectives with the GLWQA's beneficial use impairments and numerous other federal, state, tribal, and local goals to produce a clear, strategic action agenda.

THE GREAT LAKES WATER QUALITY AGREEMENT

The Purpose of the Parties is to restore and maintain the chemical, physical, and biological integrity of the Great Lakes Basin ecosystem.

LAKE MICHIGAN LaMP VISION AND GOALS
Adopted by the Management Committee August 18,1998

LAKE MICHIGAN LaMP VISION – DESIRED OUTCOME
A sustainable Lake Michigan ecosystem that ensures environmental integrity and that supports and is supported by economically viable, healthy human communities.

LAKE MICHIGAN LaMP GOAL[1]
To restore and protect the integrity of the Lake Michigan ecosystem through collaborative, place-based partnerships.

The vision, goal, and subgoals presented and discussed are based on three overarching principles: remediation, integrity and sustainability, and partnership frameworks.

REMEDIATION. Reduce loadings and emissions of LaMP critical pollutants to the Lake Michigan ecosystem and remediate contaminated sediments within the 10 Areas of Concern in the Lake Michigan basin; utilize the LaMP process to develop reduction targets (building on the Lake Michigan Mass Balance Study and the Binational Strategy); and achieve substantial reductions in human and ecological health risks in the basin.

INTEGRITY AND SUSTAINABILITY. Restore and protect key components of the Lake Michigan basin ecosystem so as to ensure levels of integrity that will provide ecosystem benefits and services to the natural and human communities in the system on a long-term basis; and have in place the means to maintain a long-term balance between environmental integrity, economic vitality and sociocultural well-being – all of which are measures of sustainability.

PARTNERSHIP FRAMEWORKS. Develop partnership frameworks and infrastructures that involve as many types of government, organizations, tribes, industries, and residents in the actual work of ecosystem protection and remediation at levels appropriate to their roles.

These principles form the basis of the LaMP Vision and Goals, and provide a framework for the development of the LaMP subgoals.

1 The Great Lakes Fishery Commission (GLFC) has adopted the Great Lakes Water Quality Agreement Goal, Joint Strategic Plan for Management of the Great Lakes Fishery, and Fish Community Objectives for Lake Michigan. The more specific goal statements for Lake Michigan are: To secure fish communities, based on foundations of stable, self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, employment and income, and a healthy human environment. In addition, the Commission has adopted fish-community objectives for Lake Michigan for each relevant sub-goal.

2.3 The Goal Structure of the Lake Michigan LaMP

The tables on the following pages, Table 2-1 and 2-2, present the subgoal organization of the Lake Michigan LaMP. There are two types of subgoals of the LaMP: those that describe end points and those that describe means. Both types of subgoals are required to achieve the goal of a sustainable Lake Michigan basin ecosystem. Icons are introduced to represent each of the subgoals to help guide the reader throughout the LaMP.

2.4 Linking LaMP Goals to Beneficial Use Impairments

The suite of subgoals for the Lake Michigan LaMP was designed to include and integrate remediation efforts aimed at beneficial use impairments – one of the three overarching principles that guided LaMP goal development. The matrix that follows (see Table 2-3) is a “cross-walk” that links LaMP subgoals and beneficial use impairments.

For Lake Michigan LaMP designation purposes, beneficial use impairments have been spatially classified as:

- ***Local*** – An AOC or other area affecting the lake
- ***Regional*** – An AOC cluster or multi-jurisdiction watershed
- ***Open water*** or ***Lakewide*** – The condition of pervasive impairment

Because all 14 beneficial use impairments have been observed in the Indiana Harbor and Ship Canal AOC, the LaMP has been prepared with the understanding that all 14 need to be addressed in the basin; however, this does not imply that impairment is uniform across the ecosystem or that sufficient data exist to quantify conditions to any fine level of detail at this time. Recognizing the limitations of focusing solely on locations where beneficial uses have been impaired, the Management Committee approved the application of the LaMP process to a broad range of places using the LaMP vision, goal, and subgoals to guide such decisions. The impact of this guidance by the Management Committee has allowed LaMP activities to focus not only on the AOC but also in places like the Chicago metropolitan area and the St. Joseph River watershed because of their impact on the ecosystem. Similarly, in keeping the LaMP Vision, other places not afflicted with beneficial use impairments have been the focus of activities to promote stewardship and preserve environmental integrity.

Table 2-1. End Point Subgoals

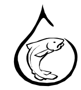
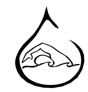
End Point Subgoals Endpoint subgoals describe the desired levels of ecosystem integrity and ecological services required to restore beneficial uses and provide for healthy human and natural communities in the basin.		
Subgoal 1	We can all eat any fish.	
Subgoal 2	We can all drink the water.	
Subgoal 3	We can all swim in the water.	
Subgoal 4	All habitats are healthy, naturally diverse, and sufficient to sustain viable biological communities.	
Subgoal 5	Public access to open space, shoreline, and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake	
Subgoal 6	Land use, recreation, and economic activities are sustainable and support a healthy ecosystem.	

Table 2-2. Means to End-Point Subgoals

Means to End-Point Subgoals Means subgoals describe the natural and organizational processes required to achieve the endpoint subgoals.		
Subgoal 7	Sediments, air, land, and water are not sources or pathways of contamination that affect the integrity of the ecosystem.	
Subgoal 8	Exotic species are controlled and managed.	
Subgoal 9	Ecosystem stewardship activities are common and undertaken by public and private organizations in communities around the basin.	
Subgoal 10	Collaborative ecosystem management is the basis for decision-making in the Lake Michigan basin.	
Subgoal 11	We have enough information/data/understanding/indicators to inform the decision-making process.	

Table 2-3. Lake Michigan LaMP - Goals and Beneficial Use Impairments (BUI) Cross Walk

Goal	Beneficial Use Impairments
We can all eat any fish	• Restriction on fish and wildlife (F/W) consumption • Tainting of F/W flavor
We can all drink the water	• Restrictions on drinking water consumption or taste and odor problems
We can all swim in the water	• Beach closings
All habitats are healthy, naturally diverse and sufficient to sustain viable biological communities	• Degradation of F/W populations • Fish tumors, or other deformities • Degradation of benthos • Eutrophication or undesirable algae • Degradation of phytoplankton and zooplankton • Loss of F/W habitat • Bird or animal deformities and reproduction problems
Public access to open space, shoreline and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem	• Degradation of aesthetics
Land use, recreation and economic activities are sustainable and support a healthy ecosystem	• Restrictions on dredging • Added cost to agriculture or industry

2.5 Linking LaMP Goals to Indicator Development

To determine whether conditions are getting better or worse over time, it is necessary to identify things that people can measure and accept as gauges regarding the condition of the system. Indicators, when tracked over time, provide information on trends in the important characteristics of a system. Ecosystem indicators are surrogates – simple values that reflect the condition of an ecosystem component.

The development of indicators is a partnership effort between the TCC and Lake Michigan Forum. The LaMP recognizes that indicators are under development in the State of the Great Lakes Ecosystem Conference (SOLEC) "Indicators for Great Lakes Basin Ecosystem Health" initiative. The Great Lakes Fishery Commission, represented on the TCC and Management Committee, has also been a lead contributor to the aquatic indicators for the LaMP. LaMP indicators under development are keyed to the condition of the endpoint subgoals (No. 1 through 6). LaMP indicators attempt to focus on ecosystem outcomes and progress made in the remediation of associated beneficial use impairments. Indicators describing the means subgoals (No. 7 through 11) are under development. Standards set for measuring the performance of federal agencies in the 1993 Government Performance and Results Act (GPRA) as well as state, tribal, and local data sources have informed the definition of LaMP indicators. The emphasis of the LaMP ecosystem indicators are the status or condition of the ecosystem and the degree of beneficial use impairment.

The set of indicators presented in Chapter 3 provides an opportunity for public comment. The final decisions on indicators will consider these comments, institutional abilities to monitor and report on the indicators, and the ability of the indicators to measure progress toward achieving LaMP goals.

2.6 Linking LaMP Goals to Monitoring and Reporting

Ecosystem indicators are directly tied to the LaMP goals and subgoals and are general in nature. These indicators should provide feedback to resource managers by describing the status of ecosystems and, therefore, the effectiveness of the programs. Program and project goals should support LaMP subgoals and link to one or more indicators. Thus, the development of indicators leads naturally to the design of a monitoring strategy to provide that feedback.

A critical component in the achievement of the goals of the LaMP and the Remedial Action Plans for AOCs in the basin is a monitoring regime that is sufficiently comprehensive to support the ecosystem indicators and is coordinated from one jurisdiction to another. While the Lake Michigan Mass Balance Project will provide important data on several critical pollutants affecting the lake, the need remains to assess the status and scope of monitoring being conducted by federal, state, tribal, and local agencies; to develop a plan for the coordination and enhancement of these efforts; and to develop a network to broadly share the results.

Enhanced Tributary Monitoring Project

From 1998 to 2000, the Great Lakes Commission is aiding the LaMP efforts to assess monitoring activities in the basin as a preliminary step in the development of an infrastructure for monitoring and reporting. The Lake Michigan Tributary Monitoring Project convened representatives from each of the 10 Areas of Concern in addition to representatives from Door County, Wisconsin; and St. Joseph River, Grand River, and Grand Traverse Bay, Michigan. The assessment included discussions among the regional planning commissions, councils of government, and other such local agencies in the basin as well as municipalities. The assessment will focus on the enumeration and description of monitoring programs for Lake Michigan tributaries; the identification of data gaps; and the training of volunteer monitors at the local and Area of Concern level. Monitoring will be viewed in the broadest sense, including not only traditional water quality parameters, but also habitat, wildlife, land use, nonpoint source pollution, and other measures of ecosystem health. The Project held its final meeting in April 2000 and the consensus was to recommend establishment of a Lake Michigan Volunteer Monitoring Network.

Lake Michigan Monitoring Coordinating Council

The Lake Michigan LaMP Committees, in partnership with regional federal agencies and the Great Lakes Commission, jointly established the Lake Michigan Monitoring Coordinating Council (LMMCC), a basin-wide collaborative body whose mission is "to provide a forum for coordinating and supporting monitoring activities in the Lake Michigan basin and to develop and make broadly available a shared resource of information, based on documented standards and protocols, that is usable across agency and jurisdictional boundaries." The Objectives of the LMMCC are as follows:

- Document monitoring activities, identify data gaps, and contribute to the development of a monitoring framework for the Lake Michigan basin

- Establish and maintain collaborative partnerships that link federal, state, tribal, and local and non-government monitoring organizations and initiatives in the Lake Michigan basin to allow for the assessment of the quality of resources in the basin

- Foster the implementation of monitoring activities that document data quality and are comparable throughout the basin

- Maintain information networks that link basinwide information systems and allow for efficient sharing and updating of monitoring information

2.7 Linking LaMP Goals to Effective Implementation

The development of the LaMP holds great promise for achieving environmental improvement in the Lake Michigan basin, but it also offers significant challenges in terms of practicing environmental restoration and protection on this scale. One of the most significant of these challenges is the need for cross-program and cross-jurisdictional coordination. This includes coordination between the US and Canada, between federal agencies, and among states, provinces, and tribes, as well as coordination across a variety of statutory authorities. Because of this, EPA has taken the approach of using existing tools, as well as developing new and innovative ones, in concert with federal, tribal, state, and local partners to achieve environmental results that are relevant to a given place. To simplify the myriad of statutes, regulations and resources affecting the management of Lake Michigan, Appendix D presents a matrix of the major governmental units, regulatory agencies, and other significant stakeholders that are responsible for managing the Lake Michigan ecosystem. The matrix includes a description of these units, their goals, and their roles and responsibilities as they pertain to the restoration and maintenance of the chemical, physical, and biological integrity of the Lake Michigan ecosystem.

2.8 Linking LaMP Goals to Other Initiatives and Efforts

Remedial Action Plans (RAP)

The GLWQA amendments of 1987 also called for the development of RAPs for specific Area of Concern. The two Federal governments were directed to cooperate with the state and provincial governments to develop and implement RAPs. The RAPs and LaMPs are similar in that they both use an ecosystem approach to assessing and remediating environmental degradation, focus on the 14 beneficial use impairments outlined in GLWQA, Annex 2, and rely on a structured public involvement process. RAPs, however, encompass a much smaller geographic area, concentrating on an embayment, a single watershed, or stretch of a river. The RAP focus is on local areas and use impairments for the local areas and the lake as a whole.

Forging a strong relationship between the LaMPs and RAPs is important to the success of both efforts. The RAPs serve as point sources discharges to the lake as a whole. Improvements in the AOC areas will eventually help improve the entire lake. Much of the expertise about use impairments, possible remedial efforts and watershed planning reside at the local level. Cooperation between the two efforts is essential in order for LaMPs to remove lakewide impairments.

Great Lakes Fishery Commission (GLFC) and Joint Strategic Plan for Management of the Great Lakes Fisheries

Imbedded in LaMP 2000 are the GLFC goals and fish community objectives for Lake Michigan. The GLFC's Joint Strategic Plan for Management of the Great Lakes Fisheries (June 1997) [www.glfc.org] responded to the need to better coordinate and integrate fisheries and environmental ecosystem management initiatives, particularly regarding implementation of the Great Lakes Water Quality Agreement. The parties have attempted to meet this challenge by incorporating strengthened fisheries management and environmental management coordination into strategic procedures and the plan. The 1997 revision created the Council of Great Lakes Fishery Agency and included representation from signatories plus EPA and Environment Canada.

Fishery management authority in the Great Lakes belongs to the individual states and the province of Ontario, subject to tribal treaty areas. Although federal agencies are actively involved in Great Lakes fishery assessments, the states maintain primacy in fisheries management. In the late 1970s, it was required that the successful restoration and management of the Great Lakes fisheries required a more holistic approach to addressing fisheries related issues. A Joint Strategic Plan for Management of the Great Lakes Fisheries (Joint Strategic Plan) was established and coordinated activities designed to achieve a common set of fish community objectives. By utilizing a non-binding, consensus approach toward achieving the fish community objectives, the legal responsibilities of the individual natural resource agencies were not usurped or weakened while accomplishing a uniformed lakewide approach to addressing fishery issues. This has proven to be an effective management approach since the Joint Strategic Plan was first ratified in 1980. A revised version of the Joint Strategic Plan maintained the four basic strategies as well as the management structure of the 1980 version when it was ratified in 1997.

The Fish Community Objectives for Lake Michigan were published in 1995 (GLFC Special Publication 95-3) and have the goal to "Restore and maintain the biological integrity of the fish community so that production of desirable fish is sustainable and ecologically efficient." This fish-community goal is an extension of the ecosystem goals established by the GLWQA and the Joint Strategic Plan.

Great Lakes Binational Toxics Strategy

Signed between the U.S. and Canada in 1997, the Binational Toxics Strategy (BTS) helps provide an overall coordinating effort across the lakes to reduce and virtually eliminate persistent toxic substances in the Great Lakes Basin. The Binational Toxics Strategy is a framework for actions to reduce or eliminate persistent toxic substances and establishes reduction challenges in the time frame 1997 to 2006 for twelve persistent toxic substances including PCBs and mercury.

The effort is important to the toxic reduction efforts of the LaMP for several reasons. It can work in the national and international arena to address out-of-basin air deposition sources, an increasingly important source of inputs to the lake. Second, because the BTS is closely coordinated with the U.S. Persistent, Bioaccumulative and Toxic Pollutant Strategy (PBT), it can disseminate the most current national and international scientific information. Lastly, the ambitious reduction time frames and schedules for virtual elimination of critical pollutants at the basin, national, and international level can help support basin level reduction efforts.

Great Lakes Five-Year Strategy

The USEPA, Great Lakes National Program Office, in cooperation with their State, Federal, and Tribal partners, is developing "Great Lakes 2000: A Strategic Plan for the Great Lakes Ecosystem." This plan will serve as an overall strategy for committing to and achieving specific environmental goals into the new millennium. The plan will focus on current cross media issues which include persistent toxic substances, habitat destruction, human, aquatic, and wildlife health, invasive species, and emerging issues facing the Great Lakes in the immediate future.

2.9 Linking LaMP Goals to Partners and Stakeholders: Examples

LaMP partners include federal agencies, state agencies, tribes, industry, and non-governmental organizations. The goals of the individual partners were considered when developing the overall LaMP goals. The following goals of state, tribal, and industry partners are examples of individual partner goals that influenced the LaMP goals.

States

The four Lake Michigan states have mature environmental programs that have been delegated the authority by EPA to issue permits, take enforcement actions, and clean up sites. Each state also has specific legislation that addresses state-specific problems. This jurisdictional difference and diversity of tools among the state partners can provide examples and new procedures if a collaborative dialogue exists.

Tribes

The ecosystem approach has particular significance to the 10 Lake Michigan tribes that continue to live in traditional ways that are dependent on healthy, sustainable resources in the Lake Michigan basin. These tribal communities are located on lands that have been reserved for their use. Tribes do not have the ability to relocate these reservation areas in response to contamination or pollution. For traditional tribal communities, environmental protection and restoration in the Lake Michigan basin is also critical for spiritual purposes. There are certain places, both on and off reservation/tribal lands, that are considered to be sacred, and their preservation is a priority. Ceremonial practices can require fresh water, specific native plants, and access to natural settings. In addition, tribal members continue to collect native medicinal plants that are used in traditional healing practices.

Foods that are significant to the Native American diet are harvested from the land and waters of the basin. For many tribes, the fishery resources both in Lake Michigan and its tributaries are of critical importance. Studies have concluded that tribal members consume much higher amounts of fish than other populations in the basin, and thus are at a higher risk for adverse health effects associated with consuming contaminated fish. Many tribes also depend upon wild rice as a primary food stock. Wild rice is very sensitive to water quality and water levels, and protection of its habitat is crucial.

Many tribal members continue to make their livelihood or supplement their income through the harvesting of natural resources within the Lake Michigan basin. A few tribal commercial fishers still operate on the lake and one of the oldest sustainable forestry management programs is in the basin. Products such as maple sugar, basketry materials, fir boughs and fur bearing animals are also harvested in the basin.

As sovereign nations, tribes have developed and continue to administer environmental protection programs for their reservations/tribal lands that address water resource protection, solid waste management, emergency response, ambient air quality, and land use planning for the lands within their jurisdiction. Land areas outside of the reservation/tribal lands are also important to the tribes, as many retain hunting, fishing, and gathering rights in ceded territories. Tribes plan, monitor, permit and enforce environmental activities and in certain programs have the ability to act under the appropriate federal statute. Tribal representatives participated in the development of the Lake Michigan ecosystem goals, and they reinforce the tribal goals described above and articulated as sustaining the environment:

> "...unto the Seventh Generation. The Creator will guide our thoughts and strengthen us as we work together to be faithful to our sacred trust and restore harmony among ourselves and our relationships with others, with all living creatures and Mother Earth."

Industry

The Great Lakes Pollution Prevention Roundtable, the various trade associations supporting EPA's Strategic Goals Program and the Chemical Manufacturers' Association, with its Responsible Care™ Program, are examples of industrial organizations promoting pollution prevention. These pollution prevention goals align with several LaMP goals.

International standards for environmental management are emerging, and are expected to accelerate the trend toward quality-based environmental management in industry, focusing on customers, shareholders and stakeholders and relating performance to the expectations of multiple segments of society. The International Organization for Standardization (ISO) 14000 is a set of voluntary international standards for environmental management in industry, which may be adopted should a company or facility wish to receive ISO 14000 certification. The ISO standard requires that an organization's policies include commitments to: (1) comply with relevant laws, regulations, and other voluntary efforts; (2) recognize community comment and input; and (3) prevent pollution and work to continually improve its management system.

The ultimate test of this system of management is the ability to help a company be more efficient and competitive while reducing its impact on the environment.

Appendix D outlines the different units of government, regulatory, local, and tribal agencies and other groups, such as citizen groups and industry, that have an important role to play in restoring and maintaining the Lake Michigan ecosystem. Each of the governmental units, regulatory agencies, and other significant stakeholders listed in Tables D-1 through D-5 in Appendix D have been given some legal authority that enables it to regulate, study, or otherwise affect Lake Michigan. The U.S. Congress, state legislatures, tribes, and local officials grant these agencies the authority to carry out various tasks, including issuing permits to discharge waste, funding studies to measure the levels of various pollutants, regulating the application of fertilizers and pesticides, and issuing buildings permits, to name a few. These diverse resources and regulatory authorities can work in concert or in conflict. Awareness and coordination among the agencies, therefore, is an important factor in the ecosystem approach to managing Lake Michigan. Many of the tools to restore and maintain the Lake Michigan ecosystem already exist, in the form of agencies with legal authority and resources to dedicate towards the ecosystem approach. As the Interagency Ecosystem Management Task Force reported in *The Ecosystem Approach: Healthy Ecosystems and Sustainable Economies*, Volume 11, *Implementation Issues*, November, 1995, page 69:

The federal government currently has significant statutory authority available to take an ecosystem approach to federal activities and to pursue collaborative efforts with state, tribal, and local governments and private parties. No single federal statute contains an explicit, overarching national mandate to take an ecosystem approach to management, and Congress has never declared that a particular federal agency has the ecosystem approach as its sole, or even primary, mission. Each agency operates pursuant to specific mandates that govern the particular lands that the agency manages, the environmental media (such as air and water) that it regulates, or the development projects that it builds or finances. However, many federal statutes provide agencies with opportunities to take an ecosystem approach, and a surprising number have been drafted with whole ecosystems in mind.

Steel Mills Report on Mercury Use

Three major steel mills in Northwest Indiana (Bethlehem, Ispat Inland, and U.S. Steel) signed an agreement in September 1998 to reduce their use of mercury through pollution prevention and recycling activities. In September 1999, the mills released a report, "Mercury Sources of Three Indiana Steel Mills" and presented it at the IJC Biennial Forum in Milwaukee.

The agreement calls for the three participating companies to:

- Conduct an inventory of purchases of mercury and mercury-containing equipment and materials; mercury in use at the facilities in equipment and liquid mercury in storage; and the presence of mercury in waste streams and non-product outputs
- Identify, where possible, alternatives to mercury containing equipment and materials, and potential recycling options
- Prepare reduction plans that indicate reduction goals, planned actions to reach the goals, and schedules.

They concluded in this report that finding and addressing a pervasive substance such as mercury is a substantiated task and that more industries and facilities need to participate in similar efforts. Conclusions drawn from this mercury inventory by the steel mills that may be useful to other facilities include:

- Most of the mercury that exists at steel mills is contained in electrical and other equipment, making it most effective to target these sources for reductions. Manufacturers and suppliers should provide mercury content information for products that are intentionally manufactured with mercury. Mercury content labels would increase the effectiveness of equipment replacement and substitution.
- A central repository should be established to facilitate technology transfer as more inventories are conducted **-** for mercury as well as other contaminants of concern.
- Mercury switches should be routinely removed from 1995 and older model year cars before they are scrapped in order to reduce potential for mercury to enter the steel making process from scrap.

The next phase of the project will result in a reduction plan identifying steps to be taken by each facility to address the sources of mercury outlined in the report. Efforts will focus on purchasing equipment that does not contain mercury and putting effective disposal and recycling programs in place for equipment and laboratory wastes.

Source: www.lkmichiganforum.org/mercury

While many laws are not written with the ecosystem approach in mind, the day-to-day business of the various agencies charged with carrying out these laws often profoundly affects Lake Michigan. For this reason, it is important that these various agencies, even those that do not have a mandate to protect the environment or manage natural resources, coordinate their efforts and resources while developing new and better ways of fulfilling their mandates. As stated in *The Ecosystem Approach: Healthy Ecosystems and Sustainable Economies*, Volume 11, *Implementation Issues*, November, 1995, page 71:

> The ecosystem approach requires agencies to do several things: to coordinate planning and management where appropriate, even where agencies operate under different mandates, to plan and manage on an ecosystem scale – that is, with ecological, not just administrative, boundaries in mind; to protect the rights of private landowners; to ensure early and active stakeholder participation; and to use adaptive management - to adjust their activities as applicable scientific principles evolve and as new information becomes available.

GLOSSARY

Key terms used in the goals and subgoals as defined by organizations working with these concepts:

Ecosystem: An interactive system of biological communities; their nonliving components (air, land, and water); and their associated activities. As used by the International Joint Commission (IJC), ecosystems include humans, their activities and institutions.

Biological Integrity: The ability of an ecosystem to support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to the best natural habitats within a region. (Karr and Dudley 1981). The term originated in the 1972 Water Pollution Control Act Amendments (PL 92-500) and has appeared in subsequent versions (PL 95-217; PL 100-1).

Ecosystem Integrity: A measure of the capacity of ecosystems to renew themselves and continually supply resources and essential services. Ecosystem integrity is the degree to which all ecosystem elements – species, habitats, and natural processes – are intact and functioning in ways that ensure sustainability and long-term adaptation to changing environmental conditions and human uses (Minnesota Department of Natural Resources, July 1997).

Ecosystem Management: The process of sustaining ecosystem integrity through partnerships and interdisciplinary teamwork. Ecosystem-based management focuses on three interacting dimensions: the economy, the social community, and the environment. Ecosystem-based management seeks to sustain ecological health while meeting economic needs and human uses (Minnesota Department of Natural Resources, July 1997).

Collaborative Approaches: Voluntary, multi-stakeholder, collaborative approaches to protect, restore, and monitor natural resources and to resolve natural resources conflicts (The President's Council on Sustainable Development [PCSD]).

Sustainable Development: Development that meets the needs of the present without comprising the ability of future generations to meet their own needs (The World Commission on Environment and Development [The Brundtland Commission] 1987).

Approaches to Sustainability: Sustainability addresses three related elements: the environment, the economy, and the community. The goal is to maintain all three elements in a healthy state indefinitely (Minnesota Department of Natural Resources, July 1997). The air, land, and water are interconnected in sustaining all life, in protecting public health and in achieving healthy diverse ecosystems and the sustainable economies that depend on these ecosystems (Wisconsin Department of Natural Resources, 1999).

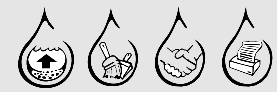
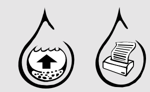
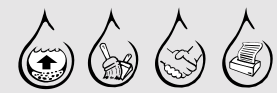
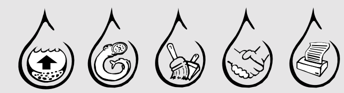
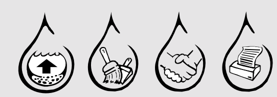
Biodiversity: The variety of life and its processes, including the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary process that keep them functioning, yet ever changing and adapting (Noss and Copperrider 1994).

Exotic Species: Species that are not native to an ecosystem and are usually introduced by purposeful or inadvertent human action (IJC).

Integrity of the Great Lakes Basin: The planning and management of the water resources of the Great Lakes Basin should recognize and be founded on the integrity of the natural resources and ecosystem of the Great Lakes Basin. The water resources of the basin transcend political boundaries and should be recognized and treated as a single hydrologic system. In managing Great Lakes Basin waters, the natural resources and ecosystem of the Basin should be considered as a unified whole (The Great Lakes Commission).

Environmental Integrity Goal: Enhance, restore, and sustain the health, productivity, and biodiversity of terrestrial and aquatic ecosystems through cooperative efforts to use the best ecological, social, and economic information to manage natural resources (PCSD).

Table 2-4. Lake Michigan LaMP Summary Table (Chapter 2)

CHAPTER 2 — Lake Michigan LaMP: Vision, Goals, and Ecosystem Objectives — Goal	Chapter 3 Indicators and Monitoring of the Health of the Lake Michigan Ecosystem	Chapter 4 Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments and Human Health	Chapter 5 Lake Michigan Stressor Sources and Loads	CHAPTER 6 — Strategic Action Agenda: Next Steps — Means to an End Goal	CHAPTER 6 — Strategic Action Agenda: Next Steps — Recommendations
1. We can all eat any fish.					
2. We can all drink the water.					
3. We can all swim in the water.					
4. All habitats are healthy, naturally diverse, and sufficient to sustain viable biological communities.					
5. Public access to open space, shoreline, and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem.					
6. Land use, recreation, and economic activities are sustainable and support a healthy ecosystem.					

7. Sediments, air, land, and water are not sources or pathways of contamination that affect the integrity of the ecosystem.

8. Exotic species are controlled and managed.

9. Ecosystem stewardship activities are common and undertaken by public and private organizations in communities around the basin.

10. Collaborative ecosystem management is the basis for decision-making in the Lake Michigan basin.

11. We have enough information/data/understanding/indicators to inform the decision-making process.

Means to an End Goals

Chapter 3:
Indicators and Monitoring of the Health of the Lake Michigan Ecosystem

This chapter outlines a set of environmental, social, and economic indicators that can be used to assess the achievement of the LaMP vision, goals and objectives. The chapter also describes a monitoring assessment project that analyzes the ability to measure indicators in the Lake Michigan basin. These indicators will allow Lake Michigan stakeholders to better gauge the status of the Lake Michigan ecosystem and guide the selection of management activities that will restore and protect the health of the system.

The list of Lake Michigan indicators included in this chapter is provided to help generate discussion and is based on previous work completed in support of the State of the Lakes Ecosystem Conferences (SOLEC), the International Joint Commission, Fish Community Objectives, the Great Lakes Fishery Commission, and others.

Environmental indicators are a measure of environmental condition such as ecological integrity, aquatic health, human health, or quality of life. Environmental indicators are a useful tool for identifying pressures on the ecosystem, the state of the environment due to these pressures, and the response or action taken by environmental agencies or other parties to address the environmental conditions and pressures.

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Chapter 3: Indicators and Monitoring of the Health of the Lake Michigan Ecosystem

3.1 About This Chapter

In the preceding chapters of this LaMP, the vision, objectives, and goals for the Lake Michigan ecosystem were defined. This chapter outlines a set of environmental, social, and economic measures that can be used to assess the achievement of those goals and objectives and discusses monitoring programs in the Lake Michigan basin. These measures, or indicators, will allow Lake Michigan stakeholders to better gauge the status of the Lake Michigan ecosystem and guide the selection of management activities that will restore and protect the health of the system.

The list of Lake Michigan indicators included in Table 3-1 of this chapter is provided to help generate discussion and ultimately achieve consensus about which environmental indicators should be monitored and reported in order to measure progress toward the vision and goals of the Lake Michigan LaMP, which includes the directive "*. . . to restore and maintain the chemical, physical, and biological integrity of the waters of the Lake Michigan Ecosystem*." This list of indicators is based on previous work completed in support of the State of the Lakes Ecosystem Conferences (SOLEC), the International Joint Commission, Fish Community Objectives, and others.

While some information and data are being collected to assess these indicators, most of these proposed indicators are yet to be fully characterized. Some of the indicator data and information collected to date are presented in Chapters 4 and 5. However, much work remains to apply these indicators in a way that will support Lake Michigan ecosystem management.

3.2 Environmental Indicators

The use of environmental indicators is not a new concept and has been recognized as a valuable tool needed to assist in the establishment of management recommendations. Environmental indicators are also a means to track both environmental improvement and environmental protection of the Lake Michigan ecosystem. State and federal agencies have tracked trends in certain environmental measures over time, such as fish populations. What has changed in the environmental indicator process is the growing need to link actual environmental condition responses directly to programs and other activities as defined and set forth by the Lake Michigan LaMP.

Environmental indicators are a measure of environmental condition such as ecological integrity, aquatic health, human health, or quality of life. Environmental indicators can measure trends over time in changes or nonchanges in environmental and ecological conditions. Environmental indicators can function as an early warning signal for identifying environmental concerns, and they are a valuable tool for measuring progress towards achieving of identified environmental goals. When properly developed and utilized, environmental indicators will affect improvements in environmental conditions, with clear linkages showing the effectiveness of programs or other activities to successfully control environmental stressors.

Environmental indicators are a useful tool for identifying pressures on the ecosystem, the state of the environment due to these pressures, and the response or action taken by environmental agencies or other parties to address the environmental conditions and pressures. This "Pressure-State-Response" approach is also the organizing framework used by the National Goals Project, the State Environmental Goals and Indicators Project, the Interagency Sustainable Development Indicators Workgroup, and Region 5/State Watershed Indicators Development Workgroup. Regardless of how the Pressure-State-Response approach is organized, in order to be successful, it is absolutely necessary to select indicators that are measurable, can be monitored, and that link the pressures with the environmental conditions. Otherwise, it will be difficult or impossible to tell whether the changes in environmental trends are due to program activities or something else.

The key to picking and tracking sound and scientifically identifiable environmental indicators is to have clearly identifiable goals. As outlined in Chapter 2, The Lake Michigan LaMP has identified one main goal with 11 supporting subgoals. The first six subgoals have been identified as endpoints or the ultimate state to be achieved in the Lake Michigan ecosystem. Subgoals 7 through 11 are identified as means to achieving the first six subgoals. These subgoals must function together to define the full ecosystem state. By developing an appropriate mix of environmental indicators and performance measures, one can better evaluate environmental conditions, identify existing and emerging environmental problems, set environmental priorities, make program specific decisions and address the highest priorities. Tracking trends in environmental indicators can serve as a means of communicating environmental successes or failures to the public and stakeholders and can serve as a tool for identifying remaining or new challenges. The environmental indicator process is as dynamic as the lake itself, and a part of the implementation of the Lake Michigan LaMP may require that new indicators be developed over time.

A defined framework for the development and selection of environmental indicators will provide a common reference point for basin management and monitoring efforts. The Lake Michigan LaMP has followed the guidelines set forth in the EPA guidance document titled “Region 5 Guide for Developing Environmental Goals, Milestones, and Indicators” (See Appendix H). In conjunction with this guidance, the Lake Michigan LaMP has incorporated environmental indicators developed by SOLEC. In 1998, SOLEC developed a set of environmental indicators for the Great Lakes Basin. These environmental indicators are still undergoing refinement following public input. The Lake Michigan LaMP is adopting the eight defined areas as presented by SOLEC. These areas are Nearshore Waters, Open Waters, Coastal Wetlands, Nearshore Terrestrial, Human Health, Land Use, Societal Indicators, and Unbounded. Using the most recent SOLEC list of environmental indicators, Table 3-1 relates the SOLEC indicators to the 11 subgoals set forth by the Lake Michigan LaMP. Work will continue in the next 2 years to identify and select these or other environmental indicators that are specific to Lake Michigan’s 11 subgoals at the appropriate scale. Once selected, the indicators will be linked to specific human activities and LaMP management actions to establish the pressure-state-response linkage needed to track progress in implementing environmental management programs. Place holders for the LaMP measurement actions are included in Table 3-1. The indicator–subgoal matrix as set forth in the chart will be used for future additions.

Table 3-1. Environmental Indicators

SubGoal 1: We can all eat any fish

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Human Health	[Unspecified detrimental effects on human health from exposure to fish contaminants]	Contaminants in edible fish tissue	Fish consumption advisories	
	[Unspecified assessment of risk to human health inferred from environmental factors related to fish]	Contaminants in recreational fish	Public perception: gauge awareness of fish safety	
	Body burden: concentration of contaminants in human tissue	Contaminants in young-of-year spottail shiners		
		Toxic chemical concentrations in offshore waters		
		Concentrations of contaminants in sediments cores		
		Atmospheric deposition of toxic chemicals		
	Deformities, eroded fins, lesions and tumors (DELT) in nearshore fish			
	DELT in coastal wetlands fish			

Table 3-1. Environmental Indicators (Continued)

SubGoal 2: We can all drink the water

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Human Health	Incidents of boil-water advisories	Drinking water quality	Use of sustainable agricultural practices	
			Drinking water treatment needs	
	Incidents of water-borne disease outbreak	Toxic chemical concentrations in offshore waters	Use of sustainable agricultural practices	
			Wastewater pollution control	
			Integration of ecosystem management principles across landscapes	
		Atmospheric deposition of toxic chemicals		
		Contaminant exchange between media: air to water and water to sediment		
		E. coli and fecal coliform levels in nearshore recreational waters		
		Susceptibility (results from source water assessments)	Source water protection plans	

Table 3-1. Environmental Indicators (Continued)

SubGoal 3: We can all swim in the water

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Human Health	Incidents of water-borne disease outbreaks	*E. coli* and fecal coliform levels in nearshore recreational waters	Use of sustainable agricultural practices	
			Beach closures	
			Integration of ecosystem management principles across landscapes	
		Wastewater pollution	NPDES permits	
Nearshore Terrestrial Integrity	Extent and quality of nearshore natural land cover	Extent of hardened shoreline	Shoreline management under integrated management plans	
		Nearshore land use intensity	Community/species plans	
	Area, quality, and protection of special lakeshore communities		Shoreline management under integrated management plans	
			Protected nearshore areas	
		Artificial coastal structures	Shoreline management under integrated management plans	
		Urban density		
		Sediment available for coastal nourishment		

Table 3-1. Environmental Indicators (Continued)

SubGoal 4: All habitats are healthy, naturally diverse, and sufficient to sustain viable biological communities

Geographic Area	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Open and Nearshore Water	Aquatic Habitat	Phosphorus concentrations and loadings	Use of sustainable agricultural practices	
		Toxic chemicals in offshore waters	Use of sustainable agricultural practices	
		Concentrations of contaminants in sediment cores		
		Contaminant exchanges between media: air to water and water to sediment		
		Atmospheric deposition of toxic chemicals		
		Contaminants in young-of-year spottail shiners		
		Contaminants in colonial nesting waterbirds		
	Lake trout and scud	Sea lamprey		
	Salmon and trout	Sea lamprey		
	Preyfish populations			
	DELT in nearshore fish	Contaminants in recreational fish		
		Concentrations of contaminants in sediment cores		

Table 3-1. Environmental Indicators (Continued)

Geographic Area	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Open and Nearshore Water (continued)	Phytoplankton populations	Phosphorus concentrations and loadings	Use of sustainable agricultural practices	
	Zooplankton populations	Phosphorus concentrations and loadings	Use of sustainable agricultural practices	
	Benthos diversity and abundance	Concentrations of contaminants in sediment cores		
	Native Unionid mussels			
	Sediment available for coastal nourishment			
Coastal Wetlands	Invertebrate community health	Contaminants in snapping turtle eggs		
		Sediment flowing into coastal waters	Use of sustainable agricultural practices	
		Nitrates and total phosphorus into coastal waters	Use of sustainable agricultural practices	
		Water-level fluctuations		
	Fish community health	Contaminants in snapping turtle eggs		
		Sediment flowing into coastal waters	Use of sustainable agricultural practices	
		Nitrates and total phosphorus into coastal waters	Use of sustainable agricultural practices	
		Water-level fluctuations		
	DELT in coastal wetland fish	Contaminants in snapping turtle eggs		

Table 3-1. Environmental Indicators (Continued)

Geographic Area	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Coastal Wetlands (continued)	Amphibian diversity and abundance	Contaminants in snapping turtle eggs		
		Sediment flowing into coastal waters	Use of sustainable agricultural practices	
		Nitrates and total phosphorus into coastal waters	Use of sustainable agricultural practices	
		Water-level fluctuations		
	Wetland-dependent bird diversity and abundance	Sediment flowing into coastal waters	Use of sustainable agricultural practices	
		Nitrates and total phosphorus into coastal waters	Use of sustainable agricultural practices	
		Water-level fluctuations		
	Wetland area by type	Water-level fluctuations		
		Land conversion		
	Gain in restored wetland area by type	Water-level fluctuations		
		Land conversion	Use of sustainable agricultural practices	
	Presence, abundance and expansion of invasive plants	Water-level fluctuations		
	Habitat adjacent to coastal wetlands	Land conversion	Use of sustainable agricultural practices	

Table 3-1. Environmental Indicators (Continued)

Geographic Area	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Nearshore Terrestrial	Extent and quality of nearshore natural land cover	Extent of hardened shoreline	Shoreline management under integrated plans	
		Nearshore land use intensity	Community / species pans	
			Shoreline management under integrated plans	
			Protected nearshore areas	
		Artificial coastal structures	Shoreline management under integrated plans	
		Urban density		
		Land conversion		
	Area, quality, and protection of special lakeshore communities	Water-level fluctuations		
		Extent of hardened shoreline	Shoreline management under integrated plans	
		Nearshore land use intensity	Community / species pans	
			Shoreline management under integrated management plans	
			Protected nearshore areas	
			Shoreline management under integrated plans	

Table 3-1. Environmental Indicators (Continued)

Geographic Area	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Nearshore Terrestrial (Continued)	Area, quality, and protection of special lakeshore communities	Nearshore plant and wildlife problem species	Community / Species Plans	
	Nearshore species diversity and stability	Contaminants affecting productivity of bald eagles	Community / Species Plans	
		Contaminants affecting the american otter	Community / Species Plans	
	Sediment available for coastal nourishment			
Land Use	Breeding bird diversity and abundance	Land conversion		
	Habitat fragmentation	Land conversion		
	Threatened species	Land conversion		
	[Unspecified integrated measure of human impact on Great Lakes ecosystem structure and function]	Urban density		
		Mass transportation		
		Water consumption		
		Energy consumption		
		Wastewater pollution		
		Solid waste generation		
			Brownfield redevelopment	
			Green planning process	

Table 3-1. Environmental Indicators (Continued)

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Societal Indicators	Aesthetics			
	Economic prosperity			
	[Unspecified measure of societal capacity, willingness and commitment to stewardship]		Capacities of sustainable landscape partnerships	
			Organizational richness of sustainable landscape partnerships	
			Integration of ecosystem management principles across landscapes	
			Integration of sustainability principles across landscapes	
			Citizen/Community place-based stewardship activities	
			Financial resources allocated to Great Lakes programs	
Unbounded	Atmospheric visibility			
	[Unspecified ecosystem effects]	Acid rain		
		Global warming: number of extreme storms		
		Global warming: first emergence of water lilies in coastal wetlands		
Unbounded		Global warming: ice duration on the Great Lakes		

Table 3-1. Environmental Indicators (Continued)

SubGoal 5: Public access to open space, shoreline, and natural area is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Societal Indicators	Aesthetics			
	Economic prosperity			
	[Unspecified measure of societal capacity, willingness, and commitment to stewardship]		Capacities of sustainable landscape partnerships	
			Organizational richness of sustainable landscape partnerships	
			Integration of ecosystem management principles across landscapes	
			Citizen/Community place-based stewardship activities	
			Financial resources allocated to Great Lakes programs	
Land Use	[Unspecified integrated measure of human impact on Great Lakes ecosystem structure and function]	Urban density		
		Land conversion		
		Mass transportation		
			Brownfield redevelopment	
			Green planning process	

Table 3-1. Environmental Indicators (Continued)

SubGoal 6: Land use, recreation, and economic activities are sustainable and support a healthy environment

Geographic Area	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Open and Nearshore Water	Salmon and trout	Sea Lamprey		
	Sport fishing			
Coastal Wetlands	Gain in restored wetland area by type	Water level fluctuations		
		Land conversion	Use of sustainable agricultural practices	
	Wetland area by type	Water level fluctuations		
		Land conversion		
Nearshore Terrestrial	Area, quality, and protection of special lakeshore communities	Extent of hardened shoreline	Shoreline management under integrated plans	
		Nearshore land use intensity	Shoreline management under integrated plans	
			Community/Species plans	
	Extent and quality of nearshore natural land cover	Artificial coastal structures	Shoreline management under integrated plans	
Human Health	[Unspecified effects due to exposure]	Coliform levels of nearshore recreational waters	Public perception of safety of recreational resources	
		Chemical contaminants in fish tissue		
		Drinking water quality chemical and microbial		
		Air quality		
Land Use	Breeding bird diversity and abundance	Land conversion		
Issue	**State Indicator**	**Pressure Indicator**	**Human Activity Indicator**	**LaMP Management Action**
	[Unspecified integrated measure of human impact on Great Lakes ecosystem structure and function]	Urban density		

Table 3-1. Environmental Indicators (Continued)

		Land conversion	Use of sustainable agricultural practices	
		Mass transportation		
		Energy consumption		
			Brownfield redevelopment	
			Green planning process	
			Ground level ozone	
Societal Indicators	Aesthetics			
	Economic prosperity			
	[Unspecified measure of societal capacity, willingness and commitment to stewardship]		Capacities of sustainable landscape partnerships	
			Organizational richness of sustainable landscape partnerships	
			Integration of ecosystem management	
			Principles across landscapes	

Table 3-1. Environmental Indicators (Continued)

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Societal Indicators (Continued)			Integration of sustainability principles across landscapes	
			Citizen/community place-based stewardship activities	
			Financial resources allocated to Great Lakes programs	

Table 3-1. Environmental Indicators (Continued)

SubGoal 7: Sediment, air, land, and water are not sources or pathways of contamination that affect the integrity of the ecosystem

Geographic Area	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Open and Nearshore Water	Sediment, land, and water habitat	Phosphorous concentrations and loadings	NPDES permits	
		Atmospheric deposition of toxic chemicals		
		Concentration of contaminants in sediment		
		Contaminant exchanges between media: air to water and water to sediment		
Coastal Wetlands		Sediment flowing into coastal wetlands	NPDES permits	
		Nitrates and total phosphorous into coastal wetlands		
			Urban density	
			Land conversion	
			Stream flow and sediment discharge	
Nearshore Terrestrial		Nearshore land use intensity		
		Contaminants affecting the American Otter	Shoreline managed under integrated management plans	
			Use of sustainable agricultural practices	
			Ground level ozone	
			Wastewater pollution	
			Solid waste generation	

Table 3-1. Environmental Indicators (Continued)

SubGoal 8: Exotic species are controlled and managed

Geographic Area	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Open and Nearshore Water	Native unionid mussels	Sea lamprey	Ship ballast water controls	
	Preyfish populations	Round goby		
	Benthic communities	Concentrations of contaminants in sediment cores		
	Phytoplankton	Spiny water flea		
	Zooplankton	Zebra mussel		
Coastal Wetlands	Presence, abundance, and expansion of invasive plants			
Nearshore Terrestrial			Community/species plans	

Table 3-1. Environmental Indicators (Continued)

SubGoal 9: Ecosystem stewardship activities are common and undertaken by public and private organizations in communities around the basin

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Community health and well-being	Aesthetics			
	Economic prosperity			
Common stewardship activities	Integration of ecosystem management principles across landscapes		Capacities of sustainable landscape partners Organizational richness of sustainable landscape partners Integration of sustainability principles across landscapes Citizen/community place-based stewardship activities Financial resources allocated to Great Lakes programs	

Table 3-1. Environmental Indicators (Continued)

SubGoal 10: Collaborative ecosystem management is the basis for decision making in the Lake Michigan basin

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action
Collaborative ecosystem management	Nearshore terrestrial development		Shoreline managed under integrated management plans	
	Basin-wide land use	Abandoned industrial sites	Brownfields redevelopment	
		Acreage in conservation tillage	Use of sustainable agricultural practices	
		Comprehensive land use planning	Green planning process	
	Commitment to collaborative ecosystem management		Integration of ecosystem management principles across landscapes Integration of sustainability principles across landscapes Citizen/community place-based stewardship activities Financial resources allocated to Great Lakes programs	

Table 3-1. **Environmental Indicators** (Continued)

SubGoal 11: We have enough information/data/understanding indicators to inform the decision-making process

Issue	State Indicator	Pressure Indicator	Human Activity Indicator	LaMP Management Action

3.3 Monitoring in the Lake Michigan Basin

If the indicators outlined in the preceding section are to provide information to support future management decision-making, they must be adopted by Lake Michigan monitoring programs and guide the selection of parameters and media to be sampled and assessed. Numerous monitoring programs and activities are underway in the Lake Michigan basin. These programs monitor water quality, sediments, fish, air quality, and habitat. They involve collecting chemical, microbiological, fish and wildlife, physical characteristics, land use, and other environmental data. These programs exist at the federal, state, county, municipal, and watershed level.

The Lake Michigan Monitoring Coordination Council (LMMCC) was established jointly by federal, state, and tribal agencies to provide a forum for coordinating and supporting monitoring activities in the Lake Michigan basin and to develop a shared resource of information, based on accepted standards and protocols, that is useable across agency and jurisdictional boundaries. The LMMCC is currently analyzing data collected from an inventory of monitoring programs in the Lake Michigan basin.

This work is being supported through a cooperative agreement with the Great Lakes Commission, EPA Region 5, and other partners involved in the Lake Michigan LaMP process to assess existing monitoring efforts in the Lake Michigan basin and subwatersheds, including the 10 AOCs and four other tributary watersheds. The project will include a comprehensive review of monitoring programs at the federal, state, and local levels for the targeted watersheds; an analysis of gaps, inconsistencies, and unmet needs; an assessment of the adequacy of existing efforts to support critical ecosystem indicators; and a plan for addressing major monitoring needs, particularly those considered most important for lakewide management decision-making. The report will also be used to train members of the Lake Michigan Forum, Public Advisory Councils, and other stakeholders to determine current, local monitoring efforts and establish community-based monitoring programs.

The project and report are consistent with the ecosystem approach of the LaMPs and RAPs especially with regard to emphasis on community involvement and participation. Monitoring will be viewed in the broadest sense, including not only traditional water quality parameters, but also habitat, wildlife, land use, nonpoint source pollution and other measures of ecosystem health. The report and future project outcomes are expected to provide stakeholders with important tools for developing RAPs and will enable them to engage their community in a valuable dialogue regarding the status of knowledge on their local watershed. Working closely with the states and tribes, stakeholders will benefit from the exchange of information and the opportunity to enhance local participation in state-sponsored monitoring programs. Finally, the project is fully consistent with the EPA Region 5 emphasis on community-based environmental protection and will comply with the Government Performance and Review Act.

One of the main purposes of the LMMCC project is to determine whether the current monitoring coverage is sufficient to support indicators proposed in the Lake Michigan LaMP. The findings and understanding gained through this project will be applied to each of the indicators, and a simple assessment will be made of each. The findings will include a list of each relevant open water, near shore, human health, land use, and coastal wetlands indicator, with a rating of the ability of the current monitoring infrastructure to provide sufficient data to assess the indicator. The project results will be released in the summer of 2000.

Mass Balance Approach

The questions confronting managers responsible for the Great Lakes are complex and regulatory action (or inaction) may have major social and economic consequences. It has become evident that rational approaches must be found to: address the issues; more clearly identify and quantify problems; locate and quantify sources of important chemicals; quantify rates of principal physical, chemical, and biological processes that control behavior of chemicals in the environment; and predict future conditions under alternative remedial actions to arrive at optimal programs. To help manage environmental quality and solve existing problems, a scientifically-based management framework has been implemented and prototyped within the Great Lakes community of managers and scientists referred to as the “Mass Balance Approach.” EPA, led by the Great Lakes National Program Office (GLNPO), conducted and intensive study of Green Bay (Lake Michigan), the Green Bay Mass Balance Study.

The Green Bay Mass Balance Study was conducted as a pilot study to test the feasibility of using a mass balance approach for the assessment of sources and fates of toxic pollutants in the Great Lakes ecosystem. It was intended to validate and refine monitoring and analytical assumptions made by the coordinating agencies, and to rigorously test the models. Specific objectives included:

1. Assessing the technical and economic feasibility of the mass balance approach for use in the management of pollutant loadings and impacts on Great Lakes ecosystems.

2. Calibrating the mass balance model for sources, transport routes, and fates of pollutants in the Great Lakes ecosystem.

3. Identifying the major sources of selected pollutants entering the Green Bay ecosystem and rank their relative significance.

4. Demonstrating methods and priorities for further studies of toxic pollutants in the Great Lakes.

The Office of Research and Development played an important role in this study and provided leadership and resources for several aspects, most importantly in leading the development of the scientific tools, including mathematical models, to assess the data and develop forecasts of expected water, sediment and food web concentrations under alternative courses of action.

Lake Michigan Mass Balance Study

The mass balance approach, demonstrated in the Green Bay Mass Balance Study, provided a consistent framework for integrating load estimates, ambient monitoring data, process research efforts, and modeling, leading to the development of scientifically credible, predictive cause-effect tools. Building on the experience of this project, the EPA GLNPO initiated a mass balance approach, the Lake Michigan Mass Balance Project (LMMB), to provide a coherent, ecosystem-based evaluation of toxics in all of Lake Michigan. The primary goal of the LMMB study was to develop a sound, scientific base of information to guide future toxics load reduction efforts for Lake Michigan at the state and federal levels. The LMMB study is discussed further in Chapter 5.

Monitoring Information

The mass balance project was based on the Enhanced Monitoring Program, a comprehensive, 1.6-year synoptic survey for selected toxic chemicals in the Lake Michigan ecosystem. In support of the mass balance study, the Environmental Research Laboratory Duluth Large Lakes Research Station in cooperation with the Atmospheric Research and Exposure Assessment Laboratory, the U.S. National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory, and other cooperations, developed a suite of integrated mass balance models to simulate the transport, fate and bioaccumulation of toxic chemicals in Lake Michigan.

Field sampling for the project covered the period from April, 1994 through October, 1995, and included the following:

Tributaries - eleven Lake Michigan tributaries were monitored intensively to determine the loads of the subject compounds to the lake. Sampling frequency varied from 12 to 45 samples per tributary in a year long period.

Atmosphere - nine sites were monitored to determine atmospheric loads to Lake Michigan. Additional field activities, part of the Great Waters Study, provided data to help determine the net atmospheric load. Additional atmospheric samples were taken during each Lake Guardian survey.

Sediment - one hundred and thirty-one sediment sampling sites ere targeted for sampling, with the majority in sediment depositional zones. Surface sediment segments from box core samples were analyzed for contaminants to determine the sediment contaminant inventory (available for resuspension and contaminant release to the water column). Additional studies will determine contaminants in sediment trap materials, and erodibility of sediment (resuspension).

In summary, over 38,000 samples were collected with more than 1 million result data points. The results of this effort are presented in Chapter 5: Lake Michigan Stressor Sources and Loads, but, it is only the beginning. The effective use of the mass balance tool will require coordinated and continued monitoring on a basin-wide scale, thus the importance of the LMMCC and the actions presented in Chapter 6 to support its mission.

Table 3-2 provides an illustration of more detailed indicators that may be developed as this process evolves. The Great Lakes Fishery Commission developed Table 3-2 to illustrate the type of specific information that could be collected to monitor and assess portions of the Lake Michigan ecosystem.

Table 3-2. Lake Michigan Indicators

Ecological Criteria and Beneficial Use Impairments	Objectives / Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish community structure and function	To restore and maintain the biological integrity of the fish community so that production of desirable fish is sustainable and ecologically efficient.				
	Salmonines: Maintain a diverse salmonine community consisting of both wild and planted fish, and capable of sustaining an annual harvest of 6 to 15 million pounds, of which 20 to 25% is lake trout.	Standing stock (biomass) of salmonines.	A predicted standing stock of salmonines ranging from about 21 to 58 million pounds (Lake Michigan Salmonine Stocking Task Group, 1998, CONNECT model).	Based upon historical yields of native lake trout, a range in catch of about 5.7 to 7.3 million pounds annually is considered to be a minimum measure of the lake's capacity to yield salmonines; the theoretical maximum yield has been estimated at about 15.4 million pounds (*Fish Community Objectives for Lake Michigan*, Eshenroder et al, 1995, GLFC).	Current standing stock biomass of salmonines is thought to be about 65 million pounds (Salmonine Stocking Task Group, 1998. CONNECT model).
	Establish self-sustaining lake trout populations.	Percentage of unmarked lake trout in assessment and sport catches.	The percentage of unmarked lake trout in assessment and sport catches is increasing towards 100% (all stocked lake trout are marked).	The percentage of unmarked lake trout in lakewide assessment catches has ranged from 0 to 8.8% since the mid-1980s without an apparent trend.	No recruitment from natural reproduction is occurring and the lake trout population is comprised entirely of stocked fish.

Table 3-2. Lake Michigan Indicators (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives / Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish community structure and function (continued)	Enhance natural reproduction of coho and chinook salmon, and rainbow and brown trout.	Proportion of unmarked salmon and trout in assessment and sport catches (<u>a known portion of each species must be marked prior to release</u>).	Stable or increasing numbers of naturally-produced fish from each species.	Naturally-produced chinook comprised an estimated 32% of the 1990-93 cohorts in Michigan waters; naturally-produced coho comprised an estimated 9.3% of the 1979 lakewide sport catch; naturally-produced rainbow trout (steelhead) comprised 6 to 18% of annual smolt production in Michigan streams in the 1980s.	Coho and chinook salmon, rainbow and brown trout are naturally-reproducing in some watersheds tributary to the lake. The Michigan DNR has estimated that from 2.2 to 2.7 million chinook smolts have been produced annually in the 1990s as compared to 0.6 to 0.8 million in the 1970s (Salmonine Stocking Task Group, 1998).
Fish community structure and function	Planktivores: Maintain a diversity of prey species at population levels matched to primary production and to predator demands; expectations are for a lakewide planktivore (alewife, smelt and bloater) biomass of 1.2 to 1.7 billion pounds.	Lakewide biomass estimates of alewife, smelt and bloater.	Alewife, smelt and bloater in varying proportions constitute the bulk of the prey fish biomass; biomass size-spectrum models suggest that a total biomass of planktivores amounting to 1.2 to 1.7 billion pounds is a reasonable range for Lake Michigan (*Fish Community Objectives for Lake Michigan*, Eshenroder et al, 1995, GLFC).	Lakewide planktivore biomass estimates (portion of population available to bottom trawls) since 1973 have increased from .14 to .88 billion pounds as the dominant planktivore shifted from alewife to bloater (USGS-BRD); <u>catches in bottom trawls represent only a portion of preyfish biomass and will therefore always be lower than the actual biomass.</u>	The 1996 lakewide planktivore biomass estimate was .65 billion pounds from bottom trawls (Note: studies are needed to understand how shifts in species composition affect biomass estimates, and the relationship between trawl catches and total biomass).

Table 3-2. Lake Michigan Indicators (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives / Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish community structure and function (continued)	Inshore fishes: Maintain self-sustaining stocks of yellow perch, walleye, smallmouth bass, esocids, catfish and panfish; expected annual yields are 2 to 4 million pounds for yellow perch and .2 to .4 million pounds for walleye.	Indices of relative abundance (CPUE).	CPUEs for yellow perch and walleye capable of sustaining the expected ranges of annual yield have not been calculated and must be derived from lakewide assessment data.	The Lake Michigan fishery management agencies are in the process of developing a lakewide assessment plan which will include yellow perch and walleye, as well as other inshore species.	Self-sustaining populations of all these species exist, however, the relative abundance of yellow perch declined an estimated 90% in the southern portion of the lake from 1990 to 1996.
	Benthivores: Maintain self-sustaining stocks of lake whitefish, round whitefish, sturgeon, suckers and carp; expected annual yield of lake whitefish is 4 to 6 million pounds.	Indices of relative abundance (CPUE).	CPUEs for lake whitefish capable of sustaining the expected range of annual yield have not been calculated and must be derived from lakewide assessment data.	The Lake Michigan fishery management agencies are in the process of developing a lakewide assessment plan which will include lake whitefish, as well as other benthivores.	Self-sustaining populations of all these species exist, however, the lake sturgeon and longnose sucker are still listed as protected within the basin.
	Maintain a self-sustaining burbot population compatible with the rehabilitation and self-sustainability of lake trout.	Relative abundance indices (CPUE).	A ratio of relative abundance of lake trout to burbot at about 3.5:1 in the southern portion of the lake and 1:1 in the northern portion.	Historical catches of native lake trout and burbot in small mesh gill nets fished lakewide for chubs by the vessel Fulmar (U.S. Bureau of Fisheries) in 1931-32 suggest mean ratios of 3.5 lake trout per burbot in southern waters and a 1 to 1 ratio in northern waters.	Current ratios have not been available from annual stock assessments but will be as the new lakewide assessment plan is implemented; studies comparing the catchability of these two species are needed to evaluate the reliability of using the proposed ratios.

Table 3-2. Lake Michigan Indicators (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives / Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Fish community structure and function (continued)	Other species: Protect and sustain a diverse community of native fishes including species such as cyprinids, gar, bowfin, brook trout, sculpins and others not previously mentioned.	Species richness.	A species is considered to be present in the lake if at least one individual (any life stage) is captured.	By 1970 five species of deepwater ciscoes had been extirpated from the lake as well as the paddlefish (*Fish Community Objectives for Lake Michigan*, Eshenroder et al, 1995, GLFC); lake herring and emerald shiner populations also have never recovered to their historical levels of abundance.	A total of 92 species are known to occur in the lake proper, of which 75 are native and 13 are naturalized (*Fish Community Objectives for Lake Michigan*, Eshenroder et al, 1995, GLFC).
	Sea lamprey: Suppress the sea lamprey to allow the achievement of other fish community objectives.	Wounding rates on lake trout.	A lakewide mean wounding rate not greater than 5 per 100 lake trout of all sizes.	The 1984-96 mean wounding rate was 4 per 100 trout, but has generally been increasing since 1987 (*Sea Lamprey Wounding of Lake Trout in Lake Michigan*, Ebener, 1997, GLFC).	The lakewide mean wounding rate was 5 per 100 lake trout in 1996.
Fish habitat	Protect and enhance fish habitat and rehabilitate degraded habitats, including historic riverine spawning and nursery areas for anadromous species.	Measure key features of the physical (substrate, water depth), chemical (dissolved oxygen, total phosphorus), and biological (vegetation) components of aquatic habitats.	A formal process such as the Classification and Inventory of Great Lakes Aquatic Habitats (CIGLAH) should be considered to classify and inventory habitats in the lake basin.	Inventories have been compiled on the general locations of many important fish spawning habitats in Lake Michigan (*Atlas of the Spawning and Nursery Areas of Great Lakes Fishes*, Vol.IV, Goodyear et al, 1982, USFWS), but specific locations, habitat characteristics (e.g. chemical and biological features), and current status has not been addressed but for a few spawning shoals for lake trout.	The classification, location, and status of important fish habitats in Lake Michigan has not been addressed in a comprehensive fashion.

Table 3-2. Lake Michigan Indicators (Continued)

Ecological Criteria and Beneficial Use Impairments	Objectives / Expectations	Metrics to be Measured	Criteria for Measurement	Baseline Data	Status
Exotic species	Minimize the unintentional introduction of new exotic species and the spread of existing exotics that may negatively impact the structure and function of existing fish communities.	The appearance of new exotic species and the expansion in range (number of locations) of existing exotic species.	An exotic species is considered to be present in the lake or in a specific area if at least one individual of any life stage is captured.	Since the 1800s some 136 non-indigenous aquatic organisms have become established in the Great Lakes (*Exotic Species in the Great Lakes: A History of Biotic Crises and Anthropogenic Introductions*, Mills et al, 1991, GLFC); most of these have come from Europe (47%), the Atlantic Coast (18%), and Asia (14%), and the rate of introduction has increased as the rate of human activity has increased; more than one-third of the organisms have been introduced in the past 30 years, coincident with the opening of the St. Lawrence Seaway in 1959.	Although various ballast water and aquaculture control measures, and importation and possession bans (bait buckets, pet stores) have been implemented at the state, provincial and federal levels to address potential pathways for the unintentional introduction of exotic species, the appearance of new introductions and range expansion of existing exotics remains a constant threat, and a vigilant watch must be kept throughout Lake Michigan.

Table 3-3. Lake Michigan LaMP Summary Table (Chapter 3)

CHAPTER 2	CHAPTER 3				CHAPTER 6	
Lake Michigan LaMP: Vision, Goals and Ecosystem Objectives	Indicators and Monitoring of the Health of the Lake Michigan Ecosystem				Strategic Action Agenda: Next Steps	
Endpoint Goal	Monitoring	Human Activity			Means to an End Goal	Recommend ations
1. We can all eat any fish.	• Chemical contamination in fish • Site assessments • Eagle reproduction	• Fish advisories • Congressional reports on: - Great Water - Mercury - Dioxin	Chapter 4 Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments and Human Health	Chapter 5 Lake Michigan Stressor Sources and Loads		
2. We can all drink the water.	• Raw water quality data • Source water assessments	• Water utility notifications • Source water protection				
3. We can all swim in the water.	• E Coli levels in recreational water	• Beach closing advisories • State 305(b) WQ reports				
4. All habitats are healthy, naturally diverse and sufficient to sustain viable biological communities.	• Fish assessments • Bird Counts • Wetlands inventories and assessments • Stream flows • Eco-rich area assessments	• Endangered species list • Wetlands mitigation and protection • Zoning • Fish stocking • Fish refuges • USFWS refuges • Ballast water exchange • Dune protection • Eco-rich cluster map				
5. Public access to open space, shoreline and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem, aquatic habitat and biological population.	• Urban density • Coastal parks acreage • Conservation easements	• Open space funding and protection statutes • Coastal zone management				
6. Land use, recreation and economic activities are sustainable and support a healthy ecosystem.	• Contaminants in recreational fish • Sustainable forests • Land conversion	• Superfund cleanups, dredging • CRP percent of eligible farm lands • Brownfields to greenfields redevelopment				

Chapter 4:
Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments, and Human Health

Chapter 4 describes the current status of the Lake Michigan ecosystem, including the Beneficial Use Impairments found at the ten Lake Michigan Areas of Concern and the status of wildlife and human populations in the basin. The Lake Michigan ecosystem includes the atmosphere, which serves as a significant pathway for contaminant load to the lake, and seven interrelated habitat types:

- Open water system;
- Coastal wetland system;
- Inland wetland system;
- Tributary system;
- Coastal shore system, and
- Lakeplain system
- Inland terrestrial system;

The chapter also describes the role Lake Michigan plays in the economic vitality of the basin.

Lake Michigan supports many beneficial uses: safe drinking water for 10 million; internationally significant habitat and natural features; food production and processing; fish for food, sport, and culture; and valuable commercial and recreational activities.

In the open waters of Lake Michigan, phosphorous and chlorophyll concentrations have decreased significantly since the late 1970s. However, chloride concentrations continue to increase and the rate of increase is accelerating. In the heavily-populated and industrial southern part of the basin, water quality is diminished. The leading stressors are urban in nature, including occasional backflows induced by combined sewer overflows, direct stormwater runoff, and industrial discharges. Throughout the basin, pollutant loads are derived from atmospheric deposition, legacy sources (contaminated groundwater and sediments), point source discharges, and nonpoint source runoff. The presence of toxic chemicals in the water and sediment continues to affect the health of fish and bird populations. Oil and gas drilling in the waters of the lake are banned due to a compact of the governors. However, slant or directional drilling from a land-based site to reach a specific target underwater up to 4,000 feet away is permitted.

The abundance and type of phytoplankton are highly variable within the lake. Changes to phytoplankton communities may occur as a result of exotic species predation and the unintentional introduction of non-indigenous algae. Increased salinity and other environmental changes may be enabling the introduced algae to adapt more readily to the environment at the lake.

Zooplankton populations may also be experiencing pressure as a result of the introduction of *Bythotrephes*, a Eurasian predator/cladoceran. Dramatic declines in *Daphnia* populations have coincided with increases in *Bythotrephes*. Benthic communities in the lake are also under pressure. Zebra mussels are having a significant impact on benthic community structures and plankton abundance. The rapid decline in amphipod (*Diporeia spp.*) populations in the southern end of the lake is linked to the introduction of zebra mussels and resulting competition for food. Because amphipods normally make up to 70 percent of the living biomass in a given area of a healthy lake bottom, their decline in Lake Michigan may affect a variety of fish species that depend heavily on them for food.

Fish communities represent the highest trophic levels within the Lake Michigan aquatic ecosystem. They are also the most visible indicators of the health of the ecosystem and represent, to most people, one of the most important resources of the lake. The alteration of fish communities has been the most obvious impairment to the aquatic ecosystem in Lake Michigan. The current status of the fish community is dependent upon human management by the various agencies responsible for the fisheries of Lake Michigan.

Overall, multiple stressors continue to degrade the open lake system. Toxic chemicals contaminate water and sediment quality. Fish advisories are still in effect. Beaches, particularly in the southern part of the lake, are closed episodically. Aquatic habitats do not sustain healthy and diverse fish communities. Exotic species continue to disrupt native plant and animal communities.

Millions of acres of inland wetlands have been lost in the Lake Michigan basin to agriculture, industry and urban development over the last century. Wetland losses in the four states at least partially within the Lake Michigan basin have been disproportionately greater than in many other U.S. regions. Since the 1780s, Lake Michigan basin states have lost an estimated 21.9 million (62.9 percent) acres of wetlands out of their 34.8 million original wetland acres. This compares with an average loss of 52.8 percent nationwide. There are an estimated 12.9 million acres of wetland remaining in the four states, representing more than 12.3 percent of the wetlands within the lower 48 states.

Multiple stressors continue to degrade the Lake Michigan coastal wetland system. Non-indigenous invasive species such as purple loosestrife are still largely uncontrolled despite chemical, physical and biological attempts to eradicate. The sediments from tributaries that nourish coastal wetlands do not contain woody debris needed by some habitats. Fast flowing tributaries deposit too much sediment and bury submergent and emergent aquatic plants.

The quality of many rivers in the Lake Michigan basin has been significantly impaired due to channelization, dredging, damming, sedimentation, loss of bankside vegetation, eutrophication, increased spring flooding, and toxic contamination. Large areas of inland forests and wetlands that once served to regulate the quantity and quality of water flowing into tributaries have been lost. As a result, tributaries pass on their pollutant and sediment loads to the lake and their suitability as spawning habitat has been seriously impaired. Pollution from agriculture, industry and urban development has polluted rivers and contaminated sediments. The result is the contamination of fish and wildlife that depend on river habitats. Many rivers, particularly at the rivermouths, have been declared Areas of Concern and have impaired beneficial uses.

Lake Michigan is home to the largest collection of freshwater dunes in the world, but uncontrolled land uses are threatening the dunes and other important coastal resources. Cities sprawling into adjacent open spaces as well as recreational home development is increasing on the Lake Michigan coast and islands. In addition, invasive non-native species are beginning to impact dune areas. Key protection needs include developing inventories of significant biodiversity areas and establishing monitoring programs for rare and threatened plants and animals. Mining of sand for use in industrial processes, continued shoreline bordering to prevent erosion of private properties, longshore sand transport disruption by jetties and other structures, invasive species introductions, and an increase in off-road dune use is altering the coastal shore system and reducing its ability to function.

The Lake Michigan basin is home for many species of mammals, birds, reptiles and amphibians. It is also a resting and feeding place for several species of migratory birds. Land use changes from industrial development, residential development, shoreline modifications, and navigation have dramatically and permanently altered Lake Michigan basin habitat available for wildlife.

Even though residents of the Lake Michigan basin are exposed to toxic substances from many sources originating within and outside the basin, the main route of human exposure to contaminants from the waters of Lake Michigan is ingestion of fish. Although there have been sporadic outbreaks of illness related to the use of drinking water, the drinking water in the Lake Michigan basin is of good quality.

At this time, the Lake Michigan ecosystem is an outstanding natural resource of global significance that is under stress and in need of special attention. Although efforts have been made to remediate damage, particularly in the area of chemical pollution at legacy sites, human impacts to the ecosystem are continuing to impair its function. Toxic air deposition and nonpoint source pollution are still problems. Fish advisories remain in effect. In some areas, drinking water supplies are susceptible to contamination. Some Lake Michigan beaches are closed periodically due to high bacteria counts. Unique habitats are fragmented by poor land use practices, including uncontrolled development. Contaminated sediments threaten nearshore waters and wildlife. Many exotic aquatic nuisance species have not been prevented from entering the ecosystem nor controlled once established.

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Chapter 4: Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments, and Human Health

4.1 About This Chapter

An ecosystem is defined as "An interconnected community of living things, including humans and the physical environment with which they interact. As such, ecosystems form cornerstones of sustainable economies." (Federal Interagency Ecosystem Management Task Force 1995)

This chapter presents information about the status of the Lake Michigan ecosystem. Section 4.2 describes the health of the ecosystem; the status of the major habitats in the basin, and the historical context for assessment in terms of geology, climate, plants, animals, and human settlement. Section 4.3 summarizes the impacts observed in the lake ecosystem and introduces management activities that are further discussed in Chapter 6. Section 4.4 concludes with a general description of the lake ecosystem status.

Appendix G contains facts and figures about land uses, Areas of Concern, and Areas of Stewardship in the Lake Michigan basin.

4.2 Current Status of the Lake Michigan Ecosystem

The boundaries of the Lake Michigan ecosystem are generally described as the Lake Michigan watershed, the land area that delivers runoff water, sediment, and dissolved substances by way of rivers and groundwater to the lake. The watershed boundary alone, however, is not sufficient to characterize the entire Lake Michigan ecosystem. The airshed, which extends beyond the watershed boundaries, is also part of the Lake Michigan ecosystem. In addition, land and water shipping brings goods from all over the world into the region. Ship ballast water or wooden pallets may bring unwanted exotic species that impact the natural Lake Michigan ecosystem.

Complex ecological processes link organisms and their environment in the Lake Michigan ecosystem. The products of these processes are often referred to as "ecological services" because they perform functions that work together to sustain life in the Lake Michigan basin. Nutrient cycling, carbon cycling, predation, and primary productivity are examples of ecological services. Ecological processes are embedded in ecological systems. The ecological systems of Lake Michigan (and of the Great Lakes basin) include open lake, coastal wetland, inland wetland, tributaries, coastal shore, lakeplain, and inland terrestrial. They overlap and intermingle in terms of boundaries and functions. Plants and animals may need one or several of these systems for habitat in the course of their life cycles (The Nature Conservancy 1994).

The ecosystem, through fully functioning ecological systems, provides the services and the resources necessary to sustain life. Humans are an integral part of the Lake Michigan ecosystem. Humans use the resources, sometimes reducing the capacity of the ecosystem to provide these resources in the future. Humans also act as stewards of the ecosystem, recognizing the necessity of protecting the services and resources to maintain a good quality of life. Thus, the Lake Michigan ecosystem is not a "closed" ecosystem. It is subject to natural and human influences both inside and outside of natural watershed boundaries.

The overall status of the Lake Michigan ecosystem is derived from an assessment of the health of the ecological systems in conjunction with the degree to which humans act sustainably to protect the services and resources provided by the ecosystem. This assessment addresses all areas of the basin: aquatic, atmospheric, terrestrial, and human health.

The following subsections summarize the status of the key components of the Lake Michigan ecosystem. Section 4.2.1 describes the Lake Michigan airshed and its importance to the Lake Michigan system. Section 4.2.2 describes and assesses specific aquatic and terrestrial habitat types in the Lake Michigan ecosystem in greater detail. Section 4.2.3 addresses the status of wildlife communities in the basin and the role that humans play in the ecosystem. Section 4.2.4 describes human systems in the basin and our interactions with the Lake Michigan ecosystem. Finally, Section 4.2.5 describes the role Lake Michigan plays in the economic vitality of the region.

Beneficial Use Impairments in the Areas of Concern

Areas of Concern (AOC) are severely degraded geographic areas where beneficial uses--activities that are dependent on the chemical, physical and biological integrity of the water--are threatened or impaired. Restrictions on fish and wildlife consumption, loss of fish and wildlife habitat and beach closings are examples of the 14 beneficial use impairments identified under the Great Lakes Water Quality Agreement. Throughout this chapter, the AOCs will be discussed as examples of the status of the Lake Michigan ecosystem. This introductory discussion provides a general overview of the AOC.

Of the 42 AOCs in the Great Lakes basin, ten are in the Lake Michigan basin: Manistique River, White Lake, Muskegon Lake and the Kalamazoo River in Michigan; the Grand Calumet River in Indiana; Waukegan River in Illinois; and Milwaukee Estuary, Sheboygan River, Fox River/Southern Green Bay, and Menominee River in Wisconsin and Michigan. Descriptions of each of the AOCs are included in Appendix F. All 14 beneficial uses are impaired at one or more of the AOCs. Remedial Action Plans (RAPs) are being developed in each AOC. The Waukegan Harbor AOC is working toward delisting. PCB contaminated sediments have been removed from the harbor.

Contaminants and Use Impairments in the Lake Michigan Areas of Concern

Area of Concern	Use Impairments	Media	Contaminants
Manistique River	- Restriction on fish and wildlife consumption - Degradation of benthos - Restrictions on dredging activities - Beach closings - Loss of fish and wildlife habitat	Water	Heavy metals detected but below levels of concern.
		Sediment	PCBs, chromium, copper, lead, heavy metals (zinc, lead and cadmium), undecomposed sawdust, oil and grease
Menominee River	- Restriction on fish and wildlife consumption - Degraded fish and wildlife populations - Degradation of benthos - Restrictions on dredging activities - Beach closings - Loss of fish and wildlife habitat	Water	PAHs. Lead, cyanide, chromium, copper, mercury, and phosphorous are at detectable levels but below levels of concern.

Contaminants and Use Impairments in the Lake Michigan Areas of Concern (Continued)

Area of Concern	Use Impairments	Media	Contaminants
Menominee River		Sediment	Arsenic problem near Ansul. Mercury, PCBs, oil and grease, copper, zinc, lead, cyanide, cadmium, PAHs and chromium.
Lower Green Bay and Fox River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Beach closings - Degradation of aesthetics - Degradation of phytoplankton and zooplankton populations	Water	Phosphorous and suspended solids, PCBs, ammonia, pesticides, PAHs and volatile organics.
		Sediment	PCBs, PAHs, chlorinated phenols, ammonia, cadmium, mercury, chromium, nickel, copper, zinc, lead, pesticides, oil and grease.
Sheboygan River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Degradation of phytoplankton and zooplankton populations	Water	Phosphorous, heavy metals, PAHs, nitrogen and suspended solids.
		Sediment	PCBs, PAHs, lead, copper, and chromium

Contaminants and Use Impairments in the Lake Michigan Areas of Concern (Continued)

Area of Concern	Use Impairments	Media	Contaminants
Milwaukee Estuary	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Beach closings - Degradation of aesthetics - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	Oil and grease, heavy metals, and dissolved oxygen
		Sediments	Mercury, cadmium, chromium, copper, lead, arsenic, zinc, PCBs, pesticides, PAHs, oil and grease, ammonia, phosphorous, and nitrogen.
Grand Calumet River and Indiana Harbor Ship Canal	- Restriction on fish and wildlife consumption - Tainting of fish and wildlife flavor - Degradation of fish and wildlife populations - Fish tumors or other deformities - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Beach closings - Degradation of aesthetics - Added cost to agriculture or industry - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	PAHs, oil and grease, arsenic, ammonia, chlorides, cyanide and phosphorous.
		Sediments	PCBs, PAHs, phosphorous, nitrogen, iron, magnesium, volatile solids, oil and grease, mercury, cadmium, chromium, lead, naphthalene, benzo(a)pyrene, zinc, and fluoranthene.

Contaminants and Use Impairments in the Lake Michigan Areas of Concern (Continued)

Area of Concern	Use Impairments	Media	Contaminants
Waukegan	- Degradation of benthos - Restrictions on dredging activities - Beach closings - Degradation of phytoplankton and zooplankton populations - Loss of fish and wildlife habitat	Water	Total phosphorous, total ammonia, chloride, sulfates, cyanide, phenols, dissolved oxygen, pH and total dissolved solids.
		Sediment	PCBs, arsenic, barium, cadmium, chromium, copper, cyanide, iron, lead, manganese, nickel, phosphorous, Kjeldahl (estimate of organic-N) nitrogen, chemical oxygen demand and volatile solids.
Kalamazoo River	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Bird or animal deformities or reproductive problems - Degradation of benthos - Restrictions on dredging activities - Loss of fish and wildlife habitat - Beach closings - Degradation of aesthetics	Water	PCBs, nonpoint source pollution (urban)
		Sediment	PCBs
Muskegon Lake	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Degradation of aesthetics - Loss of fish and wildlife habitat	Water	Phosphorous, un-ionized ammonia, dissolved oxygen, pH, and total dissolved solids at levels below concern. Heavy metals, oil and grease, phosphorous, and nitrogen of concern in localized areas.
		Sediment	PCBs, mercury, lead and arsenic, cadmium, chromium, copper, nickel and zinc.

Contaminants and Use Impairments in the Lake Michigan Areas of Concern (Continued)

Area of Concern	Use Impairments	Media	Contaminants
White Lake	- Restriction on fish and wildlife consumption - Degradation of fish and wildlife populations - Degradation of benthos - Restrictions on dredging activities - Eutrophication or undesirable algae - Restrictions on drinking water consumption or taste and odor problems - Degradation of aesthetics - Loss of fish and wildlife habitat	Water	Phosphorous, heavy metals, chloride and nitrogen.
		Sediment	Chromium, lead, arsenic, cadmium, manganese, mercury, nickel, zinc, PCBs, oil and grease.

(Source: Lake Michigan Forum. (1996). Lake Michigan Areas of Concern, [Online] http://www.lkmichiganforum.org/areasofconcern.html [1999, Jan.])

4.2.1 Atmospheric Component of the Lake Michigan Ecosystem

The atmosphere is an important and sometimes dominant pathway for Lake Michigan stressors. The very nature of Lake Michigan contributes to the intensification of air quality related problems caused by the industrial and urban heartland surrounding the lower Lake. The Lake Michigan basin houses some of the largest concentrations of steel mills (lower Lake Michigan) and paper mills (Fox River Valley) in the world. In addition, the cumulative impacts of other human activities within the Lake Michigan basin (e.g. transportation, manufacturing, agriculture) impose further stresses on the ecosystem.

Water quality conditions in the Great Lakes are greatly improved compared to a few decades ago, as the result of environmental regulatory programs and public and industrial cleanup efforts addressing primarily waterborne pollution. However, despite the improvements, the Lake Michigan ecosystem is still recovering, and it is necessary to address the more diffuse sources of pollution, including the air component, in order to attain water quality goals and to ensure protection of human health and the environment.

4.2.1.1 The Atmosphere's Influence on Lake Michigan

The role of the air pollution as an important contributor to water pollution has long been recognized and, in recent years, has been the subject of growing scientific study and concern. Over the past 3 decades, scientists have collected a large and convincing body of evidence showing that toxic chemicals released into the air can travel long distances and be deposited on land or water at locations far from their original sources. Some of the early scientific studies of air deposition are described below:

- Studies of fish from Siskiwit Lake - a small lake on an island in northern Lake Superior that is isolated from most human influences - have shown contamination with PCBs, toxaphene, and other pesticides, which have no known sources on the island. Toxaphene, a pesticide banned in the U.S. in 1982, had limited use in the Lake Superior region but was used heavily in the southeastern U.S. Cotton Belt from the late 1960s to the mid-1970s. The use pattern implies that toxaphene was probably transported by air from the Southeast to the Great Lakes region. Airborne levels of toxaphene are highest in the southeastern U.S. and decline with distance as one moves toward the Great Lakes and north Atlantic regions.

- Air and rainfall in the Great Lakes region have repeatedly been shown to be contaminated with a variety of toxic chemicals. The Integrated Atmospheric Deposition Network (IADN) has monitored elevated levels of PCBs, PAHs, lead and a number of chlorinated pesticides in rainfall and the atmosphere since 1991 on each of the Great Lakes.

- A series of studies of Wisconsin lakes indicate that the air is a major contributor of mercury to these lakes and that modest increases in air deposition of mercury could lead directly to higher levels of mercury in fish.

- It is likely that other pesticides present in the Great Lakes, including DDT, are transported long distances by the air, from their sources to the Great Lakes region. Based on the amount and chemical form of DDT present in core samples from peat bogs in the Great Lakes region, new releases of DDT are apparent and may be originating from sources outside the U.S., possibly from Mexico and Central America. Atmospheric deposition of DDT, toxaphene, HCB, and PCB in the Great Lakes region, as measured in peat cores, are consistent with the U.S. production and use history of these chemicals.

These examples, along with many similar discoveries - including the much-studied phenomenon of acid rain - provide convincing evidence that long-distance atmospheric transport is an important global pathway for the distribution of some of the pollutants of concern. Perhaps most notably, it appears that PCBs and some other persistent pollutants, including several pesticides that have not been used in significant amounts in the U.S. since the 1970s, have become widely distributed in the environment and are now, in essence, part of the global "background." These toxic chemicals remain in our environment and continue to cycle between air, water, soil, and biota even after their manufacture, use, or release has stopped.

Although these studies have documented the importance of long-range transport for some pollutants of concern (e.g. PCBs and chlorinated pesticides), more recent ongoing studies point to influence of local sources, particularly nearby urban areas, on loadings to the Great Lakes. In order to quantify the total atmospheric load, it is important to consider both long-range and local sources. The relative importance of each source to the overall loading to the Great Lakes is variable depending on the pollutant and the Lake. For Lake Michigan, it is thought that the Chicago-Gary urban area contributes to the loadings of PCBs, PAHs and mercury to the entire lake.

4.2.1.2 Atmospheric Interaction Within the Lake Michigan Ecosystem

Transport distances depend on the characteristics of the chemicals and source emissions as well as weather patterns. Scientists have long recognized the basic processes by which air pollutants can enter rivers, lakes, and other waterbodies. The steps in this process are described below and illustrated in Figure 4-1 below.

- First, pollutants are *released* to the air from a source, which may be natural or anthropogenic. Anthropogenic sources include point sources, such as industrial smokestacks or any other fixed location that releases pollutants, area sources, such as pesticide applications on agricultural fields, and mobile sources, such as exhaust from automobiles. Natural sources include forest fires, volcanic eruptions, and windblown dust. Pollutants can be released as either gases or as particles.

- Second, pollutants released to the air are *transported* away from their source to other locations. Depending on weather conditions and the chemical and physical properties of the pollutant, air pollutants may be transported either short or long distances from their sources and may under physical and chemical changes while in transit.

- Third, air pollutants are *deposited* to the earth, in most cases directly to a waterbody or to a land area that drains into a waterbody. Pollutants are deposited by "wet deposition" or "dry deposition". In wet deposition, pollutants are removed from the air by a precipitation event such as rain or snow. Dry deposition occurs when particles settle out of the air and into water. Air pollutants can also enter a waterbody indirectly, by first depositing onto surrounding land or tributaries and then moving into the waterbody by other routes, such as stormwater runoff or inflow from tributary streams.

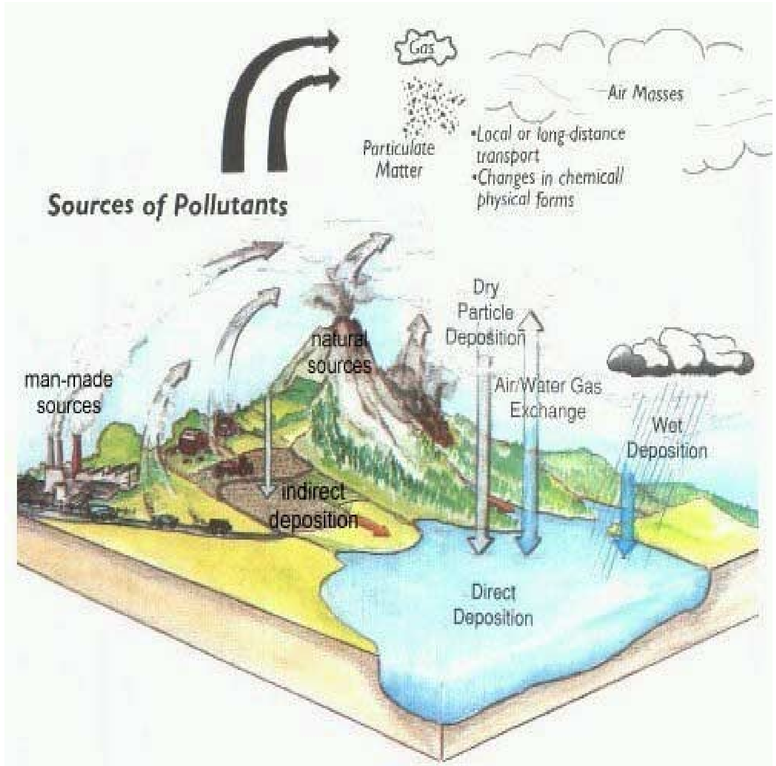


Figure 4-1. Atmospheric Sources of Pollutants

Source: EPA (www.epa.gov/owow/oceans/airdep/)

4.2.1.3 Current Status of Lake Michigan's Airshed

The Integrated Air Deposition Network (IADN) has collected data to support the following findings:

> "IADN shows that many of the measured persistent toxics are still being introduced to the Lakes from the atmosphere. Levels in air and precipitation appear stable for current-use pesticides such as endosulphan, but levels for most other pesticides, PCBs and lead are decreasing. Gas absorption appears to be the dominant deposition process for delivering semi-volatile compounds to Lake surfaces, while wet and dry deposition dominate for trace elements and heavier PAHs. For some IADN substances, like dieldrin and PCBs, the waters themselves are behaving like a source since the amount that is volatilizing from the water is greater than the amount being deposited to the water."

Although used in other parts of the world, many substances measured by IADN are no longer used in Canada or the United States. IADN data have shown that these substances are nonetheless transported through the air to the Great Lakes from areas where they are currently used, as well as from areas where they have not been used for many years but where residues still exist in soils. IADN data have also shown that the Great Lakes receive pollutants from local sources such as industry, agriculture, incineration, and automobiles and other combustion sources.

Chemical (year sampled)	Loading estimate to Lake Michigan (kg/yr)	(lb/yr)
PCBs (wet and dry)		
1988	400	880
1992	110	242
1994	69	152
1996	42	92
PCBs (net gas)		
1988	-5140	-11,308
1994	-2700	-5,940
DDT (wet and dry)		
1988	64	141
1992	25	55
1994	32	70
1996	12	26
DDT (net gas)		
1988	-480	-1.056
1994	67	147
B(a)P (wet and dry)		
1988	180	396
1992	84	185
1994	250	550
1996	117	257
Pb (wet and dry)		
1988	540,000	1,188,000
1992	26,000	57,200
1994	72,000	158,400
1996	na	na

Source: Integrated Air Deposition Network

Notes:

1) B(a)P may have been underestimated in 1992; thus over the 6 year period there is a general decline

2) "A recent study found that total wet and dry deposition for B(a)P was 50 times higher at an urban site (Chicago) than at the remote IADN site for Lake Michigan (SBD). The investigators concluded that these elevated PAH deposition rates are due to emissions from nearby urban areas. Although the total deposition of PAHs are lower in rural than urban sites, the relative amounts of individual PAHs (i.e., relative ratios of the individual PAHs) is very similar at urban and nonurban sites, suggesting that little chemical degradation occurs during transport of PAHs from urban source areas to rural and remote sites several hundred kilometers away.

3) Seasonal variations in deposition - wet and dry deposition of PCBs are similar over seasons, while net gas exchange is highly seasonal, exhibiting much greater effect with high temperatures; to date no seasonal variations have been published on PCB concentrations in water.

Furthermore, the Second Great Waters Report to Congress (pg. 104) found the following:
"...Recent research suggests that deposition of contaminated large particles carried by winds passing over urban areas can result in substantial inputs of toxic chemicals to the Great Lakes."

The influence of pollution from the Chicago-Northwest Indiana area on water quality in southern Lake Michigan was studied by Sweet and Basu (1994). The Sweet and Basu study compared data from one remote and two urban sites. The Sleeping Bear Dunes site (in the State of Michigan) is located one kilometer from the northeastern shore of Lake Michigan and 50 kilometers from the nearest urban area or major source and, thus, is considered a remote site. The first urban site is located 1.5 kilometers from the shore on the campus of the Illinois Institute of Technology, which is near major expressways and surrounded by commercial and residential areas. The second urban site is located at the Indiana Dunes National Lakeshore in the vicinity of large steel mills. Particulate concentrations were measured for target compounds (PCBs, pesticides and trace metals). Gas concentrations of PCBs and pesticides were determined, and rain was analyzed only for PCBs.

Results from Sweet and Basu indicate that for PCBs, DDT (and its metabolites), dieldrin, chlordane, and several trace metals (manganese, zinc, chromium, and lead), the measured particulate and gas concentrations values were 10 to 40 times higher in urban areas than at the remote site. For other pesticides (alpha-HCH, lindane, HCB) and trace metals (arsenic and selenium), concentrations were nearly the same at all three sites, indicating these pollutants were well mixed in the air throughout the region (and that there were probably few local sources).

Although 90 to 99 percent of the PCBs were found in the gas phase, the most toxic PCB congeners were enriched in the particulate phase. Thus, dry deposition may be an important transport mechanism for certain, especially toxic, PCBs to the lakes. Urban particulate matter also carried high concentrations of trace metals and pesticides, causing dry deposition of these materials in southern Lake Michigan. Dry deposition of large particles may be especially significant for Lake Michigan because 200 kilometers of the southwest shoreline are heavily developed. Prevailing southwest winds carry emissions over the lake where they travel for 100 to 150 kilometers before reaching land again, allowing a significant portion of deposition to enter the lake. Finally, the concentration of PCBs in precipitation is roughly the same in urban and rural sites.

Ozone levels associated with urban areas are also a continuing problem. Ozone causes oxidative damage to soft tissue in plants and animals. The impacts to animal species are largely via the respiratory tract. Impacts to plants are decreased growth due to damage to leaves and subsequent reduced photosynthetic activity. For the Lake Michigan ecosystem, the damages will be indirect. Decreased plant growth affecting terrestrial systems will affect the lake ecosystem only to the extent terrestrial systems interact with lake systems. These indirect effects are mostly the result of food chain issues.

The Lake Michigan air basin contains a number of generally contiguous ozone nonattainment areas including several major urban nonattainment areas (Chicago, Milwaukee, Northwest Indiana). The entire region is affected by ozone concentrations and ozone precursors that are generated and transported into the area. It is because of these meteorological characteristics that the ozone problem in the Lake Michigan area is considered to be a very broad geographic phenomenon.

Overall, the influence of urban areas on atmospheric deposition of certain pollutants to the Great Lakes is substantial, especially in heavily developed areas, such as the southwestern shores of Lake Michigan.

4.2.2 Status and Assessment of Lake Michigan Habitats

This section addresses the status of the basin ecosystem and is organized by habitat type. For the purposes of this section, “habitat” means that space that is or can be successfully occupied (inhabited) by a species or biotic community or some broader (taxonomic or phylogenetic) entity due to specific chemical, physical, and biological characteristics. Habitat is the place where an organism or group of closely related organisms lives. The goal of habitat preservation can only be described in terms of those biotic entities.

To facilitate this discussion, the complex web of habitat and subecosystem types found in the Lake Michigan ecosystem has been divided into the following seven categories:

- Open Water System
- Coastal Wetland System
- Inland Wetland System
- Tributary System
- Coastal Shore System
- Lakeplain System
- Inland Terrestrial System

In general, the natural distribution of habitat types within the Great Lakes depends on lake bed and shore topography, geology and climate.

The diverse forms of animals and plants associated with different habitats have received much attention, and is a reason, along with primary productivity, given for habitat preservation (Nature Conservancy 1994). For purposes of evaluating habitats in this section, two common measures of biological diversity have been separated for clarity's sake: richness or number of species and rarity.

Richness

One measure of biodiversity is the number of species or unique community types found within a habitat. A greater number of species, particularly endemic species, is generally an indicator of higher quality habitat. For example, as eutrophic and mesotrophic aquatic systems become degraded, species numbers often decrease.

However, the degradation of coldwater oligotrophic systems, such as the addition of nutrients to Lake Superior, generally results in an increase in the total number of species (Busiahn 1999). Consequently, species richness cannot be used as an absolute indicator of habitat quality, in the same manner that higher productivity is not always a sign of higher quality habitat. This phenomenon complicates the interpretation of trend data and comparisons among habitat types.

Nevertheless, the comparative species richness of habitats does give some indication of their value when combined with other information about the habitat. Recently, EPA began compiling data provided by partner organizations to begin identifying ecologically rich regions in the basin. Preliminary data are presented in Figure 4-2. These data are under review at the time of the LaMP release and will be updated. Further information is available at www.epa.gov/ecopage/err. Additional data will be needed on species richness in the various habitat types to begin to make meaningful comparisons.

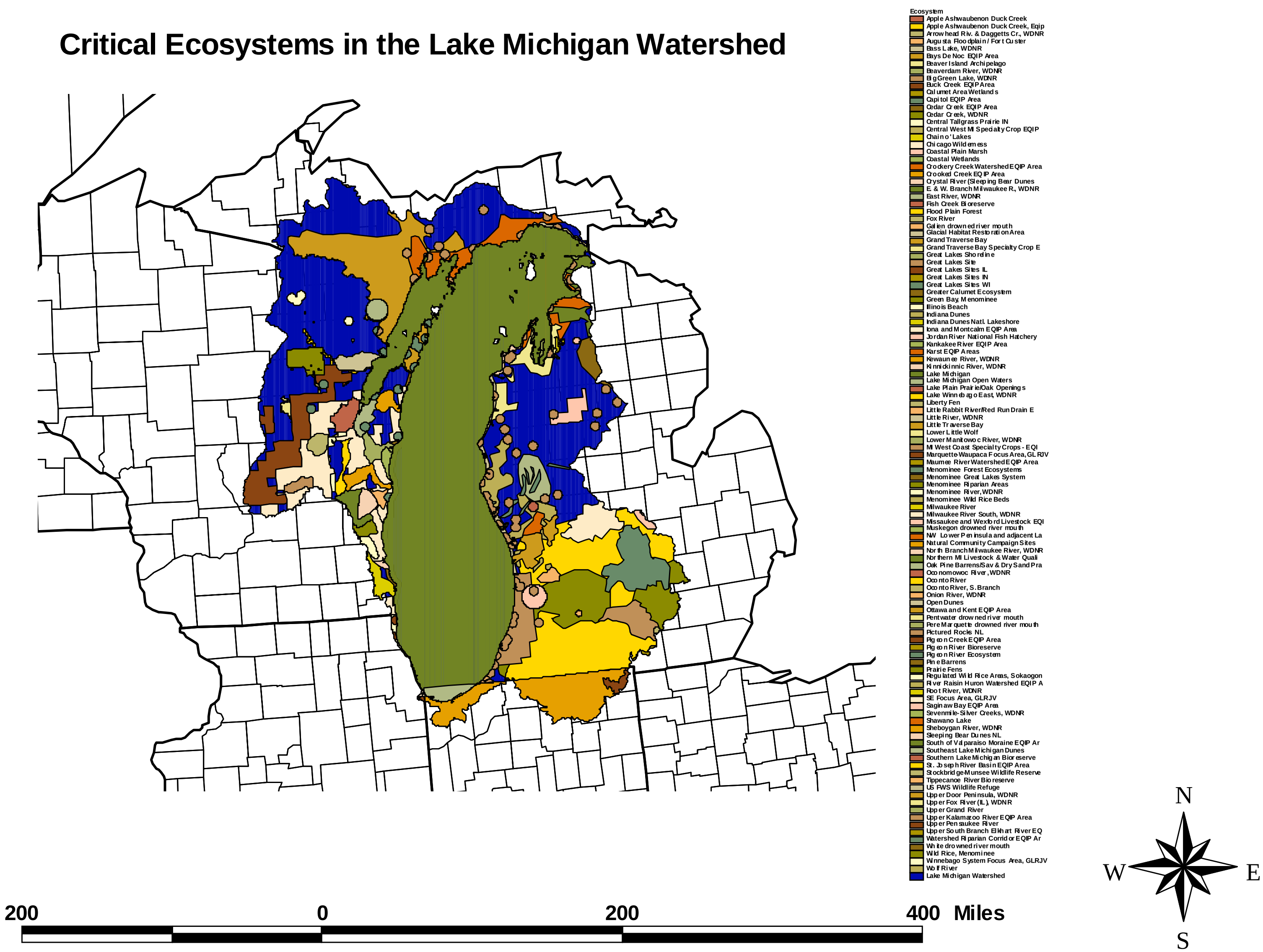


Figure 4-2. Critical Ecosystems in the Lake Michigan Watershed

Indicator Species and Rarity

Rare and endangered species often have very specific habitat needs. The number of rare species depending on a particular habitat type is a further indicator of habitat significance. Preserving species and community richness at the global level requires priority protection for habitats that host globally rare species. With regard to the Lake Michigan basin, it also means preserving the habitat of species that have become rare in the basin or in one or more of its subregions.

The U.S. Fish and Wildlife Service (1993) has compiled a list of 22 endangered and/or threatened species that are potentially affected by Great Lakes water quality. The county-level locations of several of these species are presented in Figure 4-3. Another 71 species in the Great Lakes watershed are candidates for designation as endangered or threatened species. A list of rare and imperiled elements compiled by the Nature Conservancy (1994) is especially useful because it shows what proportion of the rare and imperiled elements is found in each habitat type. The Nature Conservancy cites the network of state and provincial natural heritage programs which have identified 131 elements within the Great Lakes basin that are critically imperiled (22), imperiled (30), or rare (79) on a global basis. Of these globally significant elements, 31 are natural ecological community types; the rest are individual species, subspecies or varieties including 49 plants, 21 insects, 12 mollusks, nine fish, five birds, three reptiles and one mammal. In addition, 12 natural community types are recognized that, while not globally rare, form major components of the basin's landscape and support a wealth of biological diversity that is important to the basin's ecological integrity. The Nature Conservancy (1994) shows the distribution of species and communities that are found either exclusively or primarily in the basin, or have their best representation in the Great Lakes basin, among the ecological systems that support them. The Nature Conservancy data confirm that the coastal systems (marshes, shores and lakeplains) contain a disproportionate amount of the unique biodiversity of the Great Lakes. However, the Nature Conservancy's data tend to be weaker in wet environments compared to dry.

In isolation, rarity as an indicator of habitat value leads eventually to a view of preservation as masking the value of representative species in creating and maintaining a healthy ecosystem. Thus, rarity too, is better combined with other indicators to give a rounded view of the comparative value of any particular habitat. Rarity, reflected in state or provincial Natural Heritage inventories, used as one data source among several, and cast in the context of a broader analytical process, helps protect productive ecosystems rather than just rare species.

Healthy populations of diverse native species are one of the best indicators that habitats are of optimum quality. Accordingly, it may be simpler to monitor the health of selected indicator species rather than trading off difficult-to-compare criteria. By choosing a suite of species that require a broad range of high quality habitat types, it may be possible to read ecosystem health more accurately than measuring many attributes of different habitats in order to make comparisons that may be controversial. However, species populations are affected by other factors, such as disease, predation and harvest, that are not directly linked to habitat quality. Thus, using a small number of species as "canaries" for the habitat needs of most or all species will still require some level of complementary data gathering on habitat quality. Impacts limited to subtle changes in the lower trophic levels (e.g., relative composition of zooplankton species) while the top trophic level is relatively unaffected could be harbingers of more profound changes later on. Various governmental and nongovernmental programs are working together to develop such a coordinated monitoring effort (see Chapter 3, Section 3.3).

