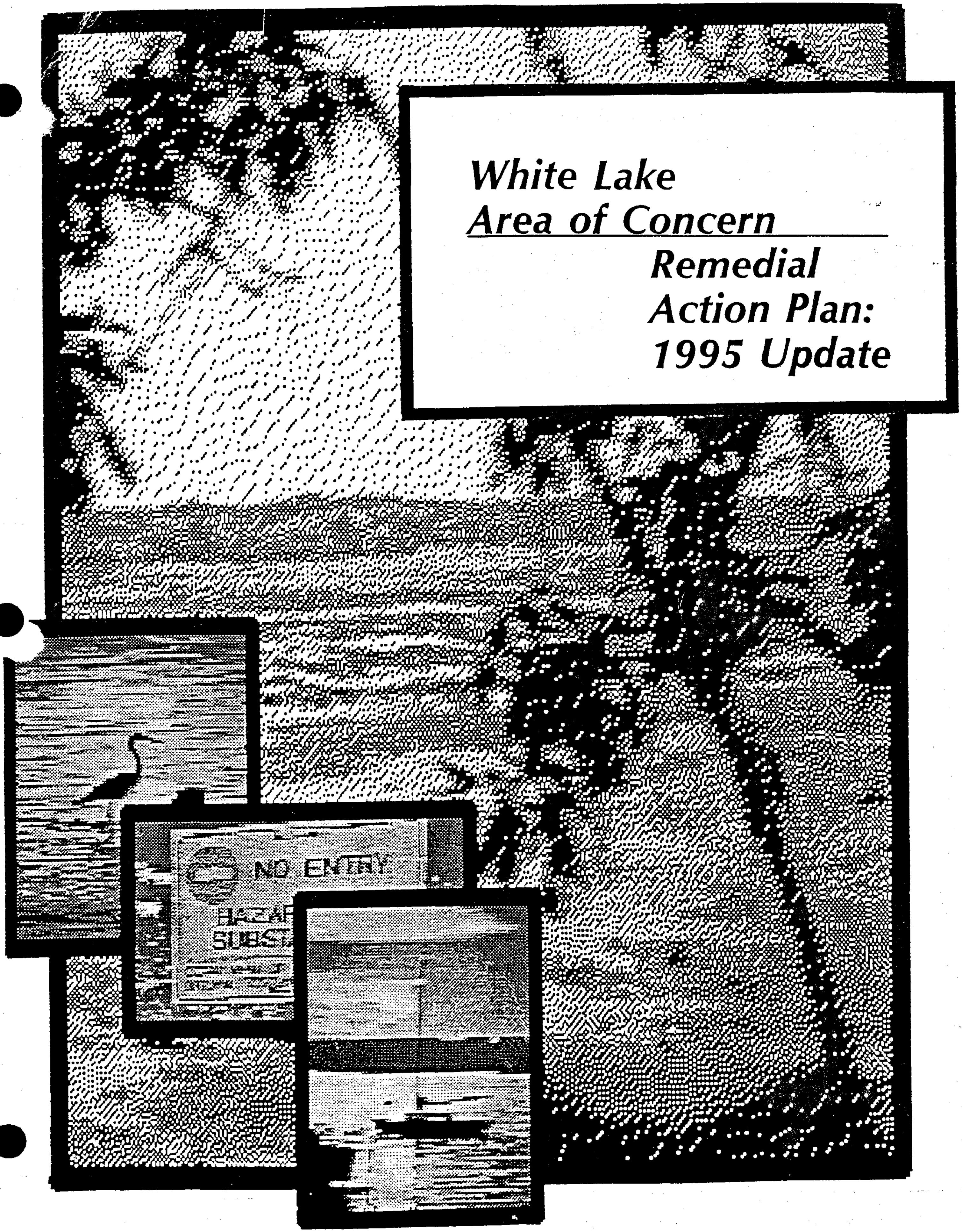
White Lake Area of Concern Remedial Action Plan: 1995 Update



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White Lake Area of Concern

Remedial Action Plan: 1995 Update

April 1995

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White Lake Area of Concern

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Contents   Page

Contents cont.

Contents cont.

Contents cont.

LIST OF REFERENCES

ACUTE TOXICITY Causes severe injury or death soon after a single exposure or dose.

ADVISORY *See* consumption advisory.

AOC Area of concern

AQD Air Quality Division of the Michigan Department of Natural Resources

BACKGROUND Naturally occurring.

BENEFICIAL USE A productive use of a water body by humans or animals. (*See also* impaired beneficial use.)

BENTHOS or **BENTHIC COMMUNITY** Organisms that live on a lake or river bottom.

BIOACCUMULATION The uptake and retention of chemical substances by organisms from its environment (e.g. food, water).

BIOLOGICAL-OXYGEN DEMAND The amount of dissolved oxygen used when a substance biologically degrades in an aquatic system.

BTEX Benzene, toluene, ethylbenzene, and xylene.

CERCLA Federal Comprehensive Environmental Response, Compensation, and Liability Act (*See also* Superfund.)

CHRONIC TOXICITY Causes injury or death after long-term exposure.

COLD-WATER FISH SPECIES In Michigan, primarily trout and salmon.

COMBINED SEWER Sewers that handle both urban storm water and sanitary sewage. During wet weather they can become overloaded and overflow, causing untreated wastewater to be released directly to surface waters. (*See also* sanitary waste.)

CONSUMPTION ADVISORY A caution issued by the Michigan Department of Public Health about eating a certain kind and/or amount of fish or fish from a particular locale.

CULTURAL EUTROPHICATION Accelerated aging of a lake caused by human activity that increases nutrients or solid loadings or both. (*See also* eutrophication.)

Glossary and Acronyms cont.

DDD Formed when DDT breaks down in the environment. Can bioaccumulate in organisms and is very persistent.

DDE Formed when DDT breaks down in the environment. Can bioaccumulate in organisms and is very persistent.

DDT Dichloro-diphenyl-trichloro-ethane. A long-lasting chlorinated hydrocarbon used as an insecticide; now banned from use in the United States because it bioaccumulates. Residual amounts remain in the aquatic environment due to its historic use and persistence.

DISSOLVED OXYGEN Free oxygen in the water; required by most aquatic organisms.

DOMESTIC WASTEWATER Sanitary waste.

DROWNED RIVERMOUTH Type of lake formed when the mouth of a river is separated from the receiving lake by a natural obstruction such as a sand dune.

ECOSYSTEM The interacting system of a biological community and its environmental surroundings.

EPA U.S. Environmental Protection Agency

ERD Environmental Response Division of the Michigan Department of Natural Resources

EUTROPHICATION A general term used to describe the aging process of a lake; over time a lake progresses from being deep and biologically unproductive to being shallow and very biologically productive. (*See also* cultural eutrophication.)

EXOTIC SPECIES Species not native to an area.

FCMP Fish Contaminant Monitoring Program; conducted by the Surface Water Quality Division of the Michigan Department of Natural Resources.

FISH-CONSUMPTION ADVISORY *See* consumption advisory.

FISH TAINTING Chemical odors or taste in fish.

FLOODPLAIN Land area over which a river flows during peak flow periods.

GROUNDWATER GRADIENT The difference in elevation between two locations at the top of a aquifer; determines the direction in which groundwater will flow.

Glossary and Acronyms cont.

GSI Ground- and surface water interface (point of intersection)

IJC International Joint Commission, composed of representatives of the United States and Canada; responsible for monitoring the implementation of the Great Lakes Water Quality Agreement between the two nations.

IMPAIRED USE or **IMPAIRED BENEFICIAL USE** (*See also* beneficial use.) A productive use of a water body which has been degraded or destroyed.

INDICATOR SPECIES A particular species whose presence or relative abundance has been demonstrated to be directly related to a particular environmental condition.

LaMP Lakewide Management Plan; prepared for each Great Lake according to the terms of the Great Lakes Water Quality Agreement.

LITTORAL ZONE Shallow water habitat.

LOADING The rate at which a substance is added to a water body.

MDNR Michigan Department of Natural Resources

MDPH Michigan Department of Public Health

MERA Public Act 307 of 1982, the Michigan Environmental Response Act

MOE Ministry of the Environment (Ontario)

NONPOINT SOURCE DISCHARGE Diffuse; does not have a single point of origin. (*See also* point-source discharge.)

NPDES National Pollution Discharge Elimination System; the federal program for controlling discharges of pollutants from point sources into the waters of the United States.

ORGANIC Referring to or derived from living organisms or, in the case of chemistry, the class of chemical compounds that contain carbon.

OUTFALL Discharge point.

PAC Public advisory council

Glossary and Acronyms cont.

PAH Polycyclic nuclear aromatic hydrocarbon. Component of crude and refined petroleum and coal; most are formed during incomplete combustion of organic matter; also may be released from oil spills, leaching of asphalt road surfaces, and wear of vehicle tires. Highly persistent in the environment and bioaccumulate in organisms.

PARAMETER Variable affecting water quality, e.g., heavy metal, nutrient, pH.

PCB Polychlorinated biphenyl. A class of persistent chlorinated hydrocarbon chemicals; toxic at low levels and bioaccumulate. Industrial use of these chemicals first was restricted in the 1970s.

PERSISTENT Breaks down slowly or not at all.

pH A measure of the hydrogen ion activity in solution, expressed in "standard units" on a scale of 0 (highly acid) to 14 (highly basic); 7.0 is neutral.

PLUME The pathway an environmental media, such as air or water, takes from a particular point.

POINT-SOURCE DISCHARGE A single, identifiable source (e.g., a pipe or smokestack) of a discharge. (*See also* nonpoint source discharge.)

PROCESS WASTEWATER Effluent from industrial processes.

PURGE WELL A well used to remove and treat contaminated groundwater.

RAP Remedial Action Plan

RECHARGE Replenish water to an aquifer.

RULE 57(2) A rule promulgated under Michigan Public Act 245 of 1929; sets standards for the maximum presence of substances in water.

RUNOFF The portion of precipitation that travels over the surface of the land, compared to that portion that infiltrates.

SANITARY WASTE Nonindustrial sewage.

STRATIFICATION Occurs when there are significant temperature differences between the top and bottom of a deep lake. During stratification, water layers are of different densities due to temperature, and they do not mix.

Glossary and Acronyms cont.

SUPERFUND Federal Hazardous Waste Trust Fund; established to clean up contaminated sites under the CERCLA program. (*See also* CERCLA.)

SURFACE WATER Rivers, lakes, streams, bogs, and so on, as differentiated from groundwater.

SWQD Surface Water Quality Division of the Michigan Department of Natural Resources

TEMPERATURE STRATIFICATION *See* stratification.

TOXICS In this document refers to toxic chemicals.

TURBIDITY A cloudy condition or degree of opaqueness of water due to the suspension of silt or organic matter.

TURNOVER The normal spring and fall mixing that occurs in moderately deep lakes that stratify. During turnover the physical and chemical measurements are nearly the same from top to bottom of the lake.

VOLATILE Evaporates readily.

WATERSHED The land or water area that drains snow melt and/or rainwater to a single, lower receiving water body.

WARM-WATER FISH SPECIES In Michigan, most species other than trout or salmon.

WHITEHALL FACILITY The Muskegon County Wastewater Management System plant at which White Lake area wastewater is treated.

WMSRDC West Michigan Shoreline Regional Development Commission

Executive Summary

Preparation of this update of the 1987 Remedial Action Plan for the White Lake Area of Concern focused on the following objectives:

- Ensuring participation in the process by a public advisory council as well as a team of specialists from the Michigan Department of Natural Resources
- Documenting water quality data collected and analyzed since the 1987 plan was published
- Analyzing the current status of AOC use impairments
- Making recommendations that when carried out will lay the foundation for the next phase of the process, implementing specific measures to remediate the water quality problems of the AOC
- Identify additional data gaps

These objectives were achieved.

The White Lake AOC Public Advisory Council was actively and effectively involved in the process, as was the MDNR RAP Team, which assisted the consultant, Public Sector Consultants, Inc., in collecting information and also provided technical support in analyzing data and interpreting the results to the council.

The update summarizes the results of the 1987 Remedial Action Plan and presents information developed over the last six years in the AOC. The information documents improvements in water quality that are directly related to the control of known point-source pollution and the remediation of groundwater contamination reaching the White Lake from the former Occidental (Hooker/Occidental) Chemical Corporation site.

Water samples collected in the channel from White Lake to Lake Michigan in 1992 indicate that water quality has improved since the previous samples were taken in 1983; all parameters measured in 1992 are within the Michigan limits established to protect water quality. Heavy metal concentrations are lower than those observed in earlier sampling; chloride concentrations are the lowest recorded since testing of this parameter began in 1963; and phosphorus and nitrogen levels have remained relatively stable since diversion of wastewater from White Lake in 1974. Although 1991 fish contaminant monitoring suggests that contaminant levels in fish have declined, 28-day caged fish studies conducted in the channel in 1992 show that chlordane, DDE, and dieldrin still exceed standards.

Analysis of recent information about the Occidental Chemical Corporation site indicates that the plume of contaminated groundwater moving from the site is being intercepted by the lake-front purge-well network and effectively treated before being discharged to White Lake. Other potential sources of groundwater contamination to White Lake and its tributaries have been identified, and remediation efforts are underway.

Water quality data gathered at the outlet of White Lake indicate that Michigan water quality standards are being met. However, these data are insufficient to determine the effect of White Lake on Lake Michigan water quality. Although the situation is much improved, concern still exists; White Lake and similarly situated, large drowned-rivermouth lakes are integral components of the larger Lake Michigan ecosystem. For example, fish and wildlife move freely between Lake Michigan and White Lake, and many species depend on habitat in the White Lake AOC at critical stages of their life cycle. Substantial impairments to water quality or natural habitats in the White Lake AOC can affect the well-being of Lake Michigan.

The public advisory council and the MDNR team have identified eight impairments to uses of the waters of the White Lake AOC; the following are of most concern to the PAC:

- The necessity for restrictions on human consumption of fish and wildlife
- Loss of habitat and degradation of fish and wildlife populations
- Degradation of benthos
- The necessity for restrictions on dredging
- Degradation of aesthetics, including the effects of eutrophication and the presence of associated algal blooms
- Effects of groundwater contamination on public health

To address water quality problems, both the PAC and the MDNR RAP Team members favor employing an ecosystem-wide approach that would incorporate consideration of physical, chemical, and biological components of the areas of concern; they believe such an approach is preferable to focusing on the individual impairments without consideration of their relationship to each other and the ecosystem as a whole. The PAC also supports a watershed approach to addressing issues affecting the lake from areas of the White River watershed system that are not part of the AOC.

Nine specific recommendations are set out in this update:

- continue all pollution abatement and monitoring programs identified in the 1987 RAP,

- develop a nutrient and organic loading model to answer questions related to the trophic status (amount of biological productivity) of White Lake,

- develop a comprehensive soil erosion and sedimentation-control strategy for the White River watershed,

- conduct research to establish objective, quantitative measures of the effect habitat changes have on animal populations dependent on near-shore areas of White Lake during at least part of their life cycles,

- reference current inventories of endangered and threatened species inhabiting the White Lake AOC to identify habitat critical to their survival,

- evaluate heavy metals, primarily chromium, in the sediments affected by the historical discharge of the Whitehall Leather Company and document effects on the biological organisms; determine feasibility of removal if the contaminated sediments are found to be contributing to the degradation of the biological community, and remove if feasible; monitor to evaluate the results of the remediation,

- fill all other data gaps,

- formalize more regular and coordinated interactions between the PAC and the RAP Team, and

- form a White River Watershed Council.

Finally, it is worth noting that when meaningful public involvement occurs in the RAP process, objectives and outcomes reflect local concerns. Residents of the AOC are very sensitive to the pollution problems in their area. Most people who live in the White Lake area are aware of the serious contamination caused by the Occidental Chemical Corporation, and many observed the past degradation. The lake is important to the quality of life of area residents and to the local economy, which depends in part on recreation and tourism. The PAC emphasized the need to provide area residents with more information on factors affecting water quality so that local actions can be taken to improve White Lake. The recommendations in this update reflect local concerns and identify steps that can lead to specific actions to remediate the water quality problems in the AOC.

Introduction

NOTE: Sources for the information in this document are listed in ***List of References***, at the end of the document. Reference numbers appear in brackets in the text where the information is presented.

International efforts to protect and manage the Great Lakes began in 1909 with the Boundary Waters Treaty between the United States and Canada. The treaty created the International Joint Commission (IJC), consisting of representatives appointed by the leaders of the two countries. Accord was furthered with the Great Lakes Water Quality agreements of 1972 and 1978; the latter was revised in 1983 and 1987.

In 1985 state and province representatives on the IJC Water Quality Board identified 42 tributaries to the five Great Lakes that potentially can negatively affect the water quality of the lakes; these are referred to as areas of concern (AOCs). The State of Michigan and the U.S. Environmental Protection Agency (EPA) classified 14 areas in the state as being "of concern." The 1987 revisions to the Great Lakes Water Quality Agreement, referred to above, include guidelines for preparing remedial action plans (RAP) to restore the water quality of the AOCs and thus eliminate their threat to the Great Lakes.

White Lake was designated an AOC in 1985, primarily because of contaminated groundwater migrating to the lake from the site of the Occidental Chemical Corporation (a wholly owned subsidiary of Occidental Chemical Corporation) located less than a mile from the lake. A RAP for the AOC was prepared in 1987. This document is an update to that report and follows the spirit of the guidelines set forth by the Great Lakes Quality Agreement of 1987; it incorporates data and information generated since 1987 about the White Lake AOC and input from a local public advisory council (PAC) as well as a team of technical specialists from the Michigan Department of Natural Resources (MDNR).

White Lake is a scenic, 2,571-acre drowned-rivermouth lake in Muskegon County. It lies very near the east shore of Lake Michigan and flows into Lake Michigan through a channel. The White Lake AOC is part of the White River *watershed* (the land or water area that drains precipitation to a single, lower receiving water body), and the river is the primary tributary to the lake, supplying over 95 percent of its water; other tributaries include Buttermilk Creek, Carlton Creek, Mill Pond Creek, Pierson Creek, and Silver Creek (see Map 1) [7].

Although the north half of the watershed supports extensive agriculture, the predominate watershed land cover is oak/hickory, maple, and elm/ash/cottonwood forest. Local soil types range from highly permeable sandy soils to poorly drained mucks and peat; the primary type is sand. Sandy soils are permeable, and groundwater in the area is vulnerable to the infiltration of contaminants [94].

As one travels up the east shore of Lake Michigan, White Lake is the first lake without extensive industrialization and commercialization, although development and urbanization are expanding in the watershed. Development around the lake, once primarily seasonal homes, has changed to largely permanent residences. As a result, approximately 15% of the original shoreline remains in a relatively "natural" state [86].

White Lake is recognized for its excellent recreational fishing and its access to Lake Michigan for boating and fishing. The lake supports a variety of sport fish including walleye, perch, small and large mouth bass, northern pike, bluegill, black crappie, and white sucker as well as trout and salmon when they are migrating from Lake Michigan to the White River. The lake also provides breeding, migratory, and winter habitat for such waterfowl species as mallard, black duck, wood duck, blue-winged teal, common merganser, Canada goose, tundra swan, and snow goose. Although the lake has no designated public swimming areas, it does have several public access sites and parks that provide lake access for boaters. Ten marinas on the lake provide boat storage, docking and launching [94].

As early as the 1940s there were public complaints about the waste discharges in the vicinity of Tannery Bay from the Whitehall Leather Company. A variety of businesses including chemical companies and a formerly active lumber industry used White Lake as a repository for their waste [18], and until 1974 Montague and Whitehall—cities located on opposite sides of White River, adjacent to White Lake—discharged *domestic* (residential) waste to White River from the former Whitehall treatment plant. By the 1960s lake quality had deteriorated significantly. With the abatement of industrial discharges (especially those of Occidental Chemical Corporation and Whitehall Leather Company) and the municipal discharge, water quality began gradually to improve in the late 1970s [94].

Some improvement in water quality was apparent in White Lake following the diversion in 1974 of all municipal wastewater and most industrial discharges to the Whitehall facility of the Muskegon County Wastewater Management System. However, in addition to groundwater contamination from the Occidental site, the lake was found to have several other problems when it was listed in 1985 as an AOC: contaminated groundwater from other sources; storm water runoff from industrial, commercial, residential, and agricultural areas (referred to as *nonpoint*, or diffused, pollution); degradation of communities of *benthic* (bottom-dwelling) organisms; accelerated *eutrophication* (aging); elevated concentrations of heavy metals and chlorinated organic compounds in lake sediments; and fish contamination [94].

