Michigan Department of Natural Resources

Remedial Action Plan

for

SAGINAW RIVER AND SAGINAW BAY

Area of Concern

September 1988

Michigan Department of Natural Resources
Surface Water Quality Division
Great Lakes and Environmental Assessment Section
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PREFACE

This Saginaw River/Bay Remedial Action Plan (RAP) was prepared by the Michigan Department of Natural Resources (MDNR) from a first draft compiled for MDNR by the East Central Michigan Planning and Development Region, the National Wildlife Federation, and graduate students from the University of Michigan. The Remedial Action Section was prepared by MDNR and a regional public organization known as the Saginaw Basin Natural Resources Steering Committee. Public and technical comment was received throughout the RAP development and review process as described in Section VI.

The RAP summarizes existing water quality data on the Saginaw Bay drainage basin and outlines initial perceptions of the remedial actions that should be taken to further address the eutrophication and toxic material problems in the Saginaw River and Saginaw Bay. The remedial actions presented here will be further refined in future versions of the RAP, which it is anticipated, will be periodically updated and revised as more data are acquired, remedial measures are implemented, and environmental conditions improve.

ACKNOWLEDGEMENTS

An extensive list of people and agencies contributed a great deal of time and effort to develop this plan. The complete list is too extensive to present here, but the following four organizations deserve special recognition:

-- The East Central Michigan Planning and Development Region who compiled the September 1, 1987, first draft of this plan and prepared Sections II and VI of that draft;

-- The National Wildlife Federation who prepared Sections III and IV of the first draft;

-- The Saginaw Basin Natural Resources Steering Committee who helped prepare Section VII of this plan; and

-- The Saginaw River/Bay RAP Technical Work Group who reviewed working drafts of the RAP for technical merit.

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EXECUTIVE SUMMARY

The Saginaw River and Saginaw Bay have been defined as one of 42 Great Lakes Areas of Concern (AOCs) by the International Joint Commission (IJC) because degraded water quality conditions impair certain uses for which these waters are designated. Environmental programs have produced substantial improvements in Saginaw River and Saginaw Bay water quality over the past 20 years, but additional efforts are needed to address the remaining problems. An effective way of dealing with these problems is to design and implement site-specific activities that are tailored to the Saginaw Bay area. This would provide a more directed effort than would be possible solely with statewide or national programs.

The International Joint Commission advocates this site-specific approach, and the eight Great Lakes states and two Canadian provinces in the Great Lakes basin have agreed to prepare a Remedial Action Plan (RAP) for each of the Areas of Concern, if any, within their jurisdiction. The Michigan Department of Natural Resources (MDNR) was responsible for developing the Saginaw River/Bay RAP and delivering it to the IJC by September 1988.

In October 1986, the MDNR contracted with the East Central Michigan Planning and Development Region (ECMPDR), a 14-county regional planning agency located in Saginaw, to prepare a first draft of the Saginaw River/Bay RAP by September 1, 1987. ECMPDR subcontracted a large portion of the RAP preparation work to the National Wildlife Federation (NWF) Great Lakes Natural Resource Center in Ann Arbor. NWF, in turn, secured the services of seven graduate students from the University of Michigan's (U-M) School of Natural Resources to work on various aspects of this plan. The ECMPDR prepared the Environmental Setting and Programs sections while the NWF/U-M coalition produced the Problem Description and the Sources and Loads sections of the first draft. This September 1988 version of the RAP was prepared by the MDNR, except for the Remedial Action section, which was produced by the MDNR and a regional public organization known as the Saginaw Basin Natural Resources Steering Committee.

The Saginaw River/Bay Remedial Action Plan has been developed to address the specific water quality problems of toxic materials and cultural eutrophication in the Saginaw River and Saginaw Bay. The objective of the RAP process is to describe and implement actions that when completed will (1) reduce toxic material levels in fish tissue to the point where public health fish consumption advisories are no longer needed for any fish species in the AOC, (2) reduce toxic material levels in the AOC to those of Michigan's water quality standards, and (3) reduce eutrophication in Saginaw Bay to a level where the bay will support a balanced mesotrophic biological community.

Saginaw Bay is a southwestern extension of Lake Huron located in the east central portion of Michigan's lower peninsula. The bay has a large surface area of 2960 square kilometers and its drainage basin of 22,557 square kilometers includes approximately 15% of Michigan's total land area. Twenty-eight rivers, creeks or agricultural drains flow directly into Saginaw Bay, but about 75% of the tributary hydraulic input comes from the Saginaw River.

The physical boundaries of the Saginaw River/Bay AOC are defined as extending from the head of the Saginaw River, at the confluence of the Shiawassee and Tittabawassee rivers upstream of Saginaw, to its mouth, and all of Saginaw Bay out to its interface with open Lake Huron at an imaginary line drawn between Au Sable Point and Point Aux Barques. Areas outside these physical boundaries, but within the Saginaw Bay drainage basin, are included in the RAP if they are known or suspected sources of contaminants to the Saginaw River and/or Saginaw Bay.

The fish consumption advisories currently in effect for several species in the Saginaw River/Bay AOC are restricted to bottom feeding fish and fish with relatively high levels of body fat. People are advised not to eat any carp or catfish from either the Saginaw River or Saginaw Bay because PCB concentrations in some fish tissue samples exceed the Michigan Department of Public Health (MDPH) criteria for levels of public health concern. Additionally, for Saginaw Bay, it is suggested that people restrict their consumption of lake trout, rainbow trout, and brown trout to no more than one meal per week. There are no advisories for walleye or yellow perch, the principal sport fish in Saginaw Bay.

Carp samples collected in the mouth of the Saginaw River in 1986 had PCB concentrations for five individual fish analyses that ranged from 5.0 mg/kg to 21.3 mg/kg for skin-off fillets; exceeding the MDPH trigger level of 2.0 mg/kg. Walleyes collected in the same area of the Saginaw River had PCB concentrations ranging from 0.36 mg/kg to 0.60 mg/kg for skin-on fillets from three individual fish; well below the trigger level. Ten walleyes collected in Saginaw Bay near Caseville in 1986 had PCB concentrations in skin-on fillets that ranged from 0.56 mg/kg to 0.88 mg/kg. Ten skin-off fillets from channel catfish also collected at Caseville showed PCB concentrations ranging from 0.73 mg/kg to 2.4 mg/kg with samples from three individual fish exceeding the 2.0 mg/kg trigger level.

Recent studies suggest that toxic materials may be impacting the reproductive success of some fish-eating bird populations in Saginaw Bay. Preliminary data from a 1987 survey of caspian terns indicate that the occurrence rate of developmental defects in eggs of a population nesting on the Saginaw Bay confined disposal facility is nearly twice as high as rates for other areas of Lake Huron. It is not presently known if toxic material body burdens of other species in the Saginaw River/Bay AOC, such as fish or benthic macroinvertebrates, are detrimental to their life histories.

Excessive phosphorus inputs to Saginaw Bay have impacted biological communities by creating eutrophic conditions that favor nuisance species and inhibit more desirable species. Extensive blue-green algae blooms created taste and odor problems in drinking water supplies drawn from the bay as recently as the late 1970s. However, since then, bay water quality has improved and eutrophic conditions have been substantially reduced due to the 1977 state ban on the use of phosphate detergents, implementation of Best Management Practices (BMPs) by area agricultural producers, and reductions in phosphorus discharges from industrial and municipal wastewater treatment plants because of facility upgrades and better operation. This has created favorable shifts in the phytoplankton community with the almost complete disappearance of the nuisance blue-green algaes, Aphanizomenon and Anacystis. However, the most recent phytoplankton survey identified several blue-green algae populations along the eastern shore of Saginaw Bay. Also, phosphorus concentrations in Saginaw Bay water remain higher than anywhere else in Lake Huron and, when last surveyed, the benthic macroinvertebrate community was composed primarily of pollution tolerant forms such as the aquatic worms Limnodrilus and midges Chironomus.

There are a variety of sources that continue to contribute contaminants to the Saginaw River and Saginaw Bay including industrial and municipal discharges, combined sewer overflows, contaminated sediments in the river and bay bottom, urban and agricultural nonpoint runoff, waste disposal sites, and the atmosphere. The majority of industrial discharges originate in one of the four major urban centers in the Saginaw River basin of Bay City, Saginaw, Flint or Midland. A large amount of land in the Saginaw Bay drainage basin is in agricultural production and an early 1980s study indicated that roughly 55% of bay phosphorus loads came from fertilizer runoff from cropland.

Public participation activities on the Saginaw River/Bay RAP started September 16, 1986 when the MDNR held a public meeting in Bay City. At this meeting, MDNR staff described the Saginaw River/Bay RAP process, the major issues that would be addressed in the RAP, and invited the public to express their opinions about what water quality issues were of most concern to them in the Saginaw River/Bay system. Many comments received at this meeting have been addressed in the RAP and a written response to each question is presented in Appendix 1.

On September 25, 1986, Great Lakes United held a public hearing in Auburn to solicit public comments with respect to the U.S.-Canada Great Lakes Water Quality Agreement and again the public responded with concerns about water quality in the Saginaw River/Bay system. All related public concerns expressed at this meeting were also considered in the preparation of the RAP.

In January and February 1987, ECMPDR and NWF conducted a series of five public meetings throughout the Saginaw Bay basin (Bay City, Au Gres, Caseville, Caro and Midland) to inform the public about the RAP process and solicit public comments on what they perceived to be the water quality problems of the Saginaw River/Bay system.

On March 5, 1987, a Saginaw Bay workshop was held at Delta College. Though this workshop dealt with many issues beyond the scope of the RAP, such as commerce and tourism, Saginaw Bay water quality was a major focus of this activity and pertinent comments were considered in preparing the RAP.

In March and April 1987, ECMPDR conducted a series of "Key Group" meetings with local officials and the public to again solicit input to the RAP process. A separate meeting was held with each of the following groups: industry, agriculture, commerce, conservation/education and municipal/local government.

From May through July 1987, ECMPDR coordinated the formation of a regional public group called the Saginaw Basin Natural Resources Steering Committee (SBNRSC). An executive core group of 47 people is made up of representatives from among the 22 counties in the Saginaw Bay basin and several public interest organizations. The steering committee is open to anyone living or working in the Saginaw Bay watershed who wishes to participate through a work-group structure. The activities of the steering committee include providing coordinated public input to the RAP process, providing public review and comment during the RAP's developmental stages and subsequent updates, and implementing certain remedial actions. The steering committee had a major role in developing the Remedial Actoins section of this document.

A Technical Work Group was also formed to review the RAP for correctness and completeness of data presentations and the technical appropriateness of remedial actions. This group is composed of approximately 30 representatives, with expertise in various subject areas, from local, state and federal agencies including ECMPDR, NWF, MDNR, IJC, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, National Oceanographic and Atmospheric Administration, U.S. Geological Survey, U.S. Soil Conservation Service, U.S. Army Corps of Engineers, Michigan Department of Public Health, Michigan Department of Agriculture, University of Michigan, and several environmental consulting firms. The Technical Work Group reviewed only portions of the Environmental Setting, Problem Description, and Sources and Loads sections of the RAP, during their developmental stages, and a July 1988 draft of the Remedial Actions section. Accordingly, substantial comment is still needed from this committee following distribution of the RAP to Work Group members for review in September, 1988.

The first draft of the Saginaw River/Bay Remedial Action Plan was distributed for review on September 1, 1987. It consisted primarily of data compilations, which formed the basis for beginning the process of developing specific remedial actions to address the eutrophication and toxic material problems in the Saginaw River and Saginaw Bay. The MDNR provided a complete copy of the RAP to each member of the Saginaw Basin Natural Resources Steering Committee and requested that the Steering Committee provide substantial input in designing and prioritizing remedial actions. Input was also requested from the general public and was solicited through a public meeting and general public participation in steering committee work groups. Complete copies of the RAP were sent to the county commission office of each of the 22 counties in the Saginaw Bay basin and were available for public review. The Executive Summary and Remedial Actions portions of the RAP were mailed to people who had attended previous public meetings and/or expressed interest in the RAP process.

Several generalized remedial actions were proposed in the first draft of the RAP. These actions were proposed on the basis of public input to date and review of the technical data. They formed a basis for discussions in the review process, during which some activities were expanded, others modified, and many additional actions added.

In September 1987, the Michigan Water Resources Commission (WRC) allocated one full day (9/16) of their monthly meeting to the Saginaw River/Bay RAP. The day began with a morning boat tour of the Saginaw River by the WRC, local legislators, local press, MDNR staff, and invited public. In the afternoon, MDNR staff made a presentation to the WRC on the RAP and the WRC passed a resolution supporting the Saginaw River/Bay RAP process (Appendix 2). The meeting was then opened for public comment on the RAP for the remainder of the afternoon.

A second draft of the Remedial Actions section was prepared based on all comments received, and distributed for public review in July 1988. Both oral and written comments were solicited through direct mailings and an August 3, 1988, public meeting in Bay City. Comments received were incorporated into this most recent version of the RAP.

Additional efforts have been made to inform the general public in the Saginaw Bay basin about the RAP process and invite public comment and participation through a variety of methods including newspaper articles, radio broadcasts, television interviews, a television talk show session on the RAP, MDNR news releases, MDNR newsletters, the ECMPDR newsletter - which is sent to all units of local government within the 14-county ECMPDR planning area - and several ECMPDR standing committees.

Saginaw Bay is a valuable resource on which to focus additional water quality improvements because of its importance to area residents, the state of Michigan, indigenous wildlife, and the water quality of open Lake Huron. It is intended that this Remedial Action Plan be used by all agencies (federal, state, local), organizations and individuals concerned with, affected by, or impacting water quality in the Saginaw River or Saginaw Bay. Extensive efforts have been made, and continue to be made, to include all interested and/or affected parties in the development, review and implementation of this plan so that it fully addresses the issues from a variety of perspectives and is broadly supported. As the RAP project progresses, more groups are expressing interest in being involved in the process and mechanisms are generally implemented or modified to accommodate this interest. Though this document is not legally binding on any agency or individual, it does outline the approach Michigan intends to take in applying expanded efforts, beyond existing programs and activities, to further address the two water quality issues of cultural eutrophication and toxic materials in the Saginaw River/Bay Area of Concern. The RAP process is viewed as an iterative, long-term effort and it is anticipated that the RAP will be periodically updated and revised as more data is acquired, remedial measures are implemented, and environmental conditions improve.

SECTION I - INTRODUCTION

The Great Lakes are a unique natural resource containing 20% of the world's surface fresh water. These waters also form a portion of the international boundary between the United States and Canada and both countries have jurisdiction over their use. In order to protect this vast resource and cooperatively address problems along their common border, the U.S. and Canada interact through an agency known as the International Joint Commission (IJC).

The International Joint Commission was established by the U.S. and Canada as a result of the Boundary Waters Treaty of 1909, which set forth the rights and obligations of both countries regarding common boundary waters. In 1972, the first Great Lakes Water Quality Agreement was signed, which established objectives and criteria for the restoration and enhancement of water quality in the Great Lakes system. Since 1973, the IJC Water Quality Board has included in its annual and biannual reports, descriptions and evaluations of problem areas in the Great Lakes basin that have serious water pollution problems, such as harbors, bays and river mouths. These locations are referred to as "Areas of Concern" (AOCs) and are defined as areas where environmental quality is degraded and designated uses of the water are impaired. These nearshore areas have been designated as AOCs by state or provincial jurisdictions based on a determination of whether or not IJC Water Quality Agreement objectives, or jurisdictional guidelines, criteria or standards for environmental quality, are being exceeded. The Saginaw River/Saginaw Bay area was first listed as an Area of Concern in 1973 and remains one today.

Presently, there are 42 Areas of Concern throughout the Great Lakes basin (Figure I-1) and 14, including Saginaw River/Saginaw Bay, are in Michigan's jurisdictional waters (Table I-1). Over the past two decades, there has been considerable improvement in the environmental quality of Michigan's Areas of Concern, particularly with respect to problems associated with conventional pollutants (such as phosphorus, suspended solids, and oil and grease) and to some extent for heavy metals such as mercury. Although conditions have improved, the problems have not been solved and much remains to be done. Two complex issues that have received increased attention in recent years are nonpoint source pollution and toxic materials.

Most of the improvements in Michigan waters and elsewhere have resulted from general regulatory programs that have been applied on a state/provincial-wide basis. Now that these state-wide programs are in place, the most effective way of obtaining additional water quality improvements in the Areas of Concern is to design pollution abatement efforts that are site-specific to each AOC. Consequently, in 1985, each U.S. state and Canadian province with jurisdiction over a portion of the Great Lakes agreed to provide the International Joint Commission with a Remedial Action Plan (RAP) for each site within its jurisdiction, if any, that had been designated as an Area of Concern. This document is the Remedial Action Plan for the Saginaw River/Saginaw Bay Area of Concern.

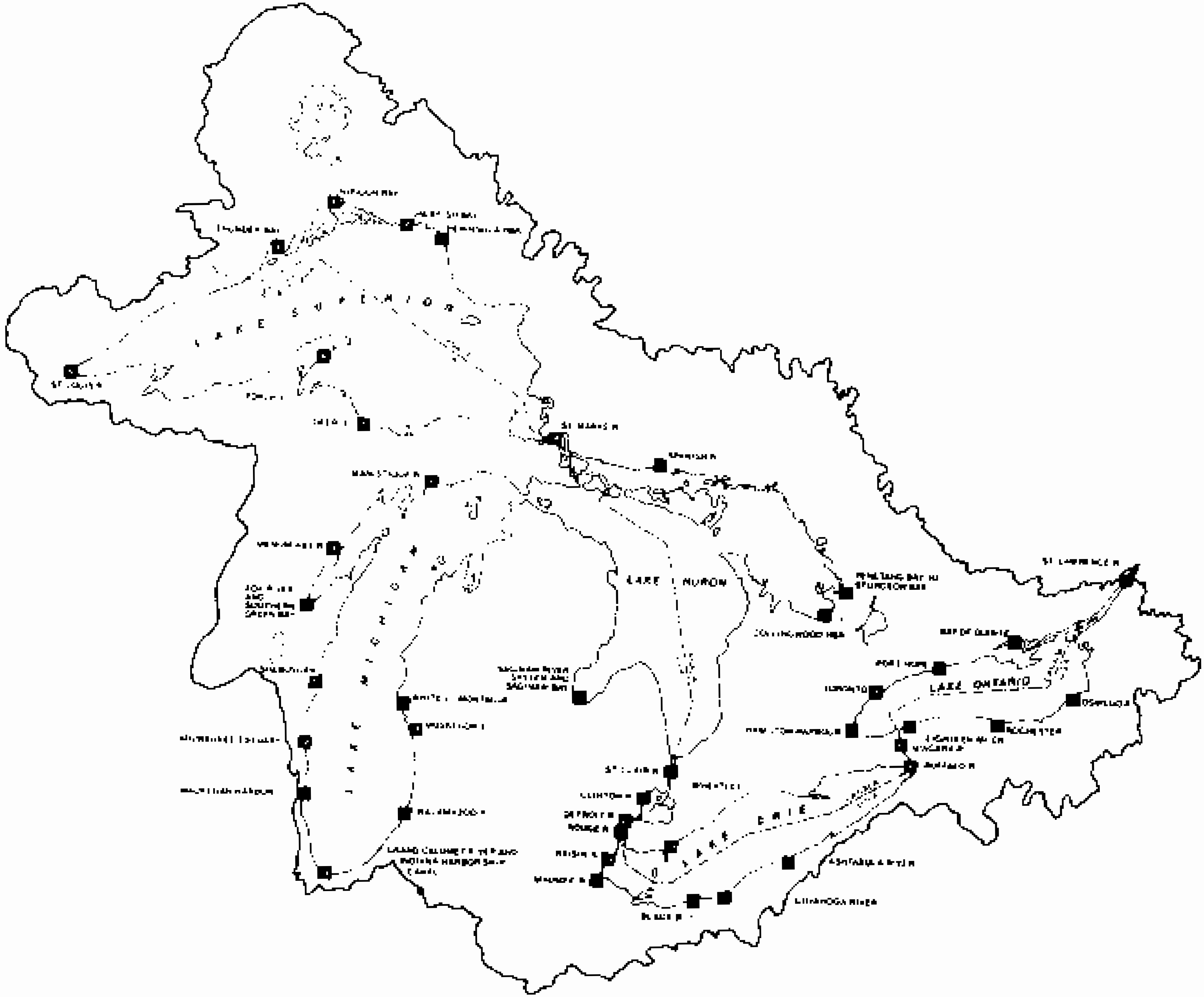


Figure 1-2. Areas of Concern in the Great Lakes Basin (Figure from IJC, 1987).

Table I-1. Jurisdictions Responsible for Developing Remedial Action Plans for the 42 Areas of Concern in the Great Lakes Basin (IJC, 1987).

MAP REF. NO.[a]	LAKE BASIN/AREAS OF CONCERN	JURISDICTION
	Lake Superior	
1	Peninsula Harbour	Ontario
2	Jackfish Bay	Ontario
3	Nipigon Bay	Ontario
4	Thunder Bay	Ontario
5	St. Louis River	Minnesota
6	Torch Lake	Michigan
7	Deer Lake-Carp Creek-Carp River	Michigan
	Lake Michigan	
8	Manistique River	Michigan
9	Menominee River	Michigan/Wisconsin
10	Fox River/Southern Green Bay	Wisconsin
11	Sheboygan	Wisconsin
12	Milwaukee Estuary	Wisconsin
13	Waukegan Harbor	Illinois
14	Grand Calumet River/Indiana Harbor Canal	Indiana
15	Kalamazoo River	Michigan
16	Muskegon Lake	Michigan
17	White Lake	Michigan
	Lake Huron	
18	Saginaw River/Saginaw Bay	Michigan
19	Collingwood Harbour	Ontario
20	Penetang Bay to Sturgeon Bay	Ontario
21	Spanish River Mouth	Ontario
	Lake Erie	
22	Clinton River	Michigan
23	Rouge River	Michigan
24	Raisin River	Michigan
25	Maumee River	Ohio
26	Black River	Ohio
27	Cuyahoga River	Ohio
28	Ashtabula River	Ohio
29	Wheatley Harbour	Ontario
	Lake Ontario	
30	Buffalo River	New York
31	Eighteen Mile Creek	New York
32	Rochester Embayment	New York
33	Oswego River	New York
34	Bay of Quinte	Ontario
35	Port Hope	Ontario
36	Toronto Waterfront	Ontario
37	Hamilton Harbour	Ontario
	Connecting Channels	
38	St. Marys River	Ontario/Michigan
39	St. Clair River	Ontario/Michigan
40	Detroit River	Ontario/Michigan
41	Niagara River	Ontario/New York
42	St. Lawrence River	Ontario/New York

a. See Figure I-1.