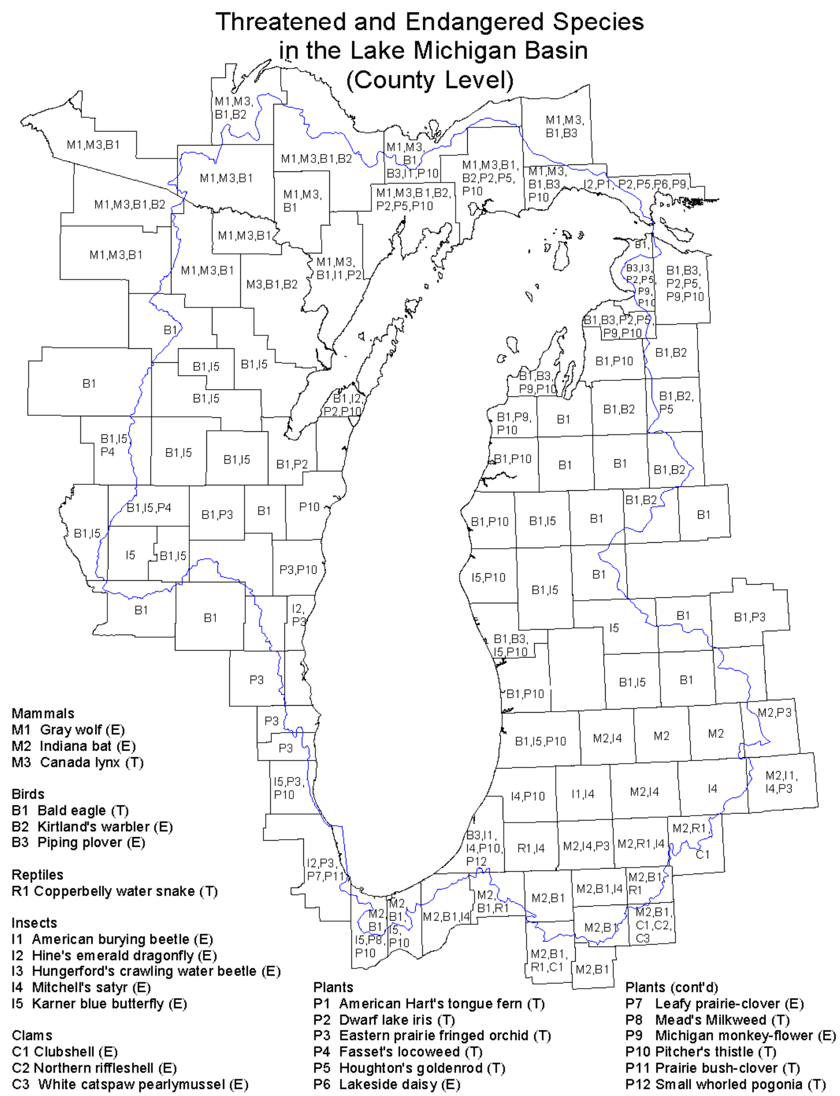


Figure 4-3. Threatened and Endangered Species in the Lake Michigan Basin

Of all the habitat types, the coastal shore and coastal wetlands rank most consistently high for all indicators of ecological and biological significance. The only exception would seem to be that they do not provide a home for a high percentage of the basin's globally rare species and communities (The Nature Conservancy 1994).

Although relatively small, the inshore zone concentrates much of the biological productivity and richness of the Great Lakes. The inshore zone plays a critical role in absorbing nutrients, organic matter and sediments, and through its high productivity removes some toxic chemicals. Coastal wetlands are uniquely adapted to and even require fluctuating water levels to maintain their vitality. Their productivity provides forage for many species from other habitats. Animals from the land, including insects, reptiles, amphibians, mammals and migrating birds, as well as, sub-adult fish that subsequently migrate to the open lake, use the inshore zone seasonally or for parts of their life cycle.

The productivity and diversity of the inshore zone stem from the interaction of the water with land. In comparison to both the land and the open lake, the inshore zone has extra dimensions in determining the fine gradations of habitat type. Both the nature and topography of the substrate, as well as the depth, flow, and temperature of the water, determine the type of communities that establish themselves.

Besides the incoming solar radiation available equally in all habitat types, the inshore zone benefits from the energy inputs of water currents, wave and wind. These forces bring dissolved nutrients, sediments and organic matter in quantities sufficient to ensure that nutrients do not limit productivity to the same degree they do terrestrial communities. At the same time, the combination of currents, waves and solar radiation ensure good circulation and resulting oxygenation. The greater warmth of inshore waters allows a higher metabolic rate and thus also contributes to overall productivity. Even when water and wind destroy the vegetation, this ultimately benefits the wetland by resetting succession and maintaining the highly productive, herb-dominated system (The Nature Conservancy 1994). To the degree that connecting channels and tributaries include a high proportion of shallow water inshore habitat, this discussion applies to them as well.

The following discussion describes and assesses the current status of the seven habitat types in the Lake Michigan ecosystem.

4.2.2.1 Open Waters

The open lake includes both the inshore and offshore waters of the lake. The inshore waters begin at the offshore edge of the coastal wetlands and extend lakeward to the point where vertical thermal stratification can be measured in summer. This point, where the thermocline intersects with the lake bed, is usually taken as the boundary between the inshore and offshore waters. This boundary is dynamic and moves progressively farther offshore and into deeper water as the summer progresses. Minor differences in water depth and distance from shore at the boundary location can occur between lakes and in response to local hydrologic conditions within each lake and at any point in time. At the end of summer the thermocline may be as deep as 30 meters (90 feet) in Lake Michigan.

Fish are the dominant fauna of the open lake. During the summer, coldwater fish including trout, salmon, and whitefish occupy the deeper, colder offshore waters, while cool and warmwater fish inhabit the shallower, warmer, inshore waters. Phytoplankton occupy the upper layers of the open lake, and benthic algae colonize the shallower portions of the lake bed where sunlight is sufficient to support photosynthesis. Light penetration may extend only a meter (3 feet) or less in some areas and to more than 60 meters (180 feet) in others. Zooplankton colonize the open lake from the surface of the water to the lake bed, and productive and diverse benthic invertebrate communities occupy the lake bed wherever it has not been degraded.

Most inputs of energy, nutrients, and pollutants to the open lake are made directly to the inshore waters. These additions may cycle in the inshore waters, but they eventually most find their way into the offshore waters, where they may be cycled less frequently or simply stored in bottom deposits in deep water. Smaller amounts of these energy and material resources, when incorporated into fish, find their way back into coastal wetland, tributary, connecting channel, and terrestrial habitats as fish migrate inshore to spawn or as avian predators and humans ingest fish from the open lake.

Open Water: System Description

The aquatic ecosystem of Lake Michigan has experienced profound changes in the past 140 years. During that time period, the science of ecology and the understanding of the mechanisms of the Lake Michigan ecosystem have greatly increased. The current status of the ecosystem is volatile and heavily dependent on human management in the form of the stocking of predator fish. Any assessment of the status and trends of ecosystem health must begin with an understanding of the catastrophic loss of habitat, biological diversity and subsequent establishment of non-indigenous populations.

The last glacier, which left in its wake the present form of Lake Michigan, retreated between 14,000 and 9,000 years ago, which is very recent in geologic terms. During and following the retreat, fauna and flora colonized the lake mostly from the surrounding watersheds that connected to the lake through channels, rivers and wetlands (Baily and Smith 1981). The fish species that colonized the lake began to evolve in response to opportunities or niches present in the form of varying depths, embayments and the corresponding food supplies and habitats afforded by geography. In particular, one fish family (the *Coregonids*) became very successful at filling these niches. This family includes the lake whitefish, lake herring, chubs and ciscoes. Expansion of this fish family into different habitats within the lake resulted in the development of separate stocks, species, and sub-species, including the deepwater ciscoe known as *C. johannae* which was endemic to Lake Michigan (Baily and Smith 1981).

Before the arrival of large numbers of settlers in the region, Lake Michigan was a more diverse ecosystem. A diverse ecosystem can “bounce back” after perturbations such as extremes in weather, water quality or even introduction of exotic species. However, the modern history of Lake Michigan illustrates that ecosystems can only endure so many perturbations before they can no longer “bounce back”. Instead, the Lake Michigan ecosystem has evolved into a less diverse form that diminishes its ability to provide services and resources.

Significant changes to the environment and ecosystem of the lake began in the mid-1800s when large numbers of people began to settle the region. By 1850, commercial fishing was a major industry and had resulted in a noticeable decline in fish populations by the 1870s (Wells and McLain, 1973; Eshenroder and others 1995). Industrial pollution had also begun to affect fish populations as the result of the damming of rivers, deforestation, and the dumping of sawmill and other industrial waste into the tributaries and lake itself. Commercial fishing and degradation of local waters continued due to greatly expanding industrial operations in the region until a significant change to the ecosystem occurred in the 1940s and 1950s. Sea lamprey, which entered the upper Great Lakes when bypasses to Niagara Falls were constructed, were first noted in Lake Michigan in 1936. By the late 1940s, the sea lamprey had decimated the top predator fish populations: lake trout and burbot. With the virtual elimination of the top predator fish, two exotic species, the alewife and rainbow smelt, flourished. By the 1960s, the lake was dominated by the alewife and, to a lesser extent, rainbow smelt. By then, the native fish community was severely disrupted, and important commercial and sport fisheries had collapsed. Coregonid populations were also affected and resulted in the extinction of several species of deepwater ciscoes including *C. johannae*. Lake trout were extirpated and to this day are not self-sustaining in Lake Michigan. (Koonce 1994)

In response to the collapse of the fisheries, the Great Lakes Fishery Commission (GLFC) was formed in 1956 to achieve two major goals: first, to develop coordinated programs of research in the Great Lakes and, on the basis of the findings, recommend measures that will permit the maximum sustained productivity of stocks of fish of common concern; and second, to formulate and implement a program to eradicate or minimize sea lamprey populations in the Great Lakes. Efforts to suppress the sea lamprey population began to pay off in the 1960s. Lake trout plantings began in 1965 and coho salmon and chinook salmon (introduced from the Pacific Northwest in 1966 and 1967, respectively) were introduced to Lake Michigan. These plantings of trout and salmon resulted in a marked decline in the alewife population in the 1970s and 1980s. Suppression of the alewife resulted in increases of native species such as bloater chub (the only remaining deepwater ciscoe species), yellow perch and deepwater sculpin - all species which are either in competition with alewife for plankton or whose fry are preyed upon by the alewife.

Open Water: Plankton

The plankton communities (phytoplankton and zooplankton) of Lake Michigan are the base of the food web and therefore are one of the most important components of the lake's ecosystem. Unlike fish populations that can be compared to historic data from fisheries records extending back to the 1800s, changes in the plankton community are more difficult to assess. However, limnological studies are available for much of the lake in recent decades.

Phytoplankton

Phytoplankton are composed of microscopic plants that convert sunlight into biomass and are therefore the true base of the Lake Michigan food web. The abundance and types of phytoplankton are highly variable within the lake depending on time of year, area of the lake and availability of phosphorous and other nutrients. The increase in phosphorus load to the lake has resulted in the greatest man-induced change to phytoplankton communities, especially in nearshore areas. In the mid-twentieth century, changes in the phytoplankton community were noted as algal blooms in nearshore areas, including: Green Bay; the extreme southern crescent of the lake from Chicago to Benton Harbor, Michigan; the northeastern coast from Ludington, Michigan to Frankfort, Michigan; and local areas near most major harbors (Wells and McLain 1973). Since that time phosphorous loadings have decreased as the result of improved technology and implementation of the Great Lakes Water Quality Agreement, the Clean Water Act, and other programs, although preliminary sampling indicates that phosphorus levels in the open waters of the lake may be increasing. In addition, changes to plankton communities may be occurring as a result of exotic species such as the spiny water flea (*Bythotrephes cederstroemi*) and the zebra mussel (*Dreissena polymorpha*). Additional monitoring is needed to confirm these trends. Many species of non-indigenous algae have also been introduced into Lake Michigan (Mills and others 1993) and studies indicate that increased salinity and other environmental changes are enabling introduced algae to adapt more readily to the environment of the Great Lakes (Sheath 1987).

Zooplankton

Zooplankton includes many different invertebrates and fish fry and comprises the bulk of the diet of planktivorous fish. Because most zooplankton feed on phytoplankton, their abundance and geographic occurrence are similarly dependent upon water temperature, seasonal changes and availability of food. In addition, certain zooplankton exhibit vertical diurnal migrations, sinking to deeper waters to avoid being eaten during the day and rising to shallower waters at night to feed. Population dynamics over the past 100 years include observations that would indicate that zooplankton community structure and abundance have changed markedly in Lake Michigan, especially during the mid-twentieth century when phosphorous loadings were higher and water quality more degraded.

Research conducted in the past 15 years also indicates that zooplankton populations may be experiencing changes induced by *Bythotrephes* (Lehman 1991). *Bythotrephes* is a Eurasian predatory cladoceran that was first documented in Lake Michigan in the 1980s. Dramatic declines in local *Daphnia* have coincided with increases in *Bythotrephes* populations. Preliminary studies indicate that between 10 and 40 percent of zooplankton production can be consumed by *Bythotrephes*. *Bythotrephes* is not a preferred prey for many fish. Thus, this new addition to the fauna is at best an extra trophic level between algae and fish, which results in greater inefficiency in energy transfer. At worst, *Bythotrephes* is an energy sink from the standpoint of fish production (SOLEC 1996).

Open Water: Benthos

There is a lack of historical information on benthic communities. Surveys of benthos in local areas of concern have been used as indicators, especially in relation to oligochaetes that are tolerant of anaerobic conditions resulting from overloading of organic matter and other pollution (SOLEC 1996).

Areas with historically degraded benthos include all 10 of the Lake Michigan AOCs, including the lower Menominee River, Green Bay, Sheboygan Harbor, Milwaukee River, the southern crescent of Lake Michigan from Waukegan Harbor to the St. Joseph River, the Kalamazoo River and Manistique harbor. While many of these areas have been assessed in the past 20 years, new assessments are needed. Improving conditions are indicated by increased abundance of certain burrowing insects, such as the mayfly. However, past studies indicated increased abundance of oligochaetes in the southern end of Lake Michigan were leading to organic enrichment (Nalepa 1987).

Further studies suggest that zebra mussels are having a significant impact on benthic community structures and plankton abundance. Zebra mussels, which can attach themselves to any hard surface in the lake, have reached densities higher than 16,000/m^2 in southern Lake Michigan (Tuchman 1999). The mussels divert energy away from the pelagic food web by filtering out a significant portion of the plankton. Negative impacts include increased competition for plankton at the expense of fry from nearshore species (such as yellow perch), increased biomagnification of contaminants in piscivores feeding on benthivores and possible zebra mussel induced mycrocystis blooms (Sea Grant 1994).

Recent research suggests that benthic species may be directly impacted by zebra mussels (NOAA 1997). Tiny shrimp-like organisms called amphipods (Diporeia spp.) that are normally found in bottom mud of healthy lakes were absent in samples taken at a monitoring site 5 miles off St. Joseph, Michigan on southern Lake Michigan, according to NOAA’s Great Lakes Environmental Research Laboratory (GLERL) in Ann Arbor, Michigan. Routine monitoring of the abundance of these environmentally sensitive organisms at 40 sites in Lake Michigan’s southern basin provides researchers with a reliable measure of the lake’s health. While the NOAA scientists have not yet determined the exact cause of the disappearance of amphipods at the St. Joseph site, they suspect it is linked to the introduction of zebra mussels in southern Lake Michigan in 1989, severely limiting food available to the amphipods. Because amphipods normally make up to 70 percent of the living biomass in a given area of a healthy lake bottom, their decline in Lake Michigan may affect a variety of fish species that depend heavily on them for food.

Open Water: Fish Communities

Fish communities represent the highest trophic levels within the Lake Michigan aquatic ecosystem. They are also the most visible indicators of the health of the ecosystem and represent, to most people, one of the most important resources of the lake. The alteration of fish communities has been the most obvious impairment to the aquatic ecosystem in Lake Michigan. The current status of the fish community is dependent upon human management by the various agencies responsible for the fisheries of Lake Michigan. Without the continued planting of predator fish by management agencies, the lake would revert to a fish community dominated by alewife.

The federal, state and tribal managers of the fisheries resource of Lake Michigan, through their participation in the GLFC, have recently reached consensus on a revised version of the Strategic Great Lakes Fisheries Management Plan (SGLFMP), which defines their common goals for the management of the Great Lakes fisheries.

Fish Community Objectives for Lake Michigan (GLFC Special Publication 95-3) recognized the following positive developments in the fisheries of the lake:

– Recovery from the highly degraded, nearly single-species (alewife) fish community of the early 1960s is evident.
– Sea lampreys are being suppressed.
– Deepwater ciscoes and whitefish have recovered - in some cases to near-historic levels.
– State and federal governments have invested in modern fish-production facilities to help maintain ongoing fisheries and rehabilitation efforts.
– Loadings of phosphorous and toxic chemicals have declined.

The document goes on to present the following remaining problems:

– Not enough natural reproduction of top predators, especially lake trout.
– Low abundance or complete loss of many native fish stocks.
– Continued problems with unintentional introduction of undesirable exotic species.
– Continued difficulties in suppression of sea lampreys.
– Continued unacceptable levels of pollution and toxic chemicals.

Fish Communities: Prey Fish

Since the early 1970s, the pelagic prey fish community in Lake Michigan changed from an assemblage dominated by (in descending order of abundance) alewives, rainbow smelt and bloaters, to one dominated by bloaters, rainbow smelt, and alewives. The reasons for these changes are unclear. It has been suggested that alewife populations may not be able to sustain desired predator populations. If true, other prey fishes such as rainbow smelt and bloaters may eventually contribute a greater proportion to the salmonid (predator) diet. Others contended that climatic effects were primarily responsible for the decline in alewife abundance. Whatever the reasons, alewife stocks and, to a lesser extent, rainbow smelt stocks have both declined greatly since the mid-1970s while bloater and other native fish stocks increased in abundance (Argyle and others 1995).

Fish Communities: Whitefish

Lake whitefish (*Coregonus clupeaformis*) is one of the most important commercial fish in Lake Michigan. Whitefish are predominantly benthivores and occur in Lake Michigan in at least 10 reproductively isolated stocks. Current assessments indicate that whitefish populations are stable and self-reproducing. Records indicate that the 1995 harvest of 20 million pounds was greater than at any other time in the twentieth century (Ebener 1997). Populations of whitefish were devastated in Lake Michigan in the first half of the twentieth century approximating the decline of lake trout. One of the main reasons for the decline appears to be the exponential population increases of alewife and rainbow smelt, both of which prey on whitefish fry. Consequently, with the suppression of sea lamprey and intense stocking of salmonids, populations of whitefish rebounded and continue to experience healthy recruitment.

Despite healthy recruitment in recent years, whitefish populations in northern Lake Michigan are showing signs of stress, including lower body mass possibly due to an explosion of the zebra mussel population in this area. There is evidence that the natural whitefish diet of *Diporeia* and other native benthic invertebrates is disappearing possibly due to ecosystem perturbations caused by zebra mussels. Routine assessments of larger whitefish from this area indicate an almost exclusive diet of zebra mussels which coincides with lower body mass in the fish themselves. More research on this phenomena is needed.

Rise and Fall of the Lake Trout

Lake trout (*Salvilinus namaycush*) is a North American salmonid which thrives in cold, fresh water. Following the retreat of the last glacier, the lake trout colonized Lake Michigan and over the subsequent 10,000 years or so became the top predator in a complex ecosystem which co-evolved with the species. Over that period of time different strains of lake trout evolved. Some strains thrived in the deepest waters of the lake feeding on the abundant chubs and deepwater ciscos, other strains thrived in shallower areas of the lake.

Starting in the mid 1800s the population of the region began to increase and cities started growing around the lake. With abundant resources and the convenient access to waterways, Lake Michigan quickly became a major industrial hub of the United States. Commercial fishing for lake trout also became an industry and by the beginning of the twentieth century the population of lake trout was in decline. The decline continued until the mid-1950s when predation by sea lamprey, overfishing and the effects of industrial pollution led to the destruction of the lake trout fisheries and the disappearance forever of many of the strains of lake trout that had evolved in the lake.

Currently, federal, state and tribal management agencies around the lake are attempting to reestablish naturally reproducing populations of lake trout by planting fry and eggs in historical spawning areas. Assessments indicate that self-sustaining populations of lake trout have yet to be established. Research into the reasons for this failure are ongoing but may include

- loss of suitable spawning habitat
- environmental contaminants
- predation on larval lake trout by alewife
- thiamine deficiency from diet of alewife
- loss of genetically distinct strains.

Fish Communities: Predator Fish

Following the introduction and annual stocking of Pacific salmon, lake trout and other trout in the 1960s, an impressive sport fishery was created on Lake Michigan. The development of the Lake Michigan sport fishery has been called one of the most successful fish management stories in North America. Predator fish were able to thrive on an abundant prey base of predominantly alewife throughout the 1970s, until the mid-1980s when the alewife population crashed. The subsequent stress of a decreased forage base resulted in the spread of bacterial kidney disease (BKD) and the collapse of the chinook salmon fishery.

Currently, BKD appears to be less prevalent (Belonger and others 1997), and salmonid populations on Lake Michigan have rebounded and are currently at levels comparable to those of the 1980s. Some recent assessments have shown, however, that populations of prey fish have decreased and may be leading to stress in chinook salmon similar to the scenario of the 1980s. Therefore, the fisheries management agencies from around the lake are developing management options to avert another crash in predator fish populations.

Fish Communities: Nearshore Fish

Nearshore fish prefer the shallow, warm and nutrient rich environments of embayments, river outflows and other shallow areas of the lake. Species of nearshore fish in Lake Michigan include yellow perch, walleye, pike, and panfish. The populations of these fish have also declined in the 20th century due to environmental degradation and habitat loss; however, they have improved in recent years due to improving environmental conditions with some exceptions. Yellow perch populations have been drastically declining throughout the lake in recent years with continued poor recruitment. It appears that adequate numbers of larval yellow perch have been produced but fail to reach maturity. Causes are unknown but may include predation, or the effects of zebra mussels, contaminants or nutrient declines. In order to address the problem, several steps are being taken including the formation of a Yellow Perch Task Group comprised of a multi-state team of fisheries managers and scientists, as well as restrictions on commercial and sport fishing of yellow perch. In addition, a number of research projects have been funded and are currently in progress.

Other localized populations of nearshore fish that have been degraded include the walleye, muskellunge and pike fisheries in Green Bay and the lake sturgeon fisheries throughout the lake. Habitat loss has been a major factor in the decline of these fisheries, including the obstruction of sturgeon spawning habitat by dams on tributaries to Lake Michigan.

Open Water: System Assessment

While the Lake Michigan open lake system has remained virtually unchanged in size, its quality has been impaired. Nutrient concentrations have been reduced from their highs of the 1960s and 1970s. As a result, growth rates of nuisance algae have also been reduced. However, agreement on ideal long-term nutrient levels has not been reached (Nielson and others 1993). Locally, such as in many AOCs, nutrient levels are still too high, leading to oxygen depletion and impaired fauna.

In the open waters of Lake Michigan, phosphorous and chlorophyll concentrations have decreased significantly since the late 1970s, primarily due to improved municipal sewage treatment and laws requiring reduction or elimination of their use in certain products such as soaps and detergents, although preliminary sampling results indicate that phosphorus levels in the open waters of the lake may be increasing. Chloride concentrations continue to increase and the rate of increase is accelerating. The primary source of chloride seems to be municipal waste water discharges (a point source) and salt from road deicing (a nonpoint source) (Michigan Office of the Great Lakes 1996). In the heavily-populated and industrial southern part of the basin, water quality is severely diminished. The leading stressors are almost entirely urban in nature, including occasional backflows induced by combined sewer overflows, direct stormwater runoff, and industrial discharges (Thorp 1996).

The presence of toxic chemicals in the water continues to affect the health of fish and bird populations. As discussed in Chapter 5, toxic chemical loads are derived from atmospheric deposition, legacy sources (contaminated ground water and sediments), point source discharges, and nonpoint source runoff.

Oil and gas drilling in the waters of the lake are banned due to a compact of the governors. However, slant or directional drilling from a land-based site to reach a specific target underwater up to 4,000 feet away is permitted. Beginning in 1979, 100 oil and gas wells with bottom-hole locations have been permitted and directionally drilled under Lake Michigan. More applications for drilling are being requested, with as many as 30 potential sites under review.

Biological sources of degradation include the introduction of non-indigenous invasive species, such as the zebra mussel. The current status of the fish community depends on human management by the various agencies responsible for the fisheries for Lake Michigan.

Zebra mussels out-compete native filter feeders and alter the substrate and water clarity. Other non-indigenous invasive species are affecting the food web. It may be argued that stresses associated with biological factors have, in fact caused more severe degradation than physical and chemical stresses. Several endemic fish species–formerly dominant species–have been eliminated, and others, such as the lake herring and the globally rare lake sturgeon, now have severely restricted distributions.

Although portions of the lake appear to support high quality benthic communities, the overall documentation of the character and quality of invertebrate biota is still scanty. The lake's biotic communities also have not been systematically described or ranked from a biodiversity standpoint. However, many communities would presumably rank as globally rare or imperiled due to restricted distribution, level of threat, ecological fragility, widespread damage and because they are part of the single largest source of fresh surface water in the world (The Nature Conservancy 1994).

Multiple stressors continue to degrade the open lake system. Toxic chemicals contaminate water and sediment quality. Fish advisories are still in effect. Beaches, particularly in the southern part of the lake, are closed occasionally. Aquatic habitats do not sustain healthy and diverse fish communities. Exotic species continue to disrupt native plant and animal communities. Unsustainable human activities, like habitat destruction, continue to threaten the ecosystem. Ecosystem stewardship activities are currently not sufficient to overcome human-induced stressors. Data gaps continue to impede remediation or restoration progress. Lake Michigan Lakewide Management subgoals 1, 2, 3, 4, 6, 7, 8, 9, and 11, have not yet been met. Great strides have been made, however, in regard to subgoal 10, as the fish community objectives set forth by the Great Lakes Fishery Commission are carried out in a collaborative fashion by fishery managers basinwide.

4.2.2.2 Coastal Wetland System

The coastal wetland system supports the greatest diversity and biological productivity of the basin. Wetlands are important because they collect nutrients and organic materials that are washed off the land into the tributaries. Tributaries carry the materials to the lake, where they are deposited on the shore by longshore currents. These materials support both the aquatic food web and the habitat for bird, mammal, reptile, amphibian, and invertebrate resident and migratory species. Most Lake Michigan fish spend a portion of their life cycle in coastal wetlands. Migratory birds use coastal wetlands as staging and feeding areas. Both lake level fluctuations and longshore sediment transport are important in maintaining this highly productive system because of their roles in bringing the materials needed to nourish and protect it (The Nature Conservancy 1994).

Coastal Wetland System: Description

It can be said that Lake Michigan is the most diverse of any of the Great Lakes. Its wetlands are equally diverse. The most common are the embayment, barrier beach, and riverine. Deltaic formation only occurs weakly at some Green Bay sites, because in all other situations the shore currents quickly carry away any alluvium or detrital accumulations.

The diverse coastal wetland is habitat for numerous species of wildlife dependent on wetlands. Many insects have an aquatic larval stage. Amphibians also depend on wet conditions, at least during the larval stage. Many reptiles spend their entire lives in or near these coastal wetlands. Coastal wetlands provide important habitat for small fish, due to the abundant food supply and relative safety from predators. A great variety of bird life uses coastal wetlands for foraging, resting, and breeding. Mammals too are an important part of the coastal wetland community.

The location of these coastal wetlands, with access both to the open lake and inland terrestrial systems, constantly augments the food chain and enhances the value of these wetlands as a refuge for a greater diversity of plant and animal life.

Great Lakes coastal wetlands differ from inland wetlands in that they are shaped by large lake processes, including waves, wind tides and especially long and short-term water level fluctuations. The fluctuating water levels result in a constant shifting of the communities in the wetland. Many species have adapted to this constant fluctuation, and indeed require it to eliminate stronger competitors that thrive under more stable conditions.

Accordingly, Great Lakes marshes can be classified based on how they are influenced by Great Lakes processes. The Lake Erie Water Level Study (International Lake Erie Regulation Study Board, 1981), identified the following six wetland types that also occur on Lake Michigan.

- **<u>Open shoreline wetlands</u>** usually exist as a fringe of aquatic plants adjacent to the shore. That fringe has expanded inland or lakeward in response to lake effects such as wave action and changes in lake levels. The dominant vegetation is usually emergent, but submergent plants can also be present and do not necessarily border on a shoreline. Examples of this wetland type are found along the north shore of Lake Michigan east of Manistique.

- **<u>Unrestricted bays</u>** are characterized by a marshy fringe along a bay shoreline. These sites are afforded some protection from such lake effects as wave action. Depending on its size and depth, the whole bay could be vegetated. Submergent plants can be a part of those vegetative communities. This wetland type also includes typical open shoreline areas that are sheltered by an island or peninsula. Examples of this wetland type are found in Little Bay de Noc.

- **<u>Shallow sloping beach wetlands</u>** are areas with very gentle to flat slopes on sand substrates. Very small variations in lake levels have had widespread effects on vegetation zones. Sand bars, if present, provide some wave protection. The large sand split formations of Lake Michigan (such as Cecil Bay Marsh) constitute most of this wetland type.

- **<u>Restricted riverine wetlands</u>** are characterized by marsh vegetation bordering a river course. The extent of the vegetated wetland is often restricted by a steep backslope on the landward side and the deeper water of the river channel on the other. The Betsie River wetlands are examples of restricted riverine wetlands.

- **<u>Lake-connected inland wetlands</u>** are typified by the presence of a barrier beach or ridge that restricts the outlet to the lake and also provides protection from wave action and other disturbances. Such wetlands can have a definite steep backslope or a gradual slope permitting some shifting of vegetation zones with changes in water regime. This type of wetland will have a connection to the lake, but a stream or groundwater discharge from its drainage basin could also contribute to its water supply. The Arcadia Lake wetlands are examples of this wetland type.

- **<u>Protected (or Barrier beach) wetlands</u>** are separated from the lake by an unbroken natural barrier beach or ridge. The natural wetlands and some of the diked wetlands obtain their water from inland groundwater discharge, streams, and, at times, from the lake, when the wetland floods during storms. There is some seepage of water through dikes, which can be magnified by extremes in lake levels. Examples of this type may be found at Seagull Bar, Marinette, Wisconsin.

In total, 411 wetlands covering almost 49,000 hectares (ha) were identified along the shores of Lake Michigan in the early 1980s (Herdendorf and others 1981). There are 61 wetlands larger than 100 ha, with 13 of these covering more than 1000 ha. The eight largest, which exceed 2,000 ha, are Big Bay de Noc (3,867 ha), Oconto Marsh (3,792 ha), Manistee River (3,705 ha), Sturgeon River (2,710 ha), and Pere Marquette River (2,532 ha), Muskegon River (2,449 ha), Seul Choix Point Complex (2,361 ha), and Peshtigo River (2,040 ha) (Wilcox 1996).

The Hine's emerald dragonfly *(Somatochlora hineana)* is one of the most endangered dragonflies in the United States. It is known to occur in three areas in the Lake Michigan basin: northeastern Illinois, Door County Peninsula, and northern Lake Michigan on the Upper Peninsula. The dragonfly's habitat is wetland found on dolomite bedrock. It is endangered because its much of its habitat has been fragmented or destroyed by development. The priority is to protect remaining populations and habitat and to reestablish populations at restored sites within the dragonfly's historic range (Zercher 1999).

A brief description of areas around the lake where coastal wetlands are found is presented in Appendix G.

The distribution of coastal wetlands in the Great Lakes system is summarized in Table 4-1.

Table 4-1. Distribution of the Approximately 300,000 Acres of Coastal Great Lakes Wetlands in the U.S.

COASTAL WETLAND	Percent
Lake Ontario-St. Lawrence	6.9
Whitefish Bay	3.6
St. Mary's River	4.4
Lake Erie-Niagara	6.7
St. Clair-Detroit	3.2
Lake Superior	14.5
Lake Michigan	40.4
Lake Huron	20.4

(Sources: Herdendorf and others 1981).

Coastal Wetland System: Assessment

Coastal wetland loss estimates from different sources have been compiled for various sections of the Great Lakes by Bedford (1992). Bedford reports that 50 percent to 72 percent of the coastal wetlands have been lost in sections of Lake Michigan.

South of Chicago and around the southern end of Lake Michigan many smaller remnant wetlands and larger interdunal wetlands remain post-industrialization. Some in the area of Lake Calumet and the Grand Calumet and Little Calumet Rivers are being restored and reconnected to the Lake Michigan water table (Maynard and Wilcox 1996).

South of Sturgeon Bay, all the way to Chicago, development in coastal wetland areas has been limited because most of the shore consists of high bluffs with narrow beaches, and few unmodified river mouths. The rivers have small watersheds limiting sediment loads. At all of the river mouths, urbanization has eliminated coastal wetlands (Maynard and Wilcox 1996).

On the Door County Peninsula, development is continuing to increase. This will result in water quality degradation and altered hydrology (Scheberle 1999).

The Green Bay area has suffered from losses and degradation of its wetlands due to industrial development, dredging, upstream damming, and toxic contamination. On the western shore of Green Bay, however, large coastal wetlands are protected and managed as state wildlife areas by the Wisconsin Department of Natural Resources (Maynard 1996).

In the less densely populated northern shore, many of the coastal wetlands remain intact. Scenic shoreline roads, however, bisect both marsh and dune communities northwest of the Mackinac Bridge (The Nature Conservancy 1994).

The drowned river mouth marshes along Lake Michigan's eastern shoreline have had their hydrology altered by road crossings, thus increasing sediment deposition, and have been affected by ditching, agricultural practices, and colonization by invasive plant species (Maynard 1996). Significant parts of the Grand River Estuaries are in public ownership; however, the highest quality marshes are in private ownership. Increased nutrient loadings from non-point sources are the greatest threats to the water quality of these marshes (The Nature Conservancy 1994).

Multiple stressors continue to degrade the Lake Michigan coastal wetland system. Non-indigenous invasive species such as purple loosestrife are still largely uncontrolled despite chemical, physical and biological attempts to eradicate. The sediments from tributaries that nourish coastal wetlands do not contain woody debris needed by some habitats. Fast flowing tributaries deposit too much sediment and bury submergent and emergent aquatic plants. The pace of shoreline modification is increasing. No comprehensive, cross-jurisdictional effort exists to monitor the status of the system or to fill research gaps. Coastal marsh system stewardship activities are not coordinated, nor are there efforts being undertaken to protect or restore all remaining fragments. Lakewide Management Plan subgoals 4, 8, 9, 10, and 11, therefore, have not yet been attained in regard to the Lake Michigan coastal marsh system.

4.2.2.3 Inland Wetland System

The inland wetland system–wetlands away from the Lake Michigan shoreline–is the reservoir for water in the Lake Michigan drainage basin. There are many types of inland wetlands, including fens, bogs, wet meadows, and wet forests. The health of inland wetlands is dependent on the quantity and quality of groundwater and surface water. Inland wetlands help to regulate the basin's volume of water as well as sediments and chemicals. They also store nutrients and serve as the nutrient exchange vehicle for the diversity of species that use inland wetlands as habitat and feeding areas. Both wetland and upland species breed and feed in Lake Michigan's inland wetlands (The Nature Conservancy 1994).

Inland Wetland System: Description

Wetlands are defined in numerous state statutes. For example, Wisconsin statute [Section 23.32 (1)] defines wetlands as areas "where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions." Federal wetland definitions are provided by the U.S. Army Corps of Engineers and the National Wetland Inventory.

The inland wetland system is composed of a variety of wetland types. Each wetland type has a different suite of animal and plant species and habitat conditions. For example, the Pine and Popple River area in northeastern Wisconsin is a wet northern forest. It occurs on acid peat and is dominated by black spruce, tamarack, white cedar, and balsam fir, as well as an understory of mosses, sedges, and shrubs. The Turner Creek Wetlands in the southwestern part of Michigan's lower peninsula, on the other hand, has a wet prairie complex, a grassland of bluejoint grass, sloughgrass, and big bluestem on wet soils (The Nature Conservancy 1994).

The inland wetland system is an important part of the water cycle for all ecosystems in the Lake Michigan basin. They are generally a buffer between lakes and ponds and upland areas. They trap sediments, remove nutrients and soak up floodwaters, thereby functioning to keep water clean. They are discharge and recharge areas for groundwater. They provide diverse habitats for many plants and animals (Wisconsin Department of Natural Resources 1995).

The role of inland habitats in maintaining water quality is perhaps overshadowed by their importance in regulating water flows and levels. From a basin-wide perspective, the inland habitats are the principal collectors of precipitation for the basin. The ability of forests and wetlands to store and release water is critical to moderating tributary and groundwater flows to the lakes (The Nature Conservancy, 1994). Inland habitats moderate tributary flows, reduce erosion and sedimentation associated with flooding, and thus moderate the seasonal and long-term fluctuations of lake levels.

Many animal species move between different habitats, with periods ranging from daily through seasonally to once or twice in their life cycle. In this way, habitats other than the one they are normally associated with, can play a critical role in the survival of the species, especially when normally dispersed populations concentrate in very small areas. In such a case, this habitat becomes far more important than what is suggested by the community of species that are more permanent residents. Examples of several different kinds of periodic use are summarized below.

Migration Stopovers

Historically, the marshes of Wisconsin's Winnebago Pool Lakes, as well as other areas in the Great Lakes such as the Detroit River, Lake St. Clair, Long Point and Western Lake Erie, have been important resting and feeding stops for the eastern population of canvasback duck, which winters on the Atlantic Coast. This population declined from 400,000 birds in the early 1950s to less than 147,000 by 1960 and has just finally recovered to its former levels.

The canvasback duck has rigid habitat requirements and behavioral traits that limit its adjustment to environmental change. It does not tolerate disturbance by boat traffic and depends strongly on wild celery. Densities of wild celery tubers decreased by 72 percent from eutrophication, sedimentation, carp, and pollution at two of five locations where ducks once fed between 1950 and 1985 (Schloesser and Manny 1990; Kahl 1991).

Several authors have suggested that the decline in canvasback numbers is at least partially linked to the reduction in forage on their migration routes (Bellrose and Crompton 1970; Mills and others 1966; Trauger and Serie 1974).

Spawning and Nursery

Many of the fishes of the open lake and tributaries move to the shallow waters or wetlands to spawn. In this respect, their needs are very specific: a certain kind of substrate, a certain amount of current, depth and temperature and within a narrow time-window. Often they return to the same places where they hatched. In a manner similar to waterfowl, during spawning a widely-dispersed population becomes concentrated in a habitat of relatively small size. For these populations, these spawning habitats become far more important than their relative size would suggest. An atlas of spawning grounds in Lake Michigan is available at http://www.glsc.nbs.gov/information/atlas/index.htm. Although artificial reefs have been created in marine waters and in small freshwater lakes and reservoirs for decades, their effectiveness in the Great Lakes as a fishery management technique is still being evaluated. Three of eleven intentional artificial submerged reefs in the Great Lakes Basin have been set up in Lake Michigan. An "International position statement and evaluation guidelines for artificial reefs in the Great Lakes"(Gannon 1990) has been developed to ensure that fishery management, not waste disposal, must be the driving force behind artificial reef construction in the Great Lakes. As of this writing, there is no basinwide policy on artificial reef construction.

Nesting

While bald eagles have attracted attention, mostly because of the effects of toxic chemicals on their reproduction and development, it has also become apparent that reestablishing viable populations of eagles in the Great Lakes requires more than clean water. For example, nesting adult eagles prefer coniferous perches that are isolated from human disturbance (Bowerman and Geisy 1991).

A survey of Lake Michigan found that 49 percent of the coast is unsuitable as eagle nesting habitat (Bowerman 1993). Sensitivity to disturbance and the large forage area require the protection of extensive coastal and inland habitat if bald eagles are to play more than an isolated and infrequent role in the ecosystem.

Of special importance are habitats where a large part of the population gathers periodically in a limited area, more so when there do not appear to be alternative habitats to which these migrations may shift if the favored habitat becomes degraded.

Overall, inland wetlands are exceptionally rich in plant and animal species. Many of these species are threatened or endangered. Plants include, among many, calypso orchid, tussock bullrush, umbrella sedge, and algal-leaved pondweed. Animals include reptiles and amphibians such as the Blanding's turtle, wood turtle, and Massausauga rattlesnake, and Blanchard's cricket frog; birds such as the trumpeter swan, yellow-throated warbler, and red-shouldered hawk; and Lepidopterans such as the silphium borer moth. It is estimated that 32 percent of the State of Wisconsin's threatened and endangered plants and animals are wetland-dependent (Wisconsin Department of Natural Resources 1995).

Numerous wetlands remain throughout the Lake Michigan basin in spite of tremendous losses. Several of the most significant remaining parcels, in terms of biodiversity and representative type of wetland, are described in Appendix G to illustrate the diversity of the inland wetland system.

Inland Wetland System: Assessment

Millions of acres of inland wetlands have been lost in the Lake Michigan basin to agriculture, industry and urban development over the last century. Over the last two centuries, wetland losses in the four states at least partially within the Lake Michigan basin have been disproportionately greater than in many other U.S. regions. Since the 1780s, Lake Michigan basin states have lost an estimated 21.9 million (62.9 percent) acres of wetlands out of their 34.8 million original wetland acres. Wisconsin has lost about 47 percent of its original ten million acres of wetlands (Wisconsin Department of Natural Resources 1995). Illinois has lost approximately 85 percent of its wetland acreage, Michigan has lost greater than 50 percent of its wetland acreage, and Indiana has lost greater than 70 percent of its acreage (U.S. Fish and Wildlife Service No Date). These figures compare with an average loss of 52.8 percent nationwide. There are an estimated 12.9 million acres of wetland remaining in the four states, representing more than 12.3 percent of the wetlands within the lower 48 states (Dahl 1990). Recent historic losses of wetlands in the Great Lakes basin have been estimated to be 20,000 acres/year (Great Lakes Basin Commission 1981).

State and federal regulatory programs have begun to stem the tide of losses; however, exemptions for agriculture, forestry, and other uses do not protect all wetlands from being destroyed. Fortunately, acquisition of major inland wetlands for waterfowl and fishery management was initiated by groups such as Ducks Unlimited and resulted in wetland protection. Management for waterfowl and fish have helped other wetland-dependent species such as wading birds and sandhill cranes. Restoration of many wetlands is also taking place, although restorations have not proved to be as rich or diverse as the original wetlands.

Subgoal 4 has not yet been met, although current efforts to protect and restore the inland wetland system have made significant progress over the last two decades. Subgoal 8 is problematic due to the invasion of exotics such as purple loosestrife. It will be some time before these invasives are controlled. Progress is being made toward the attainment of subgoals 9, 10, and 11, primarily through the cooperative efforts of agencies and organizations striving to better understand inland wetlands and share problem-solving resources.

4.2.2.4 Tributary System

Water from the basin drains to Lake Michigan by way of the tributary system. In addition to water, tributaries contribute chemicals, nutrients, organic materials, and sediments to Lake Michigan. These materials enter the lake and then are carried by longshore transport around the lake's nearshore and nourish coastal shore and marshes Tributaries are spawning habitat for many fish species as well as for invertebrates such as the Hungerford's crawling beetle, endemic to the Maple River in northwest lower Michigan. Tributaries are also major migratory corridors for many species (The Nature Conservancy 1994).

Tributary System: Description

Tributaries are connected to Lake Michigan in several ways. Energy is transferred from lake to tributary and tributary to lake by way of fish movement up and downstream and material movement downstream. Diverse plant and animal habitats are found throughout the tributary system. The range of tributary habitats depends upon the size, slope, substrate, geology and land-use in the drainage basin, groundwater characteristics, climate, and the nature of the terrestrial vegetation. Many of these habitats accommodate Lake Michigan fish. Sediments and vegetative materials are sent downstream to the lake and are transported around the coastal shores and marshes of the lake to create habitats. The connectivity to the lake maximizes fish biodiversity and production (Whelan 2000).

Of the 36,000 miles of rivers in the state of Michigan, 35 percent flow to Lake Michigan. In the north, the rivers are rough and rocky. In the south, the rivers flow through other states' gently rolling agricultural lands. Michigan's most outstanding rivers have been designated as natural rivers and protected as authorized by the Michigan Natural Rivers Act, Part 305, P.A. 451 of 1994.

Several examples of rivers that are both outstanding and impaired are listed in Appendix G to illustrate the wide range of both type and quality of rivers in the basin.

Tributary System: Assessment

The quality of many rivers in the Lake Michigan basin has been significantly impaired due to channelization, dredging, damming, sedimentation, loss of bankside vegetation, eutrophication, increased spring flooding, and toxic contamination. Large areas of inland forests and wetlands that once served to regulate the quantity and quality of water flowing into tributaries have been lost. As a result, tributaries pass on their pollutant and sediment loads to the lakes and their suitability as spawning habitat has been seriously impaired. In urban areas, degradation has been most severe. Pollution from agriculture, industry and urban development has polluted rivers and contaminated sediments. The result is the contamination of fish and wildlife that depend on river habitats. Many rivers, particularly at the rivermouths, have been declared Areas of Concern and have many impaired beneficial uses.

Information on the status of rivers and streams is available from several sources. The states regularly report on the status of their water bodies under Section 305(b) of the Clean Water Act. EPA then compiles these state reports into a *National Water Quality Inventory Report to Congress.* Information on individual water bodies and watersheds is also available on the worldwide web at EPA's "Surf Your Watershed" site (www.epa.gov/surf). Finally, the Federal *Clean Water Action Plan* requires that the states prepare "Unified Watershed Assessments" to identify priorities for watershed management. Those reports are available through the state agencies.

Subgoals 1, 2, 3, 4, 6, 7, and 8 have not been met in regard to tributaries. Although the public utilizes Lake Michigan rivers, the actions are not necessarily sustainable. Tributaries are pathways for contaminants. Exotic species are impacting waterways. Subgoals 9, 10, and 11, however, are progressing favorably. Watershed groups are working to clean up rivers. Stakeholders and governments are collaborating to remediate Areas of Concern and take down dams that impede tributary system flows. Issues relating to dam removals are further discussed in Chapter 5. Information is being gathered at all levels that will lead to more effective remediation and future management of the tributary system.

4.2.2.5 Coastal Shore System

The coastal shore system – sand beaches, sand dunes, sand spits, bluffs, bedrock and cobble beaches, etc. – buffers coastal wetland and inland systems from the waves, wind, and ice of Lake Michigan. It is ever changing, formed by deposits of sediment from rivers and other shoreline areas and carried by longshore currents around the shoreline (Reid and Holland 1997). Lake level fluctuations are an important part of this system, assisting in sediment transport and beach and dune maintenance. The coastal shore system is rich in species diversity. Sand dunes, in particular, harbor more endemic species than any other part of the Great Lakes basin (The Nature Conservancy 1994). Many natural factors act to change the shape and structure of the Lake Michigan shoreline. The most significant among them are climate, erosion, and lake-level fluctuations.

Coastal Shore System: Climate

Advancing and retreating glaciers carved out the lake basin as water levels changed in response to melting ice. The results of the glacial retreat can be seen along the varied and rugged shoreline, and in abandoned former shorelines inland from today's lake. As the ice retreated, the climate warmed at a rate of one or two degrees every 1,000 years. New plant and animal species colonized and interacted, contributing to the rich natural heritage that remains today.

Today, warm, moist air from the Pacific Ocean and the Gulf of Mexico collides with cold, dry arctic air over the Great Lakes basin. Due to their sheer size and volume, the lakes moderate the effects of both systems by acting as a heat "sink" or cold "sink." As a result shoreline temperatures around Lake Michigan are cooler than inland in the summer. In the winter, the warm lake waters moderate the air temperature and the shoreline is warmer than inland. In addition to modifying temperatures, the lake influences weather patterns, precipitation, and wind velocity and direction (Reid and Holland 1997).

Global warming resulting from human activities poses the threat of increased temperatures and changing precipitation rates. Shorelines could change quickly, submerging or exposing ecosystems accustomed to harshness and variability but unable to cope with rapid change. An abrupt change in climate could prevent ecosystems that now survive in small, isolated areas from adapting (Reid and Holland 1997).

Coastal Shore System: Lake-Level Fluctuations and Global Climate Change

Lake-level fluctuations contribute to erosion, sediment transport, and sand dune maintenance. On average, Great Lakes water levels fluctuate 12 to 18 inches per year. Three types of water level fluctuations occur. First, water may be temporarily displaced as a result of high winds or atmospheric pressure. This short-term fluctuation is called a seiche. Second, the volume of the lake changes seasonally as a result of storm actions, runoff, evapotranspiration, or groundwater flow. Third, long-term water level fluctuations are due to precipitation, temperature, and evapotranspiration changes.

Based on projections using several state-of-the-art models (Mortsch and Quinn 1996, Croley 1991), experts from the U.S. National Oceanic and Atmospheric Administration (NOAA) and Environment Canada believe that global warming could result in a lowering of lake levels by a meter or more by the middle of the 21st century. This development would cause social, economic and environmental impacts throughout the Great Lakes region (IJC, 2000). The impact of global climate change as a stressor to the lake is further discussed in Chapter 5.

Of particular concern are the predictions of poorer water quality and shifts in species composition. Increases in fish yields (warm water species) will be concurrent with eutrophic-like conditions and increased contaminant loading and bioavailability. While a warmer climate will provide longer seasons for agriculture and commercial shipping, changes in seasonal runoff patterns, decreases in total basin moisture and lake level decline will have negative consequences. Lake level decline will also result in significant loss, migration and changes in wetlands. Most impact assessment efforts have been concentrated on physical responses. The biological consequences of the physical responses to climate change have yet to be seriously explored.

Sand dunes, sand beaches, bedrock shores, and alvars are the primary coastal shore system communities on Lake Michigan. Islands are included here as well. Each is described briefly below.

Coastal Shore System: Sand Dunes

From northern Indiana and continuing northeasterly into Michigan, the most colossal shore feature in all the Great Lakes is apparent: the massive coastal dunes that flank the shore. These dunes run without interruption, except in river valleys, some cities, and roads, along the entire shore to heights of 300 feet and breadths of more than 1 mile. The dunes were formed following the last glaciation in the region and are 2,500 to 10,000 years old.

The dunes are subjected to residential development with summer homes and permanent residences, often very close to the shore. Ancient high lake levels formed the beach ridges, and as the lake receded, the prevailing on-shore winds continued to blow beach sand up the slopes. The most significant dune features lie on the shores of Lake Michigan and Lake Superior, with Lake Michigan encompassing the largest collection of freshwater dunes in the world.

Sand dunes form where sand grains from 1/16 to 2 millimeters in size are abundant, wind blows frequently, and there is a place for sand to be deposited. As saltation occurs–sand grains bouncing and colliding with other grains–over time, dunes actively move. Abundant and easily erodible quartz from the rocks of the Canadian Shield is the primary mineral component of sand (Reid and Holland 1997).

Foredunes, sand dunes closest to the beach, begin to grow as vegetation such as marram grass *(Ammophila breviligulata)* forces the winds to drop sand, which then piles up. As a foredune grows, other grasses such as sand reed *(Calamovilfa longifolia)* and little bluestem *(Andropogon scoparius)* and shrubs and trees such as cottonwood *(Populus deltoides)*, trembling aspen *(Populus tremuloides)*, sand cherry *(Prunus pumila)*, dogwood *(Cornus stolonifera)*, and willows *(Salix sp.)* gain a foothold. Numerous animals find shelter and food among the trees and shrubs (Reid and Holland 1997).

Blowouts occur most frequently in the foredune area. Wind or human activity that treads heavily and wears away vegetation creates gaps in the dune. As a break in the side of a dune is excavated by the wind, sand and vegetation quickly erode, leaving a saucer-shaped depression. Serious blowouts begin as a result of human activities (Reid and Holland 1997).

Interdunal areas lie protected from wind and waves behind the foredunes. These areas include unique sand dunes and globally imperiled communities called pannes or interdunal wetlands–calcareous, wet, interdunal depressions–which form near the water table. Vegetation in these areas may include asters *(Aster ptarmicoides)*, sedges *(Carex garberi, Carec viridula)*, and lobelias *(Lobelia kalmii)*, with jack pines *(Pinus banksiana)* and cottonwoods *(Populus deltoides)* at the edges (Reid and Holland 1997).

Parabolic, longitudinal, and transverse dunes form as a result of vegetational patterns and wind direction and are characterized by their unique shapes. Backdunes occupy inland areas. Their size and shape are more stable than those of foredunes due to the well-established vegetation that prevents wind erosion except in extreme weather. Successive ridges of backdunes contain different plant communities. At the Indiana Dunes National Lakeshore, for example, the first ridge of backdunes is dominated by jack pine *(Pinus banksiana)*, white pine *(Pinus strobus)*, juniper *(Juniperus communis)*, and an understorey of plants that includes poison ivy *(Rhus radicans)*. The second line of backdunes supports an oak community characterized by black oak *(Quercus velutina)*, white oak *(Quercus alba)*, and basswood *(Tilia americana)*. Furthest inland is the beech-maple dune community with a forest of beech trees *(Fagus grandifolia)* and maple trees *(Acer rubrum)*, well-developed soil, a complex plant understorey, and diverse populations of mammals, reptiles, and amphibians (Reid and Holland 1997).

Several unusual dune types are found at Sleeping Bear Dunes National Lakeshore. Perched dunes rest on a plateau of glacial sediment. Falling dunes form as sand migrates off perched dunes and builds on an adjacent lowland. De-perched dunes form on lowland areas beyond plateaus (Reid and Holland 1997).

Dune and swale or ridge and swale community complexes are found in several places throughout the Lake Michigan basin. They were formed as the ancestral Great Lakes receded. In the south, the dunes or ridges stretch parallel to the Lake Michigan shore and are rich in oak savanna species. The wet swales between these ridges support rich prairies and sometimes rare coastal plain marsh communities. In the north, ridges are typically dominated by red and white pine and other conifers, and the swales by white cedar swamps or sedge meadows (Reid and Holland 1997).

On the eastern shore of Lake Michigan an invasive non-indigenous species is threatening dune ecosystems. Baby’s breath is moving into sensitive areas and out-competing native species. Control measures such as hand pulling and herbiciding are being used at Point Betsie and at the outskirts of Sleeping Bear Dunes National Lakeshore.

The Lake Michigan dunes are numerous, diverse, and irreplaceable. A list of representative protected dune types are provided in Appendix G.

Coastal Shore System: Sand Beaches

Sand beaches form when waves and wind deposit sand eroded from other places on exposed shoreline. The sand settles until storms or ice transport it elsewhere or until the wind lifts and deposits it inland to form dunes. Beaches are rich areas for migrating shorebirds that feed on algal mats and for a variety of microfauna.

Sand beaches may be erosional, transitory or depositional. Erosional beaches lose more sand than is deposited by waves or wind. Transitional beaches collect and lose sand so that there is no net gain or loss. Depositional beaches receive more sand than is lost over time. Shoals, sandbars, and spits protect lagoons and coastal marshes from wave and wind action (Reid and Holland 1997).

On the psalmolittoral part of the beach, land and water constantly interact. Its inhabitants include microscopic protozoans, algae, mircrocrustaceans, and insect larvae. Next to the psalmolittoral beach lies the lower beach. Waves scour the sand, which is devoid of vegetation, most heavily during summer storms. Scavenger beetles, flies, and spiders visit here. The middle beach collects driftwood and debris deposited by winter and summer storms and ice. Tiger beetles, ground beetles, flies, spiders, and other insects, as well as shorebirds, feed here. Vegetation is sparse and hardy. The drought-tolerant sea rocket *(Cakile edentula)*, an annual herb, colonizes early. The upper beach is vegetated with biennials and perennials such as wormwood *(Artimesia campestris)*, beach pea *(Lathyrus maritimus)*, and evening primrose *(Oenothera rhombipetala)*. Butterflies, beetles, spiders, and ants frequent this drier sand habitat (Reid and Holland 1997).

Artificial shoreline structures and hardening of the shoreline have interrupted the important process of longshore sediment transport that naturally erodes and replenishes sand beaches. Tons of sand are brought in to artificially replenish beaches each year for recreational purposes.

Beaches are found all around the Lake Michigan basin. In urban areas such as Chicago where the shoreline is artificial, sand must be brought in every year to nourish the beaches, which are held in place by a series of revetments. These urban beaches are recreational and offer little in the way of wildlife habitat or nourishment as described above. Some of these beaches also experience episodic, short-term closures due to high bacteria counts. The elevated bacteria levels may be derived from urban runoff following storm events, combined sewer overflows, animals, or other sources.

Away from urban centers, more beaches with values for wildlife are protected. A series of national and state parks around the lake provide set-aside beaches for animals, particularly shorebirds and plant communities. Illinois Beach State Park and Indiana Dunes National Lakeshore, for example, have a high number of visitors each year because of their accessibility to Chicago. However, a part of their beaches are off limits to park visitors to protect rare plant and animal communities. The Indiana Dunes National Lakeshore ranks third in species diversity of all national parks.

In the north, where Lake Michigan is colder, beaches are less crowded; therefore, wildlife areas are more numerous. Several plant species are endemic to the Great Lakes and found on the northern shore of the lake. The dwarf lake iris *(Iris lacustris)*, ram's head lady's slipper *(Cypripedium arietinum),* and the federally threatened pitcher's thistle *(Cirsium pitcheri)*, which is also found at the southern end of the lake, are all endemics.

The piping plover *(Charadrius melodus)* is a Great Lakes endangered shorebird found along the north shore of the lake. Once common in the Great Lakes, its breeding range is now limited to protected areas such as Sleeping Bear Dunes National Lakeshore and Wilderness State Park.

The sites mentioned in the previous section on sand dunes also have sand beaches of ecological importance. Two sites illustrating the differences in sand beaches from north to south in the Lake Michigan basin are discussed in Appendix G.

Coastal Shore System: Alvars

The northern Lake Michigan Garden Peninsula is home to a rare ecological habitat called an alvar. Alvars are open areas of thin soil over limestone or marble bedrock, which host a distinctive vegetation community, including a considerable number of rare plants. In North America, alvars occur only in the Great Lakes basin, where they are scattered in an arc from Michigan's Upper Peninsula through southern Ontario to northwestern New York state.

Alvars undergo periodic flooding followed by drought, and their very shallow soils are subject to high surface temperatures in mid-summer. Alvars have been described as "habitats for the hardy," since plants that thrive there must be able to withstand harsh conditions. Trees are scattered and often stunted or deformed.

Alvar habitats support several types of bedrock pavement, grassland, and savanna communities, most of which are considered globally rare. Plant species include an unusual blend of boreal and prairie species, relics from the period following the last glaciers. Alvars are home to unusual wildlife species including the loggerhead shrike *(Lanius ludovicianus)* and a large number of distinctive invertebrates, such as leafhoppers and land snails (Reschke and others 1999).

Second home development and recreation are increasing in the Garden Peninsula and may have an impact on alvars. There is no known organized effort to protect alvars in the areas at this time.

Coastal Shore System: Lake Michigan Islands

Off the coast of Little Traverse Bay are 11 islands known as the Beaver Island Archipelago. They provide significant habitat for shoreline species such as colonial nesting birds, including the Piping Plover. They are important stopover sites for migratory birds. The natural landscapes found on the mainland are found on the islands. These include dunes, sand and cobble beaches, boreal and hardwood forests, and cedar swamps. The Great Lakes endemic pitcher's thistle *(Cirsium picherii),* dwarf lake iris *(Iris lacutris),* and Houghton's goldenrod *(Solidago houghtonii),* are found along the shorelines.

Several other island groupings are found in Lake Michigan. The North and South Fox Islands lie just to the south of the Archipelago. Just over 16,000 acres in size together, the islands are beach and second growth forest communities.

South of the Fox Islands and off the shore from Sleeping Bear National Lakeshore are North and South Manitou Islands. The interior of the islands are hardwood forest with small lakes. There are fragile perched dunes on the west side of South Manitou, and a grove of virgin white cedar trees is more than 500 years old. Island mammals include fox, beaver, coyote, and snowshoe hare. Much of the island is managed as wilderness.

The topography of North Manitou Island varies considerably. Part of the island is low dunes with a lake in the center and rugged bluffs to the west. Deer introduced to the island in 1927 multiplied considerably due to lack of predation. As a result, deer overbrowsing began to damage the island's vegetation. The deer population is now managed (Michigan Department of Natural Resources 2000).

Coastal Shore System: Wildlife

Of the 94 species of Wisconsin breeding birds associated with aquatic habitats, 31 rely on nearshore, shoreline, and islands of Lake Michigan for nesting, cover, roosting, or feeding (Robbins 1991). Seven of the 10 Wisconsin threatened or endangered bird species use shoreline and islands during the breeding season. Important waterfowl nesting sites for 33 percent of the breeding pairs of dabbling ducks in the Great Lakes are located on Lake Michigan at sites concentrated in Green Bay, Big Bay de Noc, and along the eastern shore.

Osprey and bald eagles are two aquatic raptors that historically nested along the shoreline of the Great Lakes and on offshore islands. While bald eagles have attracted attention, mostly because of the effects of toxic chemicals on their reproduction and development, it has also become apparent that reestablishing viable populations of eagles in the Great Lakes requires more than clean water. Nesting adult eagles use coniferous perches that are isolated from human disturbance (Bowerman 1991). A survey of Lake Michigan found that 49 percent of the coast is unsuitable as eagle nesting habitat (Bowerman 1993). The eagle's sensitivity to disturbance and need for a large forage area require the protection of extensive coastal habitat if bald eagles are to play more than an isolated and infrequent role in the ecosystem. Continuing work by Bowerman confirms these findings (Beck, personal communication).

For several species of reptiles and amphibians, the temperature moderating effects along Lake Michigan's shoreline is, in part, responsible for an extension of their range north into Wisconsin.

Species such as the western ribbon snake are adapted to sandy margins of the lake (Wisconsin Department of Natural Resources 1993).

Coastal Shore System: Assessment

Recreational home development is increasing on the Lake Michigan Islands. In addition, invasive non-native species are beginning to impact dune areas. Key protection needs include developing inventories of significant biodiversity areas, establishing monitoring programs for rare and threatened plants and animals, and developing and implementing protection programs.

Conflicting coastal shore values and uses will continue to degrade the coastal shore system. Use of sand in industrial processes, continued shoreline bordering to prevent erosion of private properties, longshore sand transport disruption by jetties and other structures, invasive species introductions, and an increase in off-road dune use will alter the coastal shore system and reduce its ability to function as a system. Beaches are a primary environmental and economic concern in the coastal shore system. Periodic, short-term beach closures due to elevated bacteria levels and the need to regularly replenish sand on the beaches impose management costs and may result in the loss of recreational revenue.

These threats have resulted in the established of protection programs for certain Lake Michigan islands. Several islands are Designated Environmental Areas under Part 323 of Michigan Act 451 of 1994, as amended. In addition, part of the Beaver Island group and some islands near the Straits of Mackinac are Designated Environmental Areas. These areas are set apart for the protection and maintenance of fish and wildlife. Permits are required for dredging, filling, soil or natural drainage alteration, vegetation cutting, and building.

Subgoals 4 and 8 have not been met. Subgoal 5 is well on its way to being met as public access to the shoreline increases in parks and protected areas. Subgoal 6, however, will not be met until conflicting land uses are sorted out and prioritized. Subgoals 9, 10, and 11 are underway in pockets throughout the basin.

4.2.2.6 Lakeplain System

The lakeplain system occupies the area of the ancestral lakebed of Lake Michigan, formed as the lake receded after the last ice age. Southern Lake Michigan has a low topography and a high water table supporting extensive beach ridges and swales, prairies, savannas, wet meadows, sand barrens, and coastal plain ponds. Lakeplain prairies and savannas, two of the most imperiled ecological communities in North America, are found here. Rare alvar communities are found on the shores of northern Lake Michigan. The lakeplain system harbors a rich diversity of plant and animal species, more than any other system. Several species, including the prairie white-fringed orchid *(Plantanthera leucophaea)* and the Karner blue butterfly *(Lycaeides samuelis)*, are federally endangered (The Nature Conservancy 1994).

Lakeplain System: Description

Lakeplains occur where the ancestral Great Lakes occupied a different basin than those present today. Those former lakebeds are characterized by low topography with sandy, silty, or clay soils and a high water table. The major topographic features are linear sandy beach ridges that were formed as the lakes receded in incremental stages (The Nature Conservancy 1994).

Hydrologic fluctuations, both of groundwater and of Lake Michigan, are important to the functioning of the lakeplain system. Lakeplain systems have two important functions. First, during times of severe weather, this system is a refuge for species that normally reside on or near Lake Michigan. Second, prior to heavy impacts to the lakeplain system due to development, this system was probably important in floodwater retention.

Although the lakeplains may extend some distance back from the shore, natural hydrological cycles associated with groundwater flow and lake level fluctuations play a key role in maintaining habitats for rare communities (The Nature Conservancy 1994). They also are a significant source of fine materials that erode to the lakes in tributary floods and contribute to the sand and clay components of littoral drift.

Four important lakeplain ecological communities–lakeplain prairies, oak savannas, sand barrens, and Atlantic coastal plain disjunct communities–are described briefly.

Lakeplain System: Lakeplain Prairies

Lakeplain prairies consist of rich and deep soils on which a variety of tall grasses and flowers grow. The grasses may reach 12 feet in height. The roots of some of the prairie plants reach as far below the ground as the plant above ground. The lakeplains on which the tallgrass prairies grow were formed from sediments deposited as the Wisconsin glacier receded more than 10,000 years ago.

Prior to European settlement, the tallgrass prairie peninsula extended from the southern Lake Michigan area in northeastern Illinois and Northwest Indiana through southern Michigan to Ontario. Since the mid-1800s, lakeplain prairies have been converted to agriculture. Only tiny parcels remain–less than 0.01 percent of the original. The best remaining fragments in the Lake Michigan basin are found at Chiwaukee Prairie in Southeastern Wisconsin, Markham Prairie in Northeast Illinois, Hoosier Prairie in Northwest Indiana, and Allegan State Game Area in Southwest Michigan (Albert 1996).

Lakeplain prairies depend on the water-level fluctuation of the lake. Their deep root systems enable these prairies to hold water, acting much as marshes do. Periodic fires and fluctuating water levels help prairies maintain their open, treeless condition. Organic material such as leaf litter is eliminated, allowing new growth.

Wet lakeplain prairies are found at the shoreline or growing contiguously with coastal marshes. Vegetation includes grasses such as blue joint grass *(Calamagrostis canadensis)* and prairie cordgrass *(Spartina pectinata)*, sedges such as *Carex stricta* and *Carec aquatilus*, red osier dogwood *(Cornus stolonifera)*, and shrubby cinquefoil *(Potentilla fruticosa)* (Reid and Holland 1997).

Dry or mesic lakeplain prairies lie at the edges of the wet prairies. Plant species include big bluestem grass *(Anropogon gerardii)*, little bluestem grass *(Andropogon scoparius)*, Indian grass *(Sorgastrum nutans)*, switch grass *(Panicum virgatum)*, tall coreopsis *(Coreopsos tripteris)*, blazing star *(Liatris spicata)*, and Ohio goldenrod *(Solidago ohioensis)* (Reid and Holland 1997). The Prairie white fringed orchid *(Platanathera leucophaea)* is a federally threatened lakeplain prairie plant (Reid and Holland 1997).

Formerly, the foremost lakeplain prairie animals were bison and elk. Both species are gone, along with other large mammals, from present lakeplain prairies. Today, muskrats are found in wet prairie areas. Prairie ant mounds and crayfish chimneys lie inconspicuously among tallgrasses. The king rail is sometimes spotted at wetter sites. Insects, including grasshoppers, true bugs, leafhoppers, spittlebugs, planthoppers, and treehoppers. *Papaipema sciata*, a moth borer dependent on Culver's root (*Veronicastrum viginicum*), is also a notable lakeplain prairie forb (Reid and Holland 1997).

Lakeplain prairie fragments retain insect populations and many plant species. However, few of these prairies remain. The tiny sites that have been preserved are disconnected from the large lakeplain system and are still at risk from being impacted by stressors from outside the preserves, such as water level changes due to nearby development. In addition, lack of prescribed fire and exotic species are major challenges for preserve managers. Since many sites are located in urban areas, conducting prescribed burns must be done with extreme caution. Exotic species are numerous and require laborious efforts to control. Examples of significant lake plain prairies are presented in Appendix G.

Lakeplain System: Oak Savannas

Oak savannas are areas that lie between the prairies of the west and the deciduous forests of the east. In pre-European settlement times, they were a transition zone, maintained by frequent fires and probably by bison, elk, and deer. A variety of oaks dominate the canopy. The understory and ground layer vegetation is characterized by few shrubs and a rich variety of grasses and forbs. Plant species vary in relation to shade and sun tolerance. Savanna plant species found in preserves today include Indiana plantain, yellow pimpernel, downy wild rye, elm-leaved goldenrod, and New Jersey tea (Wisconsin Department of Natural Resources 1995).

Savannas formerly were habitat for the timber wolf, bison and elk, now extirpated from this landscape. Long-tailed weasels, red fox, woodchuck, rabbits, and white-tailed deer, however, are doing well today. Except for the ill-fated passenger pigeon, many savanna birds species such as the American robin, indigo bunting, blue jay, and American goldfinch are still doing well. This is due to the many woodlots still found on many home sites. A number of species have begun to decline in recent years, including the red-headed woodpecker and the warbling vireo. One butterfly, the Karner blue butterfly *(Lycaeides melissa samuelis),* is currently designated as a federally endangered species, but remains in healthy populations in the savannas of Northwest Indiana and central Wisconsin as well as in oak barrens (Wisconsin Department of Natural Resources 1995).

Of the many amphibians and reptiles associated with oak savannas, many seem to be surviving well. These include gray treefrog, five-lined skink, and smooth green snake; however, the western slender glass lizard and the eastern Massasauga rattlesnake are now threatened. The Blanding's turtle is also considered rare and threatened (Wisconsin Department of Natural Resources 1995).

Although they were probably relatively dynamic, not much is known about the original savannas. Since they were attractive to early settlers, they were first settled and cleared for agriculture or used for cattle grazing. Fires were controlled, and invasive exotic species such as honeysuckle and buckthorn moved in to replace the diverse ground cover. It is estimated that of the original 5.5 million acres of oak savanna in Wisconsin at the time of European settlement, less that 0.01 percent remains, most in degraded condition. Threats to the oak savanna ecosystem continue due to increasing development, invasion by exotics, a resistance or lack of understanding about the role of prescribed burning in maintaining the ecosystem, and the acceleration of forest succession and lack of recruitment (Wisconsin Department of Natural Resources 1995).

Several outstanding examples of remaining oak savannas in the Lake Michigan basin are described in Appendix G.

Lakeplain System: Sand Barrens

Sand barrens are areas of deep sands with scattered, sometimes scrubby, oak and pine trees and a ground layer of sedges and forbs. "Sand savanna" is sometimes used interchangeably with "barrens." Barrens, however, are differentiated by their poor, sandy soils and frequent, intense fires. They are dynamic -- sometimes characterized by open-canopies with prairie-like vegetation, and sometimes characterized by denser vegetation more like woodlands (Wisconsin Department of Natural Resources 1995).

In the Lake Michigan basin, sand barrens are found on the southern lakeplain and on the eastern shore of Lake Michigan in the northern part of the lower peninsula of Michigan. Sand barrens are associated with white pines *(Pinus strobus)* and jack pines *(Pinus banksiana),* species that dominate the first back dunes. At the time of European settlement, white pines were heavily logged, and, as a result, jack pines flourished. Few white pines remain today (Wisconsin Department of Natural Resources 1995).

In addition to jack pines, pine barren communities consist of junipers *(Juniperus communis)*, shrubs such as sand cherry *(Prunus pumila)*, and forbs such as sand cress *(Arabis lyrata)*. The endangered Kirtland's warbler *(Dendroica kirtlandii)* is a jack pine barren species (Reid and Holland 1997).

Dune ridges and back dunes inland from pine barren communities are dominated by black and white oak barrens communities *(Quercus velutina and Q. alba)*. The oak communities have a lush understory of grasses, including tallgrass prairie species like big and little bluestem *(Andropogon gerardi and A. scoparius)*, sedges such as Pennsylvania sedge *(Carex pennsylvanica)*, and forbs such as lupine *(Lupinus perennis)*, hoary puccoon *(Lithospermum canescens)*, and yellow lady's slipper orchid *(Cypripedium calceolus)*. The endangered Karner blue butterfly *(Lycaeides melissa samuelis)* is an oak barrens resident. Oak barrens are also rich in bird species, including the red headed woodpecker *(Melanerpes erythrocephalus)* (Reid and Holland 1997).

Oak barrens communities are fire dependent. The suppression of fire since European settlement has had a damaging effect on oak communities. A buildup of woody debris prevents oak regeneration and may be a hazard to nearby properties as well. In addition, increased development is threatening barrens communities (Wisconsin Department of Natural Resources 1995).

Two examples of high quality oak barrens communities are Shakey Lakes and Dunbar Barrens are discussed in Appendix G.

Lakeplain System: Atlantic Coastal Plain Disjunct Communities

Atlantic coastal plain disjunct communities are whole communities of plants whose normal distribution lies in a band along the Atlantic coast of the eastern United States. In the Lake Michigan basin, these communities are concentrated around the southern end of Lake Michigan and extend northward into Michigan. These communities occur only on sandy or peaty shores with fluctuating water levels. They appear to be relic fragments of previously more extensive sandy shores associated with past higher lake levels. Coastal plain community species are thought to have migrated into the Great Lakes basin some 11,000 years ago, when a drainage channel down the Hudson River connected with the Atlantic coastal plain. These communities are vulnerable to shoreline development and stabilized water levels. Atlantic coastal plain disjunct communities are protected in the Indiana Dunes parks and in preserves in southwestern Michigan (Reid and Holland 1997).

Lakeplain System: Assessment

Because of their location primarily at the southern end of Lake Michigan and also because of their desirability as both building sites and agriculturally rich soils, the lakeplain system of the Lake Michigan basin has been largely transformed since European settlement. Many of the original plants and animals of these ecosystems survive in small protected areas, although threats are still degrading these protected areas. The ecosystems of the lakeplain system are considered rare because few remain. Of the original thousands of acres of lakeplain prairies and oak savannas, less than 1 percent exists today. The consequences are that the original services provided by the lakeplain system have been severely disrupted or are non-existent. For example, the wetland-like capacity of lakeplain system to hold water is greatly diminished due to a decrease in the size of lakeplain area, and, therefore are of little help during flooding.

Subgoals 4 and 8 have not been met. The communities are not viable or sufficient to sustain a diversity of communities. Exotic species are a major concern throughout the lakeplain. However, the actions of groups such as Chicago Wilderness and other partnership groups may help to establish a sustainable system. Therefore, subgoals 9, 10, and 11 are well on there way to being accomplished.

4.2.2.7 Inland Terrestrial System

The inland terrestrial system or upland areas of the Lake Michigan basin include numerous forest types, barrens, and prairies. The oak and pine barrens of northern Wisconsin and Michigan are globally significant ecological communities due to their rarity. The Kirtland's warbler (*Denroica kirtlandii*) is an endemic species found only in the barrens of Michigan. The inland terrestrial system is the result of a glaciated landscape and of the climatic effects, such as temperature and humidity, of the Great Lakes themselves. It is the collector of precipitation that feeds the other systems. Large forested areas, for example, influence the rate and quality of that precipitation. The system filters the water going to groundwater and to the lakes and rivers. A healthy inland system provides for erosion control as well as habitat and migration corridors for many species (The Nature Conservancy 1994).

Inland Terrestrial System: Description

Although forests, barrens and prairies are all a part of the inland terrestrial system of Lake Michigan, only forests and the Niagara Cuesta will be discussed in this section because a description of barrens and prairies appears elsewhere in this document as part of other systems. The Niagara Cuesta is included because it is a rare landform in the Great Lakes basin.

Inland Terrestrial System: Forests

In general, the inland terrestrial system of the Lake Michigan basin is forest interspersed with numerous lakes and streams. The southern forests are generally dominated by oak species and the northern forests are dominated by conifers.

Southern Forests

In the southern part of the basin, the forests are characterized by red, white, black, bur, northern pin and swamp white oaks trees, and by shagbark hickory, hackberry, boxelder, and black walnut. Conifers are generally absent except for remnant jack and white pines in sandy areas of preserves close to the lake. Although dominated by oak communities, these southern forests also have an eastern hardwood component. Sugar maple, basswood, American beech, ironwood, American elm, and white ash are found, particularly in southwest Michigan (Wisconsin Department of Natural Resources 1995).

In addition to the general absence of conifers in the southern forests, the groundlayer of southern forests is known from surveyors' notes to have differed from northern forests in that it was in general more open due to lack of small trees and shrubs. This was a result of frequent fires that were a part of the landscape for thousands of years prior to human settlement (Wisconsin Department of Natural Resources 1995).

All of the large mammals, including buffalo, bison, elk, cougar, bobcat, and black bear, have been extirpated from Lake Michigan southern forests. Generalist species and those that adapt well to human inhabitants remain, sometimes in large numbers. Racoons, skunks, red fox, and coyote have been particularly adaptive to changed landscapes. White-tailed deer are present in populations considered unsustainable by many wildlife biologists. Deer have increased greatly and are browsing on native vegetation causing great damage. Browsing is hampering the reproduction of trees and certain rare plants such as orchids (Wisconsin Department of Natural Resources 1995).

Fragmentation or elimination of southern forests has resulted in a change in the composition of bird species. The understory or groundlayer has changed from a rich assemblage of forbs and grasses to an over-grazed or mowed simplified structure and therefore does not support a variety of bird species. Songbird species, therefore, have decreased and are undergoing further declines. Even cavity nesting and insect-foraging birds have declined due to logging and wood gathering (Wisconsin Department of Natural Resources 1995).

Forests in the southern part of the basin are extremely fragmented. In some southeastern Wisconsin counties, for example, there are probably no true remaining forests. In Michigan, the percentage of forests remaining compared to pre-European settlement is not known. Current predictions are that these forests, now woodlot size for the most part, will continue to be lost due to harvest and fragmentation; forest composition will continue to shift from commercially valuable oak species to less desirable species; and the long-term economic value of the southern forests will diminish (Wisconsin Department of Natural Resources 1995).

Northern Forests

North of the transition zone that separates the predominantly deciduous southern forests from the northern forest, about 30 tree species are found interspersed among several community types. In richer soils are the hardwoods, sugar maple, basswood, hemlock, yellow birch, white ash and American beech. Before settlement, white pine was an important component. In poor, sandy soils, jack, red, and white pine, as well as aspen, white birch, red maple, and red oak dominate. Wetland forests are common and are of two types. Conifer swamps are dominated by black spruce, tamaracks, and white cedars. Hardwood swamps are dominated by black ash, red maple, and elm (Wisconsin Department of Natural Resources 1995).

With the exception of the sustainable yield forests of the Menominee Indian Reservation, the mixed-deciduous forests of the northern part of the basin have lost their coniferous component. White pine is largely absent and not regenerating in these forest types. In addition, the composition of hardwoods has changed. Sugar maple dominates, yellow birch is less common, and basswood and white ash are now more dominant. The aspen-birch forest type is the largest forest cover type in the state of Wisconsin at the present time (Wisconsin Department of Natural Resources 1995).

It is thought that few mammal species have been lost due to change in forest composition, although the relative abundance of a variety of species has decreased. At one time, the elk, woodland caribou, Canada lynx, fisher, pine marten, eastern timber wolf, and eastern cougar have been extirpated. The fisher, pine marten, and eastern timber wolf have been reintroduced. Eastern cougars and moose have been found in low numbers. A list of 389 vertebrate species of northern forests was compiled by Benyus and others (1992). Of those species, 152 were restricted by habitat type, 53 percent were uncommon, and 71 percent were birds. Lack of large blocks of uninhabited lands limits large animal populations (Wisconsin Department of Natural Resources 1995).

Interior bird species have been impacted by forest fragmentation and the changes in forest composition. Included are a variety of warblers, the eastern wood-pewee, and Swainson's thrush. Species that adapt easily to edge and young forests, such as the ruffed grouse and the rufous-sided towhee, however, have increased (Wisconsin Department of Natural Resources 1995).

The size of the northern forests will probably remain approximately the same for the near future. If forest succession progresses, the aspen-birch forest type will decrease and will be replaced by white pine, red maple, and red oak. Clearcuts and plantations will continue to fragment mature hardwood forests (Wisconsin Department of Natural Resources 1995).

Several examples of forests and their composition around the Lake Michigan basin are presented in Appendix G. They illustrate the rich variety of forest types and species present. Many more forests exist than are discussed in Appendix G, particularly in private holdings either by large corporations or by individuals.

Inland Terrestrial System: Niagara Cuesta

The Door County Peninsula and the Garden Peninsula form the western end of the Niagara Cuesta, a rocky outcrop of dolomite and limestone that arcs to Niagara Falls on the western edge of New York. The escarpment is forested with maple, beech, red oak, white pine and hemlock. The trees cool the thin-layered soils of the escarpment. Moisture seeps from the rock and harbors populations of rare land snails including *Succinea bakeri, Catinella gelida* and *Vertigo hurichti*. Until recently, the escarpment was protected from development found elsewhere in Door County because of its relative inaccessibility and the difficulty of installing wells and sewage treatment. However, an increase in tourism is putting pressure on these areas. In both Door County and the Garden Peninsula, development is increasing on the escarpment even as new species, such as the rare snails, are being discovered (Grimm No Date).

Inland Terrestrial System: Peninsula Park Beech Forest State Natural Area, Wisconsin

Peninsula Park White Cedar Forest includes cliffs of Niagara dolomite, open marshes, calcareous meadows, cedar-spruce swamps, and an upland forest of white cedar, white birch, and sugar maple. A variety of flora is seen in all the communities and includes blue joint grass and rushes, birds-eye primrose, gaywings, fringed gentian, low juniper, yellow lady's-slippers and Indian paint brush. Birds include the winter wren, red-breasted nuthatch, black-throated green warbler, blackburnian warbler, ovenbird, and veery. Peninsula Park's beech forest features sugar maple, American beech, hemlock, yellow birch, white birch, and ironwood. Relic red oak and white pine are found in the area. The bluff is terraced and forested with white cedar and hardwoods. At the base of the bluff are ferns including cliffbrake, walking, and marginal wood ferns (Wisconsin Department of Natural Resources 2000).

Inland Terrestrial System: Assessment

Currently, there is no unified forest classification system for Lake Michigan basin forests. Nor is there a regional landscape overview or forest plan in place to protect forest diversity and therefore, the economic potential of the region. Little consideration is given to forest processes and their functions in relation to the inland terrestrial system, and as a consequence, the relationships to overall basin health. Exotic species have had an impact in the southern forests and are beginning to have an impact in the north. Nevertheless, there is a potential, particularly in the northern forests, to develop ecologically sound management techniques to encourage natural processes and therefore, a richer forest ecosystem and biodiversity.

Subgoals 4 and 8 have not been met. However, strides are being made in subgoal 9 with the model of forest management offered by the Menominee Tribe. No collaborative management system is in place for forest management basinwide, and there are many data gaps yet to be filled. Thus, subgoals 10 and 11 remain unmet.

4.2.3 Wildlife

The preceding sections described and assessed the status of individual habitats in the basin. The following section provides an overview of wildlife status and health throughout the ecosystem.

The Lake Michigan basin is home for many species of mammals, birds, reptiles and amphibians. It is also a resting and feeding place for several species of migratory birds. This section chronicles a few key trends in the populations of this assemblage of wildlife. Land use changes from industrial development, residential development, shoreline modifications, and navigation have dramatically and permanently altered Lake Michigan basin habitat available for wildlife.

There is a growing body of literature supporting the use of wildlife populations as indicators of ecosystem health; it suggests that many species are sentinels for toxic chemical effects, although conclusive linkages between all such effects and chemicals remain elusive.

Lake Michigan provides migratory and nesting habitat for waterfowl. Approximately 26 percent of prime waterfowl habitat on the shores of the Great Lakes is on Lake Michigan. This habitat is so good that it supports more than its share of waterfowl nesting, accounting for approximately 33 percent of breeding pairs of dabbling ducks in the Great Lakes. These sites are concentrated in Green Bay, Big Bay De Noc, and the coastal marshes in Michigan along the eastern shore of the lake.

The only advisories for human consumption of avian wildlife in the Lake Michigan basin are for mallards in selected reaches of Lower Fox, Sheboygan, and Milwaukee Rivers in Wisconsin and for lesser scaup, black ducks, mallards and ruddy ducks in the Milwaukee River Harbor.

Top predators, such as the bald eagle and osprey are gradually making a comeback in the Lake Michigan watershed after years of decline due to reproductive failure caused by toxic chemicals. As levels of contaminants dropped in the food web, contaminant concentrations in top predators, along with the associated health effects, also decreased. However, as noted below, there are still continuing problems with wildlife in the Lake Michigan basin.

Mammals in the basin live primarily on land. A number of species, such as mink, beaver, and otter, rely on water for food, supplies or shelter. Effects of toxic chemicals on mink and otter are well documented, but current levels of contaminants in Lake Michigan wildlife are not well-known.

Not all wildlife in the Lake Michigan basin are beneficial, either because a species is non-native or because a species is locally too abundant. Gulls and geese are sources of biological pathogens that can cause problems in local areas if the birds are overly abundant. In addition, cormorants may be a nuisance to Lake Michigan fisheries. Aquatic nuisance species are documented elsewhere in this LaMP. Non-native terrestrial wildlife have not developed into serious nuisances in the Lake Michigan basin to date.

Key stressors for wildlife include habitat disruption, exotic species, and toxic contamination. Habitat disruption and exotic species are examined in Chapter 5 and are discussed briefly below. This section concludes with a discussion of the impact of toxic contamination on Lake Michigan wildlife.

Habitat Disruption

Habitat disruption is typified by physical alteration such as building, dredging and filling, roads, and deforestation. These effects are documented in the preceding habitat discussions of this LaMP, especially related to wetlands. Habitat changes have a major effect on wildlife in the Lake Michigan basin and have great potential future effect on healthy populations of wildlife due the permanent nature of the changes. The single most important factor currently impairing or threatening populations and productivity of most bird species within the Great Lakes basin is the lack of suitable habitat. This condition results from the loss of wetlands and forests, effects of dam and water course modifications, human disturbance of breeding locations, and reduction of natural nesting sites due to human encroachment (Limno-Tech 1993).

Aquatic Nuisance Species

Effects of aquatic nuisance species are documented in Chapter 5. These nuisance species have had the greatest impact on aquatic plants and fish. Tremendous changes have occurred in the Lake Michigan basin due to accidental and intentional introductions of non-native species. Some habitat and food supplies have been altered by aquatic plants in wetlands and shoreline areas. An example is the proliferation of purple loosestrife and the poor quality food supply it provides for native species of wildlife.

Toxic Contamination

This stressor's effect on wildlife populations is well documented for top predators in the Lake Michigan basin. Sources of toxic contaminant stressors are documented in Chapter 5. Top predators in the open lake waters include osprey, bald eagle, terns, cormorants, and humans.

Mammals

Mink are considered to be one of the most biologically sensitive mammals to PCB, PBB, HCB and TCDD contamination (Aulerich and others 1977), and as early as 1965 it was suggested that a diet containing fish from Lake Michigan could be causing reproductive problems in mink populations. Mink harvest numbers began to decline in the mid-1950s, reaching a low point in the 1970s and slightly recovering in the 1980s. This trend is similar to population changes witnessed for some fish-eating and predatory birds (Environment Canada 1991).

More recent reports from trappers surveyed in 1991 and 1994 found that wild mink populations throughout marshes adjacent to Green Bay were depressed (Meyer and Hurley 1991). The mink trappers' success ratio along an area within one mile of the Fox River and Green Bay shoreline was lower than any other area surveyed throughout Wisconsin. (A success ratio is developed by considering the number of trappers, number of mink trapped, and a success index equaling the amount of effort, number of traps, number of sets, etc.) While no studies have been conducted on the possible impact of PCBs on mink and otter in the Green Bay area, circumstantial evidence suggests that these mammals may be affected by contaminants in the Fox River/Green Bay ecosystem.

Mink populations have declined along the Great Lakes shoreline, industrialized rivers, and undammed rivers to which Great Lakes fish have access (Wren 1991). Likewise, the habitat in the Sheboygan AOC is suitable for mink, but population levels are thought to be below normal for this type of habitat (WDNR 1993). Fish from Green Bay and the Fox River shoreline have elevated PCB concentrations second only to those below Wisconsin's Sheboygan River Superfund site (Meyer and Hurley 1991). Rodents and shrews collected from the industrialized portion of Wisconsin's Sheboygan River had levels of PCBs and metals that exceeded background indicating that contaminants in this ecosystem are also bio-available to terrestrial species. Some rodents had whole body PCB concentrations exceeding dietary exposure known to cause reproductive impairment in mink (Heaton and others 1991). Given the known contamination of potential prey, it is highly probable that litter sizes and kit survival are lower along both the Green Bay/Fox River and Sheboygan River shorelines.

Over-harvesting of the river otter in the early 19th century resulted in the near destruction of most otter populations (WDNR 1993). Their slow recovery was probably due to a combination of factors including low reproductive potential (Burt 1972), habitat loss due to development and reproductive suppression from environmental contaminants (Environment Canada 1991). A wildlife contaminant monitoring study done by MDNR analyzed otter carcasses for PCB's, lead, cadmium, arsenic, and mercury. Twelve out of thirteen animals found in the Lake Michigan basin had detectable levels of mercury in their system (Schmitt and others 1993). The highest mercury concentration of these samples was 6.26 parts per million (ppm), found in an otter carcass in Schoolcraft County, Michigan. None of the carcass samples analyzed had detectable levels of either arsenic or lead at a 1.00 ppm level of detection (Schmitt and others 1993).

The potential impact of environmental contaminants on otter populations around the Great Lakes is speculative and based on harvest data; no laboratory studies comparable to those in mink have been performed with otter. Harvest records show that trappers in Michigan take fewer otter near the Great Lakes shoreline than they do from uncontaminated inland waters. PCBs were detected in otter collected in Michigan in 1982,1986, and 1987 with a mean lipid concentration of 3.18 ppm and range from 0.4 to 38.5 ppm. Levels were generally higher in females and juveniles (Stuht 1991). Although field toxicity data have not been collected, these observations indicate that reduced otter populations and highly contaminated prey are correlated.

Birds

Numerous studies have been conducted into chemical related reproductive problems and deformities in avian species of the Great Lakes. Published reports of contaminant-induced adverse reproductive outcomes exist for six species of colonial fish-eating birds; namely, common terns; Caspian terns; black-crowned night-herons; herring gulls; Forster's terns; and double-crested cormorant. Observed problems include congenital malformations in chicks including bill malformations, clubbed feet, abnormal eyes, and reproductive problems (Fox and others 1991). Other abnormalities have been documented in the Great Lakes areas as well. Porphyrias are a group of disorders in which the liver metabolic processes are disrupted, causing an accumulation of nitrogen containing organic compounds, or porphyrins. These excessive levels of porphyrins can cause adverse effects, including sensitivity to sunlight and skin lesions. Porphyrins can also be used to indicate liver toxicity in wildlife. Causative agents include some heavy metals, hexachlorobenzene, and some dioxins. Various polyhalogenated aromatic hydrocarbons

(PAHs) have experimentally been shown to induce the accumulation of highly carboxylic porphyrins (HCP). High levels of HCP have been found in birds from lower Green Bay, suggesting heavy contamination by PAHs (Fox and others 1988).

Cormorants

Since their introduction to the area in the early 1900s the double crested cormorant experienced population increases up to their peak numbers in the late 1940s and early 1950s (Fox and others 1991). Since that time there has been a population collapse of the double-crested cormorant. Sometime in the early 1960s this species ceased to breed in Lake Michigan and was declining elsewhere in the Great Lakes basin (Gilberston and others 1991; Fox and others 1991). There was almost total reproductive failure of double-crested cormorant in Lake Michigan caused by the breakage and disappearance of eggs (Weseloh and others 1983). Fox and others (1991) found the prevalence of malformed chicks in Green Bay was significantly greater than in all other regions in the Great Lakes, except Lake Ontario. It is believed that the problems with Lake Michigan colonies were due to environmental contamination, since numerous studies have shown the food chain in Green Bay to be tainted with contaminants (Environment Canada 1991). Studies of double-crested cormorants in the upper portion of Green Bay and Lake Michigan have established that there is statistically significant reduced hatchability and increased incidence of structural deformities in this area when compared to a relatively uncontaminated reference area in Canada (Ankley and others, 1993). The rate of deformities had remained relatively constant to the present.

Cormorants in Green Bay and elsewhere in the Great Lakes are now becoming increasingly abundant and more widely distributed and are successfully raising many of their young to fledgling. Double-crested cormorants' eggshell thickness has increased concomitantly with declining DDE levels in the egg contents, since the late 1970s (Fox and others 1991).

Bald Eagles

The bald eagle, once flourishing in Canada, the U.S., and Mexico, experienced population declines beginning in the late 1940s and early 1950s (Environment Canada 1991). The declines were associated with reproductive failure, characterized by severe eggshell thinning and poor hatchability and chick survival that was unrelated to physical habitat alteration or a microbiological pathogen (Gilberston and others 1991). Eagle reproductivity is significantly lower in those regions where nesting eagles feed on Great Lakes species. Reproductive impairments along the Lake Michigan shoreline are correlated to DDE and PCBs. DDE has been shown to cause egg shell thinning, while PCBs have been inversely correlated to reproductive productivity and success rates (Bowerman 1993). Eagle reproductive performance of the Great Lakes is lowest on Lake Michigan, with nesting pairs approaching complete failure within five years of nest establishment (Environment Canada 1991). Since the North American ban on DDT, eagle populations and their egg shell thickness have increased. However, the recovery has not been uniform and in several regions, including the Great Lakes shores, eagle populations are not reproducing at a level considered to be healthy (Bowerman 1993). Recent research confirms this trend (Beck, personal communication with Bowerman, 2000).

The first "post-DDT era" Green Bay/Lake Michigan nest was initiated on the Oconto River near the Green Bay shoreline in 1987. Six nest attempts were made at this site from 1986 to 1991 and only one young hatched. No nest attempts have been made following the 1991 nest failure. However, adult eagles are occasionally observed on this territory. Three additional territories were established along the Green Bay shoreline in Oconto, Marinette, and Brown counties from 1988 to 1994. In 1994, the first nest was established on the West side of Door County on Toft's Point. Despite 20 nest attempts for the eagles nesting on the Green Bay/Lake Michigan shoreline, only 7 young have been produced from 1987 to 1994, for a productivity rate of 0.35 young/occupied territory. A production rate of 1.0 young/occupied territory is considered indicative of a healthy, expanding bald eagle population while <0.70 young/occupied territory is associated with a declining population (Wiemeyer and others 1993).

Availability of physical habitat does not seem to be limiting expansion of the bald eagle population along the upper Great Lakes shorelines. While bald eagles are restricted from some areas due to human disturbance or physical structure of the habitat, there are still areas, deemed to be suitable nesting habitat, which are currently unoccupied by bald eagles. It is important to maintain a healthy, uncontaminated eagle population in the interior of the state to allow for re-population of the shoreline. To do this, it is necessary to protect both the essential shoreline and interior habitats (Bowerman 1993).

Terns

Terns have also been reported as having noticeable negative side effects attributable to contaminants. Increased contaminant burdens in fish eating avian species of Lake Michigan have long been implicated in reproductive and developmental anomalies (Environment Canada 1991). Bioaccumulation factors for coplanar PCB congeners from fish consumed by terns have revealed ratios of up to 176-fold, when comparing PCB concentrations in spottail shiners and Forster’s tern eggs in Green Bay (Hoffman and others 1993).

Suppression of natural reproductive productivity can have effects on population balances, as witnessed during the 1960’s and 1970’s for many avian species. Common tern numbers peaked in the early 1960s and have decreased since the late 1980’s (Environment Canada 1991). Both the Caspian tern and the Forster’s tern have been reported as having poor reproductive success in Lake Michigan (Kurita 1987). Impaired reproduction has been associated with contaminant exposure in several species. (Hoffman and others 1993). Hatching success of laboratory-incubated Forster’s tern eggs from Green Bay, Wisconsin, was only one half that of eggs from an inland control colony (Hoffman and others 1987). In 1985, hatching success of laboratory-incubated common tern eggs from Green Bay and Saginaw Bay colonies was lower ($p<0.05$) than that of eggs from the Cut River (Lake Michigan) colony (Hoffman and others 1993).

Tern populations have been increasing in the Great Lakes basin as contaminant levels have declined and nesting areas have been protected, but reproduction and survival are still being impacted. In 1988, 42 percent of the Forster’s tern nestlings in Green Bay died prior to fledging, and growth of surviving nestlings was much lower than normal (Harris and others 1992b). Nestlings were accumulating dioxins, furans, and PCBs from prey (Ankley and others 1993). Even higher exposures are predicted to occur in years following high river flows when contaminated sediments are moved into estuaries where colonies are nesting (Harris and others 1992a).

Other Wildlife

Very little information is available on reptile or amphibian populations and impacts of contaminant exposure in the Lake Michigan ecosystem or elsewhere in the Great Lakes basin. Amphibians may be particularly susceptible to waterborne pollutants because of their highly permeable skin and aquatic developmental stages (Wake and Morowitz, 1991). A study of leopard frog populations along Wisconsin’s northern Lake Michigan in the mid-1970’s found a large number of unoccupied, suitable habitats, high mortality rates at occupied sites, and acutely toxic concentrations of atrazine (Hine and others 1981). Preliminary results from a study of green frogs from wetlands along Green Bay and the Fox

River indicate that PCB and metal accumulation is occurring and that survival, development, and growth of tadpoles may be impaired by these exposures (Jung and Karasov 1995).

Snapping turtles have been used throughout the Great Lakes basin to monitor PCB accumulation because of their longevity and high fat content. A snapping turtle collected in Wisconsin's Menominee River in 1984 had 130 ppm PCBs in its abdominal fat (WDNR, 1993). A turtle collected in 1988 from Cedar Creek in the Milwaukee River basin had a PCB concentration in abdominal fat of 630 ppm, which was comparable to samples from Lake Ontario (Olafsson and others1983). Eggs from PCB-contaminated females had impaired development and a high rate of abnormalities (Bishop and others 1991). Thus, it is highly probable that snapping turtle reproduction is reduced at PCB-contaminated sites within the Lake Michigan basin.

Wildlife Assessment

This wildlife section of the LaMP has focused on two impaired beneficial uses:

- Degradation of wildlife populations
- Bird or animal deformities or reproductive problems

Deformities are documented for birds, but less so for mammals, reptiles and amphibians. Trace amounts of toxic chemicals are enough to affect reproduction and growth. The LaMP Subgoals 4, 7, and 8 are not supported for wildlife in the Lake Michigan basin, although progress is being made under Subgoal 10 to improve management activities.

4.2.4 Human Systems

While the preceding sections focused primarily on the ecological health of the Lake Michigan basin, humans are also a critical part of the ecosystem. This section addresses the role of humans in the ecosystem and trends in human populations, human interaction with the lake system, human health, and other economic activities that affect the lake ecosystem. Additional information on human health is presented in Appendix C.

Census data for 1990 indicate a basin population of 10,057,026, most of which is located in the densely populated southern portion of the basin, within the original boundary of the Lake Michigan basin. After the reversal of the Chicago River at the beginning of the twentieth century, which caused the Chicago River drainage to flow into the Illinois River system rather than Lake Michigan, the Lake Michigan watershed was reduced by 673 square miles (1.743 km^2). Because that area contains much of the current Chicago metropolitan region, the Chicago River diversion resulted in a reduction in the Lake Michigan basin population to 7,142,776.

Within the original basin boundary, Illinois contains 3,494,115 people, or 34.7 percent, of the basin's population--more than any other state. (The post-diversion figures, however, leave Illinois with the smallest portion of the Lake Michigan basin's land area (241 square km [93 square miles] or .03 percent) and contains 579,865 people, or 8.1 percent of the basin's population.) Though the water used within the diversion area is not discharged to the Lake Michigan basin, the water supply for that population comes directly from Lake Michigan.

Indiana has 1,564 square km (604 square miles), or 2.5 percent of the basin's land area and contains 10.8 percent (339,264) of the basin's population. Although only slightly more than 2.5 percent of the original Lake Michigan basin is located within Indiana and Illinois along a relatively narrow stretch of land in the southern basin, nearly one out of every two people (45.5 percent of the entire basin population) lives within this area.

Wisconsin has 2,467,463 people in its share of the basin, or 24.5 percent of the basin population. Approximately 70 percent of Wisconsin's coastal population resides in the four southwestern basin counties of Ozaukee, Milwaukee, Racine, and Kenosha in the southeastern part of the state. Over half of the state's coastal population resides in Milwaukee County alone. The population of the city of Milwaukee and neighboring Racine declined significantly from 1970 to 1980 (-11.3 percent and -9.9 percent respectively), although population decline slowed considerably between 1980 and 1990 (-1.3 percent and -1.7 percent, respectively). In contrast, the city of Green Bay had a stable population during the 1970s and experienced a significant 9.7 percent population increase from 1980 to 1990--a trend that continues into the 1990s. Lake Michigan coastal populations in Wisconsin counties outside Milwaukee increased by 4.2 percent between 1980 and 1990 and 5.3 percent between 1990 and 1995. However, trends indicate continued high rates of second-home development in the northeast portion of the basin. Seasonal populations in coastal counties peak during summer months, when there is almost one visitor for every two permanent residents.

Michigan has 3,007,954 people in its share of the basin, or 30 percent of the Lake Michigan basin population. Census population figures, based on the number of permanent residents in an area, do not reflect the seasonal aspects of a population. Seasonal populations (tourists and recreational visitors) can play an important role in characterizing certain areas in the Lake Michigan basin. A study of the 10 county area of the northeastern portion of the basin (northwest Michigan), for example, concluded that one person in six (about 16 percent) staying in the region in 1995 was not part of the permanent population. Forty percent of those were people staying in second homes. Data for the eastern basin indicate that second-home development is projected to slow somewhat between 1990 and 2010. However, counties with smaller permanent populations that have winter ski resorts experience a much higher percentage of winter seasonal populations.

Humans interact with the Lake Michigan ecosystem in many ways. The following sections discuss the manner in which humans affect and are affected by the Lake Michigan ecosystem.