REMEDIAL ACTION PLAN PROCESS

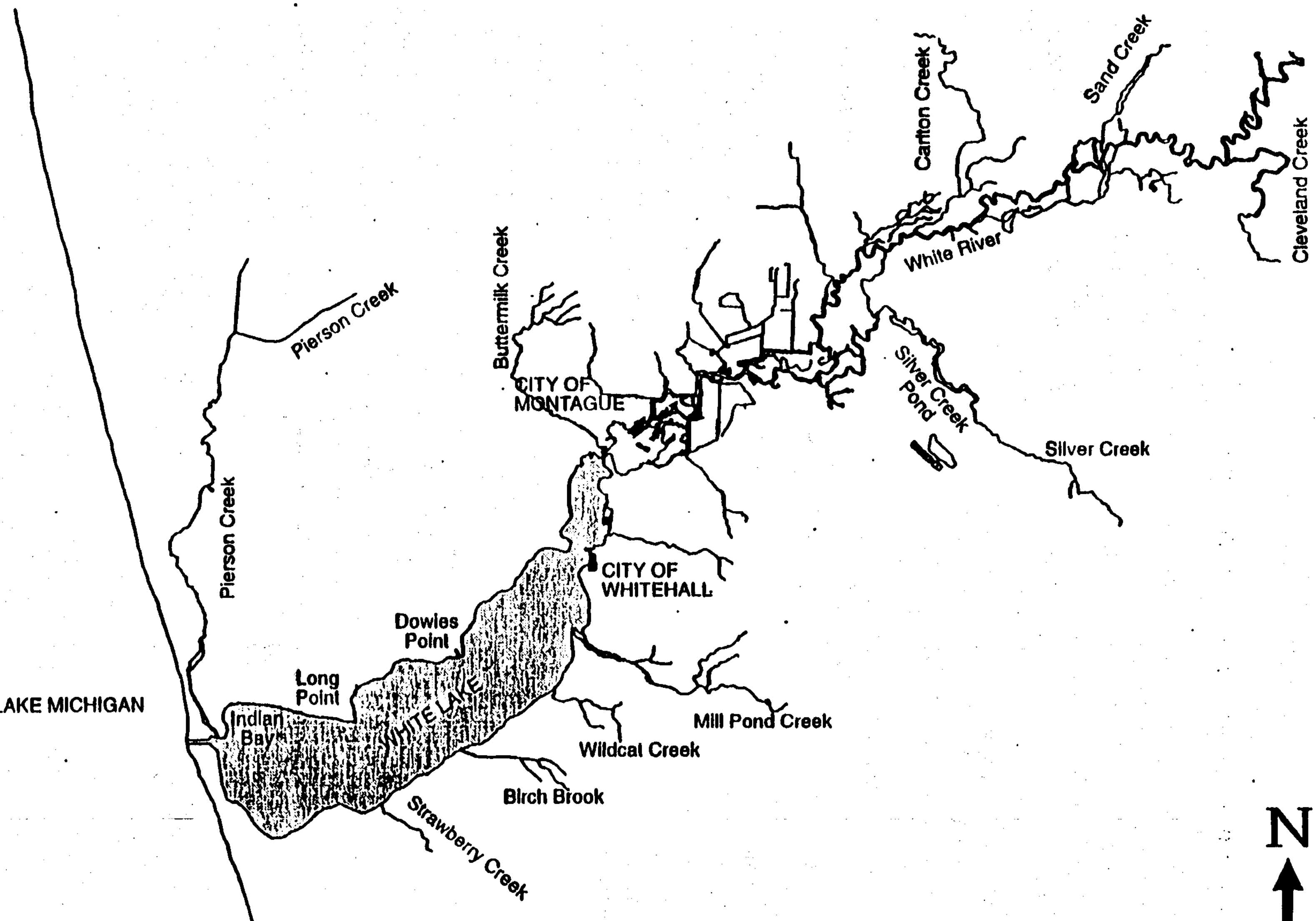
The 1987 revisions to the Great Lakes Water Quality Agreement instituted a requirement that for each AOC, (1) the status of 14 potential impairments to *beneficial uses* of the waters of the AOC (e.g., supporting a fishery, providing acceptable drinking water) be identified, and (2) remedial action plans to reduce or correct the impairments be prepared. A RAP is to be prepared in three stages, and Michigan officials view them as parallel rather than consecutive steps in the process because work on all three can proceed concurrently.

- Stage 1 defines the problem, including a determination as to which of the 14 use impairments exist, the causes of impairment, and the source of contaminants of concern.
- Stage 2 identifies remedial measures needed to restore beneficial uses.
- Stage 3 confirms that beneficial uses have been restored.

The Great Lakes Water Quality Agreement stipulates that RAPs take a comprehensive, ecosystem approach to the restoration and protection of beneficial uses; the RAPs are an important tool for the elimination of persistent toxic substances and the restoration of the biological integrity of the Great Lakes basin ecosystem.

A key element in the RAP process is participation of a local public advisory council (PAC) that represents the community surrounding each AOC. Local involvement in identifying problems and in identifying and implementing remedial actions is critical to eventual success in restoring beneficial uses. Another vital component of the RAP process is involvement of representatives from the state natural resources agency and other relevant state and federal agencies; the RAP Team provides the technical expertise needed to evaluate conditions, identify problems and potential remedial actions, and inform and assist the PAC.

MAP 1: White Lake and Tributaries



SOURCE: Public Sector Consultants, Inc., using material from Geological Survey Division, Michigan Department of Natural Resources.

WHITE LAKE PUBLIC ADVISORY COUNCIL

During preparation of the 1987 RAP there was very little participation by the public. In 1989 White Lake residents became interested in reactivating the White Lake RAP process, and community members attended the first annual Citizens' Conference on Michigan Areas of Concern, hosted by the MDNR in 1990, where they strongly supported formation of the Michigan Statewide Public Advisory Council (SPAC) to ensure long-term, statewide RAP implementation. Community representatives were nominated for council membership, and as of February 1991 White Lake was represented on the newly formed SPAC. In addition, throughout 1991 community members committed to organizing PACs for both White Lake and Muskegon Lake (a nearby lake also designated an AOC), attended informational community meetings about developing PACs for AOCs. The meetings included MDNR, EPA, and IJC staff and were hosted jointly by the White Lake and Muskegon Lake SPAC representatives. In January 1992 the Lake Michigan Federation hosted a citizen workshop to gather public input on forming public advisory councils for both lakes.

Activated by a grant from the Southeast Michigan Council of Governments (with assistance from the SPAC) to the Lake Michigan Federation, a White Lake/Muskegon Lake steering committee began enlisting public members and communicating with the general public about environmental concerns relating to the lakes and about the RAP process. During summer 1992 the steering committee distributed three newsletters, held three public meetings, prepared a slide show, surveyed White Lake and Muskegon Lake residents about their opinion on the state of the lakes, and gave close attention to attracting a balanced, broad-based membership. Representation came from the general public and environmental, business, and public sectors, although members indicate that it was difficult to get business representatives to participate. By September 1992 a PAC for each lake was established, and the White Lake PAC began meeting monthly. Since work on the update began, the PAC has been meeting more frequently than before, and the chair attends RAP Team meetings to facilitate communication between the two groups.

The White Lake group's activities first focused on organizational matters (e.g., electing officers, initiating regular monthly meetings, and expanding membership), attending other PAC and public meetings, participating in the design of a White Lake RAP poster, gathering photographs for an MDNR AOC calendar, submitting formal funding requests, and creating a tabletop display for a lake awareness campaign. Another important accomplishment was acquiring staff assistance from the Lake Michigan Federation and the Muskegon County Soil Conservation District.

In October 1993 the MDNR contracted with Public Sector Consultants, Inc., of Lansing, Michigan, to update the 1987 RAP, incorporating information generated since 1987 and including the active participation of a PAC. The informal public advisory group then was augmented and the membership officially recognized by the MDNR as the PAC for the White Lake RAP. There currently are more than 20 members. The PAC has adopted the following mission statement:

> The White Lake PAC is a coalition of representatives from various community interests. The mission is to foster the enhancement and protection of the use and environmental health of White Lake by promoting local environmental education and assisting the MDNR in preparing and implementing the RAP for White Lake.

At the beginning of the RAP update process, PAC members were asked by the consultant to examine the 14 possible lake use impairments listed in the Great Lakes Water Quality Agreement and suggest which exist in White Lake, in order of severity. Although the council did so, and added one additional concern to the list, it was a difficult exercise for the members because they felt they did not have sufficient information. They continue to feel impeded by this lack of knowledge about lake conditions and inputs. Moreover, during explanation and discussion of the 14 possible use impairments, it was clear that interpretations varied among participants. The members reached consensus with the understanding that the list of problems and the rankings are based more on perception than expertise and may change as new information becomes available to the group. The PAC's decisions and rankings are described in part 4 of this document, ***1995: Impaired Uses of White Lake AOC***. The PAC reserves the option of revising its list of problems and priorities if deemed necessary and also wishes to be on record as stating that this document—the 1995 update—is an update only and not the final, definitive document on the White Lake ecosystem.

In exchange for their individual time and commitment, PAC members have certain expectations of the RAP process and the MDNR technical experts assigned to the AOC: PAC members believe that RAP Team members and the MDNR have the responsibility either to furnish all available information related to White Lake or identify the appropriate contact person or agency from which to obtain it. The members prefer to review and interpret independently how contaminants and conditions affect their lake and their use of the lake.

The PAC is dedicated to actively participating in the continuing improvement of the quality of White Lake. The group would like to continue to interact with the MDNR and other government agencies and help gather data, solicit public input, and educate local residents about local biosystems and the effect human activity has on their integrity. It has developed a calendar for the public that contains environmental information relevant to the area, developed a local repository of RAP information at the local public library, and is working with the City of Whitehall to locate sites for osprey nesting.

MDNR RAP TEAM

The 1987 RAP was prepared primarily by the Surface Water Quality Division (SWQD) of the MDNR, with informal assistance as needed from other department divisions. For this update, the SWQD assembled an official team composed of representatives from its own and the Environmental Response, Waste Management, Fisheries, Air Quality, Land and Water Management, and Wildlife divisions of the MDNR. The MDNR RAP Team identified and provided information for the update, reviewed and advised on the list of use impairments, and evaluated and commented on the draft update. In addition, RAP Team members made presentations to the PAC on specific topics of concern.

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1987 RAP Findings

NOTE: Unless otherwise indicated, all information in this part of the document is from the 1987 White Lake Remedial Action Plan [94].

The groundwater from the Occidental Chemical site had been known to contain such organic solvents as chloroform, trichloroethylene, carbon tetrachloride and tetrachloroethylene, and there had been the additional concern that higher-molecular-weight toxic organic compounds also released at this site were being transported to White Lake by these solvents. Substantial improvement in water quality resulted after the installation of a purge-well capture system by Occidental Chemical. However, in 1987 concern remained that some contaminants from this site still were reaching the lake.

The 1987 RAP concluded that overall water quality in White Lake and its tributaries had been improving since at least the mid-1970s as a result of local, state, and federally sponsored pollution control programs. One such program is the National Pollutant Discharge Elimination System (NPDES), the federal program for controlling discharges of pollutants from *point* (specific) sources into the waters of the United States. In 1973 the EPA had delegated authority to administer this program to the MDNR. This program, which complements state water pollution control efforts, requires all point-source wastewater dischargers to obtain permits regulating their effluent. In addition, implementation of both the federal Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and Michigan Environmental Response Act (MERA) helped initiate the cleanup of some sites in the AOC that historically had contaminated surface and groundwater with hazardous wastes. Also, state and federal regulations adopted in the 1970s and 1980s on handling, storing, and disposing of solid waste and hazardous materials had reduced the potential for future contamination from such sources.

WATER QUALITY

Prior to 1987 a number of studies had noted significant problems with the water quality of White Lake; one, the 1977 West Michigan Shoreline Regional Development Commission (WMSRDC) evaluation, indicated that the lake had failed on 11 criteria to meet the "fishable and swimmable" goal established under the federal Water Pollution Control Act of 1972.

Another, a 1977 EPA study, had classified White Lake as extremely eutrophic (that is, characterized by high nutrient levels, low concentrations of dissolved oxygen in deep water during the summer temperature stratification period, and the presence of nuisance algal blooms). While some improvements had been noted in water quality, particularly following the diversion of wastewater in 1974, the 1987 RAP cited nutrient loadings, contaminated groundwater, urban storm water runoff, and contaminated sediments as remaining water quality issues.

In addition, the 1987 RAP reported that fecal coliform bacteria from untreated human waste and visible oil and grease had been cited as historical problems in White Lake but by 1987 had been successfully addressed.

Cultural Eutrophication

Through at least the mid-1970s White Lake had exhibited classic symptoms of *cultural eutrophication*, aging accelerated by human activity. Domestic waste, industrial discharges, and nonpoint urban and agricultural sources were contributing significant quantities of phosphorus and nitrogen, both major causes of eutrophication. The 1987 RAP noted that there had been some improvement following diversion of industrial and domestic waste from White Lake and White River to the Whitehall facility in 1974: periods of depressed dissolved-oxygen levels during summer *stratification* (periods when there is a significant temperature difference between the top and bottom of a water body; the water layers are of different densities and do not mix) were shorter, and algal mass and chlorophyll concentrations were reduced. Preliminary results of studies being conducted in 1987 indicated that the accelerated eutrophication of White Lake was abating.

The MDNR-established goal (a standard has not been set) for phosphorus concentrations is 30 parts per billion (ppb) or less during lake *turnover* (periods in the spring and fall when lake water mixes and the temperature is nearly uniform from top to bottom); below this level, nuisance algal blooms are minimized, and water quality is suitable for recreational uses. In 1980 phosphorus concentrations in White Lake had been measured at 58 ppb. A significant improvement was noted in 1987, when phosphorus concentrations ranged from 19 to 36 ppb at turnover, with an average concentration of 24 ppb. The 1987 RAP speculated that agricultural practices immediately upstream from the lake, particularly the periodic dewatering (pumping the water off) of muck land and nonpoint-source pollution, could be a major source of the remaining excess nutrient *loadings* (inputs) to White Lake.

Toxic Substances

Heavy metals (such as mercury) and many chlorinated hydrocarbons (such as polychlorinated biphenyls, or PCBs) are substances that can be toxic at low levels, are *persistent* (remain in the environment in their original form for some time rather than breaking down), and some *bioaccumulate* (are taken up and retained by organisms from their environment, e.g. water and food). Even at low and sometimes undetectable concentrations in water, heavy metals and chlorinated hydrocarbons can bioaccumulate in aquatic organisms to levels that cause impairment to the organisms or to animals that consume them.

In preparing the 1987 RAP, lead, copper, zinc, and arsenic levels found in 1979 water samples from White Lake were reexamined and found to exceed the limits established under Rule 57(2) of the 1986 MDNR water quality standards to protect aquatic life. In 1987, limits established under the same rule were applied to the wastewater of four major dischargers to White Lake operating under NPDES permits, and the results raised concerns about the long-term toxicity of these discharges; detail is presented in part 3 of this document, ***1995: Potential Sources of Pollution***. The 1987 RAP cited discharge from Occidental Chemical Corporation as the greatest ongoing threat to the water quality of White Lake.

MDNR studies in 1978 and 1979 had indicated that discharges from Occidental Chemical were causing chemical stratification of White Lake. Later studies revealed that some organic compounds were not being captured by the purge-well system that had been installed to remove and treat the contaminated groundwater from the site before it entered the lake. In 1987 purge-well pumping rates were increased from 135 to 685 gallons per minute, and the levels of chlorinated organics measured in White Lake decreased.

Other toxic contaminants known to be present in White Lake but usually measured in fish tissue rather than water samples, such as mercury, PCBs and chlordane, are discussed immediately below and also in ***Effects of Toxic Contaminants*** under ***Fishery***, in part 2 of this report.

CONTAMINATED SEDIMENTS

Contaminants in lake sediments are a concern for several reasons: (1) They can be resuspended when sediments are disturbed by storms or dredging, directly affecting water quality; (2) at high levels, contaminated sediments can reduce the number and diversity of benthic organisms upon which fish and wildlife feed; (3) even at concentrations not harmful to the benthic community, toxic materials may be bioaccumulated by benthic organisms and transported to animals higher in the food chain; and (4) some *volatile* (evaporates readily) organic compounds and volatile metals, such as mercury, can be released to the atmosphere when contaminated sediments are dredged.

Sediments can be an indicator of whether contaminants still are entering the lake system. *Background* (naturally occurring) levels of metals can be calculated from deep sediments; surface sediments contain more recent contamination.

Sediment samples had been collected and analyzed by the MDNR, WMSRDC, EPA, and U.S. Army Corps of Engineers from 1972 to 1986. The 1987 RAP reported that by 1980, concentrations of mercury, arsenic, cadmium, copper, nickel, and oil/grease had decreased to levels at or below EPA heavily polluted dredge spoils criteria (levels at which the presence of the substances in dredged material, or *spoils*, results in the material being characterized by the EPA as heavily polluted and thus subject to special disposal restrictions). Chromium, lead, and zinc concentrations also had been reported to be on the decrease during the preceding 14 years, however their presence continued to exceed the dredge spoils limits in Tannery Bay near Whitehall Leather Company, in the 12-meter basin off the Occidental Chemical site, east of Dowies Point, and in other deep basins in the lake. Elevated levels of these three heavy metals also had been detected in an unnamed tributary receiving Howmet Corporation discharge. The 1987 RAP cited as the most likely reason for these elevated metal levels the fact that Howmet's discharge flowed through the Whitehall Leather landfill.

The 1987 RAP concluded that PCBs and chlordane in White Lake sediments were a concern since their concentration in carp exceeded the safe consumption levels established by the Michigan Department of Public Health (MDPH) and the U.S. Food and Drug Administration (FDA); this is discussed further below, in ***Contaminant Levels***, under ***Fishery***.

BENTHIC COMMUNITY

Benthic organisms are favored over plankton as gauges of change in aquatic ecosystems because of their wide distribution, sedentary nature, relatively long life cycles, large size, and sensitivity to environmental conditions.

A 1952 survey had found that the benthic community of White Lake reflected eutrophic water conditions, and the 1987 RAP reported that in the 13 years following the survey, eutrophication had accelerated due to industrial and municipal discharges. Fingernail clams had virtually disappeared, pollution-intolerant midge larvae populations had decreased, and pollution-tolerant oligochaetes had begun to dominate. The RAP also reported that a 1976 study of the benthic community in Lake Michigan near the White Lake channel had revealed that the number of oligochaetes was slightly elevated, indicating possible nutrient enrichment from White Lake.

A 1980 survey of White Lake had indicated that the benthic community was recovering, as evidenced by an increase in fingernail clams and midges and a decrease to levels of the early 1950s in the relative abundance of oligochaetes.

FISHERY

Population

In 1987 there were only limited data available about the fish populations in White Lake. The RAP cited one study that reported that after the 1950s the populations of perch, walleye, northern pike, and, most noticeably, white bass, had declined, but the bluegill and largemouth bass numbers had improved; no reasons were provided for these changes, however. In 1983 and 1984 the MDNR and the White Lake Area Sport Fishing Association had attempted, apparently unsuccessfully, to reestablish the lake's white bass population through a restocking program.

Contaminant Levels

Contaminant levels in fish are a function of the concentration of the contaminant in the water, the concentration in the fish's primary food supply, the size and age of the fish (older and larger fish generally have higher levels), the fish's habitat (sedentary, bottom-dwelling species are more likely than others to concentrate toxics from contaminated sediments), and the species's level in the food chain (top-level predators often show higher contaminant levels due to bioaccumulation). In addition, PCBs and many other chlorinated hydrocarbons concentrate in fatty tissue; the higher the percentage of a species's or specimen's fat, the higher the level of contaminant concentration, other factors being equal. Other contaminants, such as mercury, accumulate in muscle tissue.

The 1987 RAP reported surveys revealing that White Lake carp contained chlordane at concentrations averaging 0.6 ppm (0.3 ppm is the FDA "action" level, when the agency takes steps to halt sale of the fish for human consumption) and PCBs averaging 3.7–9 ppm (2 ppm is the MDPH "trigger" for issuing fish consumption *advisories*, or warnings; 2 ppm is the FDA action level).

The 1987 RAP recommended additional fish sampling to determine if further consumption advisories were needed and also if the contamination detected in fish from White Lake and its tributaries was due to historically contaminated sediments or to such current and continuing sources as *atmospheric deposition* (contaminants falling to Earth through the air).

Tainting

Although not listed as an impairment in 1987, a 1975 study had found that carp and white sucker collected in deep water at Long Point were *tainted*—that is, they had poor flavor and an unpleasant odor. Carp and white sucker from shallow areas, as well as all other species from all the sampling sites in the lake, were found to be untainted.

IMPAIRED USE OF WHITE LAKE

Although historically, various uses of White Lake had been impaired (see Table 1), the 1987 RAP concluded that the only remaining lake-wide impaired use was the fishery, as evidenced by the necessity for consumption advisories for carp due to elevated levels of PCBs and chlordane. There were localized problems, however, including contaminated sediments and related degradation of benthos in certain areas of the lake. In general, trends evident in 1987 indicated that White Lake water quality had improved, and the RAP concluded that White Lake was having no apparent adverse effect on Lake Michigan.

TABLE 1: Historically Impaired Uses of White Lake, as Reported in 1987 Remedial Action Plan

Use Impairment	Causes	Sources	Status in 1987
Fish contaminated	Polluted bottom sediments	Occidental Chemical; Howmet; Whitehall Leather Co.	Advisory in effect against eating carp because of PCBs and chlordane
Fish tainted	Polluted bottom sediments	Organics	No longer a problem
Fish reproduction reduced	Loss of benthos	Heavy metals; chlorides; organics; nutrients	Improving
Benthic substrate eliminated	Hair and hides covering substrate	Whitehall Leather Co.	Improving
Benthic population degraded	Depleted dissolved oxygen; high levels of phosphorus and nitrogen; contaminated sediments	Point and nonpoint sources of phosphorus and nitrogen; metals; organic compounds	Improving
Recreation activities restricted; aesthetics impaired	Algal blooms	Point and nonpoint sources of phosphorus and nitrogen	Improving

SOURCES: Wuycheck, John. *1987 Remedial Action Plan for White Lake Area of Concern.* Surface Water Quality Division, Michigan Department of Natural Resources.