Saginaw Bay is a southwestern extension of Lake Huron located in the east central portion of Michigan's lower peninsula (Figure I-1). The physical boundaries of the Saginaw River/Bay AOC are defined as extending from the head of the Saginaw River, at the confluence of the Shiawassee and Tittabawassee rivers upstream of Saginaw, to its mouth, and all of Saginaw Bay out to its interface with open Lake Huron at an imaginary line drawn between Au Sable Point and Point Aux Barques. Areas outside these physical boundaries, but within the Saginaw Bay drainage basin, are considered in the RAP if they are known or suspected sources of contaminant materials delivered to the Saginaw River and/or Saginaw Bay. These areas comprise the Source Area of Concern.

The Saginaw River/Bay AOC is a large area. The bay is 83 kilometers (52 miles) long, varies in width between 21 and 42 kilometers (13 and 26 miles), and has a surface area of 2,960 square kilometers (1,143 square miles). The Saginaw Bay drainage basin of 22,557 square kilometers (8,709 square miles) contains approximately 15% of Michigan's total land area. Twenty-eight rivers, creeks or agricultural drains flow directly into Saginaw Bay, but about 75% of the tributary hydraulic input comes from the Saginaw River. The Saginaw River watershed covers 16,260 square kilometers (6,278 square miles) and is the largest in Michigan. The Saginaw River itself is only 35 kilometers (22 miles) long and most of its flow originates from the four major tributaries that empty into it - the Cass, Flint, Shiawassee and Tittabawassee rivers. Anthropogenic inputs to the Saginaw Bay basin are dominated by agriculture in the rural areas and industrial and municipal wastewater discharges from four major urban areas - Flint, Saginaw, Bay City and Midland.

The purpose of the RAP process is to identify and implement pollution abatement measures specific to the Saginaw River/Bay AOC which will restore designated water uses that are presently impaired because of degraded water quality conditions. Designated uses are those uses for which a specific water body is protected and include such items as industrial, agricultural and public water supply; body contact recreation; navigation; fish; and other indigenous aquatic life and wildlife. Designated uses for Michigan waters are defined by the General Rules of Michigan Public Act 245 of 1929 (Water Resources Commission Act) as amended, and are described more fully in Section III. Two designated uses are presently considered impaired in the Saginaw River/Bay AOC: the human consumption of fish; and, the suitability of the aquatic environment to indigenous plant and animal populations.

Public health fish consumption advisories are currently in effect for certain species in the Saginaw River/Bay AOC because of elevated levels of toxic materials in fish tissue. However, these advisories are restricted to bottom feeding fish and fish with relatively high levels of body fat. People are advised not to eat any carp or catfish from either the Saginaw River or Saginaw Bay. Additionally, for Saginaw Bay, it is suggested that people restrict their consumption of lake trout, rainbow trout and brown trout to no more than one meal per week. There are no advisories for yellow perch or walleye, the principal sport fish in Saginaw Bay. One goal for this AOC is the elimination of all fish consumption advisories.

Various biota populations in the Saginaw River/Bay AOC have been negatively impacted by degraded water quality conditions. These impacts have resulted from excessive phosphorus levels that have created eutrophic conditions which favor nuisance species tolerant of polluted environments. The second goal for the AOC is to reduce eutrophication in Saginaw Bay to a level where the bay will support a balanced mesotrophic biological community.

It is not presently known if toxic materials (from both water and contaminated sediments) bioconcentrated in the food chain are adversely affecting life histories. However, the third goal for this AOC is to reduce toxic material levels in water to those defined by Michigan's water quality standards in order to protect both human health and indigenous plant and animal communities.

Saginaw Bay is an important resource on which to focus additional water quality improvement efforts. Not only is it a valuable resource to Michigan, but water from Saginaw Bay eventually finds its way into open Lake Huron and can, therefore, potentially impact areas in other states or Canada. Saginaw Bay is important to people as a source of drinking water, recreational activities -- including pleasure boating, swimming, fishing, hunting and wildlife viewing -- commercial navigation, commercial fishing, general aesthetics, and the economic value of tourism activities it supports. The bay is also valuable to wildlife as a major fish spawning and nursery area, and provides shelter and food for waterfowl on a major migratory flyway.

It is intended that this Remedial Action Plan be used by all agencies/groups/individuals concerned with, affected by, or impacting, water quality in the Saginaw River or Saginaw Bay. The report has been prepared with several objectives in mind, including the following:

- to define the geographic extent of the Area of Concern
- to identify designated water uses that are impaired
- to describe historic and present environmental conditions
- to identify the materials causing degraded water quality
- to identify the sources of contaminant materials
- to recommend and describe remedial measures that should be implemented to restore the impaired designated uses
- to recommend and describe monitoring and/or research programs needed to acquire information necessary to (a) recommend and design specific remedial actions and (b) evaluate the effectiveness of implemented remedial actions.

Accordingly, this document serves as the technical, planning and project implementation focus for addressing water quality issues in the Saginaw River/Bay AOC. Extensive efforts have been made to include all interested and/or affected parties in the development, review and implementation of this plan (Section VI) so that it fully addresses the issues from a variety of perspectives and is broadly supported. This RAP is much more comprehensive than previous planning documents in that it examines water quality from an ecosystem perspective rather than focusing on only a single pollutant source or issue.

The RAP is not the start of this process -- water pollution reduction programs have been ongoing for over 20 years -- nor is it the end. The RAP is viewed as a long-term project and it is anticipated that it will be periodically updated and revised as more data is acquired, remedial measures are implemented, and environmental conditions improve. The RAP process itself for this AOC will eventually end when it has been documented to the IJC that both the identified designated uses, which are presently impaired, are fully restored; or, it is shown that they cannot be restored to any further extent. However, pollution control efforts will continue and it is probable that the RAP will also continue, though perhaps in a less formal form.

SECTION II - ENVIRONMENTAL SETTING

A. LOCATION AND SIZE

The Saginaw River/Bay Area of Concern is located in the east-central portion of Michigan's lower peninsula (Figure II-1). Saginaw Bay itself is a large and relatively shallow southwestern extension of Lake Huron. The bay is 42.1 km (26.2 miles) wide at its mouth along a line drawn between Au Sable Point and Point Aux Barques at the interface with open Lake Huron. From the midpoint of this transect to the mouth of the Saginaw River the bay is 83.3 km (51.8 miles) in length (Smith, et al., 1977). The bay's surface area of 2960 km^2 (1,143 square miles) is roughly 5% of Lake Huron's total surface area (Great Lakes Basin Commission, 1975).

The Saginw Bay shoreline of 240 km (149 miles) constricts the bay to a width of 20.2 km (12.6 miles) between Point Lookout and Sand Point, approximately midway along the bay's length. This constriction, along with a broad shoal area between Charity Island and Sand Point, divides the bay into inner and outer halves with equal surface areas (Table II-1). The inner bay is much shallower than the outer bay, having a mean depth of only 4.6 m (15.4 ft) and a maximum depth of 14.0 m (45.9 ft), versus mean and maximum depths of 14.6 m (47.9 feet) and 40.5 m (132.9 ft), respectively, for the outer bay. Consequently, the outer bay contains about 68.5% of the total bay volume. The total bay volume of 28.6 km^3 (6.8 cubic miles) is about 0.8% of Lake Huron's total volume (Great Lakes Basin Commission, 1975).

The Saginaw Bay watershed of 22,557 km^2 (8,709 square miles) includes portions of 22 of Michigan's 83 counties and 15% of Michigan's total land area. Four major urban areas are located within the basin - Flint, Saginaw, Bay City and Midland - along with 90 additional city or village municipalities (Figure II-2). The 1980 census indicated that 1,458,339 people live in cities, villages, and townships totally or partially within the Saginaw Bay watershed (Appendix 3). The basin includes portions of four Michigan regional planning agencies (Figure II-3), six U.S. congressional districts (Figure II-4), 10 state senate districts (Figure II-5), and 23 state representative districts (Figure II-6).

Twenty-eight rivers, creeks or drains flow directly into Saginaw Bay from three drainage basins - the East Coastal basin, West Coastal basin, and Saginaw River basin (Figure II-7). The Saginaw River basin is the largest of the three, covering 16,260 km^2 or 72% of the total Saginaw Bay watershed (Table II-2). The Saginaw River itself is relatively short, with a length of only 35.9 km (22.3 miles), and most of its flow originates from four major tributaries - the Cass, Flint, Shiawassee and Tittabawassee rivers (Figure II-7). Fifteen rivers or creeks drain the West Coastal basin - the Tawas, East Branch Au Gres (diverted via the Whitney Drain), Au Gres, Big Creek, Rifle, Pine, Saganing, White Feather, Pinconning, Johnsons, Tebo, Thume, Gregory, Railroad and Kawkawlin - which covers 3,983 km^2 or 18% of the Saginaw Bay watershed. Twelve

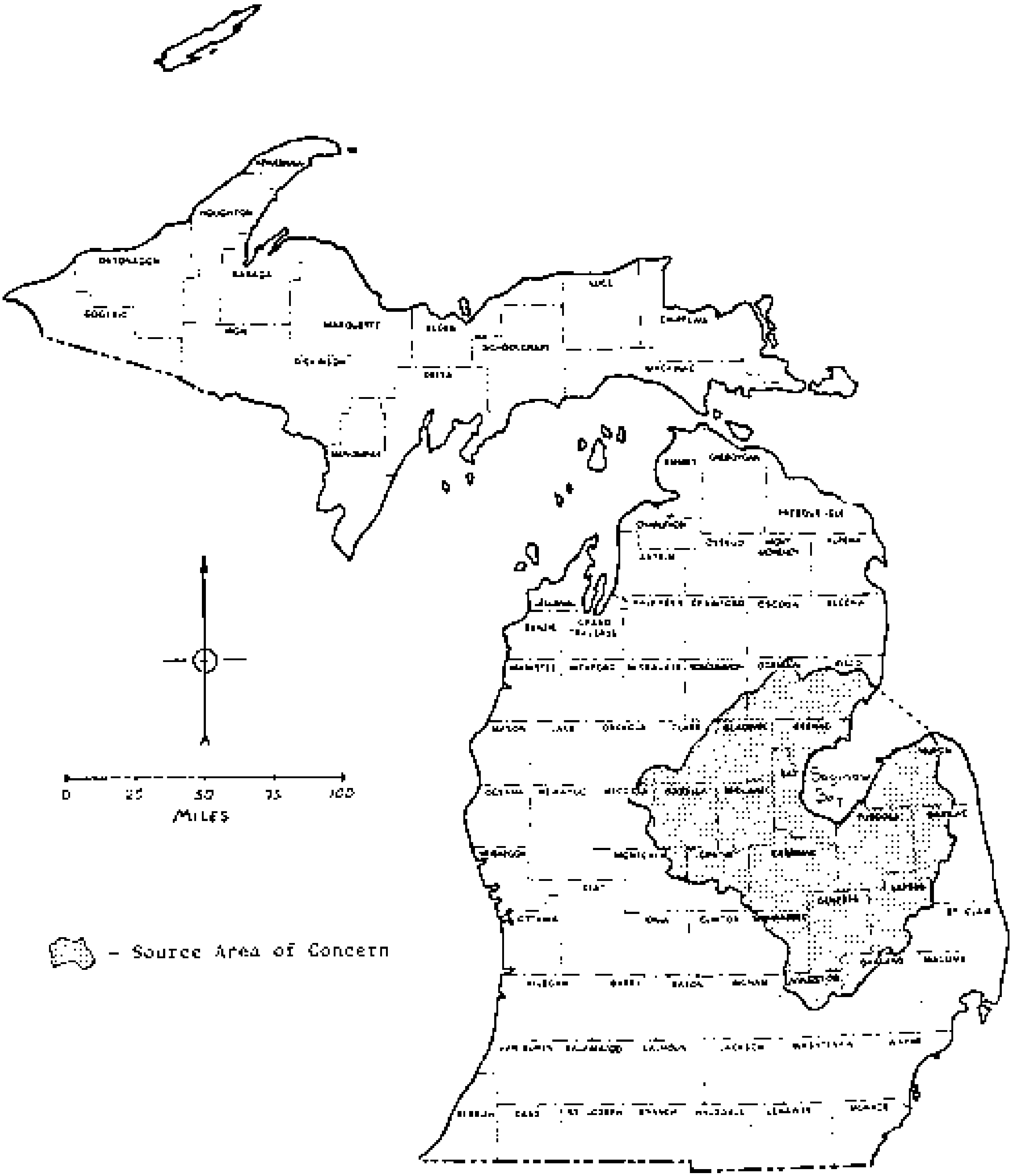


Figure II-1. Location of the Saginaw River/Bay Area of Concern.

Table II-1. Morphometric Data for Saginaw Bay[a].

Measurement	Saginaw Bay		
	Inner Bay	Outer Bay	Total
Surface Area (km^2)	1,480[b]	1,480[b]	2,960[b]
Average Depth (m)	4.6[b]	14.6[c]	9.6[b]
Maximum Depth (m)	14.0[b]	40.5[b]	40.5[b]
Volume (km^3)	6.8	21.6	28.4
Flushing Time	110[d]	---	52[d]
Surface Area/Volume	218	64	104
Shoreline Length (km)	---	---	240
Drainage Basin Area (km^2)			22,557[e]
Mean Tributary Input (m^3)			153.7[c]

[a]Chart datum for Lake Huron is 175.8 m (576.8 feet). As of June 1988, Lake Huron water levels were 176.4 m (578.8 feet).

[b]Beeton, et al, 1967.

[c]Smith, et al, 1977.

[d]Dolan, 1975. Flushing time determinations based on assumed volume of 25.3 cubic miles for total bay and 8.05 cubic miles for inner bay. Flushing times for volumes presented above would be 58 days for the whole bay and 93 days for the inner bay.

[e]From Table II-2.

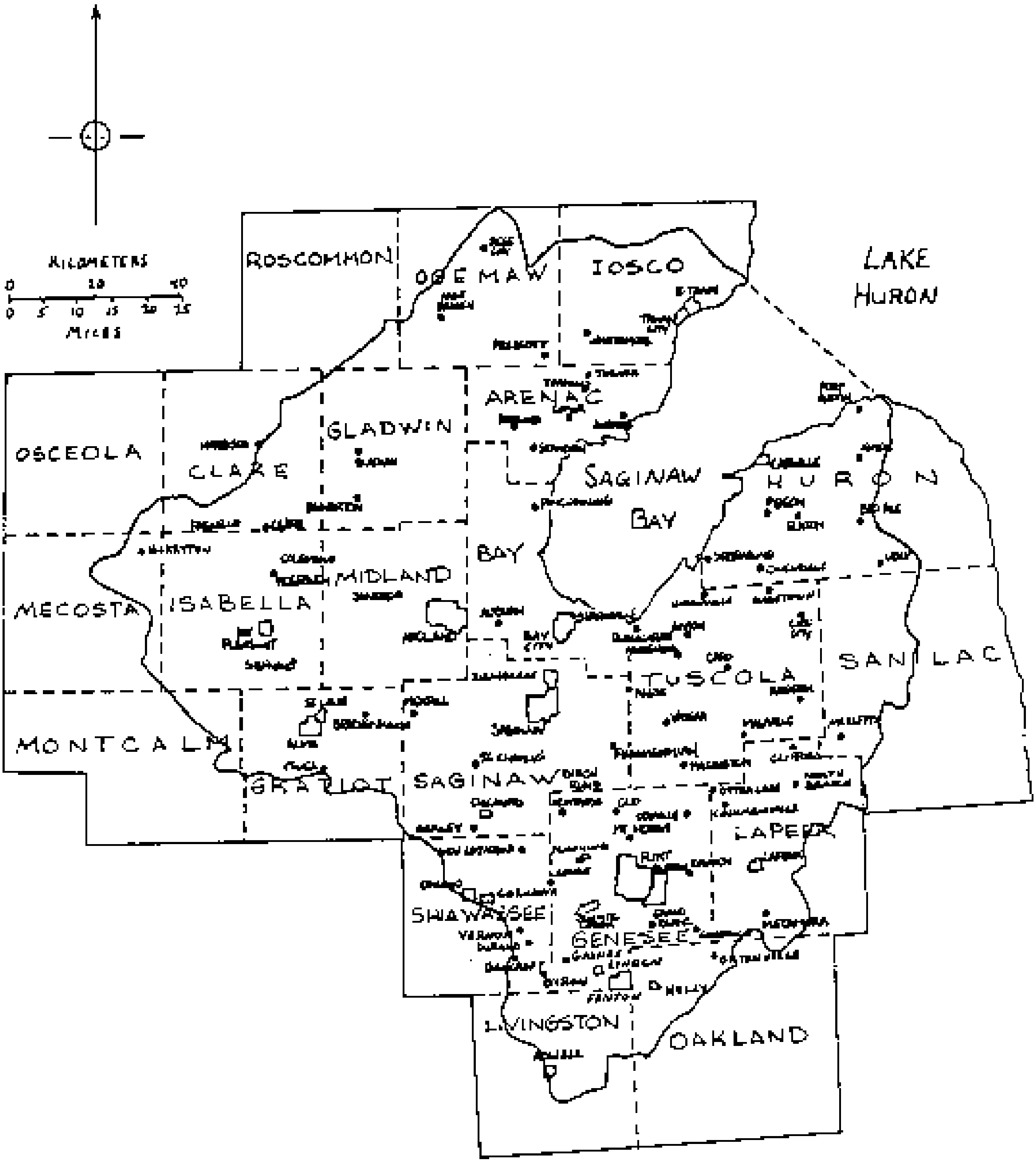


Figure II-2. Cities and villages located in the Saginaw Bay drainage basin.

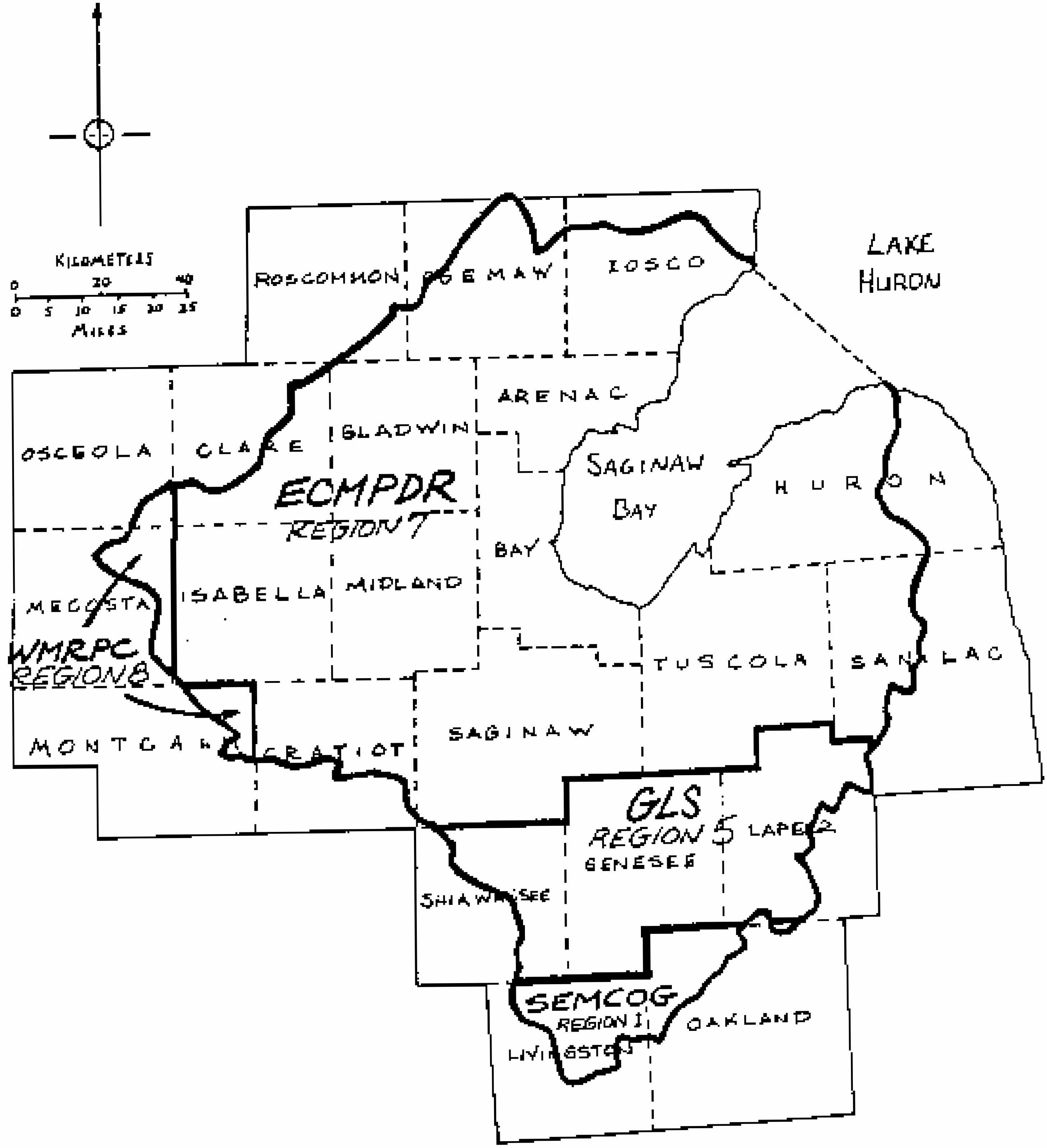


Figure II-3. Michigan regional planning agency service areas in the Saginaw Bay drainage basin.