4.2.4.1 Swimming

Lake Michigan has some of the finest beaches on the Great Lakes, particularly along its eastern shore. Of a total 3,100 coastal acres, 1,200 are publicly owned and available for use while an additional 1,200 privately owned acres have significant potential for public use. It is important to note that most shoreline areas along Lake Michigan fully support all forms of water-based recreation, including swimming, boating, and wading. However, some areas do experience closures due to contamination. Beach closings resulting from high pathogen loads have a tremendous negative effect on the tourist industry. In 1996, visitors to the Indiana counties bordering Lake Michigan spent over $523 million (MDNR 1998a) and beach closings can cost an area up to $5 million per day in lost revenue (Ting and others 1996).

Swimming: Status

Table 4-2 summarizes at what level states report that Lake Michigan is supporting the designated uses related to swimming.

Table 4-2. Swimming, Secondary Contact and Aesthetics/Industry Designated Use Impairments on Lake Michigan (miles)

Use	Supported	Threatened	Partially Supported	Not Supported
Primary Contact (e.g., swimming)	1,546	53	40	20
*Secondary Contact (e.g., bathing and wading)	1,488	5	60	
*Aesthetics/Industry	1,363		190	

References: Michigan, Indiana, Illinois, and Wisconsin 305(b) reports, 1996.
*Miles not reported by Indiana and Illinois.

More specific information on the current condition of beaches and potential population affected is available through the EPA's BEACH Program. For the 1998 Survey, 1997 beach data was received for approximately 148 miles of beaches on Lake Michigan, including Green Bay and Grand Traverse Bay. This represents 9 percent of the lake's shoreline (These data has been compiled from individual local beach survey responses to the EPA 1998 Beach Health Survey. Individual beach survey responses collected in 1999 for the 1998 swimming season are now online and can be found on the internet at http://yosemite.epa.gov/water/beach1999).

Table 4-3 lists the bacteriological water quality standards for the Lake Michigan States in 1997 and summarizes the number of exceedances reported in the EPA BEACH Program's 1997 Survey (EPA 1998) and the Natural Resources Defense Council's Testing the Waters - 1999: A Guide to Water Quality at Vacation Beaches. When reviewing these data, it is important to note that, despite the potential risks to the public from gastrointestinal illness and other infections, water quality monitoring programs vary widely at the state and local levels. Different states and jurisdictions monitor for different indicator organisms, and also have different criteria and standards for postings or advisories. In addition, frequency of monitoring bacterial contamination at public beaches is highly variable around the lake. Because of this variability, it is difficult, and potentially misleading, to compare water quality between jurisdictions or summarize data for all beaches. Even within a beach, variability in the data from year to year may result from the process of monitoring and variations in reporting, and may not be solely attributable to actual increases or decreases in levels of microbial contaminants. It is important to keep these limitations in mind when looking at Table 4-3 (EPA 1998i; NRDC 1999).

As an example, in looking at the 1997 data in Table 4-3, Illinois waters exceeded their guidance level standard more frequently than Indiana. However, Illinois' guidance level is lower than that for Indiana. Also, most Illinois beaches are monitored daily, or at least several times a week. The increased frequency of exceedances could simply be due to more frequent monitoring, or other factors, and the data above would need to be supplemented with other information if an attempt at comparisons between jurisdictions were to be made (Data summarized from EPA BEACH Program, 1999c; NRDC, 1999).

Table 4-3. Bacteriological Water Quality Standards and Total Advisories/Closures 1993-1998 for Lake Michigan States -- for the State of Michigan this chart includes beach advisories and closures for Lakes Huron, St. Claire and Erie (summarized from EPA 1998i and NRDC 1999)

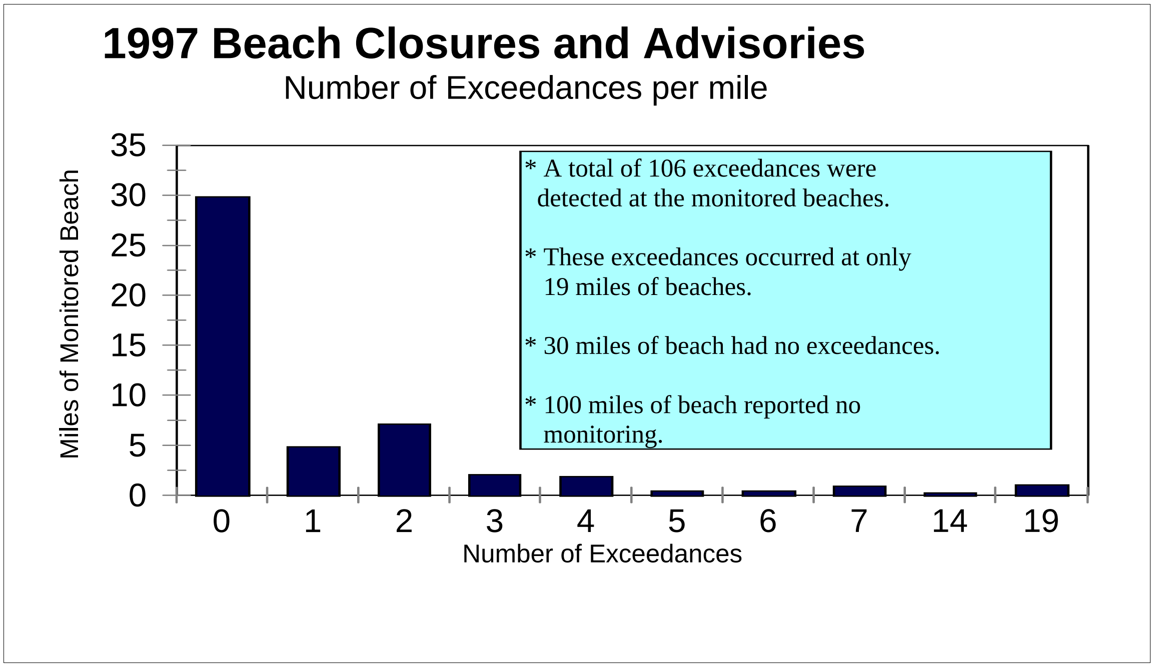
STATE BACTERIOLOGICAL WATER QUALITY STANDARDS								
State	General[1] Standard	Parameter	1993 adv./ clos.	1994 adv./ clos.	1995 adv./ clos.	1996 adv./ clos.	1997 adv./ clos.	1998 adv./ clos.
IL[2]	200 20 LM	fecal coliform	73	36	55	66	90	38
IN[3]	125 235 os	*E. coli*	30	36	14	34	30	154 +1p
MI[3,4]	130 300 os	*E. coli*	-	26 +3e	96 +1e	18 +1e	236	227 +1p
WI	200	fecal coliform	94	148	114 +1e	120	137	139 +2p

[1] All standards indicate the number of microorganisms per 100 ml of water not to be exceeded based on the geometric mean of not less than 5 samples taken over a 30-day period, unless otherwise noted.
[2] Seasonal standard
[3] Illinois monitors for both fecal coliform and *E. coli*
[4] May be exceeded if due to uncontrollable nonpoint sources. Primary standard can be temporarily suspended due to flood, accident, or emergencies that affect a sewer or wastewater treatment system.
p = permanent beach closure
e=extended closure 6-12 weeks
gm= geometric mean
os= one sample
LM= Lake Michigan Std.

The limitations in the ability to compare frequency of exceedances of microbiological guidelines has posed a challenge for the development of a lakewide indicator to evaluate trends in recreational water quality. Despite these limitations, frequency of beach postings to indicate elevated pathogen levels has traditionally been used as an indicator of recreational water quality. Microbial standard exceedances may be a better measure of actual health risk related to recreational water quality, and recent discussions are leaning toward developing an indicator that uses microbial monitoring data, supplemented by beach postings data. This combination will give a much more informative picture about microbial quality of recreational use waters (IJC, IITF Swimmability Workshop, October, 1999).

To put the number of closures in a geographic perspective, Figure 4-4 shows numbers of exceedances per mile of monitored beaches on the Lake Michigan shoreline, compiled from the EPA Beach Health Survey responses from the 1997 swimming season. In virtually every case, these measured exceedances resulted in the issuance of postings or advisories (this data has been compiled from individual 1997 beach survey responses to the EPA 1998 Beach Health Survey. Individual beach survey responses for the 1998 swimming season are now online in the EPA 1999 Beach Health Survey and can be found on the internet at http://yosemite.epa.gov/water/beach1999).

Figure 4-4. 1997 Beach Closures and Advisories



Adapted from EPA 1998 Beach Health Survey

Swimming: Human Health Issues

The Great Lakes are an important resource for recreation, including activities such as swimming and sailboarding which involve body contact with the water. Apart from the risks of accidental injuries, the major human health concern for recreational waters is microbial contamination by bacteria, viruses, and protozoa (Health Canada, 1998; WHO, 1998). Chemical pollutants may also pose health risks, but exposure to disease-causing microorganisms from sources such as untreated or poorly treated sewage is a greater risk (Health Canada, 1999).

Microbial Contaminants

Human exposure to micro-organisms occurs primarily through ingestion of water, and can also occur via the entry of water through the ears, eyes, nose, broken skin, and through contact with the skin. Gastro-intestinal disorders, respiratory illness and minor skin, eye, ear, nose and throat infections have been associated with microbial contamination of recreational waters (Health Canada, 1998, WHO, 1998). Consequently, one of the Specific Objectives of the Great Lakes Water Quality Agreement is that “recreational waters should be substantially free from bacteria, fungi, and viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections” (IJC 1987). Table 4-4 lists waterborne pathogens which could be present in contaminated water.

Table 4-4. Pathogens and Swimming-Associated Illnesses

Pathogenic Agent	Disease
Bacteria	
E. coli	Gastroenteritis
Salmonella typhi	Typhoid fever
Other salmonella species	Various enteric fevers (often called paratyphoid), gastroenteritis, septicemia (generalized infections in which organisms multiply in the bloodstream))
Shigella dysenteriae and other species	Bacterial dysentery
Vibrio cholera	Cholera
Viruses	
Rotavirus	Gastroenteritis
Norwalkvirus	Gastroenteritis
Poliovirus	Poliomyelitis
Coxsackievirus (some strains)	Various, including severe respiratory diseases, fevers, rashes, paralysis, aseptic meningitis, myocarditis
Echovirus	Various, similar to coxsackievirus (evidence is not definite except in experimental animals)
Adenovirus	Respiratory and gastrointestinal infections
Hepatitis	Infectious hepatitis (liver malfunction), also may affect kidneys and spleen
Protozoa	
Cryptosporidium	Gastroenteritis
Giardia lambia	Diarrhea (intestinal parasite)
Entamoeba histolytica	Amoebic dysentery, infections of other organisms
Isopora belli and *Isopora hominus*	Intestinal parasites, gastrointestinal infection
Balantidium coli	Dysentery, intestinal ulcers

Source: NRDC 1999.

Studies have shown that swimmers and people engaging in other recreational water sports have a higher incidence of symptomatic illnesses such as gastroenteritis, otitis, skin infection, and conjunctivitis, and acute febrile respiratory illness (AFRI) following activities in recreational waters (Dewailly 1986; WHO 1998). Although current studies are not sufficiently validated to allow calculation of risk levels (Health Canada 1992), there is some evidence that swimmers/bathers tend to be at a significantly elevated risk of contracting certain illnesses (most frequently upper respiratory or gastro-intestinal illness) compared with people who do not enter the water (Dufour 1984; Seyfried 1985a,b; EPA 1986; WHO 1998). In addition, children, the elderly, and people with weakened immune systems are those most likely to develop illnesses or infections after swimming in polluted water (Health Canada, 1998).

Despite these studies, there are challenges in establishing a clear relationship between recreational water exposure and disease outcomes. Less severe symptoms resulting from exposure to microorganisms are not usually reported, which makes statistics on cases related to recreational water exposure difficult to determine. In addition, the implicated body of water is not often tested for the responsible organism and when it is tested the organism is not usually recovered from the water. With the exception of gastro-intestinal illness, a direct relationship between bacteriological quality of the water and symptoms has not been shown -- a causal relationship exists between gastrointestinal symptoms and recreational water quality as measured by indicator-bacteria concentration (WHO 1998). Therefore, research efforts are focusing on conducting epidemiological studies to better establish the relationships between diseases and the presence of microorganisms in the water (Health Canada 1997; Health Canada 1998a; EPA 1999m).

Protecting Human Health

Annex 2 of the Great Lakes Water Quality Agreement lists "beach closings" as a beneficial use impairment related to recreational waters (IJC 1987). According to the International Joint Commission, a beach closing impairment occurs "when waters, which are commonly used for total body contact or partial body contact recreation, exceed standards, objectives or guidelines for such use" (IJC 1989).

Federal and State recreational water quality guidelines recommend bacterial levels below which the risk of human illness is considered to be minimal. For public beaches, the regional Health Departments generally monitor beach water quality (in Chicago, the Chicago Park District conducts beach water quality monitoring). When contaminant indicator levels in the bathing beach water reach levels that are considered to pose a risk to health, public beaches may be posted with a sign warning bathers of these potential health risks.

The primary tool used at present to evaluate beach water quality is the measurement of "indicator" organisms that estimate the level of fecal contamination of the water. The indicator organisms most commonly used are fecal coliforms, *Escherichia coli* (*E. coli*), and enterococci. These coliform bacteria are microorganisms that usually occur in the intestinal tract of animals, including humans. High levels of these organisms in recreational water are indicative of fecal contamination and the possible presence of intestinal-disease-causing organisms (Health Canada 1998; WHO 1998).

The EPA uses either *E. coli* or enteroccocci as indicators of recreational water quality. There is an increasing move by states toward their use, especially *E. coli*, since it is better correlated with gastrointestinal illness than fecal coliforms, and elevated fecal coliform counts do not always indicate a human health hazard (fecal coliforms include many species which are not exclusively found in human and animal wastes). See Table 4-3 for the indicators used by each of the Lake Michigan States. EPA will be developing policies to ensure that states and tribes adopt the currently recommended *Ambient Water Quality Criteria for Bacteria - 1986* and make the transition to monitoring for *E. coli* and enterococci indicators rather than total coliforms or fecal coliforms (EPA 1998j; Bartram and Rees 2000).

A number of initiatives have recently been developed to specifically address recreational water quality. EPA established the Beaches, Environmental Assessment, Closure, and Health (BEACH) Program in 1997 "to significantly reduce the risk of waterborne illness at the nation's beaches and recreational waters through improvements in recreational water protection programs, risk communication, and scientific advances" (EPA 1999n). Under the BEACH Program, the first National Health Protection Survey of Beaches, conducted in 1997, focused on the collection of beach-specific information from coastal and Great Lakes states. Data from the second annual survey, conducted in the spring of 1999, can now be accessed on the BEACH Program website at http://www.epa.gov/OST/beaches/ (EPA 1999j). EPA will also develop a national inventory of digitized beach maps which will be linked with locations of pollution sources through a Geographic Information System (EPA 1998j).

In addition, the U.S. federal Clean Water Action Plan, developed by EPA, Department of Interior, and other federal agencies, was announced in 1998, and describes a series of actions designed to strengthen core clean water programs carried out by a number of U.S. governmental agencies. As part of this plan, EPA has developed the *Action Plan for Beaches and Recreational Waters* ("BEACH Action Plan", EPA/600/R-98/079), a multi-year strategy for reducing the risks of waterborne illness to recreational water users (EPA 1999j). The BEACH Action Plan describes EPA's actions (including the Beach Program) to improve and assist in state, tribal, and local implementation of recreational water monitoring and public notification programs (EPA 1998j).

4.2.4.2 Fishing

Billions of fish inhabit the shallows and depths of Lake Michigan. About 40 species of fish are commonly found in Lake Michigan (see Table 4-5). Most species are native to the lake. A few have been added by design and others have made use of human alterations of the connecting waters and channels to gain access. Listed below are some fish species found in Lake Michigan.

Table 4-5. Fish Species Found in Lake Michigan

Common Name	Genus and Species	Common Name	Genus and Species
Sea lamprey	*Petromyzon marinus*	Northern pike	*Esox lucius*
Lake sturgeon	*Acipenser fulvescens*	Carp	*Cyprinus carpio*
Alewife	*Alosa pseudoharengus*	Emerald shiner	*Notropis atherinoides*
Lake whitefish	*Coregonus clupeaformis*	Spottail shiner	*Notropis hudsonius*
Bloater	*Coregonus hoyi*	Longnose sucker	*Catostomus catostomus*
Blackjaw cisco	*Coregonius nigripinnis*	White sucker	*Catostomus commersoni*
Longjaw sisco	*Coregonius alpenae*	Cannel catfish	*Ictalurus punctatus*
Shortjaw cisco	*Coregonus zenithicus*	Bullheads	*Ictalurus spp.*
Deepwater cisco	*Coregonus johannae*	Trout-perch	*Percopis omiscomaycus*
Kiyi	*Coregonus kiyi*	Burbot	*Lota lota*
Shortnose cisco	*Coregonus reighardi*	Ninespine stickleback	*Pingitius pingitius*
Lake herring	*Coregonus artedii*	Smallmouth bass	*Micropterus doldmieui*
Round whitefish	*Prosopium cylindraceum*	Yellow perch	*Perca flavescens*
Lake trout	*Salvelinus namaycush*	Walleye	*Stizostedion vitreum vitreum*
Brook trout	*Salvelinus frontinalis*	Freshwater drum	*Aplodinotus grunniens*
Rainbow trout	*Oncorhynchus mykiss*	Slimy sculpin	*Cottus corgatus*
Brown trout	*Salmo trutta*	Spoonhead sculpin	*Cottus ricei*
Coho salmon	*Oncorhynchus kisutch*	Fourhorn sculpin	*Myoxocephalus quadricornis*

Common Name	Genus and Species	Common Name	Genus and Species
Chinook salmon	*Oncorhynchus tshawytscha*	Rainbow smelt	*Osmerus mordax*
Gizzard shad	*Dorosoma cepedianum*	White perch	*Morone americana*

Source: Sommers, L. and others, Fish in Lake Michigan, Distribution of Selected Species, Michigan Sea Grant Program, 1981.

Over 43 percent of all Great Lakes fishing is done in Lake Michigan. Both commercial and sport fishing are significant contributors to the overall economies of the states in the Lake Michigan watershed.

Commercial fish production (non-tribal and tribal) in Lake Michigan consists of over 14.6 million pounds of fish with an estimated value of almost $11 million annually. Lake Michigan commercial fishing production resulted in the catch of the following species, with the percentage of the catch indicated:

Table 4-6. Commercial Fish Catch for Lake Michigan (Percentage by Weight) (1996)

Species	Percentages of Commercial Catch	Species	Percentages of Commercial Catch
Alewife	<0.4	Lake Whitefish	50.3
Gizzard shad	0.2	Whitefish round	0.7
Rainbow smelt	9.7	Chubs	25.1
Brown bullhead	<0.1	Chinook salmon	0.4
Channel catfish	<0.1	Lake trout	3.0
Burbot	0.3	Suckers	4.2
White perch	<0.4	Carp	<0.1
White bass	<0.1	Yellow perch	6.0
Freshwater drum	<0.1	Walleye	<0.1

Source: National Biological Service, Commercial Fish Production- pounds and value, Lake Michigan, U.S. Waters, 1996

Fish sold commercially is produced as food for humans (95 percent) and for animals (5 percent) with the remainder not sold commercially.

Harvests of sport-caught fish are difficult estimate due to incomplete data regarding all species. The harvest of Salmonines from Lake Michigan are estimated as shown in Table 4-7 below. Overall, the total value of sport fishing in all the Great Lakes is estimated at over $4 billion (FWS).

Table 4-7. Recreational Harvest of Salmonines from Lake Michigan, 1986 - 1996 (Michigan State University, Department of Fisheries and Wildlife, 1997)

	Species						
Year	Chinook	Coho	Lake	Rainbow	Brown	Brook	Total
1986	934,012	358,274	215,178	88,995	147,065	4,525	1,748,049
1987	711,295	284,304	239,399	117,926	117,851	1,287	1,472,062
1988	375,729	277,396	242,561	123,069	81,693	5,145	1,105,593
1989	361,204	393,992	257,361	140,768	84,172	2,196	1,239,693
1990	228,676	230,256	181,429	111,414	71,905	5,929	829,609
1991	282,862	150,771	241,542	166,153	93,933	1,660	936,921
1992	170,458	249,256	142,014	158,130	70,501	4,431	794,790
1993	143,539	256,919	163,245	169,735	118,664	1,967	854,069
1994	149,413	271,474	156,860	186,562	115,898	7,483	887,690
1995	242,777	180,230	189,679	166,281	89,939	1,914	870,820
1996	304,191	239,937	104,739	145,069	68,189	443	862,565

Note: Estimates of other species of sport-caught fish are not available.

Fish Consumption (includes commercial, recreational, and subsistence)

Fish species residing in waters contaminated with lipophilic pollutants (i.e., fat-soluble pollutants as PCBs) bioaccumulate these contaminants and become a further source of contamination for larger, predator fish (e.g., sport caught trout and salmon) (Humphrey 1988). This process results in a biomagnification or increase in the levels of contaminants in the predator fish which may subsequently be consumed by humans. Fish consumption has been shown to be a major pathway of human exposure to persistent toxic substances such as PCBs (Birmingham et al. 1989; Fitzgerald et al. 1996; Humphrey 1983; Newhook 1988), exceeding exposures from land, air, or water sources (Humphrey 1988). Humphrey (1988) reported that PCBs were the dominant contaminants detected in Lake Michigan trout (3,012 parts per billion or ppb) and chinook and coho salmon (2,285 ppb), surpassing other contaminants such as DDT (1,505 ppb, 1,208 ppb), hexachlorobenzene (5 ppb, 5 ppb), oxychlordane (25 ppb, none shown), trans-nonachlor (195 ppb, 162 ppb), and dieldrin (75 ppb, 53 ppb), respectively in trout and salmon. Fish specimens collected from the dinner plate of study participants were used to determine these median PCB concentrations. Recently, total PCB levels have decreased in most Lake Michigan fish species and appear to remain below the FDA action level of 2 mg/kg (parts per million or ppm) but the concentrations in chinook and coho salmon have risen slightly since the late 1980s (Stow and others 1995).

There is sufficient evidence that consumption of contaminated sport fish and wildlife can significantly increase human exposure to Great Lakes contaminants. A spectrum of major contaminants have been identified in cooked Great Lakes fish, and methods have been recommended for reducing the amount of contaminants by judiciously preparing and cooking the fish.

All four Lake Michigan states have fish consumption advisories. These advisories are necessary due to potential human health effects from contaminants found in fish flesh. Fish consumption advisories allow the public to make informed decisions and minimize their health risks while continuing to enjoy the benefits of eating fish, a healthy source of protein low in saturated fats (IDNR 1999). Fish consumption advisories are often used by states as an indicator of whether their waters meet the designated use of fishability. The fish consumption advisories are updated annually and can be found at the following web sites:

- Illinois: www.idph.state.il.us/public/press99/fish_advs_99.htm
- Indiana: www.state.in.us/isdh/dataandstats/fish/fish_99
- Michigan: www.mdch.state.mi.us/pha/fish
- Wisconsin: www.dnr.state.wi.us/org/water/fhp/fish/advisories

Wisconsin has restricted fish/wildlife consumption in the Lower Green Bay/Fox River, Menominee River, Sheboygan River (bluegill, crappie, rock bass, carp, smallmouth bass, walleye pike, trout, catfish, and coho and chinook salmon), and Milwaukee estuary. Fish and wildlife tainting/flavor problems exist in the Lower Green Bay/Fox River (Wisconsin 305b report 1996).

Illinois has designated 63 Lake Michigan coastal miles as not meeting designated use due to fish consumption advisories (PCB's and chlordane). The Waukegan area has restriction on fish consumption. Also, the Lake Michigan area has species included in a moderate to high level of contamination (lake trout, coho and chinook salmon, and brown trout (Illinois 305b Report 1996).

In Indiana, all 43 miles meet fishable designation. However, the Indiana Lake Michigan fish consumption advisory extends for 241 square miles which encompasses all of the southern most waters of the lake. The current fish consumption advisory for Lake Michigan and tributaries includes the following species: brook, brown, rainbow and lake trout; carp; catfish; chinook, pink and coho salmon; longnose and white sucker; walleye; and whitefish. Specific size categories are identified in the advisory. All fish tissue samples collected from the Grand Calumet River show a continued high level of PCB contamination. All fish in the Grand Calumet River and Indiana Harbor Ship Canal are given a Level 5 - Do not eat advisory level by the Indiana fish Consumption Advisory (Indiana 305b Report 1996; IDNR 1999).

Michigan has designated all Lake Michigan coastal miles as not meeting designated use due to fish consumption advisories (PCBs, Chlordane and Mercury). The fish consumption advisory for all areas north of Frankfort include brown trout, carp, catfish, lake trout, sturgeon, and walleye. For the areas south of Frankfort, all of these species are included with whitefish being added. The Michigan portion of Green Bay has fish consumption advisories for brook trout, brown trout, carp, catfish, lake trout, northern pike, rainbow trout, splake, sturgeon, walleye, and white bass. Little Bay de Noc has a fish consumption advisory for longnose suckers. Many Michigan tributaries to Lake Michigan also have similar fish consumption advisories (Michigan 305b Reports 1996).

The following Lake Michigan Areas of Concern have identified fish consumption as an impaired use in their respective Remedial Action Plans: Lower Green Bay/Fox River, Grand Calumet River/Indiana Harbor, Kalamazoo River, Manistique River, Menominee River, Milwaukee Estuary, Muskegon River, Sheboygan River, Waukegan Harbor, and White Lake (State 305b Reports 1996).

Table 4-8. Fish Consumption Designated Use Impairments on Lake Michigan (miles)

Use	Supported	Threatened	Partially Supported	Not Supported
Fish Consumption			538	1,121

References: Michigan, Indiana, Illinois, and Wisconsin 305(b) reports, 1996.

Fishing: Human Health Issues

Early investigations of Lake Michigan fish consumption have broadened our knowledge about transmission of contaminants from fish to humans, including maternal exposure of the fetus and infant. Investigating a cohort of Lake Michigan fisheaters, Humphrey (1988) discovered that sport anglers who regularly consumed Great Lakes salmon and trout (consumption rate of greater than or equal to 24 pounds/year [or greater than or equal to 11 kg/year]) had median serum PCB levels approximately 4 times higher (56 ppb) than those who consumed no Lake Michigan fish (15 ppb) (consumption rate of 0 to 6 pounds/year [or 0 to 2.7 kg/year]). Halogenated contaminants (e.g., PCBs) have also been detected in adipose tissue, breast milk, and cord blood, associated with consumption of contaminated fish (ATSDR 1998). Other studies have also supported these findings. For example, Schwartz and others (1983) demonstrated that consumption of Lake Michigan fish was positively associated with the PCB concentration in maternal serum and breast milk. Maternal serum PCB concentrations were also positively associated with the PCB levels in the umbilical cord serum of the infant (Jacobson and others 1983).

Although the levels of PCBs have declined in most species of Lake Michigan fish, lipophilic pollutants, such as PCBs, have a tendency to bioaccumulate in the human body. Hovinga et al (1992) reported a mean serum PCB concentration of 20.5 ppb in 1982 for persons consuming more than 24 pounds of Lake Michigan sport fish per year, and 19 ppb in 1989 demonstrating little decline within the seven year interval. For those ingesting less than 6 pounds of Lake Michigan sport fish per year, the mean serum PCB concentrations were 6.6 ppb in 1982, and 6.8 ppb in 1989. The mean serum PCB concentrations for those consuming <6 pounds of Lake Michigan fish per year are comparable to the mean serum PCB levels of 4 to 8 ppb found in the general population who do not have occupational PCB exposure (Kreiss 1985).

Research has shown that vulnerable populations and high consumption communities at risk of exposure to contaminants from fish consumption include Native Americans, minorities, sport anglers, elderly, pregnant women, and fetuses and infants of mothers consuming contaminated Great Lakes fish (Dellinger and others 1996; Fitzgerald and others 1996; Lonky and others 1996; Schantz and others 1996). These communities may consume more fish than the general population or may have physiologic attributes, such as physical or genetic susceptibilities that may cause them to be at great risk. Higher body burdens of mean serum PCBs and DDE were found in an elderly cohort of Lake Michigan fisheaters (i.e., ≥50 years of age) who were compared to nonfisheaters (Schantz and others 1996). Fisheaters had mean serum PCB levels of 16 ppb while the nonfisheaters had mean levels of 6 ppb. For DDE, fisheaters had mean serum levels of 16 ppb and the nonfisheaters had a mean level of 7 ppb.

In addition, women have been shown to consume Great Lakes fish during their reproductive years (Courval and others 1996; Lonky and others 1996; Waller and others 1996). There are also gender differences in fish consumption patterns. A Lake Michigan sport anglers study, with subjects between the ages of 18 and 34 years, also demonstrated gender differences with males tending to consume more fish than female subjects (Courval and others 1996). Research has subsequently shown that consumption of contaminated fish by these at-risk populations is associated with adverse human health effects.

Developmental, reproductive, neurobehavioral or neurodevelopmental, and immunologic effects have been reported in studies conducted within the Great Lakes basin and outside the basin. Developmental effects in the form of a decrease in gestational age and low birth weight have been observed in a Lake Michigan Cohort exposed prenatally to PCBs (Fein and others 1984).

Reproductive effects have also been reported. Courval and others (1997) examined couples and found a modest association in males between sport-caught fish consumption and the risk of conception failure after trying for at least 12 months. Studies of New York state anglers have not shown a risk of spontaneous fetal death due to consumption of fish contaminated with PCBs (Mendola and others 1995), nor an effect on time-to-pregnancy among women in this cohort (Buck and others 1997).

Neurobehavioral or neurodevelopmental effects have been documented from exposure to persistent toxic substances in newborns, infants, and children of mothers consuming Great Lakes sport fish. Early investigations of the Lake Michigan Maternal Infant Cohort revealed that newborn infants of mothers consuming >6.5 kg/year of Lake Michigan fish had neurobehavioral deficits of depressed reflexes and responsiveness, when compared to non-exposed controls (Jacobson and others 1984). The fisheating mothers consumed an average of 6.7 kg of Lake Michigan contaminated fish per year, equal to 0.6 kg or 2 to 3 salmon or lake trout meals/month. Prior to study admission, exposed mothers were required to have fish consumption that totaled more than 11.8 kg over a 6-year period. Subsequent studies of the Michigan Cohort have revealed neurodevelopmental deficits in short-term memory at 7 months (Jacobson and others 1985) and after 4 years of age (Jacobson and others 1990b), and also growth deficits at 4 years associated with prenatal exposure to PCBs (Jacobson and others 1990a). A more recent investigation of Jacobson's Michigan Cohort has revealed that children most highly exposed prenatally to PCBs showed IQ deficits in late childhood at 11 years of age (Jacobson and Jacobson 1996). Highly exposed children received prenatal PCB exposure equal to at least 1.25 ug/gram (ppm) in maternal milk, 4.7 ng/milliliter (ppb) in cord serum, or 9.7 ng/milliliter (ppb) in maternal serum.

Initial testing for neurotoxic effects were not observed by Schantz and coworkers (1999) in an elderly adult population (i.e., $\geq$50 years) of Lake Michigan fisheaters with exposure to PCB and DDE. This study is ongoing.

Immunologic effects have also been reported. Smith's study (1984) demonstrated that maternal serum PCB levels during pregnancy were positively associated with the type of infectious diseases that infants developed during the four months after birth. In addition, incidence of infections has been shown to be associated with the highest fish consumption rate of mothers (i.e., at least three times per month for three years) (Swain 1991; Tryphonas 1995).

Other health effects have been documented with PCB exposure. Elevated serum PCB levels were associated with self-reported diabetes and liver disease in cohorts of Red Cliff and Ojibwa Native Americans (Dellinger and others 1997; Tarvis and others 1997). Fischbein and coworkers (1979) found that workers exposed to a variety of PCB Aroclors reported joint pain.

Health effects studies conducted outside the Great Lakes basin have supported the reports from the Great Lakes basin. A summary of these health effects studies can be found in the recent paper published by Johnson and others (1998).

Fishing: Protecting Public Health

The purpose of fish consumption advisories is to protect public health by alerting the residents of potential health risks from consuming contaminated fish (EPA 1995). Advisories can also include information to educate the public about the healthy benefits of fish consumption and to minimize exposure to contaminants in fish by proper preparation and cooking (Tilden and others 1997). Within the Great Lakes, PCB contamination of Great Lakes fish is generally responsible for health advisories, while mercury contamination is responsible for advisories covering inland bodies of water, such as rivers and lakes (Kamrin and Fischer 1999).

The Great Lakes Sport Fish Advisory Task Force, consisting of environmental and health professionals from the eight Great Lakes states, developed a Health Protective Value (HPV) as a guideline for determining risk from consuming contaminated Great Lakes fish (Anderson and others 1993; Kamrin and Fischer 1999). The HPV is the highest acceptable daily intake of a contaminant (e.g., PCBs) in fish that would not result in a health risk, particularly reproductive and developmental effects, and applies to both sensitive and less sensitive groups (Kamrin and Fischer 1999). For PCBs, the HPV is 0.05 ug PCBs/kg/day. Species of fish are assigned a consumption category that would result in a PCB intake level below the HPV. This value is derived from animal and human study findings, and is similar to the EPA's reference dose for computing non-cancer risk. There are five consumption categories including *unlimited consumption*, *one meal a week*, *one meal a month*, *one meal every two months*, and *do not eat*. Five of the Great Lakes states have adopted this guideline and two use a version of the HPV. The five include Illinois, Minnesota, Ohio, Pennsylvania, and Wisconsin. Michigan uses the HPV and the U.S. FDA standard of 2 ppm for fish. Illinois uses the HPV for Lake Michigan, but also uses the U.S. FDA standard for inland waters. Indiana also employs the HPV and includes a safety factor for sensitive populations.

Tilden and others (1997) conducted a population-based survey of fish consumption within the eight Great Lakes states. The study results demonstrated that almost 50 percent of the Great Lakes fish consumers had an awareness of the health advisories (of the 50 percent, approximately 60 percent of the males and less than 40 percent of the females were aware of the advisories). These findings emphasize the importance of targeting health advisories to sensitive groups such as women of reproductive age. The sensitive groups include women of childbearing age and their fetuses and infants, the elderly, sports anglers, and minorities. More information about sensitive groups may be found under the "Weight of Evidence" discussion (Appendix C).

Studies have shown that having an awareness of health advisories can be successful in changing fishing and fish consumption habits (Fiore and others 1989; Velicer and Knuth 1994). The communication programs in the Great Lakes generally target caucasian, licensed anglers (Tilden and others 1997). Written information (i.e., regulation booklets and advisory brochures) is circulated by the government and the fishing industry to licensed anglers, and these sources of information appear to be effective in reducing consumption of contaminated fish. For example, Fitzgerald and coworkers (1999) found that 97 percent of the men in their study were aware of fish advisories and two-thirds of these men had reduced their fish consumption. This reduction in fish consumption was due to public health intervention strategies such as risk communication along with the use of fish advisories. More recent efforts have been directed toward groups with less awareness of health advisories such as women of childbearing age, minorities, and other frequent fish consumers (Knuth 1995; Tilden and others 1997). One of these projects is the ATSDR-funded Consortium of Great Lakes States headed by Dr. Henry Anderson. Anderson and his group have developed outreach materials for women of childbearing age and minority groups which are being used in seven of the eight Great Lakes states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Wisconsin). These outreach materials such as posters and recipe cards are being adapted by each of the states for their specific needs, and are being distributed at women and childrens' clinics, health fairs, state fairs, and fishing shows to increase health advisory awareness.

4.2.4.3 Hunting

There are many areas of the Lake Michigan watershed available for hunting. Many areas offer excellent hunting opportunities for waterfowl, deer, small game and other animals. State game areas are identified below.

Table 4-9. Wildlife Refuges and Game Areas in the Nearshore Areas of Lake Michigan. SOLEC 1996.

Areas	South Central	Southwest	Northeast	Northwest
State game areas			Betsie River Manistee River Muskegon Pentwater Petobego	Mudlake

Hunting also takes place on private lands throughout the Lake Michigan watershed.

In the Green Bay area, the small waterfowl marshes at river mouth-areas around the lake support nesting and loafing waterfowl. Significant waterfowl marshes also exist in the Fox and Wolf River drainages and at Seney, Michigan.

The open water of the Lake is important to many species of waterfowl. Migrating and wintering waterfowl use the open waters as resting areas. Large ‘rafts’ of ducks and geese have been observed many miles from land. Although many species of waterfowl use the open water, its overall value is low when compared to the shoal and marsh areas along the lakeshore. While the open water is used for resting, the shoals and marshes are used for resting, nesting, and feeding. These areas are some of the most important waterfowl hunting areas. Lake Michigan has a total of 175, 432 acres of shoal.

Table 4-10. Lake Michigan Shoal Acreages.

State	Acreage
Michigan	107,234
Wisconsin	63,388
Illinois	2,710
Indiana	2,100
Total	175,432

These shallow-water areas are one of the prime requirements for the production and maintenance of waterfowl populations and is used as spawning grounds by many Lake Michigan fishes.

Degraded habitat in the urbanized southern basin supports little wildlife. However, some paradoxes occur here. Large flocks of nesting waterfowl are to be found off the Gary Steel complex during the fall. City parklands and forest preserves support small populations of rabbits, squirrels, and furbearers.

Hunting: Human Health Issues

Schmitt and others (1993) made a determination regarding whether contaminant levels in waterfowl warrant a consumption advisory in Michigan. The Michigan Department of Community Health (MDCH) is responsible for establishing fish and wildlife consumption advisories for Michigan. The Food and Drug Administration (FDA) uses a “tolerance level” for PCBs in poultry of 3 ppm on a ‘fat basis.’ The MDCH consumption trigger level and the FDA ‘action level’ for PCBs in fish is 2 ppm on a ‘wet weight basis’ (ppm wet weight = ppm fat basis x percent fat/100 percent). The amount of duck meat consumed by people is small when compared to domestic poultry, but is close to the estimated U.S. per capita consumption of fish (6.5 g/day). A survey of Michigan waterfowl consumption shows the average number of duck meals eaten by duck hunters is 4.5 per year. Assuming an average meal size is 0.6 lb., this equates to a consumption rate of 4.4 g/day. The results of this survey are a major factor in a decision by MDCH to use the MDCH fish consumption advisory trigger levels instead of the FDA domestic poultry ‘action levels’ for contaminants when evaluating the need for consumption advisories for wild waterfowl (MDNR, 1992).

4.2.4.4 Boating

Sport fishing and recreational boating anchor an important marine-coastal recreation sector of the area economy. According to the 1991 national fishing and hunting survey, 34 percent of all Great Lakes anglers fished in Lake Michigan, a close second to Lake Erie (35 percent). These 868,000 anglers were estimated to have spent $454 million (U.S.) on their trips and equipment-related items. The stocking of huge numbers of trout and salmon has been a fundamental part of this fishing success story.

The number of recreational boats operated on Lake Michigan each year is estimated at 400,000, or nearly half of the number for all the Great Lakes. Although boating has a strong connection to fishing, which relies on clean water and productive fish stocks, much of the boating activity is tied to marina and new residential development, which alters nearshore habitat and degrades water quality in localized areas. Around the southern shore of Lake Michigan, about 1,000 new slips were added per year in the late 1980s and early 1990s. In Indiana, for example, Lake Michigan boat slips increased from 1,100 in 1985 to 2,700 in 1991, though many new marinas in Indiana are being built on previously developed sites.

4.2.4.5 Lake and Landscape Observation

There are many areas in the Lake Michigan coastal area to observe the natural beauty of the lake, the wildlife and the landscape. Table 4-11 provides a listing of most of the national lakeshores, parks, state and national forests, preserves, natural areas, environmental areas, wilderness areas, and research areas. Lake Michigan and its extensive drainage basin encompass a wide variation in vegetative and climatological situations. The basin's northern extremities are forested with a spruce-fir biome on both sides of the Lake. As one moves south through the basin, the forest cover begins to change and gives way to agricultural lands at the Green Bay latitude in Wisconsin. In Michigan, the forest cover extends further south, to approximately Muskegon. Land around the southern tip of the Lake (excluding urbanized areas) is almost completely agricultural with little tree cover remaining in Indiana and Illinois.

Nearshore waters are used periodically by a variety of waterfowl species from late summer until migratory flights the following spring are complete. Groups of dabbling ducks begin to use areas adjacent to coastal wetlands as resting and refuge sites in August and September. Sites with open water in the winter can become important to wintering flocks of mallards as resting areas.

Protecting Natural Areas in Your Community

There is a growing movement to protect and restore natural areas, including wetlands and streams, prairies and savannas, and woodlands. Leading this movement in the northwest Indiana, Chicago, and southeast Wisconsin area, is a group called *Chicago Wilderness*, a coalition of over 100 organizations that recently completed a regional *Biodiversity Recovery Plan*. The plan imagines a region "*filled with life . . . where the evening air is rich with bird calls and the scent of flowers . . . where children splash and play in clean creeks, and peer below the surface of the water at fish and other aquatic creatures . . . where people learn to gently and respectfully enter back into a positive relationship with the nature that surrounds them . . . and where rare plants, animals, and natural communities are nurtured back to health and offered a permanent home next to our own – to the benefit of our health and our economy – in preserves large enough to sustain them forever.*"

Among other things, this plan identified a critical role for local governments, including park districts, cities and counties, and wastewater agencies, in achieving this vision. To assist, the Northeastern Illinois Planning Commission (NIPC) has developed a guidebook for *Protecting Nature in Your Community*. The objectives of the guidebook are to educate local government entities regarding the benefits of biodiversity in their communities and to provide them with the tools to enable protection and restoration within existing and new developing urban areas.

There are a host of reasons for protecting natural areas and biodiversity at the local level. They include quality of life, recreation, aesthetics. For example, it has been documented that natural areas, parks and open space create a high quality of life that attracts tax-paying businesses and residents to communities. There are also strong economic reasons for protecting natural areas. A pair of 1998 studies by The Trust for Public Land found that while land conservation projects caused a short-term rise in local property taxes, over the long term, communities that had protected the most land enjoyed the lowest property tax rates. Natural landscapes – including prairies, woodlands, and wetlands – also control erosion, help retain stormwater, help clean the air of pollutants, mitigate global warming by absorbing carbon dioxide and other greenhouse gases, and help shelter and cool our homes. It is estimated, for example, that the economic benefits generated by a single acre of wetland are $150,000 to $200,000.

The recommended roles of local governments range from developing environmentally sensitive land use planning and zoning and subdivision regulations, to improving their management of stormwater and wastewater. Local governments, particularly park districts, are encouraged to prioritize natural areas in their open space acquisition programs, and to actively manage and restore existing natural areas. Local governments also are encouraged to promote the use of native vegetation for landscaping and to require better protection of streams, lakes, and wetlands from the effects of new development.

Table 4-11. Lake and Landscape Observation Areas in the Nearshore Areas of Lake Michigan. SOLEC 1996.

Areas	South Central	Southwest	Northeast	Northwest
National lakeshores	Indiana Dunes		Sleeping Bear Dunes Nordhouse Dunes Michigan Islands	
State parks	Indiana Dunes Warren Dunes Van Buren Saugatuck Holland Grand Haven P.J. Hoffmaster Muskegon	Illinois Beach	Wilderness Kohler-Andrae Charles Mears Ludington Silver Lake Orchard Beach Fisherman Island Leelanau Young Old Mission Peninsula Traverse City Petoskey	Fayette Palms Book Wells Newport Peninsula Whitefish Dunes Rock Island Potawotami
Local parks	Whihala Beach Marquette Park	Chicago Park District Cary Avenue Beach Centennial Park Gilson Park Kenilworth Beach Lakefront Park Lloyd Park Beach Moraive Park Sunrise Park Fuss Park Waukegan Harbor Complex	Marion Island	
State forests			Mackinac Pere Marquette	Point Beach Lake Superior Escanaba river
National forests			Manistee	Hiawatha
Preserves/ natural/ environmental/ wilderness areas	Gibson Woods Oak Ridge Prairie Tolleston Ridges Clark and Pine Bongi Hoosier Prairie Moraine Ivanhoe Lake Powderhorn Sand Ridge	Forest Preserve district Chiwaukee Prairie Ripon Prairie Chiwaukee Prairie Audubon Goose Pond Renak-Polak Spruce Lake Bog Sander's Park Oakfield Ledge Mayville Woods Neda Mine Vanderbloemen Bog Cedarburg Woods Sapa Spruce Bog Kurtz Woods Riveredge Creek and Pond Zinn Spring Bluff	M. Shrotleff E. Johnson Sims-Moffat Betsie River Point Betsie Lucia K. Tower Green River Cedar River Palmer-Wilcox-Gates Skegemog Swamp Oyster Bay Leffingwell Forest	Cedarburg Bog Cedar Grove Hawk RS Wilderness Ridge Maribel Caves Two Creeks Buried Forest Fairy Chasm Kohler Park Dunes Point Beach Ridges Portage Point Rapid River St. Vital Island Fishdam River Ford River Round Island Ogontz River Spider Gravel Fish Islands Peninsula Park Ridges Sanctuary Sister Islands Two Creeks Seagull Bar Toft Point Newport

Areas	South Central	Southwest	Northeast	Northwest
Preserves/ natural/ environmental/ wilderness areas (continued)				Jackson Harbor Ridges Mud Lake Whitefish Dunes Marshall's Point Moonlight Bay Beach Coffee Swamp Mink River Estuary Two Wilderness Islands Garden peninsula Escanaba River Little St. Martin Island Voight Bay Goose island Point Aux Chenes Bay Naubinway Island North Shore
Research areas			Beaver Island High Island Central Michigan Bio. Station	Nahma Sturgeon River Summerby Swamp Point aux Chenes Marsh

Five species of diving ducks (lesser scaup, canvasback, redhead, ring-necked duck, and greater scaup, listed in order of importance) and six species of sea ducks (common goldeneye, bufflehead, oldsquaw, hooded merganser, red-breasted merganser, and common merganser) use the nearshore waters of the Great Lakes for feeding and resting. Seeds, tubors, rootstocks, and vegetative parts of submerged plants, benthic organisms, and fish are eaten in accordance with availability and with each duck species' food preferences. Diving ducks are most abundant group of waterfowl: flocks of hundreds and even thousands of birds are associated with the 15 major waterfowl habitat complexes in the Great Lakes that have been identified by Prince and others (1992).

Osprey and Bald Eagles are two aquatic raptors which historically nested along the shoreline of the Great Lakes and on offshore islands. Few species of mammals use the nearshore waters. River otter, mink, beaver, muskrat, and raccoon occur in sheltered parts of the system, including embayments and tributaries.

Islands, most of which occur in water less than 30 meters deep provide nesting habitat for many species of aquatic birds. These include species of colonial nesting gulls, terns, herons, cormorants, as well as species of reptiles and amphibians.

4.2.4.6 Water Consumption (including diversion)

Public Water Supply

The following public water supply uses of Lakes Michigan water are estimated by the Great Lakes states and compiled by the Great Lakes Commission in the 1992 Great Lakes Regional Water Use Data Base Repository:

Table 4-12. Public Water Supply Uses of Lakes Michigan Water

Water Use Category	Withdrawn	(million gallon per day)	
		Diverted	Consumed
Public (municipal supply)	1,644.49	1,151.23	73.12
Self Supply - Domestic	1,190.52	4.12	175.82

Public water supply category includes water withdrawn by public and private water suppliers and delivered to users that do not supply their own water. Self supply includes water withdrawn from wells, cisterns, or other residential sources.

Within the Lake Michigan watershed, the only approved surface drinking water supplies in Wisconsin are Lake Michigan and Green Bay, Lake Winnebago, the Fox River from Lake Winnebago downstream to the upper dam in the city of Appleton and Rainbow Lake at King in Waupaca County (State 305b Reports 1996).

In Illinois, Indiana and Michigan, no drinking water impairment exists currently (State 305b Reports 1996) (see Table 4-13).

The following Lake Michigan Areas of Concern have identified drinking water as an impaired use in their respective Remedial Action Plan: Lower Green Bay/Fox River and Grand Calumet River/Indiana Harbor.

Table 4-13. Drinking Water Supply Designated Use Impairments on Lake Michigan (miles)

Use	Supported	Threatened	Partially Supported	Not Supported
**Drinking Water Supply	1,513	20	20	–

References: Michigan, Indiana. Illinois, and Wisconsin 305(b) reports, 1996.
**Not reported by Indiana.

Water Consumption: Human Health Issues

Access to clean drinking water is essential to good health. The waters of Lake Michigan and surrounding areas are a primary source of drinking water for millions of people who live in the basin. Because the average adult in Canada and the U.S. consumes about 1.5 liters (1.6 quarts) of water a day, health effects can be serious if the drinking water supply has high levels of some contaminants (Health Canada 1993, 1997). Consequently, the Great Lakes Water Quality Agreement designates “restrictions on drinking water consumption, or taste and odor problems” as an impaired beneficial use -- note that “taste and odor” is an aesthetic impairment as opposed to a health-related impairment (IJC, Annex 2.1.c. 1987).

Residents of the Lake Michigan basin use water for drinking, cooking, bathing, and other household uses. This water is obtained from a variety of suppliers, both public and private.

A variety of contaminants can adversely impact drinking water, including microorganisms (e.g. bacteria, viruses, and protozoa such as cryptosporidium), chemical contaminants (including naturally occurring chemicals and anthropogenic or synthetic chemicals), and radiological contaminants (including naturally-occurring inorganic and radioactive materials) (IJC 1996; Health Canada 1997; OME 1997). Some contaminants of raw water supplies, such as aluminum, arsenic, copper, and lead, can be both naturally occurring and/or result from human activities. Other contaminants, such as household chemicals, industrial products, urban stormwater runoff, fertilizers, human and animal waste, nitrate (from fertilizers and sewage), and pesticides may also end up in raw water supplies (EPA 1999o; Health Canada 1998c).

Microbial contamination of drinking water can pose a potential public health risk in terms of acute outbreaks of disease. The illnesses associated with contaminated drinking water are mainly of a gastro-intestinal nature, although some pathogens are capable of causing severe and life-threatening illness (Health Canada 1995). In most communities, drinking water is treated to remove contaminants before being piped to consumers, and bacterial contamination of municipal water supplies has been largely eliminated by adding chlorine or other disinfectants to drinking water to prevent waterborne disease. By treating drinking water, we have virtually eliminated diseases such as typhoid and cholera. Although other disinfectants are available, chlorination still tends to be the treatment of choice. When used with multiple barrier systems (i.e. coagulation, flocculation, sedimentation, filtration), chlorine is effective against virtually all infective agents (EPA/Government of Canada 1995; Health Canada 1993, 1997, 1998e).

Localized outbreaks of water-borne disease have been linked to contamination by bacteria or viruses, probably from human or animal waste (EPA 1999o). Recently, there has been increasing concern over the presence in drinking water of parasites such as Giardia and Cryptosporidium (the most common source of which is animal feces), which are resistant to common disinfection practices, and may pass through water treatment filtration and disinfection processes in sufficient numbers to cause health problems (Health Canada 1998[b]). For example, in 1993, the city of Milwaukee, Wisconsin, experienced an outbreak of cryptosporidiosis that affected over 400,000 residents, causing severe diarrhoea, nausea, stomach cramps, and other symptoms. The outbreak was caused by Cryptosporidium oocysts that passed through the filtration system of one of the city's two water-treatment plants (WDNR 1998; Health Canada 1997).

Cryptosporidium

Cryptosporidium is a one-celled parasite that is spread through human or animal fecal contamination. When the organisms are ingested, they cause an infection and irritation of the digestive track that leads to acute diarrhea. For healthy people, this is generally a short term condition. However, it can be an extremely dangerous for small children and adults with AIDs, cancer, or other health problems. There is no effective drug for the treatment of cryptosporidiosis and currently it is not known whether any concentration of the organisms is safe for human consumption (U.S. CDC 1994).

Cryptosporidium poses a greater hazard than other potential pathogens in drinking water supplies because of its ability to withstand traditional drinking water treatment. Individual organisms form small hard shelled oocysts when in hostile environments such as surface water. These oocysts are resistant to chlorine and small enough to evade most filter technologies. However, since the Milwaukee outbreak, EPA has strengthened turbidity requirements for finished tap water, to ensure better filtration methods. However, even in water meeting the new standards, small numbers of oocysts may still breach filters (U.S. CDC 1994).

Certain chemical contaminants are of concern in drinking water because of possible health consequences associated with these substances. These contaminants may be in the raw (untreated) water as a result of industrial and agricultural activities, or in treated wastewater discharges. Some may also be present in the treated water as a result of chemicals used in the drinking water treatment process (Health Canada 1998). A snapshot of some chemical contaminants of concern (including chlorination disinfection by-products, and PBT chemicals) is presented below.

Chlorination Disinfection By-products

Other processes commonly used by water treatment plants include the addition of disinfectants such as chlorine to inactivate or kill micro-organisms. Chlorine and other disinfectants can combine with naturally occurring organic matter in the raw water to produce chlorination disinfection by-products. Of the chlorination disinfection by-products, trihalomethanes (THMs) are present in the highest quantities. Evidence from toxicologic and epidemiologic studies suggests a link between by-products of the chlorination process and increased risk of some cancers (e.g., bladder and colon) and adverse pregnancy outcomes (e.g., miscarriage, birth defects and low birth weight). The amount of chlorination required and resulting levels of chlorination disinfection by-products are dependent upon the quality of the raw water, including microbiological quality and organic content (Health Canada 1995b, 1997). In the U.S., EPA is developing standards to address the issue of disinfectants and disinfection-by-products.

PBT Chemicals:

Food, including fish consumption, is the primary route of exposure to persistent, bioaccumulative and toxic chemicals, including PCBs and mercury. For the U.S. Great Lakes basin, measured levels of these persistent toxic chemicals in drinking water are below the Maximum Contaminant Levels (MCLs) and therefore they are not considered to be a human health concern for drinking water. (Personal communication, Doug Mandy, Minnesota Department of Health, 2000).

Protecting Public Health

Although there have been sporadic outbreaks of illness related to the use of drinking water, the drinking water in the Lake Michigan basin is of good quality. However, continuing efforts must be made to inform health professionals and the public of the results of analyses of drinking water. Information on local water quality is available from several sources, including the state public health department and local water supplier. The EPA requires public water supplies to be monitored for bacteriological, inorganic, organic and radiological contaminants. The chemical analyses of drinking water include physical and chemical characteristics of the water, as well as contaminants resulting from natural sources or human activities. In addition, the EPA's Office of Groundwater and Drinking Water's (OGWDW) web site at http://www.epa.gov/OGWDW/ provides detailed information on the nation's drinking water, including drinking water and health, drinking water standards and local drinking water information. Community water suppliers deliver high quality drinking water to millions of people every day, and a network of government agencies are in place to ensure the safety of public drinking water supplies. Our drinking water is safer today than ever but problems can, and do occur, although they are relatively rare.

The EPA has established legally enforceable standards for public water supply systems called National Primary Drinking Water Regulations. These standards are used to protect the quality of drinking water by limiting levels of contaminants in public water systems that can adversely affect public health. Public water supplies are required to monitor drinking water for a host of contaminants to ensure consumer safety. Frequency of monitoring depends on the type of system, whether the source water is surface or groundwater, the type of contaminant, whether or not a contaminant has been previously detected or has exceeded the standard, and the number of people served by the public water system.

Information on local water quality is available from several sources, including the state public health department and local water supplier. To inform the public of the results of the chemical analyses of drinking water and to demonstrate a commitment to protect human health, each community public water supply is required to generate an annual Consumer Confidence Report that is made available to all residents receiving water from that water system. Consumer Confidence Reports provide information about the source(s) of water used, its susceptibility to contaminants, the levels of contaminants detected in the water, the likely source(s) of contaminants, and potential health effects of any contaminant detected above that specific Maximum Contaminant Level. Consumer Confidence Reports can be reviewed to give an indication of overall quality of treated surface water and groundwater, and the condition of the drinking water service.

Each State also has a department that regulates drinking water systems, and these agencies can also provide information about the local water supply and its quality. In addition, the EPA maintains a data base which contains information on individual ownership, locations, violations, and enforcement actions (EPA, 1999a).

4.2.4.7 Summary of Human Health Issues: LaMP Goals and Pathways of Exposure Relevant to Human Health

The first three endpoint goals of the Lake Michigan LaMP are: (1) we can all eat any fish; (2) we can all drink the water; (3) and we can all swim in the water. The major pollutant pathways of exposure to humans is directly related to these three goals. From a public health perspective, the potential environmental pathways of human exposure to Lake Michigan pollutants include inhalation of air, ingestion of water, foodstuffs or contaminated soil, and dermal contact with water or airborne pollutants. Multimedia analyses indicate that the majority (80 to 90 percent) of human exposure to chlorinated organic compounds comes from the food pathway, a lesser amount (5 to 10 percent) from air, and minute amounts (less than 1 percent) from water (Birmingham and others 1989; Newhook 1988).

Table 4-14. LaMP Goals and Pathways of Exposure

Goal	Public Health Pathway of Exposure
We can all eat any fish	Ingestion of food (fish)
We can all drink the water	Ingestion of water
We can all swim in the water	Dermal contact

Most of the data available on human exposure to toxic substances in the Lake Michigan basin comes from the analyses of contaminant levels in drinking water and sport fish. The consumption of contaminated sport fish and wildlife can significantly increase human exposure to the Lake Michigan critical pollutants and pollutants of concern. A spectrum of these major contaminants has been identified in cooked Lake Michigan fish. Investigators have demonstrated that blood serum levels of these contaminants are significantly increased in consumers of contaminated Lake Michigan sport fish as compared to nonfisheaters (Humphrey 1983a,b; Jacobson and others 1989; Waller and others 1998).

Even though residents of the Lake Michigan basin are exposed to toxic substances from many sources originating within and outside the basin, the main routes of human exposure to contaminants from the waters of Lake Michigan are ingestion of fish and to a lesser extent ingestion of drinking water (National Health and Welfare Canada 1991). Several investigators have shown that exposure from fish far outweighs atmospheric, terrestrial, or water column sources (Swain 1983; Humphrey 1983b).

Weight of Evidence

The Agency for Toxic Substances and Disease Registry (ATSDR)reported on the most recent findings for human health in the Great Lakes used a weight of evidence approach to substantiate the public health threat from exposure to persistent toxic substances (Johnson and others 1998). ATSDR concluded that even with the limitations of individual research efforts the "collective weight of evidence" from wildlife, laboratory and human population studies shows that persistent toxic substances can cause negative human health outcomes such as cancer and neurobehavioral problems (Johnson and others 1998).

During the 1970s, the use of Lake Michigan as a disposal site for agricultural, industrial and domestic wastes became an increasingly widespread concern due to detrimental effects on fish and wildlife, and the potentially adverse effects on human health. Summary information about human health issues related to swimming, fishing, hunting, and drinking water is included in the Human Systems sections above (Swimming, 4.2.4.1; Fishing, 4.2.4.2; Hunting, 4.2.4.3; Water Consumption, 4.2.4.7). Detailed discussion of the weight of evidence and health studies related to human health issues in the Lake Michigan Basin are presented in the Human Health Appendix, Appendix C, attached at the end of the LaMP.

4.2.5 Economic Vitality

The Lake Michigan system supports a major economic base. The following section discusses the roles of the lake in the regional and world economy.

4.2.5.1 Water Used for Industrial and Agricultural Purposes

Waterborne navigation has played an important role in the history of human development around Lake Michigan. The development of the Great Lakes region proceeded along several lines that took advantage of the many resources within the basin. The waterways became major highways of trade and were exploited for their fish. The fertile land that had provided the original wealth of furs and food yielded lumber, then wheat, then other agricultural products. Bulk goods such as iron ore and coal were shipped through Great Lakes ports, and manufacturing grew.

The promise of agricultural land was the greatest attraction to the immigrants to the Great Lakes region in the 19th century. By the mid-1800s, most of the Great Lakes region was settled, where farming was possible. The population swelled tremendously, with about 400,000 people in Michigan and 300,000 in Wisconsin.

Wheat and corn were the first commodities to be packed in barrels and shipped abroad. Grist mills, one of the region's first industries, were built on the tributaries flowing into the lake to process the grains for overseas markets. As populations grew, dairying and meat production for local consumption began to dominate agriculture in the Great Lakes basin. Specialty crops, such as fruit, vegetables and tobacco, grown for burgeoning urban populations, claimed an increasingly important share of the lands suitable for them.

The rapid, large-scale clearing of land for agriculture brought rapid changes in the ecosystem. Soils stripped of vegetation washed away to the lakes. Tributaries and silty deltas clogged and altered the flow of the rivers. Fish habitats and spawning areas were destroyed. Greater surface runoff led to increased seasonal fluctuation in water levels and the creation of more flood-prone lands along the waterway. Agricultural development has also contributed to Great Lakes pollution, chiefly in the form of eutrophication. Fertilizers that reach waterways in soils and runoff stimulate growth of algae and other water plants. The plants die and decay, depleting the oxygen in the water. Lack of oxygen leads to fish kills, and the character of the ecosystem changes as the original plants and animals give way to more pollution-tolerant species.

Modern row crop monoculture relies heavily on chemicals to control pests such as insects, fungi and weeds. These chemicals are usually synthetic organic substances and they find their way to rivers and lakes to affect plant and animal life, and threaten human health. The problem was first recognized with DDT, a very persistent chemical, which tended to remain in the environment for a long time and to bioaccumulate through the food chain. It caused reproductive failures in some species of birds. Since the use of DDT was banned, some bird populations are now recovering. Other, less persistent, chemicals have replaced DDT and other problem pesticides, but toxic contamination from agricultural practices continues to be a concern. DDT levels in fish are declining but, in spite of being banned, some other pesticides, such as dieldrin, continue to persist in fish at relatively high levels.

The original logging operations in the Lake Michigan basin involved clearing the land for agriculture and building houses and barns for the settlers. Cutting was generally done in the winter months by men from the farms. They traveled up the rivers felling trees that were floated down to the lakes during the spring thaw. The logs were formed into huge rafts or loosely gathered in booms to be towed by steam tugs. This latter practice had to be stopped because logs often escaped the boom and seriously interfered with shipping. In time, timber was carried in ships specially designed for log transport.

The earliest loggers mainly harvested white pine. In virgin stands these trees reached 60 meters (200 feet) in height, and a single tree could contain 10 cubic meters (6,000 board feet) of lumber. The wood was light and strong and much in demand for shipbuilding and construction. Each year, loggers had to move farther west and north in search of white pine. The trees were hundreds of years old and so were not soon replaced. When the resource was exhausted, lumbermen had to utilize other species. The hardwoods such as maple, walnut and oak were cut to make furniture, barrels and specialty products.

Paper-making from pulpwood developed slowly. Paper production developed at Green Bay and elsewhere in the Lake Michigan basin. Eventually, Canada and the U.S. became the world’s leading producers of pulp and paper products. Today much of this production still occurs in the Great Lakes area.

During its early stages, clear-cutting was the usual timber industry practice and, without proper rehabilitation of the forest, soils were readily eroded from barren landscapes and lost to local streams, rivers and lakes. In addition, much of the cleared land was permanently converted to agriculture land uses.

Since early in the industrial age, the waterways, shorelines and woodlands of the Great Lakes region have been attractions for leisure time activities. Many of the utilitarian activities that were so important in the early settlement and industrial development became recreational activities in later years. For example, boating, fishing and canoeing were once commercial activities, but are now primarily leisure pursuits.

Recreation in the area became an important economic and social activity with the age of travel in the 19th century. The recreation industry includes production and sale of sports equipment and boats, marinas, resorts, restaurants and related service industries that cater to a wide range of recreational activities. In some areas of the basin, recreation and tourism are becoming an increasingly important component of the economy, replacing manufacturing. The Lake Michigan basin provides a wide range of recreational opportunities, ranging from pristine wilderness activities in national parks such as Sleeping Bear National Lakeshore to urban waterfront beaches in major urban areas.

The increasingly intensive recreational development of Lake Michigan has had mixed impacts. Some recreational activities cause environmental damage. Extensive development of cottage areas, summer home sites, beaches and marinas has resulted in loss of wetland, dune and forest areas. Shoreline alteration by developers and individual property owners has caused changes in the shoreline erosion and deposition process, often to the detriment of important beach and wetland systems that depend upon these processes. The development of areas susceptible to flooding and erosion has caused considerable public reaction. There is pressure to manage lake levels to prevent changes that are part of natural weather patterns and processes. Pollution from recreational sites and boats has also caused water-quality degradation.

Recreational uses are a threat to the quality of the Great Lakes ecosystem, but they also provide a basis for protecting water quality by attracting and involving people who recognize that protecting of the ecosystem is essential to sustain the recreation that they value. Today more people than ever use and value the lakes for recreational purposes.

The following industrial and agricultural Lake Michigan water uses, Table 4-15 (not drawn through municipal systems) were estimated by the Great Lakes states and compiled by the Great Lakes Commission in the 1992 Great Lakes Regional Water Use Data Base Repository:

Table 4-15. Industrial and Agricultural Uses of Lake Michigan Water (1992)

Water Use Category	(million gallon per day)		
	Withdrawn	**Diverted**	**Consumed**
Industrial	1,988.50	3.66	147.50
Thermoelectric Power - Fossil Fuel	3,697.70	0.00	40.65
Thermoelectric Power - Nuclear	5,347.12	0.00	42.70
Hydroelectric Power	5,751.96	0.00	0.00
Irrigation	31.35	0.00	24.56
Livestock	545.59	0.00	436.47

Note: Industrial category includes water used in the manufacturing of metals, chemicals, paper, and allied products.

Comprehensive water use data for Wisconsin, Illinois, and Indiana in 1992 (Michigan data are not available) indicate that about 90 percent (18,455 of 20,500 million gallons per day [Mgal/day]) of the total water used in those parts of the Lake Michigan basin came from surface water, both from Lake Michigan directly and its tributaries. The remaining water comes from groundwater sources. The largest single use of surface water for all Lake Michigan basin states is for cooling at thermoelectric power plants (more than 48 percent for Indiana, Illinois, and Wisconsin).

The second largest water-use category in the Indiana, Illinois, and Wisconsin portion of the basin is hydroelectric power, which accounts for about 31 percent of total surface water use for the non-Michigan portion of the basin. Approximately 10 percent of the surface water in the Illinois, Indiana, and Wisconsin portion of the basin is used for industrial purposes. In fact, Indiana's concentration of heavy industry, particularly in its Lake Michigan counties, has made it the nation's largest industrial water-using state. Only about 7 percent of surface water (1.369 Mgal/day) in the Indiana, Illinois, and Wisconsin portion of the basin is used for public water supply. Since 1994, about 2,573 Mgal/day have been diverted from Lake Michigan to serve the Chicago metropolitan area, about half of which is for public water supply, and about half for navigation, sanitation, and water-quality purposes. Agricultural water use for irrigation and livestock represents about 4.5 percent of total water use from all sources.

Table 4-16. Agriculture/Industry and Aesthetics Designated Use Impairments on Lake Michigan (miles)

Use	Supported	Threatened	Partially Supported	Not Supported
*Agriculture	1,513		40	
*Aesthetics	1,363		190	

References: Michigan, Indiana. Illinois, and Wisconsin 305(b) reports.
*Not reported by Indiana and Illinois.

4.2.5.2 Commercial Navigation

Lake Michigan remains an important resource for waterborne navigation in and around every lakefront community and through many of its tributaries. The U.S. Congress has authorized a total of 51 Federal navigation projects in Lake Michigan and its tributaries. Information on commerce at these harbors and channels is provided in Table 4-17. The vast majority of commerce at Lake Michigan ports is internal to the Great Lakes (materials are transported from one Great Lakes port to another). Raw materials associated with steel making (i.e., iron ore, limestone, coal) dominate the overall tonnages of commercial cargoes transported to and from Lake Michigan ports. Coal remains a common cargo at many of the smaller commercial harbors, largely for coal-fired power plants.

Many of the Lake Michigan harbors were constructed in the 19th century as deep-draft commercial harbors with depths of 18 feet and greater. While many of these harbors still receive commercial cargoes, recreational use has replaced commercial navigation at a number of Lake Michigan ports. In several cases, commercial traffic has dwindled or completely stopped.

Deposition of sediments in artificially-deepened channels necessitates periodic dredging to maintain safe depths for navigation. A summary of dredging activities at federal harbors around Lake Michigan is shown on Table 4-18. Because recreational boats do not require the draft that most commercial vessels do, the navigation channels in some harbors are not maintained at authorized depths. In some harbors, commercial vessels only access the lower portions of the channel, and the upper portions are not maintained at authorized depths.

In addition to the federal navigation projects, there are numerous facilities for commercial and recreational navigation that are managed by public or private interests. Commercial facilities include a few harbors constructed by individual industries and numerous docks, slips and berthing areas of industries and utilities located adjacent to federal navigation channels.

Table 4-17. Summary of Commerce at Federal Harbors on Lake Michigan[1]

Federal Harbor	State	Total Tonnage, 1994 (thousands)	Major Cargoes	Tons In/Outbound (thousands)
Michigan City	IN		None reported	
Burns Waterway	IN	9,344	Iron ore Iron and Steel primary forms Limestone	4,757/Zero 661/Zero 524/15
Indiana Harbor	IN	15,739	Iron ore Asphalt, tar and pitch Limestone	10,708/Zero 2/1,167 1,247/33
Calumet River and Harbor	IL & IN	18,554	Coal lignite Limestone Iron ore	Zero/843 1,117/Zero 1,007/Zero
Chicago Harbor	IL	29,422	Coal lignite Sand and gravel Cement and concrete	2,013/854 1,757/558 1,243/32
North Branch, Chicago River	IL	1,944	Sand and gravel Non-metal. min. nec. Iron and steel scrap	648/Zero 208/Zero Zero/118
Waukegan Harbor	IL	604	Cement and concrete Gypsum Sand and gravel	271/Zero 248/Zero Zero/77
Kenosha Harbor	WI		Machinery (not elec.) Textile products	Zero/Zero Zero/Zero
Racine Harbor	WI		None reported	
Milwaukee Harbor	WI	2,641	Coal lignite Cement and concrete Asphalt, tar and pitch	563/Zero 382/8 208/Zero
Port Washington Harbor	WI	335	Coal lignite	335/Zero
Sheboygan Harbor	WI	12	Nitrogenous fertilizers	12
Manitowoc Harbor	WI	330	Cement and concrete Coal lignite Waterway improvement materials	172/Zero 126/Zero Zero/19
Two Rivers Harbor	WI		None reported	
Kewaunee Harbor	WI		None reported	
Sturgeon Bay and Lake Michigan Ship Canal	WI	88	Asphalt, tar and pitch	88
Algoma Harbor	WI		None reported	
Green Bay Harbor	WI	2,288	Coal lignite Limestone Cement and concrete	897/Zero 414/Zero 235/Zero
Pensaukee Harbor	WI		None reported	
Oconto Harbor	WI		None reported	
Menominee Harbor and River	MI and WI	217	Coal lignite Non-metal. min. nec. Pig iron	89/Zero 68/Zero 44/Zero
Cedar River Harbor	MI		None reported	
Gladstone Harbor	MI	265	Coal lignite Limestone Asphalt, tar and pitch	126/Zero 44/Zero 32/Zero
Manistique Harbor	MI	1	Distillate fuel oil Gasoline	1 0
Grays Reef Passage	MI	9,763	Coal lignite Limestone Cement and concrete	234/3,079 1,010/1,722 345/1,192

Federal Harbor	State	Total Tonnage, 1994 (thousands)	Major Cargoes	Tons In/Outbound (thousands)
Mackinaw City Harbor	MI		None reported	
St. James (Beaver Island)	MI	5	Unknown or nec. Distillate fuel oil	4 1
Charlevoix Harbor	MI	1,549	Cement and concrete Coal lignite Limestone	8/1,148 300/Zero 10/Zero
Traverse City Harbor	MI	282	Gasoline Distillate fuel oil	161/Zero 121/Zero
Leland Harbor	MI		None reported	
Frankfort Harbor	MI	81	Asphalt, tar and pitch Limestone Wood in the rough	70 10 2
Manistee Harbor	MI	483	Coal lignite Limestone Coal coke	326/Zero 89/Zero 12/Zero
Ludington Harbor	MI	1,093	Limestone Metallic salts Sand and gravel	595/Zero 133/113 11/158
Pentwater Harbor	MI		None reported	
White Lake Harbor	MI		None reported	
Muskegon Harbor	MI	2,004	Coal lignite Limestone Slag	1,199/Zero 243/2 221/Zero
Grand Haven and Grand River	MI	878	Sand and gravel Limestone Coal lignite	Zero/263 183/Zero 167/Zero
Holland Harbor	MI	391	Limestone Coal lignite Slag	160/Zero 154/Zero 58/Zero
Saugatuck Harbor and Kalamazoo River	MI		None reported	
South Haven Harbor	MI	7	Limestone	7
St. Joseph Harbor	MI	631	Limestone Cement and concrete	383/Zero 248/Zero
New Buffalo Harbor	MI		None reported	

[1] Data from *Waterborne Commerce Statistics*, USACE 1996. Tonnages shown are for 1994. Cargoes reflect top three (where available).

Dredging and Dredged Material Management

Bottom sediments are dredged from Lake Michigan and its tributaries for a variety of purposes in addition to navigation maintenance, including water supply intake maintenance, waterfront development, infrastructure construction and repair, and environmental remediation. The USACE annually expends approximately $20 million for maintenance dredging at Great Lakes harbors and channels. On average, about 4 million cubic yards of sediments are dredged from 35 federal navigation projects on the Great Lakes each year.

The options for managing dredged material might be divided into the following categories:

- Open water placement
- Beach/littoral nourishment
- Beneficial use (upland)
- Confined disposal
- Treatment

Table 4-18. Summary of Dredging Activities at Federal Navigation Projects on Lake Michigan

Federal Harbor	State	Channel Depth[1] (Auth/ Maint)	Dredging Cycle (years)	Ave. Dredged Quantity[2] (cu yd)	Dredged Material Management Method(s)[3]
Michigan City	IN				BN, BU, C
Burns Waterway	IN				BN
Indiana Harbor	IN				X
Calumet River and Harbor	IL/IN				C
Chicago Harbor	IL		20+		C
Chicago River	IL		20+		C, X
Waukegan	IL		1		BN, X
Kenosha	WI		7	25,000	C
Racine	WI				
Milwaukee	WI		4	50,000	C
Port Washington	WI				C
Sheboygan	WI	25 / 25	4	30,000	BN, X
Manitowoc	WI	25 / 21	5	40,000	C
Two Rivers	WI		15	50,000	BN
Kewaunee	WI	20 / 20	4	30,000	C
Sturgeon Bay	WI	23 / 23	5	30,000	BU
Algoma	WI	14 / 14	10	25,000	BU
Green Bay	WI	26 / 26	1	234,000	C, BU
Pensaukee	WI	6 / 6	20+	201,000	BN
Oconto	WI		10	50,000	BU
Menominee	WI/MI		5	30,000	O
Cedar River	MI				
Gladstone	MI				
Manistique	MI				X
Grays Reef	MI		20+		O
Straights of Mackinaw	MI				
Mackinaw City	MI				
St. James	MI				
Cross Village	MI				
Inland Route	MI	5 / 5	10	1,000	C, BU
Petoskey	MI				
Charlevoix	MI		20	15,000	BU
Grand Traverse Bay	MI		4	10,000	BN
Leland	MI	12 / 12	1	15,000	O, BN
Frankfort	MI		10	35,000	BN
Arcadia	MI	16 / 9	1	4,000	O, BN
Portage Lake	MI		5	30,000	BN
Manistee	MI		4	30,000	BN
Ludington	MI		3	60,000	BN
Pentwater	MI	16 / 12	1	20,000	O, BN
White Lake	MI		5	30,000	BN

Federal Harbor	State	Channel Depth[1] (Auth/ Maint)	Dredging Cycle (years)	Ave. Dredged Quantity[2] (cu yd)	Dredged Material Management Method(s)[3]
Muskegon	MI		3	70,000	BN
Grand Haven	MI		1	42,500	BN, BU
Holland	MI		5	200,000	BU, BN
Saugatuck	MI		4	20,000	C, BN
South Haven	MI		8	25,000	BN
St. Joseph	MI		1	42,000	BN, BU
New Buffalo	MI		4	10,000	BN

1 Maximum authorized channel depth and maximum channel depth currently maintained. Channel depths shown are feet LWD.
2 Average quantity dredged during last three cycles. If cycle is more than 20 years, quantity show is from last dredging.
3 O = open water disposal; BN= beach/littoral nourishment; BU = upland beneficial use; C =- confined disposal; X = part or all of channel not maintained because of lack of CDF.

Open water placement involves the discharge of dredged material directly to the lake. Hydraulically dredged material may be discharged by pipeline a short distance offshore. Mechanically dredged material may be placed in bottom-dump barges or scows and towed to disposal sites several miles away. Discharged dredged material settles through the water column and deposits on the bottom at the disposal site. The dredged material may remain in a mound at the site or may disperse, depending on the materials physical properties and the hydrodynamics of the disposal site. Open water placement is used with approximately 32 percent of Great Lakes dredged material. Most open water disposal sites in the Great Lakes are dispersive in nature.

Beach/littoral nourishment involves the placement of dredged material directly onto a beach or into the shallow water. Beach nourishment is typically discharged by pipeline from a hydraulic dredge. Suitable dredged material is typically a fine sand and may only stay on the beach for a limited time before being eroded into the littoral drift. Littoral nourishment involves a discharge to near shore, shallow areas, and is typically done with bottom dump scows when a mechanical dredge is used. Beach and littoral nourishment are used with approximately 12 percent of Great Lakes dredged material.

Beneficial use of dredged material includes beach and littoral nourishment (as discussed above) and a variety of upland applications, described here. Upland beneficial uses for dredged material include construction fill, landscaping, agricultural applications and wetland and habitat enhancement. Dredged material from Great Lakes harbors has been used for these and other beneficial uses. For upland uses, dredged material is typically placed into a storage area or confined disposal facility (CDF) for dewatering and then transported by truck for use. The development of islands for wildlife habitat with dredged material is typically done by direct placement from a pipeline. The USACE has continuing authorities to provide federal funding (cost-shared) for the additional cost associated with beneficial use of dredged material for the protection, preservation and enhancement of wetlands and aquatic habitat. Port authorities in Duluth, Green Bay, Milwaukee and Toledo are actively pursuing the development of local markets or applications for dredged material.

Confined disposal is the placement of a dredged material into a secure area where the sediment is physically contained. CDFs are diked structures that have been built for the disposal of contaminated dredged material. Summary information on the 21 CDFs constructed by the USACE to serve federal navigation projects on Lake Michigan is provided in Table 4-19. The size, shape, design and level of complexity of these facilities has varied widely depending on dredging quantities, methods of disposal, sediment contamination levels, state and local requirements and site characteristics. Contaminated dredged material can also be placed in commercial landfills, although this has been done more frequently with environmental cleanup dredging than with navigation dredging.

Treatment technologies are available to destroy, extract, or immobilize sediment contaminants. These technologies are in varying stages of development, with relatively few full-scale technologies available off-the-shelf. Treatment technologies have been used at a limited number of sediment remediation projects around the Great Lakes. Most developed technologies require sediments to be dredged, placed into a holding/storage area, and dewatered prior to treatment. No single technology can address the entire suite of contaminants present in many sediments. A number of treatment technologies were evaluated by the USACE as part of a Great Lakes study conducted 30 years ago (Buffalo District 1969). In addition, the EPA Great Lakes National Program Office conducted a comprehensive analysis of sediment treatment technologies under the Assessment and Remediation of Contaminated Sediments (ARCS) Program (Averett and others1990; Allen 1994; EPA 1994c).

Table 4-19. Confined Disposal Facilities for Lake Michigan Harbors and Channels

Name/Location	State	Type[1]	Year Built	Size (acres)	Capacity (yd^3)	Percent Filled	Existing or Planned Uses after Filling	Construction Authority[2]	Construction Cost[3]
Michigan City	IN	U	1978	3	50,000	100	Recreation/Park	1	$300,000
Chicago Area	IL	L	1984	42	1,300,000	30	Park/Industry	1	$7,800,000
Grand Haven Harbor	MI	U	1974	36	310,000	100	Public Use	1	$433,000
Milwaukee Harbor	WI	L	1975	44	1,600,000	87	Expansion	1	$5,963,000
Dickinson Island	MI	I	1975	174	2,000,000	67	Wildlife Area	1	$5,072,000
Manitowoc Harbor	WI	L	1975	24	800,000	45	Land Use Dev.	1	$4,147,000
Kenosha Harbor	WI	L	1975	32	750,000	100	Public Use	1	$8,270,000
Bolles Harbor	MI	L	1978	25	335,000	44	Marina Expansion	1	$972,000
Holland Hbr-Riverview Site[4]	MI	L	1978	11	120,000	100	Recreation/Park	1	$1,583,000
Holland Hbr-Windmill Site[4]	MI	I	1978	17	160,000	100	Recreation/Park	1	$1,654,000
Sebewaing Harbor	MI	U	1979	9	84,000	100	Airport Extension	1	$1,300,000
Green Bay Harbor	WI	I	1979	60	1,200,000	99	Recreational	1	$5,565,000
Kewaunee Harbor	WI	L	1982	28	500,000	74	Recreational	1	$2,017,000
Frankfort Harbor	MI	U	1982	80	74,000	5		1	$800,000
Inland Route	MI	U	1982	9	19,500	38	Wildlife Area	1	$176,000
Bayport/Green Bay	WI	L	1965	400	650,000		City Landfill	2	City Owned
Kawkawlin River	MI	U	--	--	--	--		2	Private
Monroe Edison	MI	U	--	43	--	100	Detroit Edison	2	Private
Port Sanilac	MI	U	1979	13	143,300	100	Municipal Landfill	2	Used Once
Verplank/Grand Haven Harbor	MI	U	1974	19	134,000	100	Parking Lot	2	City Property
Whirlpool/St. Joseph Harbor	MI	U	1978	14	25,000	100	Transfer Site	2	$638,076
Malleable/St. Joseph Harbor	MI	U	1978	--	35,000	100		2	Unknown

[1] U - Upland, I - In water, Island, L - In water, Adjacent to land or breakwater

[2] 1 = Constructed under Section 123, PL 91-611, 2= Constructed under other authority

[3] Actual construction costs, not adjusted for inflation.

[4] Both facilities considered as one

4.3 Overview of Lake Michigan Status and Management Needs

This chapter documented the current status of the Lake Michigan ecosystem. Overall, the ecosystem has been impaired by habitat loss, toxic and conventional pollutants, aquatic nuisance species, resource harvesting, and climate change. The following discussion presents the status of the research and information gathering, international and U.S. protection efforts, and restoration activities that should be supported to better manage the ecosystem in the future, especially with regard to wetland resources. Many of these management activities are further addressed in Chapter 6.

4.3.1 Research and Information Gathering

Given the variety and extent of impacts on the Lake Michigan ecosystem, some effort to evaluate the relative degree of stress posed by each type of impact is needed. Busch and others (1993) set out a system for assessing the degradation of specific habitats based on measurable criteria. This system requires a detailed measuring regime, both of the habitat being studied and nearby non-degraded habitats. This system has not been implemented to date. In the absence of systematic basin-wide monitoring of relative impacts, the Nature Conservancy (1994) has used a simple ranking system based on professional judgement. Results of this evaluation showed greatest stress on biodiversity resulting from habitat destruction, alteration of lake levels and stream flows, and competition from non-native species. Unlike the addition of toxic chemicals and nutrients, whose effects were given a medium score, the physical alterations were seen to be generally irreversible. In establishing priorities to conserve and protect habitat, further analysis and consensus on the relative threat posed by different impacts seems desirable.

While systematic inventories and assessments of habitats on a basin-wide level are in their early stages. For example, the EPA Region 5 Critical Ecosystems Team is currently developing a data base and series of maps to characterize ecologically rich regions in the basin (www.epa.gov/ecopage/err).

To provide a consistent national database on wetlands, the Nationals Wetlands Inventory (NWI) is classifying and mapping all wetlands in the U.S. from aerial photographs. The information is also being entered into three database systems that will comprise the NWI Geographic Information System (GIS) and allow computer access to the data. The NWI also prepares wetland trend studies and special reports to Congress.

No comparable national program to map other habitat types has been conceived.

One obstacle to basin-wide inventories is the lack of consensus on an ecosystem-wide habitat classification system. In the U.S., the NWI is using the system developed by Cowardin and others (1979) for mapping wetlands. Busch and Sly (1992) and an international team that included many Canadian and U.S. participants reported on the Aquatic Habitat Classification (AHC) System to facilitate mapping of all types of aquatic habitat. The AHC uses the NWI system and expands it to provide more detailed application to open water and tributary habitats and should be amenable to incorporation in computer database systems (Busch and others 1993). It is not clear whether a consensus on the basin-wide use of the AHC has developed.

4.3.2 International Protection Initiatives

Numerous laws and initiatives in both Canada and the U.S. are designed to protect and restore Great Lakes habitat. The ongoing loss and impairment of habitat suggests they have not yet been successful in reversing the trend of the last two centuries. Whether or not they have slowed the rate of degradation cannot be ascertained as the data are not available or inadequate to accurately determine basin wide trends.

The North American Waterfowl Management Plan (Plan) is a joint Canadian - U.S. - Mexican effort that offers many opportunities for wetland protection and enhancement in the Great Lakes basin. The Plan has among its goals to protect approximately 407,000 acres of critical aquatic and associated upland habitat, enhance approximately 135,000 acres of wetlands, and create approximately 19,000 acres of wetlands. Ongoing losses and alteration of habitat were the reasons for setting these goals. Program implementation has evolved to restoring historical hydrology and vegetation as close as possible.

In 1986, the U.S became a signatory to the RAMSAR Convention on Wetlands of International Importance, especially as waterfowl habitat, and to date thirty wetlands, including one in the Lake Michigan basin, Horicon Marsh, Wisconsin, have been identified and protected under this treaty.

The International Tracking System standardizes reporting of wetland restoration, protection, and other data in the U.S. and Canada. Data are available for the fiscal years 1992 through 1996 (October 1, 1991 to September 30, 1996) although full accounting of acreage is sometimes not completely updated for the ensuing year (Joe Artman, pers. communication).

4.3.3 Protection Initiatives

Within the United States, wetlands are managed through a mixture of federal, state and local initiatives, with public input from citizens and interest groups. The federal government's primary tool for protecting wetlands is Section 404 of the Clean Water Act. In accordance with Section 404, the USACE and EPA regulate the discharge of dredged or fill materials in "all waters of the United States". Under Section 404 the USACE considers the advice of EPA, the U.S. Fish and Wildlife Service (Service), the National Marine Fisheries Service, other agencies and the public when deciding whether to issue or deny a permit.

One state in the Lake Michigan basin, Michigan, has assumed administration of the Section 404 program. Most, but not all, wetland permit actions are handled by the Department of Environmental Quality in Michigan. Other states in the basin also have wetland management laws that afford varying levels of protection to wetlands.

Federal agencies are obliged to comply with the Federal Wetlands Executive Order 11990, and Federal Floodplains Executive Order 11988, which direct that wetland and floodplain impacts should be avoided or minimized to the extent possible. The Order requires specific procedures for agency activities related to: 1) acquiring, managing and disposing of federal lands and facilities; 2) providing federally undertaken, financed or assisted construction and improvements; and, 3) conducting federal activities related to land use.

In 1990 the U.S. Environmental Protection Agency released National Guidance on Water Quality Standards for Wetlands (Environmental Protection Agency 1990a). In this document, EPA regional officials and State Water Quality Managers are required to (1) include wetlands in the definition of

"State waters," (2) establish beneficial uses for wetlands, (3) adopt existing narrative and numeric criteria for wetlands, and (4) adopt narrative biological criteria for wetlands, and (5) apply anti-degradation policies to wetlands.

The conservation provisions of the 1985 Food Security Act (Farm Bill) and the 1990 Food, Agriculture, Conservation and Trade Act (FACT Act) have continued to encourage the preservation of a vast acreage of agricultural wetlands and highly erodible croplands. The Swampbuster provision eliminates price supports for individuals who convert wetlands to produce agricultural commodities.

Programs and partnerships are underway by the United States Forest Service and several other U.S. Department of Agriculture Agencies. State and local governments are active in habitat initiatives. Within Lake Michigan basin states there are Natural Heritage programs, although they are focused on natural communities and species more than "habitat." Notable programs in some states include Michigan's Dune Protection Act and Wisconsin's shoreline zoning program, and local watershed councils. Private sector initiatives such as the Nature Conservancy's, Ducks Unlimited and Trout Unlimited are all vital to habitat in the basin.

The U.S. Environmental Protection Agency has included coastal wetlands as a resource class in its Environmental Monitoring and Assessment Program (EMAP) for the Great Lakes. The EPA has begun to plan pilot and demonstration studies to determine the best way to monitor the condition of wetlands on each of the Great Lakes.

4.3.4 Restoration

Wetlands and aquatic habitat restoration is still a rather young science, with long-term rewards unclear. A fair amount of restoration is being attempted around the Great Lakes system, and while its overall effectiveness in terms of quality is uncertain, it holds a clear potential in terms of offsetting historically lost or altered acreage.

Habitat loss, particularly in the case of wetlands, is in many cases a continuum - a matter of degrees of degradation and/or function loss, rather than an "all-or-nothing" proposition. This means that restoration of function is also not necessarily a simple "yes/no" question: restoration can be partial or incremental as resources or conflicting uses allow. Restoration and protection of partially degraded sites is therefore an important goal; complete restoration of all natural values is not the only worthwhile goal.

A search of the 1992 through 1996 data of the International Tracking System found that acres had been restored and acres protected in U.S. counties which are at least partly in the Lake Michigan Basin. The total combined acreage for fiscal years 1992 through 1996 was 12,033.1 acres, but some comparability is lost due to category changes, (more categories now available) through time. For the entire U.S. Great Lakes basin counties, the combined acreage was 10,858.87 acres for fiscal years 1992 and 1993 alone. Comparing this to the previously quoted estimate of 20,000 acres lost per year basin-wide, both countries still appear to be falling well short of just keeping the wetland habitat base they have.

4.3.5 Recommendations

As discussed in Chapter 6, many initiatives to protect and restore the Great Lakes ecosystem are planned and under way. Integrating habitat considerations into these initiatives will increase their effectiveness.

Some solutions to the various environmental stresses that cause losses and alteration of habitat, including wetlands, have to be implemented at the lowest levels of government. Advice, advocacy, data, education, funding and lobbying offered by any group to local clientele may facilitate a solution. Successful local management ordinances are often those with: 1) an underpinning of sound technical data, a comprehensive plan, and evenhanded administration; and 2) a partnership between the federal and state governments, the local community, and its citizens in developing and implementing the ordinance.

Conservation actions aimed at protecting diversity, productivity and function of the Great Lakes basin must strategically address the key sources of stress. First efforts should focus on protecting habitats that are most important to the basin's ecosystem. They must also concentrate on reducing key sources of stress, and do so sustainably in a variety of socioeconomic settings that represent the diversity of challenges present in the basin. Integral to all actions is the need to gain a better understanding of what key species and communities need to survive.

4.4 Overall Assessment

More than 200 years of settlement have reduced the size and extent of many Great Lakes habitats and impaired the functional integrity of many that remain. The Great Lakes contain a mosaic of types and quality of habitat: a healthy habitat type in a given lake can coexist with another that is not at all healthy, while the opposite situation may prevail in another lake. Thus, habitat area figures, even when available, do not allow accurate comparisons of areal extent of habitat types, especially across jurisdictions. Conveying habitat status remains largely descriptive and anecdotal.

At this time, the Lake Michigan ecosystem is an outstanding natural resource of global significance that is under stress and in need of special attention.

Although efforts have been made to remediate damage, particularly in the area of chemical pollution, human impacts to the ecosystem are continuing to impair its function. Toxic air deposition and nonpoint source pollution are problems. Fish advisories remain in effect. In some areas the water supply is susceptible to contamination. Some Lake Michigan beaches experience episodic closures due to high bacteria counts. Unique habitats are fragmented by poor land use practices including uncontrolled development. Contaminated sediments threaten nearshore waters and wildlife. Exotic species have not been prevented from entering the ecosystem nor have they been controlled once established.

Future progress will depend on the stewardship activities and partnerships underway throughout the basin. Public and private organizations and individuals in Lake Michigan basin communities recognize and are taking responsibility for environmental problems. From inter-agency task forces to watershed groups to industry, collaborative, place-based partnerships are finding ways to restore and protect the Lake Michigan ecosystem health. These activities are discussed further in Chapter 6.

Table 4-20. Lake Michigan LaMP Summary Table (Chapter 4)

CHAPTER 2	CHAPTER 3		CHAPTER 4			Chapter 5	CHAPTER 6	
Lake Michigan LaMP: Vision, Goals and Ecosystem Objectives	Indicators and Monitoring of the Health of the Lake Michigan Ecosystem		Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments and Human Health			Lake Michigan Stressor Sources and Loads	Strategic Action Agenda: Next Steps	
Endpoint Goal	**Pressure**	**Human Activity**	**Impairment**	**Spatial**	**Temporal**		**Means to an End Goal**	**Recommendations**
1. We can all eat any fish.	• Chemical contamination in fish • Site assessments • Eagle reproduction	• Fish advisories • Congressional reports on: - Great Waters - Mercury - Dioxin	• Restrictions on fish and wildlife (F/W) consumption • Tainting of F/W flavor	Lakewide Regional	Ongoing Episodic			
2. We can all drink the water.	• Raw water quality data • Source water assessments	• Water utility notifications • Source water protection	• Restrictions on drinking water consumption or taste and odor problems	Local	Episodic			
3. We can all swim in the water.	• *E. Coli* levels in recreational water	• Beach closing advisories • State 305(b) WQ reports	• Beach closings	Local	Episodic			
4. All habitats are healthy, naturally diverse and sufficient to sustain viable biological communities.	• Fish assessments • Bird counts • Wetlands inventories and assessments • Stream flows • Eco-rich area assessments	• Endangered species list • Wetlands mitigation and protection • Zoning • Fish stocking • Fish refuges • USFWS refuges • Ballast water exchange • Dune protection • Eco-rich cluster map	• Degradation of F/W populations • Fish tumors, or other deformities • Degradation of Benthos • Eutrophication or undesirable algae • Degradation of phytoplankton and zooplankton • Loss of F/W habitat • Bird or animal deformities or reproduction problems	Regional Local Local Local Lakewide Lakewide Local	Evolving Episodic Ongoing Episodic Ongoing Ongoing Episodic			
5. Public access to open space, shoreline and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem.	• Urban density • Coastal parks acreage • Conservation easements	• Open space funding and protection statutes • Coastal zone management	• Degradation of aesthetics	Local	Evolving			
6. Land use, recreation and economic activities are sustainable and support a healthy ecosystem.	• Contaminants in recreational fish • Sustainable forests	• Superfund cleanups, dredging • CRP percent of eligible farm lands • Brownfields to greenfields redevelopment	• Restrictions on dredging • Added cost to agriculture or industry	Local Local	Evolving Evolving			

Chapter 5:
Lake Michigan Stressor Sources and Loads

Chapter 5 addresses stressors that limit the achievement of the stated vision, goals, and subgoals of the Lake Michigan Lakewide Management Plan (LaMP). There are three general categories of stressors: physical, biological, and chemical. The primary sources of these stressors are land use, point source discharges to surface water, air emissions leading to air deposition, and in-place contaminants or legacy sites. Appendices A, B, and C provide more detailed information regarding the regulations and management programs, physical and chemical properties, and human health effects of each of the stressors described throughout the chapter. Physical stressors include land use and water use and development, primarily for agriculture, mining, urban-suburban development, navigation, waste disposal, and construction of canals. Biological stressors include exotic species and human pathogens. Since the 1830s, eight fish species, seven invertebrate species, three disease pathogens, nine algae species, and two marsh plants are known to have invaded and become established in the Lake Michigan basin. Approximately 10 percent of all exotic species have a significant ecological or economic impact. In the Lake Michigan basin ecosystem, there are currently six viruses, nine bacteria, five protozoa, two algae, one worm, and one yeast/fungi causing or potentially causing serious human health problems. Twenty chemicals or classes of chemicals are identified as chemical stressors. They are divided into three groups: critical pollutants (polychlorinated biphenyls [PCB], dieldrin, chlordane, DDT and metabolites, mercury, and dioxins/furans); pollutants of concern (arsenic, cadmium, chromium, copper, cyanide, lead, zinc, hexachlorobenzene [HCB], toxaphene, and polynuclear aromatic hydrocarbons [PAH]); or emerging pollutants (atrazine, selenium, and PCB substitute compounds). This section also addresses nutrients and radionuclides as pollutants of interest. For each chemical or class of chemical, the uses, general sources, physical and chemical characteristics, contribution to use impairments, and gaps in data collection and existing knowledge are discussed.

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TABLES

CONTENTS (Continued)

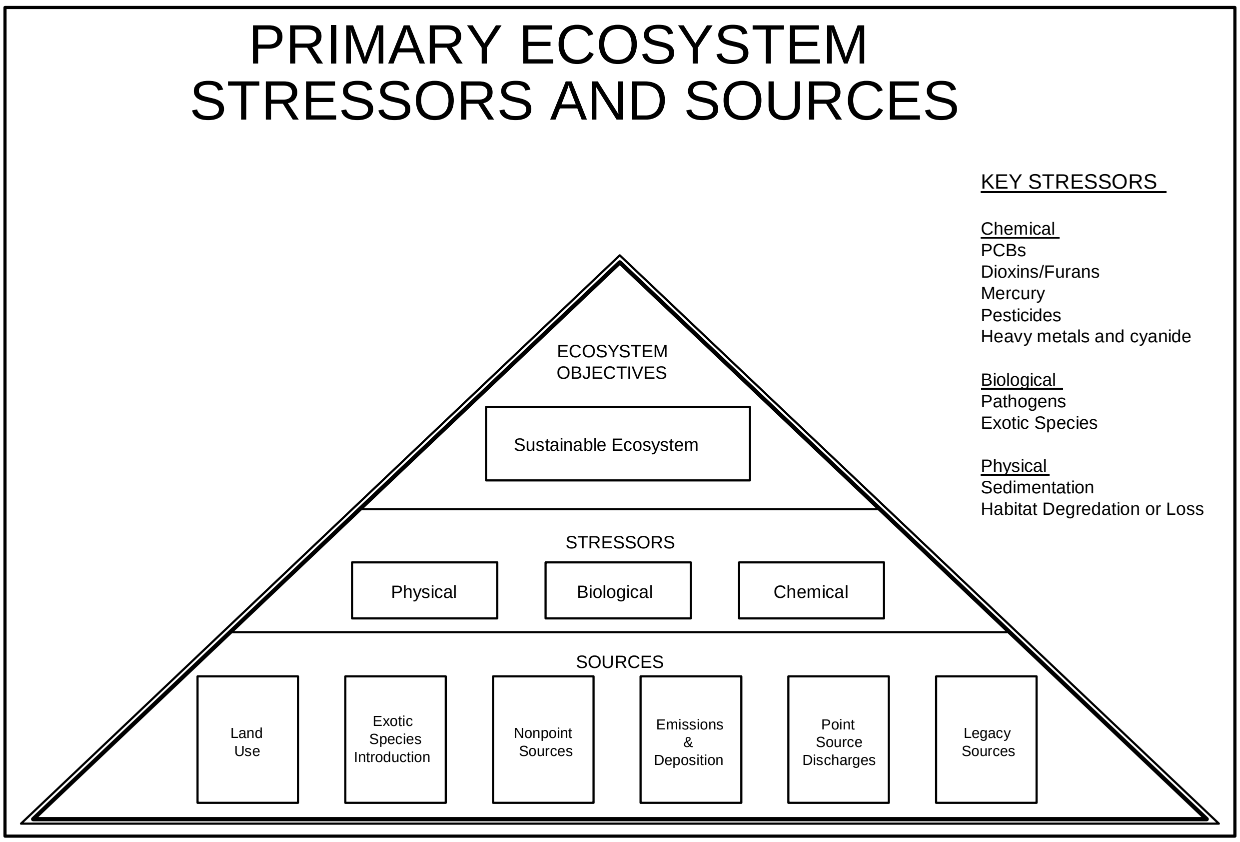
FIGURES

Chapter 5:
Lake Michigan Stressor Sources and Loads

5.1 About this Chapter

In Chapter 2, the LaMP presents the vision for the Lake Michigan ecosystem. The chapter describes the three overarching principles (remediation, integrity and sustainability, and partnership frameworks) that provide a framework for developing subgoals. Chapter 2 also identifies two overall goals that must be achieved to realize this vision: (1) restoring and protecting the lake's ecosystem and (2) using a collaborative process of placed-based partnerships to accomplish the restoration and protection. Restoring and protecting the lake's ecosystem involves understanding the stressors that have damaged or threaten to damage the ecosystem. Figure 5-1 displays the primary ecosystem stressors and sources within the Lake Michigan basin.

Figure 5-1. Lake Michigan Primary Ecosystem Stressors and Sources



This chapter addresses the stressors that limit the achievement of the vision, goals, and subgoals for Lake Michigan outlined in Chapter 2 and presented in Figure 5-2. The icons included in Figure 5-2, and previously introduced in Chapter 2, will aid the reviewer in understanding which subgoals are affected by each stressor. There are three general categories of stressors:

- Physical
- Biological
- Chemical

This section presents an overview of the stressors on the Lake Michigan ecosystem and the sources of information used to understand and describe those stressors. Section 5.2 describes the following sources of the stressors and the information collected to characterize those stressors: (1) land uses, (2) point source discharges to surface water, (3) air emissions that may lead to air deposition of contaminants in the Lake Michigan basin, and (4) existing sources of in-place or legacy pollutants. Section 5.3 discusses the loadings and effects of the physical, biological, and chemical stressors. Chemical stressor-specific information on regulatory and management programs, physical and chemical properties, and human health effects, are included in Appendices A, B, and C, respectively. By characterizing key stressors affecting the lake, the specific management activities described in Chapter 6 can be tailored and focused to address the key problems in the Lake Michigan basin.

The reader will notice that data on concentrations and loadings of the chemical stressors discussed in this chapter may vary. These should not be construed as inconsistent or conflicting data. Numerous different studies were used to describe loadings of pollutants to the Lake Michigan ecosystem. These studies may have been performed at different times for different purposes, using different sampling and analytical techniques. The different data are presented to help the reader understand the extent to which the problems have been evaluated as well as the relative magnitude of the loading of certain chemicals to the ecosystem.

In addition, data are often reported by political jurisdiction, state, or county. Ecosystems do not observe political boundaries. Where possible, loading data were attributed to specific sources at specific locations. In other cases, county-wide data were used when any portion of the county resided within the Lake Michigan watershed.