STATUS OF WHITE LAKE TRIBUTARIES

As mentioned, White Lake has several tributaries, and the lake's water quality, benthic communities, and sediments can be adversely affected by pollution from its tributaries. The 1987 RAP identified historically impaired uses of the tributaries (see Table 2); septic contamination from areas without sewers and raw domestic sewage discharges were seen as the major sources of contamination to the tributaries listed. The contamination had considerably abated by 1974, when most of the developed area around the lake, including Whitehall and

TABLE 2: Historically Impaired Uses of Tributaries to White Lake, as Reported in 1987 Remedial Action Plan

Tributary, and use impairments	Causes	Sources	Status in 1987
Buttermilk Creek			
Aesthetics impaired; recreation activities restricted	Excess phosphorus and nitrogen; fecal coliform bacteria; suspended solids; oxygen-demanding substances; oil and greases	Raw domestic sewage discharge	Corrected
White River			
Aesthetics impaired	Excess phosphorus and nitrogen above standards	Septic contamination from unsewered areas	Corrected
Carlton Creek			
Recreation activities restricted, aesthetics impaired	Excess of phosphorus and nitrogen; fecal coliform bacteria, oxygen-demanding substances	Septic contamination from unsewered areas	Corrected
Millpond Creek			
Recreational activities restricted	Potential excess of phosphorus and nitrogen; fecal coliform bacteria; oxygen-demanding substances; organic contaminants	Septic contamination from unsewered areas; contaminated groundwater	Septic contamination corrected; groundwater contamination being investigated (Koch/Howmet suspected)

SOURCES: Wuycheck, John. *1987 Remedial Action Plan for White Lake Area of Concern.* Surface Water Quality Division, Michigan Department of Natural Resources.

Montague, had been sewered, eliminating most septic tank discharges to the lake and its tributaries.

The 1987 RAP listed the former White Cloud wastewater treatment plant as potentially affecting the White River. Although this plant was too far upstream to be considered part of the AOC, its *outfall* (discharge) to the White River was examined in response to concern that it may have been affecting the portion of the river in the AOC. A 1981 study had indicated that the river was significantly degraded downstream of the discharge, but a follow-up study in 1983, after the City of White Cloud discontinued using the wastewater treatment plant and switched to a land-disposal system (in which the treated wastewater is used for irrigation), indicated that conditions downstream of the facility were virtually indistinguishable from those upstream [33,34].

Storm water runoff carried by the storm sewer systems of Whitehall and Montague also was cited as a concern because of the potential of the runoff carrying *oxygen-demanding* substances (material that uses dissolved oxygen in the water as it decomposes), suspended solids, nitrogen, and phosphorus into the White River.

Mill Pond Creek also was a concern in 1987, since it received contaminated groundwater from Koch Chemical Company (formerly Muskegon Chemical Company) and Howmet Corporation plants No. 4 and No. 5. Although several volatile organic contaminants had been detected in groundwater seeping to the creek, there was no observed effect on its benthic community. Water samples from the creek had revealed that where the Howmet plant No. 4 discharge entered the creek, contaminant concentrations were below the MDNR water quality Rule 57(2) limits, but where the Koch Chemical discharge entered the creek, concentrations exceeded the limits [96].

In 1983 the MDPH issued a warning (still in effect) against swimming and wading in the unnamed pond upstream from White Lake Drive on Mill Pond Creek because known carcinogens were present and there were contaminated groundwater seeps nearby. However, the RAP reported that biological studies conducted in 1981 and 1983 had noted the presence of benthic organisms and fish, indicating that contaminant concentrations were below *acute* toxicity (immediately harmful or deadly) levels.

SOURCES OF POLLUTION TO THE AOC

NPDES–Regulated Point-Source Discharges

The regulated point-source dischargers—both in 1987 and currently—to White Lake and its tributaries are E.I. du Pont de Nemours and Company (referred to locally as E.I. du Pont), Howmet Corporation, the Whitehall facility, and Occidental Chemical Corporation. Background information on each can be found in Section 5 of the 1987 RAP; a summary follows here.

E.I. du Pont produces fluorocarbons and halogenated hydrocarbon chemicals and is authorized by an NPDES permit to discharge treated *process* wastewater (effluent that has been used in manufacturing processes) and remediated groundwater into Lake Michigan and *intake backwash* (material screened out or otherwise removed from lake water before the water is used for manufacturing) into White Lake. Although the company had exceeded its permit limitations in the 1970s, in 1987 it was in compliance with its NPDES permit.

Howmet Corporation, a manufacturer of turbine-engine components, is permitted by the NPDES to discharge *noncontact* cooling water (water used for cooling equipment only—has no contact with manufacturing processes) to White Lake through an unnamed drain. In 1974 the process wastewater and sewage from Howmet were diverted to the Whitehall facility, eliminating problems previously associated with this discharge. In 1981 a toxicity test of the noncontact cooling water was conducted, and 100 percent of the fathead minnows subjected to the undiluted effluent for 72 hours survived.

The Whitehall facility is permitted by the NPDES to release under-drainage from its land-application site into Silver Creek. In 1987 its permit imposed limitations for various heavy metals, bis ether, bis ethane, fecal coliform bacteria, phosphorous, and ammonia nitrogen. Only a few odor complaints had been documented, and the 1987 RAP indicated that the facility was improving its operations. In addition, the Whitehall facility operations had produced two contaminated groundwater *plumes* (the pathway an environment medium, such as air or water, takes from a particular point). More detail on the contaminants is presented below, under ***Groundwater.***

While in operation, Occidental Chemical had discharged a variety of chemicals into White Lake. (It stopped production and closed its chemical plant in 1977 and completely ceased operations in 1982.) In 1987 the only surface water discharge authorized from this site consisted of treated water collected from the groundwater purge-well system, leachate from the hazardous waste disposal vault, and plant site runoff; the discharge was not named as a concern by the RAP. Contaminated groundwater not captured by the purge wells at this site was a concern in 1987, however, and is discussed below, under ***Groundwater.***

Nonpoint Sources

Urban Storm Water Runoff Storm sewers are potential conduits of conventional pollutants and toxics, including heavy metals and petroleum products. The 1987 RAP identified 25 storm water outfalls into White Lake and its tributaries, and the data indicated that suspended solids, oxygen-demanding pollutants, nitrogen, and phosphorus introduced by these outfalls to the AOC may have been substantial, but insufficient data were available in 1987 to quantify the effects.

Agricultural Runoff Agricultural activities in the White Lake watershed primarily are crop and livestock production, which can generate nonpoint pollution—sources are animal waste; fertilizer, pesticide, and herbicide residue; and soil erosion. The RAP author concluded that agricultural practices in 1987 were not a substantial source of toxins to White Lake but indicated that agricultural contributions to nutrient loadings and sedimentation (from erosion) were of concern and needed further study.

Contaminated Sediments

Even after contaminated sediments settle to the bottom of a water body, they can continue to be a source of toxics if there is a major disturbance, i.e., a violent storm or dredging, or if benthic organisms become contaminated and then are consumed by organisms higher in the food chain. Contaminated sediments were suspected of being a source of the PCBs and chlordane found to be accumulating in fish in White Lake, and the 1987 RAP recommended further study. No sediment removal remediation efforts were proposed.

Groundwater

MERA/P.A. 307 Sites Public Act 307 of 1982, the Michigan Environmental Response Act, requires the MDNR annually to list sites where there has been a release of hazardous substances. All sites discussed below were on the MERA list in 1987 and were known to have contaminated the groundwater, which was flowing to White Lake or a tributary.

As mentioned earlier, improper production and waste disposal practices by Occidental Chemical, a manufacturer of chemicals, had resulted in extensive groundwater contamination. In 1979 the State of Michigan initiated litigation to require the company to capture and treat the contaminated groundwater and contain sources of contamination on the plant property. By 1982 most of the contaminated soils had been excavated and enclosed in a clay-lined vault on the property. Although in 1979 a groundwater purge-well system had been installed to capture and treat the contaminated groundwater plume, in 1987 there was concern that the system was not capturing all of the contaminated groundwater.

E.I. du Pont, another chemical manufacturer, had engaged in disposal practices that by 1961 had contributed to the contamination of several residential wells. The RAP reported that the company had on site a large lime pile containing solids with traces of ammonia, arsenic, copper, and thiocyanate and a burial pit and dump containing drums of neoprene tar, copper chloride salts, potassium and ammonia latex, and general refuse. The RAP also noted that a number of small spills had occurred at the company's bulk storage area and released trichloroethane, tetrachloroethylene, carbon tetrachloride, and methyl chloroform to the ground. The company had installed two purge-well systems to stop the migration of the contaminated plume by 1987 and had agreed to remove the lime pile completely by 1997.

Groundwater contamination had been confirmed at Howmet Corporation's plants No. 4 and No. 5; pollutants included tetrachloroethylene, trichloroethane, and chromium, and the contaminated groundwater was discharging primarily to Mill Pond Creek. The RAP reported that in 1987 the company was making efforts to monitor and remediate contamination.

From the early 1940s until 1974, Whitehall Leather Company, a tannery, had treated its process wastewater in settling lagoons, then discharged it to White Lake. The sludge from the lagoons periodically had been dredged and piled in an adjacent wetland. In 1981 a study had indicated that the sludge piles were contaminating the groundwater, which migrates toward White Lake. The lagoons and sludge piles were capped with clay (to prevent overflow and/or infiltration) and subsequent well monitoring data indicated there was no further escape of contaminants from the site.

The Tech Cast, Inc., site (now referred to as the Anderson Road site) is located on the west side of Montague. The company, which manufactured steel casings, terminated operations in 1984. Groundwater contamination is suspected to have resulted from a spill in the vicinity of the facility, but the source was not identifiable. The MDNR believed a contaminated plume of groundwater was migrating from the site, but no information was available in 1987 on the rate or direction.

White Lake Landfill, Inc., is located approximately 0.5 miles east of Whitehall and adjacent to Interstate 31; it accepts general refuse from industries and residences and had at one time in the past accepted some hazardous waste. The RAP reported that volatile organic compounds, specifically tetrachloroethylene, trichloroethylene, 1,2-dichlorobenzene, chlorethane, and benzene, had been discovered in the groundwater at the site.

Shellcast, Inc., is bordered by the White Lake Landfill property on all sides and produces specialty castings for industry and government. The facility was suspected to be a major contributor to the groundwater contamination discovered at the White Lake Landfill, since tetrachloroethylene, trichloroethylene, and trichloroethane were disposed of at the facility. Given their closeness, the two sites often are considered together.

The 1987 RAP reported that in 1985 White Lake Landfill and Shellcast had entered into a consent agreement with the EPA to provide a permanent alternative water supply to nearby residences where wells had been contaminated.

In the early 1980s elevated levels of nutrients and organic chemicals were detected in groundwater at the Whitehall facility. Contaminants were suspected to be coming from an unlined storage lagoon. Investigation had found that residential wells west of the site were contaminated, and in 1987 corrective actions were being pursued by the MDNR.

The following contaminated water supplies and the potential sources of the contamination also were identified:

- Whitehall municipal wells No. 3 and No. 4, contaminated with volatile organic compounds; for the former the source probably was the adjacent Wash-King Laundromat, and for the latter the source possibly was Howmet plant No. 4 and Koch Chemical Company

- A White Lake Drive residential well, contaminated with low levels of benzene resulting from residential use and improper disposal

- San Juan subdivision residential wells, contaminated by a resident who improperly used degreasing compounds to clean car engines in his backyard

- Montague municipal well at Coon Creek, contaminated with trichloroethylene from the Montague city garage

CERCLA/Superfund Site Koch Chemical is the only site in the White Lake AOC being cleaned up under the CERCLA/Superfund program. The company manufactures a variety of industrial organic compounds. In 1982 a plume of contaminated groundwater had been discovered that extended from the company property to the southeast underneath White Lake Drive to Mill Pond Creek. The 1987 RAP reported that the boundaries of the contaminated plume had been well defined, and no residential wells had been affected.

Although before 1984 Koch Chemical groundwater seeping into the Mill Pond Creek had contained elevated concentrations of various chemicals (primarily volatile organic compounds), biological assessment surveys indicated no apparent effect on benthic communities, and fish analyzed in 1983 had not shown significant bioaccumulation of the substances discharged by the company. Koch Chemical installed a groundwater purge-well and treatment system in 1985. Although by 1987 the system had failed to capture the entire plume, it had reduced the amount of contamination entering the creek.

Atmospheric Deposition

Because of elevated levels of PCBs and chlordane found in the White Lake AOC, atmospheric deposition was listed as a concern in the 1987 RAP. Pollutants emitted in the area and from outside the AOC potentially were being carried in by air currents; however, air quality had not been monitored on the long-term basis necessary to ascertain if airborne pollutants were affecting the AOC. The 1987 RAP recommended increased air monitoring.

2

Findings Since 1987

For this update of the 1987 RAP, the consultant reviewed information and data obtained from several divisions of the MDNR, MDPH, Muskegon County Health Department, EPA, literature, and various other experts. In addition, anecdotal information was received from the White Lake PAC. The purpose was to ascertain the current status of numerous components of the White Lake AOC and identify changes that have occurred since 1987. The following characteristics of the AOC were evaluated: water quality, sediments, benthic community, fish population, suitability of fish for human consumption, fish habitat, wildlife population, and wildlife habitat. Groundwater contamination also was evaluated but is discussed separately, in part 3 of this report—***1995: Potential Sources of Pollution.***

WATER QUALITY

In 1963 the MDNR began routine water sampling at the south bank of the outlet of White Lake to Lake Michigan; until March 1983 samples for certain water quality *parameters* (variables affecting water quality) were taken monthly, but since then only seven samples have been taken—from March to September 1992 [52]. From 1986 to 1989 the MDNR also collected samples from the north-central and west basins of White Lake to evaluate the effect of nutrients entering the lake [50,51].

Using information available at the time from sampling at these locations and from other studies, the 1987 RAP author concluded that following the 1974 diversion of domestic and industrial waste discharges to the Whitehall facility, some improvement to water quality had occurred both in White Lake and in the AOC's discharge to Lake Michigan. The limited information available from the north-central and west basins suggests that currently, the Michigan water standards for un-ionized ammonia (a compound toxic to quatic life), phosphorus,

TABLE 3: Water Quality Data for North Central Basin of White Lake, 1986–1989

Parameter	1986	1987	1988	1989	Michigan Water Quality Standards
Un-ionized ammonia[a] (ppb)	.44–.7	NA	.67–1.39	.8–4	20 for cold-water fish protection 50 for warm-water fish protection
Phosphorus[a] (ppb)	12–19	NA	20–23	16–22	<30[b]
Dissolved oxygen[a] (ppm)	11–11.4	NA	8.5–8.8	6.9–8.0	>5
pH (standard units)	8	NA	8.1–8.65	7.0–8.8	6.5–9

SOURCE: Public Sector Consultants, Inc., using data from Surface Water Quality Division, Michigan Department of Natural Resources.

NA = Not available.
[a]During spring turnover.
[b]The level for phosphorus has been established as a goal, not a standard.

TABLE 4: Water Quality Data for West Basin of White Lake, 1986–1989

Parameter	1986	1987	1988	1989	Michigan Water Quality Standards
Un-ionized ammonia[a] (ppb)	.52–.65	NA	.86–.9	.8–1.45	20 for cold-water fish protection 50 for warm-water fish protection
Phosphorus[a] (ppb)	18–25	NA	19–21	13–21	<30[b]
Dissolved oxygen[a] (ppm)	11.32	NA	8.2–8.5	6.8–7.4	>5
pH (standard units)	7.9	NA	7.5–8.65	7.4–8.9	6.5–9

SOURCE: Public Sector Consultants, Inc., using data from Surface Water Quality Division, Michigan Department of Natural Resources.

NA = Not available.
[a]During spring turnover.
[b]The level for phosphorus has been established as a goal, not a standard.

pH, and dissolved oxygen are being met in the lake, although dissolved-oxygen levels are less than 5 ppm in depths greater than 30 feet during summer and winter stratification. (See Table 3 for data concerning the north-central basin of White Lake and Table 4 for data concerning the west basin.) Data from the outlet connecting White Lake and Lake Michigan indicate that the water is meeting Michigan water quality standards for nutrients and metals [50,51,52].

White Lake

Cultural Eutrophication Indicators that a lake is undergoing cultural eutrophication are diminished dissolved-oxygen concentrations, an increase in nuisance algal blooms, and high concentrations of nitrogen and phosphorus.

In 1988 and 1989 (the last time sampling occurred) at depths greater than 30 feet, dissolved-oxygen concentrations during summer stratification were substantially depleted. In June 1989, at 45 feet the concentration had dropped below 2 ppm in the north central basin and below 5 ppm in the west basin. The low levels lasted through at least mid-September—samples taken then indicated dissolved oxygen in the north-central basin was 1.4 ppm at 20 feet and under the detection limit of 0.1 ppm at 58 feet [50,51].

Average phosphorus concentrations in samples taken at turnover in spring 1986, spring 1988, and spring 1989 in White Lake were under 26 ppb [54]. Despite the fact that the phosphorus goal of no more than 30 ppb during turnover apparently has been reached in White Lake, significant dissolved oxygen depletion still is occurring during temperature stratification. In fact, at depths greater than 25-30 feet—which comprise a significant portion of the lake—there is insufficient dissolved oxygen during certain times of the year to support desirable sport fish species [50,51]. Without additional study, however, it is not possible to predict how water quality, particularly dissolved-oxygen concentrations, in White Lake would respond to further reductions in loadings of phosphorus and oxygen-demanding organic materials.

Un-ionized ammonia was calculated using available information, and it is determined that levels in White Lake from 1986 to 1989 were far below the Michigan water quality limits of 20 and 50 ppb for protection of cold- and warm-water fish, respectively [50,51].

Toxics Consumption warnings due to mercury apply generally to all inland Michigan lakes, including White Lake [46]. Also, in fish from White Lake, PCBs and chlordane have been found to be present at levels sufficiently high to trigger MDPH consumption warnings [47].

In 1991, under the SWQD fish contaminant monitoring program (FCMP), the MDNR conducted a statewide analysis to determine where Rule 57(2) standards for water quality are being exceeded; concentrations of mercury and selected chlorinated hydrocarbons in fish flesh were examined. The results of analysis of walleye and carp samples from White Lake indicate that standards potentially are exceeded for dieldrin, PCBs, chlordane, and DDE, a breakdown product of the banned pesticide DDT) [46]. More detail is presented below, under *Fishery*, in the discussion of the effects of toxic contaminants.

Discharge to Lake Michigan

General Water Quality Parameters For nearly all parameters measured at the outlet of White Lake in 1992, water quality has improved since the previous sampling in 1983. All heavy metals are below the Rule 57(2) limits and also lower than levels observed in samples taken from 1979 to 1984. Chloride concentrations (14-21 ppm) are the lowest overall since testing began in 1963, and pH levels (7.8-8.6 standard unit) are within established water quality limits [52,53]. Phosphorus and nitrogen levels decreased after the diversion of wastewater from White Lake in 1974 and have remained relatively stable since then. Total phosphorus was measured at 19 ppb during spring turnover in 1992, well below the MDNR goal of a maximum of 30 ppb. Estimates of un-ionized ammonia concentrations made during spring turnover in 1992 indicate a level of 0.78 ppb, significantly below the Michigan water quality levels of concern.

Toxics In the FCMP, caged fish are used to detect the presence and long-term concentration trends of certain toxic chemicals that potentially are in Great Lakes tributaries but below analytical detection limits in water samples. The fish concentrate in their tissue certain chemicals from the water in a relatively short time, and the concentration after a given length of exposure (28 days in the FCMP) can be used to compare the water quality among locations [46].

A 1992 caged-fish study in the White Lake outlet to Lake Michigan revealed detectable uptakes of chlordane, DDE, and dieldrin but none of DDT, DDD (a breakdown product of DDT), mercury, heptachlor epoxide, PCBs, or hexachloro-benzene.

SEDIMENT CONTAMINATION

Determining pollutant concentration levels through sediment sampling has limitations: Deposition rates are slow, vary widely, and are difficult to measure; sediment composition varies; pollutant concentrations within sediments vary; sediments can be disturbed by storms and dredging; and sampling techniques are imperfect. To illustrate, deposition rates in a lake can be much slower than at a rivermouth. In the former the rate can be as slow as 1/8 inch annually, which means that the 5-inch surface samples taken from White Lake in 1986 and 1990 may have been accumulating for 35 to 40 years. Near a rivermouth the sedimentation rate can be as rapid as 2 inches annually, which means samples taken from such a location may have been accumulating 2.5 years. However, despite the limitations of the sediment sampling information, the results provide a range of concentrations for various elements and compounds that can be compared to existing standards, toxicity effect levels, and background levels. In addition, areas of a water body that appear to be substantially more contaminated than others can be identified.