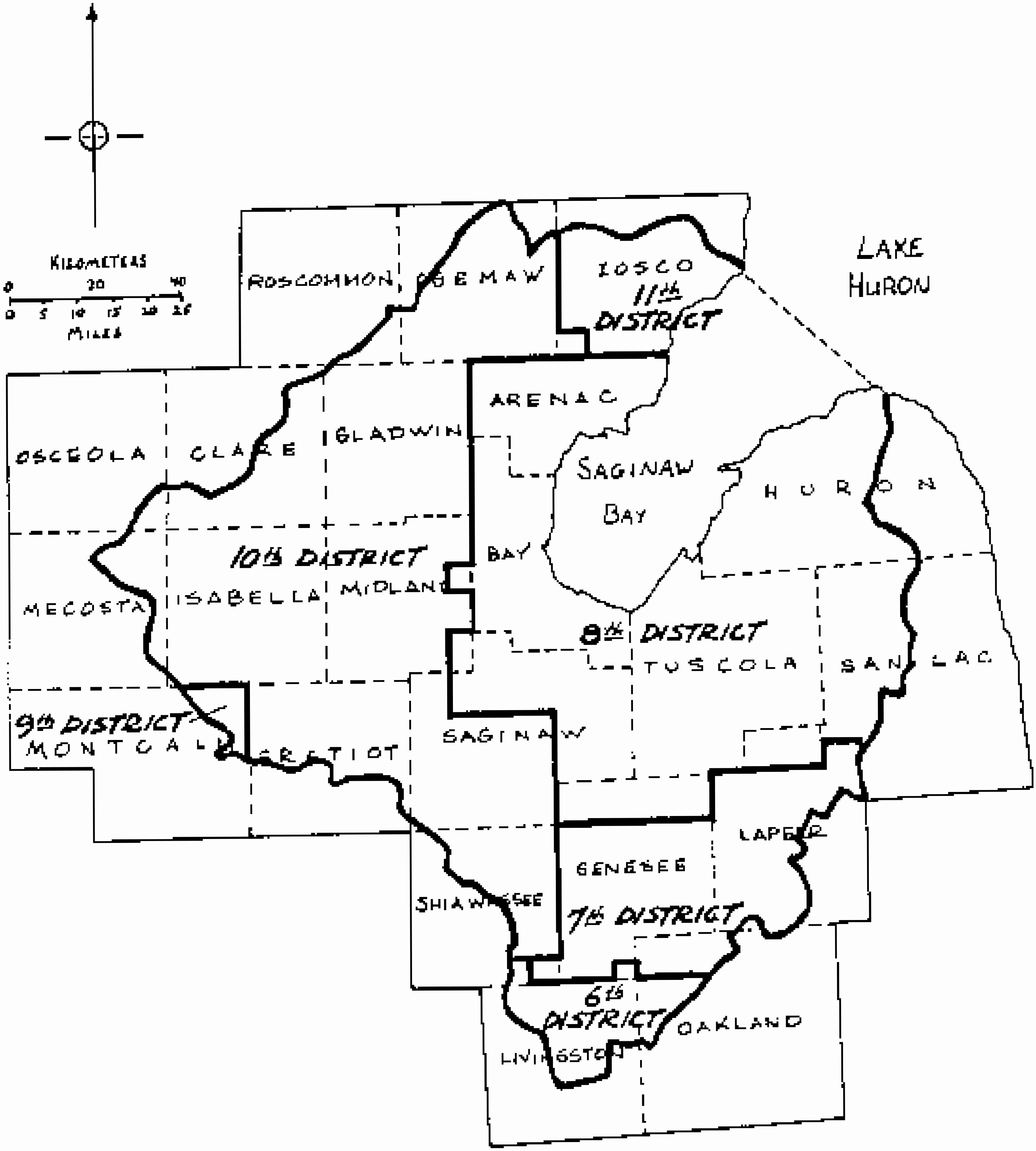


Figure II-4. United States congressional districts in the Saginaw Bay drainage basin.

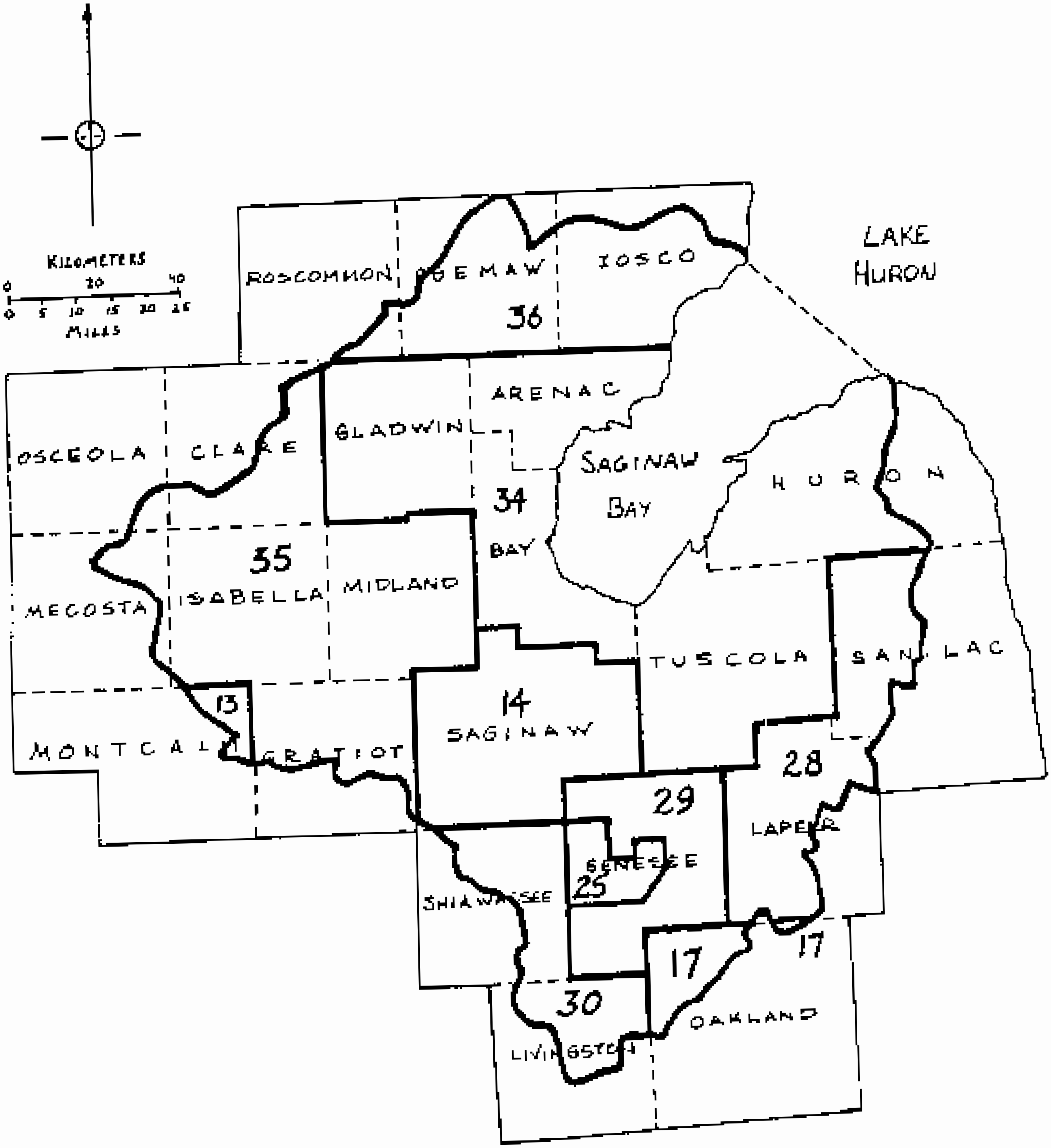


Figure II-5. State senate districts in the Saginaw Bay drainage basin.

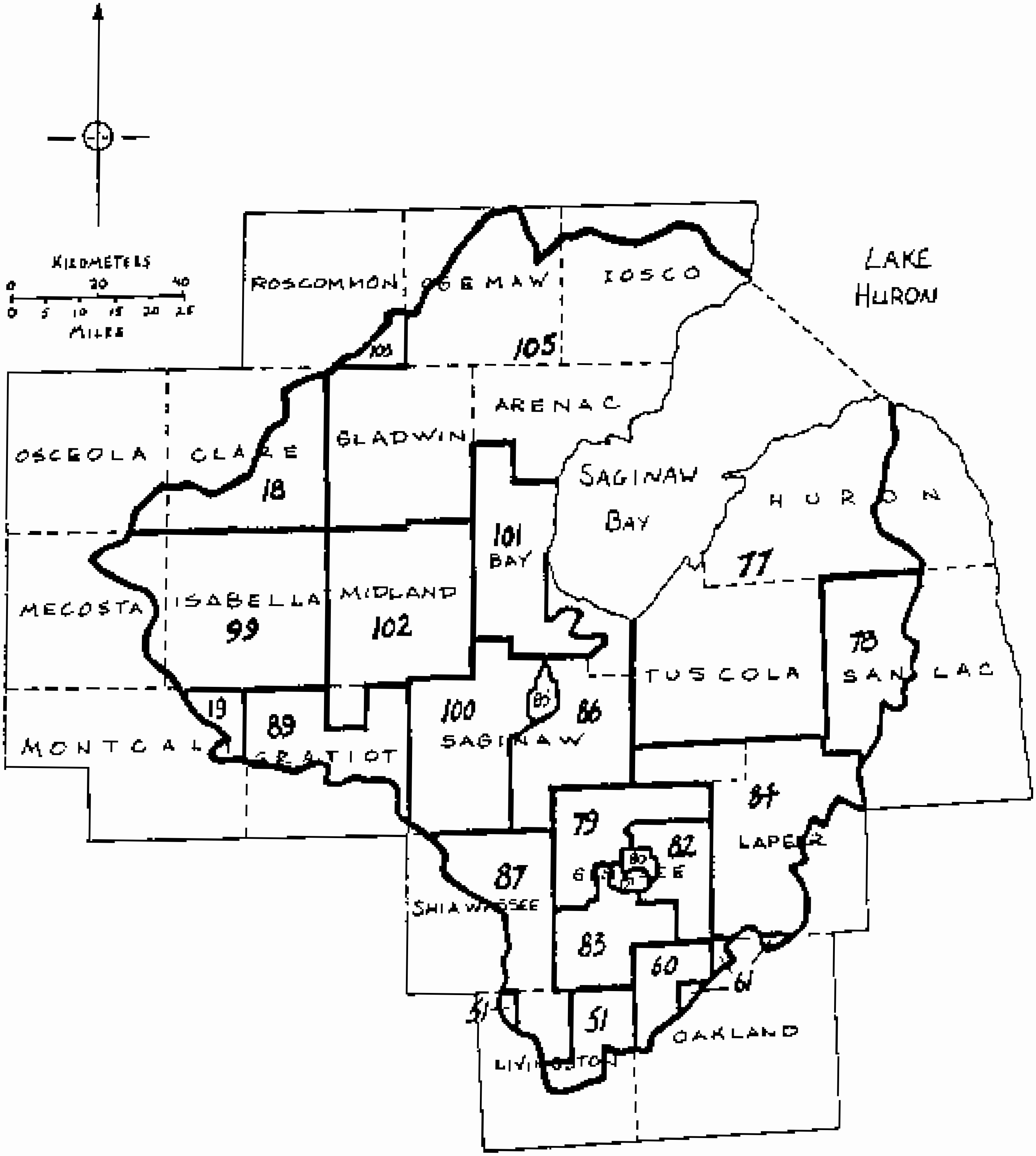


Figure II-6. State representative districts in the Saginaw Bay drainage basin.

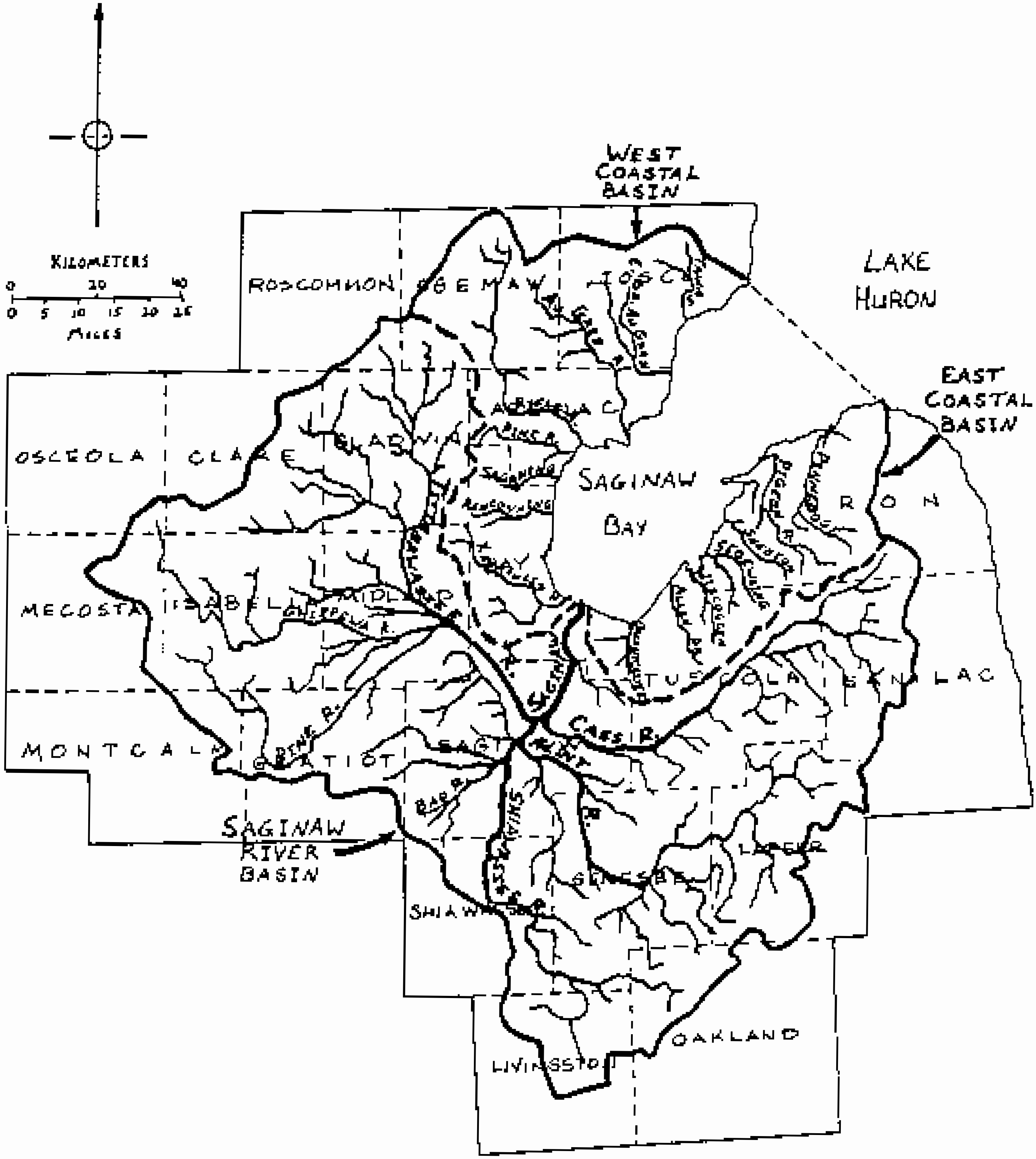


Figure II-7. Major tributaries to Saginaw Bay.

Table 11-2. River Drainage Basin Areas in the Saginaw Bay Watershed (Rick Popp, MDNR, personal communication).

Drainage Unit	Drainage Unit Area (km^2)		
Saginaw Bay Drainage Basin			22,557
<u>East Saginaw Bay Coastal</u>		2,314	
-Pinnebog R.	502		
-Pigeon R.	376		
-Shebeon Cr.	74		
-Mud Cr./Gettel Dr.	47		
-Sebewaing R.	285		
-Allen Dr.	65		
-Wiscoggin Dr.	170		
-Quanicassee R.	205		
-direct drainage to Saginaw Bay[1] including Bird, Taft and Northwest drains	590		
<u>West Saginaw Bay Coastal</u>		3,983	
-Kawkawlin R.	580		
-Pinconning R.	73		
-Saganing Cr.[2]	77		
-Pine R.[3]	254		
-Rifle R.	1,002		
-AuGres R.	728		
-E. Br. AuGres R.[4]	362		
-Tawas R.	414		
-direct drainage to Saginaw Bay[5] including Railroad, Gregory, Thume, Tebo, Johnson's and White Feather drains and Big Creek	492		
<u>Saginaw River Valley</u>		16,260	
-Saginaw R.	671		
-Cass R.	2,349		
-Flint R.	3,450		
-Shiawassee R.	3,004		
-Tittabawasse R.	6,786		

[1]Direct drainage from the East Coastal Basin obtained from U.S.G.S. (undated).

[2]Saganing Cr. basin area equals 73 km^2 upstream from State Road bridge. Four additional square kilometers added after map check.

[3]Pine R. Basin area equals 246 km upstream from State Road bridge. Eight additional square kilometers added after map check.

[4]E. Branch AuGres R. basin area 360 km^2 upstream from Co. Rd. 107. Two additional square kilometers added after map check.

[5]Direct drainage from the West Coastal basin is based on small scale map check.

rivers, creeks or drains flow directly into Saginaw Bay from the East Coastal basin - the Bird, Taft, Pinnebog, Pigeon, Mud, Shebeon, Gettel, Sebewaing, Wiscoggin, Allen, Northwest and Quanicassee - which covers 2,314 km^2 or the remaining 10% of the Saginaw Bay watershed.

B. HYDROLOGY

1. Circulation

The waters of Saginaw Bay generally circulate in a counter-clockwise fashion, with Lake Huron water entering along the western shore and bay water exiting along the eastern. Variations occur frequently within the inner portion of the bay, however, because its shallow waters respond quickly to changing winds. Stable but entirely different circulatory patterns can be established within eight hours of a wind shift in the inner bay (Allender, 1975). In the outer bay, greater depths and southward trending currents along Lake Huron's west shore result in more stable circulatory patterns.

Winds vary considerably over Saginaw Bay, but are most common from the southwest quadrant (Figure II-8). Current speed and base flow in Saginaw Bay have been found to increase significantly as southwest wind velocities rise (Limno-Tech, 1977). Persistent winds parallel to the axis of the bay result in fairly predictable circulatory patterns. Within the inner bay, the shallow water along shore or over shoals moves with the wind, while the deeper water in the middle circulates in the opposite direction (Danek and Saylor, 1975). The outer bay reacts somewhat differently. Under persistent winds from the southwest, the prevailing southward currents in adjacent portions of Lake Huron set up a clockwise gyre within the outer bay (Figure II-9); whereas, winds from the northeast drive lake currents further into the bay and result in a counterclockwise pattern (Figure II-10; Danek and Saylor, 1975).

Less predictable circulatory patterns accompany variable winds or persistent winds from the northwest or southeast. These components are assumed to primarily affect mixing and dispersion (Limno-Tech, 1977). The shallow inner bay is known to be easily and quickly mixed during the ice-free season (Limno-Tech, 1976). A total circulation model for 1974 is presented in Figure II-11. The flushing time for the entire bay using 1974 water exchange data and an assumed volume of 25.3 cubic kilometers is 52 days during the ice-free season (Dolan, 1975). Flushing times using the same exchange data but different estimates of total bay volume (23.7 to 30.0 cubic kilometers) range from 49 to 62 days.

During the winter, significant current velocity reductions occur in Saginaw Bay and adjacent portions of Lake Huron as ice cover reduces the area of open water upon which wind stress can act (Saylor and Miller, 1976). During this period, the flow of the Saginaw River beneath the ice becomes an important component of bay circulation (Dolan, 1975).

2. Water Levels

Water levels on Lake Huron have dropped from a record high in October 1986 of 177.3 m (581.6 feet) nearly 1.5 m (5 feet) above Lake Huron chart datum level of 175.8 m (576.8 feet) to 176.4 m (578.8 feet) in June 1988. Significant short term fluctuations above and below Lake Huron levels are common on Saginaw Bay. Strong and persistent winds along the axis of the bay are capable of generating waves up to 2.4

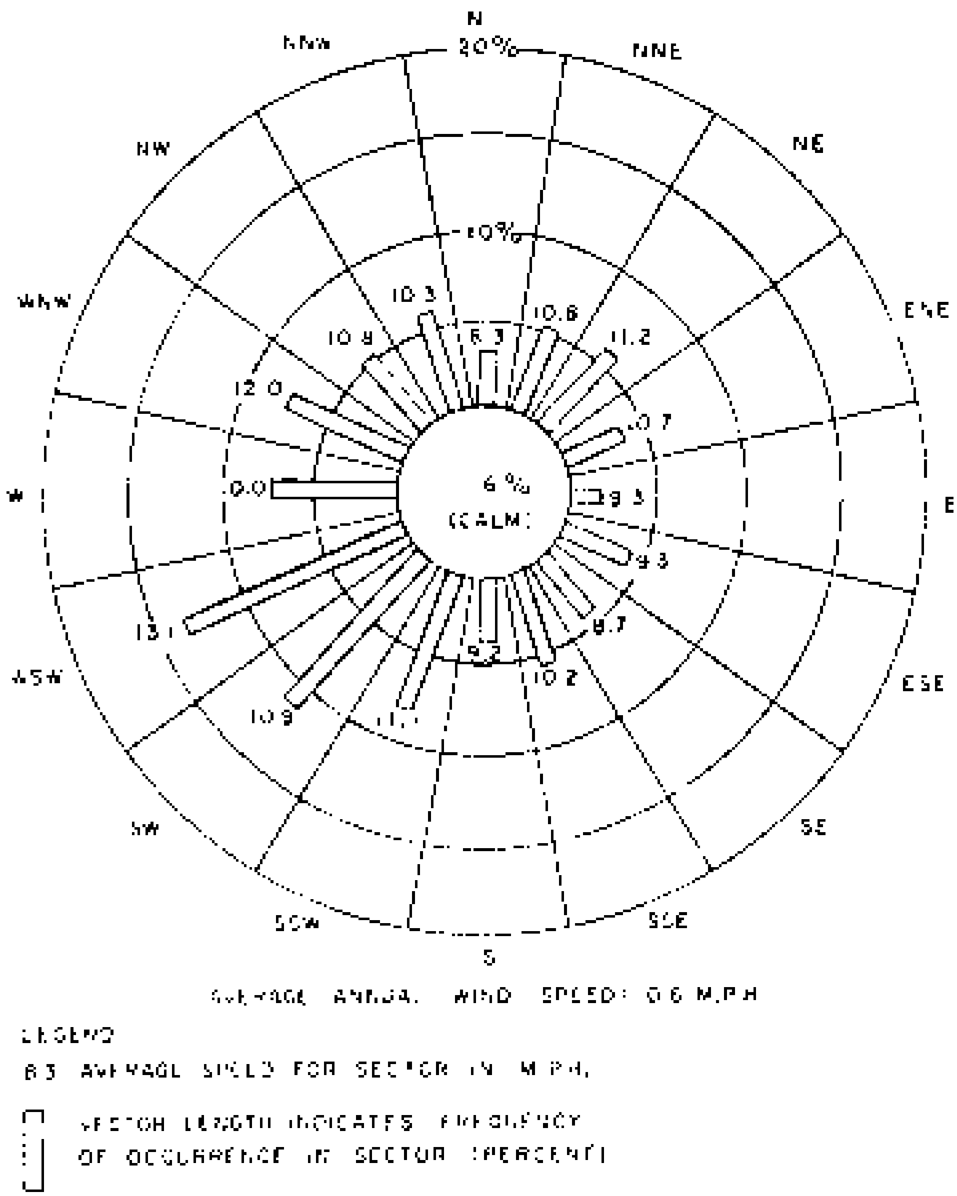


Figure II-8. Annual wind vectors for the Saginaw Bay area (Consumers Power Company, 1972).