Finally, names of individual sources are generally not provided unless they are specifically named in studies used to complete this chapter. This would include studies completed for National Priorities List sites and Areas of Concern.

Figure 5-2. Lake Michigan LaMP Subgoals

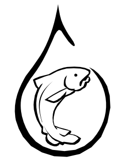
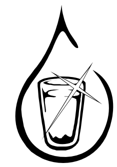
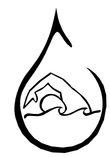
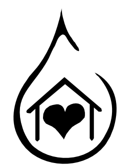
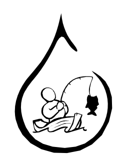
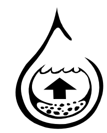
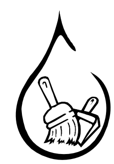
End Point Subgoals		
Subgoal 1	We can all eat any fish.	
Subgoal 2	We can all drink the water.	
Subgoal 3	We can all swim in the water.	
Subgoal 4	All habitats are healthy, naturally diverse, and sufficient to sustain viable biological communities.	
Subgoal 5	Public access to open space, shoreline, and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem.	
Subgoal 6	Land use, recreation, and economic activities are sustainable and support a healthy ecosystem.	

Figure 5-2. Lake Michigan LaMP Subgoals (continued)

Means (to End Point) Subgoals		
Subgoal 7	Sediments, air, land, and water are not sources or pathways of contamination that affect the integrity of the ecosystem.	
Subgoal 8	Exotic species are controlled and managed.	
Subgoal 9	Ecosystem stewardship activities are common and are undertaken by public and private organizations in communities around the basin.	
Subgoal 10	Collaborative ecosystem management is the basis for decision-making in the Lake Michigan basin.	
Subgoal 11	We have enough information/data/understanding/indicators to inform the decision-making process.	

5.1.1 Physical Stressors

Human activities have altered the Lake Michigan basin and created physical stressors that threaten the basin ecosystem. Most major human-related stressors are the result of post-settlement modifications to the terrestrial and aquatic elements of the basin ecosystem. This section will present an overview of physical stressors and discuss changes in land use, erosion, lake-level fluctuations, and stressor loadings and effects. A summary of the data sources used to prepare this section are presented below.

5.1.1.1 Overview of Physical Stressors

In the 1800s, forests and wetlands throughout the basin were converted to agriculture uses by early settlers. This change from natural vegetation to row crops accelerated erosion and increased turbidity in nearby waters. Mining for iron ore in the northern basin and for sand and gravel along the nearshore areas became common practice. Soon after, industrialization and rapid population growth led to the development of cities and suburban areas with high population density, especially in the southern basin. As a result, nearshore water began being used for process water, drinking water, and the disposal of pollutants. Nearshore water was also used extensively for navigation and the construction of canals, locks, dams and water-level control structures.

These stressors still play a major role in the Lake Michigan ecosystem today. Although mining and agricultural practices in the northern basin have decreased, they are still active in the Lake Michigan basin. Urban sprawl is also a prominent land use issue, primarily in the southern portion of the basin. Urban sprawl has resulted in new stresses to the ecosystem such as increased sanitary, stormwater, and combined sewage systems, decreased groundwater recharge, increased transportation infrastructure (such as, roads and highways) and reliance on vehicles, increased impervious surfaces associated nonpoint source runoff, and degradation of urban streams.

5.1.1.2 Land Use

This section describes physical changes within the Lake Michigan basin, the extent of those changes, and their impact on the sustainability of the Lake Michigan ecosystem. These physical changes or stressors involve land use and water use within the basin and present a significant challenge to achieving the Lake Michigan end point subgoals 4, 5, and 6. Land use near the Lake Michigan coastal environment degrades critical habitats, reduces the opportunity for the general public to access and enjoy the shoreline, and lessens the overall sustainability of the ecosystem. Certain land use also contributes to loading of chemical and biological stressors. Achieving sustainable land and water use within the basin also involves overcoming other challenges as described in the means to end point subgoals 9 and 10 (ecosystem stewardship and collaborative ecosystem management). Traditional federal, tribal, and state environmental regulatory programs are not well suited for addressing land and water use issues.

The following sections discuss stressors derived from agricultural, urban, and mineral extraction land uses.

AGRICULTURAL LAND USE

Land classified as farmland includes cropland, woodland, and permanent pastures. Within the Great Lakes basin, approximately 33 percent of the land is used for agriculture. Farmland in the Great Lakes basin declined by 9.6 percent between 1981 and 1992, as much of this land was converted to residential and commercial uses. These trends occurred primarily near major metropolitan areas, but many rural areas also contributed to the decline (SOLEC 1996).

These agricultural land use characteristics and trends are similar for the Lake Michigan basin. The predominant development trend in the Lake Michigan basin is low-density sprawl extending from the suburban and urban areas. The decline in farmland in the Great Lakes basin between 1981 and 1992 involved more than 1 million acres (7 to 15 percent) in Michigan and Wisconsin. In addition, the Illinois portion of the basin also experienced a 19.5 percent decline in farmland during this time period (Great Lakes Commission 1996a and SOLEC 1996).

Agricultural land use is found throughout the Lake Michigan basin, predominantly in the southern portion. Approximately 37 percent of the land in the western basin is used for agriculture, with more than 99 percent of that land in cropland and pasture. Small areas of orchards, grove, and vineyards are located on the Door County Peninsula. In the southern part of the basin, the second largest land use (after urban land use) is agriculture, which is found mostly in the St. Joseph River basin. The eastern basin is approximately 28.5 percent agricultural, including cropland, pasture land, and orchards. Parts of these areas are classified as 3 of the top 20 most threatened high quality lands (prime farm land or unique soils and climatic requirements) under development pressure by the American Farmland Trust. The three are Southern Wisconsin and Northern Illinois Drift Plain, Southwestern Michigan Fruit and Truck Belt, and Western Michigan Fruit and Truck Belt.

These areas are important to the overall balance and sustainability of the basin in order to achieve the LaMP vision and desired outcome of “A sustainable Lake Michigan ecosystem that ensures environmental integrity and that supports and is supported by economically viable, healthy human communities.” The current management of these lands stresses the Lake Michigan ecosystem by contributing sediment load to the basin water bodies that carries with it pesticides and nutrients. Urban runoff also contributes sediments contaminated with not only pesticides and nutrients but also chemicals, oils, and road salt. These substances accumulate or persist in the lake because, unlike rivers that are constantly flushed with water, the lake is a sink. A drop of water entering Lake Michigan will take an average of 100 years to either evaporate or be washed into Lake Huron. For a particle of soil, the retention time is even longer and its attached contamination can be taken up in the food web of the lake — a food web that includes the human population.

Sediments also affect the habitat systems of the lake. Lake Michigan contains 40 percent of the coastal wetlands in the entire Great Lakes system. These wetlands provide habitat for larval stages and an abundant food supply for predators. Sediment can bury submergent and emergent plants, while nutrients cause excessive growth.

A number of scientific investigations are underway to further investigate the processes governing sediment, nutrient, and contaminant cycling in the lake. For example, the Episodic Events: Great Lakes Experiment (EEGLE) led by the National Oceanic and Atmospheric Administration’s (NOAA) Great Lakes Environmental Research Laboratory began in 1996. That year a massive turbidity plume, 10 miles offshore, 200 miles long, and composed of as much as 1 million tons of material was observed by satellite. The plume can appear as early as February or as late as May, and for the last 5 years, it has been studied by more than 40 environmental scientists from federal and state agencies and universities. For more information, see Appendix A or the study web site at www.glerl.noaa.gov/eegle/

The Lake Michigan Mass Balance (LMMB) Project led by the EPA Great Lakes National Program Office collected data from air, water, sediment, the open lake, and selected tributaries in 1994 and 1995. The purpose of the study was to improve the understanding of key environmental processes governing contaminant cycling and availability within the relatively closed ecosystem of the lake. The data will be used to support modeling of lake processes, including a sediment transport model. The model will help predict how particles from near-shore locations such as tributary mouths are transported to depositional zones, usually in deep water. www.epa.gov/grlakes/lmmb/sedtrans.html

In the winter of 1999, the Lake Michigan Forum held a work shop on sediment issues in the basin followed by a summer 1999 workshop on stewardship projects. The forum has formed an Agriculture Pollution Prevention Task Force to address specific pollution prevention projects for sediments and pesticides in the Lake Michigan Basin. A report will be issued in summer of 2000. www.lkmichiganforum.org.com

Agricultural Land Use: Erosion and Sedimentation

Wind and water erode soil particles from plowed farmland and carry the particles to water bodies such as nearby streams and lakes. Once in the water body, the suspended particles are eventually deposited to the sediment. Eroded soil particles have the following effects on surface water (EPA 1997[l]):

- Cloudy water and a reduction sunlight reaching submerged aquatic vegetation
- Covered fish spawning areas and food sources
- Covered habitats for aquatic organisms
- Clogged fish gills
- Medium to retain pollutants

Traditional tilling practices expose large areas of soil to wind and water erosion. Traditional tilling has historically been heavily used in corn and soybean fields, which are the primary crops in much of the Lake Michigan basin. Conservation tillage practices, such as no-till farming, contour plowing, and maintaining vegetative cover in erosion-prone areas, expose less soil to erosion forces and reduce sedimentation in surface waters (SOLEC 1996).

Overgrazing of pastures by livestock also contributes to soil erosion and sedimentation. Overgrazing (1) exposes soil exposure to wind and water erosion and (2) reduces vegetative filtration of soil particles from runoff (EPA 1997[l]).

Agricultural Land Use: Nutrients

Nutrients, including nitrogen, phosphorus, and potassium, are applied to agricultural fields to enhance crop production. They are typically applied in commercial fertilizer, manure, sludge, or through chemigation systems. Legumes and other nutrient-rich crops can also contribute excess nutrients to surface water. When an excess of these nutrients is applied or produced, the excess is often transported to surface water bodies in runoff (EPA 1997[l]). Nutrients are necessary for a balanced, sustainable ecosystem, but increased nutrient levels in surface water beyond what is necessary can result in the following (EPA 1999e):

- Increased aquatic plant growth
- Increased algae production
- Depletion of the water’s dissolved oxygen content due to plant decay and increased nighttime oxygen uptake during algal blooms
- Foul tastes and odors from aquatic plant decay and algal blooms
- Increased turbidity from algae, which reduces the amount of sunlight penetrating the water and reaching submerged aquatic vegetation

- Decreased growth of submerged aquatic vegetation, resulting in loss of habitat for fish and other aquatic organisms

Recent trends are toward fewer livestock farms with larger numbers of animals per farm (SOLEC 1996). This trend results in larger amounts of manure at each farm location. Confined animal feeding operations (CAFO) enable farmers and ranchers to efficiently feed and maintain large numbers of livestock; however, they also produce large quantities of animal waste. Large amounts of livestock manure from farms and CAFOs contribute high concentrations of nutrients to surface water (EPA 1997[l]).

Agricultural Land Use: Pathogens

Manure from farms and CAFOs also contribute pathogens to surface water. Bacteria contained in animal waste affect surface water in the following ways (EPA 1999e):

- Fish and mass deaths of other aquatic organisms
- Food source poisoning
- High fecal coliform counts that affect humans via direct contact

The method, timing, and rate of manure application are key factors in the potential impact of the manure on surface water. For example, incorporating the manure into the soil, composting the manure, and refraining from manure application when the ground is frozen or snow-covered will reduce the potential for pathogens in the manure to reach surface water (EPA 1999e).

Agricultural Land Use: Pesticides

Pesticides include herbicides, insecticides, fungicides, and rodenticides. These compounds can be transported to surface water through direct runoff, surface water runoff, wind transport, and atmospheric deposition. The effects of pesticides on surface water include the following (EPA 1997[l]):

- Fish kills and mass deaths of other aquatic organisms
- Aquatic vegetation reduction and habitat loss
- Food source poisoning

In the Great Lakes basin, herbicides comprise approximately two-thirds of the pesticides applied to crops, with corn and soybeans requiring a large portion of the herbicides. Specialty crops such as tree fruit, which are typically grown in coastal counties, require use of insecticides and fungicides. Overall the use of pesticides is decreasing in the Great Lakes basin, due in part to the reduction in farmland, and also to reduced application rates. Greater specificity of pesticides enables farmers to reduce application rates, thereby reducing the amount of pesticides entering surface water (SOLEC 1996).

Urban Land Use

The stresses of urban sprawl are numerous. The virtually uncontrolled sprawl of low-density residential areas and other development leads to population-related generation of pollution, habitat loss, higher transportation and residential energy use, increasing encroachment on agricultural lands and natural areas, and burdensome physical infrastructure requirements. Nonpoint source pollution, including bacteria, metals, oils, biochemical oxygen demand (BOD), and nutrients, has a greater impact as population sprawl brings increased areas with impervious surfaces, increased nonpoint sources, and land modification that results in hydrologic changes. In northeastern Illinois, the overall population of the six-county Chicago metropolitan area increased only 4.1 percent from 1970 to 1990 but residential land consumption increased by an estimated 46 percent. Much of this land consumption is at the expense of agricultural land (SOLEC 1996).

As urban sprawl and residential development has encroached along the Lake Michigan shore, impervious or "hardened" surfaces such as roads, parking lots, sidewalks, and rooftops have had a significant impact on surface water runoff patterns. These surfaces cause spikes of increased runoff that damage the morphology of urban streams. They also reduce the ability of natural systems to cleanse runoff. With more pollutants and sediments remaining in the surface water runoff, the potential for environmental degradation and erosion into the receiving water body increases (SOLEC 1996).

Transportation continues to become more oriented towards private automobiles and trucking, as opposed to more efficient public transit and good rail systems. Continued urban sprawl increases reliance on cars and motor carriers and will necessitate controlling urban air pollution. Transportation congestion and commuting delays will further promote work-at-home practices (SOLEC 1996).

From 1992 to 1995, the U.S. Geological Survey (USGS) studied the Western Lake Michigan drainage area as part of the National Water-Quality Assessment Program and found that concentrations of cadmium, copper, mercury, nickel, lead, zinc, and of many toxic synthetic organic compounds were highest in fine river sediments in streams that drained urban areas compared to other land uses. Aquatic life and habitat is most degraded in urban areas with trace elements and synthetic organic compound concentrations in sediment and fish tissue exceeding aquatic-life criteria at some sites in the study (Peters 1998, USGS 1998).

Urban Land Use: Urban Industry

As the Lake Michigan basin moves from a heavy industry to an increasingly service-oriented economy, many abandoned industrial sites need to be addressed. These abandoned sites, commonly called "brownfields", are found throughout the basin. The southern portion of the basin contains hundreds of these former industrial sites that are now areas of neglect and often sources of continuing pollution. Many of these industrial sites were constructed on fill sites, where foundry slag from processing was deposited. The slag, in the presence of sand, is highly permeable and is conducive to the leaching of contaminants. About 18 percent of land in Chicago is vacant or inactive former industrial sites. These sites present unique challenges to developing and revitalizing urban areas such as cleanup costs and liability issues. As a result, developers are often reluctant to redevelop these abandoned sites and instead migrate to undeveloped areas (SOLEC 1996).

The prominent steel industry in the Lake Michigan basin has had major impacts on land use and the nearshore environment. As an industry, its facilities occupy immense tracts of nearshore land in the southern tip of the Lake Michigan basin. Past steel-making practices have generated tons of pollutants and have resulted in significant air emissions and sediment, soil, and groundwater contamination that remain a concern. Current practices have significantly improved air emissions and water discharges from the steel mills including reduced water usage, recycling, and closed-loop systems. Steel mills are also making site cleanup progress under RCRA corrective action.

Urban Land Use: Urban Erosion and Sedimentation

Soil erosion in the Lake Michigan basin can be attributed to human activities and natural forces. The natural activity of waves is the primary erosion force along Lake Michigan shores and most of the erosion occurs as a result of storms. During periods of higher than average water levels, the wave attack is much higher along the shoreline profile and bluff recession can accelerate rapidly. During periods of lower than average water levels, wave attack is less noticeable, but is occurring further offshore. Other factors, such as groundwater flow, surface runoff, agricultural practices, and human building practice can still cause coastal bluffs to recede, even when lake levels do not trigger collapses (www.lre.usace.army.mil).

The USGS conducted a coastal study of southern Lake Michigan after flooding problems in Chicago in the late 1980s and developed a model to predict the future of the coastline (USGS 1994). During the study, USGS found that the ice ridges that form along the lakeshore do not protect the shoreline from winter erosion and that the repeated formation and breakup of nearshore ice ridges results in significant transport and removal of beach sand trapped in floating ice. This sediment transfer occurs both along the shore and into the deep lake. This is one mechanism by which sand is lost from the nearshore system. USGS also measured bluff retreat along the Illinois shore and found that it averaged 20 to 25 centimeters per year (cm/yr) between Wilmette and Waukegan, Illinois; however, north of Waukegan it is close to 300 cm/yr. Sediments from the eroding bluffs provide most of the sand to the nearshore zone. As more structures are erected to protect the bluffs, less sand is available to the natural system. As the sand supply decreases, the finer-textured lakebed sediments are exposed to wave attack, accelerating coastal retreat (USGS 1994).

Not all of the damage caused by coastal erosion occurs in the lake. Erosion and flooding of Lake Michigan's coastline result in extensive damage to domestic, recreational, and industrial facilities that were built too close to the high water mark. When the lake level is high, bluff erosion increases, and beachfront property and structures are lost (USGS 1994). During times of low water levels, navigation channels and harbors in the lake have to be dredged of sediments that are often polluted and create disposal problems. Also, when the lake is low, hydroelectric output decreases, increasing the load on freshwater pumping facilities and complicating sewage disposal (USGS 1994).

Dredging marinas and bulldozing dunes for development projects remove the natural shoreline protection against wind and waves. As more homes and development projects are built along the lakeshore, the associated pedestrian and vehicle traffic destroys vegetation, degrades dunes, and weakens bluffs and banks. Inappropriate building practices in high bluff areas can cause runoff infiltration directly into a bluff, weakening and eroding the bluff. These processes are especially evident along the western Michigan shoreline where weakened shorelines have caused homes to fall into the lake (USAC 1999). In addition, as shorelines weaken, contaminated sediments around the lake are being washed into the lake, thereby contributing additional contaminant loads to the lake (EPA 1999d).

Urban Land Use: Tributary Dams

Tributaries are important sources of cool, high quality water, and they serve as spawning and nursery habitats for many species. In the 1800s, mill dams and later hydroelectric facilities were constructed and altered the habitat. Many dams remain in the Lake Michigan basin but their effects are different in warmwater and coldwater stream environments. In warmwater streams, lake fish populations are excluded from many tributaries, and habitat has been degraded badly in upstream areas through urbanization, poor agricultural practices, and physical alteration of stream channels. The dams have resulted in sediment (and associated pollutants) from warmwater tributaries burying historically important spawning reefs. Reduction in water clarity has also reduced submerged vegetation. Dam removal and better land use practices would likely improve fish community habitats. However, sea lampreys and exotic salmonids use coldwater streams as habitats. Dam removal could enhance sea lamprey populations by opening up previously unavailable spawning habitat. In addition to dams, many of the floodplain areas within the basin have been developed, and as a result, habitats such as important spawning and nursery areas have been degraded or destroyed (MDEQ 1999a).

Resource agencies are also concerned about the positive and negative effects of dams, hydroelectric facilities, culverts, diversions, or other structures that act as barriers to the movement of fish. Objectives of resource agencies include minimization and mitigation for the negative impacts of hydroelectric facilities on fish movements using adequately designed fish passage. This passage moves both potadromous and resident fish around hydroelectric facilities as determined necessary by the resource agencies (1) for the appropriate management of the river system and (2) to ensure that options for future aquatic management are protected in river systems where fish passage is not presently deemed necessary. Riverine or lake dwelling fish, like lake sturgeon, coaster brook trout, walleye, and many others, migrate within a river at different life stages. They must move between areas for food, spawning, overwintering, and population dispersion. The overall health of the ecosystem may be adversely affected in cases where passage introduces contaminated species to an upriver area where fish, wildlife, and humans consume the new food supply. To protect such species as bald eagle, mink, otter, and other fish-eating species, each passage prescription is carefully considered on a case-by-case basis by the regulatory and resource management agencies with jurisdiction in that area.

In Michigan, 113 hydropower plants are currently in operation, and in Wisconsin, there are currently 120 non-federally owned hydropower projects. Fish losses are common at thermal-electric and hydroelectric plants. Losses of young fish in Lake Michigan are significant; 3 to 10 percent of total annuals production. Plants around the basin are mitigating settlements for this damage. Although some new projects are proposed from time to time, the trend is to develop the hydro-generation potential of existing dams (SOLEC 1996).

Mineral Extraction

Mining for copper and iron ore has been significant in the northern portion of the Lake Michigan basin. As the steel industry prospered, the need for iron ore continued to grow. However, surface mining in the northern basin has altered the landscape and contributes to soil erosion and sedimentation in nearby waterways. The environmental impacts of mining include the presence of mill tailings. The tailings can be toxic to plant and animal life and can leach or erode toxic minerals into surface and groundwater.

Oil drilling also has great potential to damage Lake Michigan habitats along the eastern shore. Directional (or slant) drilling became common in Michigan in the 1970s and allowed companies to drill for oil and natural gas under the lake from shore locations up to 4,000 feet away. Ten permitted wells with bottom-hole locations are actively drilling under Lake Michigan. Thirty potential sites for drilling are located in Muskegon, Oceana, Mason, and Manistee Counties, all of them along critical dune areas (Lake Michigan Federation No date[c]).

Mineral Extraction: Sand Dune Mining

Lake Michigan has the largest concentration of freshwater sand dunes in the world. They have been in existence for 2,500 to 10,000 years. The dunes support plant and animal species that are not found anywhere else, but the dunes are threatened by human activities, especially sand mining. The Michigan Sand Dune Protection and Management Act was passed in 1976, but since then, the area permitted for mining has grown almost 50 percent. More than half of the Lake Michigan sand is exported to provide jobs in other states, and the dunes continue to disappear at a rapid rate, with about 46.5 million tons of sand extracted since the law was passed (Lake Michigan Federation 1999). Although the law was strengthened in 1986, it still does not adequately protect this unique habitat. For example, sand from three actively mined sites is used for fill and mined to clear space for residential development.

The major use of dune sand is by foundries that use sand to produce metal castings for molding parts. it. Since the passage of the Sand Dune Protection and Management Act, the demand for dune sand declined by about 30 percent. The Michigan Department of Environmental Quality attributes this to restrictions on the disposal of used foundry sand, but the USGS attributes it to a decline in the demand for foundry sand and glass. Manufacturing smaller parts requires finer sand grains, such as those left by inland glaciers, not the larger sand grains from the shore dunes. Many foundries are now reusing their sand due to the higher costs of disposal. Studies conducted by Michigan Technological University in 1978 indicated that inland glacial sand is a suitable replacement for dune sand (Lake Michigan Federation 1999). The Ford Motor Company has been using inland sand for many years.

Sand dune mining can have a negative impact on the unique species that inhabit the dunes. One species that is threatened is the piping plover, a bird on the federal endangered species list that relies on the shoreline for nesting. Threatened plant species include Houghton's goldenrod, pitcher's thistle, and dwarf lake iris, which is Michigan's state wildflower. Other rare dune species include the ram's head ladyslipper, white trillium, jack-in-the-pulpit, green-headed cone flower, and several orchids (Lake Michigan Federation 1999).

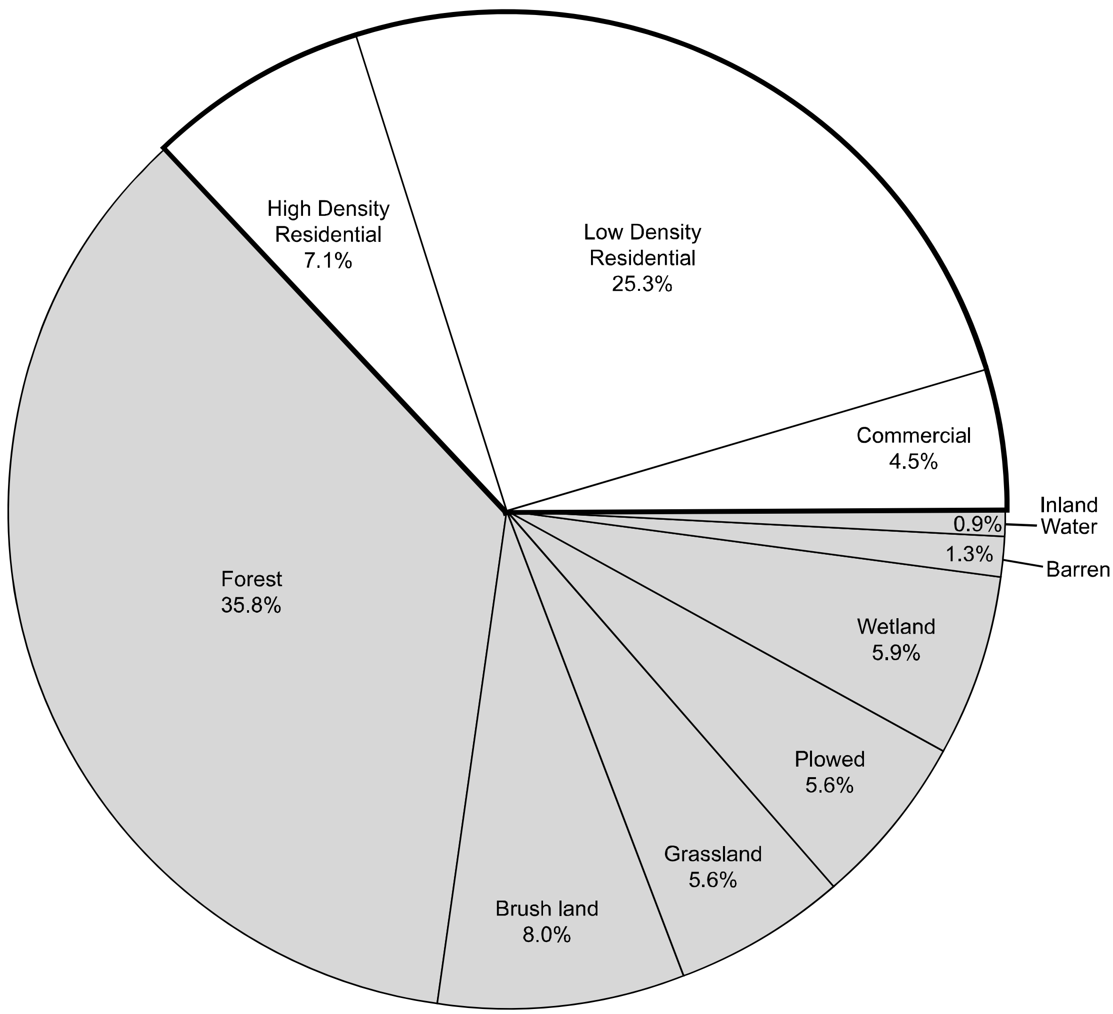
In addition to the negative impact dune mining has on species survival, it also has the potential to negatively affect the tourist industry. Sleeping Bear Dunes National Lakeshore in Michigan draws more than 1 million visitors each year. The National Park Service calculated in 1991 that the economic benefits of Sleeping Bear Dunes exceeded $39 million since the park's creation, and it has provided more than 1,000 jobs (Lake Michigan Federation 1999).

The dunes provide coastal marshes and support the species that inhabit them, they contribute to a high quality of life for shoreline communities, and they moderate winds and weather blowing in from Lake Michigan. Sand dunes are irreplaceable and could not be recreated if they are destroyed by mining activities (Lake Michigan Federation).

5.1.1.3 Other Physical Stressors

Land use and its associated impacts are significant issues in the Lake Michigan basin. As urban areas grow and agricultural and open space decrease, land use has a significant impact on the quality and sustainability of Lake Michigan. This section addresses two other sources of physical stress to the Lake Michigan ecosystem not directly related to basin land use: natural erosion and climate change. The Lake Michigan shoreline is about 1,400 miles in length and includes approximately 67,600 square miles of land. Figure 5-3 presents the land use of the Lake Michigan shoreline.

Figure 5-3. Land Use of the Lake Michigan Shoreline (1978)



Source: **Living with the Lakes: Challenges and Opportunities. A Progress Report to the International Joint Commission. 1989.**

Natural Erosion

Storms and seiches produce wave, longshore current, wind, and ice action, eroding exposed rock from bluffs or sand from beaches. Wind and tidal effects of the sun and moon generate waves. When conditions are stormy, waves often strike the shore head-on. Usually, they strike obliquely, leaving a cuspate or nonuniform beach pattern.

Longshore currents are generated by obliquely striking waves. They move at an angle to the shore, carrying sediment eroded from bluffs and beaches and from the banks of streams and tributaries to distant shores. But as well as eroding sand from beaches and dunes, waves and longshore currents are also constructive forces, depositing sand to form dunes, beaches, sandbars, shoals, or spits.

Wind also erodes sand dunes and beaches. High velocity winds cause grains of sand to bounce along and collide with other sand grains by a process known as "saltation." Eventually, a ridge of sand is formed parallel to the shore. Strong winds and human disturbances cause blowouts, or saucer-shaped gaps in dunes.

Ice erodes sand and rocky bluffs. At the shoreline, freezing waves churn with sand and build up, becoming ice shelves in the lake. During spring thaw, ice and sand break off and float free of the shore. Over time, water freezing and thawing in the fissures of rocky bluffs cracks off chunks of rock.

Groundwater and surface water runoff erode the nearshore. Groundwater seeps through the permeable layers of a bluff causing it to slump. Surface runoff, propelled by rain, snowmelt, and irrigation, removes soil from upland to nearshore areas.

The rate of change caused by these processes at any shoreline site is influenced by a host of factors, such as shoreline substrate, degree of exposure to wave action, natural or artificial barriers to alongshore sand movement, water level changes, the degree of winter ice cover, shoreline armoring, and natural and artificial disturbances. On the rockier shores of northern Lake Michigan, erosion is slow. On the sandier shores of the southern part of the lake, the effects of erosion can often be seen after a single storm event.

Another naturally-occurring source of stress is a recurrent plume of resuspended silt- and clay-like particles occurs annually during the spring isothermal period within southern Lake Michigan. Although light availability has been hypothesized to regulate, in part, Lake Michigan phytoplankton, linkages between the plume and the spring diatom bloom are unknown. Researchers are evaluating the impacts of the plume on the lake's phytoplankton and in situ water-column optics to assess the influence of light availability on phytoplankton biomass and associated rate processes. The plume appeared to alter the intensity and composition of the spring bloom; generally, values of total chlorophyll biomass values at stations severely affected by the plume were slightly greater than values at less-affected stations. Centric diatoms, particularly species of *Cyclostephanos* and *Aulacoseira*, constituted the greatest proportion of the assemblages and appeared to have greater light-harvesting ability (as determined by microphotometric techniques) than other common phytoplankton, possibly explaining their dominance during this episodic event. Although no great differences in bulk P-1 parameters were observed, phytoplankton production appeared to be suppressed to a greater degree at nearshore stations severely affected by the plume than at the less-affected offshore stations (Millie and others 1999).

Climate Warming, Water Levels and Impacts on Lake Michigan

Based on projections using several state-of-the-art models (Mortsch and Quinn 1996, Croley 1991), experts from NOAA and Environment Canada believe that global warming could result in a lowering of lake levels by a meter or more by the middle of the 21st century. This development would cause social, economic and environmental impacts throughout the Great Lakes region (International Joint Commission [IJC] 2000).

Scientists have known for more than a century that gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide produce a *greenhouse effect* by allowing short wave solar radiation to enter the atmosphere, while at the same time preventing long wave terrestrial radiation to pass back out. This is a natural and beneficial process, without which Earth would be a frozen and lifeless planet. However, scientists are concerned that human activities, such as the burning of fossil fuels and the destruction of tropical rain forests, are elevating the concentrations of greenhouse gases to the point where they could have a dangerously disruptive effect on the atmosphere by producing an artificially *enhanced greenhouse effect*.

The anthropogenic factors that produced climate warming cannot easily be controlled or reversed. It is important therefore, to encourage the use of sustainable energy alternatives, reforestation, and other practices that will reduce the emissions of greenhouse gases, as well as to formulate adaptation strategies for societal adjustment to potential climate change and variability. These strategies should be based on realistic assessments of future greenhouse emissions and predictions, or scenarios, of the future climate that would result from them. As part of its Great Lakes St. Lawrence Basin (GLSLB) Project, Environment Canada has developed such scenarios for the Great Lakes region. A report that examines in detail these scenarios and the potential impact they would have on the communities and ecosystems in and around Lakes Erie and Ontario is in preparation (Jessup in prep.).

The results of models run on the scenarios created for the GLSLB project, predict the same general results, but to varying degrees. Air temperature, precipitation, evapotranspiration, runoff, and lake surface water temperatures will increase. Total basin moisture, snow, soil moisture, groundwater levels, lake levels, and percent ice cover are predicted to decrease.

In addition to changes in the type of precipitation, there will also be an increase in precipitation variability and intensity caused by the greater frequency of intense cyclones, and the reduction of mild ones. The effect of this, coupled with increased evapotranspiration, may be a corresponding increase in both the frequency and severity of floods (IPCC 1996) and droughts.

Of particular concern are the predictions of poorer water quality and shifts in species composition. Increases in fish yields (warm water species) will be concurrent with eutrophic-like conditions and increased contaminant loading and bioavailability.

The Chicago Tribune (Kendall and Ahmed-Ullah 2000) recently reported that lower than usual snow and rainfall since 1997 adds another source of stress to Lake Michigan. The lake is at its lowest level in years, about 9 inches lower than 1999. Carriers shipping cargo on the Great Lakes will be unable to fill their holds to capacity for the second year in a row so that they will not run aground, reducing the total tonnage shipped on the lake and decreasing the raw materials and finished products available to industries that depend on them. In 1999, 1,000-ft oceangoing ships had to reduce their loads by up to 3,500 tons to make it through the locks that lead out of the lakes. The lower lake levels allow the water temperature to increase resulting in increased proliferation of the bacteria that cause beach closures. Beach closures rise as lake levels drop.

While a warmer climate will provide longer seasons for agriculture and commercial shipping, changes in seasonal runoff patterns, decreases in total basin moisture, and lake-level decline will have negative consequences. Lake-level decline will also result in significant loss, migration, and changes in wetlands. Most impact assessment efforts have been concentrated on physical responses. The biological consequences of the physical responses to climate change have yet to be seriously explored.

It should not be assumed that climate change impacts on the Great Lakes basin ecosystem will take place only gradually over the next several decades. Human-induced climate change will be superimposed on normal climate variability and natural events, intensifying storm events or climate conditions. Due to the predicted impacts of climate changes on lake levels, it is suggested that considerable caution be exercised with respect to any factors potentially reducing water levels and outflows (IJC 2000).

The Lake Michigan Technical Coordinating Committee decided early in the development process that addressing the issue of water levels in Lake Michigan was beyond the scope of the LaMP and was being addressed under other venues. However, with the potential impacts that climate change could have on the entire lake ecosystem, the Lake Michigan LaMP may need to further discuss this issue.

Falling lake levels are part of the reason the U.S. Fish and Wildlife Service(FWS) is drafting plans to manage Lake Michigan islands for the next 15 years and address issues such as hunting, boater access, protection of nesting birds, and creation of a biological inventory of plants and animals. The U.S. Army Corps of Engineers report “Living with the Lakes: Understanding and Adapting to Great Lakes Water Level Changes” can be found at www.glc.org/docs/lakelevels/lakelevels.html.

5.1.1.4 Sources of Data and Information

The following databases and documents were the primary sources of data and information used in discussing physical stressors.

1996 State of the Lakes Ecosystem Conference (SOLEC) Website
http://www.epa.gov/grtlakes/solec

This website was compiled after the 1996 SOLEC. The conference proceedings as well as papers pertaining to various land uses, land use change, and land use stresses in the Great Lakes region are presented on this website. The website is maintained by U.S. Environmental Protection Agency (EPA) Great Lakes National Program Office with input from Environment Canada (SOLEC 1996).

Great Lakes Environmental Assessment

This document was prepared by Limno-Tech, Inc. (LTI) in 1993 for the National Council of the Paper Industry for Air and Stream Improvement in an effort to characterize the state of the Great Lakes environment. Information is presented on the current status of, trends in, and likely causes for the conditions in the following areas: water and sediment quality, habitat, exotic species, human uses, and health effects on aquatic life, wildlife, and humans.

5.1.2 Biological Stressors - Aquatic Nuisance Species and Pathogens

Biological stressors cause a decline in the health of any ecosystem and negatively affect fish, plant, and wildlife populations. Biological stressors contribute to the following impairments (IEPA 1996b).

- Degraded fish and wildlife populations
- Benthos degradation
- Restrictions on drinking water consumption, odor or taste problems with drinking water
- Beach closings
- Added costs to agriculture or industry
- Degradation of phytoplankton and zooplankton populations
- Loss of fish and wildlife habitat

Introduction of aquatic nuisance species (ANS) and loss of normal habitat have been sources of biological stress in Lake Michigan for more than 150 years. The stresses caused by habitat loss and competitive pressures from ANS have a great impact on biological diversity of the lake because they affect multiple systems and tend to be less reversible than stressors in other categories (Nature Conservancy 1994). Invasion of nuisance species and loss of habitat are the two most significant, ongoing, and long-lived threats to the integrity of the lake ecosystem (LTI 1993). Consequences of such stress include loss of biodiversity in the lake, change in the make-up of the biota of the lake, losses to commercial and sport fishing industries, and threats to species that depend on the lake and surrounding areas for breeding grounds and habitat.

Aquatic Nuisance Species

Aquatic nuisance species are also called nonnative species, nonindiginous invasive species, and ANS. They are plants, animals, and microorganisms that are accidentally or deliberately introduced into an environment that is not their regular habitat. They survive at the expense of species that are already established. Aquatic nuisance species introduced anywhere in the lower Great Lakes often end up in Lake Michigan. The aquatic nuisances include fish, invertebrates, disease pathogens, algae, and marsh plants. When these species are free from the competitors, predators, parasites, and pathogens that control their populations in their native habitat, they thrive and are a major cause of continuing loss of desirable plant and animal species (MDEQ 1999b). Native Lake Michigan fish including lake trout, walleye, yellow perch, and whitefish are threatened by increasing populations of ANS, such as zebra mussels, sea lampreys, ruffe, and round goby (Anonymous 1997).

Since the mid-1800s, at least 136 ANS have become established in the Great Lakes basin. Ship ballast water is one of the most common vehicles for introducing ANS into the lake, as illustrated in Table 5-1. The invaders include 61 plant species, 24 fish species, 24 algal species, 24 mollusk species, and 7 oligochaete species. Most of them arrived from Europe (47 percent), the Atlantic Coast (18 percent)

Table 5-1. Aquatic Nuisance Species Found in Lake Michigan

Common Name	Species	Origin	Date of Discovery	Place of Discovery	Mechanism of Introduction
Fish					
Sea lamprey	*Petromyzon marinus*	Atlantic Coast	1830s	Lake Ontario	Canals, ship fouling
Alewife	*Alosa pseudoharengus*	Atlantic Coast	1873	Lake Ontario	Canals, accidental introduction with stocked fish
Common carp	*Cyprinus carpio*	Asia	1879	widespread	Deliberate release
rainbow smelt	*Osmerus mordax*	Atlantic Coast	1912	Crystal Lake, MI	Deliberate release
three-spined stickleback	*Gasteroosteus aculeatus*	unknown	unknown	unknown	unknown
white perch	*Morone americana*	Atlantic Coast	1950	Cross Lake, OH	Canals
round goby	*Neogobius melanostomus*	Eurasia	1990	St. Clair River	Shipping ballast water
tubenose goby	*Proterorhinus marmoratus*	Eurasia	1990	St. Clair River	Shipping ballast water
Invertebrates					
faucet snail	*Bithynia tentaculata*	Eurasia	1871	Lake Michigan	Shipping solid ballast, deliberate release
European ear snail	*Radix auricularia*	Eurasia	1901	Chicago	Aquarium release, accidental release
Zebra mussel	*Dreissena polymorpha*	Eurasia	1988	Lake St. Clair	Shipping ballast water
Oligochaete	*Branchuria sowerbyi*	Asia	1951	Kalamazoo River, MI	Accidental release
Spiny water flea	*Bythotrephes cederstromi*	Eurasia	1984	Lake Huron	Shipping ballast water

Table 5-1. Aquatic Nuisance Species Found in Lake Michigan (continued)

Common Name	Species	Origin	Date of Discovery	Place of Discovery	Mechanism of Introduction
Water flea	*Eubosima coregoni*	Eurasia	1966	Lake Michigan	Shipping ballast water
Parasitic copepod	*Argulus japonicus*	Asia	<1988	Lake Michigan	Accidental release, aquarium release
Disease Pathogens					
furunculosis	*Aeromonoas salmonicida*	unknown	<1902	Unknown	Release with stocked fish
microsporidian parasite	*Glugea hertwigi*	Eurasia	1960	Lake Erie	Release with stocked fish
whirling disease	*Myxobolus cerebralis*	unknown	1968	Ohio	Release with stocked fish
Algae					
diatom	*Biddulphia laevis*	widespread	1978	Lake Michigan	Shipping water ballast
diatom	*Cyclotella atomus*	widespread	1964	Lake Michigan	Shipping water ballast
Diatom	*Stephanodiscus binderanus*	Eurasia	1938	Lake Michigan	Shipping water ballast
Diatom	*Stephanodiscus subtilis*	Eurasia	1946	Lake Michigan	Shipping water ballast
Diatom	*Diatoma ehrenbergii*	widespread	1930s	Lake Michigan	Shipping ballast water
Diatom	*Cyclotella cryptica*	widespread	1964	Lake Michigan	Shipping ballast water
Diatom	*Cyclotella pseudostelligera*	widespread	1946	Lake Michigan	Shipping ballast water
Diatom	*Cyclotella waltereki*	widespread	1964	Lake Michigan	Shipping ballast water
Brown alga	*Sphacelaria lacustris*	unknown	1975	Lake Michigan	Shipping water ballast

Table 5-1. Aquatic Nuisance Species Found in Lake Michigan (continued)

Common Name	Species	Origin	Date of Discovery	Place of Discovery	Mechanism of Introduction
Marsh Plants					
Purple loosestrife	*Lythrum salicaria*	Eurasia	1869	Ithaca, NY	Canals, shipping ballast water
Seaside goldenrod	*Solidago sempervirens*	Atlantic Coast	1969	Chicago, IL	Accidental release

and Eurasia (14 percent). About 10 percent of these ANS have a significant ecological or economic impact (Great Lakes Commission 1999c). Table 5-1 shows the ANS that now inhabit Lake Michigan, their probable origin, when and where they were first discovered, and how they were introduced into the Great Lakes system. Species that are not native to Lake Michigan have been introduced in several ways over the past 150 years. Atlantic coast species such as the sea lamprey and the alewife arrived through the canals connecting the Great Lakes with the Atlantic Ocean, by ship fouling, and by accidental introduction with stocked fish. Some of the aquatic nuisance snails were deliberately released from aquariums, and some were unknowingly released with shipping ballast water. Almost all of the nonnative algae were released within the last 50 years in shipping ballast water. Marsh plants, such as purple loosestrife and seaside goldenrod, were introduced in shipping ballast and as an accidental release, respectively.

Table 5-2 shows the prevalence of the most common nuisance species in Lake Michigan.

Table 5-2. Exotic Species in Lake Michigan

Species	Prevalence
Zebra mussel	Widespread, hard to control
Sea lampreys	Widespread, under control
Alewives	Widespread, under control
Round goby	Widespread, hard to control
Ruffe	Not yet in Lake Michigan
Purple loosestrife	Widespread, hard to control
Spiny water flea	Widespread, hard to control
Eurasian water milfoil	Widespread, hard to control
Cercopagis pengoi	Widespread

This section discusses the following ANS whose effects on the Lake Michigan habitat are best documented: zebra mussels, sea lampreys, alewives, round goby, ruffe, purple loosestrife, spiny water flea, and *Cercopagis pengoi*. It also covers introductions of beneficial nonnative species used to control ANS.

<u>Zebra Mussels</u>

Zebra mussels were accidentally introduced into the Great Lakes from Eurasia around 1988 in shipping ballast water. They spread quickly to at least 20 states and two Canadian provinces bordering the Great Lakes and to the Mississippi River (FWS and others 1999). Zebra mussels can grow up to 2 inches (in), but they are usually less than 0.5 in long. They have a life span of about 5 years, and an adult female can produce more than 30,000 eggs per season (Great Lakes Commission 1999c). The larval mussels are scattered by currents over a wide area, and the adults attach in clusters to any hard, nontoxic surface.

Zebra mussels filter microscopic algae from the water column, diverting nutrients from open water to the lake bottom; this favors bottom-dwelling species and their predators over those that feed in open water, and it also gives rooted aquatic plants and associated species such as large mouth bass a chance to thrive at the expense of walleye and other species adapted to turbid water (Anonymous 1997). Zebra mussels have also had a negative impact on the population of the amphipod *Diporeia* species (spp.) in southern Lake Michigan. Nalepa's group (Nalepa 1987) at NOAA studied the densities of macroinvertebrate populations from 1980 through 1999. They found that the densities of *Diporeia* started to decline in 1992 in the southeastern part of the lake. By 1999, the area of reduced *Diporeia* populations expanded to include the southern part of the lake from Chicago on the western shore to Grand Haven on the eastern shore. Densities have declined to zero at depths of 45 meters. *Diporeia spp*. are important in the Lake Michigan food web because they feed on material that settles to the bottom and are a food source for most species of fish. Nalepa's group suspects the decline of *Diporeia* is due to the introduction and rapid growth of zebra mussel populations that filter out food material before it settles on the lake bottom, leaving little food for *Diporeia* (Nalepa 1987).

In addition to their negative impact on native species, zebra mussels damage boats left in the water, foul beaches, and clog water intake pipes (Minnesota Sea Grant Program No date), causing millions of dollars of damage to municipal power plants and water pumping stations (FWS and others 1999).

<u>Sea Lampreys</u>

Sea lampreys arrived in the Great Lakes in the 1830s by way of the Welland and Erie Canals, spread as far as Lake Michigan by 1936, and decimated the native lake trout population by the mid-1950s (Peeters 1998). They are primitive eel-like predators that attach to the body of a fish and suck blood and tissue from the prey's wound. Lampreys prey on all large Great Lakes fish such as lake trout, salmon, rainbow trout, whitefish, chubs, burbot, walleye, and catfish. Each lamprey can kill more than 40 pounds of other fish. Although the exact number of lampreys present in Lake Michigan before control efforts took effect is unknown, their effect on the lake's fishery is a good indicator. The catch of lake trout in Lake Michigan dropped from 5.5 million pounds in 1946 to 402 pounds in 1953 (Glassner-Shwayder 1999). Effective lamprey control programs were implemented by the mid-1960s, allowing reintroduction of some native species back into the lakes.

<u>Alewives</u>

Alewives were first seen in the Great Lakes in 1873. They came through the Welland and Erie Canals. Their impact on native fish populations evolved in conjunction with the decimation of the trout population by sea lampreys. Without the trout as predators, alewives flourished and became the dominant fish species in Lake Michigan, making up 85 to 90 percent of the lake's fish biomass by the mid-1960s (Grand Valley State University 1999). The alewife explosion caused the reduction or elimination of many native species. Six of seven chub species were eliminated, causing closure of the commercial chub season. Lake herring, yellow perch, and emerald shiner populations were also negatively affected, along with the commercial and sport fisheries on the lake (Grand Valley State University 1999). In the mid-1960s, before stocked predator species expanded enough to keep them under control, the alewife population explosion altered food webs, thereby increasing water turbidity. In addition, alewife corpses washed up on Lake Michigan beaches each spring causing a negative impact on the tourist industry and beach-related recreational activities (Great Lakes Commission 1999c).

<u>Round Goby</u>

The round goby was introduced into Lake St. Clair from shipping ballast water in 1990. In less than 10 years it spread to all five of the Great Lakes, including southern Lake Michigan, where it is now established in the Illinois Waterway System. The Illinois Waterway System provides a direct connection between the Great Lakes and the Mississippi River. Round goby are bottom-dwelling fish that could cause great negative impact on Great Lakes fisheries. They are aggressive, voracious feeders that can forage in total darkness. They take over prime spawning sites traditionally used by native species, and they compete with native fish populations for food and habitat, thus changing the balance of the ecosystem. Goby can survive in degraded water conditions, and they spawn more often and over a longer period than native fish. Bottom-dwelling species that are threatened by the round goby include sculpin, logperch, and darters (Glassner-Shwayder 1999).

Ruffe

Ruffe is a Eurasian percid fish not yet found in Lake Michigan, but it is likely that they will arrive soon. They were introduced into Duluth-Superior Harbor in the western part of Lake Superior in ship ballast in 1986. By 1991, ruffe was the most abundant species in the harbor. A 1992 report by the Great Lakes Fisheries Commission called ruffe a threat to North American fisheries, and a control program was established. By 1995, ruffe spread to northern Lake Huron. The impact of ruffe on other fish species is not proven, but research indicates that they cause profound changes in ecosystem energy flow, and simulation modeling indicates they will have a devastating effect on yellow perch (Glassner-Shwayder 1999). Even though ruffe are not yet established in Lake Michigan, plans are in place to control their spread to the Mississippi watershed through the Chicago, Des Plaines, and Illinois Rivers, indicating that they are expected to make their way into Lake Michigan in the future.

Purple Loosestrife

Purple loosestrife was brought to North America from Europe in the early 1800s, both in ship ballast water directly by settlers for their flower gardens. It has spread through much of the United States and Canada, including the area forming the Lake Michigan basin. About 190,000 hectares of wetland, marshes, pastures, and riparian meadows are affected by purple loosestrife each year. Purple loosestrife plants can produce nearly half a million seeds per square meter in wetland soil. This productivity has several devastating ecological effects. The plant thrives in moist soils, forming dense stands that rapidly degrade wetland areas and choke out native vegetation. The purple loosestrife stands are unsuitable as habitat for many wetlands animals, including ducks, geese, muskrats, frogs, and turtles. It threatens areas where fish spawn and where rice grows. The habitat destruction caused by purple loosestrife amounts to millions of dollars lost each year, and there is concern that the plant could spread further inland, encroaching on pastureland and cropland posing a threat to the economic health of the agriculture industry (Glassner-Shwayder 1999).

Spiny Water Flea

The spiny water flea (*Bythotrephes cederstroemi*), also called "B.C.," is a 0.5-in crustacean introduced from Eurasia in shipping water ballast in the early 1980s. Since they were first identified in Lake Huron in 1984, they have spread to all the Great Lakes and to some inland lakes. Spiny water fleas are large zooplankton that compete with small fish, such as young perch, for food. They reproduce rapidly. During warm weather each female can produce up to 10 offspring every 2 weeks, and they can produce eggs that stay dormant during cold weather (Great Lakes Information Network No date[b]). Spiny water fleas are not heavily consumed by predators because their long barbed tail makes it difficult for small fish to eat them; as a result, only some large fish feed on them. Because it has relatively few predators, spiny water flea populations remain high, and the populations of plankton they eat have declined (Great Lakes Information Network No date [b]). They can foul fishing equipment when present in large numbers (Minnesota Sea Grant College Program No date).

Eurasian Water Milfoil

Eurasian water milfoil was accidentally introduced from Europe and reached the midwestern states between the 1950 and 1980. It is a floating plant that grows and spreads rapidly, choking out native plants, harming fish habitat, and interfering with boating, fishing, and swimming (Minnesota Sea Grant College Program No date; Great Lakes Information Network No date[a]). A key factor in this plant's success is its ability to reproduce from stem fragmentation and underground runners. A single segment of stem and leaves can take root and form a new colony. Boaters can easily spread the plant from lake to lake, and the mechanical removal of weed beds for commercial and recreational use creates thousands of new stem fragments. Removing native vegetation creates a perfect habitat for Eurasian water milfoil, but it has difficulty becoming established in lakes that have healthy native plant populations. It has little direct impact on fish and other aquatic animals (Great Lakes Information Network No date[a]).

Cercopagis pengoi

In September 1999, *Cercopagis pengoi*, a crustacean smaller than the spiny water flea, was first seen in Lake Michigan in Grand Traverse Bay (Great Lakes Information Network 1999). It was probably introduced into Lake Ontario in shipping ballast water from Eurasia in 1998. This species can reproduce both sexually and pathenogenically, produce up to 13 offspring at a time, have numerous broods per season, and produce eggs that can remain dormant over the winter, making it possible to establish a new population quickly from a relatively small seed population (Glassner-Shwayder 1999). *Cercopagis* usually resides in the warmer, upper ranges of the lake where it is very vulnerable to predation by larger planktivorous fishes. To avoid predation, they migrate to lower depths during the daylight hours. *Cercopagis* fouls fishing gear for both recreational and charter boat operations, sometimes making it impossible to reel in a line. Potential ecological disruptions resulting from *Cercopagis* include decline of native zooplankton populations, disruption of established food webs in the lake, and disruption of the established fishery.

Controlling Aquatic Nuisance Species

Because the impacts of ANS are unpredictable and most likely irreversible (LTI 1993), controlling the spread of existing invaders and preventing the introduction of new ones is imperative. The zebra mussel problem played a key role in prompting passage of the federal Nonindiginous Aquatic Nuisance Species Prevention and Control Act of 1990 (P.L. 101-646) (Great Lakes Commission 1999c). In drafting this legislation, Congress recognized the need for a well coordinated research, monitoring, and prevention program at the Great Lakes and national levels. As a result of this Act, the Aquatic Nuisance Species Task Force was established to coordinate government and private efforts relating to ANS. Also as a result of this Act, the Great Lakes Panel on Aquatic Nuisance Species was convened to address problems specific to the Great Lakes basin (Great Lakes Commission 1999c). Amendments to the 1990 Act form the National Invasive Species Act of 1996 (NISA), which provides for nationwide voluntary guidelines that may be followed later by mandatory controls (Anonymous 1997).

In recent years, progress has been made to decrease the number of new ANS introduced from ships. Ships now voluntarily exchange their ballast water at sea, flushing out organisms and raising the salinity of the ballast water to kill any freshwater organisms remaining in the ballast hold. Other methods include heating the water or passing the water through ultraviolet light (MDEQ 1998b).

The Michigan Department of Natural Resources and the Michigan Sea Grant College Program distribute a pamphlet for boaters and sport fishermen identifying zebra mussels, ruffe, spiny water fleas, and Eurasian water milfoil, describing the problems they cause and the danger of unknowingly transporting them to new locations on boats and fishing gear. It describes steps to prevent further infestations (Minnesota Sea Grant College Program No date).

Zebra mussels cause millions of dollars of damage to municipal and industrial water intakes. So far there is no viable way to manage or eliminate zebra mussels, but several mechanisms have been used to control infestations including a traveling screen mesh, micro-straining fabrics, physical scraping, electrical currents, electrostatic filters, and replacement of blocked intake pipes (Great Lakes Commission 1999c).

Trapping, release of sterile males, and application of lampricide to spawning areas resulted in a significant level of cost-effective, environmentally sensitive control for the last remaining unchecked population of sea lampreys in northern Lake Michigan and Lake Huron. The control program should decrease the sea lamprey populations in this area by at least 85 percent and allow restocking of lake trout and other fishery rehabilitation programs (Anonymous 1997).

The round goby is the newest fish to invade the Great Lakes. It was first seen in the St. Clair River near Detroit in 1990 and within 10 years had spread to Lake Michigan. So far, the goby is confined to the Great Lakes basin, and efforts are underway to prevent their spread to the Mississippi River through the I&M Ship Canal in Illinois. Congress appropriated $250,000 to construct an electronic barrier to prevent their passage through the canal (Anonymous 1997).

Obvious impacts caused by ANS have been described in the literature, but little is known about subtle or chronic effects that are not highly visible, are masked in their perception by other factors, or have not affected major parts of the ecosystem (LTI 1993).

Based on the information currently available, the rate of invasion by ANS appears to be accelerating, and the geographical regions from which these species originate is expanding.

Beneficial Aquatic Nuisance Species

Much attention is focused on undesirable ANS in Lake Michigan, but the deliberate introduction of some nonnative species has had beneficial effects. Once an effective sea lamprey control program was established in Lake Michigan, native lake trout could be re-introduced into the lake in the mid-1960s (Peeters 1998). Coho and chinook salmon, both nonnative species, were also introduced at the same time as the trout because they are more efficient predators of alewives. The trout and salmon stocking program resulted in a significant reduction in the alewife population, and this has allowed an increase in native species such as whitefish, bloater chubs, lake herring, burbot, and yellow perch. Alewives are now an important source of food for the introduced predator species (Peeters 1998). The Lake Michigan fishery has evolved from a simple fishery dominated by alewives in the early 1960s to a diverse fishery with complex species interactions today (Grand Valley State University 1999).

Reef Building

Although artificial reefs do not cause habitat loss, they do modify the existing lake habitat. Three artificial reefs were constructed in Lake Michigan to create habitat for fishery management, and their effectiveness is still being evaluated (Anonymous 1997). The Great Lakes Fishery Commission set up a task force in 1987 to look at the use and value of artificial reefs in the Great Lakes, and it advised that all reefs should be carefully planned to maximize benefits and avoid negative impacts. If the reefs are placed on soft sediments, they will sink, and their value in providing favorable habitat is wasted. So far the value of artificial reefs has been to attract fish, but any broader ecological benefits, such as productivity enhancement, have not been demonstrated (Anonymous 1997). The Great Lakes Fishery Commission's 1990 report (Gannon 1990) concludes that artificial reefs should be considered experimental and that they require comprehensive monitoring and long-term evaluation of ecological and socioeconomic perspectives.

In rare cases artificial reefs are used as a replacement to mitigate unavoidable destruction of natural reef habitat, but usually this is not an acceptable use because artificial reefs cannot replace the productivity of the natural ecosystem (Gannon 1990). Reefs should not be used to mitigate dissimilar habitat types, such as compensating for the destruction of a wetland by constructing a reef.

5.1.3 Pathogens

This section discusses pathogens as biological stressors on the Lake Michigan ecosystem, including the species that pose a threat to human health, the effects these pathogens have on physical health and the economy, sources and loadings in the Lake Michigan basin, and existing management programs.

5.1.3.1 Introduction

Pathogen loadings to Lake Michigan present a challenge to achieving two end point sub goals: *No. 2 — We can all drink the water* and *No. 3 — We can all swim in the water*. The following subsections provide an overview of pathogens in the Lake Michigan basin, including general sources of pathogens, management programs to control pathogens in surface waters, economic and health effects of pathogens, and specific sources and loadings in the Lake Michigan basin.

5.1.3.2 Overview

The following table, Table 5-3, lists the types of organisms that cause waterborne diseases (EPA 1996b).

Table 5-3. Causative Organisms of Waterborne Diseases

Viruses	Bacteria	Protozoa	Algae	Worms	Yeasts, Fungi
Hepatitis A	Coliforms	*Entamoeba*	Cyclospora	Schistosomes	Candida
Norwalk	Leptospira	*Cryptosporidium*	Microcystis		
Rota	Legionella	*Giardia*			
Adeno	Salmonella	*Naegleria*			
Entero	Aeromonas	Toxoplasma			
Reo	Pseudomonas				
	Shigella				
	Staphylococcus				
	Escherichia coli				

All of these pathogens are commonly found in North America, including the nearshore waters of Lake Michigan. The most prevalent human pathogens are *E. coli*, found in localized outbreaks; *Cryptosporidium*, found in rare, localized outbreaks; and *Giardia lamblia*, which is widespread in the lake. They are more common in areas polluted by agricultural runoff, sewage discharges, and wildlife excrements.

Some of the pathogens in the nearshore waters use humans as their host organisms. Many of these same organisms also thrive in wild and domestic animals, including amphibians, reptiles, aquatic birds, beaver, moose, and cattle that live, forage, or swim in lakes and tributary streams or otherwise frequently come into contact with the water (EPA 1996b). The pathogens or their cysts or eggs are discharged into nearshore waters in excreta or sewage.

In order to cause a disease, a pathogen must successfully invade some part of the body and either produce more of itself or secrete a toxin that interferes with normal body processes (USGS No date[a]). The *E. coli* bacteria found in human and animal digestive tracts is not considered a danger to healthy individuals, but its presence increases the possibility that other pathogens may be present that can cause amoebic dysentery, hepatitis, polio, and a number of digestive ailments (Ting 1996).

5.1.3.3 Effects

Recreational use of nearshore waters, including swimming, boating, windsurfing, and fishing, may result in exposure to microbial pathogens. Waterborne illnesses have become rare in the Great Lakes basin during the past 100 years thanks to vaccinations and effective hygiene measures, especially drinking water and sewage disinfection. Children, the elderly, and people with weakened immune systems are most susceptible to developing an illness or infection after swimming in polluted water. Diarrhea, sore throat, skin infections, and eye infections are common conditions caused by exposure to pathogenic bacteria, viruses, and protozoans.

E.coli is a coliform bacteria from human and animal wastes that is found on beaches and in nearshore water when sewage is discharged without proper treatment, and it can also be in drinking water that has not been adequately treated or disinfected. It is the most common pathogen found in the waters near public beaches (EPA 1996b). Ingesting *E. coli* results in diarrhea and flu-like symptoms.

Cryptosporidium is a protozoan that can pass through water treatment and disinfection processes in sufficient numbers to cause health problems. It causes a gastrointestinal disease called cryptosporidiosis. An outbreak of cryptosporidiosis in Milwaukee, Wisconsin in 1993 was the largest outbreak of waterborne disease ever in the United States (Water Reserves USA No date).

Giardia lamblia is a protozoan that is found in the gastrointestinal tract of some mammals that live in the Great Lakes basin, and it can enter the water through fecal matter from these animals. The organism causes severe diarrhea in humans. It is present even in pristine, clear, cold streams, so people who backpack or hike in the wilderness areas of the basin are advised to treat all water before drinking it (USGS No date[a]).

There are 581 beaches listed for the Great Lakes basin, and on any summer weekend, at least a million people visit them (EPA 1998h). Beach closures most often are caused by high levels of microorganisms coming from sewage overflows and polluted stormwater runoff from cities and farms. (EPA 1998h). Trends in beach closings and the economic impacts of the closings are discussed in Section 4.2.4.1 of Chapter 4.

There are viruses and bacteria present in the lake Michigan basin that are not a threat to humans but could have a negative impact on the health of some fish and wildlife species. *Renibacterium salmoninarum* is found in Lake Michigan. It can cause bacterial kidney disease in some salmonid species. Coho salmon, domestic Atlantic salmon, and chinook salmon are relatively susceptible to infection from this bacteria. Lake trout, rainbow trout, and brook trout are fairly resistant (Starlipper, Smith, and Shatzer 1997). A decline in these species would have a negative effect on the successful sport fishery that has been established in Lake Michigan since the mid-1960s. Newcastle disease virus (NDV) was found in juvenile double-crested cormorants nesting near Lake Michigan and other sites in the Midwest. Mortality is as high as 80 to 90 percent in some nesting colonies. Adult birds were not affected. NVD has the potential to infect domestic poultry, so early recognition and confirmation of the virus in wild birds is essential (Meteyer and others 1997).

The parasite *Myxobolus scleroperca* infected the sclerotic cartilage of 26 of 100 yellow perch studied in late summer 1991 from the Indiana waters of Lake Michigan. The parasite infected fish larger than 94 mm but not smaller ones, resulting in an uneven distribution on the host population. Either smaller fish are not susceptible or the susceptible individuals could die early. If this parasitic infection results in a decreased perch population, there could be a negative impact on the Lake Michigan fishery industry.

Blooms of blue-green algae (cyanobacteria) in areas of the lake used for drinking water sources can result in degraded water quality from toxins secreted by the algae (EPA 1996b). This can result in higher water treatment costs or higher expenditures for bottled water.

5.1.3.4 Sources and Loadings in the Basin

Since 1990 the rivers, creeks, and ditches of northern Indiana have exceeded the state criteria for swimmable water (less than 235 *E. coli* per 100 ml of water). High *E. coli* counts are sometimes associated with periods of heavy rainfall, but sometimes the cause cannot be identified (MDNR 1998a). *E. coli* levels are not uniform in the nearshore waters of Lake Michigan, and scientists still do not understand how extensively tributary streams transport the bacteria into the lake. Some beaches can be closed due to high *E. coli* levels at the same time that sampling at other beaches along the shoreline show no *E. coli* present (MDNR No date[b]).

Leading sources of pathogen pollution in Lake Michigan include unspecified point sources, agriculture, contaminated sediments, municipal and industrial discharges, combined sewers, and atmospheric deposition (EPA No date[q]).

5.1.3.5 Sources of Data and Information

The following sources provided material for this section.

Anonymous. 1997. *Artificial Reefs: Growing Interest, Growing Issues.* Great Lakes Commission Advisor. May/June. Page 10.

This report explored the pros and cons of building artificial reefs in the Great Lakes and the effect such reefs have on the lake fisheries.

Dewailly, E., Poirier, C., Meyer, F., 1996. "Health Hazards Associated with Windsurfing on Polluted Water ." American Journal of Public Health. 76(6): 690-691.

EPA. 1996. "Nearshore Waters Draft 2." State of the Lakes Ecosystem Conference (SOLEC '96). Accessed December 14, 1999. http://www.epa.gov.grtlakes/solec/water/index.html

This report is the proceedings of a conference designed to further the purpose of the Great Lakes Water Quality Agreement between the United States and Canada, which is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes basin ecosystem.

EPA Office of Water, 1999. BEACH Watch Program Homepage. EPA website at http://www.epa.gov/OST/beaches/. Revised April 13, 1999.

Great Lakes Commission. 1999. "Counterattack: Great Lakes Panel Targets Aquatic Nuisance Species." Accessed November 22, 1999. http://www.glc.org/ans/glpatack.html

This report addresses the economic and environmental impacts of exotic species in the Great Lakes, especially zebra mussels.

Health Canada, 1998a. *Health Related Indicators for the Great Lakes Basin Population.* Numbers 1 to 20.

Limno Tech. 1993. *Great Lakes Environmental Assessment.* National Council of the Paper Industry for Air and Stream Improvements. Ann Arbor, Michigan.

This report described the status of the Great Lakes in the early 1990s and addressed issues of special interest to the pulp and paper industry.

Michigan Department of Environmental Quality. 1999. *Environmental Quality Report 1999.* State of Michigan, Lansing, Michigan. 1999. www.deq.state.mi.us/osep/ftp/deqeq99.pdf

This is a status report on the progress made by Michigan and the Department of Environmental Quality toward cleaning up and protecting the state's groundwater, lakes, streams, rivers, land, and air. It will provide a baseline for measuring future progress in environmental protection.

Indiana DNR. 1998. "Healthy Beaches Initiative." Accessed December 15, 1999. http://www.ai.org/dnr.lakemich/beach/htm

This web site talks about the collaborative efforts among several agencies trying to protect the health of the Indiana shoreline of Lake Michigan and the impact of lakeshore activities on Indiana's economy.

Ting, Evert and others. 1996. "Sea Grant, Others Working to Reduce Lake Michigan Beach Closings." Purdue News. August 23. Accessed December 14, 1999. http://www.uns.purdue.edu/html4ever/960823.Pope.html

This web site addresses the problem of *E. coli* and other bacterial contamination along Lake Michigan beaches, describes testing programs to target areas of pollution, and describes the impact of beach closings on the local economy.

Whitman, R.L., Gochee, Angel V., Dustman, Wendy A., Kennedy, Kevin J., 1995. "Use of Coliform Bacteria in Assessing Human Sewage Contamination." Natural Areas Journal. 15:227-233.

Water Reserves USA. Undated. "Is Your Drinking Water Safe?" Accessed December 14, 1999. http://www.angelfire.com/ct/ThreeCs/

This web site describes the problems caused by microbial contamination in drinking water supplies.

Additional information on aquatic nuisance species can be found at
http://www.great.lakes.net/enut/exotic.html

5.1.4 Chemical Stressors

In addition to the physical and biological stressors described above, chemical loading to the lake is also a significant source of impairment. This chapter describes 20 chemicals or classes of chemicals that have been identified as critical pollutants, pollutants of concern, or emerging pollutants, and introduces other pollutants of interest. Loadings of the critical pollutants and pollutants of concern specifically limit the goals to be able to eat Lake Michigan fish, drink Lake Michigan water, and maintain a healthy ecological habitat. Emerging pollutants, on the other hand, are included as a precautionary measure, either because of their widespread use in the basin, the fact that these chemicals are beginning to show up in monitoring data, or both. In the following sections, the rationale for selecting the 20 chemicals is described. The sources, characteristics, and loadings for each of the chemicals are summarized in Sections 5.2 and 5.3.

5.1.4.1 Identifying Lake Michigan Critical Pollutants

This section discusses the classification and definition of the Lake Michigan LaMP Critical Pollutants, Pollutants of Concern, and Emerging Pollutants; describes the LaMP Pollutants; presents information on their uses, general sources, physical and chemical characteristics, and contribution to use impairments; and identifies gaps in data collection and existing knowledge.

The Great Lakes Water Quality Agreement (GLWQA) defines Critical Pollutants as substances that exist at levels that impair beneficial uses due to (1) their presence in open lake waters, (2) their ability to cause or contribute to a failure to meet Agreement objectives, or (3) their ability to bioaccumulate. The Agreement defines persistent toxic substances as any substance with a half-life[1] in water of greater than weeks (Annex 12 Subsection 1(a)).

Under the GLWQA, Canada and the United States agreed to develop, in consultation with state and provincial governments, LaMPs for open lake waters. In addition to addressing persistent toxic pollutants that contribute to ecological impairments, the LaMP process identifies those pollutants that have not yet been associated with an impairment, but whose characteristics suggest the ability to affect the system. These include pollutants that are present in the Lake Michigan watershed, have known toxic characteristics, persist in the environment, and bioaccumulate. State, tribal, and federal agencies have the responsibility to identify and reduce loadings of substances to Lake Michigan waters through the LaMP process before they reach levels sufficient to cause environmental degradation.

A Critical Pollutant Work Group, consisting of technical staff from EPA, FWS, USGS, and four Lake Michigan states, has developed a process for listing and delisting substances as LaMP Pollutants and has identified those chemicals that, based on existing information, are affecting Lake Michigan and its watershed to some degree.

LaMP Pollutants are substances that, despite past application of regulatory controls, persist at levels that, singly or in synergistic or additive combination are causing or are likely to cause impairment of beneficial uses due to the following:

- Presence in open lake waters
- Ability to cause or contribute to a failure to meet agreement objectives through their recognized threat to human health and aquatic life

- Ability to bioaccumulate

Process For Categorizing Lake Michigan LaMP Pollutants

The Critical Pollutant Work Group recommended that LaMP Pollutants be categorized based on degree of association with use impairments and spatial distribution or frequency of occurrence.

Keeping faith with the GLWQA, chemicals that violate the most stringent federal and state water quality standard or criteria, exceed a U.S. Food and Drug Administration (FDA) of the Great Lakes Governors' proposed action levels in Lake Michigan fish, or are associated with lakewide use impairments are classified as **LaMP Critical Pollutants**. These substances are the focus of the LaMP program. Prevention, reduction, and remediation activities to reduce loads and ambient levels of these chemicals in the environment will be pursued by the participating agencies. The following are Lake Michigan critical pollutants: polychlorinated biphenyls (PCB), dieldrin, chlordane, dichlorodiphenyltrichloroethane (DDT) and metabolites, mercury, and dioxins and furans.

LaMP Pollutants of Concern are those toxic substances that are associated with local or regional use impairments (including impairments in the Lake Michigan Areas of Concern [AOC]) or those for which there is evidence that loadings to or ambient concentrations in the Lake Michigan watershed are increasing. Management actions for these substances will emphasize pollution prevention efforts, available load reduction opportunities, and additional information collection. Pollutants of Concern include any chemicals associated with a use impairment in an AOC, if it is not already listed as a Critical Pollutant. Listing pollutants associated with impairments in only one or a few AOCs as LaMP Pollutants of Concern is merely a recognition that these substances are present in the Lake Michigan watershed, have been associated with an impairment (albeit on a local scale), and may be transported into the lake if control measures are not taken. The Lake Michigan Pollutants of Concern include the following: arsenic, cadmium, chromium, copper, cyanide, lead, zinc, hexachlorobenzene (HCB), toxaphene, and polynuclear aromatic hydrocarbons (PAH).

Emerging Pollutants include those toxic substances that, while not presently known to contribute to impairments or to show increasing loadings/concentrations, have characteristics that indicate a potential to affect the physical or biological integrity of Lake Michigan. These characteristics include presence in the watershed, ability to bioaccumulate, persistence (greater than 8 weeks), and toxicity. A brief summary of information concerning these characteristics will be developed for any pollutant listed as an Emerging Pollutant, as well as a description of information required to determine whether it should be moved up on or removed from the LaMP Pollutant list. Listing pollutants under "Emerging Pollutants" is another mechanism to help prevent substances from becoming lakewide problems. In terms of management action for Emerging Pollutants, the Critical Pollutant Work Group recommended data collection, research, and monitoring efforts. The LaMP recommends Emerging Pollutants as priorities for data gathering and research activities. The Lake Michigan Emerging Pollutants presently include the following: atrazine, selenium, and PCB substitute compounds.

Table 5-4 summarizes the pollutant categories for all of the pollutants, and lists the primary reasons for category designation.

5.1.4.2 Other Pollutants of Interest

In addition to the critical pollutants, pollutants of concern, and emerging pollutants identified in this LaMP, three other general classes of pollutants may also impairment the lake's resource: nutrients, radionuclides, and endocrine disruptors. This section summarizes the status of these stressors in the Lake Michigan basin.

Other Pollutants of Interest: Nutrients

Nutrients, primarily nitrogen and phosphorus compounds, are essential to the survival of all living organisms. When maintained at proper levels, nutrients are key components of healthy ecosystems.

Table 5-4. Lake Michigan LaMP Pollutants (EPA 1993)

Pollutant	Category			Reason
	Critical Pollutant	Pollutant of Concern	Emerging Pollutant	
Total PCBs	#			Fish consumption advisories; strong association with fish and wildlife deformities and reproductive effects; evidence of reproductive and behavioral effects in human, fish-eating populations.
Dieldrin	#			Strong association with fish mortality and reproductive suppression in bald eagles; association with wildlife deformities and reproductive effects.
Chlordane	#			Fish consumption advisories; association with wildlife deformities and reproductive effects.
DDT and metabolites	#			Fish consumption advisories; strong association with eggshell thinning and reproductive suppression in bald eagles; association with wildlife deformities and reproductive effects.
Mercury	#			Fish consumption advisories; sediments classified as heavily polluted by mercury in 6 Lake Michigan tributaries in accordance with EPA sediment guidelines (1977(a)).
Dioxins/Furans	#			Fish consumption advisories; present in Lake Michigan fish and wildlife; fish consumption advisories for the Menominee River; additive effects of dioxin-like compounds associated with wildlife deformities and reproductive effects.
Lead, Cadmium, Copper, Zinc, Chromium, Arsenic, Cyanide		#		Sediments classified as heavily polluted by these inorganics in several Lake Michigan AOCs and tributaries in accordance with EPA sediment guidelines (1977(a)); association with degradation of benthic and planktonic communities; cause of restrictions on dredging
HCB		#		Low concentrations found in Lake Michigan fish tissues; causes porphyria (blocking of metabolic pathways) in animal and humans, possibly associated with porphyria in Lake Michigan herring gulls.

Table 5-4. Lake Michigan LaMP Pollutants (EPA 1993) (Continued)

Pollutant	Category: Critical Pollutant	Category: Pollutant of Concern	Category: Emerging Pollutant	Reason
Toxaphene		#		As a mixture of chlorinated camphenes (toxaphene mixtures consist of chlorinated camphenes), exceeds EPA water quality criteria in Lake Michigan; moderate association with fish abnormalities.
PAHs		#		Known carcinogens; widely found in nearshore waters of Lake Michigan; moderately associated with fish tumors, but no effects documented in Lake Michigan
Atrazine			#	Widely used as pesticide in Lake Michigan basin; breakdown rate is relatively slow; toxic to aquatic biota.
Selenium			#	Present throughout Lake Michigan basin with numerous sources; generally persistent and toxic.
PCB Substitute Compounds			#	Includes Isopropylbiphenyl, Santosol 100 and 150, Suresol 290, Diisopropylnaphthalene; Use in Lake Michigan basin as substitute for PCBs; detected in effluent, sediment, and fish in the basin; bioaccumulative and toxic.

However, when nutrient levels become elevated they can increase biological productivity in water bodies and ultimately degrade water quality.

Increased nutrients in waterbodies stimulate the growth of green plants, including algae. The amount of plant growth increases rapidly in the same way that applying lawn fertilizers (nitrogen, phosphorus and potassium) results in rapid, green grass growth. In the aquatic system the increased plant life eventually dies, settles to the bottom and decomposes. During decomposition, the organisms that break down the plants use up oxygen dissolved in the water near the bottom. With more growth there is more material to be decomposed, and more consumption of oxygen. Under normal conditions, when nutrient loadings are low, dissolved oxygen levels are maintained by the diffusion of oxygen into water, mixing by currents and wave action, and by the oxygen production of photosynthesizing plants.

Depletion of oxygen through decomposition of organic material is known as BOD, which is generated from two different sources. In tributaries and harbors it is often caused by materials contained in the discharges from treatment plants. The other principal source is decaying algae. As the BOD load increases and as oxygen levels drop, certain species of fish can be killed and pollution-tolerant species that require less oxygen, such as sludge worms and carp, replace the original species. Changes in species of algae, bottom-dwelling organisms (or benthos) and fish are therefore biological indicators of oxygen depletion.

By the late 1960s, the scientific consensus was that phosphorus was the key nutrient in the Great Lakes and that controlling the input of phosphorus could reduce eutrophication. In response to public concern, new pollution control laws were adopted to deal with water quality problems, including phosphorus loadings to the lakes. In 1972, Canada and the United States signed the Great Lakes Water Quality Agreement to begin a binational Great Lakes cleanup that emphasized the reduction of phosphorus entering all of the Great Lakes, including Lake Michigan.

Studies were conducted to determine the maximum concentrations of phosphorus that could be tolerated by the lakes without producing nuisance conditions or disturbing the integrity of the aquatic community. Mathematical models were then developed to predict the maximum annual loads of phosphorus that could be assimilated by the lakes without exceeding the desired phosphorus concentrations. These maximum amounts were then included in the GLWQA. Following a 1983 review of progress made through waste treatment and detergent phosphate controls, it was determined that control of phosphorus from land runoff was also necessary.

Phosphorus loads entering the lakes have been reduced to below the maximum amounts specified in the Agreement for Lake Michigan. Phosphorus concentrations in the lake are similarly below the maximum levels needed to prevent eutrophication. The return to lower amounts of phosphorus has resulted in reducing excess growth of algae lakewide, although certain embayments are still affected by eutrophication. The composition of the algal population including nuisance species has not given way to more desirable and historically prevalent species, such as diatoms. Elimination of some nuisance conditions appears to be improving the quality of the food web for some organisms. The trend appears to be toward an improved situation but one that may differ significantly from historic conditions. Certain embayments, such as the Fox-Wolf basin and Green Bay, are still experiencing impairments from excess nutrient loading (EPA 1998). Early results from the 1998 to 1999 open water monitoring also indicates the possibility that nutrient levels are rising in the open waters of the lake.

Figures 5-4 and 5-5 show the loads of sediments and phosphorous to Lake Michigan from tributaries whose drainage basins are greater than 325 square kilometers (Robertson 1996).

Other Pollutants of Interest: Radionuclides

Exposure to ionizing radiation can affect the various organs and tissues of the body, and may result from radiation originating in deep space, or emitted by the decay of radioactive elements found in the environment. These radioactive elements, or radionuclides, are unstable nuclides of a particular atomic species that return to stability by emitting ionizing radiation. Currently, there are 15 active nuclear power plant reactors in the Great Lakes basin; 8 are in the Lake Michigan basin. Specific radionuclides of interest in the Lake Michigan basin arising from natural and artificial sources include tritium (3H), carbon-14 (14C), strontium-90 (90Sr), radioiodine (129I, 131I), cesium-137 (137Cs), radon-222 (222Rn), radium-226 (226Ra), uranium isotopes (235U, 238U),and plutonium isotopes (239Pu, 240Pu, 241Pu).

By far, the greatest contribution to the average public radiation exposure is the natural background radiation that comes from radioactive elements in the earth's crust and from cosmic radiation originating in deep space. Natural sources contribute on average more than 98 percent of the human radiation dose, excluding medical exposures. The global average dose from natural sources as estimated by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1993) is about 2.4 milliSieverts (mSv – a unit of effective dose) per year.

Figure 5-4. Sediment load via tributary discharge histogram

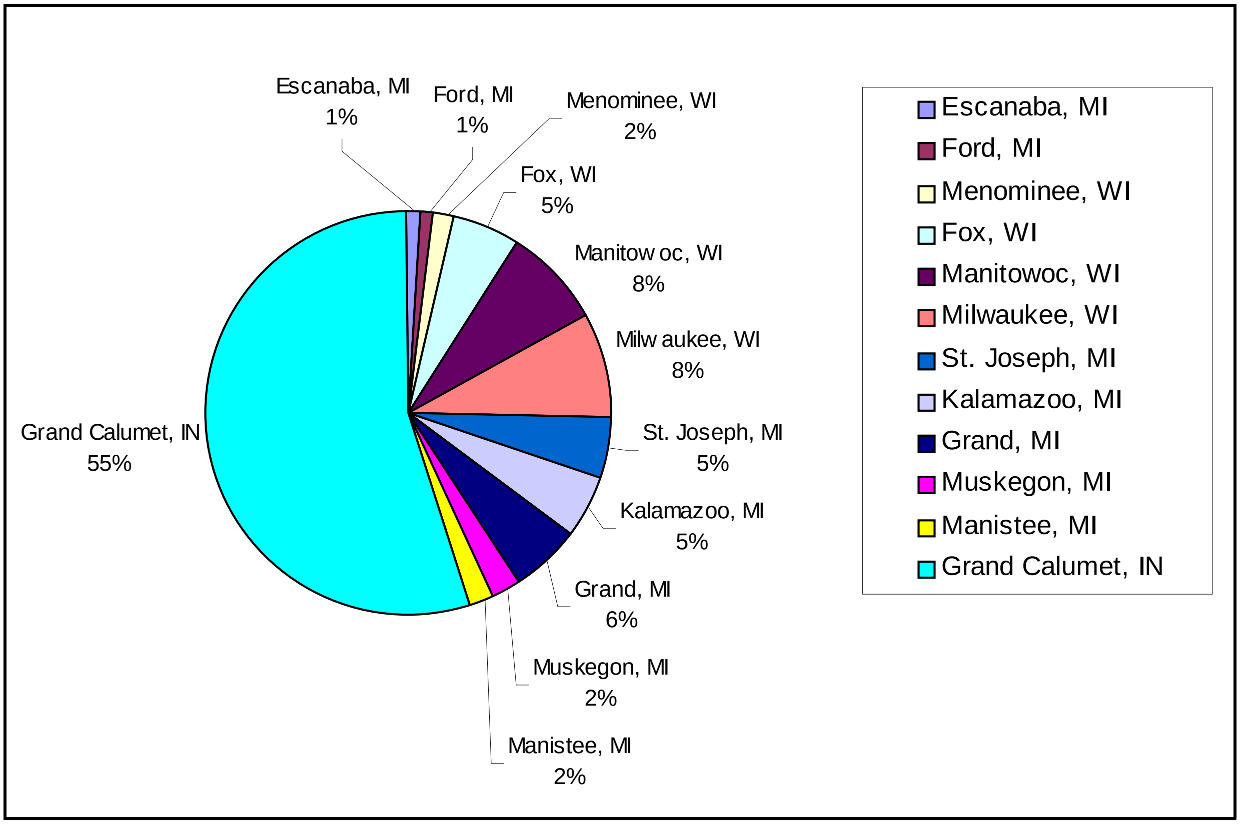
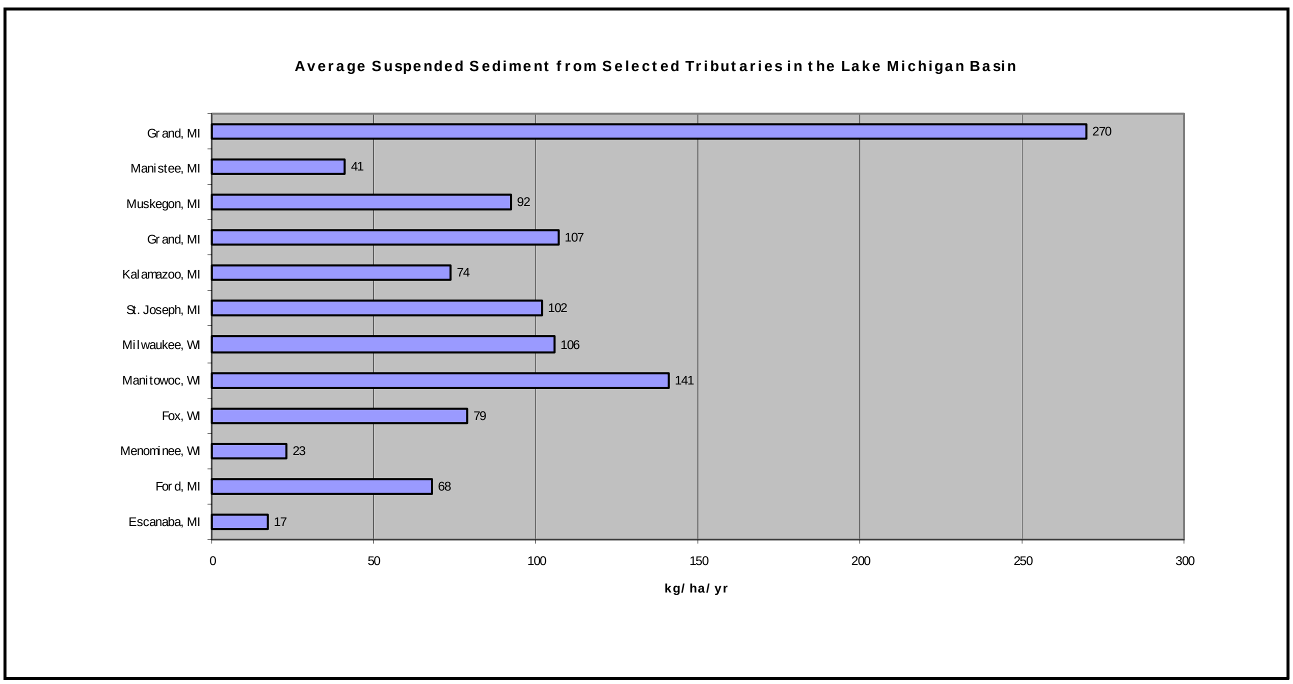


Figure 5-5. Phosphorous load via tributary discharge



Global fallout of radionuclides produced during atmospheric nuclear weapons tests has resulted in the largest total input of anthropogenic radioactivity into the lake, although the 1963 moratorium on atmospheric detonations of nuclear weapons has resulted in declining radiation levels since the mid-1960s. The total committed dose (the average total dose resulting from radionuclides accumulated in the body) to the year 2050 to each individual in the basin from weapons tests conducted between 1945 to 1980 has been estimated to be about 1.9 mSv (UNSCEAR 1993), most of which has already been received.

Increases in local exposure above background levels may result from radionuclides released during the various stages of the nuclear fuel cycle. Nearly all components of the nuclear fuel cycle are found within the basin, the main elements of which are uranium mining, fuel preparation, power generation, and waste management. Normal fuel cycle operations result in controlled and regulated release of radionuclides into the atmosphere and aquatic environments, adding to the radiation exposure from both natural sources and radioactive fallout from atmospheric nuclear weapons tests. The collective dose to the basin population from 50 years of exposure to natural background radiation is therefore of the order of 4.7×10^6 man-sievert (man-Sv). The collective dose from 50 years of fuel cycle operation in the basin based on actual radionuclide emissions from 1985 to 1989 (UNSCEAR 1993) has been estimated to be about 2.8×10^3 man-Sv, or about 3 orders of magnitude less than the exposure due to natural background radiation.

Other Pollutants of Interest: Endocrine Disruptors

The endocrine system is responsible for regulating and maintaining biological functions that are critical for normal growth, development and reproduction. It includes the brain, reproductive organs, and various endocrine glands. Endocrine glands monitor biological processes through chemicals called hormones (such as estrogen, testosterone, and adrenaline); this monitoring provide a means of communication between glands and tissues. These chemical messengers have unique locations in the body, called receptor sites, where they deliver their messages. The action of natural hormones binding to their specific receptor sites is a crucial step in the endocrine system's normal operations, and obstruction of this process can have profound effects on an organism's behavior and physiology. Moreover, the immune and nervous systems interact closely with the endocrine system, and any one of these systems can influence the others.

Recently, government, industry, and environmental groups are attempting to learn more about the environmental endocrine issue. Some man-made chemicals (such as certain pesticides, plastics, detergent ingredients, and food products) have the potential to interact with the endocrine system of humans and wildlife. Such chemicals are called ***endocrine modulators***, or as often described in the media, ***endocrine disruptors***.

Endocrine disruption by exogenic (originating externally) chemicals is not a new concept. Scientists generally agree that some chemicals could interfere with the endocrine system at high doses. For example, birth control pills, and some pesticides, such as DDT and toxaphene, now banned from use, are endocrine disruptors by design. The main question to be answered most recently is whether the health of humans and wildlife around the world is being adversely affected by the presence of *small amounts* of many different types of man-made chemicals in air, water, and food. With this and many other questions still unanswered, the potential risk associated with endocrine disruption by contaminants in the environment has become an intensely debated issue.

The Center for the Study of Environmental Endocrine Effects maintains a website with information on current developments as well as a bibliography of additional references. The Internet address is http://www.endocrine.org.

Endocrine disrupting chemicals work through several mechanisms, usually by either mimicking natural hormones, blocking receptor sites, or by delivering the inappropriate message. Reports describing endocrine-related ailments in both human and wildlife populations are emerging. Some of the more notable human physiological concerns are increases in reproductive tract cancers and abnormal sexual development. While several studies assert that there is a downward trend in male sperm counts, this is still an ongoing debate within the scientific community. Some of the more documented observations in wildlife populations are decreasing hatching success in birds, alligators, and turtles, the synthesis and secretion of a female hormone by male fish, changes in immune response, and behavioral modification. While there is disagreement among scientists on the cause and extent of the issue, there is a consensus that environmental endocrine disruption is a potential risk requiring immediate attention.

Some of the chemical classes that are receiving significant endocrine-related publicity are alkyphenols, carboxylate derivatives, and dioxins, which are found in many consumer products and industrial wastes. Also receiving attention are certain pesticides and medicinal products. Many of these chemicals are pervasive in our environment and human exposure occurs through several pathways, including inhalation, digestion, and dermal contact. Similar routes of exposure occur in wildlife. While many specific chemicals are labeled suspect, significant questions remain about their potency and efficacy to act as endocrine disruptors at environmental concentrations. Therefore, three major questions need to be answered: (1) what chemicals still need to be added to the list of those classified as endocrine disruptors, (2) how serious of a risk to humans and wildlife are endocrine disruptors at ambient environmental concentrations, and (3) how widespread in the environment are endocrine disrupting chemicals?

Evaluation of risk associated with hormonally active chemicals in the environment is based on the following: (1) *hazard*- the harmful effect that a chemical might have on the body even if it only happens at exposure levels that are unrealistic or never encountered in real life, (2) *potency*- how little of a substance is needed to cause a particular effect, and (3) *exposure*- the amount of chemical that comes into contact with the body.

There are currently efforts underway to address these issues and the above-mentioned questions by the National Academy of Sciences and the EPA Risk Assessment Forum. In addition, the Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC) is an advisory committee called together by EPA to provide guidelines for developing a screening and testing program for suspected endocrine disrupting chemicals. Under this strategy, further testing would be performed on those chemicals with significant endocrine disrupting potential.

To evaluate the potential for widespread endocrine disruptor effects in fish, EPA Region 5 initiated a program to assess whether endocrine disruptors may be adversely affecting fish populations in tributaries, harbors, and open waters of Lakes Superior, Michigan, and Erie. This effort is focused on chemicals that have only recently been shown to be endocrine disruptors to fish rather than evaluating endocrine disrupting chemicals such as PCBs and dioxins, which have already received considerable attention. Specifically, an effluent screening study funded by Region 5 and conducted by USGS at several large wastewater treatment plants in the Region was published in 1999. Survey results showed that degradation products of alkylphenol polyethxylate nonionic surfactants (APE) were present in the effluents at concentrations significantly higher than endocrine effect levels reported in the literature. This study is continuing and will analyze effluent, influent, and sludge samples at wastewater treatment plants in the following proposed locations: Duluth, Green Bay, Milwaukee, Akron (Cuyahoga River), and Detroit. Special emphasis is being placed on quantifying human hormone concentrations in these effluents, in addition to APEs. This study will also undertake a toxicity identification evaluation to determine the major chemicals and hormones responsible for fish endocrine disruption.

A second major study by the U.S. Department of Agriculture and funded by Great Lakes National Program Office can be characterized as a reconnaissance survey to assess whether there is potential for widespread endocrine disruption in Great Lakes tributaries and Lake Michigan, as typical of open Great Lakes water. This survey is evaluating known endocrine disruptor biomarkers to determine whether endocrine disruption may be occurring in fish populations in these locations. The study is also documenting concentrations of APE and a number of brominated flame retardants in fish tissue. (Chemical Manufacturers Association 1996; USGS 1999; and EPA/SOLEC 1998)

5.1.4.3 Sources of Data and Information

A variety of print and electronic information sources were reviewed to characterize chemical stressors. In general, data and information was collected through the following means:

- Electronic literature searches, using the DIALOG database of published documents
- Review of government, private organization, and university Internet sites
- Telephone calls to federal, state, and local government agencies; private organizations; and universities
- Electronic database searches

The sources used reported data in various units of measurement. Metric data reported in this document has been also converted to English units to make comparison between data more efficient. A conversion table is provided as part of Appendix B. The following databases and documents were the primary sources of data and information used in this report.

Atmospheric Exchange Over Lakes and Oceans Study

The Atmospheric Exchange Over Lakes and Oceans Study (AEOLOS), a 4-year study begun in 1993, was conducted in an effort to perform an integrated "Great Waters" deposition study to better understand the influence of toxic and nutrient air pollutants from major urban and industrial centers on the water-quality in the Chesapeake Bay and Lake Michigan. The AEOLOS strategy was to conduct a series of intensive field experiments in which pollutants were measured at fixed urban and ship-borne sites in both the Baltimore-Chesapeake Bay and the Chicago-Lake Michigan areas.

Integrated Atmospheric Deposition Network (IADN)

The Integrated Atmospheric Deposition Network (IADN) (www.epa.gov/grtlakes/monitoring/air/) is a joint U.S. and Canada monitoring and research program in operation since January 1990. The primary goal of IADN is to uncover seasonal and annual trends and then to identify sources. The first implementation plan for IADN stated that the objective of the study was the acquisition of ". . . sufficient, quality assured data to estimate with a specified degree of confidence the loading to the Great Lakes Basin of selected toxic substances." It uses a system of rural monitoring in the Great Lakes region for PCBs, PAHs, pesticides, and trace elements. Mercury is not yet included but will be in the future.

Lake Michigan Mass Balance Project

The LMMB Project (www.epa.gov/grtlakes/lmmb/) began in 1994 and will be concluded in 2001. The LMMB Project provides a coherent, ecosystem-based evaluation of toxics in Lake Michigan and will also study hazardous air pollutants for the Clean Air Act Amendments' Great Waters Program. The mass balance approach, demonstrated in the Green Bay Mass Balance Study (GBMBS), provides a consistent framework for integrating load estimates, ambient monitoring data, process research efforts, and modeling, leading to the development of scientifically credible, predictive cause-effect tools. More than

20 organizations are producing LMMB data through collection and analysis of samples. The primary goal of the mass balance study is to develop a sound, scientific base of information to guide future toxics load reduction efforts for Lake Michigan at the state and federal levels. From this goal, a number of specific objectives have been identified. Several of the plan's objectives call for identifying and quantifying the sources of toxics to Lake Michigan, as well as establishing cause-effect relationships and developing forecasting tools for the following:

- Determine loading rates for critical pollutants from major source categories (tributaries, atmospheric deposition, and contaminated sediments) to establish a baseline loading estimate to gauge future progress and to better target future load reduction efforts.

- Predict the environmental benefits (in terms of reducing concentrations) of specific load reduction alternatives for toxic substances, including the time required to realize the benefits.

- Evaluate the environmental benefits of load reductions for toxic substances expected under existing statutes and regulations and thereby determine if there is a need for more stringent, future regulations to realize further benefits.

- Improve our understanding of how key environmental processes govern the transport, fate, and bioavailability of toxic substances in the ecosystem.

The mass balance project will be based on the Enhanced Monitoring Program (EMP), a comprehensive, 1.6-year synoptic survey for selected toxic chemicals in the Lake Michigan ecosystem. In support of the mass balance study, the Environmental Research Laboratory-Duluth (ERL-D) Large Lakes Research Station in cooperation with the Atmospheric Research and Exposure Assessment Laboratory (AREAL), the NOAA Great Lakes Environmental Research Laboratory (GLERL), and other cooperators will develop a suite of integrated mass balance models to simulate the transport, fate, and bioaccumulation of toxic chemicals in Lake Michigan.

National Water-Quality Assessment (NAWQA) Program

The National Water-Quality Assessment (NAWQA) Program (www.water.usgs.gov/nawqa/nawqa_home.html) is designed to describe the status and trends in the quality of the nation's ground- and surface-water resources and to provide a sound understanding of the natural and human factors that affect the quality of these resources. The NAWQA Program is designed to assess historical, current, and future water-quality conditions in representative river basins and aquifers nationwide. As part of the program, investigations will be conducted in 59 areas called "study units," and these investigations throughout the United States are designed to provide a framework for national and regional water-quality assessment. Due to the similar design of each investigation and the use of standard methods comparison among study units can be made. NAWQA investigations measure water-discharge, sediment load, organic contaminants, aquatic biota, inorganic chemistry, sediment chemistry, trace metals, and habitat. In addition, the investigations measure marine- and coastal- salinity, freshwater flux, nutrients, and contaminants. NAWQA has national summaries for pesticides, nutrients, volatile organic chemicals, trace elements, surface water-quality modeling (SPARROW), and a compilation of findings on nutrients and pesticides.

Permit Compliance System

The Permit Compliance System (PCS) (www.epa.gov/oeca/datasys/possys.html) is a national management information system that tracks surface water discharges under the National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act. The NPDES permit program regulates direct discharges from municipal and industrial wastewater treatment facilities that discharge into navigable waters of the United States. PCS contains data and tracks permit issuance, permit limits, monitoring data, and other data pertaining to facilities regulated under NPDES. PCS records water-discharge permit data on more than 64,000 facilities nationwide. A separate program, called Effluent Data Statistics (EDS), is used to calculate loadings based on the PCS discharge data.

Because the PCS only requires facilities to report discharges of constituents on the facilities' permits, the data may be inconsistent between facilities. The Lake Michigan LaMP reports PCS data only for PCBs and mercury because studies were conducted to evaluate PCB and mercury PCS data. This data was published by the agencies that conducted the studies.

Regional Air Pollutant Inventory Development System

The Regional Air Pollutant Inventory Development System (RAPIDS) is the emissions inventory data management system used to compile the Great Lakes Regional Air Toxic Emissions Inventory Project. (www.glc.org/projects/air/rapids/rapids.html). The inventory contains statewide air emissions inventories of 49 pollutants to the Great Lakes and emissions estimates for point and area sources of toxic air pollutants. RAPIDS and the Great Lakes Emissions Inventory is a project of the eight Great Lakes states and the province of Ontario working under the Great Lakes Commission with funding from EPA. The first regional (eight states and one province) pilot inventory contains point and area source data from 1993. Inventory reports have been developed for 1993 and 1996 using emission estimates for point and area source data. The 1996 inventory includes emissions of 82 pollutants. An inventory report including estimates for emissions from mobile sources was released in March 2000. Emissions estimates reported in Section 5.3.3, for LaMP pollutants included in the inventories, include estimates for each of the counties within the Lake Michigan basin. Emission estimates for the entire county were used for counties with only a portion in the Lake Michigan basin.

Toxic Release Inventory (TRI) System

The Toxic Release Inventory (TRI) System (www.epa.gov/enviro/html/toxic_releases.html) contains information regarding more than 650 toxic chemicals and compounds that are used, manufactured, treated, transported, or released into the environment, as required under Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA). Manufacturers of these chemicals are required to report the locations and quantities of chemicals stored on-site to state and local governments. TRI stores release-transfer data by facility, by year, by chemical, and by medium of release (air, water, underground injection, land disposal, and off-site transfer). TRI also stores treatment and source-reduction data. At the facility level, TRI stores facility name, address, latitude-longitude, and parent company. At the chemical level, TRI stores Standard Industrial Classification (SIC) codes, EPA identification numbers (EPA ID), and pollution prevention data (recycling, energy recovery, treatment, and disposal). At the medium level, TRI stores names and addresses of off-site transfer recipient facilities. TRI data collected for the Lake Michigan LaMP is based on data for each of the counties in the Lake Michigan basin. If only a portion of a county is within the Lake Michigan basin, TRI data for the whole county was included.

Other Sources of Data and Information

In addition to the above databases and documents, numerous sources were used in preparation of this report. For a complete listing of information sources see the bibliography at the end of this document.

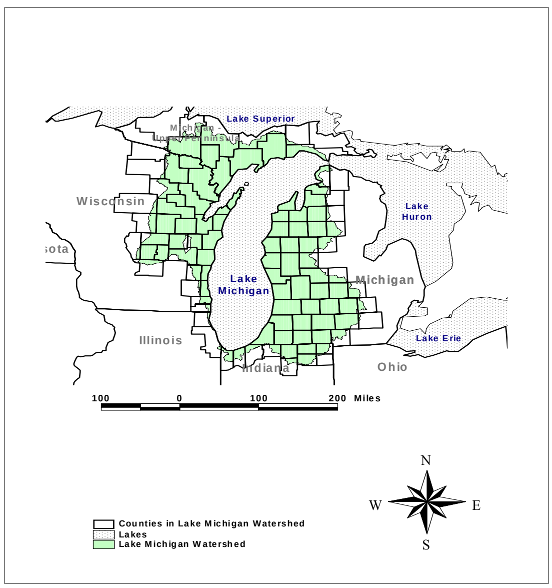
5.2 Overview of Stressor Sources

This section describes the various sources of stressors to the Lake Michigan basin other than nonpoint sources, which were discussed earlier under Physical Stressors: Land use and sources of aquatic nuisance species discussed and biological stressors. These are point source discharges, atmospheric emissions, and in-place pollution or legacy sources. Figure 5-6 shows the counties that are part of the Lake Michigan basin. These counties were the focus for research on stressor sources.