TABLE 5: Comparison of Heavy Metal Concentrations in White Lake Sediment Samples in 1986 and 1990 with Various Standards and Levels
(parts per million)

Heavy Metal	White Lake 1986 (Range)	White Lake 1990 (Range)	U.S. EPA Dredge Spoils Criterion	Ontario Ministry of Environment Low-Effect Toxicity Level	Ontario Ministry of Environment Severe-Effect Toxicity Level	Background Level for White Lake (Range)	Current Lake Michigan Level
Arsenic		<0.5-9.1	8	6	33	2.3-5.1	10.5
Cadmium	<2	<2	6	.6	10	1	.9
Chromium	<5-4300	6-4000	75	26	110	6.8-36	46
Copper	<2-34	<2-54.6	50	16	110	2-13	22
Mercury	<.2-1	<0.1-1.48	1	.2	2	.05-.14	.11
Nickel	<5-35	<5-44	50	16	75	2.5-11	24
Lead	<5-110	<5-96.5	60	31	250	2.5-13	1.2
Selenium		<5-1.5				.25-1.2	1.2
Zinc	<5-150	<5-160	200	120	820	12-52	97

SOURCE: Public Sector Consultants, Inc., using information provided by Surface Water Quality Division, Michigan Department of Natural Resources.

Sediment sample analytical results for samples collected from previously sampled sites in White Lake in 1990(97). Of the organic, inorganic, and metals tested, Table 5 presents the range of concentrations found for nine heavy metals in sediments collected from White Lake in 1986 and 1990 [94,97]. The ranges are compared to EPA heavily polluted dredge spoils criteria; Ontario Ministry of the Environment (MOE) low- and severe-effect toxicity levels; and ranges of background levels found in White Lake. The latter were determined from the deepest sediment samples taken from the lake and represent levels of certain elements present in lake sediments before there were extensive human activity and pollution [16]. For comparison, the current levels of the contaminants in Lake Michigan are provided [94].

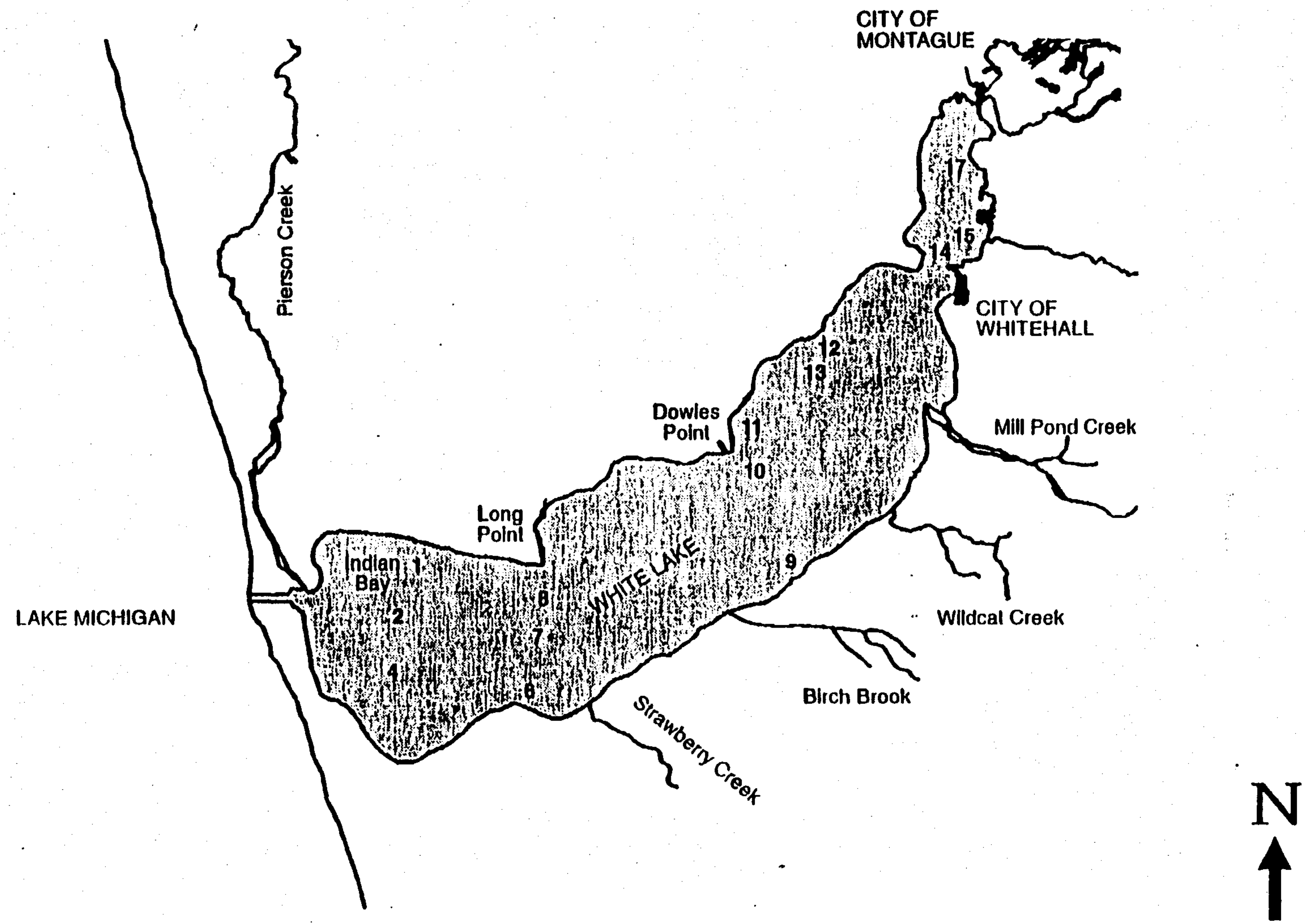
The 1986 data indicate that of the areas sampled, the most degradation was found in sediments taken near Whitehall Leather Company, from mid-lake just north of Dowies Point, near Occidental Chemical just off Dowies Point, from mid-lake off Long Point, and from mid-lake off Indian Bay. The Ontario MOE severe-effect toxicity level was exceeded for chromium at most sites sampled, and the EPA heavily polluted dredge spoils criterion for lead also was exceeded at these five stations [94].

Of the areas sampled in 1990 (see Map 2 for sampling locations), sediments taken near Whitehall Leather Company (stations 14 and 15), mid-lake just north of Dowies Point (stations 12 and 13), near Occidental Chemical just off Dowies Point (stations 10 and 11), mid-lake off of Long Point (station 7) and mid-lake off of the Indian Bay (Station 2) were most degraded. Table 6 indicates that various standards and toxicity levels were exceeded at 11 of the 14 sampling sites. At the eight most-degraded sites, the Ontario MOE severe-effect toxicity level was exceeded for chromium as was the EPA heavily polluted dredge spoils criterion for lead [97]. Sediment samples also were screened for several other toxics, including chlordane, PCBs, aldrin, DDT, DDE, DDD, and mirex; all were less than their respective detection levels.

BENTHIC COMMUNITY

Benthic organisms may be the earliest indicators of changes in water quality. Generally an increase in the relative abundance of pollution species intolerant, indicates that conditions are improving. Since chemical data on heavy metals and dissolved oxygen often are inconclusive, periodic sampling and analysis of the White Lake benthic communities are being done to determine if lake water quality is continuing to improve and thus whether pollution abatement efforts are effective or additional steps are necessary. A study of two samples of the benthic substrate in White Lake taken in 1989 at a depth of 18 feet indicated that the relative abundance of oligochaetes in the lake is declining but because of the small sample size, conclusions about whole lake benthic community health cannot be made [16]. Results of more comprehensive assessment of the benthic community done in 1990 will be available in 1995.

MAP 2: White Lake AOC Sediment Sampling Sites, 1990



SOURCE: Public Sector Consultants, Inc., using material from Geological Survey Division and Surface Water Quality Division, Michigan Department of Natural Resources.

TABLE 6: Contaminants Exceeding Selected Standards and Effect Levels, White Lake Sampling Stations, 1990

Sampling Station*	U.S. EPA Dredge Spoils Criterion	Ontario Ministry of Environment Low-Effect Toxicity Level	Ontario Ministry of Environment Severe-Effect Toxicity Level
1	None	None	None
2	Chromium, lead	Arsenic, chromium, copper, lead, nickel	Chromium
4	Chromium	Chromium, lead	None
6	None	Chromium	None
7	Chromium, lead	Arsenic, chromium, copper, lead, nickel	Chromium
8	None	None	None
9	None	Chromium	None
10	Chromium, lead	Arsenic, chromium, copper, lead, nickel	Chromium
11	Chromium, lead	Chromium, copper, lead	Chromium
12	Arsenic, chromium, lead	Arsenic, chromium, copper, lead	Chromium
13	Chromium, lead	Arsenic, chromium, copper, lead, nickel	Chromium
14	Arsenic, chromium, lead, mercury	Arsenic, chromium, copper, lead, mercury, nickel, zinc	Chromium
15	Chromium, copper, lead	Arsenic, chromium, copper, lead, nickel, zinc	Chromium
17	None	None	None

SOURCE: Public Sector Consultants, Inc., using information from Surface Water Quality Division, Michigan Department of Natural Resources.

*Map 2 shows the location of the sampling stations.
NOTE: At stations 3, 5, and 16, sediments were composed of sand or wood chips, and no samples were taken.

FISHERY

Population

General Description White Lake is described by some as one of the most popular and valuable fisheries in west Michigan. The lake maintains an excellent fishery for northern pike, largemouth bass, smallmouth bass, walleye, yellow perch, redhorse sucker, white sucker, bluegill, crappie, and carp. The MDNR conducts general fish surveys on White Lake, but they document only the number, type, and age of the individual specimens collected; estimating the total population of a particular fish species in a water body as large as White Lake is difficult and expensive [22,79].

Despite the excellence of the current AOC fishery, there has been some degradation. Populations of walleye, lake sturgeon, Great Lakes muskellunge, and white bass in White Lake have declined, are severely depleted, or have disappeared. This could be due to a combination of factors, such as historically elevated pollution levels, introduction of exotic species, loss of habitat or competition. The walleye population seems to be improving; its recovery has been augmented by a program of the MDNR and the White Lake Area Sport Fishing Association to restock walleye in the lake. The program is having success, and some natural reproduction is occurring [62]. White bass were released into the lake in the mid-1980s, but natural reproduction does not appear to be occurring at this time. The MDNR is seeking wild stocks of white bass for introduction to the lake [62].

Effects of Toxic Contaminants Although the link between toxic contaminants and the physical condition and reproductive capability of fish in the Great Lakes has not been thoroughly explored, there is some evidence of a relationship [26,71]. Studies suggest that population declines in lake trout are partially attributable to elevated contaminant concentrations, and such skin alterations as lesions, papillomas, and other deformities have been linked with the presence of polyaromatic hydrocarbons in some Great Lakes fish [71].

Lymphocystis, a viral-induced skin lesion, has been observed in 10 to 20 percent of Muskegon Lake walleye collected annually in the spring by the MDNR for propagation and later stocking in other lakes in the state [78]; no information specific to White Lake is available. "One recent study on Thames River walleye in Ontario, Canada, concluded that this common walleye disorder probably is caused by factors such as stress associated with spawning, not by environmental contaminants [76]." No specific information was found relating toxic substances to physical deformities or reduced reproductive capability of the fish in White Lake.

Toxic contaminants also affect the extent to which humans should eat fish. The 1993 MDNR FCMP annual report states that PCBs continue to be the chemical contaminant most often found in Great Lakes fish, although in most the level is not high enough to trigger the issuance of a MDPH advisory that humans should halt or restrict their consumption of fish of a particular species or locale. Generally speaking, Great Lakes carp have higher levels of PCBs and chlordane than do other species, and walleye have higher levels of mercury.

The 1987 RAP identified the MDPH's issuance of consumption advisories because of PCBs and chlordane in White Lake carp as evidence of the AOC's fishery being impaired. One advisory recommends no human consumption of White Lake carp due to PCBs and chlordane contamination. In addition, general fish consumption advisory recommends that because of statewide mercury contamination of certain fish, consumption of fish from *any* inland Michigan lake be limited to one meal a week [46].

In 1991, 10 carp and 10 walleye were collected from White Lake; Table 7 shows the mean concentrations found of the contaminants tested for in the fish and the MDPH consumption advisory trigger levels for each. The mean concentrations of all contaminants in all the fish tested were below the MDPH trigger levels. Mercury, PCB, and chlordane trigger levels were exceeded in some individual fish, however. The two largest walleye, each over 25 inches long, had mercury concentrations of 0.53 ppm; four carp, all longer than 23 inches, had individual PCB concentrations of 3.3, 2.9, 2.05, and 2.7 ppm; and one carp, 27 inches long, had a chlordane concentration level of 0.31 ppm [46].

TABLE 7: Mean Contaminant Concentrations In Fish Collected from White Lake, Compared to Michigan Department of Public Health Consumption Advisory Trigger Levels, 1991 (parts per million)

Contaminant	Carp[a]	Walleye[b]	Advisory Trigger Level
Mercury	0.2	0.23	0.5
Total PCB	1.3	0.236	2.0
Total chlordane	0.107	0.039	0.3
Total DDT	0.657	0.039	0.3

SOURCE: Public Sector Consultants, Inc., using data from Surface Water Quality Division, Michigan Department of Natural Resources.

[a]Ten were tested.
[b]Ten were tested.

Carp and walleye—the species most apt to show PCB, chlordane, and mercury contamination—collected from Lake Michigan, far offshore from the outlets of White Lake and Muskegon Lake, in 1988 had elevated mean concentrations of these contaminants (6.5 in carp, 0.46 in carp, and 0.52 ppm in walleye, respectively) [56]. Elevated levels of contaminants have been detectable in fish as far north in Lake Michigan as Little Bay de Noc [39]. Although inconclusive, this information supports the conclusion that the contamination of certain fish in White Lake due to PCBs, chlordane, and/or mercury may be a regional as well as, a local phenomenon.

Effects of Exotic Species *_Exotic* species (not indigenous to the locale where found) can affect native fish populations by competing for food and habitat. Various exotic species have invaded White Lake, including purple loosestrife, Eurasian watermilfoil, common carp, alewife, and zebra mussel.

Purple loosestrife, a fast-growing, invasive plant can colonize rapidly in shallow wetlands, forming monocultural stands that eliminate essential native food and cover for many plant and animal species. Another invasive plant, Eurasian watermilfoil, inhabits shallow water and can alter aquatic habitat by crowding out indigenous plant species. The extent to which these exotic plant species are established in White Lake is unknown at this time [23,25] .

Common carp have become firmly established in White Lake, as has alewife. Some sources indicate that the proliferation of the latter abetted the decline or elimination of particular species, such as yellow perch or white bass, in White Lake. Unfortunately, the lake also was receiving large quantities of pollution at the same time, so it is difficult to say with certainty whether alewife is the predominant cause of certain fish populations declining.

One of the more recent invading species is the zebra mussel, first reported in White Lake in 1991 [56]. Its numbers currently are limited, but appear to be growing; observers note that most wood and other suitable substrate, including clams, often have some zebra mussels attached. There are no published studies, however, regarding the colonies' densities or problems they may be causing in the lake [24,25]. Although there are no scientific data to document that it is occurring in White Lake, large populations of zebra mussels filter large quantities of suspended solids and plankton, resulting in a potential increase in water clarity. As water clarity increases, solar radiation can penetrate to greater depths, providing improved conditions for macrophytic (rooted aquatic plants) growth. Research is necessary to assess whether zebra mussels directly affect, adversely or beneficially, Michigan fish populations, their food sources, or their habitat.

Risks to Habitat

Fish habitat in some areas of White Lake has been degraded due to toxic contamination of sediments, depletion of dissolved oxygen in deep water areas, and development of the shoreline. Fish habitat in Mill Pond Creek, a tributary, has been degraded by the inflow of contaminated groundwater.

Toxic Contamination As described above, in ***Sediment Contamination***, certain areas of White Lake contain contaminated sediments; if contamination levels are sufficiently high, an area becomes uninhabitable for benthic and fish communities. In 1988 a habitat survey for Mill Pond Creek was conducted in response to recommendations in the 1987 RAP. Biological surveys indicate that benthic communities are degraded downstream from Koch Chemical's contaminated groundwater discharges to the creek. More detail on the status of Mill Pond Creek is provided in part 3 of this document, in the discussion of the CERCLA/Superfund site.

Dissolved-Oxygen Depletion As mentioned, at certain times of the year, during potential periods of temperature stratification, dissolved-oxygen levels at 45 feet and below are severely depleted; in some extreme cases, dissolved oxygen at 50-foot depths is less than one ppm. Most game fish species cannot survive for long periods in water with less than 5 ppm dissolved oxygen, therefore the depletion limits the available habitat. This phenomenon is not uncommon in the summer during stratification and may be what is expected to occur naturally in a drowned-river mouth in southern Michigan.

Development has occurred primarily along the northeast end of White Lake, near Whitehall and Montague, and is primarily residential and recreation related. In recent years, housing around the lake has undergone a transition from primarily seasonal to primarily permanent residences. Over the last 15 years, approximately 150 permits have been issued for piers, bulkheads, seawalls, dredging, marinas, and other activities associated with development in or near the lake [48]. The number of watercraft registered in Muskegon County (15,000) has increased 20 percent since 1987, and increased recreational use of White Lake has spurred marina development; four have been built on the lake since the 1987 RAP was prepared [68,94]. Because of increased recreation demand, the potential for development on the remaining natural shoreline is high.

The Fisheries Division of MDNR indicated that development can often pose a substantial risk to the White Lake fishery by eliminating shallow-water habitat. Such habitat serves several important functions, among them providing places for fish spawning, nursery, rearing, and foraging [72]. Disruption—by marina construction and operation, for example, and the installation by residences and businesses of seawalls, bulkheads, and riprap (sustaining walls of piled stones or chunks of concrete)—degrades or destroys shallow-water fish habitat.

In White Lake, shallow-water fish habitat is limited primarily to the northeast portion of the lake, above the "narrows". As much as 85 percent of the available shallow-water habitat that once existed northeast of the narrows has been dredged or filled for marinas, piers, or other development or has suffered from such other alterations to the shoreline as the installation of seawalls and riprap [78]. Such development can substantially reduce desirable fish habitat. West of the "narrows", the littoral zone habitat is more limited because in many places the bottom drops off sharply close to shore [22].

Only limited studies have been conducted to quantify the effect on fish habitat of development in littoral zones. In conjunction with the department's Land and Water Management Division staff, the MDNR Grand Rapids District fisheries staff conducted a series of electrofishing surveys in White Lake in 1989, 1990, 1991, and used the results to compare game fish use of natural and developed littoral zone habitat; as shown in Table 8, the number of fish is substantially lower in developed areas, where the littoral zone has been disturbed, than in undeveloped areas. There also are fewer fish species where shorelines have been developed [63]. Please note that these surveys can only generally compare fish populations in these areas and are not intended to be definitive scientific studies.

TABLE 8: Game Fish In Undisturbed and Developed Littoral Zone Habitats, White Lake

Year of Sample	Fish Per Foot at Undisturbed Sites	Fish Per Foot at Developed Sites	Percentage Difference
1989	0.104	0.018	-83%
1990	0.083	0.007	-92
1991	1.36	0.018	-99
AVERAGE	0.516	0.014	-97%

SOURCE: Public Sector Consultants, Inc., using fisheries survey data from Michigan Department of Natural Resources, Grand Rapids District.

To be able to accurately measure fish use of already-developed shoreline areas or predict the effect of further development, considerably more study is necessary. The Great Lakes Shorelands Section of the MDNR Land and Water Management Division is conducting a study to develop a database for decision making about proposed development on White Lake and other drowned-rivermouth lakes in Michigan; data are being collected on fish habitat, interrelationships among populations, aquatic vegetation distribution, and other relevant parameters [24,38]. In addition, information is available about threatened and endangered plant and animal species and can be referenced to identify unique characteristics of a lake that should be considered in deciding whether development shall be permitted.

Secondary potential risks to fish habitat in White Lake include nonpoint-source pollution from agricultural practices and urban storm water runoff and also from sediments flowing into the water and covering existing habitat; there are no studies, however, that quantify the effects of such pollution on fish habitat in the lake.

MDNR Fisheries Division Management Goals

The following are the current MDNR Fisheries Division water quality and habitat protection goals for White Lake:

- Protect and restore White Lake for warm-water fish species
- Limit further development in the upper lake that would adversely affect important littoral zone habitat
- Ensure that the extensive marsh complex upstream of White Lake is protected for northern pike spawning and for forage fish
- Protect tributaries to the White River and White Lake for cold-water fish species

WILDLIFE

Population

Historical accounts indicate that the Great Lakes basin once contained abundant wildlife and waterfowl. As described in 1834, "There are swans, geese, and such prodigious quantities of ducks as to blacken the water when they settle down, and when they rise the noise they make with their wings may be heard at the distance of a mile [2]." Waterfowl and wildlife use of the Great Lakes basin has diminished in modern times due to human encroachment and other factors.