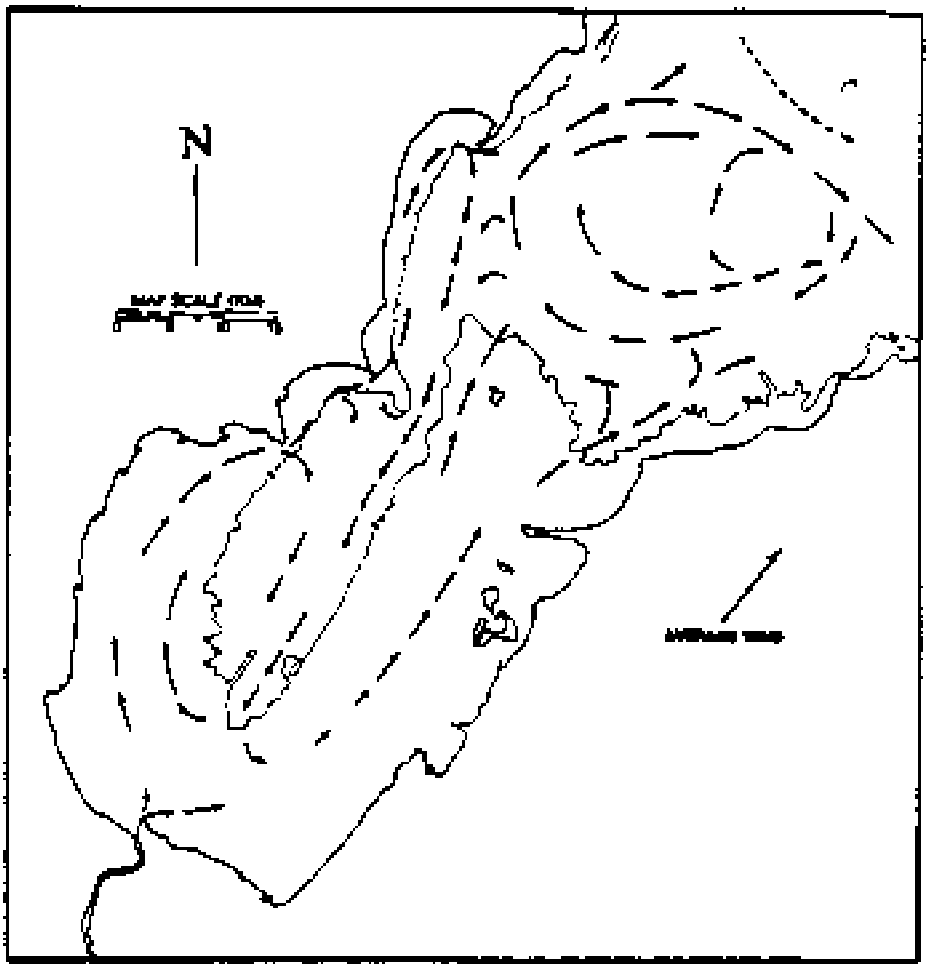


Figure II-9. Circulation pattern in Saginaw Bay for a southwest wind.

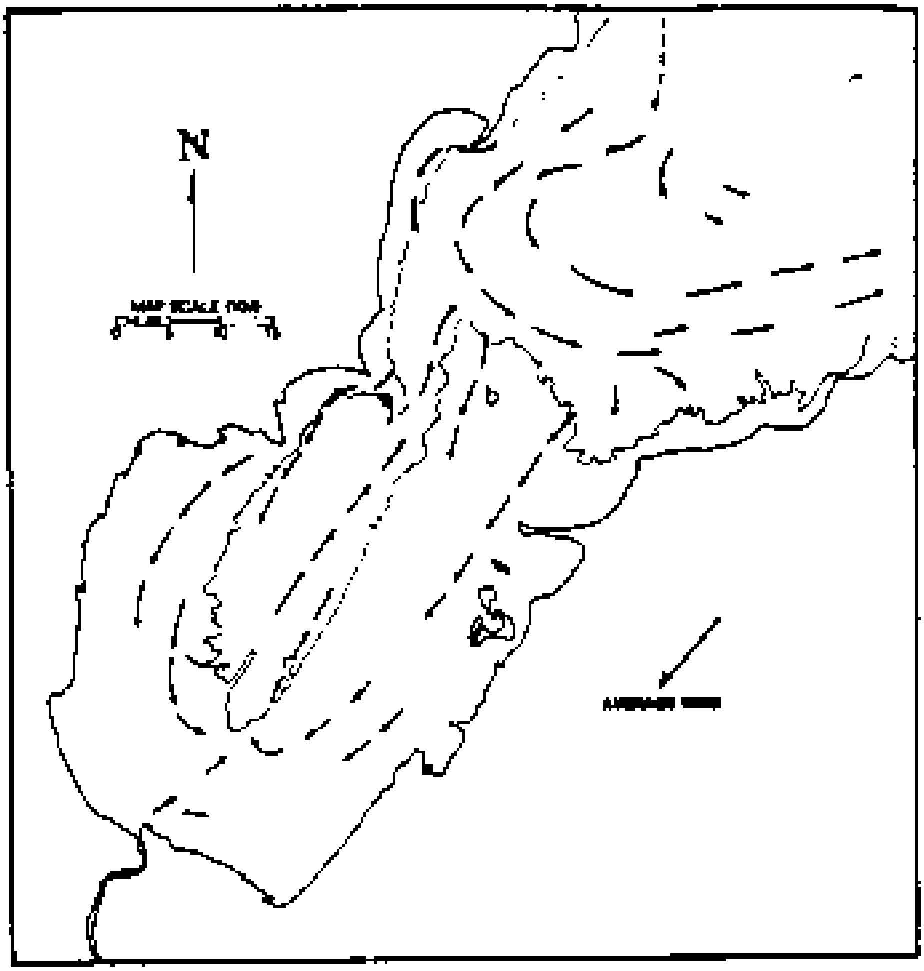


Figure II-10. Circulation pattern in Saginaw Bay for a northeast wind.

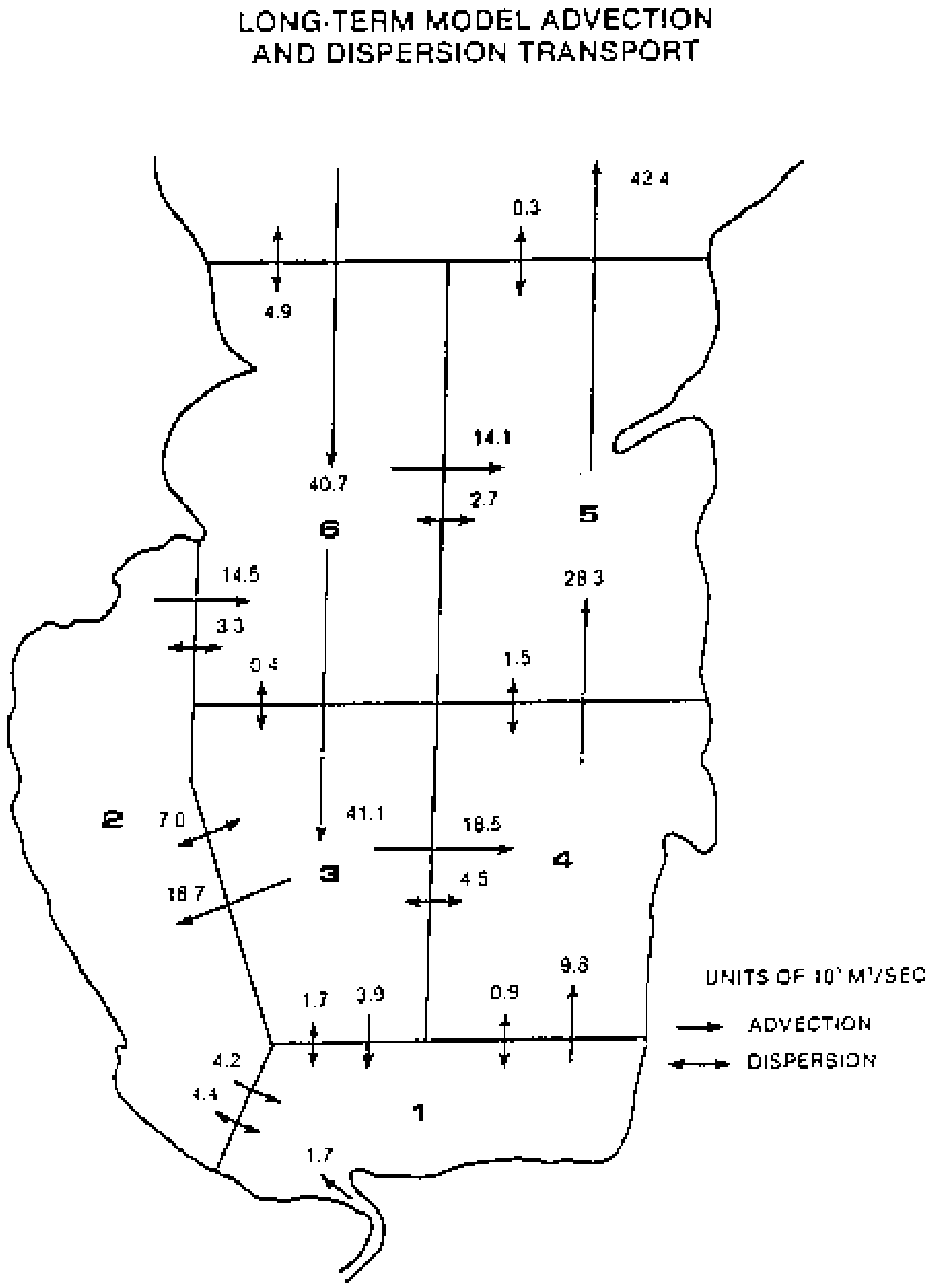


Figure 11-11. An advection and dispersion model for Saginaw Bay (Limno-Tech, 1977).

meters in height (Garcia and Jensen, 1983) and leeshore water level oscillations of as much as two meters (Smith, et al., 1977). When combined with high water levels, such oscillations or seiches can be a threat to coastal resources. They can also cause discharge rate reductions and even flow reversals on the many low gradient rivers that empty into the bay. The Saginaw River, with a gradient of 1.58 cm/km (1 inch/mile) or less (Chester Engineers, 1978), has frequently exhibited flow reversals as far upstream as river kilometer 35.4 (20.56 miles), although the continuity of these reversals below a one meter depth in the water column is unknown.

3. Flow

Saginaw Bay receives an average total tributary input of 153.7 cubic meters per second (Smith, et al., 1977). Of this, 114.5 cms (74.4%) is contributed by the total adjusted average discharge of the four major tributaries at their confluence to form the Saginaw River (river kilometer 35.9). Average discharge, as determined at each tributary's downstream gauge, is adjusted using a correlation between runoff per square mile and the drainage area known to exist below that gauge. Adjusted average discharges for the four tributaries are then totalled to represent the headwater flow of the Saginaw River (Limno-Tech, 1977). Discharge measurements at the mouth of the Saginaw River are generally considered unreliable due to the influence of seiche-induced flow reversals. However, the U.S. Geological Survey does have a mathematical model to predict flow at the Saginaw River mouth. Water discharge records for many of the Saginaw Bay tributaries are presented in Table II-3. It should be noted that rivers for which reliable long term discharge measurements were not available have not been included. This, and the necessity of placing gauges upstream from the mouths of some rivers to avoid the effect of flow reversals, accounts for the discrepancy between the 153.7 cms figure cited previously and the total average discharge of 131.9 cms for the Saginaw Bay tributaries listed in Table II-3.

Rivers within the Saginaw Bay drainage basin can generally be described as low slope and event responsive. Both characteristics reflect the long term inundation of the area by post-glacial lakes, which deposited thick layers of relatively impermeable lacustrine sediments before retreating. Because the soils that developed from these materials are generally very fertile, agricultural development succeeded the logging era of the mid to late 19th century and, accompanied by the construction of drains, ditches and field tile systems, encroached upon many of the wetlands that border the bay. Besides the known water quality implications, such changes increase the speed with which water is delivered downstream and the potential for downstream flooding. Similar consequences are associated with the large areas of impermeable surfaces and the extensively channelized river courses found in urban areas. In addition, large volumes of water are added to the drainage network by townships and municipalities that "import" drinking water from Lake Huron, Saginaw Bay, or groundwater supplies. The City of Flint, for example, adds an average of 1.2 cms (44 cfs) to the flow of the Flint River by the discharge of water originally taken from Lake Huron (Chester

Table II-3. Water Discharges Records for Rivers in the Saginaw Bay Drainage Basin.

Drainage Unit and Location	Drainage Area (km^2)	Period of Record	Average/Maximum/Minimum Discharge (cms)			USGS Gaging Station 4
-Pigeon R. near Owendale	137	1952-82	0.9	72.2	0.0	1585
-State Dr. near Sebewaing	161	1940-54	1.0	N.A.	0.0	1575
-Columbia Dr. near Sebewaing	98	1940-54	0.6	N.A.	0.0	1580
-N. Br. Kawkawlin R. near Kawkawlin	262	1951-82	1.6	45.6	0.0	1435
-Rifle R. at Selkirk	303	1950-81	4.0	78.2	1.5	1405
-Rifle R. near Sterling	829	1936-86	8.8	151.2	2.1	1420
-AuGres R. near National City	438	1950-81	2.7	77.0	0.2	1385
-E. Br. AuGres R. at McIvor	218	1950-73	1.8	37.1	0.3	1380
-Saginaw R. at Saginaw	15,695	1942-86	114.5+	1,925.6	NA	1570
-S. Br. Cass R. at Cass City	616	1948-80	3.5	181.2	0.0	1500
-Cass R. at Cass City	930	1947-86	6.1	354.0*	0.0	1505
-Cass R. at Wahjamega	1,671	1968-86	12.6	583.3*	0.6	1508
-Cass R. at Frankenmuth	2,178	1939-86	14.2	640.0*	NA	1515
-S. Br. Flint R. at Columbiaville	572	1980-86	5.4	87.5	0.4	1460
-Flint R. near Otisville	1,373	1952-86	8.9	174.1	0.1	1475
-Kearsley Cr. near Davison	256	1965-86	2.0	42.5	0.1	1481
-Swartz Cr. at Flint	298	1970-83	2.2	89.5	0.0	1483
-Flint R. near Flint	2,476	1932-86	17.0	421.9	0.3	1485
-Flint R. near Fosters	3,077	1939-84	21.0	538.0	0.8	1490
-Shiawassee R. at Linden	210	1967-86	1.7	13.5	0.0	1439
-Shiawassee R. at Byron	953	1947-83	7.1	109.9	0.5	1440

Table II-3. Continued

Drainage Unit and Location	Drainage Area (km^2)	Period of Record	Average/Maximum/ Minimum Discharge (cms)			USGS Gauging Station #
-Shiawassee R. at Owosso	1,393	1931-86	9.5	176.7	0.0	1445
-Shiawassee R. near Fergus	1,650	1939-74	11.9	212.4	0.8	1450
-Salt R. near North Bradley	357	1934-67	2.2	232.2	0.0	1535
-Chippewa R. near Mt. Pleasant	1,077	1932-86	8.8	186.9*	0.3	1540
-Chippewa R. near Midland	1,546	1947-72	12.0	241.0*	0.0	1545
-Pine R. at Alma	746	1930-86	6.1	147.8*	0.0	1550
-Pine R. near Midland	1,010	1948-86	8.5	265.0*	N.A.	1555
-Tittabawassee R. at Midland	6,216	1936-86	48.2	1,189.3*	1.1	1560

Source: Miller, et al. Water Resources Data - Michigan, Water Year 1985 (and others). U.S.G.S., June, 1986.

+Average Saginaw River discharge based on the correlation:

$$QS = 1.82\ QSh + 1.17\ QF + 1.05\ QC + 1.09\ QT$$

where: QS = Saginaw River upstream flow
QSh = Shiawassee River flow at guage #1450
QF = Flint River flow at guage #1490
QC = Cass River flow at guage #1515
QT = Tittabawassee River flow at guage #1560

(Limno-Tech. Inc., July, 1977)

*Preliminary September 1986 Flood Data courtesy of John Miller, USGS, Lansing.

Engineers, 1978). This represents 48% of the drought flow of the Flint River at its mouth. The Saginaw-Midland Water Supply Corporation delivers an average of 2.2 cms (50 mgd) to 31 municipalities and townships in Arnac, Bay, Midland, Saginaw and Tuscola Counties (Gary Peters, personal communication, 1987), although the proportion of this volume discharged into the various bay tributaries is not known.

Some areas of the Saginaw Bay drainage basin have more permeable soils than those in the agricultural areas and their soils impart a less hydrologically responsive character to local drainage systems. The Rifle River is perhaps the best example, along with some of the upstream portions of the Tittabawassee River and other northern or western rivers. A comparison of flood and low flow data for similarly sized portions of the Pigeon and Rifle river watersheds provides a good indication of stream response to the range of soil types found in the basin (Chester Engineers, 1978). The Pigeon River is located in the heavy-clay, agricultural soils of Huron County and has a one-day, two-year recurrence interval flood volume of 18.3 cms (647.2 cfs). This is almost 50 percent larger than the 11.9 cms (420.3 cfs) discharged by the Rifle, a comparatively high gradient river that drains forested sand and gravel-textured soils in Arenac and Ogemaw Counties. Seven consecutive day, ten year recurrence interval low flow data, on the other hand, indicates almost no flow (0.6 cfs) in the Pigeon, while the Rifle maintains a discharge volume of 1.6 cms (55.2 cfs). Land use and slope account for some of the differences, but the relative capacities of soils to absorb, store, and release water are the dominant factors.

4. Precipitation

Precipitation within the basin averages about 76 cm annually, 13 cm of which falls as snow and is potentially available for release en masse during spring meltoff. Considerable variation exists among 18 weather reporting stations within the Saginaw Bay drainage basin (Table II-4). For example, Gladwin averages 13 cm more precipitation annually than Bay City, although they are only 64 km apart.

The floods of September 1985 (Flint River) and September 1986 (Saginaw, Tittabawassee and Cass rivers) illustrate the magnitude of variation possible from the norms established over a single century of climatic record keeping. The September 1986 flood resulted from a rainfall of up to 30 cm over 36 hours in some areas, followed by another 8 to 18 cm during the remaining 19 days of the month. Rainfall totals officially exceeded 45 cm during a three-week period in many areas of the Saginaw Bay drainage basin (Fred Nornberger, personal communication, 1986). Estimated maximum point rainfall is extrapolated for the Midland area in Table II-5.

Annual snowfall averages 106 cm over the Saginaw Bay drainage basin, with the largest amount falling in its northern and eastern portion (Michigan Weather Service, 1971).

Table II-4. Average Monthly and Annual Precipitation Amounts (inches) at Reporting Stations within the Saginaw Bay Drainage Basin.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Alma[1]	1.47	1.20	2.06	2.98	2.79	2.98	2.62	3.66	3.04	2.47	2.31	1.99	29.56
Bad Axe[1]	1.79	1.56	2.20	2.66	2.58	2.88	2.93	3.01	2.67	2.49	2.38	2.18	29.35
Bay City[1]	1.48	1.22	2.16	2.59	2.66	2.88	2.53	3.00	2.78	2.52	2.28	1.78	27.97
Caro[1]	1.48	1.18	2.10	2.51	2.55	3.09	2.92	2.96	2.98	2.30	2.27	1.88	28.21
East Tawas[2]	1.61	1.28	2.06	2.61	2.85	3.21	2.94	3.05	2.98	2.30	2.41	2.22	29.52
Flint[1]	1.59	1.46	2.13	3.05	2.78	3.23	2.81	3.38	2.35	2.13	2.29	2.00	29.20
Gladwin[1]	1.79	1.48	2.10	2.93	3.04	3.55	3.39	3.30	3.14	2.61	2.56	2.41	32.30
Harrison[2]	1.64	1.37	1.91	2.84	2.82	3.17	3.47	3.24	2.99	2.63	2.41	1.95	30.44
Lapeer[2]	1.44	1.24	1.84	2.92	2.75	3.34	2.46	3.34	2.34	2.25	2.15	1.83	27.90
Midland[1]	1.64	1.51	2.14	2.83	2.64	3.00	2.67	3.07	2.82	2.47	2.27	2.21	29.28
Millington[2]	1.40	1.26	2.05	2.52	2.89	3.11	2.70	3.07	2.85	2.25	2.22	1.84	28.16
Mt. Pleasant[1]	1.37	1.12	1.99	3.19	2.84	3.20	3.22	3.57	2.95	2.60	2.33	1.86	30.24
Owosso[1]	1.68	1.40	2.04	2.83	2.58	3.32	2.70	3.21	2.68	2.07	2.27	2.06	28.78
Saginaw[1]	1.47	1.22	1.95	2.76	2.70	3.32	2.72	3.13	2.62	2.39	2.38	1.98	28.95
St. Charles[2]	1.62	1.34	2.13	2.43	2.49	3.09	2.83	3.29	2.76	2.74	2.17	1.91	28.30
Sebewaing[2]	1.27	1.10	1.72	2.22	2.47	2.71	2.94	2.76	2.81	2.31	2.07	1.64	26.02
Standish[2]	1.30	1.15	1.85	2.50	2.69	3.15	2.92	2.89	2.99	2.53	2.11	1.73	27.81
West Branch[1]	1.43	1.32	1.88	2.44	2.78	2.80	3.25	3.10	3.15	2.48	2.45	1.90	28.84
Basin Averages	1.53	1.30	2.02	2.71	2.72	3.11	2.89	3.17	2.84	2.39	2.30	1.96	28.93

Sources: [1]Fred Nurnberger, Climatology Division, Michigan Dept. of Agriculture. Averages compiled from data collected over 25-30 year period representing mid 1940's or early 1950's to mid 1970's or early 1980's.

[2]National Climatic Center, NOAA, Climate Normals for the U.S., 1951-80. Gale Research, Detroit, 1983.

Table II-5. Estimated Maximum Point Rainfall Extrapolated for the Midland Area.

	Rainfall (inches) Recurrence Interval (years)						
Duration	1	2	5	10	25	50	100
30 minutes	0.8	1.0	1.2	1.4	1.6	1.8	2.0
1 hour	1.0	1.2	1.6	1.7	2.0	2.2	2.5
2 hours	1.1	1.4	1.7	2.0	2.2	2.5	2.7
3 hours	1.2	1.5	1.9	2.1	2.5	2.7	3.0
6 hours	1.5	1.7	2.1	2.5	2.9	3.0	3.5
12 hours	1.6	2.0	2.5	3.0	3.3	3.5	4.0
24 hours	2.0	2.3	2.8	3.5	3.9	4.1	4.5

Source: U.S. Weather Bureau, Rainfall Frequency Atlas of the U.S. for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years, Technical Paper 40 (1961), U.S. Dept. of Commerce, Washington D.C.

C. TOPOGRAPHY AND SOILS

The topographic character of the Saginaw Bay drainage basin is a product of glacial and post-glacial processes. The track of the latest glacial incursion into east central Michigan is evident in the shape of Saginaw Bay and in the nearly continous band of glacial moraine deposited at the margins and terminus of the ice. Moraines account for the most dramatic verticle relief in the basin and represent the headland of many tributaries to Saginaw Bay. Maximum local relief ranges from approximately 20-30 meters along the eastern and southwestern fringe of the basin to over 100 meters in Ogemaw County (Figure II-12).