5.2.1 Point Source Discharges

Direct, point source discharges to Lake Michigan and its tributaries from industrial, municipal, and other sources are an ongoing source of pollutant loading to the lakes. Under Section 402 of the Clean Water Act, all point source discharges of pollutants to waters of the United States must be authorized under a NPDES permit. Certain point source discharges of storm water are not currently required to have NPDES permits, although pollution prevention activities are required for many types of storm water

Figure 5-6. Counties within the Lake Michigan Basin



discharges associated with industrial and construction activities. NPDES permits require dischargers to meet minimum, technology-based treatment requirements for their wastewater. In addition, the discharges must also meet water quality-based standards developed by the states and tribes. Discharges must meet an acceptable level of pollution control for that type of discharge, regardless of whether or not that level of control is specifically needed to protect the water body to which the discharge is directed. In general, water quality-based standards are designed to protect specific water bodies, and technology-based standards are designed to assure a minimum level of control for a particular class of discharge, no matter where that discharge takes place.

Combined sewer overflows (CSO) are remnants of the country's early infrastructure. In the past, communities built sewer systems to collect both storm water runoff and sanitary sewage in the same pipe. During dry weather, these "combined sewer systems" transport wastewater directly to the sewage treatment plant. However, in periods of rainfall or snowmelt, the wastewater volume in a combined sewer system can exceed the capacity of the sewer system or treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater directly to nearby streams, rivers, lakes, or estuaries.

Indiana - 19 CSO permittees in the Lake Michigan Basin.

In April 1996, IDEM issued its final *Combined Sewer Overflow Strategy*. Indiana places a strong emphasis on universal nine minimum controls (NMC) implementation. The state reviews and approves/disapproves NMC documentation and does not consider NMC to be "implemented" unless it has approved documentation. Many communities implemented NMC voluntarily prior to permit reissuance requiring NMC. The ninth minimum control measure (monitoring) is implemented separately through a stream reach characterization and evaluation report (SRCER), a good bridge to long-term CSO control plan (LTCP) development. All communities in Indiana must develop LTCPs. When cities develop their Long-Term Control Plans, they estimate bacterial loads entering the receiving waters in order to better understand the relative contribution of CSOs to *E. coli* loadings in state waterbodies.

Michigan - 12 CSO permittees in the Lake Michigan Basin.

In Michigan, NPDES discharge permitting addresses CSOs. Permits include minimum technology-based requirements that align closely with EPA's nine minimum controls. Long-term planning is required for all CSO communities. Michigan places strong emphasis on retention or treatment under state definition of "adequate treatment," which is analogous to the CSO Policy approach.

Long-term planning in Michigan is designed to protect the designated uses of receiving streams and to ensure that discharges meet state water quality standards. The Michigan Department of Natural Resources works closely with communities to develop the long-term plans on a case-by-case basis. To help finance CSO projects, communities are eligible for low interest loans from the State Revolving Fund.

Wisconsin - 1 CSO permit in the Lake Michigan Basin.

Milwaukee recently completed a $2.2 billion effort to reduce the frequency of overflows from combined sewers and improve the quality of effluent from the Milwaukee Metropolitan Sewerage District’s (MMSD) two wastewater treatment plants. This effort involved significant improvement to existing sewers, the construction of tunnels to store wet-weather flows for subsequent treatment, and expansion of the MMSD’s two wastewater treatment plants.

There are currently more than 1,200 point source dischargers in the Lake Michigan basin. Loads from the various source categories are addressed in Section 5.3.

Illinois

The diversion of the Chicago River from the Lake Michigan basin to the Mississippi River System in theory removed all flows into the lake. In high storm flow events, the locks are opened and the Chicago River is allowed to flow into the lake. This occurs approximately once a year.

5.2.2 Atmospheric Emissions

Chemicals emitted to the atmosphere, whether from point sources (stacks), mobile sources, or area nonpoint source legacy sites, can ultimately find their way into the Lake Michigan basin. Pinpointing the source location is problematic due to the ability of airborne pollutants to travel great distances in some instances, before deposition on the earth’s surface, in this case, into Lake Michigan.

5.2.2.1 Air Deposition

There are three major processes of direct atmospheric deposition to Lake Michigan: wet deposition, dry deposition, and gas-exchange across the air-water interface (see Section 4.2.1). Wet deposition refers to the incorporation of particles and gases into precipitation, including rain, snow, and fog. Dry deposition is when pollutants reach the surface by turbulent movements of the air or, for large particles, through gravitational settling. Some pollutants may adhere to particles in the air and then fall out. The distance and the way the pollutant is transported depends on weather conditions, the type of pollutant, the form the pollutant is in, and particle size. Gas-exchange refers to the transfer of chemicals between the gas phase in the air and the dissolved phase in the water across the air-water interface of the lake surface. The direction and magnitude of gas exchange is a function of the chemical concentrations in the air and water, wind speed, temperature, waves, physical and chemical properties of the pollutants, and characteristics of the water (Delta Institute 1999 and EPA 1999d). Loadings from each of these processes are discussed in the following studies described earlier in Section 5.1.3.3: IADN, LMMB, AEOLOS, and others.

5.2.2.2 Long-Range Transport of Pollutants

Atmospheric transport and deposition have been well documented for certain toxic air pollutants and has been demonstrated on local, regional, continental and global scales. Monitors in the Great Lakes Basin have also shown the atmosphere to be a significant pathway for certain toxic pollutants to enter the lakes. Numerous studies have documented toxic pollutants affecting several of the lakes from both long-range sources and local sources. For example, air mass back trajectory analysis based on modeling suggests that inputs of toxaphene detected near Lake Huron have their origin in the historic use of the insecticide in the southern United States and Mexico. More recent ongoing studies (including AEOLOS) point to the impact of urban areas on Lake Michigan loadings of PCBs and PAHs downwind of Chicago over southern Lake Michigan.

The pathway for the transfer of these contaminants from their origin is often very complex. The nature of the pollutants and the meteorological conditions around the Great Lakes make the identification of the sources and geographic origins of the pollutants extremely difficult. Both pollutant-specific factors, as well as meteorological conditions, determine the distance a given pollutant will travel in the atmosphere. An example is the propensity of PAHs to volatilize from the water and be re-entrained in to the atmosphere where they can travel long distances before encountering conditions that favor their redeposition into water. Some factors that influence the extent and duration of the cycling include volatility and persistence of the pollutant; molecular weight; concentrations and temperatures in air, soil, and water; and atmospheric circulation, pressure, and meteorological conditions. Warmer conditions on seasonal and global scales generally favor greater net movement into the atmosphere. Redeposition often takes place in areas of colder atmospheric temperatures. The modeling of chemical fate and concentrations of semivolatile pollutants over very large areas is challenging, and lack of data on pollutant source and release makes the validation of existing models difficult.

5.2.2.3 Status and Current Efforts Underway

A number of recent research programs, assessments and reviews have considered atmospheric transport of pollutants to the Great Lakes. Key findings from these activities area summarized below.

As part of the Clean Air Act Amendments of 1990, Congress directed the EPA to identify and assess the extent of atmospheric deposition of air pollutants to the Great Lakes, the Chesapeake Bay, Lake Champlain, and coastal waters, collectively labeled the Great Waters. The EPA mandate was to compile periodic reports (known as The Great Waters Reports) to Congress on the progress of their assessment. The Great Waters Reports focus on 15 Pollutants of Concern (POC) that include mercury, chlordane, DDT, toxaphene, tetrachlorodibenzo-p-dioxin (dioxins), tetrachlorordibenzofuran (furans), and PCBs, all of which are pollutants affecting Lake Michigan. The initial report was submitted to Congress in 1994, and a second report in 1997, and a third anticipated for summer or fall of 2000. The following are some of the significant findings in the latest Great Waters Report:

- Air deposition represents a significant portion of pollutant loading to the Great Lakes; this portion is highly variable with respect to location and pollutant (air deposition varies between 5 to 100 percent for dioxin/furan, for example).

- General trends are steady or downward for all pollutants in the Great Lakes basin except cadmium; mercury accounts for the largest single input to the Great Waters, although U.S. emission rates have been declining since 1990.

- Determining the relative roles of specific sources contributing to specific water bodies is complex, requiring monitoring, modeling, and other analytical techniques.

- EPA is developing science and tools to assess the contribution of atmospheric sources to water pollution and to reduce total pollutant loadings to affected water bodies.

- The rate of decrease in deposition rates of banned pesticides and herbicides has slowed, which may reflect the persistence of the chemicals and their ability to cycle globally.

Another recent review of current understanding of pollutant transport to the Great Lakes and its implication on policy making was prepared by the Delta Institute in a draft report entitled, "Atmospheric Deposition of Toxics: Integrating Science and Policy." Some highlights from this report and current programs discussed in it include the following,:

- PCBs and other semivolatile compounds can deposit to the earth's surface and then revolatilize to the atmosphere over time. This process can continue over long distances, and is referred to as the "grasshopper effect." This cycling is variable, with seasonal fluctuations depending on temperature, precipitation, and chemical properties.

- The IADN back trajectory analysis of toxaphene and DDT transport via air mass points to sources outside the Great Lakes basin for these substances. On the other hand, sources within the basin account for impacts caused by metals and PAHs. The IADN network provides useful trend information on pollutant concentrations and loadings over time. Results demonstrate that air concentrations of PCBs and other organochlorine compounds are declining significantly in the Great Lakes region.

- The AEOLOS targeted the southern end of Lake Michigan and the Chicago urban area. Significant findings include the following:

  - Dry deposition rates were greater than modeled predictions.
  - Ninety percent of the mass was due to particles more than 2.5 microns in diameter.
  - Mobile sources were the primary source of the coarse particulate material.
  - Urban site PCB precipitation concentrations were 2 to 3 orders of magnitude higher than in remote site locations.
  - An "urban plume" effect was confirmed in southern Lake Michigan for PCBs.
  - The trend for total PCB concentrations was downward (10 fold reduction in 14 years).

- Lake Michigan Urban Air Toxics Study (LMUATS) findings include the following:

  - Local sources are primarily responsible for higher vapor phase and particulate mercury levels in Chicago.
  - PAH results at rural air monitoring sites suggest some long-range transport is occurring; however, the median urban levels were 10 times higher than those at remote locations, reflecting local source impacts around urban locations.
  - PCB levels were 3 fold higher at the Chicago site and generally higher over the lake than at the downwind (western Michigan) or upwind sites.

- Preliminary results from the LMMB Project suggest that approximately 84 percent of the total mercury input to Lake Michigan is contributed by atmospheric deposition (wet and dry deposition and air-water exchange), whereas tributary inputs of mercury accounted for 16 percent of the total mercury input to the lake. Using a hybrid receptor model, localized urban sources in and around Chicago contributed approximately 19 percent of the total atmospheric loading to the lake (Landis 1998).

- The IJC, the binational body created by Canada and the United States to provide advice and help solve problems related to Great Lakes Basin waters, issued a modeling study in 1999. Some of the preliminary findings include the following:

  - Approximately 75 percent of dioxin deposition to the five Great Lakes originates from within the adjacent Great Lake states and provinces.
  - Sources up to 1,500 km distant were noted to have affected Lake Ontario, with about half of the dioxin deposition apportioned to sources near the lake.
  - The study results emphasize the need for continued systematic measurements of air, water, and precipitation and expanded emission inventory databases to provide additional data for modeling.

Additional studies linking emissions from air sources to water quality are discussed below.

- EPA's Mercury Report to Congress in 1997 noted that the 1994 to 1995 mercury contribution from U.S. anthropogenic sources to the atmosphere was 158 tons. Of the 158 tones, 87 percent was from combustion sources (waste incineration and utility fossil fuel plants). Estimated total annual input from all mercury sources was 5,500 tons world-wide, indicating that U.S. anthropogenic sources represent only 3 percent of global releases in 1995. Fifty-two tons (33 percent) of U.S. source emissions of mercury are deposited within the U.S. borders, while the remaining two-thirds (107 tons) are transported beyond U.S. borders, where they diffuse into the global reservoir. Depositional input to the U.S. from non-U.S. sources of mercury was estimated at 35 tons.

- In a study conducted by Pirrone and others (1998), air deposition was found to be the major contributor of mercury to the Great Lakes as indicated by sediment core analysis of mercury deposition rates over time. Atmospheric deposition fluxes in the Great Lakes were estimated to be almost an order of magnitude higher than the pre-industrial average to the whole of North America.

- Emissions and numbers of U.S. anthropogenic sources have declined for mercury, lead, dioxins and furans, and the banned and restricted use substances. For example, lead emissions in the Great Lakes region declined at a rate of 6.4 percent per year from 1982 to 1993 reflecting the national decline in lead emissions from the phase-out of leaded gasoline in automobiles.

- Emissions from U.S. anthropogenic sources have remained constant or are variable for cadmium and PAHs.

- Based on current atmospheric research by Cortes and others (1998) on atmospheric pollutant concentrations in the Great Lakes region, DDT, followed by dieldrin and chlordane, are estimated to fall below current detection limits in the atmosphere between 2010 and 2020. HCB is projected to be eliminated in the atmosphere by 2030 and 2060, respectively. These estimates assume current rates of long-range transport of these pollutants into the region. It should be noted that elimination of these pollutants in the atmosphere does not, because of their persistence, mean that concentrations would be eliminated in deposited media by these dates. However, these estimates indicate that reduction strategies in the Great Lakes, along with the original bans or restrictions on the use of these substances, are having the intended effect.

5.2.2.4 Data Gaps Identified

Even though considerable efforts and resources have been expended in characterizing and reducing the impact of several key pollutants of concern, the following data gaps still exist:

- Emission inventory databases need to be extended to include area and mobile sources and other minor sources that might provide a local or regional input to models that predict deposition rates.

- More accurate inventories of both natural and anthropogenic sources, and the chemical species emitted, are needed to better delineate long-range transport of pollutants like mercury.

- Locational information for mobile sources and area sources that may affect model predictions of deposition rate, seasonal variation, and other factors is needed.

- Spatial and temporal variability of ambient monitoring data are not adequately understood; comprehensive modeling of key pollutants along with validity testing of model predictions with observed concentration information is needed to determine representativeness of existing databases (over water measurements, simultaneous air-water measurements).

- The significance of watershed transport of pollutants deposited over land but transported into streams and channels whose inputs contribute indirectly to the riverine loading of the larger water body is uncertain.

5.2.3 Legacy Sources

The history of urban, industrial, and agricultural land uses in the Lake Michigan basin has left a legacy of contaminated sediments, land, and groundwater that is a continuing source of pollutant load to the lake. While state and federal remediation programs, such as those mandated under the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act (or Superfund) have begun to address this past contamination, many pollutants remain in the Lake Michigan system. This section briefly discusses these major, in-basin legacy sources and the pollutant stressors associated with these sources.

5.2.3.1 Contaminated Sediments

Contaminated sediments have been identified throughout Lake Michigan and its tributaries; however, the most serious levels of sediment contamination are found within the 10 AOCs in the basin: Manistique

River, Lower Menominee River, Lower Green Bay and Fox River, Sheboygan River, Milwaukee Estuary, Waukegan Harbor, Grand Calumet River-Indiana Harbor Ship Canal, Kalamazoo River, Muskegon Lake, and White Lake (see Appendix F). These sediments remain a source of pollutant load to the lake through resuspension and volatilization of certain pollutants, and by serving as a source of pollutants in the Lake Michigan food web. In particular, the LMMB Project has found that contaminated sediments are a significant source of continuing PCB and mercury load to the lake.

Examples of the sediment contamination problems found within the 10 Lake Michigan AOCs and successes and ongoing remediation efforts instituted in the AOC are discussed below.

<u>Grand Calumet River- Indiana Harbor Ship Canal AOC</u>

- The Grand Calumet River AOC contains 5 to 10 million cubic yards of contaminated sediment up to 20 feet deep. Contaminants include toxic compounds such as PAHs, PCBs, and heavy metals, and conventional pollutants such as phosphorus, nitrogen, iron, magnesium, volatile solids, oil, and grease. Ninety percent of the river's flow originates as municipal and industrial effluent, cooling and process water, and stormwater overflows (EPA No date[n]).

  Concerns over managing these contaminated sediments have resulted in a suspension of dredging activities since 1972 and have reduced shipping capacity 15 percent over that time, resulting in increasing shipping costs. However, in 1991, under a Consent Decree, LTV Steel removed approximately 116,000 cubic yards of contaminated sediments. The project was completed in 1996 after a total of 120,000 cubic yards of contaminated sediment was dredged from a slip adjacent to Indiana Harbor. (Lake Michigan Forum No date).

<u>Waukegan Harbor AOC</u>

- Waukegan Harbor experienced extensive PCB and other toxic pollutant contamination of its sediments as a result of industrial releases and urban runoff. In 1992, a series of Superfund and privately-funded remediation activities were completed that resulted in the removal of approximately 453,600 kg (1 million pounds) of PCBs. After removal of the PCB-contaminated sediments, 3 years of fish sampling showed that PCB levels in alewife, coho salmon, chinook salmon, rainbow trout, and yellow perch in the Waukegan Harbor were below levels of concern. Alewife fish samples dropped from 10.0 to 0.5 parts per million (ppm). Signs warning anglers not to eat fish caught in Waukegan North Harbor were removed in February 1997, although fish consumption advisories remain in effect. Nonetheless, a 1996 sampling effort showed that the harbor sediments still do not support healthy benthic organism populations. Dredging activities to maintain navigation are also restricted (Lake Michigan Forum No date).

- Currently, two remedial investigations are underway on adjacent property of Waukegan Manufactured Gas and Coke and the Greiss-Pfleger Tannery.

<u>White Lake AOC</u>

- The White Lake AOC contains sediments contaminated with heavy metals, chlorides, and organic pollutants. Chromium and lead are found at the most elevated levels, and arsenic, cadmium, manganese, mercury, nickel, zinc, PCBs, and oil and grease have also been detected. Benthic communities in the sediment are impaired, but recent studies indicate that the biological community health may be improving (Lake Michigan Forum No date). Also, results of water samples collected in 1992 from the navigational channel between White Lake and Lake Michigan indicate that water quality has improved since the previous samples were taken in

1983. Heavy metal concentrations are lower than those observed in earlier sampling. Chloride concentrations are the lowest recorded since testing began in 1963, and phosphorous and nitrogen levels have remained stable since diversion of wastewater from White Lake in 1974.

Menominee River Bay AOC

- The Menominee River Bay has been contaminated by paint sludge from furniture manufacturing and other industrial operations for many years. Other pollutants include mercury, PCBs, and oil and grease. In 1995, more than 10 million pounds of hazardous waste were removed from the bay. An additional 20 million pounds of contaminated sediments were removed during this effort, which was part of an enforcement order issued to the Lloyd Flanders Furniture Company in Menominee. Degradation of the benthos in the bay has been documented primarily due to arsenic contamination in the sediments. The arsenic was released from the Ansul Fire Protection Company. (Menominee River AOC Fact Sheet). A RCRA Consent Agreement between Ansul Fire Protection Company, the EPA, and the State of Wisconsin was initiated in 1990. EPA ordered Ansul to remove 10,000 cubic yards of the arsenic contaminated sediment on July 1,1997. In 1993 and 1994, 11,500 cubic meters of sediment contaminated with paint sludge (RCRA hazardous for Pb) were removed from the Lower Menominee River by Ansul. In 1999, 12,329 cubic yards of arsenic-contaminated sediment were removed from the 8^{th} Street slip.

Green Bay and Lower Fox River AOC

- Green Bay and the Lower Fox River contain high levels of PCB contamination from pulp and paper mill releases. EPA and the State of Wisconsin are currently developing remediation plans and beginning implementation activities for sediment clean-ups in the bay and river systems. In 1998, 4,600 cubic yards of PCB-contaminated sediment was removed from the Fox River. During the Deposit 56/57 dredging project, 30,000 cubic yards of PCB-contaminated sediment were removed in 1999.

Milwaukee Estuary AOC

- The Milwaukee Estuary sediment is contaminated with several heavy metals, oil and grease, and organic pollutants. The greatest concern in the AOC are PAHs and PCBs. In 1991, approximately 570,000 cubic meters (745,532 cubic yards) of contaminated sediment were isolated from the Milwaukee River by the removal of the North Avenue Dam (EPA No date[m]). In 1994, approximately 5,900 cubic meters of PCB-contaminated sediment were removed from behind Ruck Pond Dam. As a result, more than 95 percent of the mass of PCBs was removed from the area (EPA No date[m]).

Manistique River and Harbor AOC

- The Manistique River and Harbor contain large quantities of undecomposed sawdust from sawmills that have degraded sediments and aquatic life in the AOC. In the 1970s, PCBs, oils and heavy metals were identified as contaminants in the Manistique River and Harbor. Four studies by the EPA and MDEQ revealed that sediments near the Manistique Paper Company were polluted with elevated levels of PCBs, chromium, copper, and lead. The total amount of contaminated sediments in the AOC was estimated to be around 125,000 cubic yards.

  In 1995, EPA began annual dredging. From 1995 to 1998 approximately 92,000 cubic meters (120,232 cubic yards) of contaminated sediment and undecomposed sawdust were dredged from the river (EPA No date[m]). Dredging south of U.S. Route 2 bridge began June 1997. During

1998, about 31,200 cubic yards of wood chips, sawdust, and other solid material were dredged. About 1,525 cubic yards of sediment containing less than 1 ppm of PCBs was collected during the dredging process. (Lake Michigan Forum No date). EPA estimates that all dredging will be completed by winter 2000.

Sheboygan River and Harbor AOC

- The Sheboygan River and Harbor sediments contain PCBs, heavy metals, PAHs, and organic pollutants. Concerns over managing these contaminated sediments resulted in a suspension of dredging activities since 1968. The sources include several industries along the river and its tributaries, agricultural runoff, and urban runoff.

  From 1989 to 1991, a potentially responsible party (PRP) dredged approximately 5,300 cubic yards of PCB-contaminated sediments from the upper Sheboygan River. During 1989 and 1990, eight other sediment deposits were "Armored" in the upper Sheboygan River to prevent the PCB-contaminated sediment from moving downstream (EPA. No date[h]).

Kalamazoo River AOC

- The Kalamazoo River contains PCBs from de-inking operations at local paper mills. In 1997, the Kalamazoo Public Advisory Council, with support from MDEQ, appealed directly to the EPA and requested Emergency Action on the Bryant Millpond site. The result was an announcement by Allied Paper that it will commit up to $5.5 million to remove PCBs from Portage Creek (a tributary of Kalamazoo River) and contain them on site. Work done by EPA has begun. In April 1999, 165,000 cubic yards of PCB-contaminated sediment were removed.

  An emergency response team from EPA, along with MDEQ and the City of Kalamazoo, supervised the cleanup of Davis Creek (a tributary of Kalamazoo River). EPA removed about 270,000 gallons of oil, 3,200 tons of scrap metal, 1,400 cubic yards of asbestos, 33,000 gallons of flammable liquids, 15,000 gallons of caustic liquids, 25,000 tons of contaminated soil, and 18 tons of miscellaneous hazardous materials. (Lake Michigan Forum No date).

- In August 1990, the Allied Paper/Portage Creek/Kalamazoo River Superfund site was included on the National Priority List pursuant to CERCLA. Much of the field activities associated with the remedial investigations have been completed.

Muskegon AOC

- Waste lagoons, landfills, and industrial activity have contaminated the Muskegon AOC with heavy metals, volatile organic compounds, and PCBs. Concerns over managing these contaminated sediments resulted in a suspension of dredging activities. Remediation of contaminated sediment is ongoing at several locations on Muskegon Lake's south side. Also, brownfield remediation is ongoing on Muskegon Lake's south shore.

5.2.3.2 Contaminated Land and Groundwater

The Lake Michigan basin's history of industrial and agricultural activity has also left the watershed with land and groundwater contamination. Industrial activities result in releases of heavy metals, PCBs, dioxins, and other synthetic organic chemicals to the land through disposal activities, spills, and unregulated releases. Agricultural land use results in land application and land disposal of pesticides, nutrients, and other agricultural chemicals. These applications can also result in groundwater contamination, which serves as a pathway for pollutant load to the lake. Approximately half of all surface water discharge in the Lake Michigan basin is derived from groundwater as baseflow (USGS 1999). As a result, pollutants released to the land can leach to the groundwater and ultimately reach the lake and its tributaries. For example, groundwater at the Grand Calumet and Indiana Harbor AOC is contaminated with organic compounds, heavy metals, and petroleum products and is discharging these pollutants to surface waters. EPA estimates that at least 16.8 million gallons of oil float on top of the groundwater at the AOC (Lake Michigan Forum No date).

Groundwater remediation efforts, as a result of Superfund-directed cleanups, are apparent in the AOC. For example, industrial facilities in the White Lake AOC such as DuPont, Koch Chemical, Occidental Chemical (formerly Hooker Chemical), and Howmet Corporation have installed groundwater pump and treat systems to stem the flow of polluted water to the AOC. As a result, there has been improvement in the water quality of White Lake. Analytical results for water samples collected in 1992 from the navigational channel between White Lake and Lake Michigan indicate that water quality has improved since the previous samples were collected in 1983. All parameters measured in 1992 in White Lake AOC met Michigan's water quality standards.

The extent of land and groundwater contamination serving as a pollutant source in the Lake Michigan basin is not known. However, 155 Superfund sites are found within the basin and the history of industrial, agricultural, and urban land use, especially in the southern portion of the basin, has left a legacy of contamination that will need to be managed well into the future.

5.3 Stressor Loading and Effects

5.3.1 Trends in Habitat Loss

Habitat loss is a major limiting factor in the well-being of fisheries, wildlife, and avian populations in all of the Great Lakes, including Lake Michigan, and causes persistent and substantial negative impacts on lake biota (LTI 1993). Important habitat types in the Lake Michigan basin include dunes, wetlands, shoreline, reefs, nearshore water, offshore open water, and inshore terrestrial areas. Recovery or degradation of fisheries, birds, and mammal populations depends on the extent and condition of their habitat. Habitat loss and fragmentation is especially significant because it permanently alters the ecosystem. Land use stresses contributing to habitat loss in and around Lake Michigan include urban sprawl and nearshore development, industrial uses, hardening of landscape, soil erosion and sedimentation, transportation, oil drilling, mineral extraction, and agriculture (LTI 1993).

The Great Lakes wetlands are important plant and animal habitats. Draining and development have vastly reduced the areal extent of these wetlands and degraded their quality. About 70 percent of the original Great Lakes wetlands have been lost as a result of draining for agricultural use. Additional wetland acreage has been lost to urban and recreational development. Of the original Lake Michigan wetlands, less than 10 percent remain. Remaining wetlands are continually degraded by agricultural runoff, waste discharges, dam construction, filling, and dredging operations. These stressors result in high nutrient and sediment loadings (LTI 1993).

5.3.1.1 Trends in Agricultural Land Use

The predominant trend in U.S. land use is for increased development of farmland for residential and other urban uses. According to the Natural Resource Conservation Service (NRCS), between 1982 and 1992, developed land in the United States increased by 13.9 million acres, and between 1992 and 1997 it increased by 16 million acres. The majority of the newly developed acres were formerly farmland (NRCS 1997).

This trend is also occurring in the Great Lakes Basin. Between 1982 and 1992 there was a 1.8 million acre decline in farmland in the Great Lakes basin. These declines occurred primarily near metropolitan centers but also in rural areas to a lesser extent (SOLEC 1996). The predominant land use trend in the Lake Michigan basin is low-density sprawl extending into suburban and rural areas. This trend is occurring in each of the Lake Michigan states as described below.

- Between 1982 and 1992, Illinois lost 240,000 acres of farmland to urban uses; 29 percent of these acres were located in DuPage, Kane, Lake, McHenry, and Will counties, the 5 “collar” counties of Chicago, all within 50 miles of the Lake Michigan shoreline (ILUC 1999).

- Between 1992 and 1997, Indiana lost more than 500,000 acres of farmland, of which 74,623 acres were located in the northwest portion of Indiana nearest the Lake Michigan shoreline (Purdue University 1998)

- Between 1982 and 1992, Michigan lost more than 800,000 acres of farmland (MDA 1996), and between 1992 and 1998 it lost another 400,000 acres (MDA 1999)

- Between 1992 and 1997, Wisconsin lost 400,000 acres of farmland (USDA 1999).

Along with these changes in total farmland acreage are changes in individual farm characteristics and farming practices. The trend is toward fewer but larger farms. For example, the average farm size in Illinois increased by 6 percent between 1992 and 1997 (USDA 1997a) and in Michigan by 16 percent between 1982 and 1992 (MDA 1996). Other trends include fewer farms with livestock but larger numbers of livestock per farm and more intensive crop production practices (SOLEC 1996).

5.3.1.2 Trends in Urban Growth/Sprawl

The most significant population trend for the Lake Michigan basin is a shift away from central cities coupled with rapid growth in the surrounding metropolitan areas. In some places, this outlying growth reflects an increase only in the number of households (a shift in population density due to declining household size), not in population; however, in other places, it is a true increase in population in the outlying areas. In any case, this population shift to the urban periphery and suburbs together with the attendant trend towards smaller household sizes and demand for low-density development consumes vast amounts of agricultural lands and open space. It also alters the character of what once were small towns, distinct from urban areas, as these small towns are consumed by the ever-expanding metropolitan areas.

In metropolitan areas near the Lake Michigan shore, the implications for the nearshore area are even greater because, on the one hand, the lake geographically limits how far people can move lakeward away from the city and, on the other hand, the lake provides a natural attraction for new development. The result is that many of the people leaving the central cities are heading for the nearshore area. The city of Chicago, for example, lost population between 1980 and 1990, whereas the Chicago metropolitan area experienced continued growth in areas outside the central city to the south and away from the lake as well as to the northeast up along the Lake Michigan shoreline. The Milwaukee-Racine area in Wisconsin, discussed above, is another example where population decrease in the central city is countered by either lower rates of decrease or population increases at the county level.

Another trend is the remarkable population decrease in the highly urbanized areas in Northwest Indiana, which includes East Chicago, Hammond, and Gary. Between 1980 and 1990, the population in these cities declined by 14.8 percent, 10.1 percent, and 23.2 percent, respectively. This has been the trend since the 1970s and is expected to continue, though it has slowed somewhat in the 1990s. This population change has been influenced by the downsizing of steel mills and other manufacturing industries in the area. As the population declines in the tri-city area, more people move to the urban and suburban areas toward the southern watershed boundary as well as northward into Michigan along the Lake Michigan shoreline.

The automobile has facilitated the widespread emergence of urban sprawl over the last half century; resulting in the sparse settlement patterns and losses of agricultural land, open spaces, and natural areas. For example, in Michigan, the desire for large residential parcels of land has led to the loss of agricultural land at a rate of 10 acres/hour with a population that is expected to grow by 1.1 million between 1990 and 2020. Once land has been developed, it becomes nonrenewable and can never again be used for crop production. If current trends continue, the Michigan Society of Planning Officials predict that urbanized land in Michigan will increase by 63 to 87 percent between 1990 and 2020 (MDEQ 1998a).

Imperviousness, defined as the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape, is a useful indicator to measure the impacts of land development on water quality. Impervious surfaces collect and accumulate pollutants deposited from the atmosphere, leaked from vehicles or derived from other sources. During storms, accumulated pollutants are quickly washed off, and are rapidly delivered to aquatic systems.

Although urban sprawl, a principal outcome of the post-war economy, has been the dominant form of development, interest is growing in returning to higher-density, mixed-use community planning and redevelopment of underutilized or brownfields locations that would enhance the efficiency of municipal services such as transportation (SOLEC 1996).

The Lake Michigan basin, particularly the southern portion, has experienced significant transformation as the result of industrial land use. For example, steel is an important industry in the southern tip of the Lake Michigan basin where five large integrated mills with blast furnaces and three minimills produce about one-quarter of all U.S. steel. The lake has historically provided transportation, water for industrial processes, wastewater assimilation, and raw materials. However, as the regional economy shifts from a manufacturing-based to a service-based economy, the industrial activities in the Lake Michigan basin have declined or companies have relocated old operations inland rather than reinvest with modern technologies.

As industry has declined or retreated from the Lake Michigan shores, former industrial sites remain that can be used for public, commercial, or high-technology manufacturing uses. However, the costs associated with cleaning up some of these industrial sites is a difficult challenge to governments and communities.

5.3.1.3 Trends in Mineral Extraction Practices

The U.S. mining industry has experienced substantial layoffs and mine closings for decades and this trend continues. Some iron ore is still extracted in the northern basin to supply the steel industry, particularly steel production in the southern tip of Lake Michigan. Michigan and Wisconsin both have mining permitting programs that include reclamation plans.

5.3.1.4 Special Management Issues

Specific actions to address PHYSICAL STRESSORS are presented in Chapter 6, Table 6-1: RP1, RP5, RP6, RP8, SU2-5, IS4, IS13, RM 9 6

Programs that relate to the management of physical stressors are presented in Appendix A.

Special management issues include the following:

- Locally focused land use planning without considering lakewide impacts
- Managing nonpoint source pollution

5.3.2 Biological Stressors

Biological stressors in the Lake Michigan basin include ANS and human pathogens.

5.3.2.1 Trend in Aquatic Nuisance Species

Based on the information currently available, the rate of invasion by ANS appears to be accelerating, and the geographic regions from which these species come is expanding.

Special Management Issues

Specific actions to address BIOLOGICAL STRESSORS are presented in Chapter 6, Table 6-1: RP2, RP4, RP9, IS5 6

Programs that regulate and manage ANS are presented in Appendix A. Special management issues include the accelerating rate of invasion of ANS.

5.3.2.2 Trends in Human Pathogens

Table 5-5 shows the most common (prevalent) human pathogens found in Lake Michigan.

Table 5-5. Human Pathogens in Lake Michigan

Pathogen	Prevalence
E. coli	Localized outbreaks
Cryptosporidium	Rare, localized outbreaks
Giardia lamblia	Widespread

Beach closures serve as indirect indicator of excessive bacterial contamination of near shore waters near beaches (ET-1). The 36 Lake Michigan beaches in Cook County, Illinois, were often closed due to pollution prior to 1992. After a deep tunnel storage system was constructed to increase the holding capacity for stormwater, the frequency of beach closings decreased. There were no beach closing during 1993 and 1994, but isolated instances of pollution will probably continue to cause beach closings in the future (EPA 1998g).

There is currently no federal requirement that states monitor their beaches or notify the public when water quality standards are violated. Those states and counties that do choose to monitor their beaches may monitor different microorganism. EPA's Beach Environmental and Costal Health (BEACH) program recommends using standards developed for enterococcus or *E. coli* for microbial standards (EPA 1998[i]). Despite this recommendation, programs continue to monitor for other parameters, such as fecal coliform. The number of exceedances reported may be misleading because monitoring is not consistent at all beaches; some beaches do not conduct any monitoring. Different states and jurisdictions monitor for different indicator organisms, and also have different criteria and standards for postings or advisories. In addition, frequency of monitoring bacterial contamination at public beaches is highly variable around Lake Michigan. Because of this variability, it is difficult, and potentially misleading, to compare water quality between jurisdictions or summarize data for all beaches.

There are 581 beaches listed for the Great Lakes Basin, and on any summer weekend, at least a million people visit them (EPA 1998[h]). The beaches that are closed most of the time are closed because of high levels of microorganisms coming from sewage overflows and polluted storm water runoff from cities and farms (EPA 1998h).

Special Management Issues

Specific actions to address BIOLOGICAL STRESSORS are presented in Chapter 6, Table 6-1: HH1-HH7, RP1 6

Programs that regulate and manage human pathogens are discussed below and presented in more detail in Appendix A.

Biological Pathogen Management Programs

National Pollutant Discharge Elimination System (NPDES). The CWA requires wastewater dischargers to have a permit establishing pollution limits and specifying monitoring and reporting requirements. NPDES permits regulate household and industrial wastes that are collected in sewers and treated ad municipal wastewater treatment plants. The permits also regulate industrial point sources and concentrated animal feeding operations that discharge directly into receiving waters (EPA No date[s]).

Beach Monitoring. EPA has a web site giving up-to-date information about water quality and beach closings at more than 1,000 beaches nationwide, including Chicago, Milwaukee, southwest Michigan, and Indiana Dunes. The information is available at http://www.epa.gov/ost/beaches (EPA 1998h). In 1995, 28 Lake Michigan beaches out of more than 200 being monitored were temporarily closed because of poor water quality (EPA No date[t]). Indiana tests waters near beaches on a weekly basis using an EPA-recommended standard for *E. coli* (MDNR 1998a).

Healthy Beaches Initiative. This is a collaborative effort among several agencies seeking to protect the health of the Indiana shoreline of Lake Michigan. This organization is especially concerned about sporadic, unpredictable high levels of bacteria in the nearshore waters in northern Indiana (MDNR 1998a).

E.coli Interagency Task Force. In response to bacterial contamination on Indiana beaches in 1996, 18 local, state, and federal agencies formed the E.coli Interagency Task Force to share information and address bacterial contamination along Lake Michigan. The Illinois-Indiana Sea Grant Program invested about $80,000 in research to differentiate human waste from animal waste by assessing the presence of a virus and bacteria in the waste. Being able to make that distinction will indicate the source of pollution. This group is also looking at bifidobacteria and poliovirus, both indicators of human fecal pollution. Poliovirus in associated with waste from newly immunized humans (Ting 1996).

Deep Tunnel Project. The 36 Lake Michigan beaches in Cook County, Illinois, were often closed due to pollution prior to 1992. The combined storm water and sanitary sewer system combined with a limited retention capacity for storm water prior to treatment contributed heavily to the problem. When the water storage capacity was exceeded, the locks separating the Chicago Sanitary Canal and lake Michigan were opened, and untreated effluent flowed into the lake. Most beaches would be closed for several bays because of actual or potential pollution. A deep tunnel storage system was constructed to increase the holding capacity for storm water. As sections of the tunnel system were put into use, the frequency of beach closings decreased. There were no beach closing during 1993 and 1994, but isolated instances of pollution will probably continue to cause beach closings in the future (EPA 1998g).

Special management issues include the following:

- Multiple sources contribute to microbial contamination.
- Lake Michigan beach monitoring programs are not consistent.
- Lack of network to share science, monitoring, and management data.

5.3.3 Chemical Stressors

The production and use of chemicals present a *potential* for the chemicals to enter the environment, whether by its intended use, as is the case with pesticides and fertilizers, or inadvertently through spills or leaks. The manufacturing of chemicals and the use of chemicals in manufacturing a wide variety of products, produce waste byproducts that must be managed. In the past many of these waste byproducts were placed in the environment without management controls resulting in a legacy of in-place chemical pollution found today in contaminated sediments in lake and river bottoms, in soils in industrial areas and slowly moving in the groundwater from sites where spills occurred. Today several environmental management programs are in place to control these waste byproducts. Chemicals in the waste byproducts still enter the environment but under the jurisdiction of these environmental management programs that control the rate and quantity (load) of the emissions or discharges through permits. These controlled emissions and discharges, and the legacy or in-place pollutants represent the **actual** presence of chemicals in the environment. The **potential and actual** presence of chemicals in the environment provide the potential load of chemicals to Lake Michigan.

This section presents information on the potential loading of chemicals or pollutants to Lake Michigan based on the potential and actual presence of each of the critical pollutants, pollutants of concern, and emerging pollutants, in the Lake Michigan basin counties. It also contains information about the current and past actual loading of each of these pollutant pathways to Lake Michigan and what impacts these pollutants have on achieving the subgoals, goals and vision for the Lake Michigan ecosystem. Finally, this section lists unique management challenges presented by these pollutants, which provides a framework for the management activities detailed in the strategic agendas presented in Chapter 6.

5.3.3.1 Polychlorinated Biphenyls

Critical Pollutant

PCBs are a group of synthetic organic chemicals with a variety of harmful effects on humans and the environment. These compounds are subdivided according to their chemical composition, with the differentiating factor being their respective degrees of chlorination. The physical and chemical properties of PCBs are described in Appendix B. PCBs were produced commercially and used extensively from 1929 to 1979 as coolants and lubricants in electrical equipment such as transformers, capacitors, and light ballasts, as well as in hydraulic fluids, plasticizers, carbonless copy paper, inks, and other items.

PCBs are highly stable under most environmental conditions and accumulate in animal and fat tissue, especially in fish and other aquatic life. PCBs are present in some types of Lake Michigan fish at concentrations exceeding FDA limits, resulting in fish consumption advisories (EPA1997k). The major source of PCB exposure for the general public is contaminated fish consumption.

Following is a discussion of the potential and actual releases of PCBs into the environment (the potential load to the lake), the current and past loading of PCBs to the lake, the impact of PCBs on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing PCBs.

POTENTIAL RELEASES OF PCBs TO THE ENVIRONMENT

PCBs have entered the environment from sites where they were used, through spills or leaks from accidents or gradual wear and weathering of PCB-containing products, during destruction of articles containing PCBs in municipal and industrial waste incinerators, through leaching from old landfill dumps, and through improper (or illegal) disposal of PCB materials. Today, PCB use is primarily restricted to pre-existing closed systems. However, PCBs can be released to the environment from several different sources, including the following:

- **Items containing PCBs intentionally for their useful chemical properties**. The majority of PCBs were used in transformers, capacitors, light ballasts, and other electrical components. Many of these items have long useful lives and remain in service today. Under TSCA, all uses of PCBs are banned unless they fall into specific use categories. The EPA has determined that certain PCB uses contain no unreasonable risk. However, PCBs can be released into the environment from leaks or spills from such equipment containing PCBs, from poorly maintained hazardous waste sites that contain PCBs or PCB-containing products, improper (or illegal) disposal, and fires. Equipment containing PCBs remains in the Lake Michigan basin. The EPA's PCB Transformer Database provides the most current information on the number of PCB transformers currently registered in use. There are 2,818 transformers containing about 5.5 tons (5,000 kilograms [kg])of PCBs that remain in use in the Lake Michigan states - Illinois, Indiana, Michigan, and Wisconsin (EPA 1999k).

- **Combustion or incineration of materials containing PCBs**. Sources of PCB air emissions from combustion include municipal waste combustion, medical waste incineration, hazardous waste incineration, sewage sludge incineration, and utilities. The Lake Michigan basin contains many of these combustion facilities.

- **Inadvertent generation during production processes**. Any chemical process that involves carbon, chlorine, and elevated temperatures (for example, the de-inking of newsprint and recycling of carbonless copy paper by paper mills) may inadvertently generate PCBs.

- **Storage and disposal facilities**. Releases of PCBs may occur from containers or items such as transformers if they are mishandled or broken during storage.

ACTUAL RELEASES OF PCBs TO THE ENVIRONMENT

- **Point source discharges**. PCBs are released to the environment through point source water discharges. The EPA PCS is a database that tracks permit compliance and enforcement status of facilities subject to NPDES permits under the Clean Water Act. The *reported* total values for PCB discharges from permitted point sources to tributaries in the Lake Michigan basin for 1990 to 1999 is 397.31 kg (875.92 lb). Annualized data does not provide information useful for establishing trends in reported discharges. Table 5-6 indicates the amounts discharged to individual water bodies (EPA 1999k):

The TRI database had no data on releases of PCBs to water.

- **Air emissions**. According to RAPIDS, 2.93 and 3.20 pounds of PCBs were emitted to the air in the Lake Michigan basin in 1993 and 1996, respectively (Great Lakes Commission 1999c and 1999d). The TRI database had no data on air emissions of PCBs.

Table 5-6. PCBs Discharged to Individual Water Bodies (1990 to 1999)

Water Body	Amount Discharge	
Wisconsin - Fox River/Wolf Creek	333.32 kg	(734.84 lb)
Wisconsin - Green Bay	1.87 kg	(4.12 lb)
Illinois - Western Shore	26.54 kg	(58.51 lb)
Michigan - Kalamazoo River	16.36 kg	(36.07 lb)
Michigan - Menominee River	4.12 kg	(9.08 lb)
Michigan - Grand River	15.1 kg	(33.29 lb)

- **Releases to land**. According to the National Response Center, there were 11 reported spills of PCBs, in the Lake Michigan states from 1993 to 1998 (EPA 1999k). The TRI database indicated that 1 pound (0.454 kg) of PCBs has been released to land in the past 10 years.

- **Legacy PCB contamination.** The major source of PCBs today is environmental cycling of PCBs previously introduced into the environment. PCB-contaminated sediments may re-suspend PCBs in the water, allowing for bioaccumulation in the food web. In addition, volatilization of PCBs from land and water surfaces into the atmosphere can result in subsequent wet or dry deposition and then re-volatilization. For this reason, and because of their persistence in the environment, PCBs that were released to the environment many years ago play an active role in the contamination of today's environment. An example of legacy sources is the PCB contamination in the Fox River. From 1957 to 1971, several pulp and paper mills released about 250,000 pounds of PCBs into the Fox River. PCBs were primarily released during the manufacture and recycling of carbonless copy paper (Lake Michigan Forum No date). The Kalamazoo River has also been contaminated with PCBs from these processes. Both of these rivers are now AOCs in which past depositions remain a problem.

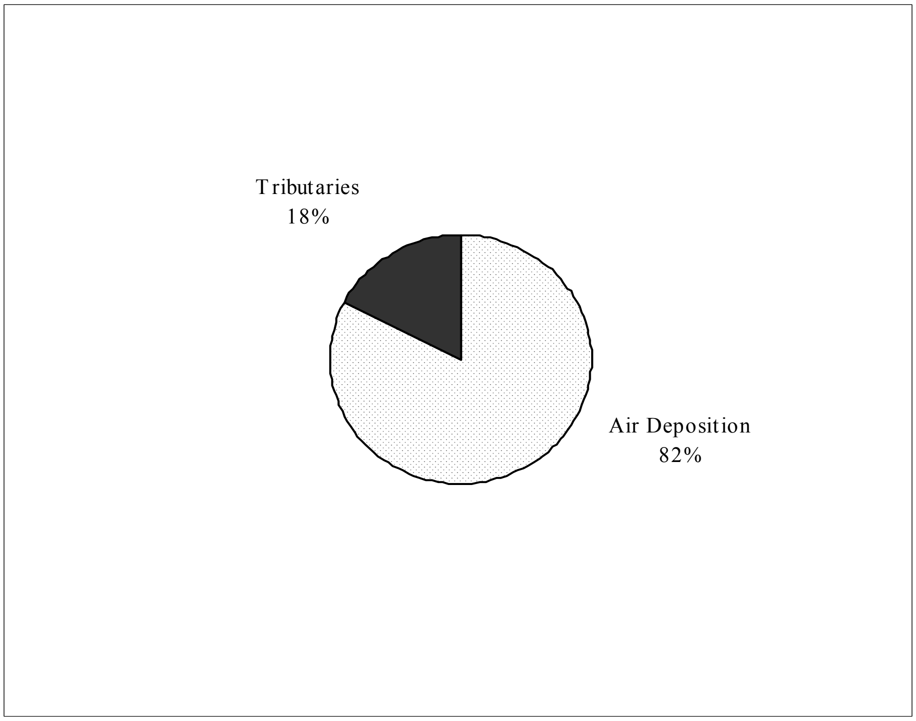
  There are 24 sites in the Lake Michigan basin listed on the National Priority List (NPL) that contain PCB contamination in soil, sediments, surface water, groundwater, or leachate. The PCBs at these sites have the potential to eventually be discharged to Lake Michigan. For example, the Allied Paper Inc./Portage Creek/Kalamazoo River Superfund site contains more than 350,000 lbs of PCBs in sediments and millions of tons of PCB-contaminated waste from the paper-making industry in five uncontained disposal areas on the river banks. PCBs continue to migrate into the environment from these areas due to river-induced erosion and surface water runoff (Lake Michigan Forum No date). Each of the 10 Lake Michigan AOCs have PCB-contaminated sediments and the Fox and Kalamazoo rivers have PCB-contaminated water. Many of these areas were heavily contaminated with PCBs in the past and now contribute significant PCB loads to Lake Michigan.

ACTUAL LOADINGS OF PCBs TO LAKE MICHIGAN

This section describes the specific sources and pathways of PCBs to Lake Michigan and the load of PCBs contributed via these pathways. Several studies have been performed to estimate loading of PCBs to Lake Michigan. This section reports recent estimates of PCB loads from air deposition, sediments, and tributaries and the AOCs. The total loading of PCBs to Lake Michigan is estimated to be 1,861 kg/yr

(4,103 lb/yr), according to the LMMB Project. Figure 5-7 shows the estimated percentage of PCBs contributed by various sources according to the LMMB Project (EPA No date[i]).

Figure 5-7. Loads of PCBs to Lake Michigan (EPA No date[i])



Atmospheric Deposition Pathway

Atmospheric deposition of PCBs plays a dominant role in PCB cycling in the Lake Michigan ecosystem. According to the LMMB, atmospheric transport and deposition of PCBs provide about 82 percent of the total PCB load to Lake Michigan. Because PCBs are no longer produced, the major source of PCBs to the atmosphere is volatilization from sites where they have been stored, disposed, or spilled; from incineration of PCB-containing products; and, to a lesser extent, PCB formation during production processes. In addition, as the following sections will describe, volatilization of PCBs from the water has been shown to be the dominant mechanism for exchange of PCBs between Lake Michigan and the atmosphere.

Concentrations of PCBs in air over Lake Michigan have been observed to range from 440 picograms per cubic meter (pg/m^3) (4.12×10^{-2} parts per trillion [ppt]) in the southern and mid region of the lake to 170 pg/m^3 (1.59×10^{-2} ppt) in the northern part of the lake (McConnell and others 1998). This section describes Lake Michigan studies that have estimated loads and sources of PCBs from atmospheric deposition.

Atmospheric Deposition Pathway: Load Estimates

There are three major processes of direct atmospheric deposition to Lake Michigan: wet deposition, dry deposition, and gas-exchange across the air-water interface. Loadings from each of these processes are discussed in the following studies: IADN, LMMB, AEOLOS, and others. Table 5-7 summarizes the findings of these studies.

Table 5-7. PCB Air Deposition Estimates

Study (year conducted)	Wet deposition kg/yr (lb/yr)	Dry deposition kg/yr (lb/yr)	Gas transfer kg/yr (lb/yr)
IADN (1993 to 1994)	110 ± 24 (243 ± 53)	32 ± 33 (71 ± 73)	-700 ± 720 (-1,543 ± 1,587)
LMMB/AELOS (1993 to 1995)	50 to 250 (110 to 551)	1,100 (2,425)	880 (1,940)
LMMB (1994 to 1995)	98 (216)	109 (240)	1,329 (2,930)

The IADN collects regional atmospheric data at the remote Sleeping Bear Dunes sampling site in Lake Michigan. The IADN estimates that wet and dry deposition of PCBs to Lake Michigan has decreased from 400 kg/yr (882 lb/yr) in 1988 to 42 kg/yr (93 lb/yr) in 1996 (EPA 1999f). In fact, some data show a net loss of PCBs to the atmosphere from Lake Michigan (Offenberg and Baker 1997).

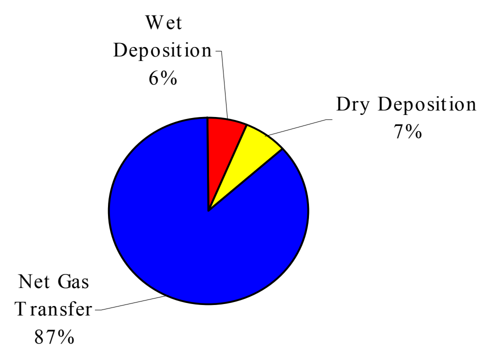
Although results from another recent IADN study indicated a substantial PCB load to Lake Michigan from wet deposition, the net deposition of PCBs to Lake Michigan was insignificant because gas transfer out of the lakes offset the flow of PCBs into the lake from wet and dry deposition, which was based on the 1993 to 1994 data from the Sleeping Bear Dunes sampling site (Hillery and others 1998). In addition, gas transfer of PCBs to the atmosphere from Lake Michigan seems to have steadily decreased. However, estimates of gas transfer and dry deposition had uncertainties, making it impossible to establish definitive trends (Hillery and others 1998). Despite these uncertainties, this study concluded that PCBs were approximately in equilibrium between the lake water and atmosphere. If PCBs are in fact at equilibrium, atmospheric PCB concentrations could be used to track changes in water PCB concentrations (Hillery and others 1998).

Franz and others (1998) conducted a study to estimate dry deposition of particulate PCBs to Lake Michigan as part of the LMMB. Samples were collected at multiple sites within the Lake Michigan basin from November 1993 to October 1995 and samples were also collected during the AEOLOS project in July 1994. This study estimated inputs of PCBs to be about 1,100 kg/yr (2,425 lb/yr) by particle dry deposition. Previous estimates for dry deposition ranged from 16 to 170 kg/yr (36 to 375 lb/yr). [The discrepancy is not clearly explained in Franz 1998.] In addition, LMMB projects have estimated PCB in puts from air-/water exchange to be about 880 kg/yr (1,940 lb/yr) and-about 50 to 250 kg/yr (110 to 551 lb/yr) by wet deposition (Franz and others 1998).

Hornbuckle and others (1995) conducted a study to determine the direction and magnitude of air-water PCB exchange on a seasonal and annual time scale. Air and water samples taken at sites throughout the northern two-thirds of Lake Michigan indicated net PCB volatilization of 71 kg/season (157 lb/season) in the spring to 190 kg/season (419 lb/season) in the fall. These results are reflective of seasonal variation in water temperature, which in turn affects volatilization rates. PCB removal from the lake via net volatilization was cited in this study to be approximately one-third the loss via sedimentation as reported in a study by Golden (1994). The Hornbuckle study and the results from the IADN suggest that the regional atmosphere and Lake Michigan are both sources and sinks for PCBs.

The LMMB Project has estimated the total Lake Michigan atmospheric loading of PCBs to be 1,536 kg/year (3,386 lb/yr). The LMMB Project estimates that 109 kg/yr (240 lb/yr) of PCBs enter Lake Michigan through dry deposition of dust, aerosols, and particulates. Lake Michigan receives about 98 kg/yr (216 lb/yr) PCBs from wet deposition of rain and snow. The LMMB Project estimates the net gas input of PCBs to be about 1,329 kg/yr (2,930 lb/yr) (EPA No date[i]). See Figure 5-8.

Figure 5-8. LMMB Estimates of PCB Air Deposition to Lake Michigan (EPA No date[i])



Based on these studies, wet deposition of PCBs to Lake Michigan ranges from 50 to 250 kg/yr (110 to 551 lb/yr) from wet deposition, 16 to 1,100 kg/yr (35 to 2,425 lb/yr) from dry deposition, and 880 to 1,329 kg/yr (1,940 to 2,930 lb/yr) for air-water exchange.

Atmospheric Deposition Pathway: Chicago as a Source

Chicago was identified as a significant source of PCBs loads within the 1-day airshed for Lake Michigan. The Chicago source includes PCB volatilization from the industrial footprint and PCB emissions from combustion and incineration facilities. The AEOLOS project was designed to estimate atmospheric deposition to the Great Waters as defined in Section 112 of the 1990 Clean Air Act. In 1994 and 1995, air concentrations of PCBs were measured in the industrial area of Chicago, IL; over southern Lake Michigan; and in a non-urban area as part of the AEOLOS project. Gas phase concentrations of total PCBs ranged from 0.14 to 1.1 nanograms per cubic meter (ng/m^3) (1.31 x 10^{-2} to 1.03 x 10^{-1} ppt) over the lake and from 0.27 to 14 ng/m^3 (2.53 x 10^{-2} to 1.31 ppt) in the urban area (Simcik and others 1997). In addition, the PCB concentrations over southern Lake Michigan were highest when the wind was from the direction of the industrial area (the lake shoreline from Evanston, IL to Gary, IN), and they were near regional background levels when the wind was from any other direction. PCB concentrations also increased with higher temperatures.

The Lake Michigan Urban Air Toxics Study (Keeler 1994) collected 12-hour atmospheric samples at three sites, by airplane, and research vessel for a full month in 1991. The study concluded that PCB levels were about 3 times higher at the Chicago sampling site than at the other sites and were generally found to be higher over the lake than at the downwind or upwind sites.

Fluxes of particulate PCBs were also higher in Chicago than less than 15 kilometers (9.3 miles) off shore and at rural sites. The geometric mean dry deposition flux is 0.2 micrograms per square meter per day (5.36 x 10^{-7} lb/acre-day) in Chicago and 0.06 µg/m^2-day (1.79 x 10^{-6} lb/acre-day) at the Sleeping Bear Dunes sampling site. However, dry deposition of PCBs in Chicago during the Franz study is about 3 times less than in 1979 and an order of magnitude less than previously reported levels using 1989 to 1990 data (Franz and others 1998). Modeling results show that more than 90 percent of PCB dry deposition is due to particles more than 2.5 microns in diameter and that duty vehicles using diesel or gasoline and soil dust are the major sources of these coarse particles (Delta Institute 1999).

Precipitation appears to be highly efficient at removing particulate matter, to which PCBs are bound, from the urban atmosphere. Under the AEOLOS project, the total concentrations of PCBs in Chicago precipitation ranged from 4.1 to 189 ng/L (4.1×10^{-3} to 1.89×10^{-1} ppt) (Offenburg and Baker 1997). Due to higher atmospheric PCB concentrations, the levels of PCBs in precipitation falling into southern Lake Michigan are from 2 to as much as 400 times greater than the measured background levels (Delta Institute 1999). Because 5 to 20 percent of the lake surface may be affected by precipitation originating from Chicago, PCBs in precipitation in and near Chicago increase the total PCB inputs to the lake by 50 to 400 percent over background loading levels (EPA 1999f). With wet deposition at background concentrations only, 50 kg (110 lb) of PCBs are input to Lake Michigan by wet deposition annually. Inclusion of the Chicago-influenced deposition over 5, 10, and 20 percent of Lake Michigan's surface area increases annual lakewide PCB wet deposition to 100, 150, and 200 kg/yr (220, 331, and 441 lb/yr), respectively (Offenburg and Baker 1997). These findings indicate that estimating atmospheric deposition based on one remote monitoring station, like the IADN, may underestimate deposition.

Finally, total PCB concentrations in southern Lake Michigan itself ranged from 80 to 350 picograms per liter (pg/L) (8.0×10^{-5} to 3.5×10^{-4} ppt) and were higher when the winds were blowing from Chicago (Delta Institute 1999). Offenburg and Baker (1997) also studied the enhancement of PCB loadings to Lake Michigan in the industrialized Chicago area. Total PCB concentrations in the lakeshore near Chicago were 2 to 3 times higher than values collected in more remote areas of the lake. However, total PCB concentrations in southern Lake Michigan have declined 10 fold over the past 14 years, resulting in a decline of 17 to 30 percent per year (Delta Institute 1999).

Sediments Pathway

Contaminated sediments are a source of PCB contamination in Lake Michigan because PCBs maybe released from sediments and resuspended in the water. PCBs are widespread at low levels throughout Lake Michigan sediment, but are concentrated at all of the AOCs. PCB loads from contaminated sediments in the Lake Michigan tributaries and AOCs are described in the following section.

Tributaries and Areas of Concern Pathway

Rivers and streams that flow into Lake Michigan are additional sources of PCB loads to the lake. The LMMB estimates that all of the tributaries combined contribute a load of about 325 kg/yr (716 lb/yr) to Lake Michigan (EPA No date[i]). Table 5-8 summarizes sediment and water PCB-loads.

PCBs continue to be a primary environmental contaminant in the 10 Lake Michigan AOCs. PCBs have been identified as contaminants in water and sediments in all of the Lake Michigan AOCs, including the Fox River and Lower Green Bay, Grand Calumet River/Indiana Harbor Ship Canal, Manistique River, Sheboygan River, Waukegan, Kalamazoo River, Lower Menominee River, Milwaukee Estuary, White Lake, and the Muskegon River. Illinois, Indiana, Michigan, and Wisconsin have all issued fish consumption advisories due to PCB concentrations.

The Lower Fox River is the source of 95 percent of the PCB load to Green Bay and is the source of the largest single load to Lake Michigan (WDNR 1997). Currents from the Fox River flush about 600 pounds of PCBs into Green Bay every year (Lower Fox River Intergovernmental Partnership 1998). As a result, an estimated 160,000 pounds of PCB have already migrated from the Fox River into Green Bay and Lake Michigan (Lake Michigan Forum No date). In addition, about 40 tons of PCBs remain in 11 million cubic yards of sediment in the river (Lower Fox River Intergovernmental Partnership 1998).

Brazner and DeVita (1998) measured PCB concentrations in young-of-the-year littoral fishes from Green Bay, Lake Michigan. Based on the PCB concentration gradient measured in fish samples, they determined that the Fox River was the primary source of PCBs. In addition, the percentage of the more-chlorinated PCB congeners observed in upper bay fish supports the hypothesis that less-chlorinated PCBs volatilize more quickly and therefore are less abundant farther from their source. Regarding Green Bay, PCB concentrations are highest in the lower bay and decrease with increasing distance from the mouth of the Fox River (Swackhamer and Armstrong 1987).

The Grand Calumet River drains about 500 million gallons of water into Lake Michigan per day. The Grand Calumet River and Indiana Harbor Ship Canal contain 5 to 10 million cubic yards, up to 20 feet deep, of sediments contaminated with PCBs and other toxic compounds (EPA No date[f]). An estimated 180 million pounds of sediments, containing 420 pounds of PCBs, are annually deposited in Lake Michigan from sediments out of the Grand Calumet River and Indiana Harbor (Chicago Cumulative Risk Initiative 1999). In addition, stormwater runoff and leachate, contaminated with PCBs, from 11 of 38 waste disposal and storage sites in the AOC are degrading water quality in the river (EPA No date [n]).

About 115,000 pounds of PCB-contaminated sediments once contaminated the Manistique River and Harbor. The total volume of PCB-contaminated sediments in the Manistique River and Harbor was estimated to be around 120,000 cubic yards.

Remediation of the Manistique AOC began in 1995 under a Superfund Emergency Removal Action because about 100 pounds of PCBs were being discharged into Lake Michigan due to natural erosion processes annually (EPA No date [f and m]). About 10,000 cubic yards of PCB-contaminated sediments were dredged in 1995. Remediation is scheduled to be completed in 2000.

The Sheboygan River and Harbor contribute about 30,000 cubic yards per year of PCB-contaminated sediments to the Sheboygan Harbor in Lake Michigan (Lake Michigan Forum No date). Total PCB concentrations in sediments from the Sheboygan River and Harbor range from 0.04 mg/kg (0.04 ppm) to more than 220 ppm. PCB concentrations decrease downstream towards Lake Michigan (David and others 1994). About 5,360 cubic yards of PCB-contaminated sediments were removed between 1989 and 1991 from the upper portion of the river.

Bioremediation was demonstrated on contaminated sediments in the Sheboygan AOC as part of the ARCS (alternative remediation of contaminated sediments) program. Under the ARCS program, a multi-organization endeavor of sediment assessment and remediation techniques were identified. EPA developed a plan with Tecumseh Products (Superfund site) to manipulate the contents of the confined treatment facility (CTF) to enhance naturally occurring biodegradation. Manipulation consisted of adding nutrients to sediments already containing indigenous populations of microorganisms (bacteria and fungi), and cycling the CTF between aerobic and anaerobic conditions (PCBs do not completely degrade either aerobically or anaerobically). The demonstration confirmed that the PCBs present in the Sheboygan River sediments had already undergone a great deal of anaerobic dechlorination (EPA 1994[e]).

Removal of 300,000 pounds of PCBs in 32,000 cubic yards of sediment from Waukegan Harbor and 700,000 pounds of PCBs in 18,000 cubic yards of soil from the OMC site resulted in removing fish warning signs in the harbor, although fish consumption advisories remain in effect. An Illinois EPA sediment sampling program has shown that the harbor is no longer a significant source of PCBs in Lake Michigan fish (IEPA 1997b). In addition, progress has been made toward de-listing the Waukegan Harbor as an AOC (Lake Michigan Forum No date).

The Kalamazoo River discharges into Lake Michigan 31 km north of South Haven. The Allied Paper Inc./Portage Creek/Kalamazoo River Superfund site contains more than 350,000 lbs of PCBs in sediments and millions of tons of PCB-contaminated waste. PCBs continue to migrate into the Kalamazoo River, and eventually Lake Michigan, due to river-induced erosion and surface water runoff (Lake Michigan Forum No date). The highest PCB concentration in contaminated Kalamazoo River sediments is 300 mg/kg (300 ppm) (EPA No date[f]).

The LMMB Project estimated annual PCB loads from Lake Michigan tributaries based on 1994 and 1995 data (see Table 5-8). According to these data, the Fox River contributes the largest load of PCBs to Lake Michigan (186 kg/yr) (EPA No date[j]).

Table 5-8. Estimated PCB Load From Lake Michigan Tributaries (EPA No date[j])

Tributary	Estimated Load (kg/yr)	Estimated Load (lb/yr)
Fox River	186.0	410
Grand Calumet	37.2	82.0
Manistique River	1.3	2.9
Sheboygan River	8.3	18.3
Kalamazoo	36.8	81.1
Grand	11.7	24.5
Menominee River	3.8	8.4
Milwaukee Estuary	7.3	16
Pere Marquette	0.5	1.1
Muskegon River	2.2	4.9
St. Joseph	9.3	20.5

IMPACT ON LAKE MICHIGAN

Trends in the concentrations of PCBs in lake trout and coho salmon in Lake Michigan have declined significantly since the 1970s, but have leveled off, or even increased in recent years in the case of coho salmon. This has occurred despite continued declines in concentrations in the water column, suggesting changes in the dynamics of the Lake Michigan food web. PCBs are still present at concentrations exceeding the Great Lakes' Governors' proposed action levels, resulting in fish consumption advisories for some Lake Michigan fish. These trends in PCB concentrations show significant declines since the 1970s, leveling off, and increasing in the early 1990s have been followed in herring gull eggs, and other wildlife. Appendix C contains detailed information on potential ecological and human health effects.

SPECIAL MANAGEMENT ISSUES

Specific actions to address PCBs are presented in Chapter 6, Table 6-1: RPPI, RPP2, RPP6, RPP10,RPP11, HH9, HH10 6

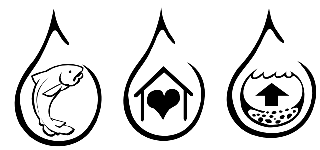
Programs regulating and controlling the management of PCBs are presented in Appendix A.

Special management issues include the following:

- Environmental cycling of legacy PCB contamination is a major source of PCB loading to Lake Michigan.
- Long-range transport of pollutants
- Urban nonpoint sources

5.3.3.2 Dioxins/Furans

Critical Pollutant



The term "dioxin" represents a class of halogenated aromatic hydrocarbon compounds including polychlorinated dibenzodioxins and dibenzofurans. There are a total of 210 possible congeners of dioxin, depending on the location and substitution of chlorine in the molecule . Those congeners with chlorine substitution in the 2,3,7, and 8 positions on the molecule are generally thought to be responsible for the greatest degree of toxicity associated with dioxin (EPA 1998b). TCDD (2,3,7,8 tetrachlorodibenzo-p-dioxin) is the most toxic and best understood of all the types of dioxin. As a result, the concentrations of all dioxin and furan compounds are typically reported as Toxicity Equivalent Concentration (TEQ) normalized to 2,3,7,8-TCDD. Dioxins and furans can be released to aquatic systems in various wastewater streams and sludges. Furans are also unwanted trace impurities of PCBs, HCB, pentachlorophenol, and phenoxy herbicides such as 2,4,5-T. Information on the physical and chemical properties of dioxin and furans is presented in Appendix B.

Both dioxins and furans are only slightly soluble in water, strongly sorb to soils and sediments, persist in soil and aquatic systems, and have a high potential for bioaccumulation. EPA classifies TCDD as a probable human carcinogen. Like herbicides such as trichlorophenols, dioxin is classified by the EPA as a limited evidence human carcinogen. Toxicological studies of furans (PCDF) indicate that the effects of this group of compounds are very similar to those of the dioxins. See Appendix C for additional information on dioxin and furan health effects.

Following is a discussion of the potential and actual releases of dioxins and furans into the environment, the potential load to the lake, the current and past loading of dioxins and furans to the lake, the impact of dioxins and furans on achieving the vision for the Lake Michigan ecosystem, and unique issues related to managing dioxins and furans.

POTENTIAL RELEASES OF DIOXINS AND FURANS TO THE ENVIRONMENT

- **Intentional use.** Dioxin is not a product formulated for use. It occurs purely as a by-product in processes such as combustion and chlorination. In the context of the Lake Michigan management activities, load reductions typically target “dioxin” in the form of 2,3,7,8-tetrachloro-dibenzo-p-dioxin because of the high degree of toxicity associated with that specific compound. Furthermore, most research completed to date has focused primarily on identifying sources of the 2,3,7,8-TCDD congener, rather than other forms of dioxins and furans.

- **Inadvertant generation during production processes.** EPA’s 1998 National Dioxin Inventory indicates that one of the primary historical sources of dioxin releases to water has been pulp and paper production processes, although the inventory found that the pulp and paper industry accounted for less than 2 percent of all releases to air, land, and water, and in products. Important potential anthropogenic sources also include releases from processes such as cement kilns and metal smelting and refining. Dioxins are also formed as unwanted impurities during the manufacturing of other organic compounds including herbicides containing 2,4,5 trichlorophenoxy acids (2,4,5 T), 2,4,5 trichlorophenol, hexachlorophene, pentachlorophenol and PCBs. The pyrolysis (heat decomposition) of technical grade PCB mixtures produces several polychlorinated dibenzofurans (CDF) (Rappe 1979; Schecter and Charles 1991). Like dioxins, a primary source of furans are emissions as by-products of the pulp and paper production processes and non-ferrous metal manufacturing.

- **Combustion or incineration**. Some of the primary historical sources of dioxins have been atmospheric deposition from municipal and medical waste incineration. The most important potential anthropogenic sources include releases from processes such as municipal, medical and hazardous waste incinerators, cement kilns, metal smelting and refining, wood combustion, and household waste burning. A primary source of furans is atmospheric deposition due to emissions from waste incineration and burning of fossil fuels.

- **Commercial Products**. Pentachlorophenol has been used to preserve a variety of commercial products, including textiles and leather goods in the United States and abroad. In the past, pentachlorophenol was widely used as a pesticide although most of those uses are now restricted. Dioxin contamination in pentachlorophenol could contribute as much as 10,500 g TEQ/yr (23.14 lb TEQ/yr) in the United States (Slants and Trends 1995). Based on the normalized population of the Lake Michigan basin, more than 200 g TEQ/yr (0.44 lb TEQ/yr) of dioxin are assumed to be found in the basin. However, dioxin levels in products are likely to decrease because of declining use of pentachlorophenol. The disposal and use of commercial products contaminated by PCDDs and PCDFs, such as certain pesticides and pentachlorophenol-treated wood, is also a potential source of dioxin. Pulp and paper mill discharges to publicly-owned treatment works (POTW) are a diminishing problem in the Lake Michigan basin.

- **Wastewater treatment plant sludge.** One POTW in the Lake Michigan basin receives indirect discharges from a bleached kraft mill. However, new cotton clothing and other household items have been found to contain dioxins; the dioxins come out in the wash and are discharged to the wastewater treatment facility (Horstmann and McLachlan 1994). In 1990, the Western Lake Superior Sanitary District treatment plant sludge contained 0.014 g (0.00049 ounce) TEQ. If similar waste streams are managed by Lake Michigan basin POTWs, sludge generated by these plants are likely to contain more than 1 g TEQ based on population.

- **Natural sources.** There are also significant natural sources of dioxins and furans, including forest fires and volcanic activity. However, in the United States, atmospheric releases of dioxins and furans from forest and agricultural fires are relatively small compared to releases from anthropogenic sources.

ACTUAL RELEASES OF DIOXINS AND FURANS TO THE ENVIRONMENT

Dioxins and furans are generated by a variety of sources in the Lake Michigan basin. The following sources are highlighted in this analysis.

Industrial

- **Forest products**. Dioxins have been generated in pulp and paper mills from the paper bleaching process, especially in plants using elemental chlorine as a bleaching agent. In recent years, pulp mills in the basin have modified their bleaching processes by substituting chlorine dioxide for elemental chlorine, thereby virtually eliminating dioxins from pulp and paper mill effluents

(Stromberg and others 1996). Monitoring data provided by NCASI indicate that reductions in TCDD and TCDF releases resulting from changes in the bleaching processes to effluent, mill sludges, and pulp products have been estimated at 92 percent, 89 percent, and 93 percent respectively (on a TEQ basis). For the remaining five bleached kraft mills in the Great Lakes Basin, TCDD/TCDF releases in 1996 were estimated at 0.42 g TEQ in effluent, 0.04 g TEQ in sludge, and 0.29 G TEQ in product (NCASI 1997).

- **Petroleum refining**. Dioxins can be formed when catalysts used in petroleum refining are reactivated by burning off coke deposits at 380 degrees C (716 °F) to 525 degrees C (977 °F) in the presence of chlorinated compounds (Bear and others 1993). Seven petroleum refiners are currently operating in the basin. Dioxins in waste effluents from these facilities are thought to be associated with the regeneration of the catalyst reformer. For example, prior to 1991, 1.5 x 10^{-5} g (5.29 x 10^{-7} ounce) TEQ/yr was measured in the effluent of the Murphy Oil facility in Superior, Wisconsin. The dioxin in the effluent was thought to be associated with the regeneration of the catalyst reformer. Wastes from this process are now typically disposed in a hazardous waste facility (LSBP 1996).

- **Wood preserving**. Past industrial use of pentachlorophenols (PCP) to treat timber, railroad ties, and utility poles are a potential source of dioxins in the basin (Tetra Tech 1996). For example, 0.29 g (0.01 ounce) TEQ was observed in the soils in the vicinity of the Koppers Inc. facility in Superior, Wisconsin. The facility used PCP to treat railroad ties until 1979. Two Superfund sites in the Lake Michigan watershed, Cordova Chemical and the Ninth Avenue Dump, report soil or sediment dioxin contamination.

- **Metal smelting and refining**. Nonferrous metal, especially copper, smelting and refining are a known source of dioxin and furan emissions accounting for approximately 1.36 x 10^{-2} lb/yr TEQ air emissions in the United States (EPA 1997d). In the Lake Michigan basin, smelting and refining operations are primarily limited to the southern end of the watershed. TRI reported dioxin air releases from this sector totaled more than 20 g (0.71 ounce) in 1996.

Fuel Combustion

The combustion of wood and coal as an energy source for industrial and residential use is a known source of dioxins (EPA 1997). Increased attention has been devoted over the past several years to estimate the dioxin emission factors associated with these processes. Table 5-9 provides estimates of the wood and coal combustion rates in the Lake Michigan Basin and the current emission factors used to estimate dioxin TEQ emissions from those sources.

Incineration

- Burn Barrels. In the past several years, research has found that household "burn barrels" may be a significant dioxin source. WLSSD (1992) estimated that burn barrels produce 20 times more 2,3,7,8-TCDD per unit of household garbage burned than a controlled incinerator (for example, a municipal waste combustor [MWC]). Lemieux (1998) estimated that 1.5 to 4 households that burn their waste in the open (for example, in burn barrels) equal the dioxin generating potential of a fully-operational MWC. Overall, household waste combustion in burn barrels appears to be an overlooked, but potentially significant source of dioxin and other toxic air emissions.

Table 5-9. Dioxin Emissions from Wood and Coal Combustion

Fuel and Combustion Type	Quantity of Fuel Burned in Lake Michigan Basin (kg)[a]	Emission Factor (ng TEQ/kg fuel combusted)	Dioxin Emissions (g TEQ/yr)[d]
Coal, coal fired utilities and industrial boilers	1.8×10^9 (1,984,140 tons)	0.087[b] (0.087 ppt)	0.16 (0.0056 ounce TEQ/yr)
Coal, commercial and residential boilers	1.7×10^7 (18,739 tons)	22[c] (22 ppt)	0.37 (0.013 ounce TEQ/yr)
Wood, industrial wood furnace	1.2×10^8 (132,276 tons)	0.82[b] (0.82 ppt)	0.10 (0.0035 ounce TEQ/yr)
Wood, commercial and residential	1.5×10^8 (165,345 tons)	2[b] (2 ppt)	0.30 (.011 ounce TEQ/yr)
TOTAL			0.93 (0.033 ounce TEQ/yr)

[a] Adapted from Tetra Tech (1996).
[b] EPA 1998b
[c] Tetra Tech 1996

The average person in the United States generates between 800 and 1,350 pounds of household waste in a year (MDEQ 1999). The EPA estimates that 40 percent of people living in non-metropolitan areas burn their waste and that 63 percent of their daily waste is burned in burn barrels. Nationally, this amounts to more than 90 billion pounds of household waste burned in burn barrels every year. Normalized for the Lake Michigan basin population, this amounts to more than 4.7 billion pounds of household waste openly burned in the basin each year.

While such household waste burning is suspected to be a significant source of dioxin and other toxic air emissions, research findings differ as to the rates of dioxin emission per unit of household waste burned (Cohen 1999). Table 5-10 summarizes dioxin generation emission factors for several recent studies. The table illustrates that emission rate estimates vary over several orders of magnitude. As a result, these emission factor estimates are provided to illustrate the potential significance of the source. Much additional work remains to be completed to properly estimate the dioxin emissions from household waste burning that is occurring in the basin.

To illustrate the potential magnitude of household hazardous waste burning in the U.S. portion of the basin, Table 5-11 applies the Cohen (1999) emission factor to potential household hazardous waste burn rates in the U.S. Lake Michigan basin counties to generate an annual TEQ dioxin emission estimate. Extrapolation of national estimates on burning rates to the Lake Michigan basin yields an estimate of about 170 g (0.0060 ounce) TEQ/yr.

Table 5-10. Emission Factors for Household Waste Combustion in Burn Barrels

Source	Emission Factor (g TCDD/lb household waste burned)	Emission Factor (ounce TCDD/lb household waste burned)
Cohen (1999)	3.6×10^{-8} [b]	1.27×10^{-9}
Lemieux (1998) (recycler)[a]	1.04×10^{-7}	3.67×10^{-9}
Lemieux (1998) (non-recycler)	7.4×10^{-6}	2.61×10^{-7}
Two Rivers Regional Council (1994)	6.2×10^{-10}	2.19×10^{-11}
WLSSD (1992)	1.8×10^{-9}	6.35×10^{-11}

[a] Recyclers were assumed to reduce the proportion of newspaper, plastic, and some metals in their household waste.

[b] Expressed as grams TEQ/yr.

Table 5-11. Dioxin Generated from Household Waste Combustion in Burn Barrels

Lake Michigan Basin County Population[a]	Estimated Annual Waste	Estimated Pounds Burned	Estimated g TEQ/yr Emissions
14,138,704	1.91×10^{10}	4,774,999,964	172

[a] includes population of Cook County, Illinois

- Medical and industrial. Medical and industrial incinerators have been recognized as a significant source of dioxin and furan air emissions. The number of incinerations in the basin is declining as medical and industrial waste combustion is phased out.

- Small incinerators. Small incinerators (such as those operated by schools, apartment buildings , and retailers) have contributed a large proportion of dioxin and furan air emissions. However, as of 1999, all small incinerators are assumed to be closed in the United States as a result of the MACT regulations (see Appendix B). As a result, no dioxin air emissions are estimated for this sector in 1999.

ACTUAL LOADING OF DIOXIN AND FURANS TO LAKE MICHIGAN

Cohen and others (1995), modeled air deposition estimates, average depositional flux, and water effluent inputs for dioxins in Lake Michigan to help explain and understand the variations in loadings and accumulations (Table 5-12). Results showed that flux trends followed the pattern of industrialization around the lake, and that waterborne inputs play a lesser role than air deposition of dioxins to Lake Michigan.

Table 5-12. Modeled Air Deposition and Waterborne Inputs of Dioxins and Furans to Lake Michigan

Total Air Deposition (g TEQ/yr)	(ounce TEQ/yr)	Waterborne Inputs (g TEQ/yr)	(ounce TEQ/yr)
5 - 43	0.18 - 1.52	1.9	0.067

Pearson and others (1998) assessed current and historical inputs of dioxins and furans to the Great Lakes, including Lake Michigan. Concentration and accumulations of dioxins and furans were determined in dated sediment cores from northern and southern Lake Michigan depositional zones. Results showed that both currently and historically there is significantly more accumulation of dioxin in the northern part than in the southern part of the lake. This finding is inconsistent with long-range atmospheric transport and deposition, because air concentrations of dioxins are known to decline in more remote areas, and in theory then the air masses over northern Lake Michigan should be less contaminated, on average, than those over southern Lake Michigan. Thus, non-atmospheric sources of dioxin to northern Lake Michigan are implicated by this study. Through analysis of dioxin homolog mixtures in the cores and the atmosphere, it was estimated that the atmosphere currently provides 100 percent of dioxin to southern Lake Michigan, 33 to 50 percent of dioxin to northern Lake Michigan, but only 5 to 35 percent of the total furan in Lake Michigan as a whole. In addition, by comparing the sediment homolog compositions to those of non-atmospheric sources, such as contaminated sediment sources and industrial waste dischargers, likely non-atmospheric sources were suggested. For southern Lake Michigan it was suggested that effluent from bleached kraft paper mills or contamination from PCB spills could produce the homolog compositions observed. In northern Lake Michigan it was suggested that by products related to PCP, effluent from paper mills using large amounts of recycled stock, or effluents from sewage treatment plants could account for the added accumulations of dioxin. Additional data is required to definitively implicate any of the possible sources.

Finally, the RAPIDS data analysis has estimated approximately 230 g (8.11 ounce) TEQ of dioxin and furan air emissions in 1996. The predominant sources of the emissions included residential wood combustion and pharmaceutical preparations.

IMPACT ON LAKE MICHIGAN

Currently, the major route of exposure of 2,3,7,8-TCDD to the general population is estimated to occur through the food web, in particular through the ingestion of fatty substances such as meat, dairy products, and fish. As they are soluble in fats, dioxins and furans will accumulate in the bodies of humans and animals. A fish consumption advisory for the Menominee River in Michigan has been established because of exceedances of the 10 µg/g TEQ level in fish tissues. No advisories are currently in effect for the open waters of the lake.

SPECIAL MANAGEMENT ISSUES

Specific actions to address DIOXINS AND FURANS are presented in Chapter 6, Table 6-1: HH9, HH10, SU6, RPP1, RM5 6

The significant, remaining sources of dioxin emissions in the Basin include small industrial and other waste incinerators and backyard burning of household waste in burn barrels. Because most large emission sources in the basin are understood, the focus must now be placed on characterizing small, disperse sources. As a result, the control strategies applicable to these sources should include public education and outreach coupled with aggressive identification of these sources. Other areas to be pursued on a long-term basis are clean up of contaminated sites and investigation of continuing pentachlorophenol use. Current regulatory and management programs for dioxin/furans are discussed in Appendix A.

Critical Pollutant

5.3.3.3 Dieldrin/Aldrin

Aldrin and dieldrin are the common names of two insecticides that are closely related chemically. They were both used primarily for crop protection from various soil-dwelling pests as well as protection against termite infestation. Dieldrin is also a primary degradation product of aldrin. The last uses of aldrin and dieldrin in the United States were canceled in 1991 and 1989, respectively. Both are persistent and toxic in the environment. See Appendix B for physical and chemical properties of dieldrin and aldrin.

Following is a discussion of the potential and actual releases of aldrin and dieldrin into the environment, the potential load to the lake, the current and past loading of dieldrin and aldrin to the lake, the impact of dieldrin and aldrin on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing dieldrin and aldrin.

POTENTIAL RELEASES OF DIELDRIN/ALDRIN TO THE ENVIRONMENT

- **Historical use, global use, and environmental cycling.** Aldrin was first synthesized in the United States as a pesticide in 1948. Aldrin and dieldrin are active against insects by contact or ingestion. The primary use of these products was for control of corn pests by application to the soil. Other past uses were in the citrus industry and in general crop protection. Non-agricultural pesticide use included application against termite infestation of structures and against soil-dwelling pests such as ants, wireworms, and white grubs.

  All pesticide uses of aldrin and dieldrin were canceled in 1974, except for subsurface ground insertion for termite control, dipping of non-food roots and tops and moth-proofing by manufacturing processes in closed systems. Twenty one product registrations that remained for non-food crop uses of aldrin were allowed to lapse or were voluntarily canceled by the registrants. Most remaining aldrin products were canceled by 1987, with the last product canceled in 1991. Thirty product registrations that remained for non-food crop uses of dieldrin were allowed to lapse or were voluntarily canceled by the registrants. Most remaining dieldrin products were canceled by 1987; the last product was canceled in 1989 (HHS 1993a).

- **Hazardous waste sites.** In addition to sources associated with direct releases and historical applications, dieldrin and aldrin have been identified as contaminants for at least 13 hazardous waste sites in the four Lake Michigan states.

- **Stockpiles.** Waste pesticide collections (Clean Sweeps) continue to recover significant quantities of dieldrin, aldrin, and other Level I pesticides from agricultural users indicating that additional stored quantities are likely to exist. Quantities of dieldrin and aldrin recovered in the Great Lakes drainage basin are presented in Table 5-13 and Table 5-14. Improper storage or illegal use of such large quantities of dieldrin and aldrin could be a significant source to Lake Michigan.

ACTUAL RELEASES OF DIELDRIN/ALDRIN TO THE ENVIRONMENT

- **Point source water discharges, air emissions, and releases to land.** There are currently no known direct releases of aldrin and dieldrin to the environment as the result of product manufacturing, and TRI records indicate no reportable releases to the environment.

- **Legacy dieldrin/aldrin contamination.** The primary source of aldrin and dieldrin to the environment has been past agricultural use and application for termite control. Although application of these compounds was canceled, historical applications resulted in persistent soil residues that continue to serve as sources into the atmosphere as well as runoff into surface water (HHS 1993a).

Table 5-13. Estimated Clean Sweeps Collections of Dieldrin in the Great Lakes Drainage Basin (EPA 1998f)

State	Years of Collection	Dieldrin Collected (kg)	Dieldrin Collected (lb)
Illinois	1994 to 1998	4	8.8
Indiana	1992 to 1997	2	4.4
Michigan	1992, 1994, 1995	913	2,012.8
Wisconsin	1993 to 1996	99	218.3
Total		1,018	2,244.3

Table 5-14. Estimated Clean Sweeps Collections of Aldrin in the Great Lakes Drainage Basin (EPA 1998f)

State	Years of Collection	Aldrin Collected (kg)	Aldrin Collected (lb)
Illinois	1994 to 1998	35	77.2
Indiana	1992 to 1997	68	149.9
Michigan	1992, 1994, 1995	1,913	4,217.4
Wisconsin	1993 to 1996	157	346.1
Total		2,173	4,790.6

In addition to residues from past applications, aldrin and dieldrin have been detected in soils, sediments, surface water and groundwater at hazardous waste sites in every state bordering the Great Lakes (HHS 1993a). Soil, sediment, and groundwater at the Muskegan Chemical NPL site in Michigan are contaminated with dieldrin and aldrin. Direct and indirect releases from these sites may continue to provide a source of aldrin and dieldrin to the environment.

ACTUAL LOADINGS OF DIELDRIN/ALDRIN TO LAKE MICHIGAN

Atmospheric Deposition Pathway

The largest use of aldrin in the United States during the 1970s was in states bordering the Great Lakes and to the south and west, the direction of most prevailing winds. Aldrin application was highest in many of the states adjacent to the southern edge of the Great Lakes. Conversely, dieldrin use was relatively low in the Great Lakes region. However, the detection frequency of dieldrin was twice as high

as for aldrin, which is not surprising, given the fact that aldrin converts readily to dieldrin in the environment (Majewski and Capel, 1995). Estimated trajectories of air masses show that model predictions support the long-range atmospheric transport of aldrin and dieldrin from these regions to the Great Lakes.
Recent fluxes of dieldrin have been measured through the IADN program at 5 locations around the Great Lakes. Dieldrin associated with both wet and dry deposition and in the gas phase was measured at all locations. Average annual concentrations of dieldrin at the IADN Lake Michigan master station are presented in Table 5-15. The wet and dry deposition fluxes of dieldrin to Lake Michigan are presented in Table 5-16. (IADN 1998)

Table 5-15. Average Annual Concentrations of Dieldrin at the IADN Lake Michigan Master Station (IADN 1998)

Year	Precipitation (ng/l or ppt)	Particle (pg/m^3)	Gas (pg/m^3)
1992	0.99	1.90 (0.0015 ppt)	34.00 (2.18 x 10^{-3} ppt)
1993	0.65	2.25 (0.0018 ppt)	39.50 (2.53 x 10^{-3} ppt)
1994	0.66	1.90 (0.0015 ppt)	36.30 (2.33 x 10^{-3} ppt)

Table 5-16. Fluxes of Dieldrin to Lake Michigan (IADN 1998)

Year	Wet (ng m^{2}d^{-1})	Dry (ng m^{2}d^{-1})
1991 to1992	2.70	0.38
1993	2.00	0.34
1994	2.60	0.46

Overall flux for the Great Lakes (except Lake Michigan, where net gas flux was not calculated) appears to be dominated by gas phase transfer out of the lakes (IADN 1998). This is consistent with the conclusions of Hillery and others (1998) for other chlorinated organics measured in the atmosphere over the Great Lakes. This trend for dieldrin was evident for data collected since 1990, although no overall decrease in either atmospheric concentrations or net flux was evident based on the average annual fluxes reported by the IADN (IADN 1998). However, Cortes and others (1998) provided estimates of temporal trends based on these same measurements using partial pressures corrected for seasonal temperature. Using this approach, Cortes and others (1998) calculated regional half-lives of dieldrin and found that there was a significant decrease of dieldrin in the atmosphere at all sites but Lake Ontario. The atmospheric half-life calculated for the Lake Michigan station was 1.5 years, resulting in an estimated date of virtual elimination from the atmosphere of 2010.

Sediments Pathway

Aldrin and dieldrin were measured in sediment cores from 5 locations in Lake Michigan (Golden 1994). The range of concentrations for both aldrin and dieldrin was relatively small and concentrations low. Aldrin was generally found at concentrations less than 2 ng/g (ppb) with little variation with depth. Dieldrin was detected at higher concentrations showing onset of contamination in approximately the

1940s. Concentrations in cores from northern Lake Michigan generally exhibited a peak around the 1970s and then a decrease in values in recent years. Although cores from Southern Lake Michigan show similar onset as those in the north, concentrations through the 1970s to the present have remained relatively constant. This trend may be a result of greater sediment activity (such as resuspension and mixing) in the southern basin rather than an indication of current inputs (Golden 1994).

Tributaries and Areas of Concern Pathway

A MDNR caged channel catfish study in the Menominee River found detectable levels of dieldrin (EPA No date[m]). Organochlorine contaminants (such as dieldrin) and heavy metals found in the Milwaukee Estuary AOC are shown to impair the bird or animal reproductive systems at that AOC. At White Lake AOC, a 28-day caged fish study conducted in the navigational channel between White Lake and Lake Michigan in 1992 showed that chlordane, DDE, and dieldrin were present. (EPA No date[m]).

IMPACT ON LAKE MICHIGAN

In Lake Michigan average dieldrin concentrations in lake trout increased from 0.27 mg/kg (ppm) in 1970 to 0.58 mg/kg (ppm) in 1979 followed by a decrease through 1986 (0.17 mg/kg [ppm]) and 1990 (0.18 mg/kg [ppm]) (DeVault and others 1995 and 1996). A similar trend is observed in dieldrin levels in whole bloaters, with an increase in tissue levels from 1970 through 1978 followed by a steady decline (Chemical Manufacturers Association 1997). There are currently no restrictions on fish consumption due to aldrin/dieldrin concentrations in fish from Lake Michigan (EPA 1997).

Concentrations of dieldrin in eagle eggs were above 2 ppm for eggs from Lake Michigan in 1986. Herring gull eggs have also been monitored for dieldrin. Some studies indicate a 30 percent decrease in dieldrin concentrations (over all Great Lakes) from 1971 to 1988 (Chemical Manufacturers Association 1997). However, even these studies indicate a possible increase in egg concentrations in the early 1990s in all of the Great Lakes, including Lake Michigan. Appendix C provides human health and ecological effects information for dieldrin and aldrin.

SPECIAL MANAGEMENT ISSUES

Specific actions to address DIELDRIN/ALDRIN are presented in Chapter 6, Table 6-1: RPP1, RPP16, IS13, RAI5 6

Programs regulating and controlling the management of dieldrin and aldrin are presented in Appendix A. Special management issues for dieldrin and aldrin include the following:

- Environmental cycling of legacy dieldrin and aldrin contamination as a major source of dieldrin to Lake Michigan.

- Long-range transport of pollutants

5.3.3.4 Chlordane

Critical Pollutant

Chlordane is a man-made chemical pesticide that was canceled in April 1988 due to concern over human cancer risk, evidence of human exposure and accumulation in body fat, environmental persistence, and danger to nonpest wildlife. If burned, chlordane emits a poisonous gas. See Appendix C for human health effects information. Chlordane is very persistent in the environment. It is resistant to both chemical and biological degradation and is strongly bioaccumulated in humans and aquatic organisms. See Appendix B for information on the physical and chemical properties of chlordane.

Following is a discussion of the potential and actual releases of chlordane into the environment, the potential load to the lake, the current and past loading of chlordane to the lake, the impact of chlordane on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing chlordane.

POTENTIAL RELEASES OF CHLORDANE TO THE ENVIRONMENT

- **Historical use, global use, and environmental cycling.** Prior to cancellation, chlordane's primary use in the United States was as a pesticide on agricultural crops, lawns and gardens, and as a fumigating agent used to control termites in houses. All uses of chlordane have been prohibited in the United States, and there is no current production or manufacture of the product in the United States Current sources of chlordane to the Lake Michigan are generally from historical use or production of the compound. On the basis of historic production figures, an estimated 70,000 tons of chlordane were produced since 1946, of which 25 to 50 percent is estimated to still exist unaltered in the environment (Dearth and Hites 1991b). Although no estimates of the percentage of application relative to the Great Lakes region are available, the primary applications in the United States were generally south and west of the region, coinciding with termite infestation. In addition, as a result of long-range atmospheric transport, uses of chlordane in other parts of the world still act as a source to Lake Michigan.

- **Hazardous waste sites.** In addition to sources associated with direct releases and historical applications, chlordane has been identified in at least 176 of the 1,350 hazardous waste sites that have been proposed for inclusion on the EPA's National Priorities List. Chlordane contamination has been identified at two Superfund sites in the Lake Michigan basin.

- **Stockpiles.** Waste pesticide collections from agricultural users (Clean Sweeps) continue to recover significant quantities of chlordane and other Level I pesticides indicating that additional stored quantities are likely to exist. Quantities of chlordane recovered in the Great Lakes drainage are presented in Table 5-17. Improper storage or illegal use of such large quantities of chlordane could be a significant source to Lake Michigan.

Table 5-17. Estimated Clean Sweeps Collections of Chlordane in the Great Lakes Drainage Basin (EPA 1998f)

State	Years of Collection	Chlordane Collected (kg)	Chlordane Collected (lb)
Illinois	1994 to 1998	397	875.2
Indiana	1992 to 1997	104	229.3
Michigan	1992, 1994, 1995	2,743	6,047.3
Wisconsin	1993 to 1996	554	1,221.4
Total		3,798	8,373.1

ACTUAL RELEASES OF CHLORDANE TO THE ENVIRONMENT

- **Point source water discharges, air emissions, and releases to land.** There are no TRI reported releases of chlordane.

- **Legacy chlordane contamination.** McConnell and others (1998) found that chlordane concentrations in air samples taken from Green Bay were 35 pg/m^3 (2.09 x 10^{-3} ppt) on average, with the lowest concentrations observed on the coldest days. This trend is consistent with an increase in the concentration of semivolatile compounds in ambient air at higher temperatures. Area air samples were also measured over open Lake Michigan. The average chlordane concentration was 247 pg/m^3 (1.47 x 10^{-2} ppt). Because all uses of chlordane are canceled, current concentrations are the result of historical use or use in other countries.

  Surficial concentrations of chlordane measured in Lake Michigan's southern and northern basin ranged from approximately 0.5 to 4 ppb. Concentrations of four chlordane-related compounds were measured in sediment cores from five locations around Lake Michigan. These profiles identify the 1940s as the onset of contamination with maximum concentrations occurring between 1960 and 1980. Concentrations associated with more recent sediments are lower, reflecting the decreased domestic use as a result of increasing regulation (Golden 1994). Concentrations of a number of chlorinated pesticides, including the three chlordane-related compounds (α- and γ-chlordane and *trans*-nonachlor), were measured in the atmosphere seasonally from January 1992 - December 1994 at Sleeping Bear Dunes, Michigan. Half-lives and virtual elimination dates for γ-chlordane and *trans*-nonachlor are presented in Table 5-18. The parameters used to calculate the half-life for α-chlordane were not significant at the 95 percent confidence level and, therefore, a virtual elimination date was not calculated. (Cortes and others 1998).

Table 5-18. Atmospheric Half-Lives and Virtual Elimination Dates at Sleeping Bear Dunes (Cortes and others 1998)

Compound	Half-Life (yrs)	Virtual Elimination Date
γ-chlordane	3.2	2015
trans-nonachlor	3.5	2015

ACTUAL LOADINGS OF CHLORDANE TO LAKE MICHIGAN

Chlordane has been detected prior to 1990 in waters of the Great Lakes at concentrations ranging from not detected to 0.3 ng/L (ppt), measured as *cis* and *trans*-chlordane (Stevens and Nelson 1989). Sediment concentrations measured from Great Lakes harbors ranged from 1.5 to 310 ppb (Puri and others 1990).

Chlordane was among the most commonly detected chemicals in fish samples taken from water bodies in Cook Country, IL and Lake County, IN (including Lake Michigan). The highest concentration, 0.58 mg/kg (ppm), was detected in a sample from Lake Michigan taken in 1986.

Atmospheric Deposition Pathway

Eisenreich and Strachan (1992) reported atmospheric loading of chlordane at 10 kg/y (22.0 lb/yr). According to the LMMB Project, the net deposition of trans-nonachlor is -57.32 lb/yr (-26 kg/yr) out of Lake Michigan (EPA No date[j]). 4.41 lb/yr (2 kg/yr) of trans-nonachlor are deposited in Lake Michigan due to dry deposition; 4.41 lb/yr (2 kg/yr) due to wet deposition; and 66 lb/yr (30 kg/yr) of trans-nonachlor leave Lake Michigan due to net gas output (EPA No date[j]).

Sediments Pathway

Data on transnonachlor will be added to future drafts.

Tributaries and Areas of Concern Pathway

A MDNR caged channel catfish study in the Menominee River found detectable levels of chlordane (EPA No date[m]). At White Lake AOC, a Michigan Department of Public Health fish consumption advisory for carp was issued due to elevated concentrations of chlordane and PCBs in carp tissue samples. A 28-day caged fish study conducted in the navigational channel between White Lake and Lake Michigan in 1992 showed that chlordane, DDE, and dieldrin are present. (EPA No date[m]). Chlordane showed decreasing levels in the Indiana Harbor Canal, a Lake Michigan tributary, from 1979 to 1994 (Chicago Cumulative Risk Initiative 1999).

The LMMB Project estimated trans-nonachlor loads from Lake Michigan tributaries based on data from January 1, 1995, to December 31, 1995 (see Table 5-19). According to these data, the Grand River contributes the largest load of trans-nonachlor to Lake Michigan (0.46 kg/yr).

Table 5-19. Estimated Trans-nonachlor Loads From Lake Michigan Tributaries (EPA No date [j])

Tributary	Estimated Load (kg/yr)	Estimated Load (lb/yr)
Fox River	0.09	0.02
Grand Calumet	0.04	0.09
Sheboygan River	0.002	0.004
Kalamazoo	0.09	0.2
Grand	0.29	0.64
Menominee River	0.02	0.04
Milwaukee Estuary	0.03	0.07
Pere Marquette	0.003	0.007
Muskegon River	0.04	0.09
St. Joseph	0.36	0.8

IMPACT ON LAKE MICHIGAN

Oxychlordane, a metabolite of chlordane, has been monitored in fish in Lake Michigan since 1977. Although levels have declined by 80 percent in lake trout from Lake Michigan over the last 10 years, fish from the southeast portion of the lake still have the highest observed concentrations of any of the Great Lakes (0.45 ppm). Oxychlordane levels in coho salmon fillets from Lake Michigan have declined from 2 ppm in 1980 to 0.5 ppm in 1984, but then steadily increased to above 1 ppm in 1992 (DeVault 1996) Oxychlordane levels in herring gull eggs from several gull colonies were above 0.3 ppm in Lakes Ontario, Michigan, Erie, and Huron in the mid-1970s and have declined to or below 0.1 ppm in all of the lakes except Lake Michigan. Concentrations in herring gull eggs from Lake Michigan have declined from levels close to 1 ppm in 1982 to about 0.25 ppm in 1989 through 1992 (Chemical Manufacturers Association 1997).

Fish consumption advisories due to unacceptable chlordane levels have been issued by the states of Wisconsin and Michigan (EPA No date).

SPECIAL MANAGEMENT ISSUES

Specific actions to address CHLORDANE are presented in Chapter 6, Table 6-1: RPP1, RPP16, IS13, RAI5 6

Programs regulating and controlling the management of chlordane are presented in Appendix A. Special management issues with chlordane include the following:

- Environmental cycling of legacy chlordane contamination is a major source of chlordane to Lake Michigan.

- Long-range transport of pollutants

5.3.3.5 DDT and DDT Metabolites

Critical Pollutant

DDT [1,1,1-trichloro-2,2-bis-(*p*-chlorophenyl)ethane] is a broad spectrum insecticide, and its use is no longer allowed in the United States. used on crops, grazing land, forest, and urban areas to control insects that transmit diseases such as malaria and typhus. DDT does not occur naturally. Its presence in the environment is the result of contamination from past production, use, disposal, and transport by air and water. Although use of DDT is currently canceled in the United States, measurable amounts of DDT and its metabolites (DDE [1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene] and DDD [1,1-dichloro-2,2-bis(p-chlorophenyl)ethane]) are still found in the air, water, sediment, and soil in and around the Great Lakes. See Appendix B for physical and chemical properties of DDT.