Other than annual surveys of waterfowl conducted by the MDNR in Muskegon County to obtain information on the types and numbers of birds in the area, there are no current data specific to the White Lake AOC regarding wildlife species and population. It is known, however, that White Lake and adjacent habitat comprise one of four open-water estuaries along the east coast of Lake Michigan that together provide two-thirds of the waterfowl habitat around Lake Michigan [64]. White Lake's approximately 2,500 acres of open water provide important habitat for migratory waterfowl, and the lake and the White River also have shallow water wetland complexes suitable habitat for feeding and nesting by a variety of wildfowl such as mallard, Canada goose, blue-winged teal, and common merganser. Other wildlife species found in the vicinity of White Lake include mute swan, bald eagle, osprey, heron, mink, and otter.

Environmental toxicology studies in the Great Lakes basin began in the 1950s, when reproductive failure and population declines were noticed in certain wildlife species [71]. Bald eagle, waterfowl, mink, otter, and other fish-eating birds and mammals have been monitored in recent years because of their particular susceptibility to certain toxic chemicals. Documented in numerous studies are developmental abnormalities in several species in the Lake Michigan watershed due to PCBs, DDT and DDE, dioxins, and other toxic contaminants [71].

The draft 1993 EPA Lake Michigan Lakewide Management Plan (LaMP) says of toxic pollutants in the Lake Michigan watershed,

> The effects of PCBs, DDT, dieldrin, and other contaminants are still being observed in the Lake Michigan watershed. Data collected during the 1980s has shown a trend toward improving conditions. Environmental data, particularly fish tissue contaminant monitoring and wildlife monitoring, suggest that progress has been made in reducing the inputs of a number of these substances through bans, suspensions, and restrictions on substance production and use, and through limitations on point source discharge [71].

As mentioned, wildlife population trends in the White Lake area are difficult to determine because there are insufficient AOC-specific data. General observations can be made about several species present in the county, however.

The bald eagle population has been closely monitored in the Great Lakes region since the mid-1970s. Bald eagles are at the top of the food chain and feed on many lower species including fish, gull, and waterfowl as well as carrion. Thus they are highly susceptible to bioaccumulation of toxic chemicals. DDT and dieldrin have been directly linked with the degradation of the bald eagle population on the Lake Michigan shoreline [12], and their use has been banned. In the last several years the number of breeding pairs in Michigan and Ohio has dramatically increased, from 102 in 1981 to 220 in 1992 [12]. Overall, the number of nests in Michigan is increasing, primarily in the Great Lakes coastal region. In the Muskegon area, bald eagles have been sighted for several years, but the first known nesting pair in recent times was observed in the lower Muskegon River area in 1992; one eaglet hatched and was successfully raised. The pair nested again in 1993, and one young was hatched. However, the hatchling was observed missing from the nest after two to three weeks and presumed dead. In 1994 the eagles produced one known egg, but stopped incubation after several weeks. The egg was recovered by the U.S. Fish and Wildlife Service. Analysis of this egg will hopefully provide some answers about the eagles' reproductive failures [32].

A species doing very well in the area is the Canada goose. Fall flight estimates by the MDNR Grand Rapids District office indicate that there has been a substantial increase in recent years, from approximately 100 in 1969 to more than 9,000 in 1993 [37]. This trend is indicative of Canada goose populations state wide, but there are no data that correlate the increase in the local Canada goose population to habitat conditions in the White Lake AOC.

Mink is a mammalian species highly susceptible to the effects of bioaccumulation of contaminants [3]. The draft LaMP reports that "mink have virtually disappeared from the shoreline areas of large portions of Lake Michigan [20]." Laboratory studies show that captive mink fed diets of Lake Michigan fish have higher adult death rates and reproductive failure than do captive mink fed fish from other areas. Although there are no data for the White Lake AOC, along the Muskegon River the mink population appears to be increasing [32].

Otter numbers also are increasing in the lower Muskegon River. The recent high incidence of otter taken in traps set for other species seems to indicate an increase in otter abundance. Because of this increase in accidentally trapped otter, and increasing observations in the entire district, an otter trapping season has been proposed for Muskegon County, which would allow one legal otter trap [32].

Unfortunately, there are no baseline data on reptile and amphibian populations for either the region or the White Lake area [3,32]. The general consensus, however, is that reptile and amphibian populations are decreasing because, of all species, they are most susceptible to contaminants and loss of littoral zone and wetland habitat.

Habitat

Wildlife habitat can become degraded through toxic contamination, loss or *fragmentation* (break up or disconnection, which reduces the amount of usable habitat for larger-sized wildlife and also threatens smaller and/or isolated species) by development, competition from exotic species, and human recreational activities [23].

Toxic substances have made some areas around Lake Michigan virtually uninhabitable by species that depend on habitat adjacent to the lake for shelter or forage [15]. In and adjacent to White Lake, however, there are no known sites officially classified as uninhabitable for wildlife [32].

Baseline data specific to the loss of wildlife habitat in and adjacent to White Lake are not available, however the MDNR Michigan Natural Features Inventory may help: One of its projects is to use original land surveyor notes and other historical sources to compile presettlement vegetation maps, which, when used in conjunction with existing land use maps, should make it possible to estimate how much wildlife habitat has been lost due to development.

The northeast end of White Lake—where there is a substantial littoral zone—has been subject to development in the past, and pressures for further development are increasing. Detail about development along the shore of White Lake is provided above, under ***Fishery***, in the discussion of risks to habitat.

The effect of exotic species on indigenous plant and animal species also is described above, under ***Fishery***. Although there are no available data to measure the effect of zebra mussels on wildlife populations in the Great Lakes, ongoing research in some European countries documents an increase in waterfowl that feed on zebra mussel [64]. Research will be necessary to assess whether recently introduced exotic species directly affect, adversely or beneficially, wildlife populations or habitat in Michigan.

The effect of human recreation on wildlife specifically in White Lake has not been studied, but such activities as boating, wind surfing, jet skiing, and swimming are known to affect both plant and animal life. For example, when such activity is heavy, it evokes a stress response in wildlife, which results in decreased feeding and increased use of stored energy; prolonged disturbances can cause weight loss and reduce the overall fitness of waterfowl. The effects of recreation activities on aquatic vegetation are documented; if vegetation becomes degraded, there is a substantial negative effect on critical wildlife feeding and nesting habitat [64].

The Wildlife Division of the MDNR identifies three factors as currently most threatening to White Lake wildlife habitat. They are, in order of seriousness, (1) the effects of dredging and development, (2) the presence of exotic species, and (3) fragmentation. Dredging, in addition to causing resuspension of contaminants and solids present in sediment, diminishes or destroys littoral habitat, eliminates plant communities, and disrupts the food chain. When exotic species, such as purple loosestrife, become established, they often alter habitats and food webs, and displace native species. Fragmentation of White Lake wildlife habitat from development has eliminated many wildlife travel corridors with the result that suitable habitat is isolated and less accessible to wildlife [32]. To document and assess the effects of the three threats specifically to White Lake wildlife habitat, additional research is necessary.

TRIBUTARIES

White River

Specific data generated since 1987 on the effects of the Whitehall facility discharge to White River are presented in part 3, under ***NPDES–Regulated Point-Source Discharges***. It can be said, however, that the effluent generally is meeting Michigan water quality standards for the protection of aquatic life.

Silver Creek

Portions of Silver Creek had been degraded by the inflow of contaminated groundwater from the Whitehall facility, mostly due to high nutrient levels, including ammonia. In 1988 liners were installed in the facility's storage lagoon, and interceptor wells were installed on the site to prevent further contamination [89]. In 1992 a biological survey was conducted by the MDNR, and the results from upstream and downstream of the Silver Creek Pond indicate that the macroinvertebrate and fish populations are "good." In addition, in 1983 un-ionized ammonia levels had been found to be elevated (20–51 ppb) in Silver Creek Pond; in 1992, after installation of the lagoon liners, un-ionized ammonia levels again were tested, and concentrations were below one ppm, indicating that groundwater contamination from the Whitehall facility was not venting to the creek, and the lagoon liners were effective [62].

Mill Pond Creek

In 1988 a biological survey downstream from where Koch Chemical's contaminated groundwater flowed in the creek showed degradation; the benthic community was diminished, and chemical odors were present [96]. Specific data generated since 1987 on the effects of Koch Chemical's discharge to Mill Pond Creek are presented in part 3, under ***Groundwater***.

Carlton Creek

In 1988 a biological and sediment contaminant assessment of Carlton Creek, in the vicinity of Kurdziel Iron Industries, a foundry, was conducted to assess the influence of the Kurdziel facility on the quality of the stream's biological community and the sediment concentrations of inorganic and organic contaminants. The study found that the benthic community both upstream and downstream of the facility was characteristic of those found in good water, and concentrations of heavy metals and organic compounds in sediment samples both downstream and upstream were similar. It appears that the Kurdziel operations are not adversely affecting the creek [95].

Pierson Creek

Investigations have not been conducted in Pierson Creek since 1978, at which time elevated levels of copper, lead, zinc, and chromium were detected in sediments. The source was an E.I. du Pont disposal area used for wastewater treatment solids, primarily carbonates.

3

1995: Potential Sources of Pollution

NPDES-REGULATED POINT-SOURCE DISCHARGES

Currently, there are four point-source dischargers to White Lake AOC waters that are regulated by the NPDES program: E.I. du Pont, Occidental Chemical Corporation, the Whitehall facility, and Howmet Corporation. The SWQD district staff indicates that all four are in compliance with the effluent limitations in their permits. Table 9 identifies the dischargers and indicates the type of effluent the facilities are permitted to discharge. Map 3 indicates the location of the dischargers.

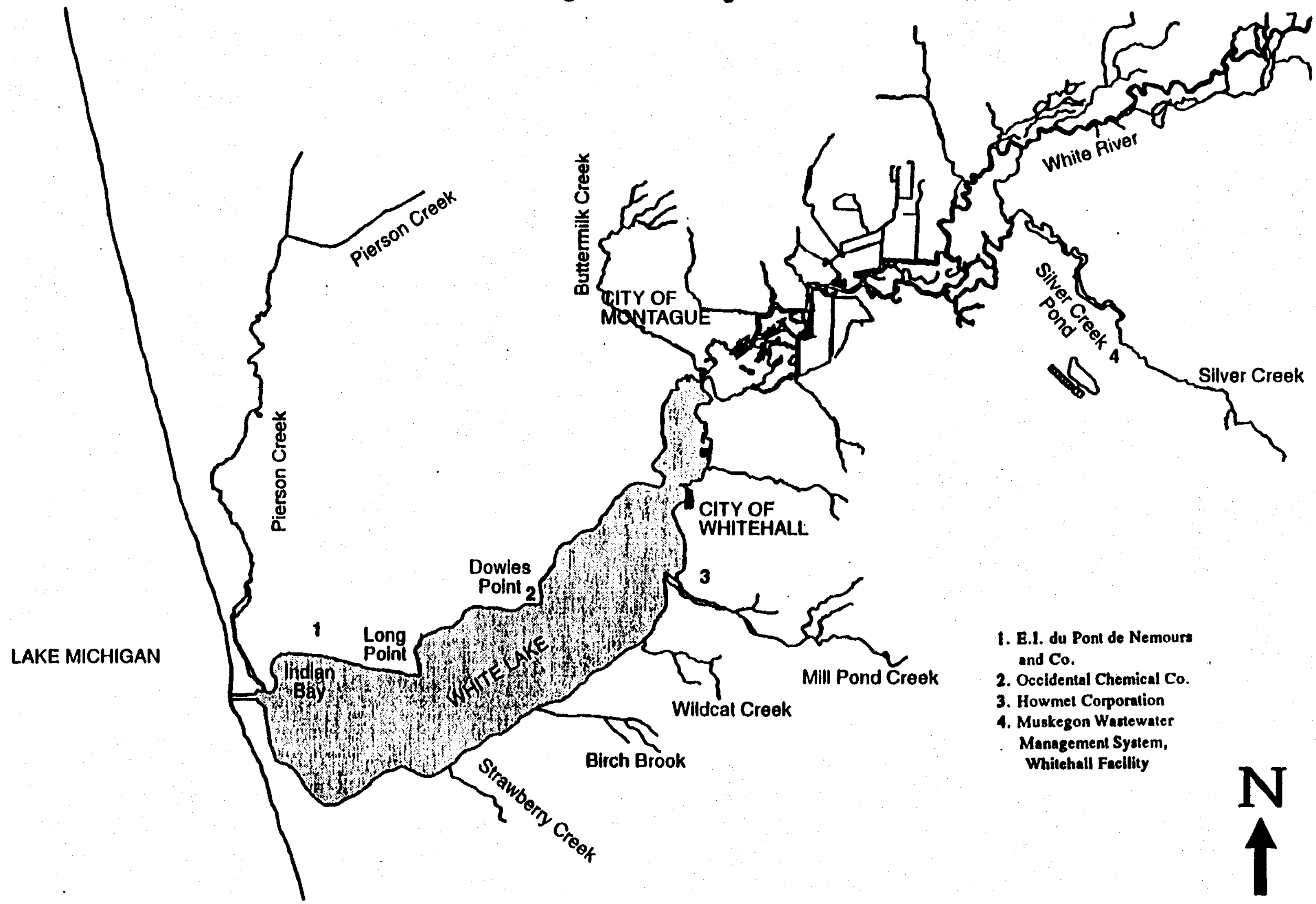
TABLE 9: NPDES-Regulated Discharges into White Lake and Tributaries, 1993

Company	Noncontact Cooling Water	Groundwater Cleanup	Process Wastewater	Intake Backwash
E.I. du Pont and Co.[a]				X
Occidental Chemical Corporation.[b]		X		
Whitehall Facility[c]			X	
Howmet Corporation[d]	X			

SOURCE: Public Sector Consultants, Inc., using data from Surface Water Quality Division, Michigan Department of Natural Resources, Grand Rapids District.

[a]Permit number MI0000884.
[b]Permit number MI0002631.
[c]Permit number MI0029173.
[d]Permit number MI0002623.

MAP 3: Location of NPDES-Regulated Discharges to White Lake and Tributaries



SOURCE: Public Sector Consultants, Inc., using material from Geological Survey Division and Surface Water Quality Division, Michigan Department of Natural Resources.

The SWQD district staff reviews the compliance status of NPDES-regulated dischargers by examining the monthly discharge monitoring reports submitted by the permittee; site visits and special studies supplement this information. The staff evaluates the overall level of compliance with established permit limits, including attention to repeated violations, severe violations, and indications that the permit holder has operational or equipment problems.

Random permit violations and minor operational problems often are resolved informally between the permit holder and the SWQD district staff without formal enforcement action being necessary. Repeated effluent-limit violations of a specific parameter, violations resulting from ongoing operational problems, and other types of violations may be addressed through formal enforcement action, which may involve a notice letter, notice of noncompliance, notice of violation, administrative consent decree, or a director's final order. The state also may pursue a judicial remedy through a civil or criminal lawsuit. Most violations are corrected through a negotiated schedule of actions that will bring a facility into compliance [4].

NPDES discharge permits, which reflect both state and federal regulations, are normally issued for a maximum period of five years; in 1993 most White Lake AOC permit holders were applying for reissuance.

The following paragraphs describe the significant issues relating to specific municipal and industrial NPDES permitted discharges to White Lake since 1987.

At three of the sites—E.I. du Pont, Occidental Chemical, and the Whitehall facility—tests have been conducted since 1987 to assess the effect of their discharge on aquatic organisms—fathead minnows or daphnids commonly are used as test organisms.

A test conducted by the SWQD on the effect of E.I. du Pont's discharge in 1989 revealed that the effluent was not acutely toxic to *Daphnia magna* and did not exceed the aquatic toxicity limits of Michigan water quality standards in Rule 82 [38].

The effect of Occidental Chemical's discharge was assessed in 1992 by the SWQD, and the results reveal that Michigan's maximum acceptable toxicant concentration for the test organism *Ceriodaphnia dubia* was reached when they were exposed to water containing 46 percent effluent from Occidental Chemical [57]. Analysis of the effluent, however, did not detect contaminants at concentrations that would have affected reproduction or survival of the test organism; no conclusion could be reached as to why the test showed toxicity at the relatively low concentrations detected. The company's current NPDES permit requires additional testing to further assess effluent toxicity effects [67]. Testing will occur following approval of the biomonitoring plan submitted by Occidental Chemical in 1994.

The effects of the outfall from the Whitehall facility have been evaluated through SWQD studies in 1983, 1991, and 1992. The first assessed Silver Creek and concluded that the facility's effluent was not impairing the stream; no adverse effect on stream benthic organisms was observed [99]. The second, in 1991, assessed the discharge itself and indicated that the effluent is not acutely toxic to *D. magna* and that it is in compliance with Rule 82 of Michigan water quality standards [32]. The 1992 assessment involved a series of toxicity tests conducted as part of the NPDES renewal process and analyzed effluent effects on fathead minnows, *C. dubia*, and *D. magna*. The tests conclude that the effluent is not *chronically* toxic (harmful or lethal after long-term exposure) to fathead minnows or acutely toxic to the *D. magna* (the data from the *C. dubia* test were not considered reliable) [66]. Contaminated groundwater from the Whitehall facility site is discussed below, in ***Groundwater.***

Since 1987 the Whitehall facility has upgraded its facilities. In 1987–88 the facility added 12 rapid-infiltration beds to its system to enlarge its treatment capacity from 1.36 million to 1.7 million gallons of wastewater a day. In addition, the facility's discharge has been rerouted from Silver Creek to White River. This latter change was prompted by the low levels of dissolved oxygen in Silver Creek; the discharge was determined to have less of an effect on the White River given the river's greater flow and assimilative capacity.

Some industries, if their effluent being discharged to the Whitehall facility is of a certain type, are required to pretreat their wastewater before it is discharged to the wastewater treatment facility. To control toxics going to such systems—which are designed primarily to process domestic, not industrial, wastewater—the industrial pretreatment program was initiated to meet requirements of the federal Clean Water Act Amendments of 1977. Toxics from industrial waste can accumulate in the sludge of a wastewater treatment facility, resulting in very high disposal costs; in addition, the presence of toxics may affect the treatment processes. As with the NPDES, under the industrial pretreatment program, maximums are placed on the amount of certain chemicals that may be present in industry effluent going to a wastewater treatment facility. The limits are based on four objectives, and the one applied is that which most restricts the particular chemical: (1) the wastewater treatment facility's NPDES permit limits, (2) protection of the system's collection system and treatment processes, (3) protection of the system's sludge disposal practices, and (4) protection of facility workers' safety and health [1].

The Muskegon County Wastewater Management System operates the Industrial Pretreatment Programs (IPPs) within Muskegon County. The IPP program required in NPDES Permit No. MI0029173 establishes the state and federal pretreatment requirements for the regulation of industrial users discharging into the Whitehall facility. Whitehall's Industrial Pretreatment Program is currently under enforcement action by the U.S. EPA (lead agency) and the MDNR. The MDNR issued Notices of Noncompliance to the Whitehall facility in June of 1992 and December of 1993 and a notice letter in December 1994 for violations of federal pretreatment program requirements. The violations prompting the Notices of Noncompliance were related to inadequate enforcement of federal and local sanitary sewer discharge limitations and incomplete IPP program development. The compliance schedule requiring corrective actions was extended by the MDNR. This action resulted in the County revising its ordinance to regulate industrial discharges. While there are many significant violations still uncorrected by the County, these violations have not been directly linked to any effluent violations at the Whitehall facility.

ACCIDENTAL DISCHARGES

The Whitehall facility has experienced pump station failures resulting in discharges of raw sewage. The most recent were February 1993 (16,800 gallons to White River) and May 1993 (3,000 gallons to White River), both from lift station W, and September 1992 (6,000 gallons to White Lake) from lift station M [4]. Such failures are accidental but occur with enough frequency to cause concern. The discharges are a public health hazard and supply nutrients that will accelerate the eutrophication of the lake. Both stations now have alternate power supplies, and their alarm systems have been upgraded; these measures are expected to reduce the problem of failures.

NONPOINT SOURCES

As more traditional point sources of pollutants come under control, attention is focusing on pollution from nonpoint sources. Erosion, construction materials, manufactured products, plants and animals, automobiles, pesticides, industrial sites, groundwater, and the atmosphere can all be sources of nonpoint-source pollution. Comprehensive protection of surface water from nonpoint-source pollution incorporates the following components: watershed master planning, zoning, development restrictions in designated areas, environmental site planning, construction site control, urban storm water runoff management, public education, and water body restoration programs [69,70].

Nonpoint sources of pollution discussed in this update are urban storm water runoff, agricultural runoff, and atmospheric deposition; the first two are discussed immediately below, the last at the end of this part of the document, under ***Atmospheric Emissions and Deposition***.

Urban Storm Water Runoff

As development occurs in an area and the proportion of impervious and compacted surface increases, the area's natural ability to absorb and store runoff becomes substantially reduced. Drainage systems installed to accommodate urban storm water runoff can alter surface waters because they (1) concentrate the flow (storm sewers collect water from a large area and deliver it to a single discharge point), (2) increase the speed (due to the storm conditions and lack of natural percolation) of water entering the lake, creek, or river, and (3) in dry periods reduce flow because no water is held in the soil that can seep to the water body. Storm water runoff also contributes to soil erosion, stream-bank erosion, and increased sedimentation in water bodies and can adversely affect water quality further as a source of nutrients, bacteria, suspended solids, toxic compounds, warmer water, and trash and debris [69].