As the ice sheet stalled and then retreated, meltwater rivers transported large volumes of debris from the ice to depositional zones downslope. Since the distance over which variously sized particles could be transported depended on the speed and volume of flow, the sediment composition of these deposits reflect seasonal hydrologic cycles. In the Saginaw Bay drainage basin, sand and gravel outwash deposits exhibiting some degree of sorting and crossbedding occur in narrow bands along the bay side of marginal and terminal moraines. Areas of mixed sand, gravel, and cobble outwash occupy large portions of Roscommon, Ogemaw and Iosco counties.

The erosional depression created by the glacial lobe that occupied east central Michigan filled with meltwater as it withdrew. The height and extent of lake levels during that period are documented in the lacustrine plain extending well inland from the eastern, southern and western shores of the modern bay. Coarse sediment lake plains, indicative of beach or nearshore environments, occupy substantial areas near the moraine deposits from which their materials were derived. In contrast, clay-rich lacustrine deposits, which were originally formed well offshore, now occupy large portions of the basin immediately adjacent to the bay and in Gladwin, Midland, Isabella, Gratiot and Saginaw counties further inland.

The varied soils of the Saginaw Bay drainage basin largely reflect the influences that glacial and post-glacial processes have exerted on the parent materials, drainage and topography (Figure II-13; Table II-6). The soils that formed on lake plains rich in clay are relatively impermeable and, in their natural state, poorly drained and erodible. These soils occur over large areas to the east, south and southwest of Saginaw Bay and have been extensively drained to permit agriculture. Soil associations with more than 13 percent clay content in their surface layer are mapped in Figure II-14.

Soils derived from outwash deposits, or from the wave-sorted sand of what were once nearshore or beach environments, also occupy a large portion of the basin. Usually flat or gently sloping, these coarser soils are often well drained and droughty; however, poorly drained variants are common in some areas due to high water tables of underlying clay pans.

The soils that developed on the varied parent materials and slopes of the marginal and terminal moraines are themselves quite varied. Loamy

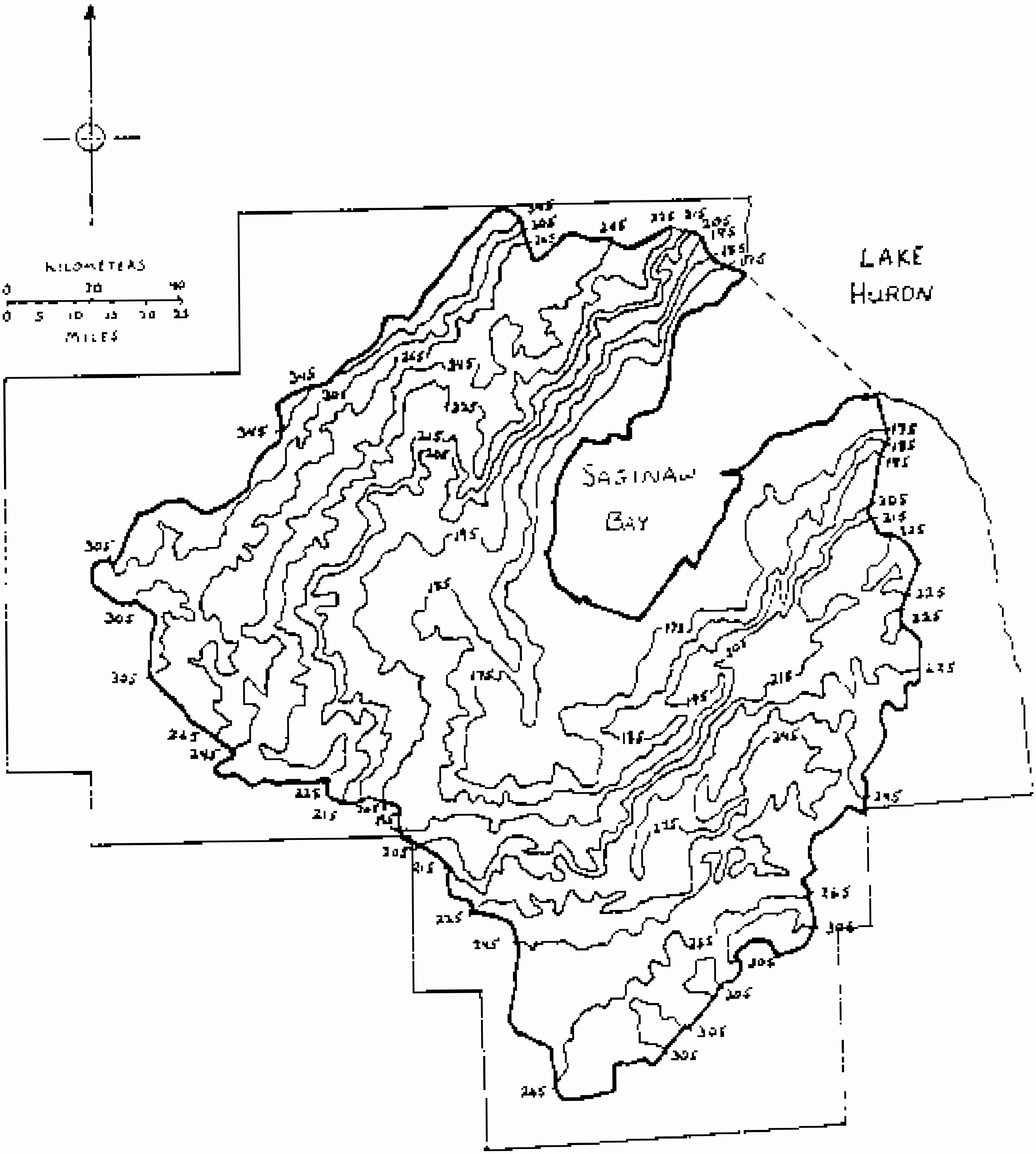


Figure II-12. Generalized contour (m) map of the Saginaw Bay basin.

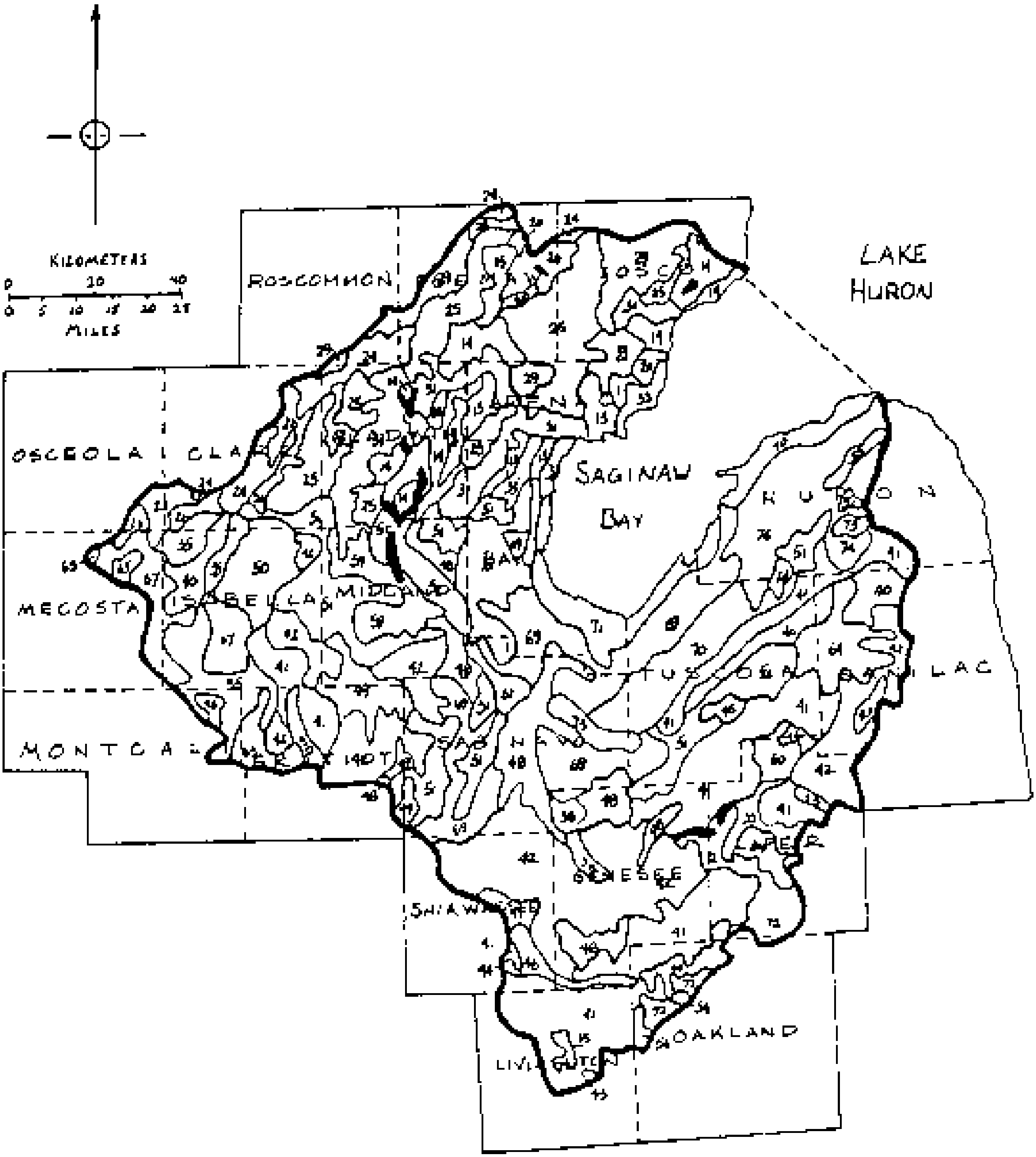


Figure II-13. Soil associations of the Saginaw Bay drainage basin (See Table II-6 for number legends; SCS, 1981).

Table II-6. Soil Associations of the Saginaw Bay Drainage Basin and Characteristics Affecting Surface Water Runoff.

Map[1] #	Association	% Clay in Surface Layer[4] by Series	K Value[2] of Surface Layer[4] by Series	Hydrologic Grouping[3] by Series
1.	Ontonagon-Rudyard-Pickford	46-45-41	.28-.37-.37	D-D-D
13.	Roscommon-AuGres-Tawas	4-4	.17-.15-0	A/D-B-A/D
14.	Rubicon	3	.15	A
15.	Kalkaska-Blue Lake	2-4-5	.09-.07	A-A
19.	Roscommon-Tawas-Rubicon	4-na-4	.08-0-.15	A/D-A/D-A
20.	Tawas-Carbondale-Greenwood	0	0-0-0	A/D-A/D-A/D
22.	Kalkcaska-Rubicon	2-5	.15-.15	A-A
24.	Graycalm-Montcalm	4-7	.15-.17	A-A
25.	Nester-Kawkawlin-Sims	18-18-26	.32-.32-.32	C-C-D
26.	Nester-Menominee-Montcalm	18-7-7	.32-.17-.17	C-A-A
28.	Emmet-Leelanau	13-6	.20-.17	B-A
29.	Grayling-Rubicon	7-5	.15-.15	A-A
31.	Iosco-Allendale-Brevort	7-6-8	.17-.17-.17	B-B-B/D
32.	Mancelona-Gladwin	3-6	.17-.17	A-A
33.	Iosco-Kawkawlin-Sims	7-18-26	.08-.11-.06	B-C-D
35.	Spinks-Oshtemo-Boyer	5-10-7	.17-.24-.17	A-B-B
38.	Tedrow-Granby	4-5	.17-.17	B-A/D
39.	Brady-Wasepi-Gilford	8-10-12	.20-.20-.20	B-B-B
40.	Oakville-Plainfield-Spinks	4-8-5	.15-.17-.17	A-A-A
41.	Marlette-Capac	9-11	.32-.32	B-B
42.	Capac-Parkhill	11-24	.32-.28	B-B/D
43.	Houghton-Palms-Sloan	15-15-31	0-0-.37	A/D-A/D-B/D
44.	Boyer-Oshtemo-Houton	7-10-15	.17-.24-0	B-B-A/D
46.	Boyer-Wasepi	7-10	.17-.20	B-B
48.	Lenawee-Toledo-Del Rey	35-45-25	.28-.28-.43	B/D-D-C
49.	Tedrow-Tedrow, Loamy Substratum-Selfridge	4-8-5	.17-.17-.15	B-B-C
50.	Perrinton-Ithica	10-18	.32-.32	C-C
51.	Pipestone-Kingsville-Saugatuck-Wixom	3-5-4-3	.17-.37-.15-.15	A-C-A/D-B
54.	Boyer-Fox-Sebewa	7-7-28	.17-.37-.24	B-B-B/D
59.	Belleville-Selfridge-Metea	7-5-2	.17-.15-.28	B/D-C-A
60.	Hoytville-Nappanee	39-8	.28-.43	D-D
61.	Kibbie-Colwood	11-15	.28-.28	B-B/D
63.	Oakville-Tedrow-Granby	4-4-5	.15-.17-.17	A-B-A/D
64.	Metamora-Blount-Pewamo-Selfridge	12-15-34-5	.20-.43-.24-.15	B-C-C/D-C
65.	Grattan	3	.15	A
67.	Spinks-Perrinton-Ithaca	5-10-18	.17-.32-.32	A-C-C
69.	Tappan-Londo	21-14	.28-.32	B/D-C

Table II-6. Continued.

Map[1] #	Association	% Clay in Surface Layer[4] by Series	K Value[2] of Surface Layer[4] by Series	Hydrologic Grouping[3] by Series
70.	Tappan-Londo-Poseyville	21-14-5	.28-.32-.17	B/D-C-C
71.	Tappan-Belleville-Essexville	21-7-12	.32-.17-.17	B/D-B/D-A/D
72.	Lapeer-Hillsdale	8-9	.26-.24	B-B
73.	Sanilac-Bach	13-17	.37-.28	B-B/D
74.	Shebeon-Kilmanaugh	22-22	.24-.32	C-C

[1] Map # from Soil Associations Map of Michigan

[2] The soil erodibility factor (K) is a relative measure of a soils susceptibility to erosion by water. It is not an indication of edge-of-field delivery rates. High K values are assigned to highly erodible soils, low K values to stable soils. K values range from 0.1 - 0.64.

[3] Hydrologic groupings are composed of soils with similar run-off producing traits; including, infiltration rates when free of vegetation, the depth and composition of any relatively impermeable layers, and/or the depth of the water table. Soils in group A have a very low run-off potential, those in group D a very high run-off potential. When a soil is assigned two hydrologic groups (eg. A/D), the first refers to its behavior when artificially drained, the second to its behavior under natural conditions.

[4] Surface layer depth varies by series.

Source: U.S.D.A., Soil Conservation Service. Soil Survey of Midland County (and others). National Cooperative Soils Survey, April 1979.

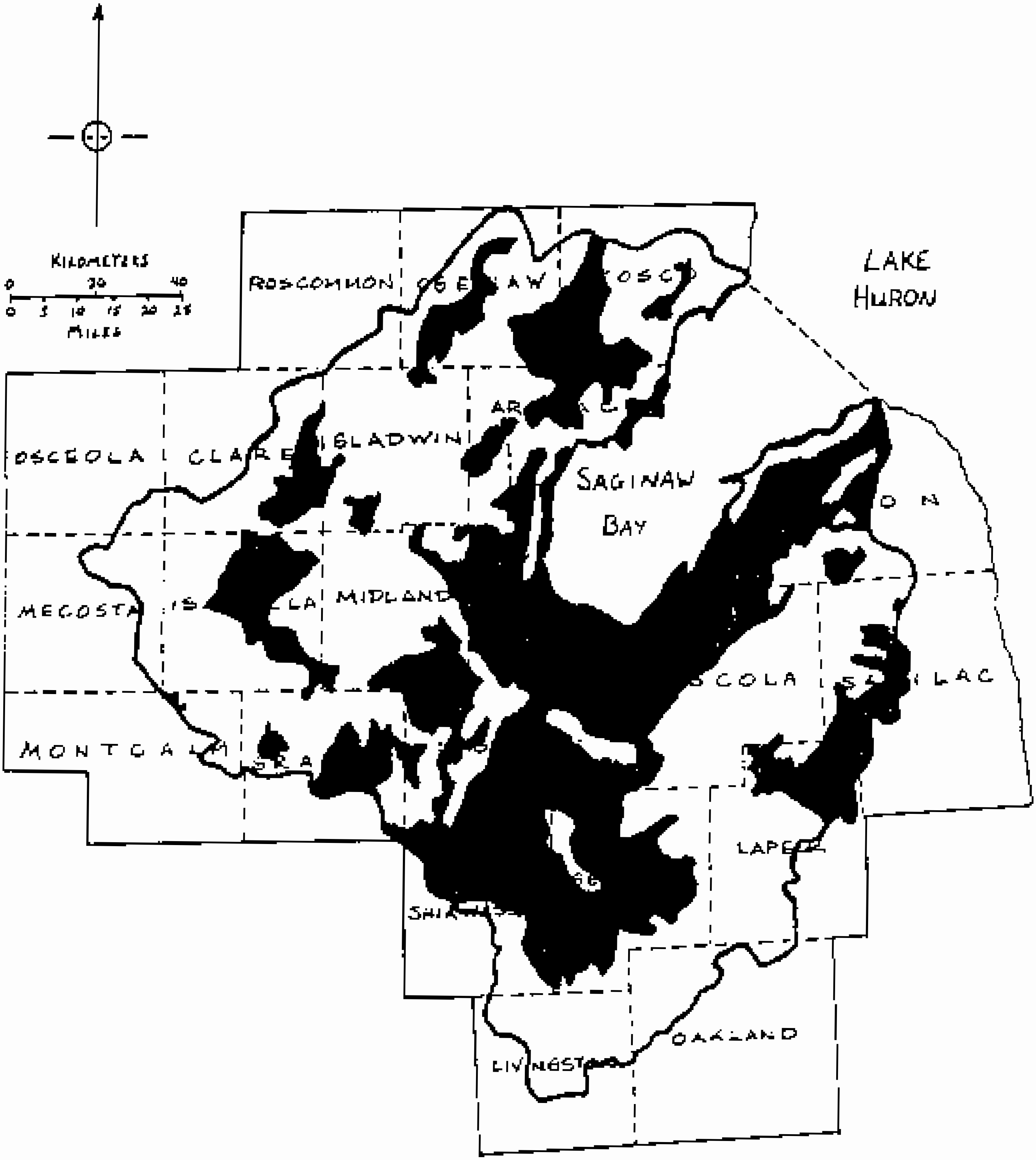


Figure II-14. Soil associations containing more than 13 percent clay in their surface layer (ECMPDR, 1987).

soils are common among the less extreme slopes in the eastern and southern hills; whereas sandy, well-drained soils on relatively extreme slopes are generally limited to the northern part of the basin. Organic soils occur in Gladwin, Arenac and parts of Iosco County. In some areas, these soils have been drained and farmed despite the susceptibility of organic soils to wind erosion.

The available water capacity of a soil has water quality as well as hydrologic implications. Characteristics affecting the production of runoff are quantified in Table II-6 for each soil series. Low water capacity soils, such as those common in the eastern part of the basin, reach saturation quickly and therefore generate runoff faster and in greater volumes than coarse soils. Surface water runoff problems are generally greatest in the spring, when the lack of vegetative cover and an increasing likelihood of heavy rainfall are likely to cause the erosion and delivery of clay particles and adsorbed agricultural chemicals to area waterways. Since low available water capacity soils contribute very little groundwater to the base flow of the rivers that drain them, drought conditions will often substantially reduce their flows.

D. LAND USE

1. Agriculture

Agriculture is the most extensive single category of land use in the Saginaw Bay drainage basin (Figure II-15) accounting for over 56 percent of the land area in the East Central Michigan Planning and Development Region alone (ECMPDR, 1978). The most concentrated areas of agricultural activity occur in lake plain soils along the eastern and southern shore of Saginaw Bay, including all of western Huron County, northwestern Tuscola County, most of Bay County, and northern Saginaw County. Other heavily agricultural areas encompass central and southeastern Isabella County, most of Gratiot County, and much of the Shiawassee River valley in southern Saginaw, northern and eastern Shiawassee, and southwestern Genessee counties.

Crop and livestock production are both well represented in basin agricultural practices. In terms of total cropland acreage, Sanilac, Huron, Tuscola, Saginaw and Gratiot counties are among the top six in the state (Bureau of the Census, 1984). Crop preferences vary from year to year and place to place, but corn is generally a popular crop across the basin (Table II-7). Localized preferences exist for soybeans in the central and southwestern portion of the basin, and for sugar beets and dry edible beans (primarily navy) within the lake plain counties.

Agricultural management practices in the basin are undergoing changes designed to reduce the loss of topsoil and the pollution of water resources by sediments, fertilizers and other agricultural chemicals. Conservation tillage methods of all kinds accounted for up to 41 percent of the acreage planted in row crops, small grains, and forage crops in some areas of the Saginaw Bay basin in 1986 (Table II-7).

Huron, Sanilac, Lapeer and Isabella counties are among the top ten statewide for both beef cattle/calves and milk cow populations (Table II-8). Poultry farms are also common in the basin, with Huron, Tuscola and Gratiot counties ranking very high. Hogs, sheep and horses, on the otherhand, are generally not as numerous within basin counties.

2. Urban Industrial

In 1980, the Saginaw Bay drainage basin supported a population of 1,458,339 people, 35.7 percent (521,325) of whom lived in the 33 cities, villages and census designated places (CDP) containing 2,500 or more residents (Table II-9). In terms of land area, those municipalities accounted for 530.6 km^2 - about 2.4 percent of the 22,557 km^2 that drain into Saginaw Bay. Projections for the year 2000 indicate a three percent decline in basin urban populations, with substantial losses in the largest cities. In contrast, the basin's population as a whole is expected to increase by 13 percent to 1,648,036 during that 20-year period (Appendix 3).