Following is a discussion of the potential and actual releases of DDT into the environment, the potential load to the lake, the current and past loading of DDT to the lake, the impact of DDT on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing DDT.

POTENTIAL RELEASES OF DDT TO THE ENVIRONMENT

- **Historical use, global use, and environmental cycling.** DDT was last used in the United States in the 1970s; however, production of DDT for export continued in the United States long after domestic applications ceased. Product manufacture and use continues outside the United States. Ninety percent of U.S. production of DDT insecticide was exported for use outside the country (Spectrum, 1998 as cited in EPA 1998a). As recently as 1985, two production sites in the United States manufactured DDT for export (HHS 1993).

  DDT's only known use in the United States was as a contact pesticide. It was applied to crops and forests, and sprayed directly on animals (mostly cattle) and human beings. Major uses were to control cotton crop pests and mosquitoes. DDT was extensively used during the Second World War among Allied troops and certain civilian populations to control insect typhus and malaria vectors. After 1945, it was primarily used as an agricultural insecticide. Domestic use of DDT was canceled in 1972 for crop production and nonhealth purposes. The last public health use was in the late 1970s.

  The patterns of use in Canada and Mexico are similar to use in the United States Most uses of DDT in Canada were phased out in the mid-1970s. Registration for remaining uses was discontinued in 1985. The use of existing stocks was allowed through 1990. DDT is still currently produced in Mexico for use in government-sponsored public health campaigns to control malaria. One private company produces DDT in Mexico subject to government approval. Mexican production is about 600 tonnes per year. Product manufacture and use also continues in other countries.

- **Current use of dicofol.** DDT is also an intermediate/reactant for dicofol, a miticide registered for use in the United States, Canada, and Europe. The U.S. imports dicofol that must contain less than 0.1 percent DDT. The USGS Pesticide Monitoring Program estimated that approximately 1.1 million pounds of dicofol is applied in the United States annually. Based on this estimate, approximately 1,000 pounds of DDT are being applied to croplands in the United States annually.

- **Hazardous waste sites.** In addition to sources associated with direct releases and historical applications, DDT has been identified as a contaminant for at least 18 hazardous waste sites in the four Lake Michigan states.

- **Stockpiles.** Waste pesticide collections (Clean Sweeps) continue to recover significant quantities of DDT and other Level I pesticides indicating that additional stored quantities are likely to exist. Quantities of DDT recovered in the Great Lakes drainage are presented in Table 5-20. Improper storage or illegal use of such large quantities of DDT could be a significant source to Lake Michigan.

Table 5-20. Estimated Clean Sweeps Collections of DDT in the Great Lakes Drainage Basin (EPA 1998f)

State	Years of Collection	DDT Collected (kg)	DDT Collected (lb)
Illinois	1994 to 1998	85	187.4
Indiana	1992 to 1997	177	390.2
Michigan	1992, 1994, 1995	2,743	6,047.3
Wisconsin	1993 to 1996	1,910	4,210.8
Total		4,915	10,835.7

ACTUAL RELEASES OF DDT TO THE ENVIRONMENT

DDT, DDE, and DDD are not TRI reported compounds.

- **Point source water discharges.** There are no reported releases of DDT.

- **Air emissions and releases to land.** Air emissions and releases to land could also result from improper use or disposal of stockpiled DDT. The use of dicofol also results in releases to air and land. Currently, there are no known producers of DDT in the United States (HHS 1994). However, long-range transport of DDT from use in other countries still has the potential to act as a source of DDT to the Great Lakes. Although studies during the 1980s indicated that the atmosphere was a sink for DDT volatilizing from the Great Lakes (Hillery and others 1998), recent measurements show that decreasing water column concentrations appear to have reversed that trend and the net flow of DDT is, for the most part, into the Great Lakes. This pattern of flow into and out of the lakes is partially seasonal and with continued global use, the potential is for the atmosphere to remain a source of DDT to the Great Lakes.

- **Legacy DDT contamination.** A major source of DDT to the environment has been past agricultural use and application for termite control. Although application of these compounds was canceled, historical applications resulted in persisting soil residues that continue to serve as sources into the atmosphere as well as runoff into surface water. (HHS 1994).

  DDT contamination of soils and sediment has been identified at three NPL sites in the Lake Michigan basin. DDT has also contaminated three Lake Michigan AOCs. Releases from these sites may continue to provide a source of DDT to the environment.

ACTUAL LOADINGS OF DDT TO LAKE MICHIGAN

Atmospheric Deposition Pathway

Although overall atmospheric concentrations of DDT are decreasing (Cortes and others 1998), the relative importance of atmospheric flux as both a source and a sink of DDT to the Great Lakes is becoming more significant. Pre-1990 measurements showed a significant net loss from the lake to the atmosphere. However, more recent data, presented in Table 5-21, shows that the trend may have reversed and the atmosphere may now be a source of DDT for Lake Michigan. Data for Lakes Superior and Erie reveal significant deposition into the lakes for 1991 to 1992 and 1993 to 1994.

Table 5-21. Air-Water Exchange Rate for DDT in Lake Michigan (Hillery 1997)

Year	Air-Water Exchange Rate (kg/yr)	Air-Water Exchange Rate (lb/yr)
Pre-1990	-460	-1,014.1
1991 to 1992	99±140	218.3 ± 308.6
1993 to 1994	76±90	167.6 ± 198.4

Some elevated concentrations of DDT have been observed around Lake Michigan. Significantly elevated levels of total-DDTs have been measured in air near South Haven, Michigan relative to other locations in the Great Lakes Basin (proposal from MDEQ, 1998). Recent levels at South Haven are also substantially greater than ambient levels that were monitored during the early 1970s at the time of peak DDT use. The range of 24-hr maximum values measured in northern Michigan by the MDEQ from 1992 to 1994 ranged from 0.030 to 0.076 ng/m^3 (2.07 x 10^{-3} to 5.24 x 10^{-3} ppt) compared to 0.986 ng/m^3 (6.81 x 10^{-2} ppt) measured at a site near South Haven. Though the reason for these elevated levels has not been determined, it is hypothesized that either DDT is volatilizing from contaminated soils during certain tillage practices, is being transported from other locations, or may be a result of legal application of the pesticide dicofol, which contains trace levels of DDT as a contaminant.

Recent data show net deposition of total-DDT was substantially into Lakes Superior, and Erie and that wet and dry deposition, at least, accounted for a significant input to Lake Michigan. Total-DDT transport was slightly out of Lake Huron while the net flow between Lake Ontario and the overlying atmosphere was not significantly different from equilibrium. The subsequent change in net direction of flow of DDT reflects the decline in water concentrations with decreased domestic use. (Hillery, Hoff, and Hites 1997).

Cortes and others (1998) estimated a virtual elimination date (for example, when the contaminant levels are below the detection limits of measurement equipment) at the IADN Lake Michigan sampling station of approximately 2010 for DDT and DDD. DDE’s virtual elimination date is estimated slightly later because of its higher atmospheric concentrations and longer half-life.

Sediments Pathway

Golden and others (1993) measured DDT and its metabolites in sediment cores from Lake Michigan. As the most rapid increase in concentrations occurred from 1960 to 1970 in all the cores, these data indicate that the majority of the input was most likely atmospheric. Rapid decreases observed in concentrations correspond with the cancellation of DDT use in 1972. However, both sediment cores from the north basin of Lake Michigan show unexpectedly high historical concentrations of DDT when compared to southern basin cores, most likely a result of inputs from the Fox River basin.

The rate of decrease in DDT concentrations in sediments of southern Lake Michigan has slowed considerably over the last decade and the continued elevated levels are probably due to continued inputs to the basin and long term movement of contaminated sediments to the main depositional basin. Eadie and others (no date) documented a major resuspension event in the spring months in the southern basin of Lake Michigan. This coastal turbidity plume persisted for over a month, progressing northward along the eastern shore. This event illustrates the process by which the large inventory of constituents stored in temporary sediment deposits can be re-supplied to the water column and redeposited into more permanent depositional environments, such as those in the northern basin. This large resuspension and mixing event, if an annual occurrence, may also account for the slower decline in surficial sediment concentrations observed in the southern basin.

Tributaries and Areas of Concern Pathway

Brazner and DeVita (1998) measured DDE (a DDT metabolite) concentrations in young-of-the-year littoral fishes from Green Bay, Lake Michigan. Based on even distribution of DDE concentrations measured in fish from throughout the bay, this study suggested that DDE appears to originate mostly from nonpoint sources rather than point sources (such as the Fox River) in the bay.

Because organochlorine contaminants (such as DDT) and heavy metals found in the Milwaukee Estuary AOC are shown to impair reproduction and development in wildlife elsewhere, the bird or animal deformities or reproductive problems use at that AOC is considered impaired. At White Lake AOC a 28-day caged fish study conducted in the navigational channel between White Lake and Lake Michigan in 1992 showed that chlordane, DDE and dieldrin are present. MDNR conducted a caged channel catfish study in 1993. The study found detectable levels of DDT and DDT metabolites (Lake Michigan Forum No date). A fish advisory for pesticides has been issued for the Menominee River (EPA No date[m]).

IMPACT ON LAKE MICHIGAN

DDE concentrations in eagle eggs collected in 1986 from Lakes Huron and Michigan were both above 30 ppm. (EPA 1998a) DDT and its metabolites have been measured in mussels at a total of 21 U.S. locations around the Great Lakes (except Lake Superior) as part of the NOAA Mussel Watch Program since 1992 (Robertson and Lauenstein 1998). The highest concentrations were observed for total DDTs in the southern basin of Lake Michigan. Concentrations greater than 160 ng/g (ppb) (dry weight) were observed in all samples collected from Milwaukee, WI to Muskegon Harbor (with the exception of one station at the southernmost tip of Lake Michigan). These concentrations were an order of magnitude higher than those detected at any of the other locations in any of the Lakes. However, the predominant compounds detected were the metabolites 4,4'-DDE and 4,4'-DDD, indicating that the source was most likely historical and that significant breakdown has occurred. Appendix C contains detailed information on potential human health effects.

SPECIAL MANAGEMENT ISSUES

Specific actions to address DDT are presented in Chapter 6, Table 6-1: RPP1, RPP16, IS13, RM5

6

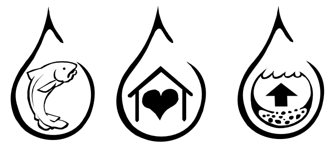
Programs regulating and controlling the management of DDT are presented in Appendix A. Special management issues for DDT include the following:

- Environmental cycling of legacy chlordane contamination as a major source of DDT to Lake Michigan

- Long-range transport of pollutants

5.3.3.6 Mercury

Critical Pollutant



Mercury is a naturally occurring metal that is ubiquitous in the environment. Mercury is released to environmental media by both natural processes and anthropogenic sources. However, with the exception of mercury ore deposits, locally elevated levels of mercury in the environment are primarily the result of human activity.

Natural mercury most commonly occurs in combination with sulfur to form more than 25 different minerals, which are found in all classes of rocks, including limestone, calcareous shales, sandstone, serpentine, chert, andesite, basalt, and rhyolite. It also occurs as a trace element in fossil fuels such as coal. Natural releases of mercury occur as a result of mercury being slowly emitted from these rocks, both in the earth and underwater. Physical and chemical properties of mercury are described in Appendix B.

Anthropogenic releases of mercury primarily occur as a result of industrial processes and the combustion of waste and fossil fuels, especially coal. Releases also occur from the use and disposal of a wide variety of consumer products. About 60 percent of mercury deposition in the United States is derived from anthropogenic sources, with some of the highest deposition rates occurring in the Great Lakes Basin (EPA 1999[l])

Mercury is toxic, persistent in the environment, bioaccumulative, and is implicated in the degradation of fish and wildlife populations, as well as phytoplankton and zooplankton communities in the Great Lakes. The organic form of mercury, methylmercury, builds up in the tissue of fish and can be a health threat for those who consume Great Lakes and inland lakes fish (Bredin 1998). Appendix C contains detailed information on potential health effects.

Following is a discussion of the potential and actual releases of mercury into the environment, the potential load to the lake, the current and past loading of mercury to the lake, the impact of mercury on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing mercury.

POTENTIAL RELEASES OF MERCURY TO THE ENVIRONMENT

Mercury has many applications in industry due to its unique properties, such as its fluidity, its uniform volume expansion over the entire liquid temperature range, its high surface tension, and its ability to alloy with other metals. See Appendix B for more information on the physical and chemical properties of mercury. Industries that utilize mercury include electrical, medical, chemical and mining. Mercury is used in a wide range of commercial products, such as batteries, barometers, thermometers, switches, fluorescent lamps, and mercury arc lamps producing ultraviolet light.

Historically, mercury compounds were used extensively as pharmaceuticals. Some organic mercury compounds were also used in fungicidal and bactericidal applications. Currently, more effective and less harmful alternatives have replaced most pharmaceutical uses of mercury. The use of organic phenylmercuric acetate as a fungicide in interior latex paints was canceled in 1990 based on evidence that mercury vapors are released as the paint degrades. Alkyl mercurial compounds were used until the mid-1970s as a treatment to disinfect grain seeds. Most other agricultural applications of mercury compounds in bactericides and fungicides have been canceled due to the toxicity of mercury. The use of mercury as a wood preservative has also ceased due to the substitution of polyurethane. Currently, most organic mercury compounds (such as methylmercury) are produced by microorganisms in the environment, rather than being formed through human activity (HHS 1993b). Research is currently underway to better understand the conditions and process by which mercury is converted to methyl mercury.

Mercury is currently released into the environment by a wide range of sources, including metals production and other industries, combustion sources, and municipal and commercial sources (including mercury-containing product use and disposal). Atmospheric deposition of mercury emitted by manufacturing, combustion, or incineration processes contributes a large portion of the mercury found in water and soils. The following categories summarize potential sources of mercury releases to the environment.

- **Metals industry.** Currently in the United States there are no mines producing mercury as their primary ore. However, mercury releases have been reported from other types of metal processing operations including lead and copper smelting, electroplating facilities, and iron and steel mills. There are 21 lead and copper smelting facilities, 128 electroplating facilities, and 74 iron and steel mills reporting TRI or PCS data in the Lake Michigan basin.

- **Use of mercury as part of a manufacturing process or within a product.** Many products contain mercury, including electrical applications, such as switches and fluorescent lamps; batteries; and various instrument devices, such as thermostats and thermometers. In addition, mercury-containing compounds are involved in several manufacturing processes. Petroleum refineries and chemical manufacturing have various processes that result in mercury emissions or mercury-containing products. The Lake Michigan basin contains several facilities that use mercury as part of a manufacturing process or within a product. There are 7 petroleum refineries and 184 chemical facilities reporting TRI or PCS data in the Lake Michigan basin.

- **Combustion or incineration of materials containing mercury.** Sources of air emissions resulting from combustion include municipal waste incinerators, medical waste incinerators, hazardous waste incinerators, sewage sludge incinerators, fuel combustion, utilities, cement kilns, coke production, and residential wood burning. The Lake Michigan basin contains many of these combustion facilities. There are 393 utilities and 2 cement kilns reporting TRI or PCS data in the Lake Michigan basin.

- **Mercury product use and disposal.** Mercury emissions can result from use and disposal of products currently in use, such as batteries and thermometers. Additional releases of mercury occur as a result of the disposal of industrial, medical and domestic solid waste products that contain mercury. Waste water treatment plants are sources of mercury releases to water and to land through land application of sludge. Many products contained mercury in the past, such as paint and fungicides. Such products may still be in use, storage, or disposal facilities. (EPA. 1997g.)

ACTUAL RELEASES OF MERCURY TO THE ENVIRONMENT

TRI data on releases of mercury within the Lake Michigan watershed is summarized in Table 5-22. All releases were reported by electronics and plating facilities in northern Indiana and southwest Michigan.

Table 5-22. TRI Mercury Releases Reported in the Lake Michigan Basin (Pounds)

Year	*Air Releases*	*Land Releases*	*Underground Releases*	*Water Releases*	*All Releases*
1987 Total	2	0	0	0	2
1989 Total	500	0	0	0	500
1990 Total	15	0	0	0	15
1991 Total	15	0	0	0	15
1992 Total	10	0	0	0	10
1993 Total	15	0	0	0	15
1994 Total	15	0	0	0	15
1995 Total	15	0	0	0	15
1996 Total	15	0	0	0	15
1997 Total	10	330	0	0	340
Grand Total	612	330	0	0	942

- **Point source water discharges.** Mercury is released to the environment through point source water discharges. PCS data on mercury discharges in the Great Lakes Basin is presented in Table 5-23. (Many POTWs have permit limits and report discharges for mercury at detection limits. It is possible that the PCS database numbers presented in Table 5-23 reflect "potential" discharges based on method detection limits, not actual discharges.)

  The majority of the mercury reported in the PCS data was released by sewerage systems that discharged 876.37 kg (1,932.06 lb). There are no reported water releases in the TRI data.

- **Air emissions** RAPIDS data for 1993 and 1996 reports mercury emissions of 6.5 tons (13, 691 pounds) and 11.9 tons (23,870 pounds), respectively. Data on U.S. mercury emissions in 1990 and 1995 is compiled in the Draft Mercury Sources and Regulations, 1999 Update (BNS). This data is presented in Table 5-24**.** The sources that emit the most mercury nationally are likely the most significant emissions sources in the Great Lakes region as well.

Table 5-23. Mercury Discharges in the Great Lakes Basin, July 1991-June 1993

SIC Code/SIC Name	Total Mercury Discharges (kg)	Total Mercury Discharges (lb)
10 Metal Mining	1.76	3.88
26 Paper & Allied Products	0.57	1.26
28 Chemicals and Allied Products	63.37	139.71
33 Primary Metal Industries	0.04	0.09
34 Fabricated Metal Products	0.08	0.18
37 Transportation Equipment	0.07	0.15
39 Miscellaneous Manufacturing Industries	14.97	33.00
49 Electric, Gas and Sanitary Services	876.61	1,932.59
Public Administration	0.01	0.02
Total	957.51	2,110.95

Table 5-24. Estimates of U.S. Mercury Emissions (Tons) (BNS 1999)

Source	1990	1995
Utility Boilers-Coal	51.0	51.6
Municipal Waste Combustors	41.7	29.6
Medical Waste Incinerators	50.2	16.0
Solid Waste Processing and Transport	32	16
Use of Steel Scrap	12	12
Chlorine Production	10.0	7.1
Hazardous Waste Incineration	5.7	7.1
Mobile Sources - Non-Road	6.8	6.8
Mobile Sources - On-Road	5.0	5.0
Portland Cement (Nonhazardous Waste Fired)	4.0	4.0
Industrial Boilers	2.1	2.1
Others	22.0	19.3
Total	242	176

Each year, approximately 10 to 15 pounds of mercury are released to the air by TRI reporting facilities. A significant exception is 1989 when 500 pounds of mercury were released to the air.

- **Releases to land.** There was only one release to land reported in the TRI data, a 330-pound release in 1997.

- **Legacy mercury contamination.** One of the major sources of mercury today is environmental cycling of mercury previously introduced into the environment. Mercury-contaminated sediments may resuspend mercury compounds in the water, allowing for bioaccumulation in the food web. In addition, volatilization of mercury from land and water surfaces into the atmosphere can result in subsequent air deposition and then revolatilization. For this reason, and because of its long retention time in the environment, mercury released to the environment many years ago plays an active role in the contamination of today's environment. The Lake Michigan AOCs are examples of this type of source. Seven of these AOCs were heavily contaminated with mercury in the past and now contribute mercury loads to Lake Michigan. The Fadrowski Drum Disposal NPL site in Wisconsin is also contaminated with mercury. Remediation is complete at the Fradrowski site and monitoring continues. Analytical results indicate mercury is no longer present in surface water or sediment but high levels of mercury are present in one groundwater monitoring well.

ACTUAL LOADINGS OF MERCURY TO LAKE MICHIGAN

Sources may provide loadings to the lake from one of three pathways: air deposition, direct discharges including sediments, and tributary loadings. Several studies estimating the mercury loadings to Lake Michigan from each of these pathways have been conducted. The results of these studies are presented below.

Atmospheric Deposition Pathway

Mason and Sullivan (1997) assessed total and particulate mercury in water column samples from offshore waters of Lake Michigan in 1994 and 1995. Their estimate of atmospheric deposition of mercury in Lake Michigan is presented in Table 5-25. Preliminary estimates of the principal sources and sinks for mercury in Lake Michigan were made. The data indicated that about 80 percent of total mercury input was due to atmospheric sources, 17 percent from riverine input, and less than 1 percent from groundwater. Localized urban sources, such as Chicago, contributed approximately 30 percent to the total regional atmospheric loading to Lake Michigan. Atmospheric volatilization via gas exchange and sedimentary burial were the major pathways for mercury loss from the lake. The preliminary mass balance assessed in this study demonstrates the dominating influence of air-water exchange processes on Lake Michigan mercury concentrations.

Mercury emissions from coal-fired power plants, a major source of mercury in the basin, are predominantly in the vapor phase. Waste incinerators, another important source in the basin, burn trash and release volatile gaseous mercury and mercury in the combined or particulate form (EPA 1997[g]). In addition to entering the lake via air-water exchange and wet/dry deposition, these emissions may be eventually deposited on the surrounding soil to subsequently reach Lake Michigan via erosion and tributary-associated loadings. These loadings are accounted for in the tributary load estimates.

Table 5-25. Estimates of Atmospheric Deposition of Mercury in Lake Michigan

Source	Estimate (kg/yr)	Estimate (lb/yr)
Mason and Sullivan 1997	965	2,127.5
LMMB 1994 and 1995	1,048	2,310.4
Eisenreich and Strachan 1992	1,600	3,527.4

Sediments Pathway

Contaminated sediments are a source of mercury contamination in Lake Michigan because mercury may be released from sediments and resuspended in the water. Mercury loads from contaminated sediments in the Lake Michigan AOCs are described in the following section.

Tributaries and Areas of Concern Pathway

Regardless of source, mercury inputs to Lake Michigan have the potential to accumulate in aquatic biota, including fish. Brazner and DeVita (1998) measured mercury concentrations in young-of-the-year littoral fishes from Green Bay, Lake Michigan. Based on a generally uniform distribution of mercury concentrations measured in fish from throughout the bay (relative to other contaminants such as PCBs), this study suggested that mercury appears to mostly originate from nonpoint sources rather than point sources in the bay. However, the study did also observe unusually high mercury levels in fish from certain sites, and a slight increase in mean mercury tissue concentrations in the upper and lower bay compared with the middle bay fish. The authors suggest that these trends may indicate possible point sources, such as tributaries or contaminated sediments, in these areas. LMMB data indicates that the combined tributary loadings in Lake Michigan total 186 kg (410.1 lb) per year.

Hurley and others (1998b) studied mercury levels in several tributaries to Lake Michigan. Total, dissolved, and particulate-associated mercury were measured in 11 selected tributaries: the Manistique, Lower Menominee, Fox, Sheboygan, Milwaukee, Pere Marquette, Muskegon, Grand, Kalamazoo, and St. Joseph Rivers, as well as the Grand Calumet River/Indiana Harbor Ship Canal. Results indicated that both the form and flux of riverine mercury input to Lake Michigan were strongly dependent on seasonal influences and land use patterns. Mercury loading generally increased during spring melt and summer/fall storm events, and was associated with particulate mercury loading during these times of increased flow.

The LMMB estimated mercury loads from Lake Michigan tributaries based on data from April 1, 1994, to March 31, 1994 (see Table 5-26). According to these data, the Fox River contributes the largest load of mercury to Lake Michigan (76 kg/yr).

Table 5-26. Estimated Mercury Loads From Lake Michigan Tributaries (EPA No date[i])

Tributary	Estimated Load (kg/yr)	Estimated Load (lb/yr)
Fox	76.2	168.0
Kalamazoo	15.7	34.6
Grand Calumet	6.7	14.7
Grand	31.9	70.3
St. Joseph	19.4	42.8
Sheboygan	0.7	1.5
Milwaukee	1.1	2.4
Menominee	8.7	19.2
Pere Marquette	1.9	4.2
Manistique	3.5	7.7
Muskegon	2.8	6.2

The highest mercury concentration (182 ng/L [ppt]) was observed in the industrialized Fox River and was primarily associated with the particulate phase. The Grand Calumet River/Indiana Harbor Ship Canal, Grand River, and Kalamazoo River, all of which are thought to be strongly affected by point sources (such as the steel industry in the Indiana Harbor) and regional atmospheric deposition, also showed high mercury concentrations (up to 45.1 ng/L [ppt]) that were associated with particulate matter. In contrast, the tributaries in northern forested sites (Muskegon, Manistique, and Pere Marquette rivers) showed relatively low mercury concentrations, and mercury was primarily found in the dissolved (that is, filterable) phase.

Results also indicate that despite the higher total mercury concentrations in the Fox River and Indiana Harbor, the St. Joseph and Kalamazoo Rivers appear to be dominant in terms of total mercury flux to the open waters of Lake Michigan. Although the Fox River was observed to discharge, by far, the highest loads of mercury, these loads are primarily deposited in the Green Bay estuary and not the lake proper. In addition, the impact of the high mercury concentrations in the Indiana Harbor Ship Canal is diminished due to its relatively small hydraulic loading rate. The authors conclude that in the open waters of Lake Michigan, the direct effect of riverine inputs of mercury is likely to be diminished due to near shore particle sinks (such as Green Bay) and the short residence time of water-column mercury. For example, the Grand Calumet River/Indiana Harbor Ship Canal AOC contains 5 to 10 million cubic yards, up to 20 feet deep, of contaminated sediments. Contaminants include mercury and other compounds (EPA No date[n]). However, mercury contamination of these near shore estuarine zones may have a greater impact in terms of biotic production, such as fish spawning.

The transport and partitioning of mercury and methyl mercury was also assessed from April 1994 to October 1995. Total mercury concentrations ranged from 1.8 to 182 ng/L (ppt), with the overwhelming majority of mercury existing as particulate-associated forms. (The median percent of mercury in particulate-associated forms was 93.6 percent across all samples collected.) With distance downstream, both water column and sediment concentrations of mercury increased. In addition, particle enrichment with mercury increased downstream (that is, particles at the river mouth were enriched with mercury relative to upstream), and particles were also enriched with mercury relative to that of the surrounding soils. These trends suggest that bottom sediment resuspension, rather than soil erosion, is likely to be the predominant source of mercury from the Fox River. Although the concentrations of total mercury in the Fox River were high, measured methyl mercury concentrations (organic fractions) were relatively low (<0.03-0.43 ng/L [ppt]). In addition, methyl mercury in sediment constituted only 0.7 percent of the total mercury measured. The authors suggest that although mercury in the Fox River is the highest of the Lake Michigan tributaries, data indicate it is in a less bioavailable form (that is, for methylation) than the other tributaries.

IMPACT ON LAKE MICHIGAN

Fish consumption advisories for at-risk subpopulations and the general population (meal size and frequency restrictions) have been issued due to excessive mercury concentrations in Lake Michigan fish. See Appendix C for detailed information on human health effects associated with mercury. In particular, fish tissue concentrations of mercury exceed FDA action levels in Little Bay de Noc and the Muskegon River (EPA 1997). In contrast, despite the presence of severely mercury-contaminated sediments in the Fox River and Lower Green Bay (Hurley and others 1996), widespread fish consumption advisories have not been issued in these areas. This suggests that the particular chemical species of mercury present in the Fox River and Green Bay areas may have limited bioavailability, and thus a limited potential to bioaccumulate in fish to levels that would warrant fish consumption advisories (Hurley and others 1998a).

The mercury contamination of sediments has been verified in many Lake Michigan tributaries and AOCs. Mercury has been identified as a contaminant in water or sediments from several of the Lake Michigan AOCs, including the Lower Menominee River, Lower Green Bay and the Fox River, Milwaukee Estuary, the Grand Calumet River/Indiana Harbor Ship Canal, the Muskegon River, the Manistique River, and White Lake (EPA No date[m]). Fish consumption advisories have been issued at four of the AOCs. Concentrations for total Hg in Lake Michigan averaged 1.60 ± 0.25pM 0.32 ± 0.05 ppt) and particulate averaged 0.60 ± 0.18 pM (0.12 ± 0.04 ppt). (Sullivan and Mason 1998).

SPECIAL MANAGEMENT ISSUES

Specific actions to address MERCURY are presented in Chapter 6, Table 6-1: HH8-HH10, RPP1, RPP3, RPP12-RPP15, RM1, RM2, RM5-RM8, RM12 **6**

Programs regulating and controlling the management of mercury are presented in Appendix A. Special management issues for mercury include the following:

- The Great Lakes Binational Toxics Strategy is an effort to reduce mercury and other persistent toxic substances in the Great Lakes. The Strategy has set reduction goals for the United States and Canada of 50 percent over the next 6 years and 90 percent over the next year for the two countries, respectively. (EPA No date[o])
- Long-range transport of pollutants
- Unregulated air emission sources of mercury such as coal combustion
- Environmental cycling

5.3.3.7 Inorganics

Pollutant of Concern

The inorganics listed as pollutants of concern in the Lake Michigan basin are lead, cadmium, copper, zinc, chromium, arsenic, and cyanide. Two other inorganics are discussed in the LaMP, mercury and selenium. Because mercury is a critical pollutant and selenium is an emerging pollutant, they are not discussed in this section.

The inorganic pollutants of concern are naturally occurring and are ubiquitous in the environment. They are released to environmental media by both natural processes and anthropogenic sources. For physical and chemical properties of these inorganics, see Appendix B.

Sediments and tributaries in several Lake Michigan AOCs are heavily polluted by one or more of these compounds. Additionally, they are associated with degradation of benthic and planktonic communities and are the cause of restrictions on dredging.

Following is a discussion of the potential and actual releases of inorganics into the environment, (the potential load to the lake), the current and past loading to the lake, the impact on achieving the vision for the Lake Michigan ecosystem, and unique issues associated with management of inorganics.

POTENTIAL RELEASES OF INORGANICS TO THE ENVIRONMENT

- **Metals Industry**. Lead emissions are generated primarily as a by-product from the operation of smelters and nonferrous foundries. Cadmium emissions are generated primarily as a by-product from mining and smelting operations. Copper is extensively mined and processed in the United States using both underground mining and open pit mining. Zinc is also mined using both underground mining and open pit mining. However, none of the Lake Michigan states is a major zinc-producing state. Zinc is used in a variety of steel production activities. Chromium has many uses in industry and is used for a variety of processes including making steel and other alloys, and metal finishing, especially chrome plating. Approximately 20 percent of the U.S. iron and steel production is contained in the Chicago, Illinois, and Gary, Indiana, area. Arsenic is used in metal mining and in metallurgy for hardening copper, lead, and alloys. No arsenic producers currently operate in the United States, and all raw materials for production of arsenic-containing products must be imported (EDF No date). Cyanide has many uses in industry and is used for a variety of processes including metal mining processes, metallurgy, and metal cleaning.

- **Use of inorganics as part of a manufacturing process or within a product**. The most significant use of lead metal is for lead-acid storage batteries used in automotive and industrial applications. One of the strongest demands for cadmium is in the production of nickel-cadmium batteries. Alloys containing copper and zinc are used to make pennies. Copper compounds are most commonly used in agriculture to treat plant diseases, like mildew, or for water treatment and as preservatives for wood, leather, and fabrics (ATSDR 1990). Zinc is used most commonly as a protective coating of other metals. Chromium is used in brick lining in industrial furnaces, manufacture of dyes and pigments, leather tanning, and wood preserving. The major use of arsenic in the United States is as a wood preservative. (National Safety Council No date). The predominant users of cyanides are the steel, electroplating, mining, and chemical industries.

- **Product use and disposal**. Lead may be present in significant levels in drinking water due to the presence of lead pipes in older structures or lead solder in copper pipes. Another source of lead is in the chips and dust of lead-based paint. According to EPA, in 1995, approximately 14 million homes had more than 5 square feet of damaged lead-based paint and nearly 7 million homes had excessive dust levels. Leaded gasoline use of many decades has also resulted in widespread lead contamination of soils in areas of high traffic density. Lead-containing waste products include storage batteries, ordnance, solder, pipes, items with lead-based paint, and solid wastes created by ore processing, iron and steel production, and smelting (HHS 1999b).

  Cadmium can be released during fuel combustion, disposal of metal-containing products, and application of phosphate fertilizer or sewage sludge. As a result of cadmium's presence in pigments, it can also be released from burning inks and dyes. Cadmium in soil may be increasing due to the application of municipal sludge or phosphate fertilizers, which may result in accumulation in plants and animals and human exposure. Another potential source of cadmium releases to the soil is land disposal of cadmium-containing wastes, primarily batteries. Coal and oil used in some thermal power plants is responsible for 50 percent of the total cadmium released to the air.

  Copper and copper compounds not recycled are disposed of in landfills or released into wastewater. Methods of copper-containing sludge disposal from wastewater treatment facilities include landfilling, landspreading, incineration, or ocean disposal.

  Waste products containing zinc are commonly used as a source of zinc for electrogalvanizing. Zinc is not regulated by the federal government as a constituent in hazardous waste. Unsalvageable zinc waste may be buried in an approved landfill. (HHS 1994c).

  Waste streams from electroplating as well as leather tanning, textile industries, and dye/pigment manufacturers can often contain chromium in the discharge to surface waters. Chromium III and VI concentrations can increase in soil as a result of disposal of commercial products containing chromium, chromium industrial waste, and coal ash from electric utilities. Most chromium released to the environment by industries is released on land and most of this waste is disposed of in landfills.

  Arsenic is regulated by the federal government as a constituent in hazardous waste. The primary route of disposal of solid wastes containing arsenic is landfilling. Other disposal alternatives for arsenic-containing wastes include incineration and recycling. There is, however, essentially no recycling of arsenic from its principal uses in wood preservatives or agricultural chemicals

  Cyanide is also found in a variety of industries' waste streams. Thiocyanates are present in water primarily because of discharges from coal processing, extraction of gold and silver, and mining industries. Thiocyanates in soil result from direct application of weed killers and disposal of by-products from industrial processes. Additional sources of thiocyanate include damaged or decaying tissues of certain plants such as mustard, kale, and cabbage (HHS 1997a).

ACTUAL RELEASES TO THE ENVIRONMENT

Table 5-28 presents TRI reported air, land, underground, and water releases of inorganics.

- **Point source discharges.** Point source discharges of inorganics to Lake Michigan include industrial steel industries, electric services, mining and smelting operations, municipal effluents, plating and polishing facilities, leather tanning operations, and wood preservation facilities.

- **Air emissions.** Industries with significant air emissions of inorganics include blast furnaces and steel mills, secondary metals facilities, foundries, electrical generating facilities, storage battery facilities, paving mixtures and blocks operations, sewerage systems, refuse systems, plating and polishing facilities, and the motor vehicle parts and accessories industry Table 5-27 indicates the mass of each inorganic that was emitted to the air in the Lake Michigan basin according to the RAPIDs database.

- **Releases to land.** Mine tailings, use of ammunition, sludge application, fertilizer use, coal and bottom fly ash, and smelter slugs and waste, are sources of releases of inorganics to land.

- **Legacy inorganic contamination.** Inorganics are contaminants at 34 Superfund sites in the Lake Michigan basin. Nine of the 10 AOCs are also contaminated with inorganics.

Table 5-27. RAPIDS Data on Air Emissions in the Lake Michigan Basin

Inorganics	Pounds released in 1993	Pounds released in 1996
Lead	266,771	173,011
Cadmium	121,469	119,294
Copper	52,346	162,816
Zinc	Not available	Not available
Chromium	62,480	98,864
Arsenic	22,484	24,603
Cyanide	Not available	Not available

ACTUAL LOADINGS OF INORGANICS TO LAKE MICHIGAN

Following is a description of the inorganic loadings contributed via the air deposition pathway, sediments, and tributaries.

Atmospheric Deposition Pathway

Hillery and others (1998) presents atmospheric loading data collected at Sleeping Bear Dunes, Michigan, the IADN master station for Lake Michigan for lead. Dry deposition of lead is 16,000 ± 13,000 kg/yr (35,274 ± 28,660 lb/yr). Although there is no significant change over time in the lead deposition data presented in Table 5-29, data from 15-20 years before these estimates were made shows that deposition is about a factor of five lower. The authors attribute this to the elimination of leaded gasoline.

Table 5-28. TRI Data on Releases of Inorganics (Pounds) in Lake Michigan Basin

Inorganics	**Air Releases**		**Land Releases**		**Underground Releases**		**Water Releases**		**All Releases**
	Max annual	Total	Max annual	Total	Max annual	Total	Max annual	Total	
Lead	144,650	845,157	2,186,750	7,034,794	0	0	21,831	115,658	7,995,609
Cadmium	4,050	8,460	9,516	11,182	0	0	0	0	19,642
Copper	823,041	2,453,924	245,294	1,196,641	16,720	19,203	13,087	81,394	3,751,162
Zinc	752,074	5,317,697	12,454,162	41,595,605	0	0	99,296	454,240	48,471,949
Chromium	188,003	694,913	2,671,350	17,420,881	72,869	187,677	65,451	187,508	18,490,979
Arsenic	21,178	26,981	6,702	12,702	0	0	5	6	39,682
Cyanide	465,278	2,578,339	25,417	79,723	48,000	50,800	40,744	209,710	2,918,572

Table 5-29. Net Atmospheric Loading of Lead in Lake Michigan (Hillery and others 1998)

Year	**Loading (kg/yr)**	**Loading (lb/yr)**
Pre-1990	130,000	286,601
1991 to 1992	72,000 ± 37,000	158,733
1993 to 1994	150,000	330,693

Dry deposition fluxes of inorganics associated with fine (<2.5 µm) and PM_{10}-coarse (2.5 to 10 µm) particles are presented in Table 5-30.

Sediments Pathway

Scudder and others (1995) sampled Lake Michigan sediments in 1992, 1994, and 1995 to determine the occurrence of a broad suite of trace elements, including lead, cadmium, chromium, copper, arsenic and zinc, in biota and stream bed sediment in selected streams in the Western Lake Michigan Drainages, a study unit of the NAWQA Program of the USGS. Urban land use was found to be the dominant factor influencing sediment concentrations of lead, copper, and cadmium because the highest concentrations were found at urban and integrator sites. Table 5-31 presents the number of observations in the western Lake Michigan drainages that equaled or exceeded Ontario Ministry of Environment and Energy (OMEE) LELs.

Table 5-30. Dry deposition fluxes (mg/km^2-h) to Lake Michigan

Element	Pirrone and Keeler (1995)		Holsen and others. (1993)		Eisenreich and Strachan (1992)	Clark (1992)	
	Fine	PM_{10}-Coarse	Fine	PM_{10}-Coarse	Total	Fine	PM_{10}-Coarse
Lead	2.1	22	1.2	9.3	26	123	502
Cadmium	2.8	27	0.6	4.2	4.1	4.1	14.2
Copper	4	48	6	45			
Zinc	13	75	16	120			
Chromium	1.6	10	1.1	8.4		5.74	25.9
Arsenic	1.5	8			6.5	11.6	37.6

Table 5-30a. Dry deposition fluxes (lb/mi^2-h) to Lake Michigan

Element	Pirrone and Keeler (1995)		Holsen and others. (1993)		Eisenreich and Strachan (1992)	Clark (1992)	
	Fine	PM_{10}-Coarse	Fine	PM_{10}-Coarse	Total	Fine	PM_{10}-Coarse
Lead	1.20×10^{-5}	1.26×10^{-4}	6.85×10^{-6}	5.31×10^{-5}	1.48×10^{-4}	7.02×10^{-4}	2.87 x 10-3
Cadmium	1.60×10^{-5}	1.54×10^{-4}	3.43×10^{-6}	2.40×10^{-5}	2.34×10^{-5}	2.34×10^{-5}	8.11×10^{-5}
Copper	2.28×10^{-5}	2.74×10^{-4}	3.43×10^{-5}	2.57×10^{-4}			
Zinc	7.42×10^{-5}	4.28×10^{-4}	9.14×10^{-5}	6.85×10^{-4}			
Chromium	9.14×10^{-6}	5.71×10^{-5}	6.28×10^{-6}	4.80×10^{-5}		3.28×10^{-5}	1.48×10^{-5}
Arsenic	8.57×10^{-6}	4.57×10^{-5}			3.71×10^{-5}	6.62×10^{-5}	2.15×10^{-4}

Table 5-31. Number of Observations from the Western Lake Michigan Drainages that Equaled or Exceeded OMEE LEL Concentrations in Sediment (Scudder and others 1995)

Element	Number of Observations	Number of Observations Exceeding OMEE LEL
Arsenic	40	18
Cadmium	41	25
Chromium	42	42
Copper	42	30
Lead	42	12
Zinc	42	17

Tributaries and Areas of Concern Pathway

Table 5-32 presents information on the number of Superfund sites and AOCs in the Lake Michigan basin contaminated with inorganics. There are a total of 34 Superfund sites contaminated with the inorganics listed in the table. Nine of the 10 Lake Michigan AOCs are also contaminated with the inorganics.

All of the inorganics have been identified as contaminants at AOCs; however, arsenic has been specifically identified as a primary cause of the identified use impairments in the Menominee River. Arsenic contamination has been identified in the sediment, groundwater, and surface water of the turning basin The turning basin cannot be dredged or used for large vessel navigation due to arsenic contamination of river sediments. Much of the arsenic contaminated sediment in the turning basin would be classified as a hazardous waste if it were removed without treatment. Furthermore, there is a localized degradation of fish populations and benthos, primarily due to arsenic-contamination of sediments. (EPA 1997c). The Grand Calumet River/Indiana Harbor Ship Canal AOC contain 5 to 10 million cubic yards, up to 20 feet deep, of contaminated sediments. Contaminants include cadmium, chromium, lead, and other pollutants (EPA No date[n]).

Table 5-32. Contaminated Superfund Sites and AOCs in Lake Michigan Basin

	Number of Superfund sites in basin	Kalamazoo River	Muskegon Lake	Manistique River	Menominee River	Green Bay and Lower Fox River	Sheboygan River	Milwaukee Estuary	White Lake	Grand Calumet River/ Indiana Harbor Ship Canal	Waukegan Harbor
Lead	25		S	S	S	S	S	S	S	S,W	S
Cadmium	11		S	S	S	S		S	S	S	S
Copper	5		S	S	S	S	S	S		S	S
Zinc	5		S	S	S	S	S	S	S	S	
Chromium	21		S	S	S	S	S	S	S	S	S
Arsenic	23		S		S		W	S	S	W	S
Cyanide	7				S		W			W	S,W

Sources: CERCLIS List and AOC fact sheets

Notes: s = sediment contaminant
w = water contaminant

Table 5-33 displays the levels of contamination in Indiana Harbor and Lake Michigan sediment. Sediments in the Indiana Harbor have higher concentrations of contaminants than those in Lake Michigan. Concentrations of cadmium, lead, and zinc in Indiana Harbor are about 200, 80, and 80 times, respectively, higher than those in Lake Michigan sediments (EPA 1994d).

Table 5-33. Contaminant Concentrations in Indiana Harbor and Lake Michigan Sediments (μg/g or ppm)

Inorganic	Indiana Harbor	Lake Michigan
Lead	879.0	11.9
Cadmium	20.0	0.1
Copper	Not available	Not available
Zinc	4,125.0	54.1
Chromium	650.0	4.4
Arsenic	29.5	10.1
Cyanide	Not available	Not available

IMPACT ON LAKE MICHIGAN

Elevated concentrations of inorganics have resulted in dredging restrictions and reductions in benthic habitat quality and populations at AOCs in Lake Michigan. Appendix C contains information on potential human health effects of exposure to these inorganics.

SPECIAL MANAGEMENT ISSUES

Specific actions to address INORGANICS are presented in Chapter 6, Table 6-1: RPP1, RPP5, RPP7, RPP12, RPP17 6

An overview of the regulations and programs targeted at inorganics in the Lake Michigan basin may be found in Appendix A.

Pollutant of Concern

5.3.3.8 Hexachlorobenzene

HCB was synthesized and used from the 1940s to the late 1970s as a fungicide on grain seeds such as wheat. HCB has been used as a solvent and as an intermediate and additive in various manufacturing processes, including the production of synthetic rubber, PVC, pyrotechnics and ammunition, dyes, and pentachlorophenol. Although HCB is no longer produced as an end product, it is formed as an inadvertent by-product at trace levels in a variety of combustion and incineration processes, and in the production of several currently used products, including pesticides.

HCB is a white, crystalline solid that is a highly persistent environmental toxin. It is not highly water soluble and will quickly adsorb to the sediments where it may persist for a very long time. HCB degrades slowly in air and remains in the atmosphere through long range transport. There is evidence of continuing long range transport across North America. See Appendix B for a discussion of the physical and chemical properties of HCB.

HCB bioaccumulates in fish, marine animals, birds, lichens, and animals that feed on fish or lichens. HCB can also accumulate in wheat, grasses, vegetables and other plants. Environmental levels appear to have peaked in the 1970s and declined since that time.

Following is a discussion of the potential and actual releases of HCB into the environment, the potential load to Lake Michigan, the current and past loading of HCB to the lake, the impact of HCB on achieving the vision for the Lake Michigan ecosystem, and unique management issues of HCB.

POTENTIAL RELEASES OF HCB TO THE ENVIRONMENT

HCB was manufactured as an end product from the 1940s to the late 1970s. Its use as a pesticide was voluntarily canceled in 1984 and it is no longer intentionally manufactured in the United States Currently, HCB releases to the environment are primarily due to industrial processes and agricultural activities.

- **HCB produced as a by-product of manufacturing processes.** HCB is produced as a by-product from the manufacture of chlorinated solvents (such as tetrachloroethylene, trichloroethylene, and carbon tetrachloride), tires and pesticides. Facilities that inadvertently manufacture HCB reportedly store an estimated total of 0.15 to 1.52 million pounds of HCB on-site per year (HHS 1998).

- **Volatilization during the application of pesticides.** HCB is known to be a minor contaminant in several currently used pesticides including dacthal, picloram, pentachlorophenol (PCP), and chlorothalonil. The use of contaminated pesticides may release HCB through volatilization during the application process. Emissions of HCB from dacthal, chlorothalonil, and PCNB account for 95 percent of the total emitted from pesticide application, due to a combination of HCB content and annual usage (BNS Sources and Regulations). HCB is also a contaminant in the wood preservative, PCP, which is used to protect utility poles, railroad ties, and roadway guardrail posts. This may also cause releases of HCB through volatilization (at a 12 to 36 percent rate) or may leach into the surrounding soil (BNS Sources and Regulations).

- **Combustion and incineration processes**. HCB is emitted to the atmosphere in flue gases and fly ash generated at waste incineration facilities. It may also be produced and released through utility coal combustion and incineration. EPA estimates that utility coal combustion accounts for 30 percent of total national air emissions of HCB annually. Hazardous waste, municipal refuse, and medical waste incinerators, as well as cement kilns co-fired with organic waste, have the potential to emit HCB. The open burning of household wastes in backyard burn barrels may contribute to area sources of HCB, although quantities are not known.

- **Wastewater from manufacturing facilities.** HCB has been detected in treated wastewater from nonferrous metal manufacturers**.** It may also be found in the waste streams of wood-preserving plants**.**

ACTUAL RELEASES OF HCB TO THE ENVIRONMENT

- **Point source water discharges.** In 1997, TRI data indicate total releases of 250 pounds of HCB from the alkalies and chlorine industrial sector and 26 pounds from the agricultural chemicals sector nationally (BNS Sources and Regulations). Industrial and municipal sewage treatment plants may release HCB directly to water. There were no releases of HCB in the Lake Michigan basin reported to the TRI.

- **Air emissions.** According to RAPIDS, 0.122 pound of HCB was released in the Lake Michigan basin in 1996 from agricultural applications in Wisconsin. According to the EPA Final Report of Emission Inventory Data for Clean Air Act Section 112(c)(6) Pollutants (1998), an estimated 2.3 tons of HCB are released to the air annually in the United States EPA estimates national annual emissions of HCB from tire production to be 870 pounds per year based on 1993 data (BNS Sources and Regulations). According to EPA, tire manufacturing may account for 19 percent of total annual air emissions (EPA 1998). The manufacture of chlorinated solvents may release 1,162 pounds per year (BNS Sources and Regulations), accounting for 25 percent of total annual air emissions of HCB (EPA 1998). Pesticides production may release 916 pounds per year (BNS Sources and Regulations), accounting for 20 percent of total annual air emissions of HCB nationally (EPA 1998). The application of pesticides is estimated to release 292 pounds per year nationally to the air, or 6 percent of total annual national air emissions of HCB (EPA 1998). There were no releases of HCB in the Lake Michigan basin reported to the TRI.

- **Releases to land.** The application of HCB-contaminated pesticides and the use of HCB-contaminated utility poles may result in the release of HCB to the land, where it will adsorb to the soil. In addition, landfills and land disposal of sewage sludge may release HCB to the land.

- **Legacy HCB contamination.** Eleven NPL sites within EPA Region 5 and two NPL sites in the Lake Michigan basin identify HCB as a contaminant of concern for all media. Two AOCs in the Lake Michigan basin have identified HCB as a contaminant.

ACTUAL LOADINGS OF HCB TO LAKE MICHIGAN

This section describes the specific sources of HCB and the loading contributed by each source to Lake Michigan.

Atmospheric Deposition Pathway

Many of the facilities that produce HCB as a by-product, such as chlorinated solvent production facilities, do not exist within the Great Lakes Basin. However, because HCB is a highly stable compound, it remains in the atmosphere through long range air transport and is a major source of HCB loading to Lake Michigan. Long range air transport and deposition is a far greater source of HCB loading to the Great Lakes than are direct discharges to the lakes (Delta Institute 1999).

The southern portion of the lake appears to be greatly affected by HCB loadings from pesticides use, most likely due to the heavy agricultural land use throughout that portion of the basin (BNS Sources and Regulations).

Total annual air deposition of HCB into Lake Michigan is estimated to be 15 kg, based on 1993 source and emissions data from the 1,329 identified sources in the United States and Canada (Delta Institute 1999). Should sources outside the United States and Canada be taken into account, air deposition estimates could increase by a factor of 10 (Delta Institute 1999, citing Cohen and others 1995).

Sediments Pathway

HCB has been identified as an organic chemical contaminant in sediments in the Lower Fox River and the Manistee River.

Tributaries and Areas of Concern Pathway

Direct discharges of HCB to water are a minor source of loading to Lake Michigan. Water discharges of HCB are estimated to be 0.8 kg per year for the lake (EPA 1999). HCB has been listed as a toxic pollutant contaminating the Manitowoc River (BNS Sources and Regulations).

IMPACT ON LAKE MICHIGAN

Measurements of gas phase absorption and volatilization indicate that HCB is in near equilibrium, but is slightly loading Lake Michigan (EPA 1999). Bioconcentration and biomagnification of HCB in aquatic species are expected to be important on the basis of a high octanol-water partition coefficient (K_{ow}) value. HCB has also been associated with embryo mortality and loss of eggs due to a lack of adult attentiveness in incubating eggs of herring gulls. See Appendix C for a detailed discussion of potential ecological and human effects of HCB.

SPECIAL MANAGEMENT ISSUES

Specific actions to address HEXACHLOROBENZENE are presented in Chapter 6, Table 6-1: RPP1, RPP16, IS13, RM5, RM6 **6**

Programs regulating and controlling the management of HCB are presented in Appendix A. Special management issues for HCB include the following:

- Long-range air transport of HCB from across North America

5.3.3.9 Toxaphene

Pollutant of Concern

Toxaphene, also known as camphechlor, was one of the most heavily used insecticides in the United States. The primary application of toxaphene was for insect pest control on cotton in the southern United States, although it was also used on other agricultural crops, livestock, and in the northern United States and Canada to kill unwanted fish in lakes. Due to toxaphene's implication in various adverse health and environmental effects, all uses are currently canceled in the United States (most uses of toxaphene were canceled in 1982 [EPA No date (p)]). Despite the fact that toxaphene is no longer used, measurable amounts of toxaphene are still found in the air, water, sediment and soil in and around Lake Michigan. Long range atmospheric transport from the southern United States has been identified as the major pathway of toxaphene input to the Great Lakes Basin. Information on the physical and chemical properties of toxaphene is presented in Appendix B.

Following is a discussion of the potential and actual releases of toxaphene into the environment, the potential load to the lake, the current and past loading of toxaphene to the lake, the impact of toxaphene on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing toxaphene.

POTENTIAL RELEASES OF TOXAPHENE TO THE ENVIRONMENT

- **Historical use, global use, and environmental cycling.** Toxaphene is a man-made insecticide, first produced in 1946. As toxaphene was the primary replacement insecticide for DDT after its cancellation in the early 1970s, toxaphene became one of the most heavily manufactured and prevalent pesticides in the United States. The name "toxaphene" was originally a trade name; however, over the years, the name toxaphene has come to refer to the various camphechlor mixtures.

Toxaphene was used agriculturally in the United States to control insects living on cotton, peas, corn, fruit, vegetables, and small grains such as rice, in addition to other crops. It acts as a nonsystemic stomach and contact insecticide. Toxaphene has a relatively low toxicity to bees, and therefore was used to treat many flowering plants. In addition to its use as a crop insecticide, toxaphene was also used to control livestock parasites such as scabies, lice, flies, ticks, and mange. In the northern United States, including the Great Lakes Region, toxaphene was used for control of unwanted fish stocks in small inland lakes (Swackhamer, Pearson, and Schottler 1998).

- **Hazardous waste sites.** In addition to sources associated with direct releases and historical applications, toxaphene may be a contaminant at hazardous waste sites in the Lake Michigan basin.

- **Stockpiles.** Waste pesticide collections (Clean Sweeps) continue to recover significant quantities of dieldrin, aldrin, and other Level I pesticides indicating that additional stored quantities are likely to exist. Quantities of toxaphene recovered in the Great Lakes drainage are presented in Table 5-34. Improper storage or illegal use of large quantities of toxaphene could be a significant source to Lake Michigan.

Table 5-34. Estimated Clean Sweeps Collections of Toxaphene in the Great Lakes Basin (EPA 1998f)

State	Years of Collection	Toxaphene Collected (kg)	Toxaphene Collected (lb)
Illinois	1994 to 1998	0	0
Indiana	1992 to 1997	5	11
Michigan	1992, 1994, 1995	315	694
Wisconsin	1993 to 1996	271	597
Total		586	1,292

ACTUAL RELEASES OF TOXAPHENE TO THE ENVIRONMENT

- **Point source water discharges, air emissions, and releases to land.** Currently, there are no known producers of toxaphene or toxaphene-like pesticides in the United States or in any other countries. Data indicate that toxaphene was most recently produced in 1992 in Mexico, India and Russia (Ritter and others 1995). TRI records indicate no reportable releases to the environment. Hazardous waste sites containing toxaphene also have the potential to act as sources of toxaphene to the environment through run-off and volatilization. Recently, however, toxaphene was not detected in confined disposal facilities in the Great Lakes Region (HHS 1998d).

- **Legacy toxaphene contamination.** Toxaphene is still widely distributed in the atmosphere as a result of volatilization from soil and water reservoirs that contain toxaphene from past usage. Therefore, long-range atmospheric transport of toxaphene has the potential to be a major source of toxaphene to Lake Michigan. While historical inputs appear to have a non-atmospheric component, the primary nonpoint source of toxaphene to Lake Michigan is currently due to atmospheric cycling between the lake and toxaphene transported long distances in the atmosphere (EPA 1997f and Pearson and others 1997).

ACTUAL LOADINGS OF TOXAPHENE TO LAKE MICHIGAN

Atmospheric Deposition Pathway

Concentrations of toxaphene in the airshed of the Great Lakes are summarized in Hoff and others (1992a). Other unpublished data were presented and discussed at a workshop on toxaphene in the Great Lakes held in Windsor, Ontario in March 1996 (Eisenreich 1996). The data presented indicated that toxaphene concentrations in air were about 30-50 pg/m^3 (1.77×10^{-3} - 2.95×10^{-3} ppt) in samples collected from 1989 to 1990 and ranged from approximately 2-12 pg/m^3 (1.18×10^{-4} - 7.09×10^{-4} ppt) in samples collected from 1992 to 1996 using a somewhat different quantification protocol. There was little geographic variation over the Great Lakes. McConnell and others (1998) measured the concentrations of toxaphene in air from Green Bay in 1989 and over Lake Michigan in 1990. Average concentrations of toxaphene in Green Bay were 59 pg/m^3 (3.48×10^{-3} ppt) , and analysis of back-trajectory data from Green Bay showed that the atmospheric concentrations were likely to originate from air masses originating in the southern United States Over Lake Michigan, however, the average concentration of toxaphene was 65 pg/m^3 (3.48×10^{-3} ppt) and back-trajectory analysis indicated that atmospheric sources of toxaphene (at the time of the sampling) were more likely to be from local or regional volatilization.

Sediments Pathway

Analysis of sediment cores in Lake Michigan indicate that, with the exception of northern Lake Michigan, atmospheric inputs via gas absorption are the dominant source of toxaphene to Lake Michigan (Pearson and others 1997). In the Pearson and others (1997) study, historical concentrations and loadings of toxaphene to sediments from Lake Michigan, based on depth and accumulation rate analysis of sediment cores, were determined. The total burden of toxaphene delivered to the sediments of Lake Michigan from onset of deposition (1940 to 1950) to present day was estimated to be 10,200 kg (22,487 lb).

The maximum concentrations occur in the early 1970s to early 1980s, and surficial concentrations (representing current deposition) in most cores throughout the lake were similar at 15 ± 4 ng/g (ppb). This even horizontal accumulation of toxaphene in the sediments is typical of a pollutant entering a lake via air-water exchange, and thus provides strong evidence that the primary source of toxaphene to Lake Michigan is atmospheric input. However, in northern Lake Michigan, surficial concentrations of toxaphene in sediments were 2 to 4 times greater than southern Lake Michigan sediments (33 ± 12 ng/g [ppb]). This localized increase, due to lack of mixing throughout the lake, is typical of a non-atmospheric source (such as a point source). Pearson and others. (1997) estimated that northern Lake Michigan may be receiving up to 30 to 50 percent of its current toxaphene inputs from non-atmospheric sources.

The loss (via degradation) of toxaphene from Lake Michigan sediments was also investigated by Pearson and others (1997) through analysis of the congener homolog composition. Patterns suggested degradation of toxaphene in the sediments, although the rates were determined to be very slow with half-lives ranging from 40 to >100 years (Pearson and others 1997).

Tributaries and Areas of Concern Pathway

The non-atmospheric source of toxaphene to northern Lake Michigan has not been identified, though Green Bay and the Fox River have been suggested as possible sources. Localized origins of toxaphene around upper Lake Michigan (especially Green Bay) may include previous local use of the pesticide (for example, agricultural or to kill fish in small lakes). However, in 1997 a number of tributaries were sampled at locations that were felt most promising based on past pesticide use and current industrial activity.

IMPACT ON LAKE MICHIGAN

Dissolved aqueous concentrations of toxaphene measured in Lake Michigan between 1991 and 1996 ranged from 0.13 (±0.05) - 0.38 (±0.12) ng/L (ppt) (Eisenreich 1996 and Swackhamer and others 1998).

Concentrations of toxaphene in fish and birds have not been monitored long enough to fully evaluate possible trends. One study (Glassmeyer and others 1997) reported a decrease in toxaphene levels in lake trout and smelt from Lake Michigan between 1982 and 1992. However, these observations are based on data collected only from 1982 and 1992. In 1990, toxaphene concentrations of 1.91 ppm in lake trout in Lake Michigan were observed (DeVault and others 1995). Evans and others (1991) traced the biomagnification of toxaphene in the Lake Michigan food web and found that toxaphene was strongly biomagnified, increasing on average by a factor of five from plankton to fish (as cited in Environment Canada 1997c). In a more recent study, toxaphene concentrations were measured in Lake Michigan phytoplankton and zooplankton, and ranged between 5 to 250 mg/g (parts per thousand) dry weight (Swackhamer and others 1998). Bioaccumulation factors (mean normalized log BAFs) calculated in this study were 5.82 and 6.53 for phytoplankton and net zooplankton, respectively. In addition, the homolog distributions for the different phytoplankton showed a greater predominance of the more highly chlorinated compounds with increasing trophic level. These data indicate that toxaphene significantly biomagnifies in the food web in Lake Michigan. Thus, despite the fact that measured fish tissue concentrations of toxaphene currently do not exceed the FDA Human Health Guidelines, continued atmospheric toxaphene loading and the potential for bioaccumulation suggest the future potential for toxaphene-based fish advisories, as well as ecological effects. Information on the human health effects of toxaphene is presented in Appendix C.

SPECIAL MANAGEMENT ISSUES

Specific actions to address TOXAPHENE are presented in Chapter 6, Table 6-1: RPP1, RPP16, IS13
6

Programs regulating and controlling the management of toxaphene are presented in Appendix A. Special management issues for toxaphene include the following:

- Environmental cycling of legacy toxaphene contamination as a major source of toxaphene to Lake Michigan
- Long-range transport of pollutants

5.3.3.10 PAHs

Pollutant of Concern

PAHs are a group of organic chemicals found ubiquitously in nature. PAHs exist in more than 100 forms, most as complex mixtures found in soot or other burning residue. See Physical and Chemical Properties of PAHs in Appendix B. Pure chemical PAHs are used in medicines and to make dyes, plastics, and pesticides. They are also found in asphalt used in road construction, crude oil, coal, coal tar pitch, creosote, and roofing tar (HHS 1995). However, the commercial production of PAHs contributes little to the overall environmental load as the majority of PAH contamination is formed through the incomplete combustion of organic materials and fossil fuels.

PAHs do not readily dissolve in water. They are generally present in the environment as air vapor, or bound to solid particles in the air, soil, or water. Human exposure occurs through breathing contaminated air (cigarette smoke, wood smoke, exhaust, etc.) or by ingesting contaminated foods or liquids. Some PAH forms have been determined to be probable human carcinogens (HHS 1995). PAHs may also cause other detrimental human health effects to the skin, body fluids, and the ability to fight disease (Chicago Cumulative Risk Initiative 1999). Other adverse human health effects from PAHs are detailed in Appendix C.

Following is a discussion of the potential and actual releases of PAHs into the environment, the potential load to the lake, the current and past loading of PAHs to the lake, the impact of PAHs on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing PAHs.

POTENTIAL RELEASES OF PAHs TO THE ENVIRONMENT

The primary source of PAHs in the environment is the incomplete combustion of organic materials and fossil fuels. The commercial production of PAHs contributes little to the overall environmental load. Few forms of PAH are produced commercially in the United States. The Agency for Toxic Substances and Disease Registry (ATSDR) under the U.S. Health and Human Services (HHS), lists five PAHs and their commercial or industrial use:

- **Anthracene** is used as an intermediate in dye production, in the manufacture of synthetic fibers, as a diluent for wood preservatives, in smoke screens, as scintillation counter crystals, in organic semiconductor research, and to synthesize a chemotherapeutic agent.

- **Acenaphthene** is also used as a dye intermediate as well as in the manufacture of pharmaceuticals and plastics, and as an insecticide and fungicide.

- **Fluorene** is used in the formation of polyradicals for resins and in the manufacture of dyestuffs.

- **Phenanthrene** is used in the manufacture of dyestuffs and explosives and in biological research.

- **Fluoranthene** is used as a lining material to protect the interior of steel and ductile-iron drinking water pipes and storage tanks. (HHS 1995)

PAHs enter the environment through various methods, including the following:

- **Combustion Activities**. Forest fires, residential wood burning, auto exhaust, burning of municipal waste, cigarette smoke, industrial smoke or soot, char-broiling foods, and residential oil and gas heating systems (HHS 1995, Simcik and others 1997, Delta Institute 1999) all produce PAHs through incomplete combustion. According to the Great Lakes Regional Air Toxics Emissions Inventory Report, residential wood combustion is the largest source of atmospheric beuzo-a-pyrene (B[a]P) concentration. The residential wood combustion category included wood burned in fireplaces, wood stoves, furnaces, and fireplace inserts. Wood stoves are the primary concern due to their higher frequency of use over fireplaces. Newer wood stoves (post-1990 production) are required to meet EPA standards for emissions. However, wood stoves typically have a long usable life, so the majority of wood stoves still in use are older, non-EPA certified devices (EPA No date[l]).

- **Inadvertent generation during production processes**. Petroleum refining is the second largest contributor to atmospheric B[a]P load identified by the Great Lakes Regional Air Toxics Emissions Inventory Report, contributing an estimated 41.5 percent of the total B[a]P emissions to the Great Lakes region. Specifically, the catalytic cracking units that break down heavy weight hydrocarbons into lighter weight hydrocarbons are responsible for the emission. Two types of fluidized-bed catalytic cracking unit (FCCU) regenerators are used for this process: complete and partial burn combustion regenerators. The partial burn units use an oxygen-poor environment that leads to incomplete combustion, and therefore the formation of PAHs. The majority of units currently in use are complete burn FCCU regenerators (EPA No date[l]). The production of coke in coke oven batteries at blast furnaces and steel mills accounts for just under 10 percent of the B[a]P emissions estimated for the entire Great Lakes Basin. Emission of B[a]P in the coking process is related to charging, pushing, and quenching operations. The B[a]P release is related to flaws in the process, and are dependent on the maintenance of the coke ovens and individual worker practice (EPA No date[l]).

- **Storage and Disposal Facilities**. Discharges from industrial plants, waste water treatment plants, and hazardous waste sites may contribute water or soil contamination if PAHs inadvertently contaminate site runoff or waste streams, or leak from storage containers (HHS 1995). Eighteen sites in EPA Region 5 are currently on the National Priorities List (NPL) with B[a]P listed as one contaminant of concern (EPA No date[l]).

- **Nonpoint Source Runoff from Urban Areas**. PAHs are commonly found in parking lot and street runoff associated with vehicle wear, oil, and gasoline.

- **Natural Sources.** Natural sources of PAHs include forest fires, volcanoes, crude oil and shale oil (HHS 1995).

Table 5-35 identifies the leading sources of PAHs nationally. Several of the leading sources of PAHs listed below are working to reduce PAH emissions under EPA's MACT (maximum achievable control technology) standard, through the Binationl Toxics Strategy (BNTS) program.

Table 5-35. National PAH Emissions (EPA 1998b)

Source Category	Emissions (tpy)	Percent Contribution
Residential wood/ wood residue combustion	8855	32
Consumer products usage	5732.8	20.8
Aerospace industry (surface coating)	136	5.9
Open burning: forest and wildfires	1417	5.1
Open burning: prescribed burning	1123	4.1
Petroleum refining: all processes	783	2.8
Primary aluminum production	662	2.4
Pulp and paper: Kraft recovery furnaces	649	2.4
Coke ovens: charging, topside and door leaks	538.5	2
Coke ovens: pushing, quenching and battery stacks	517	1.8
Blast furnace and steel mills	500	1.8
MON - continuous processes	440	1.6
Gasoline distribution: Stage II	374	1.4
Gasoline distribution: Stage I	354.5	1.3
Petroleum refining: catalytic cracking units	313	1.1
Open burning: scrap tires	294.4	1.1
Others (>1 percent each)	2789.5	10.1
Total	26976	

ACTUAL RELEASES OF PAHs TO THE ENVIRONMENT

- **Point source water discharges**. A small amount of PAHs are released to the environment through water discharges every year. TRI data in Table 5-36 show PAH releases to the water in the Lake Michigan basin from facilities in northern Indiana for the years 1995 to 1997, with a total of 18 pounds for those 3 years.

- **Air emissions**. According to RAPIDS, 4,263,783 pounds of PAHs were emitted to the air in the Lake Michigan basin in 1996 (Great Lakes Commission 1999c and 1999d). TRI data in Table 5-36 present PAH releases in the Lake Michigan basin from facilities in northern Indiana, with a total of 7,670 pounds over a 3-year period.

- **Releases to land**. The TRI database indicated that 138 pounds of PAHs were released to land in the Lake Michigan basin in the years 1995 to 1997, as shown in Table 5-36 below.

- **Legacy PAH contamination.** Volatilization of PAHs from land and water surfaces into the atmosphere can result in subsequent wet or dry deposition and then re-volatilization. For this reason, and because of their persistence in the environment, PAHs that were released to the environment many years ago play an active role in the contamination of today's environment.

The TRI database lists PAH releases to the Lake Michigan Basin environment. The data listed below represents emissions from blast furnace and petroleum refining facilities in northern Indiana.

Table 5-36. TRI Annual PAH Releases in the Northern Indiana Lake Michigan Basin

Year	Air Releases (lb)	Land Releases (lb)	Underground Releases (lb)	Water Releases (lb)	All Releases (lb)
1995	1750	0	0	7	1757
1996	3460	110	0	6	3576
1997	2460	28	0	5	2493
Grand Total	7670	138	0	18	7826

ACTUAL LOADINGS OF PAHs TO LAKE MICHIGAN

This section describes the specific sources of PAHs to Lake Michigan and the load of PAHs contributed by these sources.

Atmospheric Deposition Pathway

Current studies indicate that the majority of the contamination of surface waters, such as Lake Michigan, with PAHs occurs through deposition of contaminated airborne particles (Delta Institute 1999; Simcik and others 1997; Franz, Eisenreich, and Holsen 1998). PAHs began accumulating in Lake Michigan sediments between 1880 and 1900, when the Lake Michigan basin experienced a rise in industrialization that caused a subsequent increase in coal combustion (Delta Institute 1999). The maximum PAH accumulation in Lake Michigan occurred between 1950 to 1975. The maximum accumulation rates in the southern basin were 70 ng/cm^2/ yr (0.1 ounce/acre/yr) and 100 to 150 ng/cm^2/ yr (0.14 to 0.21 ounce/acre/yr) in the northern basin. The higher accumulation rate in the northern basin is due to the south to north transport of sediment-bound PAHs. A slight decrease was observed in recent years in some cases due to a switch from coal to oil and natural gas and because of industrial emissions controls (Simcik and others 1996).

The EPA's 1990 Emissions Inventory of Section 112(c)(6) Pollutants lists additional sources of B[a]P. Wildfires, primary aluminum production, prescription burning, burning of scrap tires, coal combustion, on-road vehicles, residential coal combustion, non-road vehicles and equipment are listed as sources of B[a]P, in addition to the sources listed above. Wildfires were estimated to account for approximately half of the national PAH emissions in 1990 (EPA. No date[l]).

Atmospheric Deposition Pathway: Load Estimates

Various estimates of the total load of PAHs to Lake Michigan exist. A conservative estimate of PAH loading to Lake Michigan through particle dry deposition was estimated to be 5,000 kg/yr (11,023 lb/yr), according to a study that measured dry deposition of 17 parent PAHs at multiple sites in the Lake Michigan basin (Franz, Eischreich, and Holsen, 1998). The EPA, in its 1993 Great Lakes Regional Air Toxics Emissions Report, estimated the total B[a]P load to the entire Great Lakes Basin to be 121,563 pounds (EPA No date [l]). A 1996 report cited PAH atmospheric deposition to Lake Michigan of 600-800 mg/m^2/yr (5.35 to 7.14 lb/acre/day) from coke and steel production emissions (Delta Institute 1999).

An analysis of data collected for IADN estimates that the following loadings of B[a]P (Table 5-37) have occurred in Lake Michigan during the years 1988 to 1996 (Delta Institute 1999).

Table 5-37. B[a]P Load to Lake Michigan, 1988 to 1996

Year	Lake Michigan B[a]P Load (kg/yr)	Lake Michigan B[a]P Load (lb/yr)
1988	180	397
1992	84	185
1994	250	551
1996	117	258

EPA broke down the total estimated load to the Great Lakes Basin of B[a]P into sources, as listed below in Table 5-38 (EPA No date[l]).

Table 5-38.   B[a]P Load to the Great Lakes Basin

Source Category	Percent B[a]P Load to Great Lakes Basin
Residential Wood Combustion	45.8
Petroleum Refining	41.5
Blast Furnaces and Steel Mills	7.6
Other Sources	5.1

One study of atmospheric levels of PAHs in the Great Lakes regions found that the air deposition of phenanthrene (PAH compound) into Lake Michigan increased significantly from 1991 to 1992 and 1993 to 1994 (Hillery and others 1998).

Atmospheric Deposition Pathway: Chicago as a Source

While the majority of the PAH load to the environment likely originates from a variety of natural and human-induced sources, most studies corroborate the fact that anthropogenic sources contribute a significant load, as is determined by the high levels of atmospheric and sediment PAH concentrations in and around urban centers such as Chicago and Milwaukee (Scudder and others 1995; Delta Institute 1999; Keeler 1994; Simcik and others 1997; and Franz, Eisenreich, and Holsen 1998).

PAHs in Lake Michigan sediments originate from several sources, including vehicular emissions; wood, oil, and natural gas burning for home heating; coal-fired power plants; and coke and steel production. A study by Simcik and others (1996) that focused on an urban area concluded that the dominant source of PAHs to the entire lake from around 1900 to the present is coke and steel production in the urban complex of Chicago, Illinois, and Gary, Indiana. This conclusion differs from a study conducted by Karls and Christensen in 1998, which found a regional historical pattern for central Lake Michigan with a significant contribution from wood-burning and an increasing dominance of oil-burning sources (as opposed to coal-burning by coke and steel production), which is consistent with U.S. fuel consumption data. Karls and Christensen also found that PAH loadings at Green Bay, the Fox River, and the Kinnickinnic River were strongly influenced by local industrial activities, primarily coke production at the Milwaukee Solvay Coke Company that operated from 1900 to the 1970s (Simick and others 1996).

These differing findings support the notion that urban sources are different and often much larger than regional sources. For example, Simcik and others (1997) reported the results of two intense sampling events in the mid-1990s that found ambient PAH air concentrations over Chicago averaged 27 to 430 ng/m^3 (2.62 to 41.7 ppt) while gas phase PAH concentrations over the lake approximately 10 to 20 km (6.2 to 12.4 miles) offshore ranged from 0.8 to 70 ng/m^3 (0.078 to 6.79 ppt). Overall, Keeler (1994) reported that PAH concentrations are generally 10 times higher at urban air monitoring sites as compared to rural monitoring stations.

Sediments Pathway

Anthropogenic input of PAHs to aquatic sediments exceeds natural sources. Airborne particles, contaminated with PAHs from anthropogenic activities, are often deposited in surface waters and result in contaminated aquatic sediments (Christensen 1997). PAHs have been identified as a contaminant in sediments in several Lake Michigan AOCs. In the Menominee River AOC, high concentrations of PAHs have been detected in river sediments adjacent to the Marinette wastewater treatment plant. Also, in the Muskegon Lake AOC, a sediment characterization study in the vicinity of the Division Street storm sewer outfall and Hartshorn Marina indicated elevated levels of PAHs.

Tributaries and Areas of Concern Pathway

PAHs are considered a key contaminant in 5 of the 10 AOCs in the Lake Michigan basin. The Lake Michigan AOCs are examples of legacy PAH contamination. Seven of the AOCs have PAHs listed as one of the contaminants of concern: The Muskegon Lake, Lower Menominee River, Lower Green Bay and Fox River, Sheboygan River, Milwaukee Estuary, Waukegan Estuary, and the Grand Calumet River/Indiana Harbor Ship Canal (Lake Michigan Forum No date). The Grand Calumet River/Indiana Harbor Ship Canal AOC contains 5 to 10 million cubic yards, up to 20 feet deep, of contaminated sediments. The contaminants in the sediments include PAHs (EPA No date[n]).

IMPACT ON LAKE MICHIGAN

Elevated concentrations of PAHs have resulted in dredging restrictions at several AOCs in Lake Michigan. Appendix C contains information on potential human health effects of exposure to PAHs.

SPECIAL MANAGEMENT ISSUES

Specific actions to address PAHs are presented in Chapter 6, Table 6-1: SU1, SU6, RM5, RM6, RM8, RM11, RPP5, RPP9 6

An overview of the regulations and programs targeted at PAHs in the Lake Michigan basin may be found in Appendix A.

5.3.3.11 Atrazine

Emerging Pollutant

Atrazine is one of the chloro-triazines, which also include simazine and cyanazine. See Appendix B for information on the physical and chemical properties of atrazine. Atrazine is a widely used herbicide for control of broadleaf and grassy weeds in corn, sorghum, rangeland, sugarcane, macadamia orchards, pineapple, turf grass sod, forestry, grasslands, grass crops, and roses. Trade names for atrazine include Aatrex, Alazine, Crisazina, Malermais, Primatol, and Zeapos. Atrazine has been widely used in the agricultural regions of the Great Lakes basin since 1959 when it was registered for commercial use in the United States Atrazine was estimated to be the most heavily used herbicide in the United States in

1987 to 1989, with its most extensive use for corn and soybeans in Illinois, Indiana, Iowa, Kansas, Missouri, Nebraska, Ohio, Texas, and Wisconsin.

Following is a discussion of the potential and actual releases of atrazine into the environment, the potential load to the lake, the current and past loading of atrazine to the lake, the impact of atrazine on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing atrazine.

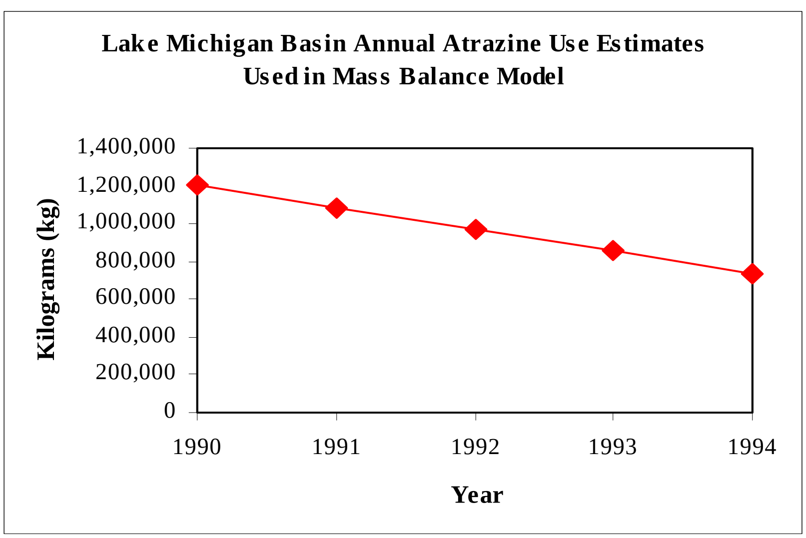
POTENTIAL RELEASES OF ATRAZINE TO THE ENVIRONMENT

- **Historic uses.** Atrazine is a herbicide used primarily to control broadleaf and grasses on corn crops and is one of the primary herbicides used in the Great Lakes. It is usually applied in the spring before or after emergence of the crop. Atrazine use is concentrated in the southern half of the Lake Michigan drainage basin. It also was used until 1993 for control of vegetation in fallow and in noncrop land. Effective in 1993, use for noncrop vegetation control was eliminated, and use was restricted by a requirement for a buffer zone between application sites and surface water. Atrazine is also used, to a much lesser extent, as a herbicide in industrial and commercial applications (for example, conifer reforestation) and for home and garden use. It is available in dry, liquid, granular, and powder formulations.

- **Production and distribution.** Atrazine may be released into the environment via effluents at manufacturing sites and from herbicide application on agricultural lands. There are no atrazine production facilities in the Lake Michigan basin. Atrazine's chemical properties make it susceptible to leaching and runoff, especially during heavy rains (Ribaudo and Bouzaher 1994).

Currently, there are four producers of technical grade atrazine in the United States and 36 registrants of atrazine-containing products available. Atrazine use has declined in recent years most likely because of label changes and increased environmental concerns; annual sales still range between 80 and 90 million pounds (Ribaudo and Bouzaher 1994). Estimated annual atrazine use during 1994 in the Lake Michigan basin is 740,000 kg (1,631,419 lb) (Schottler and Eisenreich 1997). Figure 5-9 shows the decrease in atrazine use from 1990 to 1994. Atrazine use estimates were obtained from "Mass Balance Model to Quantify Atrazine Sources, Transformation Rates, and Trends in the Great Lakes" (Schotter and Eisenreich 1997).

Figure 5-9. Lake Michigan Basin Annual Atrazine Use Estimates Used in Mass Balance Model



ACTUAL RELEASES OF ATRAZINE TO THE ENVIRONMENT

- **Point source water discharges, air emissions, releases to land**. According to RAPIDS, 1,420,276 pounds of atrazine were emitted to the air in the Lake Michigan basin in 1996. There are no TRI reported releases of atrazine.

- **Intended use.** In the 1950s through the 1970s, atrazine was used for only grass and broadleaf control. About 2 to 4 pounds of atrazine were used per acre. In the 1970s, atrazine was able to be applied in tank mixes that allowed for 1.5 to 2.5 pounds of atrazine per acre. For quackgrass control in Wisconsin and Michigan, 4 to 6 pounds were applied per acre. When a popular herbicide Roundup7 was introduced, the application rates for quackgrass control were able to be reduced to 1.5 to 2.5 pounds per acre. In the 1980s and 1990s, prepacks were used and resulted in a current average use rate of 1.1 pounds per acre (EPA 1998a). In 1995, atrazine accounted for 13.8 percent of the total pesticide use in the Lake Michigan Basin. 1.8 million pounds of atrazine were applied to agricultural fields in 1995 (Brody, Furio, and Macarus 1998).

ACTUAL LOADINGS OF ATRAZINE TO LAKE MICHIGAN

The major loading processes of atrazine in Lake Michigan include tributary, wet and dry deposition, and air-water exchange. Through a grant from the Great Lake National Program Office, Shawn Schottler and Steven Eisenreich developed a mass balance model to quantify atrazine sources, transformation rates, and trends in the Great Lakes. Sedimentation, air-water exchange, and dry deposition were estimated from chemical and physical properties of atrazine, lake hydrology and climatology, and published reports. Tributary and precipitation loadings were taken from existing data or estimated from physical properties in combination with herbicide use trends and watershed hydrology. Table 5-39 shows average values and standard deviation of measured concentrations in ng/L of atrazine in Lake Michigan from a Schottler and Eisenreich study (1997) and the LMMB Project (EPA No date[i]).

Table 5-39. Measured Concentrations (ng/L or ppt) of Atrazine in Lake Michigan

Year	Schottler and Eisenreich Study Concentrations	Standard Deviation of Measured Concentrations	LMMB Project Concentrations[a]
1991	35	2.0	34 (16)
1992	37	1.8	Not available
1993	37	Not available	37 (24)
1994	37	2.2	38 (38)
1995	39	Not available	40 (47)

Note: [a] Concentrations in parentheses include atrazine metabolites DEA and DIA.

The LMMB Project and Schottler and Eisenreich's mass balance model also calculated annual inputs and losses in kg/year of atrazine to Lake Michigan. Table 5-40 shows the average annual inputs and losses of atrazine to Lake Michigan as calculated in both studies. The Schottler and Eisenreich model found that the inputs are relatively constant for Lake Michigan so the inputs and thus outputs from 1991 to 1994 data were averaged. The data for the LMMB Project is presented for 1994 to 1995.

In 1990 and 1991, research for the EPA Great Lakes Program was conducted to quantify the concentrations, sources, and fate of atrazine and its transformation products, alachlor and metolachlor in

Lakes Michigan, Huron, Erie, and Ontario. Water column profiles of herbicide concentrations representing 4 to 10 depths per site were constructed for 10 sites in Lake Michigan. Atrazine and DEA were detected in 100 percent of the samples analyzed from Lake Michigan. No consistent vertical trends were able to be determined from the concentration profiles. In addition, the lack of vertical difference in atrazine concentration may show that the major inputs of atrazine occur before lake stratification or atrazine inputs are uniform to stratified waters. The data also showed little or no lateral variation in atrazine concentration. The study concluded that because lateral and vertical concentrations showed little to no variation, the measured concentrations probably reflected lake-wide averages. The vertically and laterally well mixed atrazine also suggests that the water column residence time has half-lives on the order of months to years (Schottler and Eisenreich 1997).

Table 5-40. Average Annual Inputs and Losses in kg/yr (lb/yr) of Atrazine for Lake Michigan (EPA No date[i])

Inputs and Losses	Schottler and Eisenreich Mass Balance Model Load	Percent of Total Load	LMMB Project Load[a]
Tributary	9,040 (19,930)	76	1,600 (3,527)
Wet Deposition	2,600 (5,732)	22	1,043 (2,299)
Dry Deposition	160 (353)	1	210 (463)
Air-water exchange	30 (66)	<1	*Need to obtain*
Net gas input	Not available	Not available	445 (981)
Net gas output	Not available	Not available	40 (88)
Outflow	2,900 (6,393)	24	*Need to obtain*
Transformation	8,890 (19,599)	76	*Need to obtain*
Sediment	25 (55)	<1	*Need to obtain*

a Load calculation includes transnonachlor

Average concentrations were also compared on a site-by-site basis. The results showed that 1992 concentrations were statistically greater than 1991 concentrations, which may suggest that atrazine is accumulating in the water column. Because the monitoring period was short, a longer period of data gathering is needed to confirm this hypothesis (Schottler and Eisenreich 1997).

Atmospheric Deposition Pathway

The Lake Michigan Urban Air Toxics Study conducted during the summer of 1991 in the lower Lake Michigan area consisted of integrated 12-hour atmospheric samples collected daily from July 8 through August 9 at three ground sites: Kankakee, Illinois; the Illinois Institute of Technology (IIT) in Chicago; and South Haven, Michigan. Micrometeorological parameters and pollutant concentrations were also measured at offshore locations near Chicago. Average concentrations for atrazine were 2 to 3 times higher at the background Kankakee site than the IIT site. These results are likely due to the higher pesticide usage in this rural agricultural area. The study also found significant concentrations for many pesticides at over-water sites in both the eastern portion of the lake and offshore of Chicago (Keeler 1994).

Of the 38,146 samples collected during the LMMB Project, 3,239 samples had detections of atrazine. Analytical data for atrazine were collected from a network of seven shoreline sites and one rural background site in the LMMB Project between April 1994 and October 1995 (Sweet, C.W. and K.S. Harlin 1997). Gas phase concentrations of atrazine were found only at the Illinois Water Survey's Bondville Environmental and Atmospheric Research Station near Champaign, Illinois. Atrazine was found in precipitation samples at all of the Lake Michigan sites. Concentrations of particulate atrazine were found in spring and summer samples of airborne particles at all sites, but the highest particulate concentration was found at Bondville.

A defined seasonal variation in monthly atrazine concentrations in rain were apparent at three sites from northern to southern Lake Michigan in the LMMB Project. Highest concentrations were seen in the spring (April to June), coinciding with application of atrazine to corn crops. In July, concentrations declined dramatically, and levels of atrazine were commonly not detected in rain samples between late fall and the following spring. High levels of atrazine in rain at all three sites from northern to southern Lake Michigan in April 1994, despite low levels of atrazine applied to crops, suggest that long-range transport from areas farther south contributed to the wet deposition of atrazine to Lake Michigan.

Sediments Pathway

The chemical properties of atrazine make it susceptible to leaching and runoff, especially during heavy rains. It has a large potential to leach or to move in surface solution, and a medium potential to adsorb to sediment particles (Ribaudo and Bouzaher 1994). Tributary inputs are the major source of atrazine to the lake. Minimal research has been conducted on atrazine in Lake Michigan sediments but it appears to have little effect on atrazine loading to Lake Michigan.

Tributaries and Areas of Concern Pathway

According to Schottler and Eisenreich's study and mass balance model, tributaries account for more than 75 percent of the total load of atrazine to Lake Michigan. Tributary loading was calculated based on the amount of atrazine used in the basin and the percentage of applied atrazine that is typically removed by runoff.

Between 1983 and 1985, 4,155 wells were sampled in the western Lake Michigan drainage basin as a part of the USGS NAWQA program. Atrazine and its degradation products exceeded the Wisconsin preventive action limit (PAL) of 0.3 mg/L (ppm) in about 10 percent of all wells sampled. Atrazine was detected in all 143 surface water samples collected including some at very low concentrations (0.005 mg/L [ppm]) from forested areas most likely due to wet deposition. Drinking water standards were exceeded in 6 percent of surface water samples for atrazine, and 1 percent of samples for simazine and alachlor (Peters 1998).

The LMMB Project estimated atrazine loads from Lake Michigan tributaries based on 1995 data (see Table 5-41) indicate that the St. Joseph River contributes the largest load of atrazine to Lake Michigan (605 kg/yr).

Table 5-41. Estimated Atrazine Loads From Lake Michigan Tributaries (EPA No date[j])

Tributary	Atrazine Estimated Load (kg/yr)	Atrazine Estimated Load (lb/yr)
Fox	255.3	562
Kalamazoo	83.5	184
Grand Calumet	25.4	56
Grand	362.3	797.1
St. Joseph	605	14.3
Sheboygan	3.2	7.04
Milwaukee	9.6	21.1
Menominee	11.5	25.3
Pere Marquette	19	41.8
Manistique	3.8	8.4
Muskegon	36.5	80.3

IMPACT ON LAKE MICHIGAN

Most of the atrazine use is concentrated in the southern portion of the basin, as the northern portion of the basin is highly forested. The intensive use of atrazine in Lake Michigan for about 25 years and its long half-life in these waters may make Lake Michigan act as end points in the environmental transport of atrazine. Tributary loading is the most important input to Lake Michigan. Information on the human health and ecological effects of atrazine is presented in Appendix C.

According to the Tierney, Nelson, Christensen, and Kloibery Watson model, available monitored atrazine concentrations in Lake Michigan are very similar to the most-likely loading rate and indicate a half-life of 2 years (Tierney, Nelson, Christensen, and Watson 1999). According to this study, historical and current atrazine concentrations are below the U.S. drinking water lifetime MCL of 3.0 μg/l (ppb). However, the Schottler and Eisenreich model predicts a half-life for atrazine exceeding 5 years in Lake Michigan. This long-half life has allowed atrazine to accumulate in Lake Michigan over the last decades. Schottler and Eisenreich's model shows that if atrazine use remains at current amounts and that the atrazine concentration remains at current amounts until the year 2010, the atrazine inventory will show minimal change.

SPECIAL MANAGEMENT ISSUES

Programs regulating and controlling the management of atrazine are presented in Appendix A. Special management issues for atrazine include the following:

Specific actions to address ATRAZINE are presented in Chapter 6, Table 6-1: RM11, IS1, IS9, IS13 6

- Internal transformation and outflow may produce a water column residence time of greater than 5 years in Lake Michigan.

- Although quantity of atrazine applied to crops has decreased, atrazine is still a widely used herbicide in the southern portion of the Lake Michigan basin.

- Atrazine is considered a key component to successful conservation tillage by the agricultural community.

5.3.3.12 Selenium

Emerging Pollutant

Selenium is a naturally occurring element widely distributed in the earth's crust and commonly found in sedimentary rock formations. Selenium is released to the environmental media by both natural processes and anthropogenic sources.

Naturally, selenium is not often found in its pure form but is usually combined with other substances. Selenium in rocks is combined with sulfide minerals or with silver, copper, lead and nickel minerals. Selenium and oxygen combine to form several compounds such as sodium selenite and sodium selenate. See Physical and Chemical Properties of selenium in Appendix B. Although it is an essential food element needed by humans in small amounts, too much selenium can be harmful to health.

Following is a discussion of the potential and actual releases of selenium into the environment, (the potential load to the lake), the current and past loading of selenium to the lake, the impact of selenium on achieving the vision for the Lake Michigan ecosystem, and unique issues with managing selenium.

POTENTIAL RELEASES OF SELENIUM TO THE ENVIRONMENT

Selenium enters the air, water, and soil as a result of both natural processes and human activities. Most selenium enters the environment as the result of human activities.

In the Lake Michigan basin, selenium compounds are released to the air during the combustion of coal and petroleum fuels, and during the smelting and refining of other metals. Other selenium emissions are released to the environment from glass manufacturing, electronics and electrical manufacturing, milling operations, duplicating equipment, pigments, fungicides, gaseous insulators, and solid waste (EPA No date[k]).

- **Metals industry**. Selenium has many uses in industry and is used for a variety of processes including making metal alloys. There are 271 metals industry-related facilities in the basin that may serve as sources of selenium.

- **Use of selenium as part of a manufacturing process or within a product.** The greatest use of selenium compounds is in electronic and photocopier components, but they are also widely used in glass, rubber, textiles, petroleum, medical therapeutic agents, and photographic emulsions.

- **Selenium product use and disposal.** Selenium is regulated by the federal government as a nonradioactive hazardous element. Disposal of selenium consists of treating an acidified solution of selenium with sodium sulfite to form the reducing agent, sulfur dioxide. The selenium solution is then heated to produce elemental selenium, which is less mobile in the environment and less bioavailable, and the solution is filtered and washed (HHS 1996b).

ACTUAL RELEASES OF SELENIUM TO THE ENVIRONMENT

From 1987 to 1993, according to the TRI database, selenium releases to land and water in the United States totaled more than 1 million pounds. These releases were primarily from copper smelting industries. The largest direct releases of selenium to water occurred in Indiana (about 5,300 pounds) (EPA No date[k]).

- **Point source discharges.** Point source discharges of selenium to Lake Michigan include industrial (primarily coal and petroleum manufacturers) and municipal sites (releases from disposal or run-off). According to the TRI database, there were no point source releases of selenium to the Lake Michigan Basin water from 1989 to 1997.

- **Air emissions.** The TRI database indicated that 171 pounds of selenium were emitted to the air in the Lake Michigan Basin. The largest selenium emissions occurred in 1990 from biological production facilities (according to the TRI SIC code). Selenium is not a listed chemical in the 1993 and 1996 RAPIDS database.

- **Releases to land.** The TRI database indicated that 580 pounds of selenium was released to land in 1997 in the Lake Michigan basin. Blast furnaces and steel mills were the primary sources of the selenium release.

- **Legacy selenium discharges.** Selenium is not a primary contaminant at any Superfund sites in the four Lake Michigan states or at any Lake Michigan AOC.

TRI data on releases of selenium within the Lake Michigan watershed is summarized in Table 5-42. All releases were reported by electronics and plating facilities in northern Indiana and southern Michigan.

Table 5-42. TRI Data on Releases of Selenium in Lake Michigan Basin

Year	Air Releases (lb)	Land Releases (lb)	Underground Releases (lb)	Water Releases (lb)	All Releases (lb)
1989	14	0	0	0	14
1990	79	0	0	0	79
1991	26	0	0	0	26
1992	13	0	0	0	13
1993	10	0	0	0	10
1994	11	0	0	0	11
1995	8	0	0	0	8
1996	10	0	0	0	10
1997	0	580	0	0	580
Grand Total	171	580	0	0	751

ACTUAL LOADINGS OF SELENIUM TO LAKE MICHIGAN

This section describes the specific sources and pathways of selenium to Lake Michigan and the load of selenium contributed via these pathways.

Atmospheric Deposition Pathway

The Lake Michigan Urban Air Toxics Study (1994) found a load of 0.93 ton of selenium from dry deposition due to sources from Chicago and Gary, Indiana. The dry deposition loads from Chicago and Gary to Lake Michigan are estimated to be 2 to 10 times greater than the loads from other regional sources of Lake Michigan (Keeler 1994).

Sediments Pathway

Contaminated sediments are a source of selenium contamination in Lake Michigan because selenium may be released from sediments and resuspended in the water. The average concentration of selenium in Lake Michigan sediment is 1.2 μg/g (ppm)(Chicago Cumulative Risk Initiative 1999).

Scudder and others (1995) sampled in 1992, 1994, and 1995 to determine the occurrence of a broad suite of trace elements, including selenium, in biota and stream bed sediment in selected streams in the Western Lake Michigan Drainages, a study unit of the NAWQA Program of the USGS. Sediment was sampled at 31 sites for trace elements and biota were collected at a subset of sites. They determined that forested land use was related to high concentrations of selenium in sediment; however, surficial deposits type was an additional factor for selenium. Selenium concentrations in caddishfly larvae were high in areas of shale or clayey deposits and areas with sulfide-bearing rocks. Sediment high in organic carbon contained high concentrations of selenium. They also determined that selenium concentrations in sediment were significantly higher at sandy sand and gravel sites. The highest sediment selenium concentration observed during this study was at one agricultural indicator site, Duck Creek in northeast Wisconsin, where rock bass collected in 1995 contained 17.5μg/g (ppm) selenium (Scudder and others 1995). In addition, Peters and others assessed the water quality of the Western Lake Michigan Drainages in 1995 and found slightly elevated selenium concentrations in fine sediments (Peters and others 1998).

Tributaries and AOC Pathway

Industrial discharge of selenium is prevalent in the Lake Michigan Basin.

IMPACT ON LAKE MICHIGAN

Selenium inputs to lake Michigan have the potential to accumulate in aquatic biota. In 1993, Custer and others collected 20 great blue heron eggs from a colony at the Indiana Dunes National Lakeshore. The eggs were artificially incubated until pipping and were then analyzed for organochlorines, mercury, and selenium. Selenium concentrations in eggs were above background levels, but below a concentration threshold associated with reproductive impairment (Custer and others 1998).

See Appendix C for a detailed discussion of potential ecological and human effects of selenium.

SPECIAL MANAGEMENT ISSUES

Specific actions to address SELENIUM are presented in Chapter 6, Table 6-1: RM11

6

Programs regulating and controlling the management of selenium are presented in Appendix A.

5.3.3.13 PCB Substitute Compounds

Emerging Pollutant

Following the 1979 U.S. restrictions on PCB use, other compounds began being used in dielectric fluids, in hydraulic system lubricants, and in solvents and carriers in carbonless copy paper manufacturing. Little was known about the potential impact of these substitutes on the basin; therefore, it was designated an emerging pollutant needing further evaluation. Compounds used in place of PCBs include the following:

- Mineral and silicone oils
- Bis(2-ethylhexyl)phthalate (DEHP)
- Isopropylbiphenyls
- Diphenylmethanes
- Butylbiphenyls
- Dichlorobenzyldichlorotoluene
- Diisopropylnaphthalene
- Phenylxylyl ethane

Information on most of these compounds is limited at this time. More extensive information is available for DEHP.

DEHP

DEHP is a semivolatile organic compound (SVOC) that belongs to a group of compounds called phthalates and phthalic acid esters (EPA 1999b). Appendix B contains detailed chemical and physical information for DEHP, and Appendix C contains human health effects information for DEHP. Although DEHP is used in place of PCB in dielectric fluids, it is most commonly used as a plasticizer for polyvinyl chloride (PVC) and other polymers such as rubber, cellulose, and styrene. DEHP is also used for the following purposes:

- In insect repellants, cosmetics, rubbing alcohol, liquid soap, detergents, decorative inks, lacquers, munitions, industrial and lubricating oils, defoaming agents used in paper and paperboard manufacturing, vacuum pump fluids, photographic film, wire and cable, and adhesives

- As a pesticide carrier

Presented below are discussions on the potential sources and pathways for PCB substitutes to enter the environment, actual known releases to the environment, known loading of these compounds to the lake, their impacts on the Lake Michigan ecosystem, and management issues that are unique for these compounds.

Potential Releases of PCB Substitutes to the Environment

DEHP

Primary sources of DEHP to the environment include releases from manufacturing facilities that make or use DEHP, releases from DEHP-containing products during use, leachate from landfills where DEHP-containing materials are disposed of, and incineration of materials containing DEHP.

- **Manufacturing losses**. DEHP is released to the environment during its production, transport, and use in manufacturing. Releases during DEHP production are primarily through waste water streams. Releases during DEHP transport are primarily through volatilization to air. Releases during the manufacture of DEHP-containing products are primarily through volatilization to air and in waste water streams (HHS 1987).

- **Product losses**. DEHP is released from manufactured products, such as rubber and PVC components, during their usable lifetime. Releases from these products are through volatilization to air and leaching to wastewater and storm water (HHS 1987).

- **Landfill leachate**. The most common disposal method for DEHP-containing products and wastes is landfilling (ATSDR 1987). DEHP may be released from landfills in leachate and through volatilization.

- **Incineration emissions**. Incineration is also used to dispose of DEHP-containing products and wastes. DEHP is released to air in the emissions from these incineration facilities (HHS 1987).

DEHP released to terrestrial systems will strongly adsorb to both the mineral and organic fractions of soil. It is degraded in soil under aerobic conditions but only very slowly in anaerobic environments (HHS 1987). DEHP adsorbed to soil can be transported to water bodies through surface runoff.

DEHP released to aquatic systems will either (1) adsorb to sediment or suspended matter, (2) be taken up by biota, or (3) biodegrade in approximately 2 to 3 weeks. DEHP does not readily evaporate or undergo hydrolysis in aquatic systems (HHS 1987, EPA 1999i). Because hydrolysis and biodegradation of DEHP is low, DEHP adsorbed to sediment provides a steady source of DEHP to overlying surface water and to downstream locations (HHS 1987).

DEHP released to the ambient air has a strong tendency to adhere to atmospheric particles that can be carried long distances until removed by rainfall (HHS 1987, EPA 1999i). DEHP removed from the ambient air by rainfall can be transported to water bodies by wet deposition or surface runoff.

DEHP is highly lipid soluble and, therefore, is readily absorbed by biota. It is degraded by microorganisms and metabolized by invertebrates, fish, and other mammals, thereby reducing its biomagnification potential (HHS1987). Thus, rapid bioconcentration factors are often seen in aquatic organisms, but biomagnification is less than for other compounds that resist degradation and metabolism.

Other PCB Substitutes

The other identified PCB substitutes are used in hydraulic systems, in the manufacture of carbonless copy paper, and in dielectric fluids. Releases of these compounds could occur from spills of the raw compound, volatilization, discharge in waste water effluent, and leaching from waste material containing the compounds.

Addison, Paterson, and Mackay (1983) modeled the predicted environmental distribution of several PCB substitute compounds in comparison to the PCB 2,4,5,4',5'-pentachlorobiphenyl. Their model predictions are presented below.

- More than 70 percent of diisopropylnaphthalenes and butylbiphenyls will be distributed to air compared to 5.7 percent of the PCB.

- More than 80 percent of phenylxylylethanes will be distributed to soil and sediment compared to more than 90 percent of the PCB.

- More than 70 percent of isopropylbiphenyls will be distributed to soil and sediment compared to more than 90 percent of the PCB.

ACTUAL RELEASES OF PCB SUBSTITUTES TO THE ENVIRONMENT

The available information on known releases of the identified PCB substitutes are limited. Information for DEHP is the most readily available and is presented below along with the results of one research study of several other PCB substitutes.