The federal Clean Water Act Amendments of 1987 require large point-source discharges of storm water to be regulated by NPDES permits, but the regulation applies only to municipalities of medium (100,000–250,000) or large (more than 250,000) population [13].

Although the high levels of contamination in the sediments adjacent to storm water outfalls and tributaries to White Lake could be due to storm water runoff, no communities that discharge storm water into White Lake are required to have permits [13,28].

The same amendments require regulation of construction projects of over five acres. Michigan has chosen to meet these federal requirements through its existing soil erosion and sedimentation control program administered by local governments. Before construction begins, a permit must be obtained in accordance with the Michigan Soil Erosion and Sedimentation Control Act; site-specific measures to control soil erosion and sedimentation are required. When a permit holder receives notice of coverage under the act and presents it to the MDNR, the permittee is considered also to be in compliance with the federal requirements. This program is in effect in Muskegon County to reduce runoff from construction sites [49,77].

A third element of the 1987 federal regulations to control pollution from storm water runoff involves regulating certain industrial production facilities, commercial warehousing sites, waste treatment and disposal facilities, centralized transportation terminals, and raw-material extraction activities. The MDNR recently adopted new statewide rules consistent with federal requirements to control pollution from such sites; the new regulations generally apply when new or expanded uses occur at regulated sites [49,77].

Agricultural Runoff

There is very limited information about the type and amount of pollutants entering White Lake and its tributaries from agricultural runoff. Potential sources of pollutants from agricultural areas are sediments, pesticides, fertilizers, herbicides, and animal waste [94].

A nonpoint source assessment of the White River watershed was conducted in 1988 by the MDNR and the Soil Conservation Service of the U.S. Department of Agriculture. The report indicates that throughout the watershed, water quality and fish communities are being impaired by sediments and nutrients. The primary sources of the sediments identified were stream banks and agricultural-related soil erosion [57].

The Muskegon County Soil Conservation District, in addition to participating in such community projects as storm drain stenciling (imprinting notices on storm drains advising that anything dumped into them goes directly into the lake or tributary), is involved in several projects to reduce agricultural runoff; these are listed in part 6 of this document, ***1995: Current and Scheduled Studies and Programs***.

SEDIMENTS

Contaminated sediments can be a source of pollution when they are disturbed by dredging or a violent storm, because they and the toxics in them can become resuspended. In 1990 surface sediment samples were collected from White Lake. Chromium and lead seem to be the metals of most concern, and the most degradation appears to be near Whitehall Leather

Company, Occidental Chemical, and in the mid-lower lake. However, we do not know to what extent contaminated sediments represent a continuing source of pollution. The information currently available and the limitations of sediment sampling are summarized earlier in the document, in part 2 under ***Sediment Contamination***.

Dredging Restrictions

For activities that would disturb sediments in certain waters and wetlands—altering the shoreline, placing permanent structures in the water, or dredging and filling, permits are required under federal and state law. The permits, which fulfill both federal and state purposes, are issued by the MDNR and specify both the method of dredging (i.e., hydraulic or mechanical) and the method of spoil disposal (e.g., upland unconfined or licensed solid waste Type II landfill) [73,74].

Under federal law, such permits are needed for all of White Lake up to the first bridge on the White River; these waters are regulated by the U.S. Army Corps of Engineers under Section 10 of the federal Rivers and Harbors Act of 1899. The applicable state law is the Michigan Inland Lakes and Stream Act and is administered by the Land and Water Management Division of the MDNR. If wetlands will be affected by any proposed development, the provisions of the Michigan Wetlands Protection Act and Section 404 of the federal Clean Water Act must be met [73,74].

A joint permit application form is used, which may be submitted to either the Corps or the MDNR and is jointly reviewed by the two agencies. The agencies decide which regulations apply in each case. Although for so-called Section 10 waters the federal government exercises independent authority and can issue or deny a permit for regulated activities regardless of state action, the MDNR often is the lead agency for reviewing applications for fill and dredging, and its requirements usually are more restrictive than the federal requirements. For Section 404 waters Michigan is one of two states delegated authority to control activity in federally regulated wetlands; unless specific concerns are raised by the EPA during the notice period, the final action under state law serves to meet federal requirements [73,74].

In addition to the normal review and notice requirements, the MDNR has instituted special review for fill and dredge activities proposed for lakes with contaminated sediments. Because White Lake is an AOC with known sediment contamination in portions of the lake, removal and disposal of material dredged from the lake are carefully assessed. The MDNR Land and Water Management Division consults with the MDNR Waste Management Division on all applications that involve dredging in White Lake. The latter determines the protocol for the sediment sampling that must occur to complete the application, reviews the sampling results, and sets appropriate restrictions for disposal of the dredged material. The SWQD is consulted if the samples reveal that bottom sediments are highly contaminated and removal would pose a risk to water quality [73,74]. Regardless of contaminant levels, depositing dredged sediments in the lake is not permitted.

GROUNDWATER

There is considerable documentation about contaminated groundwater within the AOC, but little is known about the effect on the lake itself. Groundwater is known to be contaminated at many sites and is suspected to be slowly moving toward the lake.

P.A. 307/MERA Sites

Public Act 307 of 1982, the Michigan Environmental Response Act (which took effect in 1991 and is very similar to the federal CERCLA) was enacted to create a priority listing of contaminated sites and establish owner and operator liability. Administrative rules adopted in 1990 established three types of cleanup—A, B, and C—and set criteria for each.

- Type A cleanups require that hazardous substances at a site be removed to background level or a level at which the chemical cannot be detected.

- Type B cleanups are risk-based; that is, the criteria set to guide such cleanups are based on the level at which, using standardized exposure assumptions and accepted risk levels, the hazardous substances will no longer pose unacceptable risk. (For example, for carcinogens, any level above a one-in-a-million risk for increased cancer is unacceptable). Groundwater contamination is covered by Type B criteria.

- Type C cleanups involve containing the hazardous substances on the site and long-term monitoring and/or restriction of future site uses to assure there are no unacceptable routes of exposure affecting public health or the environment.

For this report, the Environmental Response Division of the MDNR Grand Rapids District Office identified eight MERA sites as potentially affecting the water quality of White Lake. Map 4 indicates all of the sites[1] immediately around White Lake listed as priorities under either P.A. 307 or the Superfund; not all, however, necessarily are affecting the lake. The MERA sites named by the MDNR and discussed below are specifically identified.

In the following discussion, references are made to Type B groundwater cleanup criteria and to groundwater/surface-water interface (GSI) criteria. The former are intended to protect human health and the latter to protect aquatic life; their restrictiveness in relation to each other varies [31].

Occidental Chemical Corporation Historical activities at the Occidental Chemical site resulted in contaminated groundwater; the contaminants of concern in the groundwater include chloroform, carbon tetrachloride, trichloroethylene, perchloroethylene, hexachlorobutadiene, hexachlorocyclopentadiene, octachlorocyclopentene, and hexachlorobenzene. Hexachloroethane, 1,2-dichlorobenzene, 1,3-dichlorobenzene and 1,4-dichlorobenzene have been observed in some wells at low concentrations. The lateral extent of groundwater contamination flowing from the Occidental Chemical site is only approximately known. The general migration pathway for the groundwater contamination from the site appears to be south-southeastward towards the purge well network along White Lake. The depth of the contamination is believed to be limited to the upper unconfined aquifer by a clay layer that forms its base.

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[1]MDNR NOTE: These sites are known to be contaminated with any one or a combination of hazardous substances that are or may be injurious to human health or the environment. These hazardous substances may include industrial or municipal wastes, pesticides, solvents or heavy metals. The map indicates the approximate center of each site where either a source of hazardous substances has been determined or hazardous substances have been detected by the source is unknown.

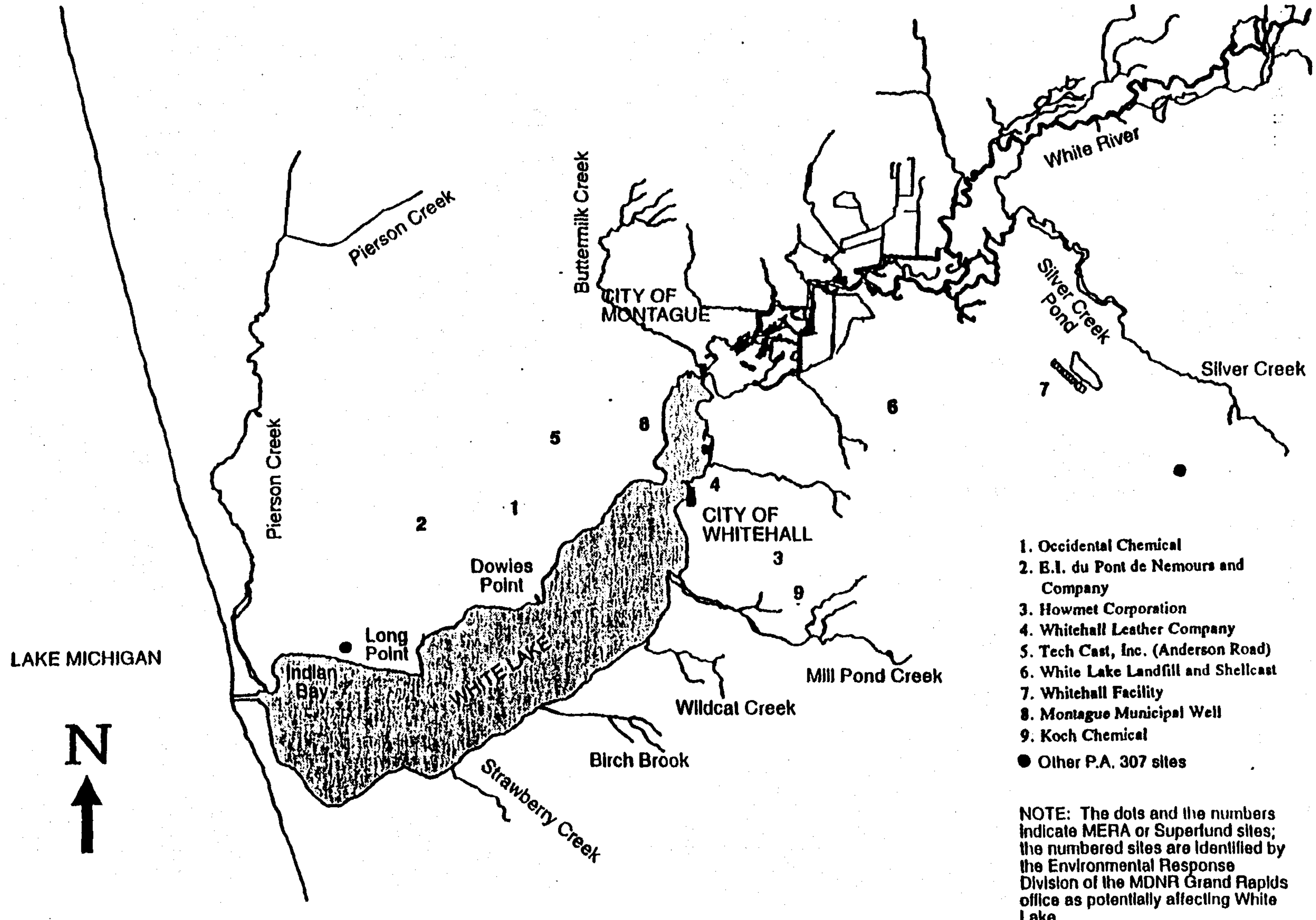
Each site may be larger or smaller than the map symbol, depending on the type, severity or the migration path of hazardous substances. The map symbol indicates neither the site boundary nor the lateral extent, flow direction, or relative severity of the actual plume of hazardous substances.

These sites are called Act 307 sites from Public Act 307 or 1982, as amended. Sites that are contaminated as a result of leaking underground storage tanks (LUST) are on the Act 307 list. However, due to the large number of LUST sites and their rapidly changing status, they are not part of the current mapping effort. The Michigan Environmental Response Act provides for the identification, risk assessment, evaluation, and the clean up of contaminated sites in the state. All locations on this map have been verified by the Michigan Department of Natural Resources.

It is important to note that the Act 307 list is under annual revision as new information becomes available. Consequently, if this map was produced prior to the release date of the latest list, it may not reflect the current information due to addition and/or deletion of contaminated sites.

The Act 307 program is administered by the Michigan Department of Natural Resources, Environmental Response Division, P.O. Box 30028, Lansing, MI 48909. Please contact the Act 307 section if more information is required concerning the listing process or the site assessment model used for evaluation.

MAP 4: P.A. 307 and Superfund Sites Adjacent to White Lake and Tributaries



SOURCE: Public Sector Consultants, Inc., using material from Geological Survey Division, Michigan Department of Natural Resources.

The lakefront purge well system was installed in the early to mid 1980's pursuant to the 1979 consent order between the MDNR and Occidental Chemical to prevent the discharge of impacted groundwater from entering White Lake. Both the purge well water and leachate from the site's closed and secure landfill vault are treated in a carbon activated adsorption system operated in accordance with a 1979 consent order. The treated effluent is regulated by the site's NPDES permit and discharged to White Lake [86]. MDNR and EPA believe that the current purge well system appears adequate to prevent groundwater contamination within the purge well system's capture zone from reaching White Lake as long as the pumping and monitoring system are properly maintained. It is impossible to determine whether all of the impacted groundwater from the site is being captured by the purge well system until the lateral extent of the groundwater contamination is fully defined.

A 1993 federal administrative order requires Occidental Chemical to conduct a Resource Conservation and Recovery Act facility investigation to determine: 1) the actual lateral and vertical extent of the groundwater plume; 2) evaluate the competence of the confining clay layer to determine the potential for impacts to the lower confined aquifer; and 3) to determine whether the entire extent of contaminated groundwater flowing from the site is being captured by the purge well and treatment system discussed above.

E.I. du Pont de Nemours and Company As part of a 1986 consent agreement with the MDNR, E.I. du Pont has initiated remediation of the problems caused by the lime pile on the site that was reported in the 1987 RAP as a potential source of groundwater contamination.

Four inactive solid waste landfills at the facility also were named as sites of concern in the 1987 RAP, however Pierson Creek Landfill is the only one of the four that may have an adverse effect on White Lake water quality. The landfill may have received neoprene tars, reactor bottom residuals, latex polymers, porcelain packing rings, copper catalyst salts, and waxes from the plant's neoprene manufacturing processes, and it also may have been used for disposal of freon-production sludge [29].

Groundwater monitoring wells placed down-gradient (the direction in which groundwater flows) from the landfill, toward Pierson Creek, indicate the presence of contaminants; tetrachloroethylene as high as 254 ppb has been detected in one (the GSI groundwater criterion is 22 ppb). Nine nearby residential wells were sampled in 1991 at the request of the homeowners, but no facility-related constituents were detected in them [10]. At the request of MDNR, E.I. du Pont has installed additional wells to determine whether the GSI water quality limits are (or are likely to in the future) being exceeded at the groundwater/Pierson Creek interface. In summer 1994 the company is expected to issue a report proposing remedial measures to address the landfill contamination problems [29].

Howmet Corporation (Plants No. 4 and No. 5) and Koch Chemical Company Various organic chemicals have contaminated the groundwater at the Howmet site, located adjacent to Mill Pond Creek, a White Lake tributary. A monitoring well at the groundwater/surface-water interface with the pond showed 63 ppb tetrachloroethylene, nearly three times the GSI limit of 22 ppb set out in MDNR Rule 57(2) standards. In response to requests by the MDNR, Howmet has proposed additional sampling and a remediation plan. The plan is expected by the MDNR in early 1994 [30].

In 1988 the MDNR conducted a biological assessment of Mill Pond Creek near Howmet Corporation and Koch Chemical (also a CERCLA/Superfund site; see below) and detected no detrimental effects to the creek from contaminated groundwater from the Howmet site but found that the contaminated groundwater from the Koch Chemical site is adversely affecting the creek's water quality [96]. Based on the direction of the groundwater flow and these assessment results, the MDNR advises that there is no evidence that the contaminated groundwater plumes from the two sites are intermingling [88].

Whitehall Leather Company Until April 1994, no soil or groundwater investigations had been conducted at the Whitehall Leather Company site since 1987. Results of the April 1994 testing are currently under review. The EPA considers Whitehall Leather a site of continuous investigation and it may be recommended for placement on the National Priorities List [27]. The MDNR conducted an Integrated Assessment (IA) at the site on April 19, 1994, analysis of samples from the settling ponds and the sludge disposal area detected high concentrations of arsenic, chromium, cobolt, lead, mercury, silver, copper, magnesium, vanadiums and zinc. Groundwater, surfacewater and soil migration pathways were identified as routes of contaminant migration and sensitive receptors include White Lake and wetland between the ponds and the lake. The State of Michigan recommends that the Whitehall Leather Company site be considered for nomination to the National Priorities List by the Regional Decision Team. This recommendation is based on the presence of heavy metals in potential source areas, the detection of these constituents in site specific migration pathways, the lack of controls to prevent the continued migration of contaminants from source areas, and the historical resistance of the potentially responsible party to take constructive remedial action [9]. White Lake sediment core samples were collected at 22 stations near Whitehall in the vicinity of the Whitehall Leather Company from October 24 through October 26, 1994, by the EPA and the MDNR. The EPA-Great Lakes National Program Office research vessel "Mudpuppy" was equipped with a vibracorer and essential in the coring process. Preliminary results indicted that there was high concentrations of metals, especially chromium in may of the samples. Discussions are now proceeding to determine what additional measures will be taken.

Anderson Road (former Tech Cast) site Tetrachloroethylene and trichloroethylene groundwater contamination at the Anderson Road site remains a concern. After an extensive investigation, the cause remains unknown. A MDNR hydrogeological investigation determined that at depths exceeding 90 feet from the surface, the aquifer is contaminated with up to 230 ppb tetrachloroethene (the MERA Type B limit to protect drinking water is 0.7 ppb, and the MDNR

GSI water quality limit is 22 ppb) [91]. Based on the modelling conducted for the MDNR's revised remedial investigation report, in three to five years the center of the mass of the contaminated groundwater plume from the site will reach White Lake [91].

Although the site's contaminated groundwater currently is not affecting White Lake, interim response measures, such as pumping the contaminated groundwater out and treating it, may be necessary to prevent the contamination from discharging into the lake. Groundwater will be monitored for tetrachloroethane semiannually by the MDNR [7].

White Lake Landfill and Shellcast, Inc. These two sites were listed on the CERCLA national priority list as a source of contamination to the groundwater of Whitehall municipal well no. 3 (also a CERCLA site and abandoned in 1989). After investigation, it was concluded that contamination to the municipal well was not due to Whitehall Landfill and Shellcast, but both sites remain on the MERA and CERCLA lists. No federal funds have been spent at the location and therefore they are not considered Superfund sites, but the MDNR and EPA continue to monitor them. The extent of the groundwater contamination emanating from these sites has not been fully defined. Additional assessment of the volatile organic chemicals detected in the plume, such as benzene, trichloroethylene, tetrachloroethylene, trichloroethane, and arsenic will be necessary to determine whether they are detrimental to any surface waters [36].

Shellcast plans to continue to monitor the groundwater wells on its site and work with the landfill to determine the extent of the plume. In addition, the EPA has indicated that it may conduct a preinvestigation report of the site as part of its continued monitoring program [36].

Whitehall Facility According to the terms of a 1984 consent agreement (and modifications in 1987) between the MDNR and the Whitehall facility, in 1988 the storage lagoon from which contaminated groundwater was migrating was sealed with a high-density polyethylene liner to prevent further contamination of the groundwater. In addition, to intercept the groundwater plumes migrating from the facility, seven interceptor wells were installed in the northwest corner of the site and nine along the northeast corner. The wells have intercepted the groundwater plumes that were of concern in 1987. The contaminant levels of ammonia, bis (2-chloroethyl) ether, and 2-chloroethoxyethane in the nearby contaminated residential wells are decreasing, and no organics have been discovered in them within the last three years.

CERCLA/Superfund Site

The main federal statute governing cleanup of hazardous materials is the 1980 Comprehensive Environmental Response, Compensation, and Liability Act, or CERCLA. The CERCLA (1) sets cleanup priorities, (2) establishes legal liability for cleanup costs, and (3) established the Hazardous Waste Trust Fund (the "Superfund"), which pays for cleanups in emergencies and when the responsible parties cannot be identified or have not yet been made to pay. Although "Superfund" properly should be used only to refer to sites on which Hazardous Waste Trust Fund monies are being expended, it commonly is used to describe *all* sites on the CERCLA priority list (83 in Michigan). Koch Chemical is the only CERCLA site in the White Lake AOC on which trust fund monies are being spent for cleanup.

A hydrogeologic investigation in 1980 identified three primary organic contaminants of concern in the groundwater at the Koch site: 1,2 dichlorethane, bis (2-chloroethyl) ether, and triglycol dichloride. In 1981 it was discovered that the contaminated groundwater was discharging to Mill Pond Creek [94].