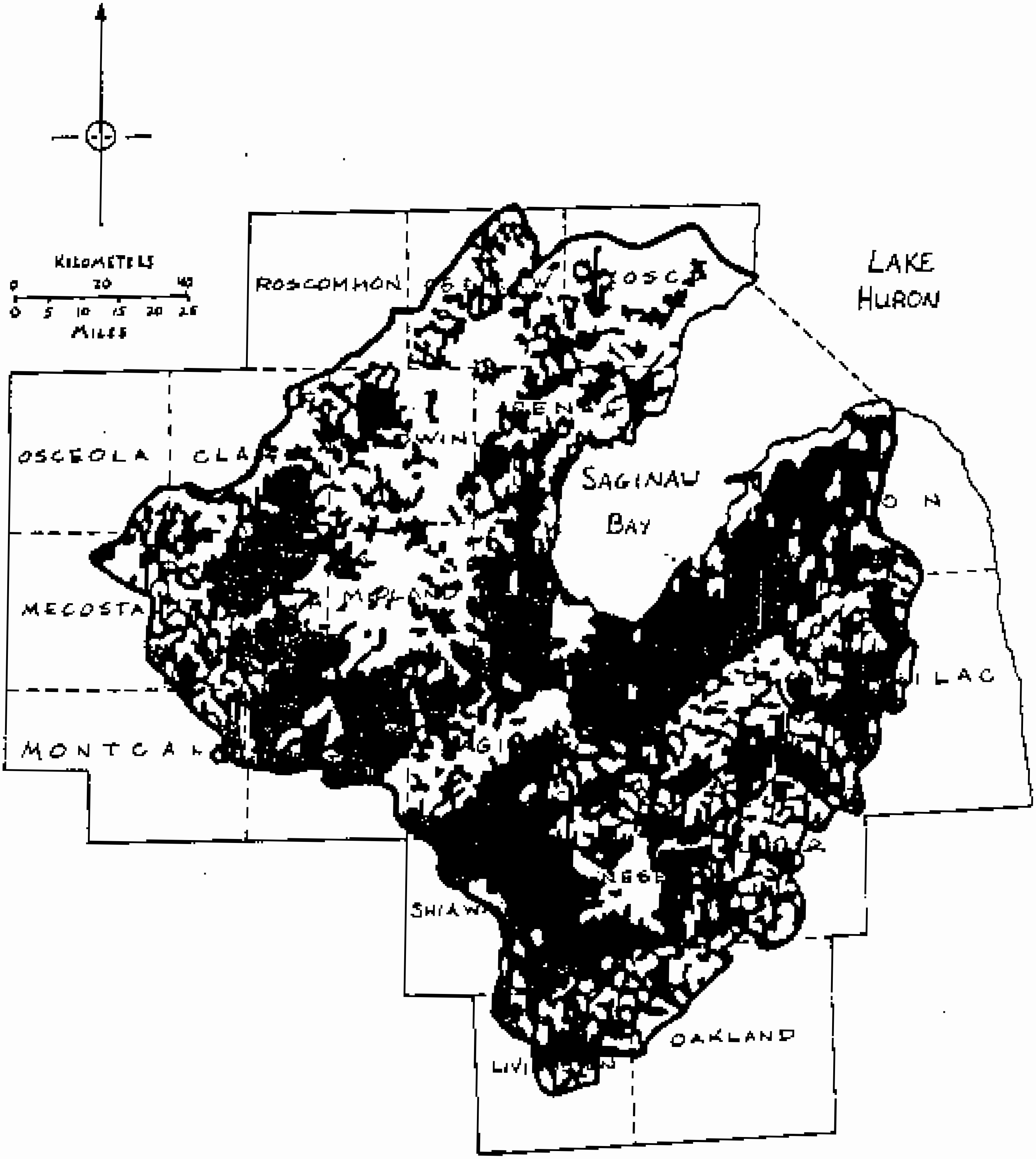


Figure II-15. Agricultural land in the Saginaw Bay drainage basin (ECMPDR, 1987).

Table II-7. Crop Acreage Totals for Counties in the Saginaw Bay Drainage Basin.

County	Total Cropland	% CT Impl.[1]	Seed & Feed Corn	Wheat	Oats	Soybeans	Dry Edible Beans	Sugar Beets	Vegets. Sweet Corn Melons	% of County in Basin
Arenac	68,355	24	13,424	4,041	3,305	6,978	12,825	2,193	1,693	100
Bay	161,143	19	45,976	6,757	2,060	18,879	48,969	16,134	3,478	100
Clare	50,215	28	6,826	2,286	3,453	356	-	-	43	54
Genesee	134,134	26	45,652	4,648	10,370	31,532	1,216	-	618	100
Gladwin	32,844	15	10,461	3,419	3,576	1,650	2,902	324	143	100
Gratiot	248,451	31	70,343	14,972	8,165	65,918	48,128	4,985	2,650	63
Huron	384,598	26	111,847	23,145	24,420	4,901	105,66	21,449	16	63
Iosco	35,022	16	6,971	1,244	2,370	434	968	-	31	66
Isabella	159,774	29	41,941	10,568	8,786	13,255	17,094	-	352	100
Lapeer	178,853	27	58,614	7,065	11,221	9,168	7,413	-	3,427	71
Livingston	103,952	34	38,519	6,784	4,758	4,351	299	-	-	43
Mecosta	93,022	35	17,943	4,469	3,352	180	2,928	-	724	24
Midland	72,404	7	22,886	3,259	1,676	17,164	14,130	2,254	375	100
Montcalm	183,585	41	55,428	20,374	8,511	6,340	20,415	-	1,142	33
Oakland	50,530	33	15,793	2,762	1,971	987	-	-	657	18

Table 11-7. Continued.

County	Total Cropland	% CT Impl.[1]	Seed & Feed Corn	Wheat	Oats	Soybeans	Dry Edible Beans	Sugar Beets	Vegets. Sweet Corn Melons	% of County in Basin
Ogemaw	46,970	8	5,268	1,360	3,555	-	-	-	11	79
Osceola	76,293	20	6,064	1,508	3,721	-	-	-	-	5
Roscommon	3,391	4	-	-	78	-	-	-	-	11
Saginaw	282,524	30	62,878	17,761	6,853	117,778	39,716	13,436	2,233	100
Sanilac	391,182	13	93,981	14,604	42,785	37,794	46,979	10,871	763	32
Shiawassee	203,254	32	49,343	13,526	19,321	68,900	2,553	135	93	57
Tuscola	301,425	19	96,423	20,816	12,409	22,162	72,865	23,490	1,998	100

[1]CT Impl. is the percentage of total row crop, small grain, and forage crop acreage planted using conservation tillage methods in 1986.

Table II-8. Livestock Populations and Acreage Totals for Hay and Pasture within the Saginaw Bay Drainage Basin (Bureau of the Census, 1984).

County	Cattle	Milk Cows	Hogs	Sheep	Horses	Chickens	Hay Acreage	Pasture Acreage	% County
Arenac	9,109	3,146	3,769	154	210	6,347	10,094	3,791	100
Bay	4,736	1,501	3,231	55	292	4,634	3,776	69	100
Clare	14,215	3,012	6,282	1,796	502	29	15,995	12,151	54
Genessee	18,478	4,464	12,139	1,513	1,336	12,821	15,918	4,981	100
Gladwin	10,568	1,805	3,543	1,410	378	3,774	13,876	9,244	100
Gratiot	28,096	8,774	17,880	1,046	443	162,570	34,036	4,887	63
Huron	77,272	19,514	34,078	292	280	1,406,243	38,144	10,912	63
Iosco	11,167	1,535	2,151	518	296	706	10,990	5,778	66
Isabella	35,429	11,077	15,125	438	608	–	32,720	10,034	100
Lapeer	36,040	10,795	13,132	3,344	2,104	11,608	38,264	12,723	71
Livingston	23,961	7,229	6,315	3,279	1,896	8,197	24,601	8,189	43
Mecosta	451	6,160	4,336	1,170	620	3,734	33,114	12,041	24
Midland	170	650	5,304	225	497	1,982	3,939	1,503	100
Montcalm	557	10,361	10,769	1,230	760	10,279	31,321	7,768	13
Oakland	6,371	1,111	2,246	1,147	2,408	3,130	12,981	6,056	18

Table II-8. Continued.

County	Cattle	Milk Cows	Hogs	Sheep	Horses	Chickens	Hay Acreage	Pasture Acreage	% County
Ogemaw	14,498	4,246	1,026	456	222	1,311	18,926	9,608	79
Osceola	22,518	8,094	2,936	1,390	561	-	36,500	16,798	5
Roscommon	321	3	50	-	185	887	1,043	-	11
Saginaw	15,543	4,629	8,192	1,381	856	38,419	10,725	3,239	100
Sanilac	75,180	30,891	11,014	1,042	886	29,942	71,643	17,499	32
Shiawassee	24,463	8,325	13,039	1,841	1,019	35,861	23,317	7,806	57
Tuscola	23,838	7,455	18,487	1,166	823	477,759	21,753	8,743	100

Table II-9. Population, Area, Density and Drainage Basin Location of Selected Cities and Villages within the Saginaw Bay Drainage Basin (Bureau of the Census, 1983).

City	Population	Area (km^2)	Density (per km^2)	Drainage Basin
Alma	9,652	14.2	678	Saginaw River
Bad Axe	3,184	4.9	647	East Coastal
Bay City	41,593	28.0	1,487	Saginaw River
Beecher CDP[a]	17,178	15.3	1,124	Saginaw River
Burton	29,976	60.9	493	Saginaw River
Caro	4,317	5.4	794	Saginaw River
Chesaning	2,656	7.3	366	Saginaw River
Clare	3,300	5.2	637	Saginaw River
Clio	2,669	2.6	1,031	Saginaw River
Corunna	3,206	7.8	413	Saginaw River
Davison	6,087	4.7	1,306	Saginaw River
Durand	4,241	4.4	963	Saginaw River
East Tawas	2,584	6.2	416	West Coastal
Essexville	4,378	3.4	1,300	Saginaw River
Fenton	8,098	18.1	447	Saginaw River
Flint	159,611	83.9	1,902	Saginaw River
Flushing	8,624	10.4	832	Saginaw River
Frankenmuth	3,753	6.0	630	Saginaw River
Grand Blanc	6,848	10.4	661	Saginaw River
Holly	4,874	7.0	697	Saginaw River
Howell	6,976	8.8	792	Saginaw River
Ithaca	2,950	10.4	285	Saginaw River
Lake Fenton CDP	3,154	7.8	406	Saginaw River
Lapeer	6,198	11.7	532	Saginaw River
Midland	37,250	70.7	527	Saginaw River
Mount Morris	3,246	3.4	964	Saginaw River
Mount Pleasant	23,746	17.6	1,348	Saginaw River
Owosso	16,455	12.7	1,297	Saginaw River
Saginaw	77,508	45.1	1,720	Saginaw River
St. Louis	4,107	6.5	634	Saginaw River
Swartz Creek	5,013	10.9	461	Saginaw River
Vassar	2,727	6.7	405	Saginaw River
Wurtsmith AFB CDP	5,166	12.2	424	West Coastal
Basin Total	521,325	530.6	983	

[a]CDP – Census Designated Place

All three of the basin's standard metropolitan statistical areas - Bay City, Flint and Saginaw - and 27 of the remaining 30 urban places identified in Table II-9 are in the Saginaw River watershed. Their combined 1980 population of 510,391 was spread over a total area of 507.3 km^2 (3.1 percent) of the Saginaw River watershed.

Industry is quite diversified in the Saginaw Bay basin due to a wide range of natural resources, a well developed transportation network, and the early establishment of automobile manufacturing and related primary industries. The transportation equipment industry, despite recent and projected plant closures, remains the largest employer in the basin and is located almost entirely within the Saginaw River watershed in Genessee, Saginaw, Bay and Shiawassee counties (Appendix 4). Other large industries include fabricated and primary metals, nonelectric machinery, chemicals, electronic equipment, and food processing. With the exception of metal fabrication facilities in Huron, Iosco and Ogemaw counties, all of the largest employers, and the vast majority of smaller employers, in each category are located in the Saginaw River basin.

There are a total of 78 industrial dischargers to tributaries of Saginaw Bay, 13 of which are considered major in regard to the size and/or toxicity of the waste stream and the potential threat to the environment or human health (MDNR, 1987). The Saginaw River basin accounts for 60 of these dischargers, including all but one of the major sources. The West Coastal Basin and East Coastal Basin contain 12 and 6 industrial dischargers respectively, with the only major discharger located in Sebewaing.

There are 133 discharges from municipal sources such as sewage treatment plants or lagoons, water filtration plants, mobile home parks, rest areas, and rural hotels or motels 18 of which treat more than one million gallons per day and are considered major dischargers (MDNR, 1987). The Saginaw River basin receives municipal waste from 97 sources including all 18 of the major dischargers. The remaining 36 are split evenly between the East Coastal and West Coastal drainage basins. Information on the total geographic area served by sewer systems in the basin is not readily available; however, basin populations served by municipal wastewater treatment systems in the early 1980s totalled over 780,000.

3. Extractive

Extractive land uses in the Saginaw Bay basin primarily involve nonmetallic minerals, brine wells, aggregates, and oil or natural gas wells (Figure II-16). Midland County yields the greatest mineral production value in the basin, primarily as a result of the intensive utilization of natural brine for its constituent chemical products (Tables II-10, II-11). Gratiot county also produces natural salines, as well as a sulfur byproduct of the oil refining in that process. In general, oil and natural gas production represents the most important component of mineral value for counties in the northwestern and southeastern portions of the basin. Central and coastal counties receive the bulk of their mineral revenues from industrial sand, aggregates,

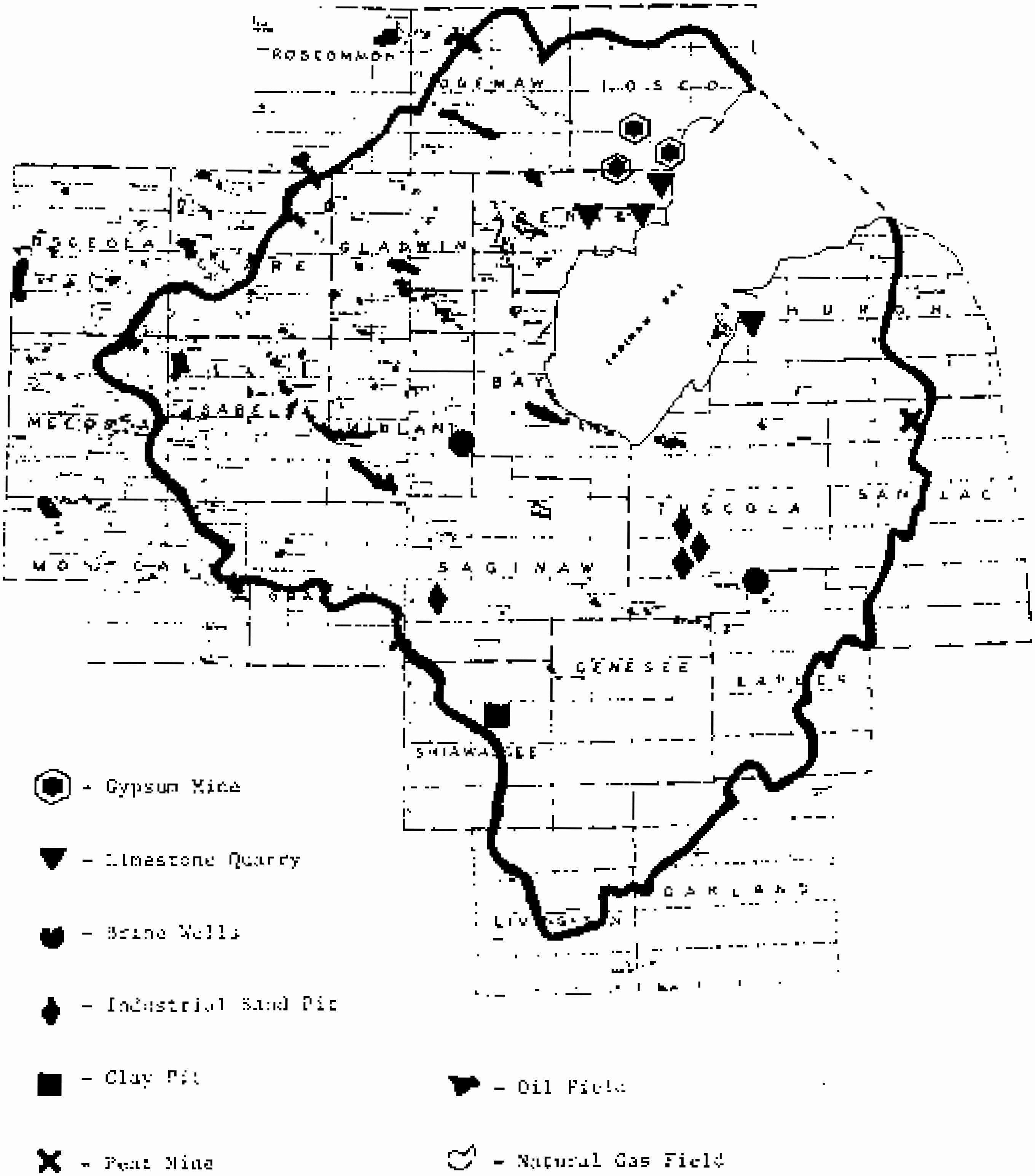


Figure II-16. Extractive land uses in the Saginaw Bay drainage basin (MDNR, 1978; 1982).

Table II-10. County Mineral Facilities and Valuation in 1977 (MDNR, 1978 and 1982).

County	Stone	Total Sand and Gravel	Ind. Sand	Salt	Peat	Natural Salines	Lime	Gypsum	Clay & Shale	Cement	Crude Oil	Nat. Gas	Mineral Production Values (in thousands)
Arenac	15	65									20		3,229
Bay							6			6	22		13,789
Clare*		42									15	22	4,029
Genessee		43									35		670
Gladwin		78									19		2,988
Gratiot*		33		4		4					40	29	10,243
Huron*	10	60					3						1,957
Iosco*		72						2					9,794
Isabella*		22									24		2,494
Lapeer*		20			2	5					25	25	4,063
Livingston*		7									50	16	4,310
Mecosta*		39	11		6						32	23	903
Midland				5		3					23		33,218
Montcalm*		23									28		1,808
Oakland*		1			4						49	19	20,791
Ogemaw*		45									12	20	7,052
Osceola*		36									21	27	2,531
Roscommon*											14	18	4,188
Saginaw		17	7				5				38		2,034
Sanilac*		32			1		7						3,158
Shiawassee*		37			3				3		44		2,384
Tuscola		12	9								31	2	3,214

*Counties only partially within Saginaw Bay drainage basin.

Table II-11. Oil and Gas Production during 1982 in the Saginaw Bay basin (MDNR, 1978; 1982).

County	Oil (Barrels)	Gas (MCF)
Arenac	168,754	---
Bay	281,312	---
Clare*	431,351	456,873
Genessee	19,924	58,483
Gladwin	289,975	---
Gratiot*	6,967	---
Huron*	1,882	---
Iosco*	---	---
Isabella	262,112	---
Lapeer*	331,385	1,883,658
Livingston*	1,177	284,460
Mecosta*	17,382	5,710
Midland	172,419	---
Montcalm*	95,475	---
Oakland*	197,541	1,575,624
Ogemaw*	551,131	58,645
Osceola*	68,037	4,318
Roscommon*	416,684	490,190
Saginaw	40,761	---
Sanilac*	---	---
Shiawassee	6,309	---
Tuscola	91,534	---

*Counties only partially within Saginaw Bay drainage basin limestone, peat or gypsum. Two of the three gypsum mines in Iosco County are among the largest in the nation (MDNR, 1978).

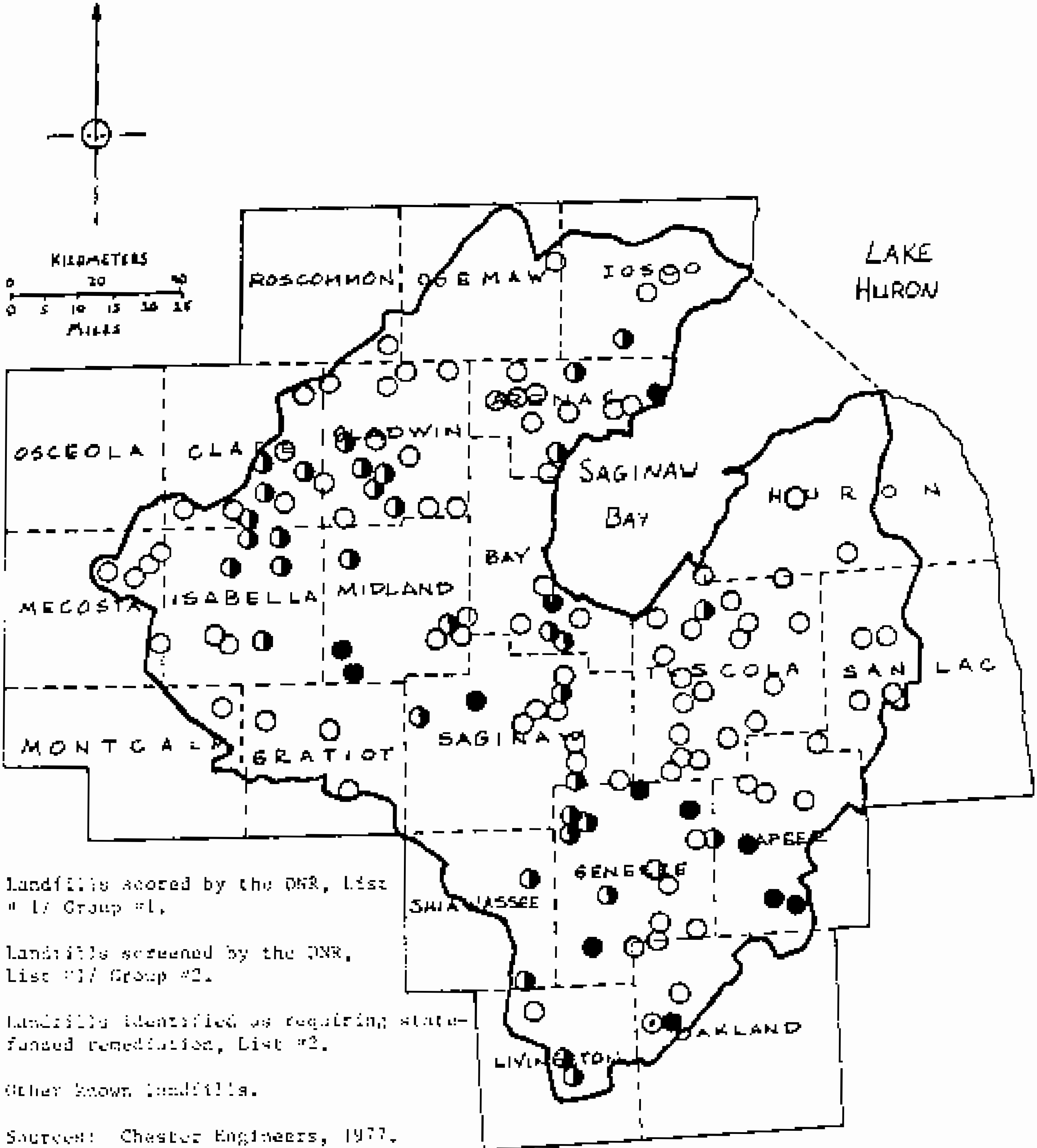
4. Waste Disposal

Solid waste disposal sites are common throughout the Saginaw Bay basin. However, relatively few remain in sanctioned operation under the guidelines of Act 641, the state's legislative response to growing concern over the safety of such sites. Of the 136 known landfills or dumps in the basin (Figure II-17), 47 have been identified as contaminant sources to surface waters, groundwaters or soils under the Michigan Act 307 program (MDNR, 1986). Because this assessment process is a response to resource impairments rather than a preventative action, it is expected that more disposal sites will be linked to environmental problems as time and additional resource development goes on. As of March 1988, fifteen landfills had been identified as sources of contaminants to surface waters in the Saginaw Bay watershed.