DEHP

The Agency for Toxic Substances and Disease Registry (HHS 1987) reported the following distribution of releases from the 1986 U.S. supply of DEHP:

- 0.4 percent was released to wastewater during DEHP production.
- 0.08 percent was released during transport of DEHP.
- One percent was released to air and 2 percent was released to water during manufacture of DEHP-containing products.
- One percent was released to air and 0.5 percent was released to water during use of DEHP-containing products.
- 92 percent was released in landfill leachate from disposal of DEHP-containing waste materials and products.
- 3 percent was lost through incineration emissions from disposal of DEHP-containing waste materials and products.

The TRI reports that in EPA Region 5 between 1987 and 1997, more than 89,000 pounds of DEHP were released to air, land, and water as discussed below.

- **Air emissions**. According to the TRI database, 52,707 pounds of DEHP were released to air.

- **Point Source Discharges.** According to the TRI database, 2,805 pounds of DEHP were released to water with more than 99 percent of the releases occurring in Indiana.

- **Releases to Land**. According to the TRI database, 30,501 pounds of DEHP were released to land with more than 95 percent of the releases occurring in Michigan.

- **Legacy DEHP Discharges.** DEHP is not a primary contaminant at any Lake Michigan AOC.

Other PCB Substitutes

The other identified PCB substitutes have not been extensively studied; therefore, information on releases to the environment is limited. Peterman and Delfina (1990) conducted sampling and analysis of several media from the Fox River in Wisconsin to determine if PCB substitutes were present. The study identified the PCB substitutes isopropylbiphenyls, diphenylmethanes, diisopropylnaphthalenes, and butylbiphenyls in the following matrices (Peterman and Delfino 1990):

- Effluent from a de-inking-recycling paper mill
- Effluent from a waste water treatment plant that received wastewater from a carbonless copy paper manufacturing plant
- Fish collected near both discharge points
- Sediment

ACTUAL LOADING OF PCB SUBSTITUTES TO LAKE MICHIGAN

Information is not available at this time regarding loading of PCB substitutes to Lake Michigan.

IMPACTS ON LAKE MICHIGAN

The impact of PCB substitutes on the Lake Michigan ecosystem is unknown at this time.

SPECIAL MANAGEMENT ISSUES

Specific actions to address PCB SUBSTITUTES are presented in Chapter 6, Table 6-1: RM11 6

Appendix A summarizes current regulations and non-regulatory programs pertinent to DEHP management in the Lake Michigan Basin. Special management issues with PCB substitutes involve a lack of information about their fate and transport in the environment from their use as a PCB substitute.

Table 5-43. Lake Michigan LaMP Summary Table (Chapter 5)

CHAPTER 2	CHAPTER 3		CHAPTER 4			CHAPTER 5		CHAPTER 6	
Lake Michigan LaMP: Vision, Goals and Ecosystem Objectives	**Indicators and Monitoring of the Health of the Lake Michigan Ecosystem**		**Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments and Human Health**			**Lake Michigan Stressor Sources and Loads**		**Strategic Action Agenda: Next Steps**	
End Point Goal	**Indicating**	**Monitoring**	**Impairment**	**Spatial**	**Temporal**	**Stressors**	**Source**	**Means to an End Goal**	**Short-term Activities**
1. We can all eat any fish.	• Chemical contamination in fish • Site assessments • Eagle reproduction	• Fish advisories • Congressional reports on: -Great Waters - Mercury -Dioxin	• Restrictions on fish and wildlife (F/W) consumption • Tainting of F/W flavor	Lakewide Local	Ongoing Episodic	• Chemical - PCBs - Mercury - Dioxin - DDT - Chlordane	• Air deposition • Legacy sites • Sediments • Incinerators • Burn barrels		
2. We can all drink the water.	• Raw water quality data • Source water assessments	• Water utility notifications • Source water protection	• Restrictions on drinking water consumption or taste and odor problems	Local	Episodic	• Biological - Pathogens - ANS	• Land use • Point source • Nonpoint source		
3. We can all swim in the water.	• *E. Coli* levels in recreational water	• Beach closing advisories • State 305(b) WQ reports	• Beach closings	Local	Episodic	• Biological - Pathogens • Physical • Chemical	• Land use • Point source • Storm water • CSO/SSO		
4. All habitats are healthy, naturally diverse and sufficient to sustain viable biological communities.	• Fish assessments • Bird counts • Wetlands inventories and assessments • Stream flows • Eco-rich area assessments	• Endangered species list • Wetlands mitigation and protection • Zoning • Fish stocking • Fish refuges • FWS refuges • Ballast water exchange • Dune protection • Eco-rich cluster map	• Degradation of F/W populations • Fish tumors, or other deformities • Degradation of Benthos • Eutrophication or undesirable algae • Degradation of phytoplankton and zooplankton • Loss of F/W habitat • Bird or animal deformities or reproduction problems	Regional Local Local Local Lakewide Lakewide Local	Evolving Episodic Ongoing Episodic Ongoing Ongoing Episodic	• Physical - Sedimentation - Habitat destruction • Biological - ANS • Chemical - Nutrients - Toxics	• Land use/sprawl • Point source • Air deposition • Ballast water • Storm water • Agriculture runoff		
5. Public access to open space, shoreline and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem.	• Urban density • Coastal parks acreage • Conservation easements	• Open space funding and protection statutes • Coastal zone management	• Degradation of aesthetics	Local	Evolving	• Physical - Sprawl • Biological - ANS	• Land use		
6. Land use, recreation and economic activities are sustainable and support a healthy ecosystem.	• Contaminants in recreational fish • Sustainable forests	• Superfund cleanups, dredging • CRP percent of eligible farm lands • Brownfields to greenfields redevelopment	• Restrictions on dredging • Added cost to agriculture or industry	Local Local	Evolving Evolving	• Physical • Biological • Chemical	• Land use • Point source • Legacy sites		

Chapter 6:
Strategic Action Agenda: Next Steps

Status of the Lake Michigan Ecosystem

" An outstanding natural resource of global significance, under stress and in need of special attention"

Lake Michigan supports many beneficial uses: safe drinking water for 10 million; internationally significant habitat and natural features; food production and processing; fish for food, sport and culture; and valuable commercial and recreational activities. The quantity and quality of Great Lakes water has recently caused international debate over exporting possibilities.

Nonetheless, despite 20 years of overall reductions in conventional and toxic pollutant loads, data indicate pollutants still exert negative impacts on the chemical, physical and biological components of the Lake Michigan ecosystem. The irreversible damage of aquatic nuisance species demands immediate attention, as does monitoring for the potential effects of global climate change. The current rate of sprawl and resulting habitat destruction is causing irreversible habitat loss in the basin.

The remaining challenges are significantly related to legacy contamination that results in fish consumption advisories, impairment to aquatic organisms and wildlife. Nonpoint source pollutants result in episodic beach closures, drinking water impacts and pesticides have been detected in the open water. The long-range transport of both airborne pollutants and non-native species into the ecosystem pose serious environmental and national/international management issues. The lake, as a natural system, is also a moving target and presents the challenge to have continual monitoring and assessment based on indicators of environmental status collectively agreed upon.

Lake Michigan has 10 Areas of Concern that have documented from 5 to 14 beneficial use impairments on a local level. A number of major and hot spot removals and other measures are addressing and preventing pollution but much remains to be accomplished in these areas and sufficient commitments are not in place.

Recommended Short Term Strategic Agendas

Human Health Agenda: Determine what level of statutory protection is adequate for the drinking water source for 10 million people and convene coastal communities to determine what are the necessary actions to open all the lake's beaches, focusing attention on sewer systems and runoff.

Restoration and Protection Agenda: Identify the eco-rich areas in the basin, the connecting corridors and flyways, the fish spawning areas, the status of protection, and provide the data on line.

Sustainable Use Agenda: Provide assistance to LaMP partners to enable them to more effectively manage, maintain and beneficially use the Lake Michigan ecosystem. Ensure lakewide ecosystem perspectives are integrated into land use planning activities.

Remediation and Pollution Prevention Agenda: Address all legacy sites so that plans are under way in the next two years at all 10 AOCs and other Superfund sites. Begin at least one pollution prevention project for a major source of mercury, aquatic nuisance species (ANS), non-point source pollution and pesticides in the basin by 2002.

Information Sharing, Collaboration, and Stewardship Agenda: Work in partnership to provide information and tools to the coastal communities and promote watershed planning, including agriculture pollution prevention. Coordinate with the Great Lakes Fishery Commission on ANS and other issues.

Research and Monitoring Agenda: Complete the LMMB model runs and EEGLE project, and promote dialogue and research on long range transport issues. Implement the Lake Michigan Monitoring Coordinating Council and collaboratively develop a monitoring plan for the basin that supports data needs for long range air transport research and TMDL efforts.

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Chapter 6:
Strategic Action Agenda: Next Steps

6.1 About This Chapter

The purpose of this chapter is to present a Strategic Action Agenda by moving the issues and action items forward from previous chapters. Attempt has been made to match the sources and stressors with actions from programs that are addressing the problem, new actions, and determine gaps in data that identify research and monitoring needs. Reduction targets have been pulled from other initiatives to use as a reference point in discussions. In some cases, they represent national commitments, while others are challenges. Section 6.2 of this chapter highlights the next steps leading to LaMP 2002.

Lake Michigan LaMP Goals and Objectives

Great Lakes Water Quality Agreement of 1978
The purpose of the Parties is to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem.

Lake Michigan Vision Statement-Desired Outcome
A sustainable Lake Michigan ecosystem that ensures environmental integrity that supports and is supported by economically viable, healthy, human communities

Lake Michigan LaMP Goal
To restore and protect the integrity of the Lake Michigan ecosystem through collaborative, place-based partnerships.

Agencies Actions

In the 30 years since the first Earth Day in 1970, much of the tall stacks and end-of-the-pipe pollution has been effectively controlled by what are now core regulatory programs at the federal, state, and tribal level. We are left with a set of difficult, persistent problems that remain due to their multifaceted nature. In response, agencies are developing new tools to address the complexity (for example, Total Maximum Daily Loads [TMDL], mass balance models, and layering information on maps using Geographic Information Systems [GIS]). All of these tools pull together multiple sources of data and provide insights to solving the problem. The effective use of these tools to remediate and preserve an ecosystem requires the convening of multiple agencies and stakeholders in the LaMP process described in Chapter 1. This requirement recognizes the importance of partnerships and education and outreach actions that are included in the action agenda.

The most sobering findings are the documentation of emerging problems. The global scale of both the long-range transport of air pollution and the irreversible damage of aquatic nuisance species (ANS) presents management challenges on an equally large scale. The very real potential of global climate change and endocrine disrupting pollution effects, adding to an already full environmental agenda, requires that issues be prioritized with the lead role assumed at the most effective level. Determining a value-added role for a lake basin LaMP for these issues involves a very pressing need for public discussion in the next 2 years. The discussions leading toward the development of a Great Lakes Five-Year Strategy may be the most appropriate scale and level to address these types of issues.

As part of adaptive management, assessments of existing programs have recently taken place, with the results to be announced or to become effective in the next 2 years. For example, the Clean Water Action Plan was issued in 1998 to address nonpoint source programs that were not achieving the predicted results, and a number of new and refocused methods and procedures are revitalizing ways to address this important source of pollution to Lake Michigan. This suite of actions, involving both regulations and guidance, will work best with appropriate and effective watershed land use plans as a base.

EPA has delivered assessment reports to U.S. Congress on mercury, dioxin, and the impact of long-range transport of air pollution on Great Waters. By 2001, EPA will determine whether to regulate mercury emissions from electric utilities. In addition, a number of new standards and guidelines for municipal waste combustion will reduce mercury and dioxins from these sources by 78 and 98 percent, respectively, when fully implemented in 2000. Similar standards for medical waste incinerators will be implemented by 2002. EPA is also reviewing the effectiveness of the current ballast exchange program to respond to a petition that requested EPA to require permits for discharge of ballast water. A decision on this is expected in 2000.

The large amount of programs and projects in the basin are just barely covered in this document. We have attempted to present examples of some of the efforts that the LaMP process initiated or works with to address an impairment. We present the stakeholders directory and internet addresses to provide linkages to some of the other programs.

LaMP Action Discussion

The next few years will produce not only new tools but also the pressing need to use the available tools, scientific understanding, and predictive models based on mass balance data to stimulate dialogue and decisions about the targets for further load reductions, preservation, and pollution prevention activities. The LaMP actions outlined in this chapter that are underway and proposed are based on the 1998 goals and objectives work, but they can be refined or reprioritized based on new data and modeling results, if necessary.

As part of the 1998 Green Mountain Institute for Environmental Democracy exercise to set goals and objectives using comparative risk tools, the Lake Michigan Technical Coordinating Committee (TCC) and Forum utilized the following framework for determining goals, objectives, and priority actions. While there was not a completed LaMP at the time, the general knowledge and findings were generally known and discussed with the participants.

The following criteria were used in establishing LaMP priorities:

1. Restore, protect, and enhance human and ecological health
   - Does the activity result in a decreased threat to human health?
   - Does the activity result in protecting the ecosystems capacity to (1) promote biodiversity, (2) support species of interest, (3) perform ecological functions, (4) remain resilient to other threats (natural and anthropogenic)?

2. Foster partnerships, leverage funds, and raise awareness of the LaMP effort
   - Does the activity result in linkages among organizations that can work together to protect, enhance, and restore Lake Michigan's environmental status?
   - Are there links to other organizations or activities that are able to increase their investment as the result of this activity?
   - Will this activity raise the awareness of issues surrounding Lake Michigan's ecosystem?

3. Build capacity, utilize existing structures, promote commitment, and timeliness

   - Will this activity provide the infrastructure, staff capability, and knowledge base for additional activities that improve the quality of Lake Michigan's ecosystem?
   - Does this activity rely on existing infrastructure, staff capability, and knowledge base thereby elevating the importance of those previous investments and activities?
   - By carrying out this activity, will managers and leaders better recognize the overall benefits of protecting the Lake Michigan ecosystem, or at least some aspect of its protection?
   - Does carrying out this activity NOW provide benefits that will be lost if the activity is carried out only at a later date?

4. Reduce uncertainty and link science with management

   - Will the completion of this task provide some information that will allow further decisions regarding the lake's ecosystem to be made with more certainty regarding the impacts?
   - Will this activity make it easier to introduce information into decision-making that affects the lake?

5. Technically, politically, and fiscally feasible

   - Do we have the technical knowledge and tools to carry out the activity?
   - Is there political will and authority among those providing the resources and making the decisions to make this activity take place?
   - Are the resources available to carry out this activity?

6. Fits within the scope and scale of the LaMP

   - Is the responsibility for this activity affected by the responsibilities of the agencies and stakeholders involved in the LaMP process?

In 1999, a series of meetings were held. The Lake Michigan Mass Balance Project and its early results were presented to state agencies in each state capital, to the Lake Michigan Forum, and at the State of Lake Michigan Conference, Muskegon, Michigan. The Forum conducted three public workshops on Sediments, Biological Pollution, and Sustainable Urban and Rural Landscapes. The results of the workshops and recommendations were forwarded to the TCC and provide additional input to the priority setting.

Lake Michigan LaMP: General Recommendations 2000-2010 and Specific Action Examples

The Lake Michigan ecosystem is a moving target. We find it is an outstanding natural resource under stress and in need of special attention. Actions will not provide immediate results, so working toward an improved lake for 2010 requires a concerted and aggressive time frame for efforts in the first decade of the 21st century. The following 15 general recommendations evolved from the Green Mountain Institute for Environmental Democracy exercise and continued discussions at meetings, workshops, and conferences. The long-term goal of a pollution- and problem-free lake must happen project by project. The recommendations describe *what* needs to be done, and we hope that all parties will see the potential for their roles and programs. There are many *hows*, and we hope we have provided some clear direction for partners and others.

Recommendations

1. **Ballast Water Control -** The Great Lakes are not only impacted by aquatic nuisance species causing irreversible damage but also serve as a pathway to other connected ecosystems. Standards or guidelines should be developed for ballast water treatment, working toward zero discharge.

2. **Clean Legacy Sites -** The Lake Michigan Mass Balance Project has confirmed that contaminated sediment sites in the lake remain an ongoing source of contamination in the food web, causing fish advisories and delaying dredging of navigable waterways, both of which affect local economies. In order to move swiftly to clean up contaminated legacy sites, both on land and at sediment sites, we will convene federal and state Superfund, RCRA Corrective Action, Drinking Water, and Surface Water programs for planning discussions focused on the Lake Michigan ecosystem. The goal is to complete almost all plans by 2005 and actions by 2010. A few of the major sediment sites may require additional time.

3. **Protect Source Water -** As the drinking water source for 10 million people, with globally significant features, it is important to determine if the level of protection is sufficient using the state assessments that delineate source areas and assess significant potential sources of contamination. If the assessment indicates that the intake is not affected by potential shoreline contaminants, then RAP, LaMP, and mass balance materials would be used. Consideration should also be given to the question of exporting the resource.

4. **Protect Habitat -** It is important to determine a priority for preservation sites within the recently mapped ecologically rich clusters, including connecting corridors between clusters as well as the sites identified in the North American Waterfowl Management Plan. Wetland areas, particularly those with connection to the lake that are important to many species, and restoration of coastal brownfields to greenfields, should be highlighted. Natural areas not only provide habitat but also serve to filter sediments and nutrient runoff as well as to store flood waters and recharge groundwater. Provide this information on line.

5. **Fish Collaboration -** Develop joint projects with the Great Lakes Fishery Commission that implement both the LaMP and the Joint Strategic Plan for Management of Great Lakes Fisheries. Collaborate on the development of fish spawning maps to aid protection and provide adjacent land use planners with tools and data.

6. **Match Decision Makers with Issues -** Convene and engage the appropriate level of government and other nontraditional groupings to accomplish LaMP goals and match the needed control with the most likely control point by promoting the following:
   - National dialogue for control of aquatic nuisance species and air deposition of toxics
   - Academic and agency dialogue to promote sharing of data, define research needs, and develop lake-related courses
   - Local dialogue to provide tools and a lakewide perspective to land us planners

7. **Control Combined Sewer Overflows (CSO) Sanitary Sewer Overflow (SSO) -** The mixed discharge of storm water and domestic waste causes beach closings and is a pathway for pathogens to enter the lake. Provide tools, training, and data to local governments to promote full compliance with CSOs, SSOs, and storm water regulations, and system maintenance with awareness of land use planning on a watershed basis.

8. **Develop Agriculture P2 Strategy -** Include and coordinate among states, NRCS, and the Lake Michigan Forum's Agriculture Task Force to promote nonpoint source pollution prevention using stream planted buffer strips and pollution prevention for pesticides, confined animal feed operations, and nutrient controls. Food web disruptions in Lake Michigan relate to sedimentation and continuing nutrient pollution.

9. **Implement Areas of Concern (AOC) Remedial Action Plans (RAP) -** AOC RAPs are in various stages of completion. Many RAP and watershed groups, as well as local communities, have included the watershed in their planning and have developed a list of priorities found in Addendum 6-B. These groups need support that include tools, technical assistance and training, and some level of funding to provide the ability to leverage scarce resources.

10. **Fill Data Gaps -** Promote research with the following goals:
    - Define in-basin and out-of-basin air pollution
    - Develop technology to control aquatic nuisance species in ballast water
    - Understand pesticides, pathways, and longevity in open water
    - Reuse contaminated sediments
    - Understand endocrine disrupters, their effects, sources, and possible controls
    - Identify fish spawning site locations
    - Review and refine Lake Michigan pollutants list

11. **Clean Sweep Strategy -** Years after certain pesticides were canceled and restricted, pesticides such as DDT/DDE, dieldrin, and chlordane; they are still recovered in clean sweep operations, indicating the effectiveness of the tool. However, there is no special source of funding for these activities; therefore there is a need to develop a strategy to ensure long-term consistent funding or ownership of annual pesticide, household hazardous waste, and small business PCB/mercury Clean Sweep programs for each state.

12. **Measure and Report -** Continue development of the Lake Michigan Monitoring Coordinating Council and jointly develop a Monitoring Plan for Lake Michigan that includes expanding the USGS National Water-Quality Assessment Program (NAQWA) monitoring to Michigan's eastern shore and drainage. Develop a strategy for duplicating the coordinated monitoring (simultaneous air, water, land, open water and tributary mouths) of the Lake Michigan Mass Balance Project (LMMB 1994) in 2004 to have data for a 10-year analysis. Establish a beach community monitoring network and a volunteer basin monitoring network.

13. **On-Line Information, Public Involvement Activities -** Promote sharing of public information and public involvement by providing the following: (1) on-line data site that includes public health information, (2) an on-line habitat atlas of the basin showing ecologically rich areas, and (3) a running summary of comments and responses. Continue the Forum's public meetings, workshops and boat tour in partnership with organizations such as Grand Valley State University, which also sponsors the State of Lake Michigan Conference.

14. **TMDL Strategy -** Total Maximum Daily Loads (TMDL) must be developed when waters do not meet state-adopted water quality standards, even after the implementation of technology-based controls. TMDLs are calculated to return waters to their designated uses. States develop TMDLs for their tributaries, and a strategy for cooperative TMDL work for Lake Michigan that includes a public involvement process is needed.

15. **Stewardship Actions -** The majority of the land that drains to the lake is privately owned and managed. America's cities and towns account for 80 percent of energy use. Of that 80 percent, land use planning and urban design affect about 70 percent, or 56 percent of the nations total energy use. Energy production and transportation are major sources of air pollution. The message from these statistics is that every basin resident is a "Lake Michigan Manager." We need to strengthen partnerships with other education and outreach efforts to promote the activities necessary to accomplish the following: (1) promote recycling efforts, energy and water conservation, and trash barrel burning awareness; (2) place special emphasis on preventing the spread of aquatic nuisance species by boat owners for the next 2 years; (3) communicate the importance of private efforts in habitat preservation on both public and privately owned land; and (4) develop an Areas of Stewardship program for local communities and watersheds.

Action Examples

Figure 6-1 presents the goals, objectives, and actions by subgoal and places them in strategic groupings called agendas to aid "implementers" who will approach the LaMP with a point of view (such as a researcher, regulator, or volunteer steward). Addendum 6-A to this chapter contains a comprehensive list of all the objectives and short, medium, and long-term actions needed to achieve these objectives. Addendum 6-B contains a list of the Lake Michigan AOC RAP priorities. Table 6-1 includes several examples of short-term actions, both planned and proposed, which were extracted from the information presented in the two addendums.

Much of the work reflected in the Strategic Agenda can be accomplished by focusing the efforts of existing programs. However, success will require coordination among those programs as well as special basin-wide initiatives because of the basin's size and multiple political jurisdictions. While government agencies are in a position to provide leadership for implementing the LaMP, success will depend on leveraging private sector and nongovernmental organization involvement and resources. A major component of success will require engaging local government, whose authority and local decision-making collectively have a significant impact on the natural resources and sustainability of communities throughout the Lake Michigan basin. All of these steps require institutionalized coordination and strong communication among government agencies and stakeholders. Therefore, the Strategic Action Agenda presents a Lake Michigan LaMP implementation process and roles for not only participating governmental agencies, but also the Lake Michigan Forum, other basin stakeholders, and the general public.

Figure 6-1 Strategic Groupings

<table>
<tr><th colspan="2">End Point Subgoals</th><th></th><th>Strategic Action Agenda</th></tr>
<tr><td>Subgoal 1</td><td>We can all eat any fish.</td><td></td><td rowspan="3">Human Health
Actions that prevent human exposure to pollutants in the ecosystem and prevent or minimize sources</td></tr>
<tr><td>Subgoal 2</td><td>We can all drink the water.</td><td></td></tr>
<tr><td>Subgoal 3</td><td>We can all swim in the water.</td><td></td></tr>
<tr><td>Subgoal 4</td><td>All habitats are healthy, naturally diverse, and sufficient to sustain viable biological communities.</td><td></td><td>Restoration and Protection
Actions that restore, enhance, and sustain the health, biodiversity, and productivity of the ecosystem</td></tr>
<tr><td>Subgoal 5</td><td>Public access to open space, shoreline, and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem.</td><td></td><td rowspan="2">Sustainable Use
Actions that concurrently sustain the health of the environment, the economy, and the communities of the ecosystem</td></tr>
<tr><td>Subgoal 6</td><td>Land use, recreation, and economic activities are sustainable and support a healthy ecosystem.</td><td></td></tr>
</table>

Means (to End Points) Subgoals		**Strategic Action Agenda**
Subgoal 7	Sediments, air, land, and water are not sources or pathways of contamination that affect the integrity of the ecosystem.	**Remediation and Pollution Prevention** Actions that achieve substantial pollution reduction by remediating sites, controlling pathways, preventing or minimizing sources
Subgoal 8	Exotic species are controlled and managed.	
Subgoal 9	Ecosystem stewardship activities are common and undertaken by public and private organizations in communities around the basin.	**Information Sharing, Collaboration, and Stewardship** Actions that provide data access and exchange, facilitate involvement, and build capacity
Subgoal 10	Collaborative ecosystem management is the basis for decision-making in the Lake Michigan basin.	
Subgoal 11	We have enough information/data/understanding/ indicators to inform the decision-making process.	**Research and Monitoring** Actions that monitor the ecosystem, reduce uncertainty, and inform our decisions

The following matrix of actions (see Table 6-1) are examples of the work both planned and underway to accomplish the goals and objectives. These actions are grouped by strategic agenda. Some actions are stand-alone actions but many are linear, with a first step defined in the short term in order to accomplish the long-term objective. For the purpose of this plan, short term refers to the next 2 years. Stewardship actions could also make a significant impact on the lake if begun now, utilizing partners and the data, tools, and training provided by the LaMP process. The listing is not complete and suggestions are welcome for funding items that lack funding and for new projects that should be highlighted.

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

HUMAN HEALTH AGENDA - Actions that prevent human exposure to pollutants in the ecosystem and prevent or minimize sources	
Impairment: Drinking Water Restrictions ***Stressors: Pathogens, Chemicals***	**Funding Status**
HH1. **Assess Sources of Drinking Water** EPA and all the Great Lakes states, tribes, and local water utilities have adopted a Great Lakes Source Water Protection Protocol for use in source water assessments to be conducted by 2003. The standardized protocol for conducting assessments of public drinking water supplies will delineate source areas and assess significant potential sources of contamination in order to protect water supplies and inform beach managers.	Lead: LK MI States, Tribes Assist: EPA, local communities **Forum Priority**
Impairment: Beach Closings ***Stressor: E. Coli in Surface Water***	**Funding Status**
HH2. **Convene Great Lakes Beach Conference** Convene a National Great Lakes Beach Conference in Chicago in 2001 to provide the latest in *E. coli* guidance, research and other beach issues such as lake levels. Research is underway to develop quicker methods of testing for *E. coli* and using DNA to help pinpoint the contamination source responsible for beach closings. This will build upon East and West Coast Conferences but add the fresh water focus.	Lead: EPA Headquarters, Region 5 Assist: City of Chicago, National Park Service, **RAP Priority**
HH3. **Convene Lake Michigan Beach Communities** Convene the Lake Michigan Beach Communities to explore establishing a Lake Michigan Beach Task Force to facilitate communication, technology transfer, and data sharing at the local level of government with beach management responsibilities. The Task Force could benefit from the work of the Northwest Indiana *E. coli* Task Force and the Lake Michigan Monitoring Coordinating Council.	Lead :EPA Assist: LK MI States, NW IN E-Coli Task Force, **Funding needed for local government participation and facilitation**
HH4. **Implement EPA Region 5 Capacity, Management, Operation and Maintenance Pilot (CMOM)** EPA will work with one state and beach community to run a pilot to review the wastewater collection and treatment systems to pinpoint system problems and solutions. Possible follow up to pilot involves work with states to provide local governments with planning tools as a key to addressing control strategies for CSOs, SSOs, storm water permits, and other issues.	Lead: EPA **Forum Priority**
HH5. **Provide On-Line Human Health Information** By the end of 2000, utilize the Great Lakes Information Network (GLIN) to provide a human health information site with links to each state department of health site and other federal agencies sites.	Lead: EPA grant to Great Lakes Commission
HH6. **Promote Epidemiological Research on Water-Borne Disease in the Lake Michigan Basin** Promote epidemiological research on exposure and health effects from water borne diseases for both recreational and drinking waters.	Lead: NIEHS, ATSDR, EPA Funded nationally; no funding targeted for Great Lakes Basin.

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

HH7. **Continue Development of Rapid Sampling Technologies and Techniques for Microbial and Viral Contamination** Promote the dissemination and use of the instrument and sampling methods to local governments.	Lead: EPA Beach Program
Impairment: Restrictions on Fish and Wildlife Consumption ***Stressor: Mercury***	**Funding Status**
HH8. **Remove Mercury from Dairy Farms (Michigan and Wisconsin)** Michigan Department of Agriculture and Wisconsin Department of Natural Resources, at reduced cost to farmers, will replace mercury manometer gauges used on dairy farms with nonmercury gauges, reducing the potential for spilling mercury into the environment. Mercury gauges will also be collected from inactive dairy farms.	Lead: MI and WI Assist: EPA GLNPO Grant
HH9. **Increase Awareness, Use, and Effectiveness of Fish Advisories** Increase awareness, particularly among high consumption populations in the Lake Michigan basin (minority, subsistence fishers, and immigrants) and sensitive population (women of childbearing age, children, and the elderly)	Lead: EPA, ATSDR Assist: IL, IN, Sea Grant
HH10. **Research Health Benefits of Fish Consumption** Research the health benefits of fish consumption to better quantify those benefits for use in risk assessment for developing fish consumption advice.	Lead: EPA/OST Unfunded Future Project Assist: IL, IN, Sea Grant
Other actions to address this impairment are included under the Restoration and Protection Agenda and the Means to an End Subgoal Agendas	

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

RESTORATION AND PROTECTION AGENDA - Actions that restore, enhance, and sustain the health, biodiversity, and productivity of the ecosystem	
Impairment: Loss of Fish and Wildlife Habitat ***Stressors: Physical Destruction, Nonpoint Source, and Invasive Species***	**Funding Status**
RP1. **Protect Tributaries from Agricultural Loading (Wisconsin, Indiana, and Michigan)** Wisconsin Department of Natural Resources and Michigan Department of Agriculture are undertaking new efforts to protect tributaries from the nonpoint discharge of ammonia, pathogens, and other unregulated pollutants from confined animal feeding operations with greater than 1,000 or more animal units. They will be using compliance assistance activities, and Wisconsin will issue WPDES permits in state priority areas.	Lead: WI, IN and MI Assist:
RP2. **Implement (or develop) Great Lakes Aquatic Nuisance Species Action Plan** The Great Lakes Panel on Aquatic Nuisance Species Spring 2000 Great Lakes Action Plan responds to the need for a formal mechanism to facilitate interstate decision-making and joint actions to pursue nuisance species prevention and control and has been presented to the Council of Great Lakes Governors. A national plan is also called for in the February 1999 Executive Order on Invasive Species and is due in 2000.	Lead: ANS Panel Assist: GLC GLNPO grant, Great Lakes Fishery Commission, IL and IN Sea Grant **Forum Priority**
RP3. **Implement Great Lakes Aquatic Habitat Network and Fund** The Tip of the Mitt Watershed Council will help increase citizen involvement in aquatic habitat protection at the local level by providing direct support to local initiatives through the Great Lakes Aquatic Habitat Network and Fund mini-grant programs to local groups.	Lead:TIP of the MITT Assist: GLNPO grant **Need funding to expand** **Forum Priority**
RP4. **Ballast Water Management and Pollution Prevention** Develop clear and concise biological standards or guidelines for treatment of ballast water tanks working toward zero discharge. Focus on best practical technology and devise a short-term plan for dealing with the No-Ballast-On-Board (NOBOB) issue. Require newly built ships to incorporate technology as pollution prevention for the ballast water problem.	
RP5. **Identify Clusters of Eco-rich Regions, Species by County** EPA, federal, state and tribal partners have produced an analysis of clusters of remaining ecologically rich regions remaining in the basin and will provide it on-line by 2002. The Region's and the USFWS' analysis of species by county provide the base for a discussion of protection targets and is another useful tool for land use planners providing lakewide perspective on eco-rich regions. This data will be incorporated into the on-line Lake Michigan atlas and will serve as the base for prioritizing protection activities in the basin and clarifying connecting coordinators and other elements that should be considered for protection	Lead: EPA, USFWS, States, Tribes Assist: Conservation groups **RAP and Forum Priority** **Follow-up unfunded**

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

RP6. **Develop Habitat and Biodiversity Recovery Plans** The fate of habitat and biodiversity is controlled by local land use planners. A biodiversity recovery plan tailored to different basin areas would provide tools and information on protection and restoration methods. The Chicago Wilderness/Southern Lake Michigan (including Indiana and Wisconsin areas) biodiversity pilot has developed an implementation manual for the local planners in the Illinois area of the basin. This pilot provides a template for developing similar implementation manuals for the whole lake, tailored by state or area, and could be provided on line. The basic data exists but a partnership and committee will be needed to reformat or add data.	Lead: Northeastern Illinois Planning Commission Assist: **Need partners, funding** **Rap Priority**
RP7. **Convene LaMP/RAP/Superfund Forum on Habitat Restoration** LaMP and RAP habitat priorities will be presented to EPA Remedial Project Managers in 2000 at a forum to exchange site information and discuss the potential to include habitat restoration as part of site remediation.	Lead: EPA Assist:
RP8. **Inventory Northwest Indiana Wetlands** Northwest Indiana Advanced Identification of Wetlands (ADID) project will be complete by the end of 2000. This wetlands inventory in the Lake Michigan basin portions of Lake, Porter, and La Porte Counties will provide an assessment of their biological and hydrological functions. It will include floristic diversity, wildlife habitat, stormwater retention, and water quality or mitigation functions. The GIS-produced maps will use the National Wetlands Inventory with a variety of overlays that includes nature preserves, flood control, and recreation areas and the Area of Concern. This effort is intended to assist community planners and developers with the advance notice of high quality wetland locations in this fast developing area.	Lead: EPA Assist: IDEM, IDNR, and many local partners
RP9. **Develop and Implement Purple Loosestrife Control Strategies for Urban Wetlands** The City of Chicago, Department of Environment is devising a strategy of manual, biological, and chemical controls specifically suited to the urbanized wetlands of the Lake Calumet, southern Lake Michigan area. Implementation of herbicide treatment and leaf-eating beetles will focus on the 140-acre Indian Ridge Marsh.	Lead: City of Chicago Assist: GLNPO grant **Forum Priority**
RP10. **Continue "Go Native! With Native Plants" Program** Michigan Association of Conservation Districts will continue their program to develop prototypes of successful native plants working with private growers and other local, state, and federal agencies throughout the Great Lakes Basin with the goal of stimulating commercially available materials and education programs.	Lead: MACD Assist: EPA GLNPO, Partners **Forum Priority**
RP11. **Provide Funds for Coastal Restoration** USFWS coastal program is providing small grants to restore stream-side habitat important to native recreational fisheries, restore shoreline wetlands to improve fish spawning success, and to acquire habitat for Piping Plovers and Bald Eagles. These small grants will leverage partners funds.	Lead: USFWS Assist: Partnerships

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

SUSTAINABLE USE AGENDA - Actions that concurrently sustain the health of the environment, the economy, and the communities of the ecosystem	
Impairment: Degradation of Aesthetics ***Stressor: Physical - Land Use***	**Funding Status**
SU1. **Provide Brownfields to Greenfields Technical Assistance** Superfund will assist LaMP/RAP partners to provide education and technical assistance on Brownfields redevelopment and possibilities of restoration and increased acreage of naturalized spaces in the Lake Michigan basin through outreach to land use planners and holding a conference in 2001.	Lead: EPA Assist :States **RAP and Forum Priority**
SU2. **Develop Land Use GIS-Based Decision Support System Software** By 2001 EPA will make available on line two software programs as decision support systems to estimate the hydrological and water-quality impacts of alternative land use development scenarios; the second program calculates environmental impacts for transportation-derived air quality parameters.	Lead: Purdue Assist: EPA
SU3. **Provide Tools and Lakewide Perspective to Land Use Planners** Develop a "Green Area" Contrast Map for the basin to contrast the percentage change in development of the basin between 1970 and 1990 and make it available on line and to basin land use planners.	Lead: EPA/ORD Assist Region 5 **RAP Priority**
SU4. **Map Sensitive Area Maps for the Lake Michigan Basin** By 2002 completed GIS maps of the basin will be available on line. The maps include detailed data on location of sensitive species, tribal lands, natural areas, managed lands, economic resources, and potential spill sources. Superfund commits to ongoing refinement of these plans to enhance local capacity in identification of important habitat and species in the basin and plans to prevent and respond to emergencies.	Lead: EPA Assist: States, NOAA
SU5. **Develop and Implement Sand Dune Education and Protection Project** The Lake Michigan Federation will develop and disseminate an educational program on the ecological and economic value of Lake Michigan's sand dunes working toward consensus on protection and preservation efforts.	Lead: Lake MI Federation Assist :EPA GLNPO
SU6. **Reduce Energy Use and Production of Toxics** The Delta Institute will focus on achieving toxics reductions through commitments from private and public sector owned and operated energy production units. They will look at promoting energy efficiency and pollution prevention and barriers that exist to investments in these practices. Methods to quantify the reduction of toxics from energy efficiency and conservation will be explored.	Lead: Delta Institute Assist: EPA GLNPO
SU7. **Expand Lake-Based Recreation Opportunities** Develop a Lake Michigan "Water Trail Plan" for use by canoes and other water craft for all four Lake Michigan states; coordinate at the boundaries and join with the 1999 Northeastern Illinois Trail Plan and Partnership.	Lead: Northeastern IL Plan Commission Assist: **Funding Needed**

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

REMEDIATION AND POLLUTION PREVENTION AGENDA - Actions that achieve substantial pollution reduction by remediating sites, controlling pathways, preventing or minimizing sources	
Impairments: Restrictions on Fish and Wildlife Consumption, Tumors or Other Deformities, Restrictions on Dredging Activities ***Stressors: PCBs, Mercury, Dioxin, and Canceled Pesticides***	**Funding Status**
RPP1. **Develop EPA/ State Superfund Strategy: All Lake Michigan Sites Addressed by 2005** EPA Superfund Program will convene a meeting with the Lake Michigan states to discuss development of a coordinated strategy for sites affecting the lake with a **September 2005** target for completing the decision documents and remedial plans and a target of **2010** for completing the construction phase of all but the most complex sediment cleanup portions, which may take longer.	Lead: EPA Assist: States **RAP and Forum Priority**
RPP2. **Expand and Formalize PCB Phasedown Program** Formalize the PCB Phasedown Program pilot project with the major utilities in the Great Lakes basin, which is designed to encourage phaseout of PCB-containing equipment. Expand the program to federal departments and agencies in the basin. Follow up by sending letters to determine actions taken and compile a status report.	Lead: EPA Assist: **Follow-up unfunded**
RPP3. **Remediate White Lake, Spring 2000 (Michigan)** The remediation of White Lake contaminated sediments by the State of Michigan is planned for Spring 2000. An estimated 36,000 cubic yards, up to eight feet, of contaminated sediment and tannery wastes will be dredged from Tannery Bay on White Lake, Muskegon County, Michigan.	Lead: MI Assist: EPA GLNPO **RAP Priority**
RPP4. **Conduct White Lake Outreach Project** The Lake Michigan Federation (LMF) and the White Lake Public Advisory Council (PAC) plan to conduct public outreach on the cleanup effort, explaining its benefits and involving community members.	Lead: LMF,PAC Assist: MI, EPA GLNPO **RAP Priority**
RPP5. **Assess Contaminated Sediments in Muskegon Lake** This project will assess the nature, extent, and ecological significance of sediment contamination in Muskegon Lake, Muskegon County, Michigan, by Grand Valley State University. The fate and transport of sediments in drowned river mouths will also be investigated.	Lead: Grand Valley State University Assist: MI, EPA GLNPO **RAP and Forum Priority**
RPP6. **Perform Additional Site Assessment for Michigan and Wisconsin** EPA Superfund working with state and local partners will assess one geographic area in Michigan and Wisconsin in areas with an industrial history and abandoned facilities or areas with sediment contamination concerns.	Lead: EPA Assist: MI and WI **RAP and Forum Priority**

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

RPP7. **Develop Contaminated Sediment Assessment Guidance Manual** The Sustainable Fisheries Foundation will review relevant literature and develop an ecosystem-based framework for assessing and managing contaminated sediments consistent with the International Joint Commission guidance and publish the framework as an EPA-GLNPO document.	Lead: Sustainable Fisheries Foundation Assist: EPA GLNPO **RAP and Forum Priority**
RPP8. **Implement Michigan GIS Contaminated Assessment Project** Michigan Department of Environmental Quality will purchase software, hardware, and training to assess and define hot spots and volumes of sediment contamination at five sites. Project results will be used as a model for other efforts in the future.	Lead: MI Assist: EPA GLNPO
RPP9. **Develop Rapid PAH Screening Tool for Sediment Assessment** University of Wisconsin-Milwaukee will measure sediments with the rapid screening technique with a detection limit of 1 ppm in sediment samples and will demonstrate the system at two Areas of Concern.	Lead: UW/MIL. Assist: EPA GLNPO
RPP10. **Assess Fox River Contaminated Sediments** Wisconsin Department of Natural Resources has undertaken a remedial investigation and feasibility study of the Fox River. Concurrently, dredging demonstration projects have been undertaken to remove PCBs. Final decisions based on the assessment work are expected in 2000.	Lead: WI Assist: EPA and GLNPO
RPP11. **Decide Sheboygan River Dredging Needs** A responsible party study and plan on the PCB-contaminated sediments in the Sheboygan River is needed to complete additional dredging after follow-up assessments to hot spots removal indicated additional actions were necessary. A final decision is expected in 2000.	Lead: EPA Assist: WI
RPP12. **Expand the Forum's Mercury Pollution Prevention Project to the Basin** Expand the Lake Michigan Forum's primary metals mercury P2 Project to another Lake Michigan state building on the success of the Indiana steel mill project.	Lead: EPA Assist: Four states
RPP13. **Perform Southwest Lake Michigan Scrap Yards Compliance Assistance Inspections** EPA will conduct at least three compliance assistance/pollution prevention inspections focusing on mercury in automobile scrap and salvage yards in the southwest area of the Lake Michigan basin. A similar pilot project sponsored by the New York Department of Environmental Conservation will prevent an estimated 500 pounds of mercury from entering the basin from crushing and shredding operations at scrap and salvage yards.	Lead: Assist:
RPP14. **Share Mercury Pollution Prevention Methodology** By the end of 2000, EPA will publicize, including through posting on its web site, information on how to develop a mercury reduction plan at a manufacturing plant. This information will include mercury reduction plans developed at three steel mills under a voluntary agreement between the mills, EPA, the Indiana Department of Environment, and the Lake Michigan Forum.	Lead: EPA Assist: States
RPP15. **Distribute "Mercury Education and Reduction In Schools" Information** By the end of 2000, EPA will distribute through the Binational Toxics Strategy Mercury Workgroup a package of information related to mercury reduction at schools, including advice on how to eliminate mercury from school laboratories.	Lead: UW Assist: EPA GLNPO states, other partners

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

RPP16. **Continue "Clean Sweep" Projects** Clean sweeps for household hazardous waste and agriculture pesticide products at no fee to the user collect and remove from the environment LaMP and RAP targeted substances that are impacting the basin. The very successful results of these efforts have demonstrated an ongoing need to provide disposal options to households, farms, commercial sector, and local government participants. There is no one source of annual funding for these projects.	Lead: State and Local government Assist: EPA GLNPO **Funding needed**
RPP17. **Remedial Action (RA) Start at Petoskey Municipal Well Field** In November 1999, RA began for Operable Unit 1, which included soil excavation and operation of a Soil Vapor Extraction Unit to remove trichloroethene (TCE) in subsurface soils. RA for Operable Unit 2 - Groundwater is schedule for May 2000. Groundwater contaminants include TCE, vinyl chloride, and chromium; soil contaminants include lead, mercury, barium, and zinc.	Lead: EPA Assist:

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

INFORMATION SHARING, COLLABORATIONS, AND STEWARDSHIP AGENDA - **Actions that provide data access and exchange, facilitate involvement, and build capacity**	
Impairment: Adding Costs to Agriculture or Industry ***Stressor: Unsustainable Actions Based on Lack of Ecosystem Knowledge***	**Funding Status**
IS1. **Share Lake Michigan Mass Balance Model for Basin Wide Discussion** Present LMMB model runs data on LaMP pollutants to four Lake Michigan states, forum and other interested groups, and the Lake Michigan Management Committee to (1) better target reduction of sources of loadings and emissions, (2) prioritize enforcement and compliance efforts, and (3) prioritize P2 work and monitoring.	Lead: EPA Assist: States **RAP Priority**
IS2. **Conduct Education Conference and Outreach Boat Tour Summer 2000** Replicate the Lake Michigan/Grand Valley State boat tour of AOCs, Chicago, and other ports with ties to teachers and university level courses. Roosevelt University, in Chicago, Illinois, will sponsor a Pedagogical Conference that will tie in to the Great Lakes Commission development of network and web site for Great Lakes-related educational materials, including curriculum and other tools.	Lead: Grand Valley State University, Roosevelt University Assist: EPA, GLC **Only Partially funded**
IS3. **Develop the Lake Michigan On-line Atlas** Provide on-line maps and technical assistance to support local watershed-based ecosystem management efforts that are linked with lakewide activities. Include greenness/development contrast maps, ecologically rich areas, wetlands, threatened and endangered species by county, key connecting corridors, fish spawning areas, and other sensitive elements.	Lead: Great Lakes Commission, USFWS Assist: EPA **RAP Priority**
IS4. **Promote Local Planning on a Watershed Basis** Target local government planners in AOC areas and other key models of Lake Michigan Forum's Kalamazoo's Watershed Project to identify new tools and methods, utilize developed materials and conferences to influence land use/watershed decisions in at least four Lake Michigan communities to reduce nonpoint source loadings and habitat protection.	Lead: Assist: IL, IN sea Grant **RAP and Forum Priority** **Unfunded**
IS5. **Coordinate with the Great Lakes Fishery Commission on Aquatic Nuisance Species and Other Issues** Work with Great Lakes Fishery Commission's Lake Michigan Committee to coordinate issues affecting the aquatic resources of the lake, including aquatic nuisance species, identifying and protecting spawning areas, and adding to the on-line atlas.	Lead: EPA, States Assist: **Unfunded** **Forum Priority**
IS6. **Provide On-line Response to LaMP Comments** Maintain a Lake Michigan Home Page with key links to partners. Communicate LaMP comments and responses during 2000 to 2002. Develop new fact sheets on stressors and areas of stewardship.	Lead: EPA Assist: **RAP Priority**
IS7. **Develop and Maintain RAP Priority List of Projects** Develop and maintain a list of priority projects that have been developed by the RAP Committees to provide opportunities for partnerships.	Lead: EPA, States Assist: **RAP and Forum Priority**

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

IS8. **Implement LaMP Public Involvement Plan** Implement LaMP 2000 communications plan including the reproduction and distribution of the "Lake Michigan Explorer" software and LaMP 2000 fact sheets, mailings, press releases, Federal Register notice, and public meeting opportunities.	Lead: EPA Assist: States, Forum
IS9. **Conduct St. Joseph River (Indiana and Michigan) Bi-State Stewardship Dialogue** The Great Lakes Commission will work with the Friends of the St. Joseph River and Indiana and Michigan to develop and implement a St. Joseph River Bi-State Stewardship Dialogue for pesticides and nonpoint source issues.	Lead: GLC Assist: IN, MI Friends of the St. Joseph River
IS10. **Expand On-Line Sediment Data** Expand on-line sediment data, identify basin issues, and research needs related to beneficial reuse of contaminated sediments working with the Region 5 Sediment Team and the EPA/State Corps Dredge Team; support possible pilot project.	Lead: EPA Assist: States **RAP Priority**
IS11. **Develop a list of Priority Actions for Supplemental Work for Possible Use in Enforcement Cases** Develop a Lake Michigan Supplemental Environmental Project (SEP) inventory utilizing documented remediation and protection needs for RAP priorities and ecologically rich areas.	Lead: EPA Assist:
IS12. **Support Partnership Efforts** Continue support of state and tribal staffing and Public Advisory Councils' efforts that provides multiagency, multimedia dialogue in LaMP development and implementation for further collaborative efforts, refine the grant and planning process, and facilitate the Lake Michigan Forum.	Lead: Assist: **Funding Needed**
IS13. **Support Agriculture P2 Task Force** The Lake Michigan Forum will begin a basin-wide dialogue that addresses sustainable agriculture and pollution prevention for nutrients, pesticides, and sediments. Current efforts at the committee level will need funding to provide a basin-wide dialogue project.	Lead: Forum Assist: EPA, NRDC **Funding needed**

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

RESEARCH AND MONITORING AGENDA - Actions that monitor the ecosystem, reduce uncertainty, and inform our decisions	
Actions in Support of All Six End Point Subgoals to address information gaps noted in research in preparing the LaMP Document	**Funding** **Status**
RM1. **Continue Grand Calumet River, Indiana Harbor TMDL** The Indiana Department of Environmental Management, in cooperation with the US Army Corps of Engineers, have begun work on developing a TMDL for the East and West Branches of the Grand Calumet River and Indiana Harbor Ship Canal. The partnership has completed a round of "pay for your own samples" and hopes to have models by summer 2000 and begin developing an implementation plan by fall 2000.	Lead: IN, USCOE Assist: Partnership
RM2. **Complete Wisconsin TMDL Pilot** EPA will complete the pilot project to establish TMDL allocations for two waterbodies receiving mercury from atmospheric deposition to (1) evaluate the integration of air and water program technical tools and authorities and (2) examine emission reduction options. EPA will also work with states that have identified waterbodies whose impairment may be the result of atmospheric deposition to develop tools to assist in establishing TMDLs that account for air sources. For example, based on the outcome of the pilot project, EPA will explore the possibility of providing states with modeled regional baseline (1996) and projected (2010) deposition estimates.	Lead: EPA, WI Assist:
RM3. **Add Organic Contaminants Study to Episodic Events (EEGLE) Project** The University of Iowa in conjunction with the EEGLE research project, which is studying the large annual sediment and nutrient plume in Lake Michigan, will study toxics in the plume. The study should provide data necessary to determine the spatial and temporal variations of loadings across the lake.	Lead: UI Assist: EPA GLNPO
RM4. **Implement Lake Michigan Monitoring Coordinating Council** Implement the Lake Michigan Monitoring Coordinating Council and provide leadership, secretariat, and on-line guide to monitoring activities. Develop a coordinated Lake Michigan monitoring plan with corresponding indicators that can be utilized on both a local and lakewide basis. Explore a volunteer network that reports on similar indicators around the lake. Establish a beach community monitoring network and a volunteer basin monitoring network.	Lead: GLC Assist: EPA, USGS, MI **RAP Priority**
RM5. **Conduct Air Deposition Research** Identify the relative importance of air deposition in loadings to the lake and location of emissions sources in and out of the basin for regulatory and nonregulatory control strategies using mass balance models, RAPIDS, IADN, Great Waters report, TMDL work, and other data.	Lead :Delta Institute Assist: EPA **Forum Priority** **Funding Needed**
RM6. **Implement Integrated Atmospheric Deposition Network : Phase II** This binational project provides data to determine loadings of air toxics to the Great Lakes as mandated by Annex 15 of the Great Lakes Water Quality Agreement.	Lead: EPA GLNPO Assist:

Lake Michigan LaMP 2000-2002 Actions In Response to Identified Impairments

Table 6-1 Examples of Short-Term Actions

RM7. **Support Mercury Research in a Number of Priority Areas** EPA has committed approximately $6 million in FY2000 and FY2001 funds to support mercury research in a number of priority areas, including transport, transformation, and fate; and human health and wildlife effects of methyl mercury. These research activities are aimed at reducing the uncertainties currently limiting EPA's ability to assess and manage mercury and methyl-mercury risks. A particular target of research will be collection and analysis of information on mercury emissions and control options for coal-fired utilities to support Office of Air and Radiation (OAR)'s mandate for a regulatory determination on mercury controls for utilities by December 15, 2000.	Lead: EPA Assist:
RM8. **Complete Regional Air Toxics Emissions Inventory of Hazardous Air Pollutants** By 2001 EPA and the Great Lakes States will create a picture of the 1999 inventory of point, area, and mobile sources for all 188 hazardous air pollutants. The Great Lakes Commission provides the report and on-line site.	Lead: Great Lakes States Assist: Great Lakes Commission
RM9. **Initiate Marsh Monitoring Volunteer Program** The Great Lakes United will recruit and coordinate volunteers for monitoring the flora and fauna of the marshes of the Great Lakes.	Lead: GLU Assist: EPA GLNPO
RM10. **Discuss Follow-up Monitoring for the LMMB (LMMCC)** Hold a planning meeting to plan and obtain commitments for years 2004 and 2005; 2005 sampling to complement 1994 and 1995 LMMB sampling, with consideration given to fish food web, mercury, and indicators of long-range transport.	Lead: EPA, States Assist: LMMCC
RM11. **Review Lake Michigan LaMP Pollutant List For 2002** Review and report in LaMP 2002 research data and, if needed, respond with possible changes in LaMP pollutant list and recommendations for LaMP partners for action due to environmental effects on human health, such as fish advisories or emerging data on endocrine disruptors.	Lead: LK MI TCC Assist:
RM12. **Baseline Clam Monitoring Study at Cannelton Industries Site** Baseline clam monitoring was conducted in 1997 to determine if the site remedy was effective at reducing concentrations of bioavailable trace elements (including mercury and methyl mercury) in Tannery Bay at the Cannelton Industries Site in Sault Ste. Marie, Michigan. Though not in the Lake Michigan basin, the results of this study may be useful for understanding similar remediation efforts in the basin. Monitoring is still being conducted.	Lead: NOAA Assist:

6.2 Next Steps

LaMP

The public involvement process outlined in Chapter 1 is not just to inform the public about the LaMP but to engage the public in discussions about the findings and suggested actions. Many aspects of this plan are incomplete, and the public dialogue process is intended to gain input, fill data gaps, and move the decision-making process forward. Comments are needed on the following :

Chapter 1. The concept of Area of Stewardship

Chapter 3. Priorities for the indicator list

A list of indicators cross-walked with the LaMP subgoals is presented for public comment. The LaMP will be working with the Lake Michigan Monitoring Coordinating Council to develop a monitoring plan that will provide clear monitoring commitments and the data to measure an indicator.

Chapters 4 and 5. Efforts needed to continue to fill in data gaps

The LMMB models will be completed within the 2000 to 2002 time frame, as will the EEGLE Project lead by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory www.glerl.noaa.gov/eegle/. EEGLE will incorporate currents, temperature, wave, and ice along with sediment transport and food web simulations to determine the impact of the massive spring turbidity plume along 200 miles of southern Lake Michigan shoreline. EEGLE and LMMB models will presented to ecosystem managers and the public in 2002.

Additional monitoring is needed to fill in the gaps in our data. We need to plan now to sample some of the same locations on the 10-year anniversary of the LMMB (in 2004) to document trends and gather data for TMDL efforts in the basin.

Chapter 6. Actions, priorities, and other concerns such as the following:

♦ **Ecologically rich areas and habitat identification placed on-line in GIS mapping**

Identification of ecologically rich areas where protection activities should be a priority are underway. The Great Lakes Commission has been funded by EPA to gather Lake Michigan data to produce an on-line atlas as a tool for basin-wide land use planning and protection. USFWS is mapping the threatened and endangered species in the basin by county. The EPA Region 5 Ecosystem Team, in partnership with Region 5 states, is preparing ecologically rich area maps. EPA Office of Research and Development is preparing "greenness contrast" maps for all the Great Lakes, beginning with Lake Michigan, in spring 2000. The purpose of these maps is to present a large scale overview of the amount of green cover that has been lost to development in the last few decades.

- **TMDL Strategy**

  There are many efforts underway that provide an opportunity to use the LaMP and LMMB Project data and models. We are requesting comments on the TMDL Strategy in Appendix E as soon as possible as work on developing the strategy and gathering data need to begin soon.

- **Quantified Targets for Pollution Reduction**

  Reduction targets presented have been pulled from national EPA commitments and from other initiatives like the Binational Strategy and are therefore funded through EPA Regional Office and State grants. They are presented as interim or working targets. The public and multi-agency discussion on specific reduction targets is pending the results of the LMMB model runs. Specific targets and commitments will be part of the 2002 report.

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LaMP 2000 is not the end but the beginning of a basin-wide dialogue on which pollutants and stressors we should prioritize, what reduction targets should be applied to them, and which ecologically rich areas should be preserved. Some issues, like aquatic nuisance species, legacy sites, and drinking water protection require immediate attention. Others will be the subject of public dialogue at workshops. LaMP 2002 will present the latest data and research findings, status reports on the action projects, a list of indicators, monitoring plan and a list of target reductions.

Table 6-2 Lake Michigan LaMP Summary Table (Chapter 6)

CHAPTER 2	CHAPTER 3		CHAPTER 4		
Lake Michigan LaMP: Vision, Goals and Ecosystem Objectives	Indicators and Monitoring of the Health of the Lake Michigan Ecosystem		Lake Michigan LaMP: Current Status of the Ecosystem, Beneficial Use Impairments and Human Health		
Endpoint Goal	Monitoring	Human Activity	Impairment	Spatial	Temporal
1. We can all eat any fish.	• Chemical contamination in fish • Site assessments • Eagle reproduction	• Fish advisories • Congressional reports on: - Great Waters - Mercury - Dioxin	• Restrictions on fish and wildlife (F/W) consumption • Tainting of F/W flavor	Local Local	Ongoing Episodic
2. We can all drink the water.	• Raw water quality data • Source water assessments	• Water utility notifications • Source water protection	• Restrictions on drinking water consumption or taste and odor problems	Local	Episodic
3. We can all swim in the water.	• *E Coli* levels in recreational water	• Beach closing advisories • State 305(b) WQ reports	• Beach closings	Local	Episodic
4. All habitats are healthy, naturally diverse and sufficient to sustain viable biological communities.	• Fish assessments • Bird counts • Wetlands inventories and assessments • Stream flows • Eco-rich area assessments	• Endangered species list • Wetlands mitigation and protection • Zoning • Fish stocking • Fish refuges • USFWS refuges • Ballast water exchange • Dune protection • Eco-rich cluster map	• Degradation of F/W populations • Fish tumors, or other deformities • Degradation of Benthos • Eutrophication or undesirable algae • Degradation of phytoplankton and zooplankton • Loss of F/W habitat • Bird or animal deformities	Regional Local Local Local Lakewide Lakewide Local	Evolving Episodic Ongoing Episodic Ongoing Ongoing Episodic
5. Public access to open space, shoreline and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem.	• Urban density • Coastal parks acreage • Conservation easements	• Open space funding and protection statutes • Coastal zone management	• Degradation of aesthetics	Local	Evolving
6. Land use, recreation and economic activities are sustainable and support a healthy ecosystem.	• Contaminants in recreational fish • Sustainable forests	• Superfund cleanups, dredging • CRP percent of eligible farm lands • Brownfields to greenfields redevelopment	• Restrictions on dredging • Added cost to agriculture or industry	Local Local	Evolving Evolving

Table 6-2 Lake Michigan LaMP Summary Table (Chapter 6) (continued)

CHAPTER 5		**CHAPTER 6**	
Lake Michigan Stressor Sources and Loads		Strategic Action Agenda: Next Steps	
Stressors	Source	Means to an End Goal	Recommendations
• Chemical - PCBs - Mercury - Dioxin - DDT - Chlordane	• Air deposition • Legacy sites • Sediments • Incinerators • Burn barrels		Implement AOC RAPs Clean Legacy Sites Clean Sweep Strategy TMDL Strategy Stewardship Actions
• Biological - Pathogens - ANS	• Land use • Point source • Nonpoint source		Protect Source Water Fill Data Gaps
• Biological - Pathogens • Physical • Chemical	• Land use • Point source • Storm water • CSO/SSO		Control CSO, SSO Develop Agricultural P2 Strategy On-Line Information, Public Involvement Activities
• Physical - Sedimentation - Habitat destruction • Biological - ANS • Chemical - Nutrients - Toxics	• Land use/sprawl • Point source • Air deposition • Ballast water • Storm water • Agriculture runoff	Control pathways Manage ANS Ecosystem stewardship Collaboration Research	Ballast Water Control Protect Habitat On-Line Information, Public Involvement Activities Stewardship Actions Fish Collaboration Fill Data Gaps Measure and Report
• Physical - Sprawl • Biological - ANS	• Land use		On-Line Information, Public Involvement Activities Stewardship Actions
• Physical • Biological • Chemical	• Land use • Point source • Legacy sites		Fill Data Gaps On-Line Information, Public Involvement Activities Stewardship Actions Match Decision Makers with Issues

ADDENDUM 6-A

LAKE MICHIGAN STRATEGIC ACTION PLAN OBJECTIVES AND ACTIONS

ADDENDUM 6-A

STRATEGIC AGENDA: Protect Human Health (SUBGOALS 1,2,3) - Actions that prevent human exposure to pollutants in the ecosystem and prevent or minimize sources

Subgoal 1: We can all eat any fish

Contaminated sediments, non-point source run off and airborne transport of persistent, bioaccumulative chemicals are major sources of contamination to the lake, fish consumption advisories are still needed due to many of these toxic substances, most often PCBs.

OBJECTIVES

1.1 Reduce LaMP pollutant loadings from non-point urban air sources.

Short-term actions

♦ *By 2001, collect PCBs, mercury, and banned pesticides through Cleansweep Projects (A pilot project is underway in Cook County, IL. Results will be reported in 2002.)*

♦ *By 2002, develop and publish a work plan for the TMDL Lake Michigan Strategy (The draft strategy can be found in Appendix E of the LaMP.)*

♦ *By 2002, develop a schedule for preparing workplans in order to define tributary loadings, utilizing TMDL models for priority waterbodies determined by the 303(d) list and the LMMB data*

1.2 Reduce loadings from in-place (contaminated sediments) sources, principally, at the 10 AOC sites in Lake Michigan.

Short-term actions

♦ *By 2002, EPA will convene the four Lake Michigan State Superfund, surface water, and dredging programs to develop a coordinated strategy for sites impacting the lake; provide technical methods exchange; and function as the LMMCC Superfund Subcommittee for reporting purposes.*

♦ *By 2002, obtain commitments to delineate sediment problems in Milwaukee and White Lake.* (Proposed milestones will be developed at the Superfund, surface water, and dredging programs meeting.)

Intermediate actions

♦ *By 2005, Lake Michigan Basin National Priority List sites impacting the lake will have a decision document and a remedial plan scope of work.*

♦ *By 2005, TMDL identified loadings limits for certain tributaries will begin to be factored into permits and unified watershed assessments and remedial nonpoint source plans that will help achieve a 20% reduction from 1992 levels.*

- ♦ *By 2006, remedial activities will have begun at sediment sites with a completion target of 2010.*

Long-term action

- ♦ *By 2010, remedial activities will be substantially complete except for the most complex sediment cleanups.*

Subgoal 2: We can all drink the water

<u>OBJECTIVES</u>

2.1 Reduce loadings of LaMP pollutants to Lake Michigan waters.

Intermediate action

- ♦ *By 2005, discharges from key point sources and nonpoint source runoff will be reduced by at least 20% from 1992 levels*.
  (EPA National Strategic Plan)

2.2 Reduce loadings of pathogens in Lake Michigan waters**.**

Short term actions

- ♦ *By 2003 , EPA hopes to develop management agreements with states and tribes to adopt E.Coli ambient water quality criteria under Section 303(c) of the CWA.*

- ♦ *By 2003 the TCC will review State source water protection assessments for basin in order to determine lakewide actions and provide suggested actions by state, federal and research agencies*
  (Federal regulations under the SDWA require that the assessments be completed by 2003.)

<u>GLFC:</u> Pursue the reduction and elimination of toxic chemicals, where possible, to enhance the fish survival rates and allow for the promotion of human consumption of safe fish.

Subgoal 3: We can all swim in the water

<u>OBJECTIVES</u>

3.1 Reduce loadings of pathogens to Lake Michigan waters.

Short-term action

- ♦ *By 2002, examine O and M programs for successful models of system failure prevention with consideration given to (1) checking all system failures for possible basin wide problems; (2) developing a Four State communication network, and (3) piloting the capacity, management, operation, and maintenance (CMOM) at one beach community*. (Proposed by EPA)

Intermediate action

- *By 2005, annual point source loadings from Combined Sewer Overflows, Publicly Owned Treatment Works and industrial sources will be reduced by 30% from 1992 levels (EPA National Strategic Plan)*

3.2 Reduce pollution-related health risks to swimmers in Lake Michigan waters**.**

Short-term actions

- *By 2001, EPA, the City of Chicago, and other partners will sponsor a Beach Conference to provide exchange of information to basin residents and beach managers at state and local levels*

- *By 2002, convene a Four State E.Coli Network to function as the LMMCC beach monitoring subcommittee and provide transfer of methods for rapid collection and reporting of research and monitoring data*

- *By 2002, develop an on-line beach status report providing real time data and advice. EPA's current national "Beach Watch" at www.epa.gov/ost/beaches, will be expanded to other links and regional sites.*

3.3 Complete additional research.

Short-term actions

- *By 2000, EPA will develop Implementation Guidance for Bacteria Criteria to provide recommendations to help states, territories, and authorized tribes implement EPA's recommended water quality criteria for bacteria.*

- *By 2001, EPA will complete development of the guidance for recreational beach managers, which will be used as a tool for public health officials to reduce the risk of disease to users of recreational waters through improvements in water quality monitoring and public notification programs.*

Intermediate actions

- *By 2004, EPA will develop feasible techniques for isolating and quantifying viruses and parasites in recreational waters.*

- *By 2004, EPA will conduct research to determine pathogen occurrence and indicator relationships associated with wet weather flows.*

- *By 2004, EPA will conduct research to better understand the health risks associated with inhaling contaminated aerosols generated by vigorous recreation water activity.*

STRATEGIC AGENDA: RESTORATION AND PROTECTION (SUBGOAL 4) - Actions that restore, enhance, and sustain the health, biodiversity and productivity of the ecosystem

Subgoal 4: All habitats are healthy, naturally diverse and sufficient to sustain viable biological communities

OBJECTIVES

4.1 Identify, maintain and protect environmentally sensitive/biodiversity investment areas**.**

Short-term action

- ♦ *By 2002, EPA will provide an on-line atlas (Phase 1) of Lake Michigan environmentally sensitive areas that highlights ecologically rich areas*

Intermediate actions

- ♦ *By 2005, identify and map critical habitat in the Lake Michigan watershed for all listed species - endangered/threatened/special concern/vulnerable*
- ♦ *By 2005, complete recovery plans for listed species where those plans do not already exist*
- ♦ *By 2005, identify and map habitat for species of economic and cultural significance*

4.2 Increase the amount of wetlands protected and restored.

Short-term actions

- ♦ *By 2002, the on-line atlas (Phase II) will include dunes, wetland protection and restoration priorities*
- ♦ *By 2002, identify environmental corridors between fragmented habitats and migratory bird flyways.*
- ♦ *By 2002, prevention of isolation of wetlands from Lake Michigan will be recognized through partnership agreements and MOAs*

Intermediate actions

- ♦ *By 2005, 75% of basin waters will support healthy aquatic communities*
  (EPA National Strategic Plan)
- ♦ *By 2005, at least one ecologically-rich wetland area per state will be placed into protective status, targets: Door County, Milwaukee River , SE Chicago Lake Calumet area, IN Grand Calumet area, St. Joseph River and Grand Traverse Bay in Michigan based on SOLEC information on eco-rich areas.*

4.3 Increase acres of naturalized or restored coastal brownfields**.**

Intermediate actions

- ♦ *By 2004, the term and classification criteria for coastal brownfield will be agreed upon and commonly used by local land use planners in the basin through LaMP land use training efforts and an on-line atlas.*

- ♦ *By 2004, the on-line atlas (Phase II) will include corridors and coastal brownfields*

<u>GLFC:</u>

- Protect and enhance fish habitat and rehabilitate degraded habitats.

- Achieve no net loss of the productive capacity of habitat supporting Lake Michigan's fish communities. High priority should be given to the restoration and enhancement of historic riverine spawning and nursery areas for anadromous species.

STRATEGIC AGENDA: SUSTAINABLE USE (Subgoals 5, 6) - Actions that concurrently sustain the health of the environment, the economy, and the communities of the ecosystem

Subgoal 5: Public access to open space, shoreline and natural areas is abundant and provides enhanced opportunities for human interaction with the Lake Michigan ecosystem

<u>OBJECTIVES</u>

5.1 Increase information from the entire lake perspective regarding the sufficient quality, quantity, and availability of diverse recreational opportunities on Lake Michigan.

Short-term action

- ♦ *By 2002, begin development of the Lake Michigan canoe water trail plan building on the Illinois Lake Michigan Water Trails Plan adopted in 1999.*

5.2 Engage the recreational community of Lake Michigan in a sustainability dialogue.

5.3 Promote the need to increase the acreage of natural and restored areas on Lake Michigan shoreline, with possible utilization of brownfields, to land use planners.

Short-term action

- ♦ *By 2001, convent Brownfields to Greenfields Conference.*

Subgoal 6: Land use, recreation and economic activities are sustainable and support a healthy ecosystem

OBJECTIVES

6.1 A strong infrastructure(infrastructure includes indicators, local capacity, lead agencies identified, responsibilities defined, plans in place, etc) is in place to support protection or healthy aquatic communities utilizing the Clean Water Action Plan tools.

6.2 A strong infrastructure is in place to support restoration of degraded aquatic communities.

6.3 Increase the acreage of existing high quality wetlands in permanently protected status.

6.4 Increase the acreage of degraded wetlands restored each year.

Short-term action

- ♦ By 2001, pilot Purple Loosestrife control strategies for urban wetlands

6.5 Increase the quantity and quality of information about wetland landscape functions such as corridors and linkages into land use planning.

Short-term action

- ♦ *By 2001, inventory Northwest Indiana wetlands*
- ♦ *Please refer to Short-Term and Intermediate Actions under Objectives 4.1 and 4.2*

6.6 Increase the number of communities incorporating ecological sustainability (see definitions) into community planning and development.

Short-term action

- ♦ *By 2002, develop habitat/biodiversity recovery plan manuals*

6.7 Increase the use of science-based ecological assessments in local land use decision making process.

Short-term action

- ♦ *By 2001, develop a green area contrast map (1970 - 1990) and land use GIS software*

6.8 Increase the number of site cleanups which go beyond human health and incorporate habitat requirements into clean up standards.

6.9 Decrease the acreage of brownfields in the Lake Michigan Basin by increasing the percentage of coastal brownfield projects incorporating habitat restoration.

- ♦ *Please refer to Intermediate Actions under Objective 4.3*

6.10 Increase capacity and infrastructure for collaboration and partnership.

- ♦ *Please refer to Short-Term Action under Objective 5.3*

6.11 Increase institutional capacity for assessing/addressing emerging issues.

6.12 Decrease the number of navigable areas with dredging restrictions.

6.13 Increase the implementation of Remedial Action Plan measures which relate to sustainability.

6.14 Increase the acreage of natural and restored areas on Lake Michigan shoreline.

- ♦ *By 2001, provide habitat restoration grants to improve spawning and bird reproduction*

6.15 Increase the consideration of environmental justice and equity in LaMP planning.

Short-term action

6.16 Develop brownfields for increased open space habitats within urban areas.

<u>GLFC:</u>

- Establish self-sustaining lake trout populations.
- Establish a diverse salmonine community capable of sustaining an annual harvest of 2.7 to 6.8 million kg (6 to 15 million pounds) of which 20 to 25% is lake trout.
- Maintain self-sustaining stocks of yellow perch, walleye, smallmouth bass, pike, catfish, and panfish. Expected annual yields should be 0.9 to 1.8 million kg (2 to 4 million pounds) for yellow perch and 0.1 to 0.2 million kg (0.2 to 0.4 million pounds) for walleye.
- Maintain a diversity of planktivore (prey) species at population levels matched to primary production and to predator demands. Expectations are for a lakewide planktivore biomass of 0.5 to 0.8 billion kg (1.2 to 1.7 billion pounds).
- Maintain self-sustaining stocks of lake whitefish, round whitefish, sturgeon, suckers, and burbot. The expected annual yield of lake whitefish should be 1.8 to 2.7 million kg (4 to 6 million pounds).

STRATEGIC AGENDA: REMEDIATION AND POLLUTION PREVENTION (SUBGOALS 7, 8) - Actions that achieve substantial pollution reduction by remediating sites, controlling pathways, preventing or minimizing sources

Subgoal 7: Sediments, air, land and water are not sources or pathways of contamination that affect the ecosystem health.

<u>OBJECTIVES</u>

7.1 Reduce loadings of human pathogens to Lake Michigan waters.

- ♦ *Please refer to Short-Term and Intermediate Actions under Objectives 2.2 and 3.1*

7.2 Reduce non-point source loadings of pesticides into Lake Michigan.

Short-term action

- ♦ *By 2002, implement a St. Joseph River Bi-State Stewardship Dialogue regarding the use of pesticides and other non-point source issues in partnership with the Great Lakes Commission*

7.3 Reduce non-point source loadings of nutrients into Lake Michigan.

7.4 Reduce non-point source loadings of sediment into Lake Michigan.

Short-term action

- ♦ *By 2002, convene a basin-wide Agriculture P2 Task Force in cooperation with NRCS, Conservation Districts, and the Lake Michigan Forum.*

7.5 Reduce the quantity of LaMP listed substances in use throughout the basin.

Intermediate action

- ♦ *By 2004, develop targeted P2 projects.*

7.6 Reduce the quantity of PCBs, mercury, and banned pesticides improperly stored throughout the basin.

Short-term actions

- ♦ *By the end of 2000, EPA will publicize, including through posting on its web site, information on how to develop a mercury reduction plan at a manufacturing plant. This information will include mercury reduction plans developed at three steel mills under a voluntary agreement between the mills, EPA, the Indiana Department of Environment, and the Lake Michigan Forum.*

- ♦ *By the end of 2000, EPA will distribute through the Binational Toxics Strategy mercury workgroup a package of information related to mercury reduction at schools, including advice on how to eliminate mercury from school laboratories.*

- *By 2001, review the PCB, Mercury Clean Sweep Pilot to determine usefulness and need to move to other basin areas- target other urban areas.*

7.7 Increase the number of Superfund sites cleaned up.

- *Please refer to Short-Term and Intermediate Actions under Objective 1.2*

7.8 Increase the remediation rate of non-superfund contaminated sites in the Lake Michigan basin.

7.9 Reduce tributary loadings of LaMP pollutants.

- *Please refer to Intermediate Actions under Objective 1.2.*

7.10 Reduce loadings from in-place (sediment) sources of LaMP listed pollutants.

- *Please refer to Short-Term and Intermediate Actions under Objective 1.2.*

Long-term action

- *By 2010, reduce air toxic emissions by 75% from 1993 levels* (EPA National Strategic Plan)

CANADA-UNITED STATES STRATEGY FOR THE VIRTUAL ELIMINATION OF PERSISTENT TOXIC SUBSTANCES IN THE GREAT LAKES

Table 6-A-1

(* indicates LaMP pollutant)

Level I Substances	**Level II Substances**
Aldrin/dieldrin*	Cadmium*
Benzo (a) pyrene [B(a)P]	1,4-dichlorobenzene
Chlordane*	3,3-dichlorobenzidine
DDT (+DDD+DDE)*	Dinitropyrene
Hexachlorobenzene (HCB)*	Endrin
Alkyl-lead	Heptachlor
Mercury ad mercury compounds*	Hexachlorobutadiene
Mirex	Hexachlorocyclohexane
	4,4-methylenebis
Octachlorostyrene	Pentachlorobenzene
PCBs*	Pentachlorophenol
PCDD (dioxins) and PCDF (furans)*	Tetachlorobenzene
Toxaphene*	Tributyl tin

7.11 The Lake Michigan LaMP supports the efforts of the Great Lakes Binational Toxics Strategy (BNS). The U.S. Environmental Protection agency, working in cooperation with their partners, have accepted the following challenges as significant milestones on the path toward virtual elimination of substances listed in Table 6-A-1 (the Canadian challenges in the Strategy are not directly applicable to Lake Michigan). Through the Binational Toxics Strategy, USEPA has committed to work with their partners on the following:

Short-term actions

- *By 2002, confirm that there is no longer use or release from sources that enter the Great Lakes basin of five bioaccumulative pesticides (chlordane, aldrin/dieldrin, DDT, mirex, toxaphene), and of the industrial byproduct/contaminant octachlorostyrene.*

- *By 2002, confirm that there is no longer use of alkyl-lead in automotive gasoline.*

- *By 2002, promote pollution prevention and the sound management of Level II substances to reduce levels in the environment of those substances.*

- *By 2002, assess atmospheric inputs of Strategy substances to the Great Lakes (data gap).*

Intermediate actions

- *By 2006, seek a 90% reduction nationally of high-level PCBs (>500 ppm).*

- *By 2006, seek a 50% reduction nationally in the deliberate use of mercury and a 50% reduction in the release of mercury from sources resulting from human activity.*

- *By 2006, seek a 75% reduction in total releases of dioxins and furans from sources resulting from human activity.*

- *By 2006, complete or be well advanced in remediation of priority sites with contaminated bottom sediments in the Great Lakes Basin.*

Subgoal 8: Exotic species are controlled and managed.

A strong federal lead through federal/state/tribal/local partnerships, like the national Aquatic Nuisance Species Task Force, is needed to address the problem of ballast water introductions of aquatic nuisance species into the Great Lakes, along with continually evaluating current prevention and management tools.

<u>OBJECTIVES</u>

8.1 Prevent exotic species introduction to Lake Michigan and Tributaries.

Short-term actions

- *Continued research, development, monitoring and implementation of the effective measures to exclude nonindigenous nuisance species from the Great Lakes through ANS Task Force.*

8.2 Reduce and manage existing nuisance species to minimize ecosystem impacts.

Short-term actions

- ♦ *Continue development, approval, and funding to implement state management plans for Lake Michigan States.*

- ♦ *Enhanced coordination with the Great Lakes Fishery Commission to coordinate/conduct fisheries research and management activities. This includes maintenance of a full sea lamprey control program; re-registration of lampricides; and research development of alternative (non-pesticide) control technologies.*

8.3 Increase Aquatic Nuisance Species education and outreach.

Short-term actions

- ♦ *Continued information outreach to industry, recreational boaters and anglers regarding containment and control of aquatic nuisance species.*

8.4 Increase the use or development of management tools based on the effectiveness of current methods.

<u>GLFC:</u>

- Suppress the sea lamprey to allow the achievement of other fish-community objectives.

- Protect and sustain a diverse community of native fishes, including other species not specifically mentioned earlier (for example, cyprinids, gars, Lepisostedius spp., bowfin (*Amia calva*), brook trout, and sculpins). These species contribute to the biological integrity of the fish community and should be recognized and protected for their ecological significance and economic values.

STRATEGIC AGENDA: INFORMATION SHARING, COLLABORATION, AND STEWARDSHIP (Subgoals 9, 10) - Actions that provide data access and exchange, facilitate involvement, and build capacity

To achieve sustainability in the ecosystem, a policy of stewardship is required on the part of individuals, governments, and nongovernmental organizations at three scales: local, watershed and lake basin. In order to be a steward at any of these scales there is a need for competence for the tasks undertaken, an ethic of responsibility and knowledge of the ecosystem condition at the local, watershed and basin scale.

Subgoal 9: Ecosystem stewardship activities are common and undertaken by public and private organizations in communities around the basin.

<u>OBJECTIVES</u>

9.1 Increase the understanding of the relationship between individual land use decisions and the cumulative effects on habitat integrity and water quality.

Short-term actions

- ♦ *By 2002, inventory the information available to landowners, developers and local governments on the impacts of land use on aquatic habitats.*

- ♦ *By 2002, distribute information/communication materials that summarize the linkages between land use and aquatic community health in the basin.*

- ♦ *By 2002, develop a packet of incentives to encourage local governments and landowners to foster healthier land-water linkages.*

Intermediate actions

- ♦ *By 2004, develop and distribute decision support tools using GIS data and models.*

- ♦ *By 2004, focus attention on restoration and maintenance through environmental education.*

9.2 Increase the acreage of existing high quality wetlands in permanently protected status. (See Objective 6.3)

9.3 Increase the number of communities incorporating ecological sustainability (see definitions) into community planning and development. (See Objective 6.6)

9.4 Create a strong Lake Michigan/LaMP Great Lakes Fishery Commission habitat partnership as the infrastructure to support restoration of degraded aquatic communities.

9.5 Decrease the acreage of brownfields in the Lake Michigan Basin. (See Objective 6.9)

9.6 Increase the percentage of coastal brownfield projects incorporating habitat restoration. (See Objective 6.9)

9.7 Increase capacity and infrastructure for collaboration and partnership.

9.8 Increase the consideration of environmental justice and equity in LaMP planning.

Subgoal 10: Collaborative ecosystem management is the basis for decision-making in the Lake Michigan basin

This means goal is the responsibility of the Management Committee that of implementing the actions identified as needed in order to restore and protect the Lake Michigan basin ecosystem. The LaMP process is one of not only gathering data, but also making collaborative decisions on strategies and priority actions needed and to secure the commitments necessary for implementation. The LaMP represents the data gathering and detailed statement of the problem that can be utilized by many basin entities as the basis for independent, but coordinated action. The action items will have a wide range, utilizing enforcement as well as compliance assistance, government and non-governmental actions. For many of the actions, tools and authority exist but resources are scarce. Therefore, priorities need to be established and phases and/or timing need to be considered.

OBJECTIVES

10.1 Increase capacity and infrastructure for collaboration and partnership.

10.2 Increase institutional capacity for assessing/addressing emerging issues.

10.3 Increase the implementation of Remedial Action Plan measures using partnerships and enhanced interagency cooperation.

Short-term action

- *By 2002, publish a prioritized, phased list of actions by AOC.*

10.4 Ensure the consideration of environmental justice policies in LaMP planning and decision making processes.

10.5 Increase infrastructure for multi-agency communication and decision-making.

STRATEGIC AGENDA: RESEARCH AND MONITORING (Subgoal 11) - Actions that monitor the ecosystem, reduce uncertainty, and inform our decisions

Subgoal 11: We have enough information/data/understanding/indicators to inform the decision-making process.

OBJECTIVES

11.1 Increase the quantity and quality of information about landscape sensitive ecological habitat functions such as corridors and linkages.

- *Please refer to Short-Term and Intermediate Actions under Objectives 4.1, 4.2, and 4.3.*

11.2 Incorporate science-based ecological assessments into planning and decision making by providing an on-line atlas.

- *Please refer to Short-Term and Intermediate Actions under Objectives 4.1, 4.2, and 4.3.*

11.3 Increase the scientific knowledge base for ecological assessments by providing an on line directory of monitoring programs.

- *Please refer to Short-Term and Intermediate Actions under Objectives 4.1, 4.2, and 4.3.*

11.4 Develop and use an integrated monitoring and reporting system to support decision making for LaMP goals.

Short-term action

- *By 2002, complete the Lake Michigan Monitoring Plan and continue cooperative efforts to maintain the Lake Michigan Monitoring Coordinating Council.*

11.5 Increase institutional capacity for assessing and addressing the ecosystem status.

11.6 Increase scientific knowledge base for assessing and addressing emerging issues like endocrine disruptors.

11.7 LMMB models run and a report issued with recommendations for modification or additional actions for LaMP endorsement.

- ♦ *By 2002, all 10 Lake Michigan areas of Concern will have a completed Stage 2 RAP defining sources and loadings from the area, prioritized identified remedial actions.*

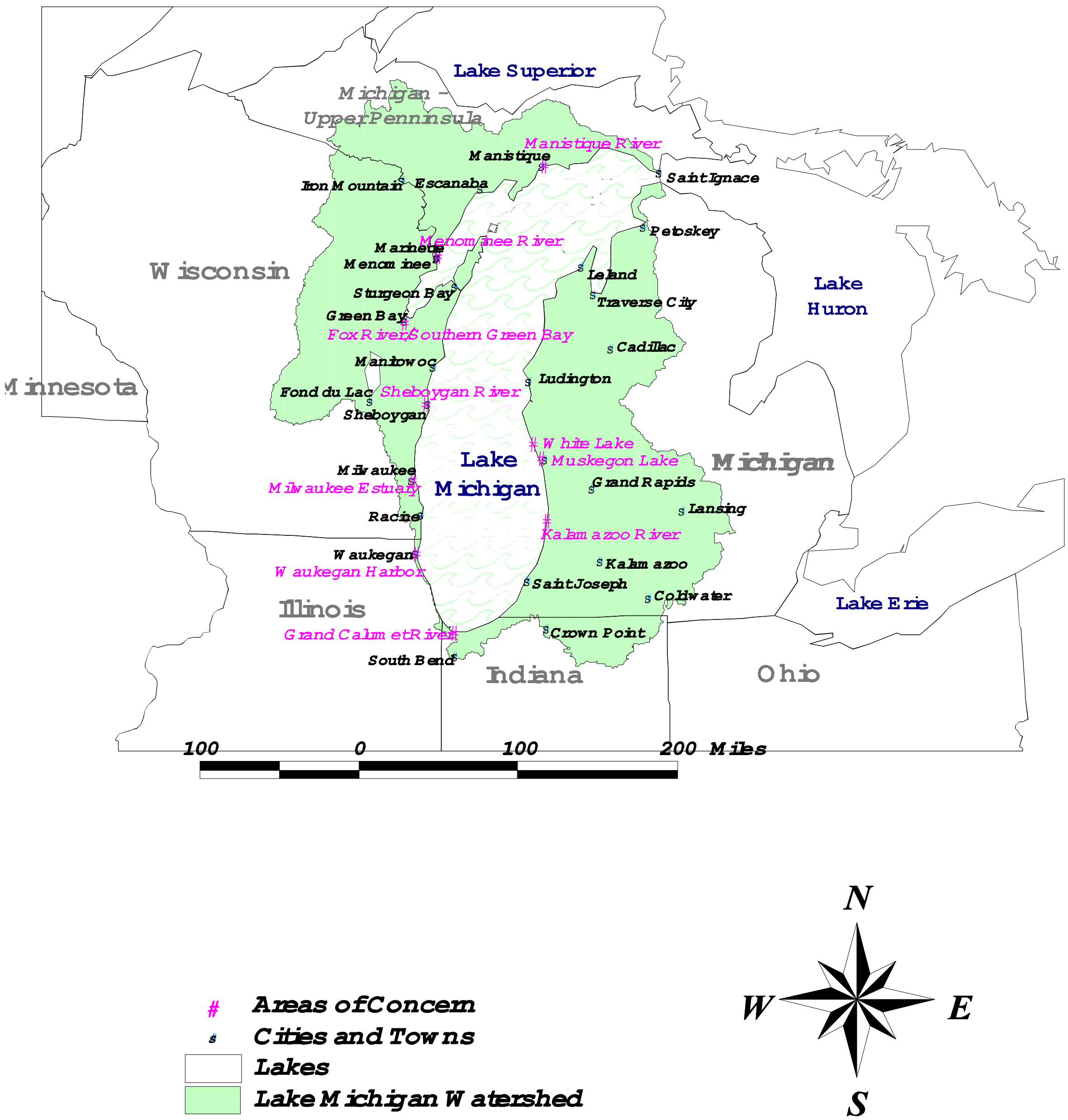
11.8 Begin plans for LMMB follow-up monitoring and sampling in 2005.

Short-term action

- ♦ *By 2002, hold a planning meeting to plan and obtain commitments for years 2004 and 2005 sampling to compliment 1994 and 1995 LMMB sampling.*

Addendum 6-B

Lake Michigan AOC RAP Priorities



Lake Michigan AOC: List of RAP Priorities

Grand Calumet River

Priorities

The Stage 2.5 will be complete by autumn 2000. The CARE committee will propose a suite of short-term and long-term environmental indicators and endpoints to delist each beneficial use. The CARE committee expects to have a list by the end of 2000.

☑ **Remediation**

- Complete design of the proposed confined disposal facility that will hold dredged sediments from the Canal's Federal Navigation Channel
- Continue planning USX project to dredge five miles of Grand Calumet River

☑ **Habitat/Resource Management**

- Continue the Natural Resources Damages Assessment

☑ **P2/Nonpoint Source**

- Complete year 2 of the 3-year Total Maximum Daily Load for the River and Canal

☐ **Human Health**

☐ **Stewardship Sustainability**

☐ **Education and Outreach**

☐ **Research Projects/Data Gaps**

Kalamazoo River

Priorities

The Kalamazoo River Watershed Council (KAWC) believes that the clean-up level used for PCB contaminated sediments should be the most stringent ones applicable and protective of life in and along the river. The KRWC has published the Position Statement on the Clean-up and Protection of the Kalamazoo River, and is actively seeking endorsements. To date, a number of organizations, county and local governments, and state and federal elected representatives have endorsed this position statement.

☑ **Remediation**

- Superfund Records of Decision finalized and recommendations implemented.

☑ **Habitat/Resource Management**

- Habitat restoration at sites identified by local organizations and district staff.

☑ **P2/Nonpoint Source**

- Nonpoint source pollution control projects completed at sites identified by local organizations and district staff.

☐ **Human Health**

☑ **Stewardship Sustainability**

- Local land use planning educational efforts for elected and appointed local officials. GIS data is available for this application.

☑ **Education and Outreach**

- Public education on health issues and pollution prevention.
- Support for the Kalamazoo River Watershed Council.

☐ **Research Projects/Data Gaps**

Manistique River

Priorities

EPA anticipates that all the dredging activities will be completed by winter 2001: Most of the BUI's should be restored; and the process for delisting the AOC may begin.

☑ **Remediation**

- Completion of the EPA Superfund dredging of contaminated sediments in the harbor.

☐ **Habitat/Resource Management**

☑ **P2/Nonpoint Source**

- Streambank erosion control (with nonpoint source pollution best management practices) is needed in the upper watershed to restore fish habitat and prevent sedimentation in the harbor.

☐ **Human Health**

☐ **Stewardship Sustainability**

☑ **Education and Outreach**

- Several local educational projects have been accomplished, but additional efforts by and support for the PAC are needed.

☐ **Research Projects/Data Gaps**

Menominee River

Priorities

☑ **Remediation**

- Local brownfields restoration projects.

☑ **Habitat/Resource Management**

- Fish population and habitat restoration.
- Local waterfront redevelopment projects.

☑ **P2/Nonpoint Source**

- Pollution prevention education and projects.

☐ **Human Health**

☐ **Stewardship Sustainability**

☑ **Education and Outreach**

- Support for Citizens Advisory Committee.

☐ **Research Projects/Data Gaps**

Milwaukee Estuary

Priorities

The restoration of the Milwaukee Estuary AOC will require a long-term commitment, spanning 25 or more years. Approximately 70 recommendations have been developed thus far by the RAP workgroups. Thirty-one recommendations are targeted for implementation in the next few years (i.e. 12 recommendations pertaining to assessment and monitoring in order to make informed, cost- and resource-effective decisions; six recommendations pertaining to demonstration projects like controlling runoff from storage piles, creating buffer strips, restoring streambanks and increasing public access; twelve recommendations pertaining to community information and education and one recommendation pertaining to supporting and advancing federal stormwater regulations). As these projects are completed and programs are set in place, a better understanding of what it will take to restore and maintain the Milwaukee Estuary AOC will be obtained. Subsequent recommendations will be developed to address identified needs.

☑ **Remediation**

- The highest priority in the AOC continues to be addressing contaminated sediments. Funding is needed to continue moving forward with the sediment management strategy.

☐ **Habitat/Resource Management**

☑ **P2/Nonpoint Source**

- Continue various demonstration projects being conducted throughout the basin.

☐ **Human Health**

☐ **Stewardship Sustainability**

☐ **Education and Outreach**

☐ **Research Projects/Data Gaps**

Muskegon Lake

Priorities

The Muskegon Lake PAC is dedicated to actively participating in the continuing improvement of the quality of Muskegon Lake. RAP Team and PAC coordination is being pursued through scheduling regular monthly meetings, developing common objectives, and developing timetables and budgets for recommended actions.

☑ **Remediation**

- Contaminated sediment remediation on Muskegon Lake’s south side.
  - Division St. Stormwater Outfall in Muskegon Lake between Heritage Landing & the YFCA;
  - Former Grand Trunk Railroad/Sweetwater brownfield/State-City Public Launch Ramp site at Lakeshore Dr. and McCracken St.;
  - Ruddiman Creek and mouth at Muskegon Lake including the Amoco Tank Farm brownfield site;
  - Ryerson Creek and mouth at Muskegon Lake including the Teledyne brownfield site;
  - Westran Corporation Lake Fill and Harshorn Marina site on Muskegon Lake’s south side;
  - Muskegon River mouth wetland buffer zone including the Zephyr site and the Causeway/City Dump site;
  - Coal gasification “tar ball” site offshore from Morris St. on Muskegon Lake’s south side.

- Brownfield remediation on Muskegon Lake’s south shore.
  Numerous brownfield sites are adjacent to the contaminated sediments sites listed above. Three priority sites for a coordinated soil and sediment cleanup approach are:
  - Amoco site at Ruddiman Creek mouth;
  - Teledyne site at Ryerson Creek mouth;
  - Former Grand Trunk Railroad/Sweetwater/Public Launch site.

☑ **Habitat/Resource Management**

- Remove and prevent sediment load at mouth of river in Muskegon Lake’s northeast end to restore critical fish and wildlife habitat
- Restoration of native habitat landscapes on brownfield/foundry fill areas along Muskegon Lake’s south and east shoreline
- Permanent easement/conservancy of identified sensitive wildlife habitat and critical fish habitat areas (based on existing natural features inventory; pre-settlement vegetation maps; 1995 Muskegon Lake Habitat and Aquatic Plant Assessments; MDNR Fisheries Division information).

☑ **P2/Nonpoint Source**

- Phase II Voluntary Stormwater ordinance and technical assistance program to incorporate Best Management Practices (BMP) into shoreline and watershed brownfield redevelopments.
- Implement BMPs on sites identified in the Muskegon River Streambank Erosion Inventory.

☑ **Human Health**

- Identify and correct sanitary sewer integrity and cross connection problems to prevent direct sewage discharge and health advisories for Muskegon Lake and immediate tributaries.
- Determine impact of contaminated groundwater on the ecosystem in the Bear Creek, Bear Lake and Zephyr Oil sediment/wetland areas.
- Drinking water protection assessments (correlate Lake Michigan Mass Balance information with Lake Michigan and Muskegon Lake current and discharge information).

☑ **Stewardship Sustainability**

- Develop a coordinated volunteer water quality monitoring program in Muskegon Lake, tributary creeks and Muskegon River watershed tributaries (based on results of the lake Michigan Tributary Monitoring project).
- Sustainability Training Program to institutionalize "Adopt-A-Watershed" activities throughout the Muskegon Lake AOC/River watershed (initiating sustainable volunteer and school programs to monitor ecosystems, restore habitat, clean up waterways, stencil storm drains, provide teacher training on ecosystems and watersheds).
- Single contact/gateway program established for public access to technical information, public involvement opportunities and long term training for public stakeholders capacity, leadership and empowerment for natural resources stewardship.

☑ **Education and Outreach**

- Increase youth/adult public knowledge on ecosystem principles, remediation of contaminated sites, needs, management via programming in schools, conservation districts, university extensions and community colleges.

☑ **Research Projects/Data Gaps**

- Identify health of benthic/ecosystem of nearshore sediments adjacent to brownfield (high potential redevelopment/dredge areas).
- Map/Identify groundwater quality from contaminated sites discharging/leaching into the lake and rivermouth area.
- Identify atrazine "tributary source" and Mass Balance pollutant "soil source" hot spot areas in the Muskegon River watershed for best management practice, education and remediation potential.
- Muskegon Lake nutrient budget (TMDLs, sediment loads, etc).
- Identify point source water quality discharged from regulated sources to lake/tributaries/storm drains.
- Sediment characterization in Bear Lake at Bear Creek mouth.

Lower Green Bay and Fox River

Priorities

Substantial progress has been made in developing the RAP and implementing recommended actions. However, despite incremental improvements implemented to prevent water pollution, restore habitats, improve public access, and further define the causes of impaired uses, none of the problems in the AOC has been completely solved. Recommendations are being implemented sequentially–the easiest have been started, the more difficult have yet to be implemented. Full RAP implementation will be well beyond the year 2000.

☑ **Remediation**

- Contaminated (PCB) sediment remediation in 39 miles of the Lower Fox River

☑ **Habitat/Resource Management**

- Restore an eroded chain of barrier islands and associated aquatic habitats (Cat Island archipelago)
- Restore littoral habitats
- Protect remaining wetlands
- Exotic Species Prevention

☑ **P2/Nonpoint Source**

- Comprehensive watershed projects to abate runoff pollution
- TMDL for phosphorus and suspended solids in the Fox-Wolf Basin
- Riparian buffers throughout the Fox-Wolf Basin

☐ **Human Health**

☑ **Stewardship Sustainability**

- Sustainable Green Bay Initiative
- Enhance public access

☐ **Education and Outreach**

☑ **Research Projects/Data Gaps**

- State of the Bay Report

Waukegan Harbor

Priorities

Four major remedial actions have been completed that will significantly reduce the quantity of contaminants in Waukegan Harbor and the nearshore area. Approximately 453,600 kg (1 million pounds) of PCBs were removed during remediation activities at the Outboard Marine Corporation site. The other three major remedial actions include the Johns-Manville Company, Waukegan Paint and Lacquer and the Waukegan Tar Pit. At Waukegan Paint and Lacquer, approximately 15 m3 of paints, solvents and flammable solids were removed from weathered tanks before leaking into sandy soil next to Lake Michigan. At the Johns-Manville site, asbestos covering nearly 24 ha has been remediated to prevent entry into Lake Michigan. Two remedial investigations are underway on adjacent property of Waukegan Manufactured Gas and Coke and the Greiss-Pfleger Tannery. Both of these sites are suspected of contributing to surface and groundwater contamination. These remedial investigations are being funded by private parties through coordination with state and federal regulatory agencies.

The Waukegan CAG has been instrumental in obtaining cooperation from local parties involving additional investigations. Groundwater monitoring from local parties was completed in an area south of the harbor. The CAG helped obtain access from private businesses and federal grant money to install the monitoring wells. An adjacent salvage yard ceased operation in 1993 and the CAG is working with a local bank, who holds the property title, to resolve environmental concerns about the site.

☑ **Remediation**

- Facilitate an agreed upon location for a confined disposal facility that would house sediment dredged from the shipping channel.
- Raise funds to fulfill the local share match for the U.S. Army Corps of Engineers dredging of the shipping channel.

☑ **Habitat/Resource Management**

- Fish sampling of the harbor during Spring, 2000.

☐ **P2/Nonpoint Source**

☐ **Human Health**

☐ **Stewardship Sustainability**

☑ **Education and Outreach**

- Co-sponsor the GLWQB annual meeting in May, 2000.

☐ **Research Projects/Data Gaps**

White Lake

Priorities

The White Lake PAC is dedicated to actively participating in the continuing improvement of the quality RAP Team and PAC coordination is being pursued through regular meetings, development of common objectives, and developing timetables and budgets for recommended actions.

The Lake Michigan Federation and the White Lake PAC have completed a study of habitat and wetlands around White Lake. The study was undertaken in response to the 1995 White Lake RAP Update, which noted loss of fish and wildlife populations and recommended that a habitat assessment be conducted.

The study was designed to establish a baseline of information to assist in making future decisions regarding development around the lake. Conducted by a wildlife biologist, the study noted that sixty percent of the quarter-mile study area was already developed. It also found four high-quality marsh areas worth preserving and nearly continuous forest cover along most of the shoreline that provides valuable habitat for birds and other animal species.

Remediation of contaminated sediments in Tannery Bay is scheduled for as early as summer 1999.

☑ **Remediation**

- The Hooker Chemical/Occidental Chemical Company is currently sampling and evaluating sediment contamination. Remediation of specific lakebottom sites is likely and would benefit from a match of federal funds.
- Further study of the extent of contamination from the Whitehall Leather Company is needed, in addition to possible remediation funds.
- Assessment is needed of sediments at discharge points for other contaminated sites, including Muskegon Chemical/Koch Chemical, the White Lake landfill, an old Whitehall city wastewater treatment facility, and a former landfill on the marsh upstream of the lake.

☑ **Habitat/Resource Management**

- Acquisition of two large, undeveloped shoreline tracts owned by Dupont and Hooker Chemical/Occidental Chemical.
- Funds for outreach and implementation of habitat study recommendations.
- Native fish species (white bass, Great Lakes spotted muskellunge) restoration.

☑ **P2/Nonpoint Source**

- Assessment and remediation of shoreline sewage gaps.

☐ **Human Health**

☑ **Stewardship Sustainability**

- Public education programs on ecosystems for schools and adult populations.

☑ **Education and Outreach**

- School curriculums, tying environmental issues to state tests, such as the MEAP.
- Habitat education programs for shoreline property associations and schools, including fact sheets that can be tailored to specific ARCs.

☑ **Research Projects/Data Gaps**

- Quantitative information on the extent and impact to sediments of historical pollution from contaminated sites around the lake.
- Regular assessment of the health of benthic populations.
- Specific fish and wildlife contaminant monitoring data based upon knowledge of contaminated sites and sediments to direct sampling.

Sheboygan River and Harbor

Priorities

Improving the quality of the Sheboygan River Basin ecosystem and achieving the "desired future state" will require a long-term commitment from all levels of government, as well as local interest groups and citizens. RAP implementation must promote such involvement at a feasible pace, allowing results to materialize one step at a time. This step-by-step implementation will pivot on RAP recommendations. The RAP recommendations, which are implementable in two to five-year periods, will be important steps toward basin restoration. These are not the first steps, many projects and programs are underway. Recommendations will continue to materialize as more is understood about the most efficient and lasting ways to restore the Sheboygan River and Harbor.

☑ **Remediation**

- Superfund Record of Decision finalized and sediment remediation initiated.

☑ **Habitat/Resource Management**

- Completion of the Natural Resource Damage Assessment

☐ **P2/Nonpoint Source**

☐ **Human Health**

☑ **Stewardship Sustainability**

- Completion of the Franklin Dam project

☑ **Education and Outreach**

- Web site to manage volunteer water quality monitoring data using the Pigeon River watershed pilot project as an example.

☑ **Research Projects/Data Gaps**

- Compile data from the stream assessments for the State of the Basin report.

GLOSSARY

2,3,7,8, tetrachlorodibenzo-p-dioxin TCDD
See Dioxin.