In 1988 a habitat survey for Mill Pond Creek was conducted in response to recommendations in the 1987 RAP for White Lake [96]. The objective was to determine stream quality in the vicinity of two groundwater contamination plumes from the Koch Chemical and Howmet Corporation plants No. 4 and No. 5. Good water quality was evident upstream of the groundwater plumes, as evidenced by the presence of a diverse benthic community, but the habitat was impaired by deposits of sand covering desirable substrate such as logs and rocks. Downstream of the groundwater plumes, stream quality was worse, as evidenced by an impaired benthic community and the presence of chemical odors; habitat quality here too was reduced by sand deposits. The problem with benthos was attributed to the groundwater plume from Koch Chemical, but while it apparently caused this local stream degradation, there is no evidence linking the degraded conditions in Mill Pond Creek with an adverse effect on fish populations in White Lake [96].

In 1990 the site was placed on the CERCLA national priority list, which means the contamination must be investigated and remediated according to the act's provisions. In 1991 Koch Chemical and the MDNR agreed on an administrative consent order under which Koch Chemical must conduct an interim response action, remedial investigation, and feasibility study as directed by the MDNR [59]. The MDNR-proposed interim response plan was accepted by Koch Chemical in 1992 [60].

The remediation of the Koch Chemical site involves (1) installing groundwater purge wells on the bluff adjacent to Mill Pond Creek to capture the contaminated groundwater plume and prevent further discharge to the creek; (2) extracting the contaminated groundwater, treating it in Koch Chemical's existing treatment system, and discharging it to the municipal sanitary sewer system; and (3) sampling the soil and groundwater in the floodplain. If the investigation reveals that residual contaminants in soils pose a potential threat to human health and the environment, additional response measures may be necessary [60].

Koch Chemical ceased production at the site in 1992. In December 1992 and January 1993 the company sampled the Mill Pond Creek floodplain and then installed the bluff purge-well system. Three purge wells now are pumping at a combined rate of approximately 68 gallons per minute [61].

Additional Sites of Concern

The Whitehall municipal well no. 3 was listed in the 1987 RAP as a contaminated water supply. In 1980 the MDPH detected volatile halogenated organics, specifically tetrachloroethylene and 1,1,1-trichloroethane, in well water, and in 1984 the well was placed on the CERCLA national priority list. The EPA conducted a remedial investigation to identify the nature and extent of the possible contamination at and near the well site and found that residential wells northeast of municipal well no. 3 and groundwater at the nearby Shellcast and Whitehall Landfill sites were contaminated with volatile organic compounds [79]. Further investigation revealed that the contamination of the residential wells and municipal well no. 3 were not related. Monitoring wells were installed adjacent to the municipal well; testing since 1982 has shown only trace levels of contaminants, and tests of well no. 3 have shown no contamination. No remedial actions were recommended, and well no. 3 was officially closed in 1989 and removed from the national priority list [6].

In 1980 trace elements of dichloroethane and trichloroethane were detected in the Whitehall municipal well no. 4, but the MDPH has been monitoring the well and has detected no contamination since 1982 [6].

The Montague municipal well, Coon Creek site, was listed in the 1987 RAP as of concern. It was abandoned in 1987, and a new well on Lasley Street has been supplying the city since 1991.

A White Lake Drive residential well was listed in the 1987 RAP as potentially contaminated with benzene, but no further findings of the chemical have been found there since October 1987; the well has been retested five times since and declared "clean" by the MDPH [8].

Correspondence in the MDPH file for the San Juan subdivision wells show that testing conducted in 1987 indicated that levels of 1,1,1-trichloroethane previously detected had decreased—at one the level was nondetectable, and at the other it was only 2 ppb [8].

Efforts by Muskegon County to Reduce Contamination

Since 1987 efforts in Muskegon County to reduce sources of groundwater contamination have expanded, and the county's solid waste management plan, which endorses recycling to reduce the use of landfills for disposing of solid waste, was approved by the MDNR in 1992. Two recycling centers now are operating in the county, and additional centers, along with source reduction and composting, are being promoted. Other efforts to reduce contamination resulting from waste disposal include the county's Household hazardous waste collection program, in operation for the past three years [35].

ATMOSPHERIC EMISSIONS AND DEPOSITION

Air, or atmospheric, pollutants can come from natural nonpoint sources (e.g., degassing that naturally occurs from Earth's crust), *anthropogenic* (human-related) nonpoint sources (e.g., automobile emissions), and anthropogenic point sources (e.g., industrial emissions). Among the factors that determine the effect that atmospheric pollutants have on an area are local emissions, meteorological conditions and seasonal influences, conditions on a particular day, and chemical characteristics of emitted compounds [41].

Recent studies indicate that pollutants deposited from the atmosphere contribute significant levels of organic chemicals and heavy metals both to land and to surface waters. After being emitted—naturally or from anthropogenic activities—air pollutants can attach to particles and be deposited (referred to as *dry deposition*), or they may adhere to moisture such as rain or snow and fall with the precipitation (*wet deposition*). A 1992 study suggests that of atmospheric deposition in the Great Lakes, dry deposition comprises 40 percent and wet deposition 60 percent [14].

"Criteria" pollutants (those that the EPA requires states to monitor and ascertain whether their presence exceeds the levels set by established criteria)—nitrogen dioxide, sulfur dioxide, lead, ozone, particulate matter less than ten microns, carbon monoxide, and volatile organic compounds—have been monitored over the last 10 years in compliance with the National Air Quality Standards. In Michigan, standards were met for lead, carbon monoxide, sulfur dioxide, and nitrogen dioxide at all sampling sites in 1992 (the most recent data available).

The text that follows refers to toxic air deposition information general to the state of Michigan because there is only limited information available about toxics emitted from facilities in the AOC. In addition, not much is known about the distance air emissions can travel from their source, what affects their transport, and the effect of toxic air contaminants on ecosystems.

Current Studies and Programs

Several studies are being conducted and programs implemented at the state, regional, and federal levels that include air monitoring, modelling, and emission inventories. The result should be better understanding of the sources, transport, and effect of atmospheric pollutants.

In 1990 the MDNR Air Quality Division (AQD) began a study that monitored the presence and levels of several toxic compounds in the atmosphere at three sites—Saginaw Bay, Traverse City, and Sault Ste. Marie. Results indicate high variability, but all monitored toxic compounds were found to be under the levels established as being harmful to humans. The study will continue, expanding its database and improving modelling [41].

Additional monitoring studies are being conducted by the AQD in cooperation with the University of Michigan. These studies, started in 1992 and to conclude in 1994, are monitoring atmospheric concentrations, transport, and deposition pathways of several persistent pollutants including PCBs, polyaromatic hydrocarbons, hexachlorobenzene, dieldrin, and 13 trace metals (including mercury) [42].

The AQD is serving as the lead agency for developing a comprehensive, computerized regional emissions inventory of air toxics emission sources for pollutants of concern for the Great Lakes basin. The inventory, which began in 1990 and will continue until 1995, is housed at the EPA Great Lakes National Program Office.

Toxic Release Inventory (TRI) reporting is required under Title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986. Facilities which meet the criteria for inclusion, are required to estimate and report to the U.S. EPA and the states the total amount of listed chemicals they use or release into the environment - either accidentally, through routine regulated plant operations, or by transporting as waste to other locations. The data provide no indication of frequency, intensity or duration of releases. The TRI report for 1991, the most recent available, includes both air point sources and air nonpoint sources for Muskegon County.

The Michigan Atmospheric Deposition Network, part of the Great Lakes Atmospheric Deposition sampling network, began in 1981 and was transferred to the University of Illinois state water survey in 1988. The program estimates atmospheric loadings to the Great Lakes and assesses trends [40].

The federal Clean Air Act Amendments (CAAA) of 1990 mandate that extensive air deposition monitoring and research be conducted for the Great Lakes, certain other lakes in the country, and the ocean coastal areas; the extent of atmospheric deposition of hazardous air pollutants will be assessed. The amendments require the EPA to identify and promulgate standards for the categories of sources (e.g. coke ovens, dry cleaners, smelters) that in total account for 90 percent of total emissions of seven critical classes of pollutants (mercury; PCBs;

alkylated lead; polycyclic organic compounds; hexachlorobenzene; and 2-,3-,7-,8-tetrachlorodibenzo (p) dioxin; and 2-,3-,7-,8-tetrachlorodibenzo furan. Another requirement is the study of hazardous air pollutants being emitted from electric utilities; if deemed necessary, the sources will be regulated [40].

In Michigan, new air quality rules (effective in 1992) require that new sources of toxic air contaminants use the best available control technology [42].

Mercury

A pollutant of particular concern in Michigan is mercury; a study of numerous lake sediment samples reveal that the amount of mercury in the state's environment is increasing [12]. Because of the general uniformity of the increase, atmospheric deposition appears to be the most likely source. In 1992 Gov. John Engler requested the Michigan Environmental Science Board to investigate the risks posed to Michigan residents from exposure to mercury, identify its sources and transportation pathways, and propose recommendations to control or eliminate discharges of it into the environment [55]. Unfortunately, information about mercury in the Michigan environment is limited, and because mercury has a great ability to reconfigure when exposed to different environmental media (e.g., water, air), it is very difficult to evaluate.

The science board's study estimates that 50 percent of mercury observed in the environment comes from natural sources, such as the breakdown of soil by microbes and the degassing from Earth's crust. Large, known sources of mercury due to human activity are waste incineration, coal combustion, and latex paint use prior to 1990–91. Local sources can contribute to mercury levels, but the extent depends on how fast gaseous mercury is converted to particulate mercury. Based on preliminary calculations, the study estimates that only 10 percent of the *ambient* (air-borne) mercury in Michigan is due to human activity in Michigan; the balance could originate from other regions or be the result of recirculation of previously deposited mercury.

The primary way that humans accumulate mercury is through eating fish contaminated with methyl-mercury. Methyl-mercury is formed by bacterial action in mercury-contaminated sediments and accumulates, primarily through the food chain, in muscle tissue of fish. Due to high levels of mercury found in tests of fish from Michigan inland lakes and the potentially hazardous effects mercury has on humans, a general, restricted-consumption advisory has been issued that advises members of the general population to limit to one meal a week certain types and sizes of fish. The advisory is more strict for women of child-bearing age and for children, suggesting no more than one meal a month.

The science board report concludes that recently enacted federal and state legislative regulatory programs will help reduce the contribution of mercury to the Great Lakes environment from anthropogenic sources. It also recommends several additional state actions to reduce mercury loadings to the environment and to establish effective trend-monitoring programs for mercury in sediments, water, air, fish, wildlife, and humans.

4

1995: Impaired Uses of White Lake AOC

PAC PRIORITIES AND RAP TEAM COMMENTS

In fall 1993, at the beginning of the RAP update process, PAC members were asked by the consultant to list the beneficial uses of the White Lake AOC that they perceive to be impaired. They also were asked to label each impairment as being of "high," "medium," or "low" concern. Because the members felt that as yet they did not have sufficient information or expertise to be more definitive, the following were identified preliminarily as being of high concern (they are not listed in any particular order):

- Restrictions on fish and wildlife consumption
- Degradation of fish and wildlife populations
- Degradation of benthos
- Restrictions on dredging
- Restrictions on drinking water consumption; groundwater contamination; human health implications
- Degradation of aesthetics

The PAC is concerned about impairments to fish and wildlife for several reasons. Although the restriction on human consumption of AOC fish because of the elevated levels of PCBs and chlordane in large carp was the only officially listed impairment for the White Lake AOC in the 1987 RAP, there is concern about other contaminants in fish. Also troublesome to the PAC is the observable loss of fish and wildlife habitat due to development and alteration of the lake shoreline; such loss affects the lake ecosystem, the quality of life of AOC residents, and the natural resources/recreation uses of the AOC that comprise a significant part of the economic well-being of the White Lake community.

The health of the benthic community in the AOC is important to the PAC, because if benthic organisms are impaired it may indicate poor water quality or the presence of toxic materials in the sediments. The PAC is concerned that substantial reductions in the number of benthic organisms could limit the abundance of fish and wildlife that depend on them directly or through the food chain. The fact that toxics in water and sediments can be accumulated by benthos and passed up the food chain to fish, wildlife, and humans, also is problematic.

The imposition of restrictions on dredging activities is important because the need for them indicates the presence of contaminated sediments, which adversely affect benthos, fish, wildlife, and, to some extent, human recreational use and enjoyment of some parts of the lake. In addition, the restrictions on the disposal of dredged material can increase the cost to the U.S. Corps of Engineers, which is responsible for maintaining the navigation channel between White Lake and Lake Michigan, and to businesses and other public agencies when contaminated dredged sediments must be removed to specially constructed and maintained disposal areas.

Groundwater contamination is of great concern to the PAC because the White Lake community depends on groundwater for drinking. Industrial practices already have contaminated area groundwater, and remediation has been difficult and expensive. The PAC places high priority on protecting human health by preventing further contamination of groundwater and restoring already contaminated areas.

White Lake residents acknowledge the improvement in water quality in recent years but continue to believe that to protect lake-wide aesthetics, further efforts are needed to reduce eutrophication and further development of the shoreline should be limited.

To the impaired uses listed above, the PAC added two additional concerns: the need for a watershed-wide approach to remediation, development, and resource management and the need for greater public awareness about the AOC and its condition.

The MDNR RAP Team also identified and prioritized impaired uses of the AOC, and its listing closely parallels the PAC's except in the priorities assigned to drinking water restrictions and degradation of aesthetics and eutrophication. The difference of opinion about the priority on drinking water restrictions was one of interpretation—the RAP Team was considering the restrictions in the context of surface water, and the PAC in the context of groundwater; after explanation, the RAP Team agreed that groundwater contamination is indeed a serious problem for the White Lake community. The difference of opinion about degradation of aesthetics and eutrophication is one of perspective—the RAP Team looks at the substantial progress already achieved, and the local residents look at the progress yet needed.

THE 14 USE IMPAIRMENTS: STATUS OF EACH IN THE WHITE LAKE AOC

The PAC, RAP Team, and consultant agreed that structuring the update process rigidly around the current status of the individual 14 use impairments delineated in the Great Lakes Water Quality Agreement would be difficult and, in the end, probably not best serve this particular AOC. The problem was that dealing strictly and individually with each delineated impaired use would preclude recognizing the interrelationships among them. The PAC and the RAP Team prefer (and the consultant concurs) to invoke an ecosystem-wide approach, recognizing that the physical, chemical, and biological components of the White Lake ecosystem are interdependent and that changes in one can affect the others.

The Great Lakes Water Quality Agreement list of use impairments really is a list of *symptoms*, and the apparent abatement of one of the symptoms does not necessarily mean that the problem itself has been eliminated. Evaluated collectively, the 14 use impairments can help fix attention on certain problems, but the participants in the 1995 White Lake AOC update were cautious about placing too much weight on the status of any one particular use.

In addition, the update participants found it difficult to apply the use impairments as delineated to the specific conditions in the White Lake AOC. For example, "restrictions on drinking water consumption or taste and odor problems" frequently is interpreted to mean problems associated with the use of surface water as a municipal water supply. Neither White Lake nor any of its tributaries is used as a primary source of domestic water, but groundwater flowing into the lake and its tributaries is a significant source of domestic water, and contamination of it seriously affects AOC residents and the waters of the AOC as well.

Table 10 presents the status of each of the 14 impairments delineated by the Great Lakes Water Quality Agreement; the statuses are based on the 1987 RAP, findings of the update, and input from the PAC and RAP Team. The following summarizes the PAC and RAP team's reasons for the status assigned to each impaired use.

Restrictions on Human Consumption of Fish and Wildlife

For carp from White Lake there are consumption advisories in effect because of elevated levels of PCBs and chlordane. Although fish contaminant monitoring results for White Lake indicate mercury levels less than the MDPH 0.5 ppm trigger level, the general advisory to limit consumption of fish from all inland Michigan lakes still applies because of the presence of mercury. It appears, based on the limited data available, that fish contamination problems in the White Lake AOC are not unique to the AOC but rather a problem of the entire Great Lakes region. Toxics are the cause of the contamination, but the extent of contribution from various potential sources is not entirely known. Past discharges of PCB's from Howmet

TABLE 10: Summary of Impaired Uses, White Lake, 1995

PAC/RAP Team Priority	Impairment	Status	Extent	Suspected Cause	Potential Sources	Change in Last 20 Years
X	Restrictions on fish and wildlife consumption	Known	Regional; lake-wide	Toxics	Contaminated sediments; nonpoint pollution; atmospheric	Remained the same
	Tainting of fish and wildlife flavor	Historical; no current problems				Improved
X	Degradation of fish and wildlife populations	Known	Regional; lake-wide	Toxics; nutrient enrichment; physical alterations to shoreline	Contaminated sediments; nonpoint pollution; atmospheric deposition; development	Unknown
	Fish tumors and other deformities;	No current problems				NA
	Bird or animal deformities or reproductive problems	Suspected	Regional; may be lake-wide	Toxics	Contaminated sediments; groundwater; nonpoint pollution; atmospheric deposition;	Improved
X	Degradation of benthos	Known	May be lake-wide; localized	Toxics; nutrient enrichment; physical alterations to shoreline	Contaminated sediments; groundwater; nonpoint pollution; atmospheric deposition	Unknown
X	Restrictions on dredging	Known	Localized	Toxics	Contaminated sediments; nonpoint pollution;	Remained the same
X*	Eutrophication or undesirable algae	Known	Lake-wide	Nutrient enrichment	Nonpoint pollution	Improved
X	Restrictions on drinking water consumption; human health implications	Known	Localized	Toxics	Groundwater	Degraded

TABLE 10: Summary of Impaired Uses, White Lake, 1995 (cont)

PAC/RAP Team Priority	Impairment	Status	Extent	Suspected Cause	Potential Sources	Change in Last 20 Years
	Beach closings	No current problem				NA
X*	Degradation of aesthetics	Known	Localized	Nutrient enrichment; physical alterations to shoreline	Nonpoint pollution; development	Improved
	Added costs to industry or agriculture	No current problems				NA
	Degradation of phytoplankton and zooplankton populations	Suspected	Localized	Toxics; nutrient enrichment; physical alteration to shoreline	Groundwater; nonpoint pollution; development	Unknown
X	Loss of fish and wildlife habitat	Known	Lake-wide	Nutrient enrichment; physical alteration to shoreline	Nonpoint pollution; development	Degraded

NA = Not applicable; impairment not documented.

SOURCE: Public Sector Consultants, Inc.; includes information from the White Lake Area of Concern PAC and MDNR RAP Team.

NOTE: Regional refers to Lake Michigan region.
*PAC only.

Corporations, and mercury and chlordane from Occidental Chemical Corporation are possible sources. Mercury, PCBs, and chlordane have been measured in statewide air deposition, and they also may be present in contaminated sediments and in storm water runoff.

Available data (although limited) indicate that mercury levels in inland-lake fish have declined during the last 20 years [80], and PCBs in fish have shown some decline regionally since restrictions first were placed on its use in the early 1970s. Chlordane was banned in 1988, and levels of exposure to the contaminant are expected to decline. Large specimens of certain species, however, still contain concentrations of mercury, chlordane, and PCBs above levels of concern. Insufficient data are available to reveal current trends of mercury, PCBs, or chlordane contamination of fish in the White Lake AOC.

Tainting of Fish and Wildlife Flavor

Fish tainted with a chemical taste and odor once were a problem in White Lake, but no such problems have been reported to the MDNR for more than a decade. The source of the problem likely was industrial and municipal waste discharges to the lake that have been halted.

Degradation of Fish and Wildlife Populations

Precise information on fish and wildlife populations in the White Lake AOC is not available. MDNR fish and wildlife biologists familiar with recent shoreline development are convinced that habitat critical to the survival, reproduction, and growth of certain important fish and wildlife species has been impaired by dredging, filling, and related shoreline alterations.

Excessive nutrient loadings have contributed to accelerated eutrophication of White Lake. Among the problems this brings is a decrease in dissolved oxygen in the deeper parts of the lake during summer and winter temperature stratification, which reduces the habitat available to fish species that require high levels of dissolved oxygen.

The invasion of exotic species, such as alewife, also is thought to be contributing to the decline of certain species in White Lake. There is concern that new exotic species, particularly zebra mussel, could significantly alter fish populations in the lake.

Because population estimates have not been made for most wildlife species in the White Lake AOC, it is not possible to determine population trends. Data available on bald eagles in the Lake Michigan region indicate that the number began to decline in the 1950s, but recent data reveals that the number is increasing, probably in response to lower levels of chlorinated hydrocarbons (e.g., DDT, PCBs, chlordane) in the environment. Analysis of samples for organochlorine compounds in the addled bald eagle collected at the Muskegon State Game area were completed in 1994. U.S. Fish and Wildlife indicated that levels of total PCB's, dieldrin, and P, P'-DDE.... exceed levels correlated to healthy bald eagle reproduction. Although wildlife on the White River is not monitored, MDNR wildlife biologists report that in the lower Muskegon River, numbers of wildlife species sensitive to environmental contaminants, such as mink, otter, and osprey, are observed to be increasing. In the 1994/95 trapping season, Muskegon County was included for other trapping with a limit of one other per season per trapper.

Fish Tumors and Other Deformities

No fish tumors or other deformities associated with chemical contamination have been reported in the White Lake AOC. External tumors often found on large walleye have been diagnosed as a naturally occurring disorder often associated with stress during spawning.