5. Wildlife Habitat and Recreational Lands

Lands suitable for wildlife habitat or recreational use occur over much of the northern and coastal portions of the Saginaw Bay basin, and large areas have been placed into public ownership under a variety of management agendas (Figure II-18). The Shiawassee National Wildlife Refuge in Saginaw County and numerous state wildlife areas within the coastal wetlands bordering Saginaw Bay provide refuge along the flyway routes of many waterfowl species, as well as habitat for other water dependent birds and animals. Until recently, coastal wetland resources had been continually reduced by drainage projects tied to agricultural expansion and by lakeshore developments. Of the estimated 467 km^2 (115,000 acres) that fringed the inner bay prior to settlement, only about 162 km^2 (40,000 acres) remained as of the early 1970s (Great Lakes Basin Commission, 1975).

Other administrative policies govern the management of the remaining public land in the basin. State game areas are scattered over the otherwise heavily agricultural central portion of the basin, providing wildlife habitat and hunting opportunities. Multiple use policies are practiced within the large tracts of state forest along the Tittabawassee and Chippewa rivers, as well as in the relatively hilly portions of the Huron National Forest extending into Ogemaw and Iosco counties. Water-oriented recreational opportunities are provided at the five state parks located on the shores of Saginaw Bay and at the Rifle River recreation area.



● Landfills scored by the DNR, List # 1/ Group #1.

◐ Landfills screened by the DNR, List #1/ Group #2.

⊙ Landfills identified as requiring state-funded remediation, List #2.

○ Other known landfills.

Sources: Chester Engineers, 1977.
GLS, Region 5, 1978.
SEMCOG, 1978.
MDNR, 1986.

Figure II-17. Landfills in the Saginaw Bay basin.

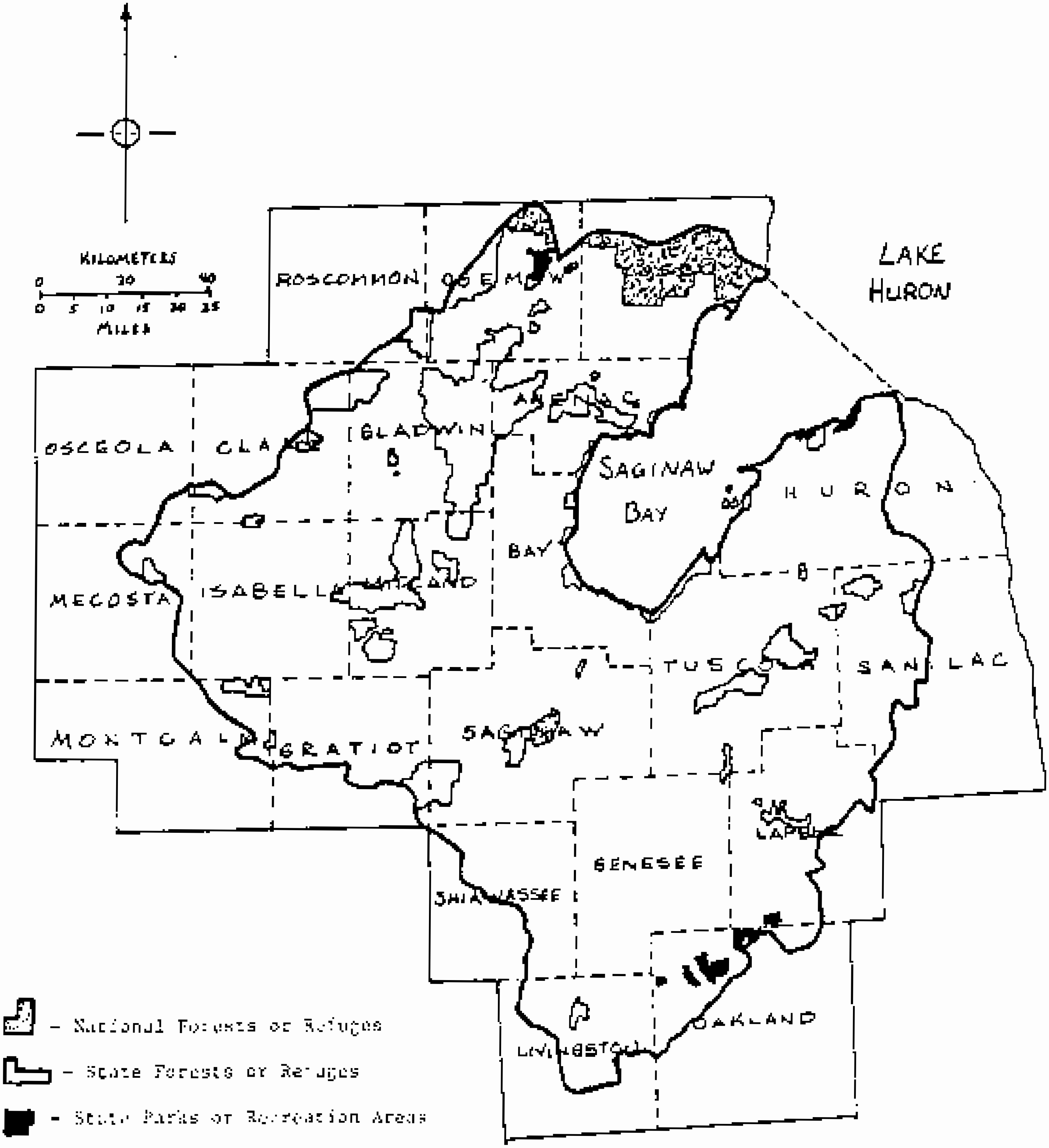


Figure II-18. Public land in the Saginaw Bay drainage basin.

E. WATER USES

1. Fish and Wildlife Habitat

Wildlife Habitat The most outstanding habitat feature of the Saginaw Bay shoreline is the expansive coastal wetlands, concentrated in the inner bay. Despite the reduction in wetland acreages over the past several decades, as land has been converted to agricultural and other uses, the area is still considered vital to the support of North American waterfowl populations, as well as the populations of other water dependent species. During spring and fall migrations, "rafts" containing as many as 250,000 ducks have been counted during aerial surveys of open water areas like Wildfowl Bay (U.S. Fish and Wildlife Service, 1970). Aggregations of Blue Geese and Canada Geese numbering up to 30,000 have also been recorded. Waterfowl breeding occurs in both the coastal wetlands and in isolated pockets of inland habitat near the bay shore, with mallards, teal and Canada geese being the most important species. In all, over 30 species of waterfowl use Saginaw Bay habitats during the breeding and migration season.

Much of the remaining wetlands surrounding Saginaw Bay are now in public ownership under the authority of the Michigan Department of Natural Resources (MDNR). There are six designated State Game Areas or Wildlife Areas along the Saginaw Bay Shoreline: Fish Point Wildlife Area (Tuscola County), Nayanquing Point Wildlife Area (Bay County), Quanicassee Wildlife Area (Bay and Tuscola counties), Tobico Marsh State Game Area (Bay County), Wigwam Bay Wildlife Area (Arenac County), and Wildfowl Bay Wildlife Area (Huron County).

Wildlife habitat within the Saginaw River basin is characterized by extreme diversity. Along the Saginaw River itself, much of the immediate watershed is urban/suburban or agricultural, but a substantial portion is comprised of the remnants of extensive wetlands that dominated the basin in recent history. As is the case with Saginaw Bay, much of the remaining wetlands in the vicinity of the Saginaw River are in public ownership and are of great importance to a wide variety of wetland dependent wildlife, particularly waterfowl.

The Shiawassee National Wildlife Refuge, operated by the U.S. Department of the Interior's Fish and Wildlife Service, contains several thousand acres of wetland habitats managed for waterfowl. The refuge is important for both brood production and as a resting area for migrating ducks and geese on several major flyways during spring and fall migrations.

The Crow Island State Game Area, operated by MDNR, is located along the Saginaw River between Saginaw and Bay City. Approximately 2000 acres in size, this area is also managed primarily for waterfowl.

Fish Habitat The shallow, productive waters of Saginaw Bay provide outstanding habitat for a wide variety of fish species. Over 90 fish species have been recorded in Saginaw Bay (Freedman, 1974). The bay is attractive to a broad range of species because of the great diversity of aquatic habitats found there, which provide spawning and nursery areas and plentiful food sources for larval and adult fish. However, populations of several important species have declined, and the fish community in the bay is substantially different from that which existed at the turn of the century.

Lake herring, once an important part of the commercial fishery in Saginaw Bay, has all but vanished. Historically, the waters of the bay served as both spawning and nursery areas, but the most recent documented spawning of lake herring occurred in 1956 (Goodyear, et al., 1982). The cause of the collapse of lake herring stocks in Saginaw Bay has never been determined.

Lake trout were also abundant in outer Saginaw Bay at one time. This species previously spawned throughout the bay, from Tawas Point on the western shore to Port Austin in the east, over reefs of honeycombed rock at depths ranging from 6 to 120 feet (Great Lakes Fishery Commission, 1979). Populations of lake trout are now maintained through stocking of hatchery reared fish. Some spawning activity has been recorded in recent years in several areas around the bay, including Tawas Point, Point Au Gres, Charity Islands and Sand Point, but without success (Goodyear et al., 1982).

Alteration of spawning habitats and over fishing have been implicated as the causes of the historical decline of walleye stocks in Saginaw Bay (Schneider and Leach, 1977). Once the premier commercial species in the region, walleye populations are now maintained through plantings of artificially propagated fish and, as a result, a thriving sport fishery has developed over the past five years. Some evidence of natural reproduction of walleye in the bay and its tributaries has been recently documented. However, the magnitude of this has yet to be determined (Mrozinski, personal communication). Historically, inner Saginaw Bay and its tributaries were considered the primary walleye spawning area in Lake Huron, particularly at the mouth of the Saginaw River, along Coryon Reef, and in the vicinity of the Charity Islands, in shallow waters over a variety of substrates (Goodyear, et al., 1982). Increased turbidity, siltation and the impoundment of many tributary streams are among the factors that contributed to the decline.

Despite the habitat alteration problems experienced in recent years, Saginaw Bay remains a productive habitat for a variety of species. Yellow perch populations in the bay are extremely high, although the growth of individual fish seems to be suppressed. Most of the documented spawning grounds of smallmouth bass in the U.S. waters of Lake Huron are in Saginaw Bay, as are all of the known spawning areas of the largemouth bass (Goodyear, et al., 1982). Carp and channel catfish populations in the bay support an important commercial fishery, and the production of forage fishes remains high. While the fish community of Saginaw Bay has been substantially altered, the shallow waters of the bay are still among the most productive fish habitats in the Great Lakes (Keller et al., 1987). However, a potential emerging problem exists now that white perch have become established in Saginaw Bay (Mrozinski, personal communication). If their numbers increase in the future, white perch may compete with more desirable sport fish species for forage organisms.

The Saginaw River and its tributaries provide habitat for various game and non-game fish species. In the Saginaw River itself, recent surveys indicate the presence of a variety of species and a community composition that changes seasonally. Thirty-nine species were collected in 1984 (Mrozinski, personal communication). The river supports sizeable populations of carp, catfish, quillback and drum, and smaller populations of largemouth bass, yellow perch, black and white crappie, and other species. In addition, moderate to heavy spawning runs of walleye, white bass, suckers and other species pass through the Saginaw River on their way up to the various tributaries, and Goodyear et al. (1982) report that the lower Saginaw River contains excellent spawning habitat for northern pike. Emerald shiners and spottail shiners are also numerous; and gizzard shad, an excellent forage species, occur in tremendous numbers (Mrozinski, personal communication).

2. Water Supply

Saginaw Bay is a major source of water for a variety of uses, including municipal drinking water, irrigation, cooling for thermoelectric power generation, and industrial process supplies.

There is currently only one electric power generation facility withdrawing water from Saginaw Bay - the Bay City Electric Light and Power plant. This facility uses a wet-tower discharge system and withdraws an average of only 0.01 MGD. A Consumers Power Corporation Karn-Weadock power plant complex, also located near Bay City, withdraws water from the mouth of the Saginaw River. Four of the six generating units at Karn-Weadock utilize a once-through cooling process. The once-through system, while requiring the withdrawal of relatively large quantities of water, actually consumes less than one percent of the water withdrawn. The first of the two remaining units employs a wet-tower discharge cooling system, which consumes approximately 13 percent of the total withdrawn. The final unit employs a dry cooling process that requires no water. Together, the Bay City Electric Light and Power facility and the Karn-Weadock complex withdraw approximately 523 MGD (Van Til and Scott, 1986). Data are not available for calculating actual water consumption by the thermoelectric power industry in the Saginaw Bay basin, but it is believed that consumptive use is less than five percent of the total withdrawn. Of the six other thermoelectric power generation facilities in the Saginaw River basin, none draw water from the Saginaw River or any other inland surface waters (Van Til and Scott, 1986).

According to Bendell (1982), most municipal water supplies originating from Saginaw Bay come from one of two sources; the Saginaw-Midland Water Supply System, drawing water from off Whitestone Point, and the Bay City Water Supply System, drawing water from a point on the bay just west of the mouth of the Saginaw River. The Saginaw-Midland system serves a total of 227,792 people and withdraws an average of 54.96 MGD throughout the year. The Bay City system serves 80,315 people, withdrawing an average of 11.87 MGD. There are three other municipal supplies drawn from the bay, each serving less than 5,000 people. East Tawas, serving approximately 4,600 people, withdraws an average of 0.66 MGD. Pinconning draws an average of 0.30 MGD, serves less than 2,000 people and intends to close its intake site within the next year and purchase water from the Bay City system. The Port Austin system serves less than 1,000, and draws an average of 0.11 MGD. In addition, the Village of Caseville is developing a plan for its own water intake for municipal purposes. Details of this plan are unavailable at this time.

At present, there are no active municipal withdrawals from the Saginaw River, however, the City of Saginaw does have an emergency intake located in the river. Municipalities within the Saginaw River basin acquire their water supplies from several sources including Saginaw bay, groundwater or a water supply system outside the basin (eg. the Detroit Municipal Water Supply System). The City of Alma maintains a water intake on the Pine River upstream of St. Louis. The Genessee County Water Supply System maintains an emergency withdrawal system on the Flint River at Flint, to be used only in the event of a failure of current sources, and this system is only operated periodically to test the equipment.

Summary information for industrial water withdrawals in the Saginaw Bay basin is not readily available. The Great Lakes Basin Commission (1975) reported that most industrial users drew water from sources other than Saginaw Bay, but provided no specific information on sources. It is known that water is withdrawn from the Saginaw River for industrial use by the Bay City General Motors Auto Plant and by sugar beet processing plants located in Bay City and Carrollton.

Water amounts withdrawn from Saginaw Bay and the Saginaw River for irrigation use cannot be reliably estimated because data are not reported in a way that allows the identification of specific sources. However, irrigation water use by agriculture has been increasing in the Saginaw Bay basin.

3. Commercial Fishing

Historically, Saginaw Bay has provided a productive commercial fishery, but stocks have generally been declining since the early part of the twentieth century (Figure II-19). Eile and Boettner (1958) indicated that the peak year for commercial fish harvest was 1902, with a total catch of 14.2 million pounds. The lowest catch on record for the period of 1885-1983 was approximately 1.6 million pounds, recorded in both 1973 and 1974 (Hendrix and Yocum, 1984). The drastic decline in commercial harvest was accompanied by a shift in species dominating the commercial fishery. Lake trout once contributed heavily to the catch, with a peak harvest of 325,000 pounds in 1931, but were reduced to insignificant levels by the late 1940s, and are entirely absent from the commercial harvest at present (Keller, et al., 1987). Walleye, once the staple of the fishery, is also no longer harvested commercially. Only 68,000 pounds of yellow perch were harvested in 1986, well below the long term average commercial catch of 465,000 pounds. Carp, which did not enter the commercial harvest until 1918, and channel catfish, which formerly made up only a small percentage of the commercial catch, now dominate other species taken commercially from Saginaw Bay (Figure II-20).

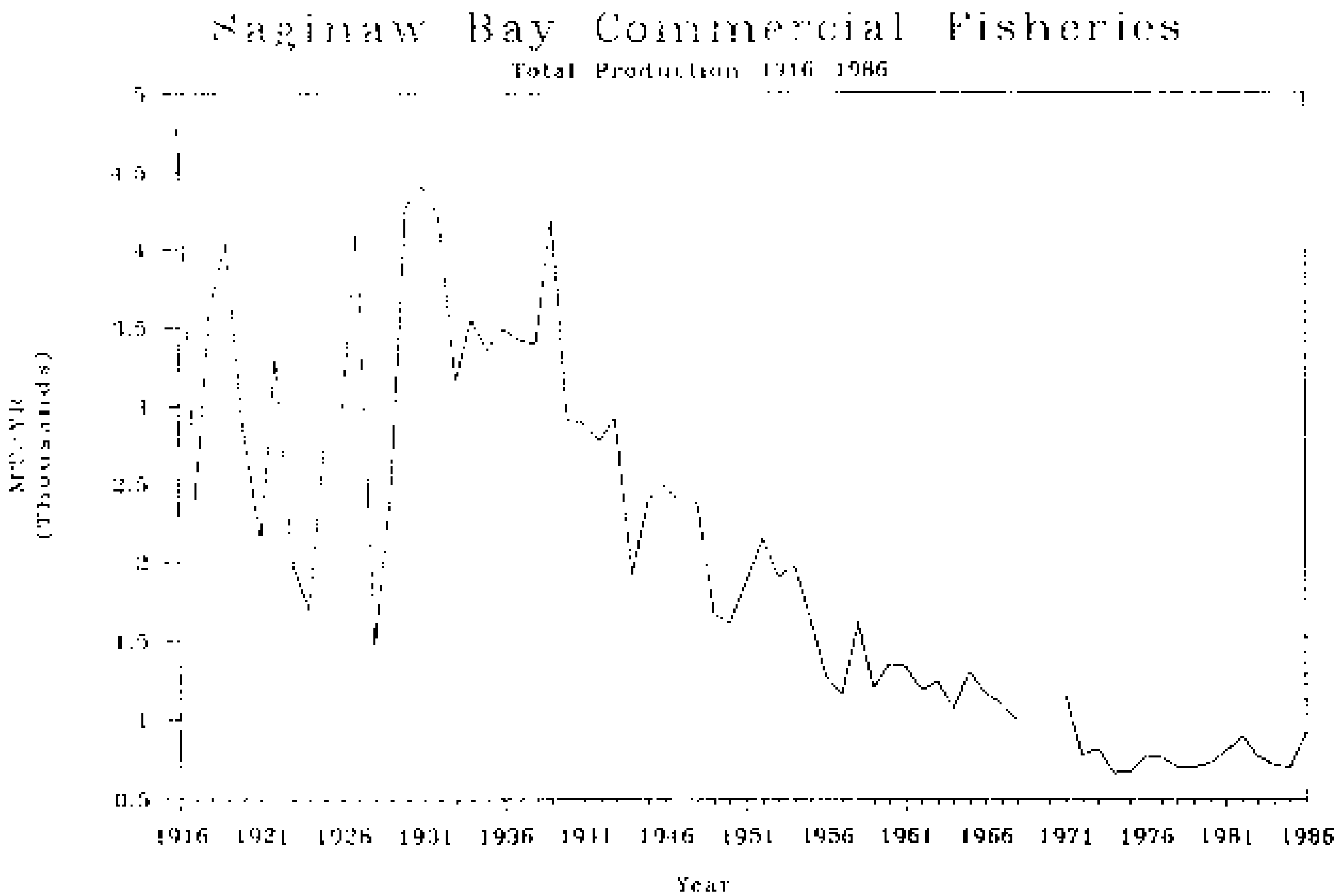


Figure II-19. Total commercial fisheries catch in Saginaw Bay, 1916-1986 (CDNR unpublished).

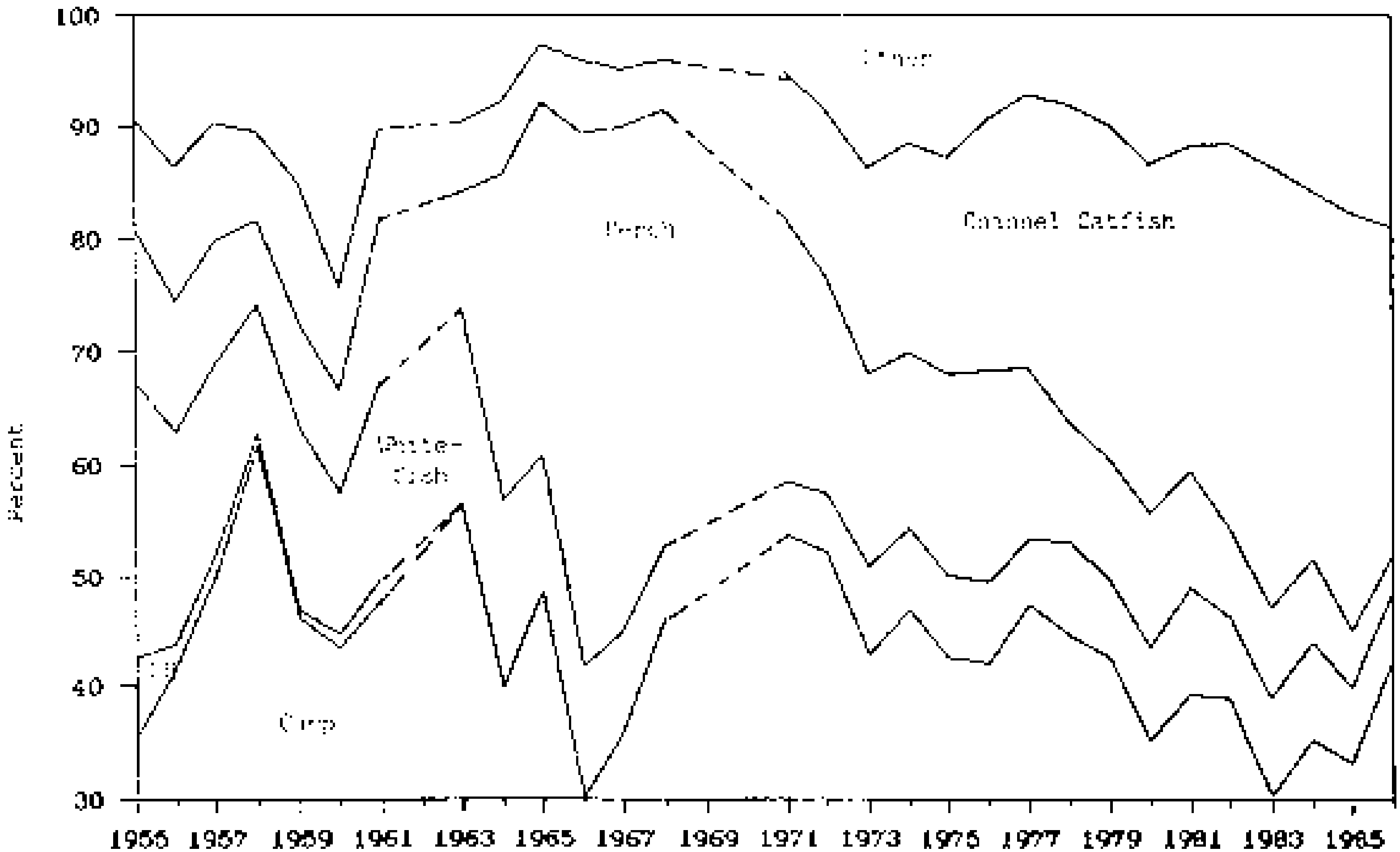


Figure 11-20. Fish species composition of the commercial catch in Saginaw Bay, 1955-1986 (MDNR, unpublished).