33 CFR 320-330
Federal regulations which identify Army Corps of Engineers (ACOE) general policies to implement Section 404 of the Clean Water Act. Part 320 outlines the ACOE's general policies; Part 321 -- permit regulations for dams and dikes; Part 322 -- permit regulations for structures; Part 323 -- permit regulations for dredged materials; Part 324 -- permit regulations for ocean dumping; Part 325 -- permit regulations for discharges to navigable waters and wetlands; Part 326 -- enforcement policies; Part 327 -- public hearings; Part 328 -- definition on navigable waters regulations; and Part 330 -- nationwide permit program regulations.

40 CFR
Federal regulations for air, waste, and water-related programs. Water-related regulations include the National Pollutant Discharge Elimination System (NPDES), water quality standards, discharges to navigable waters, other discharges, and test procedures. *See also* Code of Federal Regulations.

Abatement
A reduction in the degree or amount of pollution.

Accumulation
The build-up of a substance in a plant or animal due to repeated exposure to and uptake of that substance from the environment. *See also* bioaccumulation.

Acid Deposition
The total amount of pollutants that make up what is commonly referred to as acid rain. This includes both the wet deposition and dry deposition components that settle out of the atmosphere. *See* acid rain.

Acid Rain
Occurs when sulfur dioxide and nitrogen oxide emissions are transformed in the atmosphere and return to the earth in rain, fog, or snow. Acid rain can damage lakes, forests, and buildings, contribute to reduced visibility, and may harm human health. Regulations have been implemented at the federal and state level to reduce acid rain. Related program: Clean Air Act.

Acute Test
A comparative study in which organisms are subjected to different treatments and observed for a short period, usually not constituting a substantial portion of the organism's life span.

Acute Toxicity
Adverse effects to a plant or animal that result from an acute exposure to a stimulant, such as a pollutant. The exposure usually does not constitute a substantial portion of the life span of the organism. In standard laboratory toxicity tests with aquatic organisms, an effect observed in 96 hours or less is typically considered acute. Also described as a stimulus severe enough to induce an effect.

Aerobic
A term that describes organisms or processes that require the presence of molecular oxygen.

Agency for Toxic Substances and Disease Registry (ATSDR)
The ATSDR was created in 1980 by the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund) as an agency of the U.S. Department of Health and Human Services. It is the principal federal public health agency involved in hazardous waste issues. The ATSDR helps prevent or reduce harmful health effects of exposure to hazardous substances. It is not a regulatory agency, but it advises EPA on health aspects of hazardous waste sites and spills and makes recommendations.

Air Toxics
Substances that cause or contribute to air pollution and which can cause serious health and environmental hazards, such as cancer or other illnesses. *See also* Hazardous Air Pollutants. Related program: Clean Air Act.

Airshed
The term has been used to describe those areas where significant portions of air emissions result in the deposition of various air pollutants to specific land or water areas. The airshed may be substantially larger than the watershed.

Algae
Simple plants found in water and elsewhere that have no roots, flowers, or seeds. These are usually microscopic plants and are the primary producers in lakes. *See also* phytoplankton and periphyton.

Ambient Toxicity
A measurement made using a standard toxicity test to determine how toxic a natural water body is. In some cases a water body may already possess some degree of toxicity before a known pollutant is discharged into it.

Anaerobic
A term that describes processes that occur in the absence of molecular oxygen. *See also* anoxia.

Anoxia
The absence of oxygen or a deficiency of oxygen that is harmful to living organisms. Anoxic conditions can develop in a lake bottom when oxygen is depleted by decomposition processes. This often happens in eutrophic lakes and can result in fish kills. *See also* anaerobic.

Anthropogenic
Anything that is human-caused or derived.

Anti-Backsliding
A federal policy to ensure that water bodies that have been improved are kept at that higher quality. Point source dischargers are required by governments to meet effluent limits, but if discharges become cleaner, or fall below the limit, they are not allowed to go up again. Relaxation of National Pollutant Discharge Elimination System permit limits are not allowed except in certain, limited circumstances.

Anti-Degradation
A federal policy to protect water quality. The policy states that the existing high quality of a particular water resource cannot get worse unless justified by economic and social development considerations. Contained in the U.S. Water Quality Guidance for the Great Lakes System. Related programs: Clean Water Act.

Aquatic Life Criteria
Water quality criteria designed to protect aquatic organisms, including fish, plants, and invertebrates. Related programs: Great Lakes Initiative, Clean Water Act.

Aquatic Nuisance Species (ANS)
Water-borne plants or animals that pose a threat to humans, agriculture, fisheries, and/or wildlife resources. *See also* non-indigenous species, zebra mussel, Bythotrephes, Eurasian ruffe, Eurasian watermilfoil.

Aquatic Nuisance Species Great Lakes Panel
A federal organization formed in 1991 by the Great Lakes Commission to advance exotic species research, monitoring, and control activities. The activities conducted are based on federal legislative and budgetary needs and research and management requirements. Activities include Great Lakes-wide education.

Aquatic Nuisance Species Task Force
An international organization that develops and implements programs to prevent the introduction and distribution of aquatic nuisance species. Their goal is to monitor, control, and study these species, and to disseminate technical and educational information. Made up of 19 provincial, state, and federal organizations.

Area of Concern (AOC)
Areas of the Great Lakes identified by the International Joint Commission as having serious water pollution problems requiring remedial action and the development of a Remedial Action Plan. AOCs are defined in the Great Lakes Water Quality Agreement as: “a geographic area that fails to meet the general or specific objectives of the Great Lakes Water Quality Agreement, or where such failure has caused or is likely to cause impairment of beneficial use or of the areas ability to support aquatic life.” Initially, there were 43 AOCs in the Great Lakes Basin. The 10 AOCs in Lake Michigan are: Waukegan Harbor in Illinois; Grand Calumet River/Indiana Harbor and Ship Canal in Indiana; Muskegon Lake, White Lake, Kalamazoo River, and Manistique River in Michigan; and Lower Green Bay/Fox River, Milwaukee Estuary, Sheboygan River, and Menominee River in Wisconsin. Related programs: Great Lakes Water Quality Agreement, Remedial Action Plans.

Area of Stewardship
An Area of Stewardship is an area, most often a watershed, for which a level of ecosystem integrity has been established as a goal and where an integrated, multi-organizational initiative or partnership is actively working to achieve that goal. Examples of such areas include the Chicago Wilderness, the Kalamazoo Multi-Jurisdictional Watershed Agreement, and the work in Grand Traverse Bay and Door County.

Army Corps of Engineers (ACOE)
The federal agency that administers the Section 404 permit program on dredging or filling navigable waters, including wetlands.

Arsenic
Arsenic is one of 11 pollutants of concern addressed in the LaMP. It is an inorganic pollutant which is naturally occurring in the environment as well as being used for the hardening of copper, lead, and alloys. The major use of arsenic in the U.S. is as a wood preservative.

Assessment and Remediation of Contaminated Sediments Program (ARCS)
The 1987 amendments to the Clean Water Act added Section 118(c)(3), authorizing the EPA Great Lakes National Program Office to coordinate and conduct a five year study and demonstration project related to the appropriate treatment of toxic pollutants in the sediments of the Great Lakes. ARCS was an integrated program which examined new and innovative ways to both assess and treat contaminated sediments. Five sites were given priority for study, including Sheboygan Harbor, Wisconsin and the Grand Calumet River, Indiana. Information from the ARCS Program will be used to guide the development of remedial action plans and lakewide management plans.

Atmospheric Deposition
Pollution that travels through the air and falls on land and water. Related programs: Clean Air Act, Great Lakes Toxic Reduction Effort.

Atmospheric Exchange Over Lakes and Oceans Study (AELOS)
AELOS was a monitoring and modeling study initiated in 1993 by five universities conducted in and downwind of Baltimore and Chicago areas for nitrogen and toxics, respectively. The objectives of the study were (1) dry depositional fluxes of critical urban contaminants to northern Chesapeake Bay off Baltimore and southern Lake Michigan off Chicago; (2) the contribution of urban source categories to measured atmospheric concentrations and deposition; and (3) air-water exchange of contaminants and their partitioning into aquatic phases. The monitoring in Lake Michigan included mercury, PCBs, PAHs, and trace metals.

Atrazine
Atrazine is one of three emerging pollutants addressed by the LaMP. It is a widely used herbicide for the control of broadleaf and grassy weeds in corn, sorghum, rangeland, sugarcane, macadamia orchards, pineapple, turf grass sod, forestry, grasslands, grass crops, and roses. It has been used in the Great Lakes basin since 1959 and most heavily used in 1987-89.

Basin
The land area that drains into a lake or river. This area is defined and bounded by topographic high points around the water body. *See also* watershed.

Beneficial Use
The role that the government decides a water body will fulfill. Examples of these uses include healthy fish and wildlife populations, fish consumption, aesthetic value, safe drinking water sources, and healthy phytoplankton and zooplankton communities. Restoring beneficial uses is the primary goal of the Remedial Action Plans for the Areas of Concern and of the Great Lakes Water Quality Agreement. Related programs: Great Lakes Water Quality Agreement, Lakewide Management Plans, Remedial Action Plans.

Beneficial Use Impairment
A negative change in the health of a water body making it unusable for a beneficial use that has been assigned to it. Examples of the 14 use impairments designated in the Great Lakes Water Quality Agreement, include: restrictions on fish and wildlife consumption, beach closings, degradation to aesthetics, loss of fish and wildlife habitat, and restrictions on drinking water consumption. Local use impairments occur in Areas of Concern or other area affecting the lake. Regional use impairments occur in an Area of Concern cluster or multi-jurisdictional watershed. Open water or lakewide impairment is a condition of pervasive impairment. Related programs: Great Lakes Water Quality Agreement, Lakewide Management Plans, Remedial Action Plans.

Benthic
A term that describes both organisms and processes that occur in, on, or near a lake's bottom sediments. *See also* benthos.

Benthic Invertebrate
Refers to animals with no backbone or internal skeleton that live on the bottom of lakes, ponds, wetlands, rivers, and streams, and among aquatic plants. Benthic invertebrates provide an essential source of food for young and adult fish, wildlife, and other animals. Examples include caddisflies, midge larvae, scuds, waterfleas, crayfish, sponges, snails, worms, leeches, and nymphs of mayflies, dragonflies, and damselflies. The benthic invertebrate *Diaporeia*, is an ecosystem indicator.

Benthos
A term applied to organisms that live on or in a lake's bottom and/or bottom sediments. *See also* benthic.

Best Available Control Technology (BACT)
Technology required to reduce emissions of air pollutant. Defined in the Great Lakes Permitting Agreement as: "emission limits, operating stipulations, and/or technology requirements based on the maximum degree of reduction which each Great Lakes state determines is achievable through application of processes or available methods, systems, and techniques for the control of listed pollutants, taking into account energy, environmental, and economic impacts, and other costs."

Best Available Technology (BAT)
The most effective, economically-achievable, and state-of-the-art technology currently in use for controlling pollution, as determined by the U.S. EPA.

Best Management Practice (BMP)
Methods used to control nonpoint source pollution by modifying existing management practices. BMPs include the best structural and non-structural controls and operation and maintenance procedures available. BMPs can be applied before, during, and after pollution-producing activities, to reduce or eliminate the introduction of pollutants into receiving waters. Related programs: Clean Water Act, Coastal Zone Management, Section 319.

Bioaccumulation
The net accumulation of a substance by an organism as a result of uptake from all environmental sources. As an organism ages it can accumulate more of these substances, either from its food or directly from the environment. Bioaccumulation of a toxic substance has the potential to cause harm to organisms, particularly to those at the top of the food chain. The pesticide DDT is an example of a chemical that bioaccumlates in fish and then in humans, birds, and other animals eating those fish. *See also* accumulation and biomagnification.

Bioaccumulation Factor (BAF)
The ratio of a substance's concentration in an organism's tissue to its concentration in the water where the organism lives. BAFs measure a chemical's potential to accumulate in tissue through exposure to both food and water. *See also* bioconcentration factor. Related programs: Great Lakes Initiative.

Bioaccumulative Chemicals of Concern (BCCs)
Any chemical which, upon entering surface waters, bioccumulates in aquatic organisms by a bioaccumulation factor greater than 1000. This formula takes into account metabolism and other factors that might affect bioaccumulation. Related programs: Great Lakes Initiative.

Bioassay
A test used to evaluate the relative potency of a chemical or mixture of chemicals by comparing its effect on a living organism with the effect of a standard preparation on the same organism. Bioassays are frequently used in the pharmaceutical industry to evaluate the potency of vitamins and drugs.

Bioavailability
A measure of how available a toxic pollutant is to the biological processes of an organism. The less the bioavailability of a toxic substance, the less its toxic effect on an organism.

Bioconcentration Factor (BCF)
The ratio of a substance's concentration in tissue versus its concentration in water in situations where the organism is exposed through water only. BCF measures a chemical's potential to accumulate in an organism's tissue through direct uptake from water (excludes uptake from food). *See also* bioaccumulation factor.

Biocriteria
See biological criteria.

Biodiversity
The variety of life and its processes, including the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting. Also known as biological diversity.

Bioindicator
An organism and/or biological process whose change in numbers, structure, or function points to changes in the integrity or quality of the environment.

Biological Control
A method of controlling a disease-causing organism or pathogen or an exotic species. A biochemical product or bioengineered or naturally-occurring organism is used to cause death, inhibit growth, or inhibit the reproduction of an unwanted organism. One example is the import and use of the European beetle that feeds exclusively on purple loosestrife.

Biological Criteria
Biological measures of the health of an environment, such as the incidence of cancer in benthic fish species. Biological criteria can consist of narrative statements (in the simplest case) or of numeric statements.

Biological Integrity
The ability of an ecosystem to support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to the best natural habitats within a region.

Biological Oxygen Demand (BOD)
This is a measurement of the oxygen depletion in a water sample incubated under controlled conditions over a period of time. The aerobic decomposition of organic matter by bacteria in the sample requires oxygen. BOD is an important measurement of the impact that sewage discharge may have upon a water body because a certain amount of oxygen will be used in the breakdown of the wastewater.

Biomagnification
The process by which the concentration of a substance increases in different organisms at higher levels in the food chain. For example, if an organism is eaten by another organism, these substances move up the food chain and become more concentrated at each step. *See also* bioaccumulation and accumulation.

Biomonitoring
The process of assessing the well-being of living organisms. Often used in water quality studies to indicate compliance with water quality standards or effluent limits and to document water quality trends.

Biosphere
A term that includes all of the ecosystems on the planet along with their interactions. The sphere of all air, water, and land in which all life is found.

Boundary Waters
See Interstate Waters.

Boundary Waters Treaty
The international treaty between the United States and Great Britain signed on January 11, 1909, regarding the waters joining the United States and Canada and relating to questions arising between the two nations. It gave rise to the International Joint Commission. Related programs: Binational Program, International Joint Commission.

Bythotrephes BC
Also called the spiny water flea, this non-indigenous species has spread to all of the Great Lakes and some inland lakes. The impact that this new predator will have on the Great Lakes has yet to be determined, though it may compete for food with some fish.

Cadmium
Cadmium is identified in the LaMP as one of 11 pollutants of concern. It is a naturally occurring inorganic substance which is frequently generated as a byproduct from mining and smelting operations. Commercially, it is used for nickel-cadmium batteries.

Carcinogen
A substance that is known or suspected to cause cancer.

Chlordane
A critical pollutant that was used as a pesticide until banned by the U.S. in 1983 (except for use in controlling underground termites). Chlordane bioaccumulates in the food chain. Concentrations are highest in fat and liver tissue of predatory species. It has been detected in lake trout and other wildlife.

Chlorinated Organic Compounds
Organic chemicals that contain PCBs, DDT, chlorinated dioxins and furans, dieldrin, and hexachlorobenzene. Also called organochlorines or chlorinated organics.

Chlorination
The addition of chlorine to water for disinfection. Used in drinking water purification and sewage treatment prior to discharge.

Chlorine
A common, naturally-occurring element. One form of chlorine is a highly poisonous gas that is typically used for water disinfection, sewage treatment, and the manufacture of bleach and other chemicals.

Chromium
One of 11 pollutants of concern, chromium is a naturally occurring inorganic substance. It also has many uses in industry, such as in steel making and metal finishing. It is also used in lining industrial furnaces, the manufacture of dyes and pigments, leather tanning, and wood preserving.

Chronic Test
A comparative study in which organisms are subjected to different treatments and observed for a long period or a substantial portion of their life span.

Chronic Toxicity
A harmful and delayed response (such as death, unusual growth, reduced reproduction, or disorientation) to a chemical that causes adverse effects over a long period of time relative to an organism's natural life span. In standard laboratory tests an effect observed in 96 hours or more is considered a chronic effect. *See also* toxicity test.

Clean Air Act (CAA)
Federal law originally passed in 1970 for the purpose of protecting and enhancing the quality of the nation's air resources. *See also* Clean Air Act Amendments of 1990.

Clean Air Act Amendments of 1990 (CAAA)
Federal legislation passed in 1990 that amended the Clean Air Act. It resulted in major changes further limiting the generation of air pollution in the United States. Significant sections of the 1990 CAAA include:

Title I - National Ambient Air Quality Standards;
Title II - Mobile Sources (e.g. automobiles);
Title III - Air Toxics;
Title IV - Acid Rain;
Title V - Permit Program; and
Title VI - Ozone-depleting Chemicals.

Related programs: Clean Air Act.

Clean Water Act (CWA)
A federal law that identifies national requirements to protect the nation's waters. Originally known as the Federal Water Pollution Control Act. The CWA is divided into six subchapters:

Subchapter I - Research and Related Programs;
Subchapter II - Grants for Construction of Treatment Works;
Subchapter III - Standards and Enforcement;
Subchapter IV - Permits and Licenses;
Subchapter V - General Provisions; and
Subchapter VI - State Water Pollution Control Revolving Fund.

The law provides for pretreatment standards, plans involving point and nonpoint source pollution, and effluent limitations that satisfy the act's intent.

Clean Water Act Reauthorization (CWAR)
The name for a federal legislative process to amend the Clean Water Act. It is anticipated that the CWA will be reauthorized in the mid- to late-1990s.

Coastal
Waters in the Great Lakes basin, coastal waters are defined in the Coastal Zone Management Act as the waters within the territorial jurisdiction of the United States, consisting of the Great Lakes, their connecting waters, harbors, roadsteads, and estuary-type areas such as bays, shallows, and marshes. Related programs: Coastal Zone Management Act.

Coastal Zone Act Reauthorization Amendments of 1990 (CZARA)
Federal legislation reauthorized by Congress in 1990, resulting in states being asked to combat the problems of coastal water quality, specifically nonpoint source pollution. CZARA also encourages states to tackle issues such as wetland loss, cumulative and secondary impacts of growth, increased threats to life and property from coastal hazards, and dwindling opportunities for public access to the shoreline. Related program: National Oceanic and Atmospheric Administration, U.S. EPA.

Coastal Zone Management Act (CZMA)
A federal law enacted in 1972 to deal with increasing stresses on the nation's coastal areas, including the Great Lakes. Administered by National Oceanic and Atmospheric Administration (NOAA), the CZMA provides money, technical help, and policy guidance to states for balancing conservation and development of coastal resources. Under CZMA, states voluntarily develop their own Coastal Zone Management programs. Related program: National Oceanic and Atmospheric Administration.

Code of Federal Regulations (CFR)
Federal regulations on how to implement federal law.

Combined Sewer Overflow (CSO)
Occurs when heavy rainfall or thaw conditions overload a sewer system designed to carry both waste and stormwater. Often the result is the discharge of untreated sewage into receiving waters. Also refers to the outfall structures themselves.

Comparative Risk Analysis
A procedure for ranking environmental problems by their seriousness (relative risk) for the purpose of assigning program priorities. Typically, teams of experts put together a list of problems, sort the problems by types of risk, then rank them by measuring them against standards, such as the severity of effects, the likelihood of the problem occurring among those exposed, the number of people exposed, and the like. Relative risk is then used to set priorities. *See also* risk assessment, risk management, ecological risk assessment.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Superfund
A federal law, better known as Superfund, enacted in 1980 to give the EPA authority and money to take corrective measures and clean up hazardous waste sites. The 1986 Superfund Amendment Reauthorization Act (SARA) outlined preferred cleanup methods, including permanent on-site treatment.

Confined Disposal Facility (CDF)
A facility providing a contained disposal area for contaminated sediments removed during dredging operations.

Copper
Copper is a naturally occurring inorganic substance which is extensively mined and processed in the U.S. It is a pollutant of concern in Lake Michigan. Copper compounds are most commonly used in agriculture to treat plant diseases, for water treatment, and as a wood, leather, and fabric preservative.

Cost-Benefit Analysis
The determination of how much it will cost to achieve a benefit, for example from pollution control, and the comparison of this amount to the cost of obtaining a higher or lower level of the benefit, or the cost of using some other alternative method.

Council of Great Lakes Governors (CGLG)
An organization comprised of the governors of the eight Great Lakes States who declared their shared intention to manage and protect the water resources of the Great Lakes basin through the Great Lakes Charter and the Great Lakes Toxic Substances Control Agreement.

Council of Great Lakes Industries (CGLI)
An organization that represents businesses with significant investments, facilities, products, and/or services in the Great Lakes basin, including manufacturing, utilities, telecommunications, transportation, financial, and trade. CGLI provides a focal point for offering industry's views and resources. It strengthens regional efforts to integrate social, economic, and environmental issues as a way to build a more vital Great Lakes basin.

Council of Great Lakes Research Managers
A binational advisory group to the International Joint Commission to evaluate the status of Great Lakes research.

Criteria
See water quality criteria.

Criteria Pollutants
A group of air and water pollutants regulated by the EPA under the Clean Air Act and Clean Water Act on the basis of criteria that includes information on health and environmental effects. Criteria pollutants include particulates, some metals, organic compounds, and other substances attributable to discharges.

Critical Pollutant
Chemicals that persist at levels that are causing or could cause impairment of beneficial uses lakewide. The Lake Michigan LaMP has identified six critical pollutants: PCBs, dieldrin, chlordane, DDT and its metabolites, mercury, and dioxins/furans. *See also* Great Lakes Critical Pollutants. Related program: Lakewide Management Program.

Cyanide
One of 11 pollutants of concern, cyanide is a naturally occurring inorganic substance with many industrial uses. The major cyanide users are the steel, electroplating, mining, and chemical industries.

Decomposition
The breakdown of complex organic substances into more simple organic chemicals or substances. The ultimate product of decomposition in an aerobic environment is carbon dioxide.

Designated Uses
The role that a water body is slated to fulfill, such as a drinking water source. Uses are specified in water quality standards for each water body or segment, whether or not the current water quality is high enough to allow the designated use. Other typical uses of a water body include propagation of fish and wildlife, recreation, agriculture, industry, and navigation.

Dichlorodiphenyltrichloro-ethane, DDT
DDT, one of the six critical pollutants, was commonly used as an insecticide after World War II and is now banned in the U.S. and Canada. DDT and its metabolites are toxic pollutants with long-term persistence in soil and water. They concentrate in the fat of wildlife and humans and may disrupt the human body's chemical system of hormones and enzymes. DDT caused eggshell thinning in a number of fish-eating birds and is associated with the mortality of embryos and sterility in wildlife, especially birds. DDT still enters the Great Lakes, probably from a number of sources including airborne transport from other countries, leakage from dumps, and the illegal use of old stocks.

Dieldrin
Dieldrin, a critical pollutant, was used as a pesticide for veterinary uses and to control soil insects. In the U.S. and Canada, its use is now restricted to termite control. Dieldrin has a long half-life in shallow waters compared to most chlorinated organic compounds. It is acutely toxic and poses a potential carcinogenic threat to humans. This chemical enters the Great Lakes System from the air or contaminated sediments and has been detected in fish and wildlife in all of the Great Lakes.

Dioxin
A critical pollutant considered to be highly toxic, 2,3,7,8 tetrachlorodibenzo-p-dioxin, or TCDD, is a variant in a family of 75 chlorinated organic compounds referred to as dioxins. An unwanted chemical byproduct of incineration and some industrial processes that use chlorine, dioxin tends to accumulate in the fatty tissue of fish. Dioxin is a suspected human carcinogen.

Discharge
Any release or unloading of a substance or materials from a pipe, or other emission source. The addition of any pollutant to the waters of the state or to any disposal system from a point source.

Discharge of Dredged or Fill Material
Any addition of dredged or fill material into navigable waters or into the waters of the United States. This includes the driving of pilings and the addition of any material that changes the bottom elevation or configuration of a water body or material that might destroy or degrade any navigable water. Related programs: Section 404, 33 CFR.

Dry Deposition
The deposition of pollutants from the atmosphere (such as dust and particulate matter) that occurs during dry weather periods. Dry deposition rates are often drastically different than wet deposition rates.

Ecological Risk Assessment
An organized procedure to evaluate the likelihood that adverse ecological effects will occur as a result of exposure to stressors related to human activities, such as the draining of wetlands or release of chemicals.

Ecosystem
A biological community and its environment working together as a functional system, including transferring and circulating energy and matter. It is an interconnected community of living things, including, humans, and the physical environment with which they interact.

Ecosystem Approach
The goal of the ecosystem approach is to restore and maintain the health, sustainability, and biological diversity of ecosystems while supporting sustainable economies and communities. The 1994 SOLEC Integration Paper prepared by the EPA and Environment Canada defined the ecosystem approach to management as “a holistic approach that recognizes the interconnectedness of and addresses the linkages occurring among air, water, land, and living things.”

Ecosystem Charter for the Great Lakes Basin
Initiated by the Great Lakes Commission, this is a binational statement of goals, objectives, principles, and action items for the Great Lakes with a plan for achieving it. This non-binding agreement supports a philosophy of "ecosystem management that recognizes natural resources as part of a dynamic and complete matrix that pays no heed to political boundaries or jurisdictions. Related programs: Great Lakes Commission.

Ecosystem Indicator
An organism or community of organisms that is used to assess the health of an ecosystem as a whole. When tracked over time, an ecosystem indicator provides information on trends in important characteristics of the system. Also known as environmental indicator.

Ecosystem Integrity
A measure of the capacity of ecosystems to renew themselves and continually supply resources and essential services. Ecosystem integrity is the degree to which all ecosystem elements -- species, habitats, and natural processes -- are intact and functioninng in ways that ensure sustainability and long-term adaptation to changing environmental conditions and human uses.

Ecosystem Management
The process of sustaining ecosystem integrity through partnerships and interdisciplinary teamwork. Ecosystem-based management focuses on three interacting dimensions: the economy, the social community, and the environment. Ecosystem-based management seeks to sustain ecological health while meeting economic needs and human uses.

Effluent
Liquid wastes that are discharged into the environment as a by-product of human-oriented processes, such as waste material, liquid industrial refuse, or sewage.

Effluent Limitation
Any restriction placed on quantities, discharge rates, and concentrations of pollutants that are discharged from point sources into waters of the United States or the ocean. Related programs: 40 CFR, Clean Water Act.

Emerging Pollutant
The Lake Michigan Lakewide Management Plan addresses emerging pollutants, which include those toxic substances that, while not presently known to contribute to use impairments or to show increasing loadings or concentrations, have characteristics that indicate a potential to impact the physical or

biological integrity of Lake Michigan. These characteristics include presence in the watershed, ability to bioaccumulate, persistence (greater than 8 weeks), and toxicity. Emerging pollutants include atrazine, selenium and PCB substitute compounds.

End Point Subgoal
End point subgoals describe the desired levels of ecosystem integrity and ecological services required to restore beneficial uses and provide for healthy human and natural communities in the basin. *See also* means subgoals. Related program: Lake Michigan Lakewide Management Plan.

Endangered Species Act (ESA)
Federal statutes passed in 1973 that protect endangered and threatened species. The act has 16 sections.

Endangered Species Act Reauthorization (ESAR)
The name for the federal legislative process to amend the Endangered Species Act. It is anticipated that reauthorization will occur in the mid- to late-1990s.

Environmental Impact Assessment (EIA)
A decision-making process mandated under the National Environmental Policy Act (NEPA) which may require a detailed environmental impact statement analyzing the potential significant environmental impacts and alternatives to the action before the action is permitted. A public comment period takes place on each EIA.

Environmental Impact Statement (EIS)
A statement detailing the environmental impacts of and the alternatives to an action. *See* Environmental Impact Assessment.

Environmental Indicator
See ecosystem indicator.

Environmental Monitoring and Assessment Program (EMAP)
A federal program initiated by the EPA in 1988 to provide improved information on the current status and long-term trends in the condition of the nation’s ecological resources. Seven resource categories are defined: near coastal waters, the Great Lakes, inland surface waters, wetlands, forests, arid lands, and agroecosystems. Related programs: Environmental Protection Agency.

Environmental Protection Agency (EPA)
A federal agency whose primary goal is to prevent or mitigate the adverse impacts of pollution on human health and the environment.

Episodic Events -- Great Lakes Experiment (EEGLE)
The EEGLE project will incorporate water currents, temperature, waves, and ice, along with sediment transport and food simulations into the Lake Michigan Mass Balance Model to determine the impact of the massive spring turbidity plume along 200 miles of southern Lake Michigan shoreline. The model will be presented to ecosystem managers and the public in 2002. Related program: Lake Michigan Mass Balance.

Erosion
The wearing away of the land surface by running waters, glaciers, winds, and waves. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to farming, residential or industrial development, road building, or timber cutting.

Estuary (Freshwater)
Areas of interaction between rivers and nearshore lake waters, where seiche activity and river flow create a mixing of lake and river water. These areas may include bays, mouths of rivers, marshes, and lagoons. These ecosystems shelter and feed fish, birds, and wildlife. Most importantly, Great Lakes estuaries provide habitat for wildlife and for young-of-the-year and juvenile fish.

Eurasian Ruffe
A non-indigenous species now found in Lake Superior and Lake Huron. This relatively new invader is a member of the perch family. It is usually less than 6 inches long, has a perch-like body shape, and is very slimy when handled. This fish may be competing with native perch and other fish for food. There is a great deal of concern over the potential for this fish to expand its range into other North American waters. It has also been called the European ruffe and river ruffe. *See also* aquatic nuisance species.

Eurasian Watermilfoil
An exotic aquatic macrophyte that forms thick underwater stands of tangled stems and vast mats of vegetation on the surface of inland lakes. In many shallow areas this plant can crowd out native plants and interfere with water recreation such as boating, fishing, and swimming. The plant can spread from lake to lake by stem fragments that cling to boats and trailers. Public education campaigns aimed at preventing unintentional transport of the plant by boaters have successfully slowed its spread in some states. *See also* aquatic nuisance species.

Eutrophic
A term used to classify those lakes of high primary productivity as indicated by high algal concentrations or high nutrient levels. *See also* eutrophication.

Eutrophication
The process of physical, biological, and chemical changes that occurs in a lake when enriched by nutrients, organic matter, and/or silt and sediments. The process can occur naturally, but if accelerated by human activities such as agriculture, urbanization, and industrial discharge, it is called cultural eutrophication.

Exotic Species
See non-indigenous species, aquatic nuisance species.

Exposure
Contact with a chemical or physical agent.

Exposure Assessment
Estimates the amount of a substance something is exposed to.

Fecal Coliform
Bacteria that come from the intestines of humans and other large animals. A high coliform count in a water body indicates human or animal sewage is leaking or being dumped into the lake.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
Originally adopted in 1947 and currently enforced by EPA, this law regulates the marketing of pesticides.

Federal Register
The official document of the U.S. government that announces proposed federal rules and regulations. It signals the beginning of a period of time for public review and comment.

Federal Water Pollution Control Act (FWPCA)
A federal law that identifies national requirements to protect the nation's waters. Commonly referred to as the Clean Water Act (CWA). Related programs: Clean Water Act.

Fill Material
Material used to convert a water body into dry land or change its configuration or bottom elevation. Related programs: Section 404, 33 CFR.

Fish Consumption Advisory (FCA)
An advisory issued by a government agency recommending that the public limit their consumption of fish. Advisories are issued to limit exposure to toxic substances in the fish that have the potential to impact human health. A fish consumption advisory is prepared annually by each state. Fish caught from selected lakes and streams are tested for toxic substances. Many of the lakes tested have restrictions on fish consumption due to high mercury levels. PCBs and dioxin levels in fish have also resulted in suggested restrictions on fish consumption in some lakes and streams.

Five-Year Strategy
See Great Lakes Five-Year Strategy.

Flushing Time
See residence time.

Gas Exchange
The amount of gaseous contaminant absorbed by, or volatilized from, the lake. It is more complex to assess than atmospheric deposition (wet or dry). Gas exchange is calculated after measuring many environmental parameters, including substance concentrations in air and water.

General Permit
An Army Corps of Engineers (ACOE) authorization that is issued on a nationwide or regional basis for categories of human activities within navigable waters of the U.S. General permits are issued when: (1) these activities are substantially similar in nature and cause only minimal individual and cumulative environmental impacts; or (2) the general permit would result in avoiding unnecessary duplication of the regulatory control exercised by another federal, state, or local agency provided it has been determined that the environmental consequences of the action are individually and cumulatively minimal. There are three types of general permits: regional permits, nationwide permits, and programmative permits. Related programs: Section 404, 33 CFR.

Great Lakes
Lake Ontario, Lake Erie, Lake Huron (including Lake St. Clair), Lake Michigan, and Lake Superior, and the connecting channels (St. Mary's River, St. Clair River, Detroit River, Niagara River, and St. Lawrence River to the Canadian border).

Great Lakes Atmospheric Deposition Network
See Integrated Great Lakes Atmospheric Deposition Network.

Great Lakes Basin
See Great Lakes System.

Great Lakes Charter
An international organization formed in 1985 by the premiers of Ontario and Quebec and the governors of the 8 Great Lakes States in response to the increased interest in diverting Great Lakes water to arid regions of the U.S. The Charter does not encourage these diversion proposals, but has no enforcement powers to prevent their implementation.

Great Lakes Commission (GLC)
A Great Lakes states' organization formed in 1955 by the states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin to promote a cleaner environment, stronger economy, and better quality of life for residents of the Great Lakes states. Although Canada is not an official member of the Commission, it is on the task force. Through policy development, intergovernmental coordination, and advocacy, the Commission offers a variety of services to member states, and provides a unified and influential regional voice on policy, program, and legislative matters affecting the Great Lakes. It maintains an active observer program with representation from federal agencies, provincial governments, regional organizations, and tribal authorities. The Commission also maintains the Great Lakes Information Network and initiated the Ecosystem Charter for the Great Lakes Basin.

Great Lakes Critical Pollutants (GLCP)
Substances (a total of 138) currently identified as most critical to improving water quality under four major Great Lakes initiatives: the Great Lakes Water Quality Initiative, the Lake Michigan Lakewide Management Plan, the Lake Ontario/Niagara River Four Party Agreement, and the Lake Superior Binational Program Agreement. Each of the four initiatives may define critical pollutants differently.

Great Lakes Critical Programs Act
Amendments to Section 118 of the federal Clean Water Act in 1990 to improve the effectiveness of EPA's existing programs in the Great Lakes. The Critical Programs Act established the Great Lakes Water Quality Initiative and identified key treaty agreements between the United States and Canada in the Great Lakes Water Quality Agreement. The Act required the EPA to establish statutory deadlines for treaty activities and increased federal resources for the program. It also requires the EPA to publish proposed water quality guidelines for the Great Lakes System. The guidelines must specify minimum requirements for waters in the Great Lakes system in three areas: water quality standards; anti-degradation policies; and implementation procedures. Related programs: Clean Water Act, Great Lakes Initiative.

Great Lakes Enforcement Strategy
A federal program that is a joint effort of the eight Great Lakes States and the EPA. The strategy is a part of the process for implementing the Great Lakes Five-Year Strategy for the National Pollutant Discharge Elimination System program by reducing dischargers' non-compliance in the Great Lakes basin and reducing toxics loading. A key element of the strategy is the use of screening criteria that are more stringent than the national definition of significant non-compliance.

Great Lakes Environmental Research Laboratory (GLERL)
A federal research facility run by the National Oceanic and Atmospheric Administration located in Ann Arbor, Michigan. The GLERL's mission is to conduct integrated, interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine water, with special emphasis on the Great Lakes. GLERL's research provides federal, state, and international decision and policy makers with scientific understanding of:

- sources, pathways, and fates of toxicants;
- natural hazards;
- ecosystems and their interactions;
- hydrology and Great Lakes water levels; and
- regional effects related to global climate change.

Related programs: National Oceanic and Atmospheric Administration.

Great Lakes Fishery Commission (GLFC)
An international organization established in 1955 by Canada and the United States. Located in Ann Arbor, Michigan, the GLFC works to improve the Great Lakes fishery, coordinates efforts of the two nations, and implements management of the sea lamprey. The Commission also advises the two governments on other non-indigenous species. The USFWS is the U.S. agency that acts for the Commission. Related programs: United States Fish and Wildlife Service (Dept. of Fisheries and Oceans), Sea Lamprey Control Program.

Great Lakes Five-Year Strategy (1992)
A federal (EPA) program that commits the states, tribes, and U.S. federal agencies responsible for environmental protection and natural resource management in the Great Lakes basin to achieving specific environmental goals. This overarching EPA strategy provides a framework for EPA's Great Lakes Programs and contains three major areas of focus: reduction of toxic pollutants; restoration of habitat; and protection of the health of all species. Specifically, regarding toxics reduction (as set forth in the Great Lakes Water Quality Agreement with Canada), the Strategy calls for "...reducing the level of toxic substances in the Great Lakes System with an emphasis on persistent toxic substances, so that all organisms are adequately protected and toxic substances are virtually eliminated from the Great Lakes ecosystem." Related program: National Pollutant Discharge Elimination System.

Great Lakes Indian Fish and Wildlife Commission (GLIFWC)
An organization of Native American tribes from Michigan, Wisconsin, and Minnesota that assists member tribes in the management of natural resources, in the protection of ecosystems, and in the development of institutions of tribal self-government.

Great Lakes Information Network (GLIN)
A nationwide Internet information exchange service for the Great Lakes basin. GLIN ties together a host of databases and file servers from a wide range of government and academic groups in an easy-to-access format. Maintained by the Great Lakes Commission. Related Program: Great Lakes Commission.

Great Lakes Initiative (GLI)
GLI is the commonly used name for the Water Quality Guidance for the Great Lakes System. This federal guidance, drafted in 1993 and finalized on March 23, 1995, has regulatory implications, establishing minimum water quality standards, anti-degradation policies, and implementation procedures for waters in the Great Lakes system. Related programs: Great Lakes Toxic Reduction Initiative, Great Lakes Toxic Reduction Effort, Clean Water Act.

Great Lakes National Program Office (GLNPO)
A federal EPA office created in 1978 to oversee the U.S. fulfillment of its obligations under the Great Lakes Water Quality Agreement with Canada. It was mandated by the Clean Water Act in 1987 to be responsible for coordinating the U.S. response to the water quality agreement. Located in Chicago, Illinois, GLNPO is made up of scientists, engineers, and other professionals who work with staff throughout the EPA, Great Lakes states, other federal agencies, Environment Canada, Ontario provincial government, International Joint Commission, colleges, universities, and the public. GLNPO developed the Great Lakes Five-Year Strategy to focus the activities of these groups on the following objectives: reduction of toxic substance levels, protection and restoration of habitats, and the protection of health. Related programs: Great Lakes Water Quality Agreement, Environmental Protection Agency, Great Lakes Five-Year Strategy, International Joint Commission.

Great Lakes Natural Resource Center
This is a private wildlife protection group located in Ann Arbor, Michigan and run by the National Wildlife Federation.

Great Lakes Protection Fund (GLPF)
A program initiated by the governors of the Great Lakes states as the United States first multi-state environmental endowment, the Fund is guided by principles stressing regional cooperation and communication with the purpose of promoting a healthy and sustainable Great Lakes ecosystem.

Great Lakes Regional Office
See Great Lakes Water Quality Advisory Board.

Great Lakes Research Office
This federal office, administered by the National Oceanic and Atmospheric Administration, identifies issues relating to Great Lakes resources on which research is needed, inventories existing research programs, establishes a mechanism for information exchange, and conducts research through the Great Lakes Environmental Research Laboratories, the National Sea Grant College Program, and other federal labs and the private sector. Related programs: Clean Water Act, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratories, National Sea Grant College Program.

Great Lakes Science Advisory Board (SAB)
See Science Advisory Board.

Great Lakes Sea Grant Network
A U.S. network consisting of Sea Grant programs in Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, and New York.

Great Lakes Sport Fishing Council
A binational organization of the Great Lakes sportfishing community concerned with the present and future health of sportfishing, natural resources, and the Great Lakes ecosystem in general.

Great Lakes States
The states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin.

Great Lakes States Air Permitting Agreement
A federal program signed by the environmental administrators of the Great Lakes states in 1988 to assure consistent implementation of the Toxic Substances Management in the Great Lakes basin through the permitting process agreement.

Great Lakes System
All the streams, rivers, lakes, and other bodies of water within the drainage basin of the Great Lakes.

Great Lakes Toxic Substances Control Agreement
An interstate agreement signed by the governors of the eight Great Lakes states in 1986, this agreement seeks uniform water quality standards for the Great Lakes. The purpose of the governors' agreement was to establish a framework for coordinated regional action in controlling toxic substances entering the Great Lakes system.

Great Lakes Toxics Reduction Effort (GLTxRE)
This is a federal/state partnership that seeks to reduce the generation and release of toxics to the Great Lakes basin, with an emphasis on nonpoint sources. It supports the Great Lakes Water Quality Agreement and Great Lakes Five-Year Strategy. EPA and the Great Lakes states have established a process to deal with gaps or barriers to effectively preventing, controlling, or eliminating toxics loadings from nonpoint sources. An EPA team works with federal and state Great Lakes agencies to enhance efforts to reduce Great Lakes critical pollutants through three parallel projects: Virtual Elimination, Lake Michigan Mass Balance, and source pathway analysis. Related program: Great Lakes Initiative.

Great Lakes Toxics Reduction Initiative (LtxRI)
The original name for the Great Lakes Toxics Reduction Effort.

Great Lakes Water Quality Advisory Board
A binational advisory group to the International Joint Commission to assist in evaluating progress by Canada and the U.S. in accomplishing the Great Lakes Water Quality Agreement goals and to make recommendations regarding the development and implementation of programs. Related programs: Great Lakes Water Quality Agreement, International Joint Commission.

Great Lakes Water Quality Agreement (GLWQA)
An international agreement signed by the United States and Canada in 1972 and updated in 1978 and in 1987. The Agreement seeks to restore and maintain full beneficial uses of the Great Lakes system. Language committing the two nations to virtually eliminate the input of persistent toxic substances in order to protect human health and living aquatic resources was included when the agreement was updated in 1978. The philosophy adopted by the two governments is zero discharge of such substances. Related programs: Lakewide Management Program, Remedial Action Plans.

Great Lakes Water Quality Guidance (GLWQG)
See Water Quality Guidance for the Great Lakes System and the Great Lakes Initiative. Related programs: Great Lakes Toxic Reduction Initiative, Clean Water Act.

Great Lakes Water Quality Initiative (GLWQI)
A federal program initiated in 1989 by the EPA and the Great Lakes states to further address the environmental concerns identified in the Great Lakes Toxic Substances Control Agreement. The GLWQI was intended to provide a forum for the Great Lakes states and the EPA to develop uniform water quality criteria and implementation procedures for the Great Lakes basin so as to create an even

playing field for all industries in the region. This was proposed in 1993 as the Water Quality Guidance for the Great Lakes System. Related programs: Great Lakes Toxic Reduction Initiative, Great Lakes Initiative.

Great Waters Program
This program was mandated by Title III of the 1990 Clean Air Act Amendments to assess the extent of atmospheric deposition of hazardous air pollutants to the Great Lakes and other designated waters. It includes setting up the Great Lakes Atmospheric Deposition Network and reporting the monitoring results from the network to investigate sources and deposition rates of air toxics, to find out what proportion of pollutants come from the atmosphere, and to evaluate any harmful effects to public health or the environment. Related program: 1990 Clean Air Act Amendments.

Great Waters Study
See Great Waters Program.

Ground Water
Water that occurs beneath the ground surface in soils and geologic formations.

Habitat
That space that is or can be successfully occupied (inhabited) by a species or biotic community or some broader (taxonomic or phylogenetic) entity. Habitat is simply the place where an organism or group of closely related organisms live.

Half-Life
The period of time necessary for one half of a substance introduced to a living system or ecosystem to be eliminated or disintegrated by natural processes.

Hazardous Air Pollutants (HAPs)
Any air pollutant listed as such in Title III of the 1990 Clean Air Act Amendments. These are chemicals that have the potential to cause serious health effects. HAPs are released by mobile sources and industrial sources. Also referred to as air toxics. Related program: Clean Air Act.

Hazardous Waste
A waste which, because of its quantity, concentration, or characteristics, may be hazardous to human health or the environment when improperly treated, stored, transported, or disposed. Specific definitions of hazardous waste vary by statute or regulation.

Heavy Metals
Metallic elements with relatively high atomic weights that can contaminate ground water and surface waters, wildlife, and food. Heavy metals have the potential to be toxic at relatively low concentrations. Examples relevant to the Lake Michigan Lakewide Management Plan include arsenic, cadmium, chromium, copper, lead, mercury, selenium, and zinc.

Hexachlorobenzene (HCB)
A LaMP pollutant of concern once used as a pesticide for grain protection until banned by the U.S. in 1976. It is still produced as a byproduct during the manufacture of other chlorinated hydrocarbons. It is a persistent toxic substance and is found in the tissues of fish, animals, and humans from the Great Lakes basin. Limited uses of HCB are still permitted.

House Great Lakes Task Force
A bipartisan coalition of U.S. Representatives from Great Lakes states that works to advance the economic and environmental health of the Great Lakes region.

Human Health Criteria
These are descriptive or numeric expressions that specify how much of a pollutant can be allowed in a water body and still allow for the protection of human health. *See also* water quality criteria. Related program: Great Lakes Initiative.

Hydric Soils
Soils that are saturated, flooded, or ponded long enough during the growing season to develop anoxic conditions in the upper part of the soil profile.

Hydrocarbons
A class of compounds that contain hydrogen and carbon. This group of compounds includes the naturally occurring hydrocarbons produced by plankton, as well as many petroleum-based products like gasoline and motor oil. Chlorinated hydrocarbons, a subclass of hydrocarbons, are human derived and generally toxic.

Hydrophytic Vegetation
Plant life capable of growing in wet conditions, such as in water or in soil or other substrate that is periodically saturated with water. The presence of hydrophytic plants is one of the indicators used in wetland identification and delineation.

Illinois Department of Agriculture
The Illinois Department of Agriculture’s Bureau of Land and Water Resources distributes funds to 98 soil and water conservation districts for programs aimed at reducing soil loss and protecting water quality.

Illinois Department of Natural Resources (IDNR)
The IDNR promotes appreciation of the state's natural resources and works with the people of Illinois to protect and manage those resources to ensure a high quality of life for present and future generations.

Illinois Environmental Protection Agency (IEPA)
The IEPA administers many programs (similar to U.S. EPA’s) for protection of water quality in ground water and surface waters, including the National Pollutant Discharge Elimination System (NPDES) permit program, water quality standards regulations, the nonpoint source pollution program, and ambient statewide monitoring programs. IEPA is participating in the development of the LaMP for the state of Illinois.

Indiana Department of Agriculture
The Indiana Natural Resources Director in the Office of the Commissioner of Agriculture works to ensure that the needs of Indiana constituents are met with regards to natural resources. The Natural Resources Director works closely with the 92 Soil and Water Conservation Districts, the USDA, the Purdue University Cooperative Extension Service, and the Indiana Department of Natural Resources. The director cooperates and partners with individuals and organizations in the public and private sector to help conserve and protect our nation's natural resources.

Indiana Department of Environmental Management (IDEM)
IDEM administers many programs (similar to EPA's) for protection of water quality in ground water and surface waters, including the NPDES permit program, water quality standards regulations, the nonpoint source pollution program, and ambient statewide monitoring programs. IDEM is participating in the development of the LaMP for the state of Indiana.

Individual Permit
An Army Corps of Engineers permit that is issued following a case-by-case evaluation of an application to perform dredge or fill activities in the waters of the U.S., including wetlands. Related programs: Section 404, 33 CFR.

Industrial Waste
Any liquid, gaseous, or solid waste resulting from any process of industry, manufacturing, trade, or business or from the development of any natural resource.

Inflow and Infiltration (I and I)
The penetration of water from the soil into sewer or other pipes through defective joints or connections and/or the penetration of water through the ground surface into the subsurface soil.

Intake Credits
A process that allows a point source discharger to take into account the quality of its source water when determining its effluent limitation standards.

Integrated Great Lakes Atmospheric Deposition Network (IGLADN)
A joint effort of the U.S. and Canada to measure atmospheric deposition of toxic material to the Great Lakes. It was mandated by the Great Lakes Water Quality Agreement. The network also fulfills the requirements of the Great Waters Program mandated by the 1990 Clean Air Act Amendments calling for a Great Lakes atmospheric deposition network. One master sampling station was installed at each of the Great Lakes by the end of 1991 to monitor for deposition of selected toxic pollutants, including mercury. Related program: Great Lakes National Program Office.

Integrated Pest Management (IPM)
A management system that uses all suitable techniques in an economical and ecologically-sound manner to reduce pest populations and maintain them at levels that do not have an economic impact, while minimizing danger to humans and the environment.

International Association for Great Lakes Research (IAGLR)
An international association of scientists that studies the world's large lakes. They publish a research periodical called the Journal of Great Lakes Research and hold yearly meetings within the Great Lakes basin.

International Joint Commission (IJC)
An international organization formed by Canada and the United States in 1909 as a result of the Boundary Waters Treaty to assist in preventing disputes and resolving issues involving all water bodies shared by the U.S. and Canada and to make recommendations about their management, particularly water quality issues and the regulation of water levels. Three commissioners are appointed by each country. Under the Great Lakes Water Quality Agreement, the IJC is also required to monitor progress by Canada and the United States as the two countries implement the goals and objectives of the Agreement. The IJC analyzes and publishes data, provides advice and recommendations and undertakes other initiatives as

requested. Two advisory boards, the Great Lakes Water Quality Advisory Board and the Science Advisory Board, exist to assist the Commission with the Agreement-related responsibilities. Related program: Great Lakes Water Quality Agreement.

International Tracking System
The International Tracking System is a binational effort to standardize reporting of wetland restoration, protection, and other data in the U.S. and Canada. Data are available for fiscal years 1992-96, although it may not be fulling updated.

Interstate Waters
Rivers, lakes, and other waters that flow across state or international boundaries. These include waters of the Great Lakes.

Invertebrates
The classification for animals that do not have a backbone or internal skeleton. *See also* zooplankton and benthic invertebrates.

Lacey Act
This act, enforced by the U.S. Fish and Wildlife Service, is designed to control environmental releases of injurious fish and wildlife. This law includes species that threaten non-agricultural interests.

Lake Carriers Association
This organization, established in 1880, represents U.S. maritime shipping companies throughout the Great Lakes. Its mission includes safe, efficient shipping procedures; Great Lakes shipping statistics; consultation on ice-breaking issues; harbor and channel dredging; sediment disposal; and environment and commerce regulations and legislation.

Lake Michigan
Lake Michigan is the only one of the five Great Lakes wholly within the U.S. border. It is bounded by the states of Michigan, Indiana, Illinois, and Wisconsin. It is connected with and flows into Lake Huron through the Straits of Mackinac.

Lake Michigan Basin
Used to describe Lake Michigan and the surrounding watersheds emptying into the lake.

Lake Michigan Forum
The Lake Michigan Forum provides EPA with public input from stakeholders on the Lake Michigan Lakewide Management Plan (LaMP). The stakeholders include industry, environmental groups, sport fishing groups, academia, agriculture, and Native Americans. As the nongovernmental component of the LaMP process, the Forum has established a work plan in an effort to identify and stimulate nongovernmental activities that are consistent with or implement the goals set through in the LaMP process. The Forum work plan covers a variety of issues ranging from specific activities (such as developing pollution prevention and watershed initiatives) to broader ideas like pressing for commitment to the LaMP process and improving education and outreach efforts.

Lake Michigan Lakewide Management Plan (LaMP)
This document is both a reference document and a proposal for a process that will guide remediation of past errors and the achievement of sustainable integrity of the basin ecosystem. It contains clear, comprehensive goals, specific objectives, a strategic plan, and a system of indicators and monitoring for

use in judging envireonmental status and effectiveness of current actions. Related programs: Great Lakes Water Quality Agreement, Areas of Concern, and Remedial Action Plans.

Lake Michigan Management Committee (LMMC)
The LMMCguides the overall development and implementation of the Lake Michigan LaMP. The current membership includes: EPA (Lake Michigan Team, Great Lakes National Program Office, and Office of Research and Development), U.S. Fish and Wildlife Service, Army Corps of Engineers, U.S. Geological Survey, U.S. Department of Agriculture - Natural Resources Conservation Service, Illinois Environmental Protection Agency, Indiana Department of Environmental Management, Michigan Department of Environmental Quality, Wisconsin Department of Natural Resources, Great Lakes Fishery Commission, Chippewa/Ottawa Treaty of Fishery Management Authority, and the Grand Traverse Band of Ottawa and Chippewa Indians, Michigan.

Lake Michigan Mass Balance Study (LMMB)
This mass balance research project begun in 1994 is part of the Lake Michigan Lakewide Management Plan and is designed to develop a sound, scientific base of information that will guide future toxic pollutant load reduction and prevention activities. Related Programs: Great Lakes Toxic Reduction Effort, Lakewide Management Plan, Clean Air Act, Clean Water Act.

Lake Michigan Monitoring Coordinating Council (LMMCC)
The Council provides a forum for identifying gaps and establishing monitoring priorities, exchanging information, and forming partnerships. It responds to the need for enhanced coordination, communication, and data management among the many agencies and organizations that conduct or benefit from environmental monitoring efforts in the basin.

Lakewide Management Plan (LaMP)
The binational programs called LaMPs provide a process for coordinating and prioritizing activities designed to reduce loadings of critical pollutants. The emphasis is on identifying the major sources of these pollutants and concentrating regulatory efforts where they will have the most impact. LaMPs are being developed for each of the Great Lakes. *See also* Lake Michigan LaMP.

LaMP Technical Coordinating Committee (TCC)
The TCC develops documents and programs, and recommends strategies, goals, and objectives. The current membership includes the same agencies/entities as the Management Committee, plus the Oneida Tribe of Wisconsin. There is a steering committee and six subcommittees under the TCC.

Large Lakes Observatory (LLO)
This University of Minnesota organization established in 1994 supports and performs research on large lakes of the world, including Lake Superior. It was formerly called the Institute for Lake Superior Research. Related program: University of Minnesota.

Leachate
The contaminated liquid resulting from water seeping through a landfill or other materials. Chemicals such as fertilizer are leached from the soil when rainwater travels through the soil.

Lethal Concentration 50% (LC50)
A statistically or graphically estimated concentration that is expected to be lethal to 50% of a group of organisms under specified conditions.

Lethal Dose 50% (LD50)
A statistically or graphically estimated dose that is expected to be lethal to 50% of a group of organisms under specified conditions.

Levels Reference Study
A report that suggested methods to alleviate the adverse consequences of fluctuating water levels in the Great Lakes-St. Lawrence River System. The Levels Reference Study Board, appointed by the International Joint Commission, completed the report in 1993 after an intensive public involvement process in the U.S. and Canada.

Limnology
The scientific study of freshwater, especially the history, geology, biology, physics, and chemistry of lakes.

Load
An amount of water, sediment, nutrients, pollutants, heat, etc. that is introduced into a receiving water. Loading may be either of anthropogenic origin (pollutant loading) or natural (natural background loading). Related programs: Water-related Code of Federal Regulations (parts in chapter 40 of the CFR), Clean Water Act.

Load Allocation (LA)
The portion of a receiving water's load capacity that is attributed either to nonpoint sources of pollution or to natural background sources. Load allocations are best estimates depending on the availability of data and prediction techniques. Wherever possible, natural and nonpoint source loads are distinguished. Related program: Water-related Code of Federal Regulations (parts in chapter 40 of the CFR).

Load Capacity
The greatest amount of load that a water body can receive without violating water quality standards. Related programs: Water-related Code of Federal Regulations (parts in chapter 40 of the CFR), federal and state statutes.

Local Governmental Unit (LGU)
A county board, joint county board, watershed management organization, watershed district or a township, or city.

Lowest Observable Effect Concentration (LOEC)
For toxic substances, it is the lowest tested concentration at which adverse effects are observed in aquatic organisms at a specific time of observation.

Macrophytes
This term literally means "large plant." Usually refers to rooted, seed-producing aquatic plants.

Management Measures (MM)
A management measure is an economically achievable way to control the addition of pollutants from existing and new nonpoint sources. These measures call for the best available nonpoint pollution control practices, technologies, processes, site specific criteria, operation methods, or other alternatives. Related programs: Coastal Zone Management Act, Clean Water Act.

Mass Balance
A scientific approach that studies the sources, movement, and destination of any substance, for example a contaminant, that enters a lake system. A mass balance budget for a particular pollutant is the amount that enters a lake minus the amount that is tied-up in the sediment, broken down by chemical or biological processes, or removed by some other means. This should equal the amount that flows out of the lake system. This exercise enables scientists to assess the possible long-term effects of a pollutant and possible remediation actions. *See also* Lake Michigan Mass Balance Study. Related programs: Great Lakes Toxic Reduction Effort, Lakewide Management Programs.

Means Subgoal
Means subgoals are included in the Lake Michigan LaMP and describe the natural (ecological) and organizational processes required to achieve end point subgoals. *See* end point subgoals. Related program: Lake Michigan LaMP.

Mercury (Hg)
A heavy metal, mercury is a neurotoxin that is toxic if breathed or ingested at sufficiently high concentrations. Mercury is present naturally in the environment. It has commonly been used in a wide variety of applications including thermometers, fluorescent bulbs, mirrors, hide preservation, paints, plastic coloring, inks and stains, and golf course pesticides. Because of its common use, mercury is released during garbage incineration. It is also released through the combustion of fuels such as coal and wood for energy production. Mercury readily bioaccumulates in all aquatic organisms, especially fish and shell fish and in humans and wildlife that consume fish. Many lakes in the Great Lakes region have fish consumption advisories due to high levels of mercury primarily caused by atmospheric deposition. Mercury is one of the six critical pollutants addressed by the Lake Michigan LaMP. Related program: Remedial Action Plans.

Mercury Deposition Network
The objective of the Mercury Deposition Network is to develop a national database of weekly concentrations of total mercury in precipitation and seasonal and annual flux of total mercury in wet deposition. The data will be used to develop information on spatial and seasonal trends in mercury deposited to surface waters, forested watersheds, and other sensitive receptors.

Mesotrophic
A term used to describe a lake of moderate primary productivity. *See also* eutrophic and oligotrophic.

Michigan Department of Agriculture
The Michigan Department of Agriculture sponsors programs for aerosol container recycling, groundwater stewardship, and pollution prevention in farming.

Michigan Department of Environmental Quality (MDEQ)
Michigan administers many programs (similar to U.S. EPA's) for protection of water quality in ground water and surface waters, including the NPDES permit program, water quality standards regulations, the nonpoint source pollution program, and ambient statewide monitoring programs. Michigan DEQ focuses on environmental regulatory, permitting, and related enforcement functions. The MDEQ is participating in the development of the LaMP for the state of Michigan.

Michigan Department of Natural Resources (MDNR)
The MDNR is responsible for the stewardship of Michigan's natural resources and for the provision of outdoor recreational opportunities since creation of the original Conservation Department in 1921. The

MDNR focuses on promoting diverse outdoor recreational opportunities, wildlife and fisheries management, forest management, state lands and minerals, state parks and recreation areas, conservation, and law enforcement.

Mid-Continent Ecology Division (MED)
The EPA's freshwater ecology and water pollution research laboratory in Duluth, Minnesota. Established in 1967, the lab develops methods for predicting and assessing the effects of pollutants on freshwater resources. It is also involved in Great Lakes research, such as work in food chain contaminants, modeling, coastal wetlands, and the Environmental Monitoring and Assessment Program. MED was formerly called the Environmental Research Lab-Duluth. Related program: Environmental Protection Agency.

Mitigation
See wetland mitigation.

Mixing Zone
A limited area or volume of water where initial dilution of a point source pollutant discharge takes place. The zone is extended to cover the secondary mixing in the surrounding waterbody. Numeric water quality criteria can be exceeded, but acutely toxic conditions are prevented from occurring in this zone. Related programs: Clean Water Act, National Pollutant Discharge Elimination System.

Multi-media Risk
The human health risk due to exposure to a pollutant through all pathways, such as inhalation, ingestion, or skin contact.

Mutagen
A substance that is known or suspected to cause mutations.
Mutation
A permanent change in the hereditary material involving a physical change in chromosomes or genes.

Nation's Waters
See Waters of the United States.

National Ambient Air Quality Standards (NAAQS)
Standards that EPA sets under the Clean Air Act to protect public health with an adequate margin of safety (primary standards) and to protect the environment (secondary standards). These standards apply to sources that emit pollutants into the atmosphere. Related program: Clean Air Act.

National Biological Service (NBS)
A federal bureau within the U.S.Department of the Interior. The mission of the NBS is to provide, with others, the scientific understanding and technologies needed to manage the nation's biological resources.

National Environmental Policy Act (NEPA)
A federal law passed in 1990 that promotes efforts to prevent or eliminate damage to the environment and biosphere and stimulates the health and welfare of people. It established a Council on Environmental Quality. It is comprised of two Titles: Title I - Declaration of National Environmental Policy; Title II - Council on Environmental Quality.

National Oceanic and Atmospheric Administration (NOAA)
A federal agency, NOAA's mandate is to conserve and manage wisely the nation's coastal and marine resources, and describe and predict changes in the earth's environment to ensure sustainable economic opportunities. NOAA administers the National Sea Grant College Program, National Underseas Research Program, National Marine Fisheries Service, National Coastal Resources Research and Development Institute, National Weather Service, and others.

National Park Service (NPS)
An agency of the U.S. Department of the Interior that manages the national park system. Active participant in the Binational Program.

National Pollutant Discharge Elimination System (NPDES)
Federal regulations that constitute the national program for issuing, modifying, revoking, re-issuing, terminating, monitoring and enforcing permits, and enforcing pretreatment requirements for point source discharges to surface waters under the Clean Water Act, Section 402. Related programs: Clean Water Act, 40 CFR.

National Priorities List (NPL)
A list of inactive, hazardous waste sites designated under Superfund as needing long-term remedial actions. Currently, there are about 1,200 sites on the NPL. Related program: Comprehensive Environmental Response, Compensation, and Liability Act.

National Sea Grant College Program (NSGCP)
A nation-wide partnership with public and private sectors combining research, education, and technology transfer for public service. A national network of universities meeting changing environmental and economic needs of people, industry, and government in coastal, ocean, and Great Lakes states. The program is administered by National Oceanic and Atmospheric Administration. Related program: National Oceanic and Atmospheric Administration.

National Water Quality Assessment Program (NAWQA)
The NAWQA is designed to describe the status and trends in the quality of the nation's water and to provide an understanding of the natural and human factors that affect the quality of these resources. It has national summaries of pesticides, nutrients, volatile organic chemicals, trace elements, surface water quality modeling, and finding on nutrients and pesticides.

National Wetlands Inventory (NWI)
This U.S. EPA program is classifying and mapping all wetlands in the U.S. from aerial photographs. The information is being entered into three database systems that will comprise the NWI Geographic Information System and will allow computer access to the data. The NWI also prepares wetland trend studies and special reports to Congress.

Nationwide Permit (NWP)
A type of general permit issued by the Army Corps of Engineers allowing certain activities to take place in the waters of the U.S. If certain conditions are met, the specified activities can take place without the need for an individual or regional permit. Related programs: Section 404, 33 CFR.

Natural Resources Conservation Service (NRCS)
A federal agency within the United States Department of Agriculture that provides technical assistance to land users in cooperation with other federal, state, and local agencies in carrying out a variety of natural

resources-related programs designed to promote protection and wise use of these resources on private lands. Formerly the Soil Conservation Service.

Naturalized Species
An intentionally or unintentionally introduced species that has adapted to and reproduces successfully in its new environment. Some Great Lakes examples include the rainbow smelt, the alewife, and some salmon and trout species.

Navigable Waters
Navigable waters of the United States are waters subject to the ebb and flow of the tide and/or used to transport interstate or foreign commerce. Once the determination of navigability is made, it applies over the entire surface of the water body, and is not changed by later actions or events which impede or destroy navigable capacity. Also referred to as waters of the U.S. Related program: 33 CFR.

Neurotoxin
A substance that is known or suspected to be poisonous to nerve tissue.

Nitrogen Oxides (NOx)
Pollutants that can be a component of smog and also can contribute to acid rain. One of the criteria pollutants regulated by the 1990 Clean Air Act Amendments. Sources include automobiles and industrial point sources.

No Net Loss
A federal policy to achieve no overall net loss of the nation's remaining wetlands base as defined by acreage and function and to restore and create wetlands where feasible, to increase the quality and quantity of the nation's wetland resource base. Related program: Section 404.

No Observable Effect Concentration (NOEC)
For toxic substances, it is the highest tested concentration at which no adverse effects are observed in an aquatic organism at a specific time of observation.

Non-Chemical Stressors
Physical and biological factors that can impact water quality or ecosystem health. Examples include heat, sediment, and non-indigenous species.

Non-Indigenous Aquatic Nuisance Prevention and Control Act of 1990
A federal law to prevent the unintentional introduction and dispersal of non-indigenous species into the waters of the U.S. The act mandates the establishment of: a national ballast water control program; the Aquatic Nuisance Species Task Force; initial research funding; technical assistance and education for federal and state agencies; state management plans; and grant programs to prevent, monitor, and control the spread of zebra mussels and other exotic species. It also provides for the establishment of regulations that control the introduction of and dispersal of these organisms. *See also* aquatic nuisance species.

Non-Indigenous Species
Those species found beyond their natural ranges or natural zone of potential dispersal. Also referred to as exotic species. *See also* aquatic nuisance species.

Nonpoint Source
See nonpoint source pollution.

Nonpoint Source Pollution (NPS)
Pollution where the sources cannot be traced to a single, distinct, identifiable point. Nonpoint source pollution can come from atmospheric deposition, erosion, and runoff from parking lots, farms, and streets.

Nutrients
Elements or compounds essential as raw materials for organism growth and development, such as carbon, nitrogen, and phosphorus. Nutrients are identified as pollutants of interest in the LaMP.

Oligotrophic
Refers to an unproductive, nutrient poor lake that typically has very clear water. Lake Superior is classified as an ultra-oligotrophic lake.

Ordinary High Water Mark (OHW)
The elevation marking the highest water level which has been maintained for a sufficient time to leave evidence upon the landscape. Generally, it is the point where the natural vegetation changes from predominately aquatic to upland species. For streams, the OHW is generally the top of the bank of the channel. The OHW is generally the elevation from which building and sewage setbacks are measured. OHWL means the ordinary high water level.

Organic Chemicals
Nearly all of the millions of compounds that contain carbon atoms are organic chemicals. More than 90% of all known compounds are organic. The few carbon compounds that are not considered organic include carbon dioxide and bicarbonate. Hydrocarbons like methane are simple organic chemicals that contain only hydrogen and carbon. Other organic chemicals include most pesticides and chemicals based on benzene.

Outfall
The location or structure where wastewater or drainage empties into the surface water from a sewer, drain, or other conduit.

Outstanding National Resource Waters (ONRW)
This proposed designation contained in the Clean Water Act Reauthorization would establish special areas within the Lake Michigan basin where new or expanded point source discharges of persistent toxic substances would be prohibited as part of the Great Lakes Initiative. Related program: Clean Water Act.

Ozone
A pollutant formed in the lower atmosphere by the reaction of nitrogen oxides and hydrocarbons in sunlight, commonly called smog, for which National Ambient Air Quality Standards have been established. Ozone is also found naturally in the upper atmosphere where it acts as a protective filter, screening out ultra-violet rays.

PAHs
See Polycyclic Aromatic Hydrocarbons.

Part 70 Permit
A federal regulation that defines the requirements for permitting facilities for air emissions. States with federally-approved permit programs administer the permitting of facilities within their state. Related program: 1990 Clean Air Act Amendments.

Particulates
Very small separate particles composed of organic or inorganic matter.

Parts per Billion (ppb)
The number of parts of a substance per billion parts of another substance into which it is combined. Often expressed as micrograms per liter for water and micrograms per kilogram for fish and sediments.

Parts per Million (ppm)
The number of parts of a substance per million parts of another substance into which it is combined. Often expressed as milligrams per liter water or milligrams per kilogram for fish tissue and sediments.

Parts per Thousand (ppt)
The number of parts of a substance per thousands parts of another substance into which it is combined. Often expressed as grams per liter of water or grams per kilogram for fish tissue and sediments.

PCB Substitute Compounds
PCB substitute compounds are emerging pollutants addressed in the LaMP. They include: mineral and silicone oils; bis(2-ethylhexyl)phthalate (DEHP); isopropylbiphenyls; diphenylmethanes; butylbiphenyls; dichlorobenzyldichlorotoluene; diisopropylnaphthalene; and phenylxylyl ethane. Information on most of these compounds is currently limited.

Periphyton
Algae that grow attached to surfaces such as rocks or larger plants.

Permit Compliance System (PCS)
The PCS is a national management information system that tracks surface water discharges under the NPDES program. It contains data on permit issuance, permit limits, monitoring data, and other data pertaining to facilities that discharge into navigable waters of the U.S.

Persistent Toxic Substance
A toxic pollutant that remains in the environment for a substantial period of time, potentially causing injury to ecosystem health.

pH
A numeric value that indicates relative acidity and alkalinity on a scale of 1 to 14. A pH of 7.0 is neutral, higher values indicate increasing alkalinity; lower values indicate increasing acidity.

Phytoplankton
Algae that grow suspended in the water column or open waters of a lake.

Plankton
A term used to describe bacteria, tiny plants (phytoplankton), and animals (zooplankton) that live in the water column of lakes.

Point Source
See point source pollution.

Point Source Pollution
Pollution from a distinct, identifiable source, such as a pipe, smokestack, or exhaust.

Pollutant
Chemicals or refuse material released into the atmosphere, water, or onto the land.

Pollutant of Concern
Lake Michigan LaMP pollutants of concern are those toxic substances that are associated with local or regional use impairments or those for which there is evidence that loadings to or ambient concentrations in the Lake Michigan watershed are increasing. The LaMP pollutants of concern include arsenic, cadmium, chromium, copper, cyanide, lead, zinc, hexachlorobenzene, toxaphene, and polycyclic aromatic hydrocarbons (PAHs).

Pollutant of Interest
The Lake Michigan LaMP identifies two general classes of pollutants as pollutants of interest because they may cause use impairments of the lake. These include nutrients and radionuclides.

Pollution Prevention (P2)
See source reduction.

Pollution Prevention Act of 1990
A federal law that establishes a national policy of pollution prevention, and requires the EPA to develop and implement a strategy to promote source reduction. This act declares as national policy that pollution prevention is the preferred approach to environmental protection.

Polychlorinated Biphenyls (PCBs)
One of the six critical pollutants, PCBs are a group of over 200 nonflammable compounds formerly used in heating and cooling equipment, electrical insulation, hydraulic and lubricating fluids, and various inks, adhesives, and paints. These compounds are highly toxic to aquatic life, persist in the environment for long periods of time, and are bioaccumulative. PCBs are suspected carcinogens, and are linked to infant development problems. Fish from some lakes and streams contain measurable amounts of PCBs. *See also* Fish Consumption Advisory. Related program: Remedial Action Plans.

Polycyclic Aromatic Hydrocarbons (PAHs)
PAHs are identified in the Lake Michigan LaMP as pollutants of concern. They are a family of organic chemicals based on the chemical structure of benzene which result from incomplete combustion of organic chemicals and are associated with grease and other components derived from petroleum byproducts. Some examples of the many PAH compounds include: benzo(a)anthracene, benz(b)fluoranthene, benzo(a)pyrene, chrysene, phenanthrene, and pyrene.

Pressure-State-Response Approach
The pressure-state-response approach involves linking environmental indicators to stressors that impact the environment and to program activities. The use of this approach should promote consistency in the development and application of environmental indicators. It is an organizing framework used by U.S. EPA Region 5 in its “Guide for Developing Environmental Goals, Milestones and Indicators.”

Pretreatment
Partial wastewater treatment required for some industries. Pretreatment removes some types of industrial pollutants before the wastewater is discharged to a municipal wastewater treatment plant.

Primary Productivity
The amount of production of living organic material through photosynthesis by plants, including algae, measured over a period of time.

Primary Treatment
The first step in wastewater treatment in which most of the debris and solids are removed mechanically.

Priority Pollutants
Pollutants identified in certain federal and state regulations. Priority pollutants have different definitions in air, water, and waste programs.

Public Waters
Generally, public waters are water bodies determined by statutes to have significant public value and are controlled by the state.

Publicly Owned Treatment Works (POTW)
Any device or system that is used in treatment, including recycling and reclamation, of municipal sewage. Related programs: Clean Water Act, 40 CFR.

Purple Loosestrife
A wetland plant from Eurasia that quickly invades water bodies, including the Great Lakes, forming dense stands unsuitable as cover, food, or nesting sites for fish, amphibians, waterfowl, and wildlife. Imported as an ornamental plant, it spread quickly across North America along roads, canals, and drainage ditches. Research on the use of European beetles that attack only purple loosestrife shows promise for biological control in North America.

Quagga Mussel
A close cousin to the zebra mussel, this exotic mussel was brought into the Great Lakes in the ballast water of transoceanic ships and is expected to have impacts similar to those of the zebra mussel. Although some evidence suggests that it prefers the deeper waters of the Great Lakes, it has, like the zebra mussel, quickly infested inland river systems. The name quagga comes from an extinct member of the zebra family.

Radionuclides
Radionuclides are unstable nuclides of a particular atomic species that return to stability by emitting ionizing radiation. They may arise naturally or as a result of human activities. Radionuclides are pollutants of interest in Lake Michigan, particularly trituim, carbon-14, strontium-90, radioiodine, cesium-137, radon-222, radium-226, uranium isotopes, and plutonium isotopes.

Receiving Waters
Rivers, streams, lakes, or any body of water into which wastewater is discharged.

Region 5
The EPA's regional office that covers Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. Related program: Environmental Protection Agency.

Regional Air Pollutant Inventory Development System (RAPIDS)
RAPIDS contains statewide air emissions inventories of 49 pollutants of concern to the Great Lakes. The inventory contains emissions estimates for point and area sources of toxic air pollutants.

Regional Environmental Monitoring and Assessment Program (REMAP)
Environmental Monitoring and Assessment Program work on a regional scale. The St. Louis River is a Great Lakes example of a REMAP study. Cooperators include MED, GLNPO, NRRI, MPCA, UWS, and EPA Region 5. Related programs: Environmental Protection Agency, Environmental Monitoring and Assessment Program.

Regional Permit
A type of general permit that may be issued by a division or district engineer (Army Corps of Engineers), after compliance with other procedures, for activities in navigable waters of the U.S. or wetlands. Related programs: Section 404, 33 CFR.

Regulation
Rules that outline specific procedures developed by federal or state agencies which are used to implement laws.

Remedial Action Plan (RAP)
These are federally-mandated local plans designed to restore environmental quality to Areas of Concern on the Great Lakes (there are 10 in Lake Michigan and there were initially 43 throughout the Great Lakes). The Areas of Concern were identified for their persistent pollution problems. Remedial Action Plans were called for by a protocol added to the Great Lakes Water Quality Agreement in 1987. Related program: Great Lakes Water Quality Agreement.

Report to Congress on Toxic Air Deposition to the Great Waters
See Great Waters Study.

Residence Time
The time required for a water body to exchange its entire volume of water. Lake Michigan takes about 99 years to flush its entire volume. This is an important factor used in determining the residence time of toxic pollutants in the lake. Also referred to as flushing time.

Resource Conservation and Recovery Act (RCRA)
A federal law that established a comprehensive cradle-to-grave system for regulating hazardous waste.

Riparian Area
Vegetated ecosystems found along any stream or river. These areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent water body.

Riprap
Rock or other large material that is placed to protect streambanks or lakeshores from erosion due to runoff or wave action.

Risk Assessment
A complex process by which scientists determine the harm that a substance, activity, lifestyle, or natural phenomenon can inflict on human health or the environment. The process involves analyzing scientific data to describe the form, dimension, and characteristics of risk. Assessments are usually predictive estimates of how risky a particular situation is. *See also* risk management, ecological risk assessment, comparative risk analysis.

Risk Management
The process by which risk assessment results are used with other information to make regulatory decisions. Risk management asks, "What shall we do about this risk?" *See also* risk assessment and ecological risk assessment.

Risk Reduction
Anything, such as education, regulation, or remediation, that reduces the adverse effects of exposure to risks from a substance, activity, lifestyle, or natural phenomenon.

Rivers and Harbors Act of 1899
A federal statute that allows the Army Corps of Engineers to regulate the creation of obstructions and filling of navigable waters of the U.S.

Ruffe
See Eurasian ruffe.

Ruffe Control Plan
The Ruffe Control Task Force Committee (appointed by the Aquatic Nuisance Species Task Force) developed this integrated plan encompassing the legal requirements mandated by the Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 to control the Eurasian ruffe. The program provides assessment and control measures including range reduction by chemical treatments, prevention of ballast water transport, and monitoring and surveillance. The plan also emphasizes research and public education as essential components of a ruffe control effort.

Ruffe Control Task Force Committee
An organization representing academic, business, shipping, fisheries management, and fishing interests Great Lakes-wide that developed a five-part plan aimed at controlling the spread of ruffe to western Lake Superior. Chaired by the U.S. Fish and Wildlife Service, this task force was established in 1991 by the Great Lakes Fisheries Commission.

Rule
See Regulation.

Science Advisory Board (SAB)
A binational advisory group that provides advice on the adequacy of Great Lakes science and research to the International Joint Commission and the Water Quality Board. The board is responsible for developing recommendations on all matters related to research and the development of scientific knowledge pertinent to the identification, evaluation, and resolution of current and anticipated problems related to Great Lakes water quality. Related programs: Great Lakes Water Quality Agreement, International Joint Commission.

Sea Grant
See National Sea Grant College Program.

Sea Lamprey
An exotic, eel-like animal that attaches to fish with a sucking disk and sharp teeth. A native of the Atlantic Ocean, the lamprey made its way into all the Great Lakes following the opening of the Welland Canal in 1829 and its deepening in the 1900's. By the 1930's, sea lamprey were found in all of the Great Lakes. During the 1940's and 1950's, lamprey caused the collapse of lake trout, whitefish, and chub

populations in all the Great Lakes with the exception of Lake Superior. It has been estimated that one sea lamprey can kill up to 40 pounds of lake trout during its lifespan. *See also* Sea Lamprey Control Program.

Sea Lamprey Control Program
The U.S. Fish and Wildlife Service and the Department of Fisheries and Oceans in Canada work together, under the direction of the Great Lakes Fishery Commission, to minimize sea lamprey populations in the Great Lakes. Lamprey are controlled by applying a selective toxicant, TFM, to streams during the lamprey's most vulnerable life stage. Other control techniques include barriers, pheromone release, and sterilization of male lamprey.

Secchi Disk Depth (SDD)
An estimate of the transparency of a lake, obtained by lowering a small (20 cm) disk into the water until it is no longer visible and noting the depth at which it disappears from view. Oligotrophic lakes are typically more transparent (and have a greater Secchi depth) than more productive, or eutrophic lakes.

Secondary Treatment
The second step in most publicly-owned treatment systems, where bacteria consume the organic parts of the waste.

Section 10
Refers to Section 10 of the federal Rivers and Harbors Act of 1899.

Section 118
A term used to refer to Section 118 of the federal Clean Water Act that identifies program requirements for the Great Lakes. Related program: Clean Water Act.

Section 305 (b)
The term refers to Section 305 (b) of the federal Clean Water Act, which requires a report on the status of fishable, swimmable waters. The states submit a biennial report to the EPA, which compiles the reports into a report to Congress. Related program: Clean Water Act.

Section 319
A term used to refer to Section 319 of the federal Clean Water Act that identifies the program requirement for nonpoint source management programs. Related program: Clean Water Act.

Section 401
A term used to refer to Section 401 of the federal Clean Water Act which requires water quality certification by the appropriate state agency. Under Section 401, no federal permit to discharge pollutants into the waters of the U.S. is valid unless the state where the discharge occurs grants or waives its right to certify that the permit will not violate the state water quality standards. A federal agency cannot issue a permit when the state has denied water quality certification. Related program: Clean Water Act.

Section 402
A term used to refer to Section 402 of the federal Clean Water Act that identifies permit requirements for point source discharges, known as the National Pollutant Discharge Elimination System. Related program: Clean Water Act.

Section 404
A term used to refer to Section 404 of the federal Clean Water Act that outlines permit requirements for dredging and other filling activities in waters of the U.S.. This is the primary federal law that regulates activities affecting wetlands. The Section 404 program is administered by the Army Corps of Engineers in accordance with the EPA. Related program: Clean Water Act.

Section 6217
A federal regulation that is a part of the Coastal Zone Act Reauthorization Amendments of 1990 entitled, Protecting Coastal Waters. This provision requires states with Coastal Zone Management Programs that have received federal approval under Section 306 of the Coastal Zone Management Act, to develop and implement Coastal Nonpoint Pollution Control Programs. These programs are to be used to control sources of nonpoint pollution which impact coastal water quality. Related programs: Coastal Zone Act Reauthorization Amendments of 1990, Coastal Zone Management Act.

Sediments
Soil particles that are or were at one time suspended in and carried by water as a result of erosion and/or resuspension. The particles are deposited in areas where the water flow is slowed such as in harbors, wetlands, and lakes. This process is referred to as **sedimentation**.

Seiche
Seiches are lakewide displacements of water that are wind-induced. Water pushed by the wind can pile up on shore causing noticeable increases in water depth. When the wind is reduced the water mass continues to slosh back and forth like water in a bathtub.

Selenium
Selenium is a naturally occurring element found in sedimentary rock formations, generally combined with sulfide minerals or silver, copper, lead, or nickel. It is released to the environment through natural processes or by such anthropogenic sources as coal combustion, petroleum fuel combustion, and smelting and efining of metals. There are 271 metals industry-related facilities in the Lake Michigan basin that may serve as sources of selenium.

Sequencing
A term used in wetlands regulations to define a process that involves avoiding, minimizing, and mitigating impacts.

Site-Specific Criteria
Water quality criteria that have been developed to be specifically appropriate to the water quality characteristics and/or species composition at a particular location. Related programs: Great Lakes Initiative, National Pollutant Discharge Elimination System.

Soil and Water Conservation Districts (SWCDs)
Local county units of government that assist landowners with implementation of soil and water conservation measures and practices. Related program: Board of Water and Soil Resources.

Soil Conservation Service (SCS)
See Natural Resources Conservation Service.

Source Reduction
A term that means reducing pollution at its source. It includes management systems, technologies, and other practices which reduce or eliminate the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment prior to recycling, treatment, or disposal. The term includes equipment or technology modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control. Often referred to as pollution prevention. Related programs: Pollution Prevention Strategy, Clean Water Act, Great Lakes Initiative.

Standard
See water quality standard.

State Implementation Plan (SIP)
A state plan that sets out the process for complying with the Clean Air Act requirements. If approved by the EPA it will give the state the authority to run the federal clean air program for the state. Related program: Clean Air Act.

State of the Lakes Ecosystem Conference (SOLEC)
A conference sponsored by Environment Canada and EPA, held every two years to review and make available information on the state of the chemical, physical, and biological integrity of the Great Lakes basin ecosystem. A major purpose of the conference is to cooperate in implementing the Great Lakes Water Quality Agreement by supporting better decision-making through improved availability of information on the condition of the living components of the system and the stresses which affect them. Working papers are prepared as background for the conference.

Statute
An enactment of the legislative body of a government that is formally expressed and documented as a law.

Storm Sewers
The underground infrastructure designed to collect storm runoff from urban areas which is typically not treated by sewage treatment facilities before being discharged into nearby surface waters. Storm sewer runoff has been found to be a major contributor to nonpoint source pollution in the Great Lakes.

Storm Water
Rainwater runoff, snow melt runoff, surface water runoff, and discharges that are collected by storm sewers. Related programs: National Pollutant Discharge Elimination System, CFRs.

Strategic Great Lakes Fisheries Management Plan (SGLFMP)
The Strategic Great Lakes Fisheries Management Plan was developed by fisheries managers at the federal, state, and tribal levels through the Great Lakes Fishery Commission. The Management Plan defines the common goals for management of the Great Lakes fisheries, recognizes the positive developments in the fisheries of Lake Michigan, and presents remaining problems.

Stressor
Any chemical, physical, or biological entity that can induce adverse effects on individuals, populations, communities, or ecosystems and be a cause of beneficial use impairments. Examples of stressors include: pathogens, fragmentation, and destruction of terrestrial and aquatic habitats, exotic nuisance species, and uncontrolled runoff and erosion.

Sulfur Dioxide (SO_2)
A chemical compound that when emitted to the atmosphere is considered to be a major component of acid rain. One of the criteria pollutants regulated by the 1990 Clean Air Act Amendments, SO_2 is emitted mainly by anthropogenic sources. Sources include industrial point sources, such as coal fired electric utilities.

Sunsetting
A process to restrict, phase out, and eventually ban the manufacture, generation, use, storage, discharge, and disposal of a persistent toxic substance.

Superfund
See Comprehensive Environmental Response, Compensation, and Liability Act.

Superfund Amendment Reauthorization Act (SARA)
See Comprehensive Environmental Response, Compensation, and Liability Act.

Surface Water
All water above the surface of the ground including, but not limited to lakes, ponds, reservoirs, artificial impoundments, streams, rivers, springs, seeps, and wetlands.

Sustainable Development
Sustainable development is the process of economic development to meet the needs of the present without compromising the ability of future generations to meet their own needs.

Teratogen
A substance that can cause malformation in the fetus following exposure of the mother. The malformation or abnormality may be biochemical or anatomic and be of genetic or environmental origin.

Tertiary Treatment
The advanced cleaning of wastewater that goes beyond secondary treatment. This process removes nutrients, such as phosphorus and nitrogen, and most biological oxygen demand and suspended solids.

Thermal Stratification
The layering of warmer waters over colder waters that can occur in lakes, usually in the summertime. This layering occurs because as surface waters are warmed they become less dense than the underlying colder waters.

Total Maximum Daily Load (TMDL)
TMDLs are set by regulators to allocate the maximum amount of a pollutant that may be introduced into a water body and still assure attainment and maintenance of water quality standards. Related programs: water-related CFRs and rules, federal and state statutes.

Toxaphene
One of the nine critical pollutants, toxaphene is an insecticide that was developed as a substitute for DDT. Its use is now restricted in the U.S. and Canada. Toxaphene has been detected in wildlife as far north as the Arctic.

Toxic Pollutant
A substance or combination of substances, including disease-causing agents, which may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including reproductive malfunctions), or physical deformation in organisms or their offspring. Also refers to those substances listed under Section 307(a) of the Clean Water Act. Related programs: Clean Water Act, parts of chapter 40 of the CFR.

Toxic Release Inventory System (TRI)
The TRI system contains information regarding more than 650 toxic chemicals and compounds that are used, manufactured, treated, transported, or released into the environment, as required under Section 313 of the Emergency Planning and Community Right-to-Know Act. TRI contains release-transfer data by facility, year, chemical, and medium of release, as well as treatment and source reduction data.

Toxic Substances
See Toxic Pollutants.

Toxic Substances Management in the Great Lakes Basin Through the Permitting Process Agreement
A binational agreement entered into by the environmental administrators of the Great Lakes States in 1986 requiring that best available control technology be installed wherever possible on all new and existing sources of persistent air toxic pollutants which impact the Great Lakes. This agreement is pursuant to implementing the governors’ Great Lakes Toxic Substances Control Agreement.

Toxicity
The inherent potential of a substance to cause adverse effects in a living organism. *See* acute toxicity and chronic toxicity.

Toxicity Test
A procedure that measures the degree of effect caused by a chemical or effluent, by exposing living test organisms to the substance. *See also* acute toxicity and chronic toxicity.

U.S. Army Corps of Engineers (ACOE)
See Army Corps of Engineers.

U.S. Ballast Water Management Regulation
Mandatory regulations, enforced cooperatively by the U.S. and Canadian Coast Guards, that prohibit a commercial trans-oceanic vessel from importing ballast water having salinity values less than 30 parts per thousand into the Great Lakes in an effort aimed at preventing further introductions of harmful exotic species.

U.S. Coast Guard (USCG)
As mandated by federal law, the Coast Guard promotes safe and efficient passage of marine and air traffic in coastal waters by providing: (1) a continuous, accurate, all-weather radio navigation service; (2) warnings of dangers and obstructions by providing visual or electronic signals, buoys, and lights; and (3) search and rescue services for commerce and recreation. They also help prevent pollution by inspecting vessels and aiding in pollution clean-up efforts.

U.S. Coast Guard Auxiliary (CGAUX)
A volunteer civilian organization established by Congress in 1939 to assist the U.S. Coast Guard in promoting safety in U.S. recreational boating.

United States Code (USC)
An abbreviation used to identify federal statutes. It is used when referring to a specific code section(s). For example, the Clean Water Act is 33 U.S.C. 1251-1387.

U.S. Department of Agriculture (USDA)
A federal agency that administers the Natural Resources Conservation Service and the U.S. Forest Service, among others.

U.S. Department of Agriculture - Animal and Plant Health Inspection Service (APHIS)
An agency that inspects incoming agriculture, livestock, and produce for disease and pest-related disease.

U.S. Environmental Protection Agency (EPA, U.S. EPA)
See Environmental Protection Agency.

U.S. Fish and Wildlife Service (USFWS)
A federal agency whose mission is to conserve, protect, and enhance the Nation's fish and wildlife and their habitats for the continuing benefit of people.

U.S. Geological Survey (USGS)
A federal agency that performs surveys, investigations, and research covering topography, geology, and the mineral and water resources of the U.S.

Variance
A mechanism or provision that allows modification to or waiver of requirements or standards.

Virtual Elimination
A term that refers to the elimination of inputs and discharges of persistent toxic substances with the end goal being their elimination from the Great Lakes ecosystem. Because it is not practical to completely remove persistent toxic substances, especially from contaminated sediments, the qualifier virtual is appropriate. It may not be possible to achieve total elimination from the Great Lakes system for some persistent toxic substances produced by natural processes and/or by the release of toxins from contaminated sediments. Because of these impediments, virtual elimination is seen by many as a more realistic objective than zero discharge. *See also* Zero Discharge.

Virtual Elimination Pilot Project
A federal project undertaken by the EPA in response to the Great Lakes Water Quality Agreement, that has as its goal the virtual elimination of persistent bioaccumulative chemicals of concern from the Great Lakes basin. Related program: Great Lakes National Program Office.

Virtual Elimination Strategy
A binational report produced by the Virtual Elimination Task Force for the International Joint Commission that outlines a conceptual framework to achieve the virtual elimination of persistent toxic substances from the Great Lakes basin. Related programs: International Joint Commission, Great Lakes Water Quality Agreement.

Virtual Elimination Task Force
A binational organization established by the International Joint Commission to address specific virtual elimination issues in the Great Lakes ecosystem.

Volatile Organic Compounds (VOCs)
Organic chemicals that evaporate readily into the atmosphere, providing a path for transport through the environment.

Voluntary PCB Phasedown Program
A federal program initiated by EPA Region 5 requesting electric utilities in the Great Lakes basin to voluntarily remove from service all electrical equipment containing PCBs at levels greater than 500 parts per million.

Wasteload Allocation (WLA)
The portion of a receiving waters total maximum daily load that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation. Related programs: water-related CFRs and rules, federal and state statues.

Wastewater Treatment Plant (WWTP)
A facility that receives sewage and stormwater from collection structures, then uses various levels of treatment to purify the water. Most modern publicly-owned treatment works in larger municipalities provide primary treatment, secondary treatment, tertiary treatment, and disinfection techniques to kill disease-producing organisms.

Water Quality Advisory Board
See Great Lakes Water Quality Advisory Board.

Water Quality Agreement of 1987
A binational agreement that amends the Great Lakes Water Quality Agreement of 1978. Related program: Great Lakes Water Quality Agreement.

Water Quality Board
See Great Lakes Water Quality Advisory Board.

Water Quality Criteria
Numeric or narrative expressions that specify concentrations of water constituents (such as toxic chemicals or heavy metals) which, if not exceeded, are expected to support an ecosystem suitable for protecting life in water and life dependent on water for its existence. States incorporate water quality criteria into their water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. Related programs: Clean Water Act, parts of chapter 40 of the CFR.

Water Quality Guidance for the Great Lakes System
The official name for the Great Lakes Initiative. The final version of the guidance was published on March 23, 1995 and has regulatory implications. The guidance establishes minimum water quality standards, anti-degradation policies, and implementation procedures for waters in the Great Lakes system. Related programs: Great Lakes Toxic Reduction Initiative, Great Lakes Toxic Reduction Effort, Clean Water Act.

Water Quality Standard
A water quality standard defines the water quality goals of a water body, or portion thereof, by designating the use or uses to be made of the water, by setting water quality criteria necessary to protect the uses, and by preventing degradation of water quality through anti-degradation provisions. States adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the Clean Water Act. Related programs: Clean Water Act, parts of chapter 40 of the CFR.

Water Table
The upper surface of the ground water or that level below which the soil is saturated with water.

Waters of the United States
A term used in federal regulations that defines all water bodies regulated as waters of the U.S. It includes: (1) all waters which may be susceptible to use in interstate or foreign commerce; (2) all interstate waters, including interstate wetlands; (3) all other waters, such as intrastate lakes, rivers, streams (including intermittent streams), mud flats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation, or destruction of which could affect interstate or foreign commerce including any such waters; (4) all impoundments of waters otherwise defined as waters of the United States; (5) tributaries of waters identified in this section; (6) the territorial seas; (7) wetlands adjacent to waters (other than waters that are themselves wetlands) identified in this section. Related programs: Clean Water Act, 33 CFRs.

Watershed
The drainage basin or area in which surface water drains toward a lake, stream, or river at a lower elevation. Related programs: Coastal Zone Management Act, Clean Water Act.

Wet Deposition
The deposition of pollutants from the atmosphere that occurs during precipitation events. Acid rain is one form of wet deposition. Wet deposition is calculated by multiplying precipitation amounts by the pollutant concentration. Wet deposition rates are often very different than dry deposition rates.

Wetland Mitigation
A regulatory requirement to replace or enhance wetland areas destroyed or impacted by proposed land disturbances with artificially created or restored wetlands.

Wetlands
The lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have a predominance of hydric soils and be inundated or saturated by surface water or ground water at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation. This is a legal definition and controversy still exists among scientists and policy makers as to how many of these characteristics must be present in order for an area to be defined as a wetland. Related programs: Clean Water Act, Section 404.

Whole Effluent Toxicity Test (WET)
The total toxic effect of a complex effluent measured directly by a toxicity test. Related programs: 40 CFR, Great Lakes Initiative.

Wildlife Criteria
Water quality criteria designed to protect wildlife. These are surface water concentrations of toxic substances that will cause no significant reduction in the viability or usefulness (in a commercial or recreational sense) of a population of animals that use the waters of the Great Lakes system as a drinking and/or foraging source over several generations. Related program: Great Lakes Initiative.

Wisconsin Department of Agriculture
The Wisconsin Department of Agriculture administers programs in land and water resource management, atrazine prohibition, conservation engineering, drainage districts, ground water protection, shoreland management, and soil conservation.

Wisconsin Department of Natural Resources (WDNR)
The Wisconsin state agency responsible for overall management of the state's natural resources and environmental quality. The WDNR administers many programs (similar to U.S. EPA's) for protection of water quality in ground water and surface waters, including the NPDES permit program, water quality standards regulations, the nonpoint source pollution program, and ambient statewide monitoring programs. The WDNR administers both natural resources programs and environmental law enforcement.

Zebra Mussel
An exotic species originally introduced into the Great Lakes via the ballast water of transoceanic ships. This small bivalve mussel poses a multibillion dollar threat to industrial, agricultural, and municipal water supplies across North America by clogging water intake pipes. It can also have impacts on fisheries, native freshwater mussels, and natural ecosystems. By moving along contiguous waters of the Great Lakes, attached to ships, barges, and recreational boats, this Eurasian native has rapidly spread throughout the Mississippi River basin and many of its major tributaries, such as the Ohio River. Free-swimming larvae are also spread by river currents. Boater education campaigns focus on preventing further spread of this species.

Zero Discharge
Zero discharge refers to halting all inputs from all human sources and pathways to prevent any opportunity for persistent toxic substances to enter the environment from human activity. To completely prevent such releases, the manufacture, use, transport, and disposal of these substances would have to stop.

Zinc
Zinc is a naturally occurring inorganic chemical considered a pollutant of concern in the LaMP. It is most commonly used as a protective coating for other metals.

Zone of Initial Dilution (ZID)
The region of initial mixing surrounding or adjacent to the end of an outfall pipe or diffuser. The ZID may not be larger than allowed by mixing zone restrictions in applicable water quality standards.

Zooplankton
Small, mostly microscopic animals that swim or float freely in open water. Zooplankton eat algae, detritus, and other zooplankton and in turn are eaten by fish.

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Acronyms and Abbreviations

ADID	Advanced identification of wetlands
AEOLOS	Atmospheric Exchange Over Lakes and Oceans Study
AFRI	Acute febrile respiratory illness
AHC	Aquatic habitat classification
ALA-D	Amino levulinic acid dehydratase
ANS	Aquatic nuisance species
AOC	Area of concern
APE	Alkylphenol polyethxylate nonionic surfactant
ARCS	Assessment and Remediation of Contaminated Sediments
AREAL	Atmospheric Research and Exposure Assessment Laboratory
ATSDR	Agency for Toxic Substances and Disease Registry
BEACH	Beach Environmental and Coastal Health
BEC	Binational Executive Committee
BKD	Bacterial kidney disease
BNS	Binational Toxic Strategy
BOD	Biological oxygen demand
BUI	Beneficial use impairments
CAFO	Confined Animal Feeding Operation
CDF	Confined disposal facility
CMOM	Capacity, Management, Operation and Maintenance Pilot
CSO	Combined sewer overflows
CTF	Confined treatment facility
DDD	1,1-dichloro-2,2-bisp-chlorophenylethane
DDE	1,1-dichloro-2,2-bisp-chlorophenylethylene
DDT	Dichlorodiphenyltrichloroethane
DEHP	Bis2-ethylhexylphthalate
DELT	Deformities, eroded fins, lesions and tumors
EDS	Effluent data statistics
EDSTAC	Endocrine Disruptor Screening and Testing Advisory Committee
EEGLE	Episodic Events-Great Lakes Experiment
EMAP	Environmental Monitoring and Assessment Program
EMP	Enhanced Monitoring Program
EPA	U.S. Environmental Protection Agency
EPA ID	EPA identification numbers
EPCRA	Emergency Planning and Community Right-to-Know Act
ERL-D	Environmental Research Laboratory-Duluth
F/W	Fish and wildlife
FCCU	Fluidized-bed catalytic cracking unit
FDA	U.S. Food and Drug Administration
GBMBS	Green Bay Mass Balance Study
GIS	Geographic information system
GLERL	Great Lakes Environmental Research Laboratory
GLFC	Great Lakes Fishery Commission
GLIN	Great Lakes Information Network
GLSLB	Great Lakes St. Lawrence Basin

Acronyms and Abbreviations (Continued)

GLWQA	Great Lakes Water Quality Agreement of 1978
GPRA	Government Performance and Results Act
ha	Hectares
HCB	Hexachlorobenzene
HCP	Highly carboxylic porphyrins
HHS	U.S. Department of Health and Human Services
HPV	Health protective value
HRS	Hazard ranking system
IADN	Integrated Air Deposition Network
IEPA	Illinois Environmental Protection Agency
IIT	Illinois Institute of Technology
IJC	International Joint Commission
ISO	International Organization for Standardization
LaMP	Lakewide Management Plan
LMF	Lake Michigan Federation
LMMB	Lake Michigan Mass Balance
LMMCC	Lake Michigan Monitoring Coordinating Council
LMUATS	Lake Michigan Urban Air Toxics Study
LTCP	Long-term CSO control plan
LTI	Limno-Tech, Inc.
MCL	Maximum contaminant level
MDA	Michigan Department of Agriculture
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MFO	Mixed function oxidase enzymes
MMSD	Milwaukee Metropolitan Sewerage District
MWC	Municipal waste combustor
NAWQA	National Water-Quality Assessment
NCASI	National Council of the Paper Industry for Air and Stream Improvement
NDV	Newcastle disease virus
NIPC	Northeastern Illinois Planning Commission
NISA	National Invasive Species Act of 1996
NMC	Nine minimum control
NOAA	U.S. National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NRCS	Natural Resource Conservation Service
NWI	National Wetlands Inventory
OAR	Office of Air and Radiation
OGWDW	Office of Groundwater and Drinking Water
OMEE	Ontario Ministry of Environment and Energy
PAC	Public Advisory Council
PAH	Polycyclic aromatic hydrocarbons
PAH	Polyhalogenated aromatic hydrocarbons
PAL	Preventive action limit
PBT	Persistent, Bioaccumulative and Toxic Strategy
PCB	Polychlorinated biphenyls

Acronyms and Abbreviations (Continued)

PCDF	Polychlorinated dibenzofurans
PCP	Pentachlorophenol
PCS	Permit Compliance System
POC	Pollutant of concern
POTW	Publicly-owned treatment works
ppb	Part per billion
ppm	Pars per million
ppt	Parts per trillion
PRP	Potentially responsible party
PSCD	President Council on Sustainable Development
PVC	Polyvinyl chloride
RA	Remedial action
RAPIDS	Regional Air Pollutant Inventory Development System
RAP	Remedial action plans
RCRA	Resource Conservation and Recovery Act
RTE	Rate, threatened, and endangered
SBD	Sleeping Bear Dunes
SEP	Supplemental Environmental Project
SGLFMP	Strategic Great Lakes Fisheries Management Plan
SIC	Standard Industrial Classification
SOLEC	State of the Great Lakes Ecosystem Conference
SRCER	Stream reach characterization and evaluation report
SVOC	Semivolatile organic compound
TCC	Technical Coordinating Committee
TCDD	2,3,7,8-tetrachlorodibenzodioxin
TEQ	Toxicity equivalent concentration
TMDL	Total Maximum Daily Loads
TRI	Toxic Release Inventory
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USACOE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDNR	Wisconsin Department of Natural Resources
WPDES	Wisconsin Pollutant Discharge Elimination System