Bird or Animal Deformities or Reproductive Problems

Bird and animal deformities and reproductive problems have been historical concerns in the Great Lakes region. Of the native species, such fish-eating birds and mammals as bald eagle, osprey, cormorant, mink, and otter seem to be the most susceptible to environmental contaminants bioconcentrated in fish. Recent studies in the Great Lakes region and observations in the lower Muskegon River indicate that populations of fish-eating birds and mammals previously reduced by environmental contaminants now are increasing. The recent failure of a bald eagle egg to hatch in a nest in the lower Muskegon River, however, may indicate a continuing long-term problem for this species in the Muskegon Lake AOC. Information specific to the White River watershed is not available.

Toxic chemicals are documented to have caused reproductive failures in fish and wildlife in the Great Lakes region. Although many have been banned or their production and use severely restricted, consumer products, incinerated waste, and soils still contain them, and atmospheric deposition, nonpoint storm water runoff, contaminated groundwater, and the release of these chemicals from contaminated sediments are suspected of continuing to adversely affect fish and wildlife.

Degradation of Benthos

Benthic communities are known to be degraded in areas of the AOC. Localized degradation has been caused by toxics and the dissolved-oxygen depletion that nutrient enrichment causes. The sources of the toxics are contaminated sediments, contaminated groundwater, and nonpoint storm water runoff. Shoreline alteration, particularly filling, also has reduced suitable habitat for the production of benthic organisms in White Lake. Studies of benthic communities conducted just prior to preparation of the 1987 RAP indicated that water quality improvements may be occurring but a larger sample size is required to confirm this. Samples collected in 1990 are being analyzed, and the data should be written up in 1995.

Restrictions on Dredging

Dredging is restricted in the White Lake AOC because in some areas sediments are contaminated. Toxic chemicals in the waste historically discharged by municipal and industrial facilities in the past are the source of the contamination. The current restrictions, which apply both to removing and disposing of dredged material, have not changed much in recent years. Both RAP Team and PAC members note that in addition to dredging, other shoreline alterations are a concern from the standpoint of degradation of fish and wildlife habitat.

Eutrophication or Undesirable Algae

The accelerated eutrophication of White Lake historically has caused serious problems. Nuisance algal blooms, severely depressed dissolved-oxygen levels in deeper portions of the lake, and related degradation of benthic communities are associated with excessive nutrient loadings. Diverting municipal and most industrial wastewater discharges to the Muskegon County wastewater management system reduced point-source nutrient loadings to White Lake, and since then nuisance algal blooms have decreased and the severity and duration of dissolved-oxygen depletion have declined. As reported in the 1987 RAP, benthic populations are showing signs of recovery. Macroinvertebrate samples collected in 1990 will be evaluated in 1995 to determine whether there has been an improvement in the lakes benthic populations, since 1980.

Phosphorus currently is the limiting (controlling) nutrient for algal growth in White Lake although MDNR's goal for the maximum level of phosphorus (<30 ppb) in the lake during turnover has been met. Depletion of dissolved oxygen in deeper areas, a phenomenon common to many inland and some drowned-rivermouth lakes during summer stratification, is occuring in White Lake. The dissolved oxygen levels in these areas of the lake may be close to those expected to occur naturally during the summer months and may not improve with further reductions in nutrient and organic loadings (partially decomposed plant and animal material) to White Lake. More study is needed to identify remaining nutrient and organic inputs, and models are needed to predict movements to White Lake that would result from further reductions.

Restrictions on Drinking Water Consumption and Implications for Human Health

Although White Lake itself is not used for domestic water, the community around it depends on groundwater for drinking water. Groundwater in the White Lake AOC has suffered severe contamination from past waste storage and disposal practices and from accidental spills of pollutants. Significant progress has been made in identifying and remediating groundwater contamination problems in the last 10 years, but in certain areas, groundwater that formerly could be used for domestic purposes remains contaminated. While current remediation efforts are reducing the discharge of contaminated groundwater to surface waters, and alternative, clean drinking water is available, the contaminated groundwater is expected to remain a long-term problem in the area.

Beach Closings

Human health-related beach closings have not been a problem in White Lake, and neither the PAC nor the RAP Team considers beach use to be impaired.

Degradation of Aesthetics

The PAC and the RAP Team interpret aesthetics to refer primarily to water clarity and the absence of nuisance algal blooms, oil slicks, and similar visual symptoms of poor water quality. Applying these standards, the aesthetics of White Lake are considered overall to have improved over the last 20 years; nuisance algal blooms are less severe than in the past, oil slicks are not often observed, and the water is clearer.

At the confluence of the White Lake outlet channel and Lake Michigan, there is a stark contrast in the appearance of the water of the two bodies; the outlet water is discolored and often is mentioned by local residents as being of concern. The current and historic sediment loadings of the White River watershed and the urban storm water runoff from around White Lake may account for most of the difference; soil erosion and sedimentation and nonpoint urban and agricultural runoff are notable problems in the White Lake AOC and the White River watershed.

Some local residents believe aesthetics also are degraded by continued development of the White Lake shoreline. The upper portion of the lake has been the most extensively developed, and because of the increasing use of the lake for recreational and tourism purposes, the potential for further development is high.

Added Costs to Industry and Agriculture

The presence of impairments does not add any known costs to agricultural or industrial use of AOC water.

Degradation of Phytoplankton and Zooplankton Populations

There has been no comprehensive evaluation of phytoplankton and zooplankton (free-swimming or free-floating microscopic plants and animals) populations in White Lake. These organisms may have been impaired in the past from (1) discharges of toxic chemicals that reduced survival and growth of certain planktonic organisms and (2) excessive nutrient inputs that stimulate and support growth of certain nuisance blue-green algae. The nuisance conditions that existed earlier in the lake have substanitally improved and indicate that populations, have stabilized. There are no apparent signs of lakewide degradation of either zooplankton or phytoplankton populations.

Loss of Fish and Wildlife Habitat

Although eutrophication of White Lake has been reduced in the last 20 years, during winter and summer stratification, oxygen levels in deep water remain depleted, making these areas uninhabitable for some fish and the species they eat. It is not known if additional reductions in nutrients and organic loadings from nonpoint sources would improve this situation.

RAP Team and PAC members are concerned about development destroying the lake's littoral zone, a critical fish and wildlife habitat. The shoreline continues to be altered by dredging and by installation of seawalls, bulkheads, and riprap. Because the lake is attractive for recreation, residential, and business uses, the potential for further development is high, and the debate about shoreline use likely will continue.

5

1987 RAP: Studies Recommended

The 1987 RAP recommended that several studies be conducted. Following are the recommendations; the status follows each in parentheses:

- Conduct biological assessments and evaluate sediment contaminants at sites affected by storm water (not implemented)

- Evaluate nonpoint-source nutrient loadings and contaminants to ascertain seasonal loadings and determine the need for a nonpoint-source nutrient loading minimization plan (not implemented)

- Conduct sediment contamination and benthic community trend monitoring in White Lake to evaluate lake-wide habitat quality (sediments sampled and analyzed; benthic samples collected and being analyzed)

- Monitor air toxics to determine the amount of PCBs and chlordane being deposited on the White Lake area (assessment not conducted)

- Assess Lake Michigan carp to determine if PCB and chlordane contamination in White Lake is site-specific or regional (assessment conducted)

6

1995: Current and Scheduled Studies and Programs

STATE AND FEDERAL STUDIES AND PROGRAMS

The studies listed below are being conducted or are planned for the near future and will provide information and data applicable to the White Lake AOC.

Atmospheric Deposition

None of the atmospheric deposition studies listed below is specific to the White Lake AOC or Muskegon County, but all are/will be instrumental in improving understanding of the type, amount, and source of pollutants deposited on the Lake Michigan region from the atmosphere.

- The MDNR AQD, for one year (1990--1991) monitored air at sites in Traverse City, Saginaw Bay, and Sault Ste. Marie to confirm the presence and amount of persistent toxic pollutants; the purpose of which was to collect baseline data to use in directing future projects. A report was completed in 1993 and is available from the AQD upon request.

- AQD, in conjuction with the University of Michigan, conducted weekly monitoring for polychlorinated biphenyls (PCBs), pesticides, polyaramatic hydrocarbons (PAHs), and trace metals for 2 years (1991--1993) at four sties in Michigan (Pellston, South Haven, Dexter, and Deckerville). A reprot of this study is slated for completion in early 1996.

- The AQD, in collaboration with the University of Michigan, is monitoring mercury at four sites to determine its source(s) and to estimate the associated atmospheric deposition to the waters of Michigan.

- As an extension to the immediately above-mentioned study, the University of Michigan has received funding from the Great Lakes Protection Fund to establish a regional mercury air monitoring network; the network was initiated by a regional work group which began meeting in spring 1994.

- The AQD is the lead agency for developing a comprehensive, computerized regional database on air toxics emission sources for pollutants of concern for the Great Lakes basin called RAPIDS (Regional Air Pollutant Inventory Development System). The inventory will be housed at the EPA Great Lakes National Program Office and is expected to be completed in 1995.

- The Great Lakes National Program Office is directing a loadings and mass balance study of Lake Michigan; the study is described below under ***Lake Michigan***. The following pollutants will be monitored for the atmospheric portion of the study: PCBs, polyaromatic hydrocarbons, several pesticides, mercury, and other trace metals.

- The federal Clean Air Act Amendments of 1990 require the EPA to administer a program to identify and assess the extent of atmospheric deposition of hazardous air pollutants to the Great Lakes, the Chesapeake Bay (on the Atlantic seaboard), Lake Champlain (in Vermont and New York), and ocean coastal waters; the project is referred to as the Great Waters Study. Investigations will be conducted to determine the sources, rates, and adverse affects of hazardous atmospheric deposition. "The first Great Waters Report to congress was submitted in May of 1994.

Fishery

- The Surface Water Quality Division of the MDNR will continue periodically to monitor and test fish from White Lake as part of the FCMP.

Lake Michigan

- The Great Lakes National Program Office is directing a loadings and mass balance study of Lake Michigan for the Lake Michigan Lakewide Management Plan. It began in March 1994 and will continue through September 1995. The purposes are to (1) identify loading rates of critical pollutants, (2) identify rates contributed by three environmental media (tributaries, atmospheric deposition, and contaminated sediments), (3) develop the capability to predict the benefits of specific load reductions, and (4) enhance understanding of the environmental processes that affect the presence of contaminants within an ecosystem.

Land and Water Management

- The MDNR Great Lakes Shorelands Section of the Land and Water Management Division is evaluating habitat, fisheries use, aquatic vegetation distribution, and other parameters to develop a database to facilitate decision making with regard to development in selected drowned-rivermouth lakes.

Surface Water Quality

- The discharges of the municipal NPDES permit holders will continue to be evaluated for aquatic toxicity by the MDNR at least once every five years.

- The discharges of industrial NPDES permit holders will continue to be tested for aquatic toxicity periodically by the MDNR; necessity will be occasioned by permit renewals and/or frequency and seriousness of past problems.

- For NPDES permit renewal, industrial permit holders will continue to be required to describe the character of their discharge, and the MDNR will continue to test discharges as deemed necessary.

- As part of the fish contaminant monitoring program, caged-fish studies will continue to be conducted every five years in the channel from White Lake to Lake Michigan.

Wildlife

- The U.S. Fish and Wildlife Service will continue to monitor the status of bald eagles (statewide, not specific to the White Lake AOC).

- The Fish and Wildlife Service, in cooperation with other groups, will continue to monitor statewide bird mortality and migration patterns.

MUSKEGON COUNTY SOIL CONSERVATION DISTRICT PROGRAMS

The Muskegon County Soil Conservation district is involved in several projects to reduce agricultural runoff, including the Muskegon and White Lake Water Quality Project, which focuses on reducing sediments and nutrients entering the lakes by providing the following services:

- Beach grass nurseries—makes beach grass available to Muskegon County residents for transplanting to reduce soil erosion
- Land resource management—helps landowners with plans to conserve cropland, woodland, wetlands, and shoreline and stabilize stream banks
- Technical engineering—designs, lays out, and supervises installation of conservation practices
- Agricultural waste management—designs and manages waste systems, including composting
- Conservation tours, educational programs, and a quarterly newsletter—informs youth and adults in Muskegon County about soil conservation
- Construction of sediment basins on Montague and Pierson Drains is planned for 1995

7

1995 Update: Recommendations

***This update recommends continuance of all pollution abatement and monitoring programs identified in the 1987 RAP,** including CERCLA/Superfund and P.A. 307/MERA regulatory actions to clean up contaminated groundwater sites, regulation of NPDES discharges, and MDNR fish contaminant monitoring to ascertain toxic contaminant trends and update the MDPH consumption advisory for White Lake.*

Based on data and information generated since 1987 and the input of the White Lake PAC and the MDNR RAP Team, several studies are proposed to identify the specific remedial actions required to restore impaired uses of the White Lake AOC.

Measures to Abate Eutrophication

Realistic goals cannot be established for water quality improvement in White Lake until a better understanding of the present status of the lake is reached. This is particularly true for issues related to eutrophication. Indicated earlier, phosphorus now is the limiting nutrient in White Lake, and concentrations have been reduced to less than the MDNR goal of a maximum of 30 ppb during turnover. Nuisance algal blooms are less common, and pollution-intolerant benthic populations may be increasing. Several questions remain, however. Is White Lake still recovering, and is the rate of eutrophication caused by human activity slowing? Will dissolved-oxygen levels during summer stratification in deep areas of the lake improve with further reductions in phosphorus and organic loadings, or are they close to those expected to occur naturally in a drowned-rivermouth lake in southern Michigan?

The historic, and in some cases irreversible, changes around White Lake and in the White River watershed may limit the water quality improvements that could be achieved from further phosphorus reductions. A better understanding of the factors contributing to the present water quality of the AOC is essential in developing a strategy to control existing sources of nutrients and organic loadings and forestall new sources that can develop as land use in the watershed changes.

It is recommended that a nutrient and organic loading model be developed to answer questions related to the trophic status (amount of biological productivity) of White Lake. When the questions are answered, realistic goals and specific objectives can be set. Such a model likely will require at least the following data:

- Estimates of annual loadings and contributions of phosphorus from storm water runoff, point-source NPDES discharges, and White Lake tributaries (including the White River)

- Estimates of organic loadings during runoff, including measurement of suspended solids, total organic carbon, and biological-oxygen demand

- Measurement of phosphorus concentrations in White Lake during spring and fall, when mixing occurs during turnover

- Measurement of dissolved-oxygen levels during both winter and summer stratification to determine the current extent and duration of depletion

- Evaluation of nutrient loading in the White Lake basin from on-site septic and fertilizers from urban agricultural sources-surface and groundwater inputs

The critical physical and chemical parameters identified by the nutrient and organic loading model should be analyzed in conjunction with continued biological evaluation of the benthic community of White Lake. Changes in the relative abundance of certain pollution-intolerant and pollution-tolerant benthic organisms may provide the additional information needed to confirm current lake conditions.

Installation of in-stream sedimentation basins was recommended in the 1987 RAP as a remedial measure to reduce the amount and effect of solids loadings to White Lake. Sediment basins have been in place for several years in various trout streams in Michigan—including the headwaters of the Muskegon River—through cooperative public-private efforts to improve trout habitat. *The 1987 recommendation regarding in-stream sediment basins is repeated and expanded to include development of a comprehensive soil erosion and sedimentation-control strategy for the White River watershed.* Such a strategy should include

- in-stream sedimentation basins;

- stream bank erosion-control measures;

- storm water filter basins;

- wetland restoration at critical areas to trap sediments and nutrients and reduce the volume of storm water flowing into lakes or rivers of concern; and

- application of "best management practices" (BMP) to land use to control soil erosion from both urban and rural land.

Soil erosion and sedimentation control measures will slow the rate at which solids are deposited in White Lake, improve aesthetics by increasing water clarity, and improve the habitat for aquatic organisms in both the lake and tributaries.

It is recommended that Land use/Zoning needs be addressed on a local, regional and state level to determine the root cause of related problems in White Lake such as:

- local control of boat/marina access on lakes

- over development of sensitive areas, groundwater contamination from septic tanks and lawns via sandy soils, etc.

- industrial/commercial development in various units of government with out consideration of duplication and the evaluation of its effects on human, environmental and economic resources.

Measures to Determine the Effects of Development and Exotic Species on Habitat

Balancing the economic benefits of development that alters shoreline with the need to preserve critical near-shore aquatic habitat is a major concern of residents of the White Lake AOC, local government officials, and the MDNR. The lack of quantitative data about fish and wildlife populations in the AOC and the cost of acquiring such information have made it difficult to thoroughly assess the biological effect of shoreline alteration proposals. MDNR decision making on individual permit applications involving shoreline development could be substantially improved if quantitative biological information were available. More important, such information would facilitate local land-use planning decisions that could balance long-term economic and environmental concerns. *A survey of boat traffic would aid in evaluating development and recreation pressures on wildlife habitat.*

It is recommended that in addition to the information being collected by the Great Lakes Shoreland Section of the MDNR Land and Water Management Division, research be conducted to establish objective, quantitative measures of the effect habitat changes have on animal populations dependent on near-shore areas of White Lake during at least part of their life cycle. Such studies should (1) inventory and categorize near-shore habitat critical to the survival, growth, and reproduction of fish, birds, mammals, reptiles, amphibians and other wildlife, (2) determine population dynamics of these wildlife, and (3) interpret these multivariate data to understand important relationships between available habitat and population abundances, to manage accordingly.

It is further recommended that current inventories of endangered and threatened species inhabiting the White Lake AOC be referenced to identify habitat critical to their survival.

At least one exotic species has invaded White Lake relatively recently—zebra mussel; in other locations the species has shown the potential for exponential population growth. It is recommended that the rate of zebra mussel colonization and population growth in the AOC be monitored so that the effect on habitat available to native species can be assessed. Control measures should be implemented if evidence indicates that the species's abundance threatens significant wetland habitat on or adjacent to the lake.

Native wildlife habitat should be protected, and where possible, enhanced. The effects of exotic species on endemic wildlife should be determined, and mitigated, if feasible.

Measures to Reduce Levels of Toxic Substances

Historic waste disposal and chemical storage practices and the use of agricultural fertilizers, herbicides, and pesticides are of concern in the White Lake AOC. Elevated levels of mercury, PCBs, and chlordane are found in fish; dieldrin and DDE are found to be accumulating in fish (although at low levels); and a variety of heavy metals are present at above-background levels in the sediments of the AOC.

Although the level of contaminants in fish taken from White Lake are in the range of those found in fish from other waters in the region, area residents are eager to have explored every available option to reduce levels of toxic chemicals in White Lake.

There are many potential sources of these toxic chemicals, and the extent to which each may be contributing to the problem is not known. *In addition to the NPDES programs and the air and groundwater monitoring programs in place and scheduled, it is recommended that the following studies be conducted and remedial actions implemented:*

- *Further investigation/confirmation of the sources of toxics contaminating fish and wildlife should be made*

- *Characterization of atmospheric contributions to the White Lake AOC should b done*

- *Additional surface and ground water quality data should be collected*

- *An evaluation of heavy metals, primarily chromium, in the sediments affected by the historical discharge of the Whitehall Leather Company and documentation of the contaminated sediments' effects on the biological organisms in the vicinity of the former discharge*

- *A determination of the feasibility of removal if the contaminated sediments are found to be contributing to the degradation of the biological community; if feasible, sediments should be removed*

- *Sediment and benthic community sampling to monitor the results of the remediation efforts*

RAP Team and PAC Coordination

During preparation of this update, the RAP Team and the White Lake PAC interacted in two ways: the PAC chair attended RAP Team meetings, and members of the RAP Team made presentations to the PAC on various topics. Pooling local resources and technical expertise is critical to the eventual remediation of use impairments in the White Lake AOC. *It is recommended that the interaction between the PAC and the MDNR RAP Team become more regular and coordinated*; this could be accomplished by

- scheduling three meetings a year between the two groups,

- developing common objectives for the RAP process from this point forward, and

- developing a timetable and budget for the studies recommended above.

It is further recommended that *membership on the RAP Team be expanded to include representatives from other state and federal agencies whose work ultimately may contribute to the restoration of the AOC*

Establishing a White River Watershed Council

The White Lake AOC comprises only a part of the White River watershed, and problems and practices in the larger area affect the AOC. Because the river is the source of 95 percent of the water entering White Lake, its condition has a significant bearing on the water quality of the lake. The quality of the water in the river is affected by adjacent land use practices.

Throughout the state, watershed councils are forming to facilitate communication among communities within a watershed and give them a mechanism through which they can work cooperatively to address water pollution problems. A White River watershed council would allow people throughout the area to better understand the effect of their activities on the watershed and help prevent future pollution problems. *Although a past effort to form such a group was not successful, it is recommended that the effort to form a White River watershed council be revived.*

Public Education

Many of the preventive and remedial activities required to restore beneficial uses of White Lake will be greatly expedited with an environmentally knowledgeable public. To that end, *public education, awareness and involvement activities for implementation of non-point source best management practices (BMPs), proper use and disposal of household hazardous waste, habitat protection, etc. should be an integral component of RAP implementation.*

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