While it is not possible to attribute the decline in commercial fishing in Saginaw Bay to specific causes, various researchers have implicated a variety of factors including destruction of essential spawning habitats (Schneider, 1977), the introduction of non-native fish species (Hile and Buettner, 1956), eutrophication (Francis, et al., 1979), over exploitation of fish stocks (Schneider and Leach, 1979), and toxic contamination of the ecosystem (Hendrix and Yocum, 1984).

Despite the decline in the commercial fishery in Saginaw Bay, commercial fishing remains an important element of the regional economy. In 1986, 27 licensed commercial fishing operations harvested approximately two million pounds of fish from Saginaw Bay. Included in this catch were carp (850,000 pounds), channel catfish (600,000 pounds), yellow perch (60,000 pounds), suckers (56,000 pounds), and freshwater drum (37,840 pounds) (Keller et al., 1987). Ports with the greatest amount of fishing activity are Sebewaing, Bay Port, Pinconning, Au Gres and Standish.

The future of commercial fishing in Saginaw Bay is uncertain. Sullivan et al. (1981) have suggested that further reductions in phosphorus loading to the bay could result in a 24 percent decline in commercial harvest by 1990 by reducing the productivity of the bay. However, Hendrix and Yocum (1984) point out that this conclusion was reached without consideration of the potential effects of possible restoration of spawning habitats or the stocking of artificially propagated fish may have on Saginaw Bay fish stocks. Limited knowledge of the effects of toxic chemicals in aquatic systems does not allow prediction of the future impacts of toxic materials upon commercial fishing in Saginaw Bay. Past and current fish consumption advisories and fishing bans testify to the potential for toxic materials to adversely affect the commercial fishing industry in the bay. Finally, continued conflicts between sport and commercial fishers over perch stocks have led to a program, adopted by the Michigan Natural Resources Commission in July 1987, where commercial licenses may be bought out by the state on a willing buyer/willing seller basis.

Although the Saginaw River and its tributaries once supported a thriving commercial fishery, commercial fishing has not been successful in the Saginaw River system since 1908 (Schneider, 1977).

4. Sport Fishing

Sport fishing opportunities in Saginaw Bay are available throughout the year for a variety of species, including yellow perch, walleye, largemouth bass, smallmouth bass, brown trout, lake trout, coho salmon, chinook salmon, and steelhead. The recreational fishery is of tremendous economic importance in the bay region. Keller et al. (1987) estimate that there were approximately 2.2 million angler hours spent on Saginaw Bay in the seven month period of May through November of 1986, an estimated 60% of the total sport fishing effort spent on Lake Huron during that period. The economic value of this fishery is in the millions of dollars annually.

The walleye fishery is growing as Saginaw Bay walleye populations continue to increase. Nearly one million walleye fingerlings are released in the bay annually, which may account for the bulk of walleyes found in the bay. Natural reproduction has been documented but the magnitude is unknown. Walleye spawning runs attract thousand of anglers and ice fishing for walleye is also becoming extremely popular. The estimated sport harvest of walleye in the bay from May to November of 1986 was 59,000 fish (Keller et al., 1987). The growth rate of Saginaw Bay walleye exceeds that of any other population in the Midwest.

Saginaw Bay also supports an active trout and salmon fishery, particularly in the outer bay. Spawning runs of these fish take place in many bay tributaries, including Whitney Drain and the Rifle River in Arenac County, and the Pigeon River in Huron county. Spring runs of suckers and smelt also draw thousands of anglers to sites along the bay shoreline.

The sport fishery for yellow perch remains among the most popular recreational activities in the region, although perch are presently exhibiting some growth problems (i.e. dense populations of small perch not suitable for the sport fishery). Early 1987 surveys are encouraging, however, in that they indicate that perch size has improved somewhat (Mrozinski, personal communication). Keller et al. (1987) report a sport harvest of 1.8 million perch from Saginaw Bay from May to November of 1986.

The shallow waters of Saginaw Bay provide excellent fishing for many other species of game fish, particularly in the inner bay. Panfish, largemouth bass, smallmouth bass, and northern pike are concentrated in nearshore areas such as Wildfowl and Wigwam bays. Other species, such as carp, channel catfish, and bullheads are locally common and provide additional opportunities for the sport angler (Hendrix and Yocum, 1964; EMIA, 1984).

Despite various water quality problems, the Saginaw River has always provided a diverse and popular sport fishery. With the continued expansion of a resurgent walleye population, angler use of the river and its tributaries is on the increase. Good fisheries now occur in the Saginaw and Tittabawassee Rivers from September through May (Keller et al., 1987), with daily angler counts as high as 2,000 during the winter of 1986-87. Fishing for several other popular sport fish has also improved in recent years, including yellow perch, largemouth bass, smallmouth bass, northern pike, crappie and bluegill. Additionally, the Saginaw River system supports spawning runs of salmonids, white bass, suckers and other species that contribute to the expanding sport fishery. It is expected that recreational fishing will continue to gain in popularity in the foreseeable future.

5. Contact Recreation

Saginaw Bay is used extensively for many types of contact recreation including swimming, water skiing, and pleasure boating. Public access for boaters is provided at sixteen sites along the Saginaw Bay shoreline including one site in Iosco County, two in Arenac County, three in Bay County, four in Tuscola County, and six in Huron county (Figure II-21). In addition, there are 17 state, county and local parks or campgrounds along the shoreline providing opportunities for contact recreation activities: three in Iosco County, two in Arenac County, two in Bay county, one in Tuscola County, and nine in Huron County (Figure II-21). Activities at these sites include swimming, sunbathing, camping and various other day-use activities.

The Saginaw River receives limited use for contact recreation activities exclusive of fishing, but its tributaries are used for swimming, pleasure boating, and water skiing. There are no public beaches on the Saginaw River and the demand for swimming is low due to poor water quality.

Recreational boating is the primary contact use on the Saginaw River. There are six public boat launches along the Saginaw River (Figure II-22). Wickes Park, operated by the city of Saginaw, has two launch sites, one of which receives periodically heavy use. Veterans Memorial Park, a Saginaw County facility near the Bay County line, has a single ramp that also receives heavy use at times. There is also a Veterans Memorial Park in Bay City with boat access to the river. Immediately upstream from the mouth of the Saginaw River are two sites popular with boaters bound for Saginaw Bay, Smith Park in Essexville on the east side of the river, and a state maintained access site on the west side closer to the river mouth. In addition to these public facilities, there are 11 commercial marinas and several private access sites in Saginaw and Bay counties.

6. Noncontact Recreation

Facilities for noncontact recreation activities, such as camping, bicycling, walking and hiking, picnicking, nature study, and others, are readily available along the shoreline of Saginaw Bay. Level of use figures are available for the four Michigan state parks (Figure II-21): Tawas Point, Bay City, Albert E. Sleeper and Port Crescent (MDNR, 1987). The 175 acre Tawas Point State Park in Iosco County received 250,512 visitor-days of use in the state fiscal year 1986 (October 1, 1985 through September 30, 1986), divided between camping (78,248) and day use (172,270). Bay City State Park, 200 acres in size, was the most heavily used of all state parks on Saginaw Bay, receiving 582,418 visitor-days (75,898 camping, 506,520 day use). Sleeper State Park, a 1,000 acre facility, totalled 212,774 visitor days of use (89,007 camping, 123,767 day use). Port Crescent State Park covers 565 acres and received 171,923 visitor-days of use (88,806 camping, 83,117 of day use). The total number of visitor-days recorded at the four State Park facilities was 1,217,627 (331,959 camping, 885,674 day use) over a 12-month period indicated.

In addition to state parks, there are 10 sites identified as county, township, or municipal parks and/or campgrounds, with frontage on Saginaw Bay (Figure II-21). No use data are available for these sites, but their location suggests that water-related noncontact recreation activities

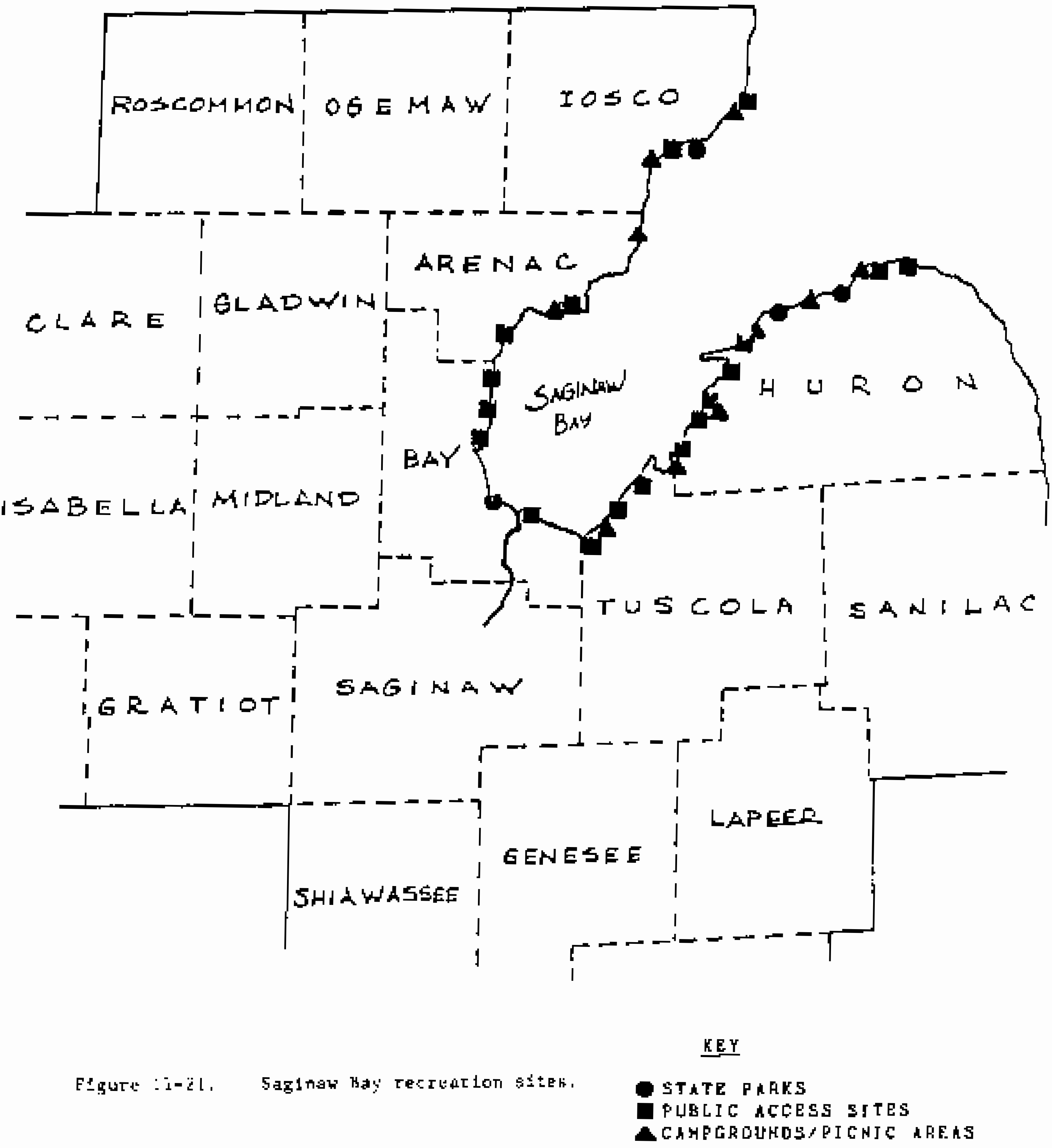


Figure II-21. Saginaw Bay recreation sites.

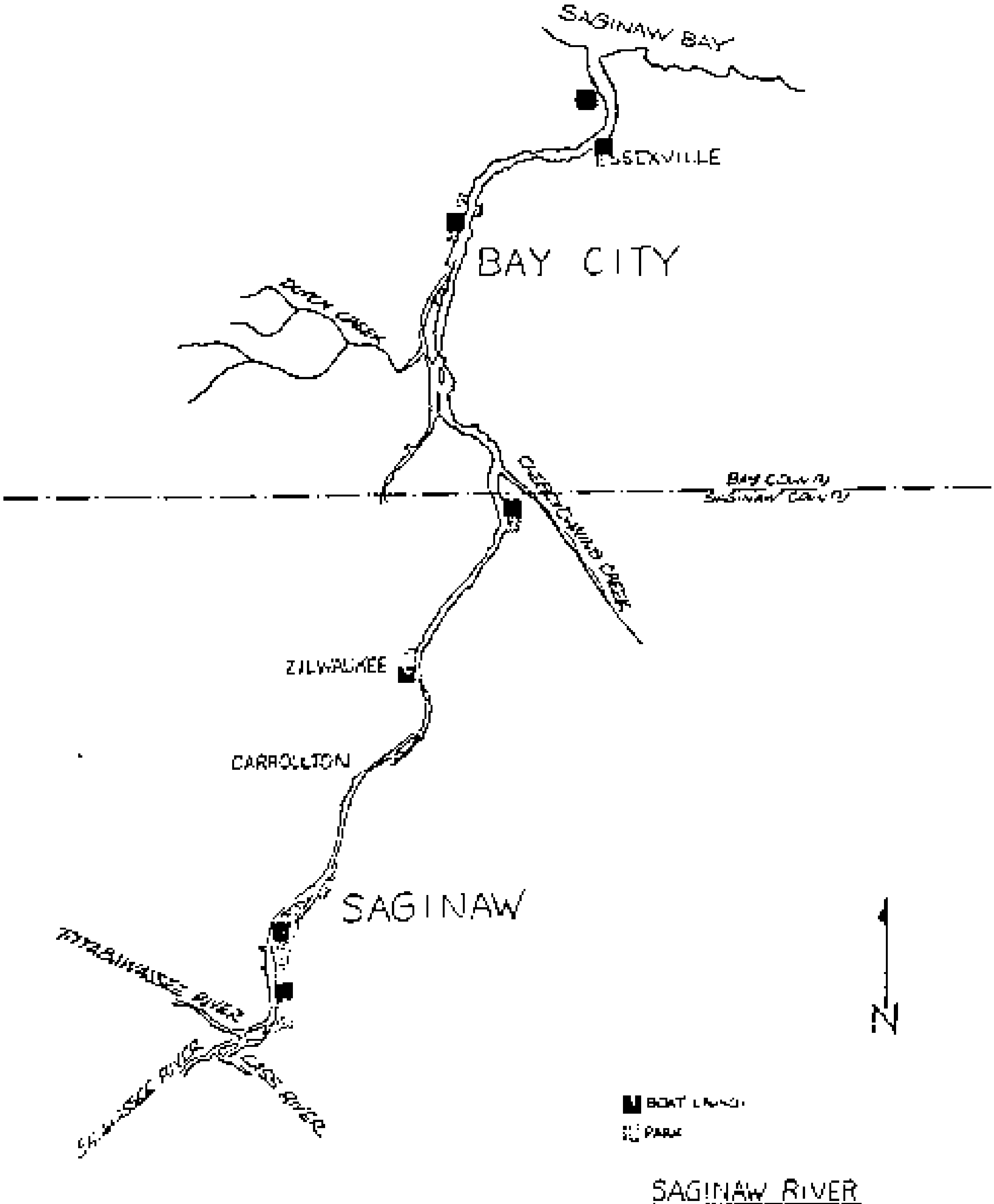


Figure II-22. Saginaw River recreation sites.

take place. In addition, noncontact uses are likely to be present at the public access sites and state game and wildlife areas along the bay shoreline (Figure 11-18). There are also numerous private beaches, campgrounds and other recreation facilities, particularly in Iosco, Arenac and Huron counties, for which reliable data was unavailable.

The Saginaw River has a large amount of public frontage along its length that is used for a variety of noncontact recreational activities, including picnicking, walking, bicycling and others. Wickes Park, Ojibaway Island, and several smaller parks in the city of Saginaw are being joined by a riverfront bicycling/walking trail to form an almost continuous park development from the confluence of the Tittabawassee and Shiawassee rivers to downtown Saginaw (Figure 11-22). Facilities at Zilwaukee and at the Bay County/Saginaw County line, while primarily boat launching facilities, also provide for some noncontact activities. Bay City has a well developed park system on the river, including Bigelow Park, Veterans Memorial Park, and Wenonah Park, which combine to provide facilities for team sports, picnicking, skating and other activities. Smith Park in Essexville, also primarily a boat launching facility, has limited opportunities for noncontact activities.

7. Commercial Navigation

The U.S. Army Corps of Engineers maintains several navigation projects in Saginaw Bay. Commercial navigation, exclusive of Saginaw River traffic, is primarily commercial fishing that is scattered among several ports, and the shipment of bulk gypsum products from the U.S. Gypsum Company terminal near Alabaster.

There are six federal navigation projects in Saginaw Bay, other than the Saginaw River channel, which receive periodic maintenance dredging; Tawas Bay, Point Lookout, Sebewaing, Caseville, Bay Port and Port Austin. These projects receive only periodic maintenance dredging, and three of these, Tawas Bay, Bay Port and Port Austin have not been dredged since prior to 1970. Point Lookout has been dredged two times: originally in 1973-1974, and maintenance dredging in 1983-1984. Sebewaing has been dredged three times: in 1977, 1980, and 1981. Caseville was dredged in 1971 and 1980. Much of this dredging is conducted to provide refuge for shallow draft vessels and to accommodate recreational boat traffic as well as limited commercial interests in these harbors.

The Corps of Engineers maintains a navigation channel from several miles beyond the mouth of the Saginaw River to the Sixth Street turning basin in Saginaw. The channel varies in depth from 27 feet at the river mouth to 20 feet at the Sixth Street turning basin, and in width from 350 feet to 200 feet at the same points, respectively. The Corps identifies forty-four terminal facilities along the channel, although not all of these are currently active. In addition to the turning basin at Sixth Street, two additional turning basins are maintained, one at Essexville (project depth 25 feet) and one near Clements Municipal Airport between Bay City and Saginaw (project depth 22 feet). The navigation channel from Sixth Street to Green Point (project depth 16.5 feet) has not been maintained for several years. Its current depths are adequate for present traffic use. The ice-free navigation season in the Saginaw River usually runs from March 24 to December 31.

In the 1983 navigation season, the most recent year for which statistics are available, commercial freight traffic in the Saginaw River totalled 2,385,719 tons. Of this total, 382,440 tons were foreign in origin or destination, and the remaining 2,003,279 were domestic. In terms of foreign traffic, 60,114 tons were exported and 322,326 tons were imported. The primary export commodities were wheat (29,391 tons), sand, gravel, and rock (12,950 tons) and animal feeds (9,592 tons). Imported commodities were primarily potassic chemical fertilizers (101,732 tons), iron ore and concentrates (101,235 tons), and residual fuel oil (31,380 tons). Canada was the most active foreign trading partner, with 94.9 percent of all foreign shipping traffic being Canadian in origin or destination.

Domestic freight traffic in the Saginaw River during the 1983 navigation season was primarily inbound, with receipts amounting to 1,982,491 tons, or 99.0 percent of the total. Outbound domestic shipments totalled 21,476 tons. The most prevalent domestic commodities received at Saginaw River terminals were limestone (1,061,676 tons), coal and lignite (433,522 tons), non-metallic minerals (54,561 tons), and building cement (53,089 tons). Only tow domestic commodities were shipped from terminals in the Saginaw River; distillate fuel oil (12,279 tons) and gasoline (9,197 tons). Local commercial shipping traffic in 1983 was negligible.

8. Waste Disposal

Exclusive of the waste load from the Saginaw River, Saginaw Bay is little used for disposal of municipal and industrial wastes. Of the 211 active industrial and municipal dischargers in the whole of the Saginaw Bay drainage basin, only 54 are found outside of the Saginaw River watershed. The East Coastal drainage basin has 22 dischargers, 6 industrial and 16 municipal. The West Coastal drainage basin has 12 industrial and 18 municipal dischargers. Of these 54 discharges, only one, an industrial discharge located in Sebewaing, is listed as a major discharger (MDNR, 1987).

Because the Saginaw River basin is heavily industrialized and relatively densely populated, the waters of the basin are called upon to assimilate waste loads from a large number of municipal wastewater treatment plants and industrial complexes. There are 60 industrial dischargers on the Saginaw River and tributaries, including 13 major dischargers, which are concentrated in the industrial centers at Flint, Midland, Saginaw and Bay City. The basin also contains 97 municipal wastewater treatment facilities, 18 of which are considered major dischargers (MDNR, 1987).

SECTION III -- PROBLEM DESCRIPTION

A. WATER QUALITY STANDARDS

1. Surface Water

a. Michigan

The legislation that protects existing and future uses of Michigan surface waters is the Michigan Water Resources Commission Act (PA 245 of 1929), as amended in November 1986. The Act provides general rules that (1) establish water quality requirements applicable to the Great Lakes, their connecting waterways, and all other surface waters of the state, (2) protect public health and welfare, (3) enhance and maintain the quality of water, (4) protect the state's natural resources, and (5) serve the purposes of the Michigan Water Resource Commission (WRC) Act, the federal Clean Water Act, and the U.S.-Canada Great Lakes Water Quality Agreement.

The rules designate specific uses for which all Michigan surface waters must be protected at a minimum. These uses include agricultural, industrial, and public water supply; use by warmwater fish, other indigenous aquatic life, and wildlife; navigation; and partial body contact recreation. Additional protection is afforded to waters that are protected for use by coldwater fish; this includes the Great Lakes, their connecting waters (except for the Keweenaw Waterway), and all waters designated by the Michigan Department of Natural Resources (MDNR) as trout streams or trout lakes. All waters of the state are designated for, and shall be protected for, total body contact recreation from May 1 to October 31. The rules also specify that all waters be protected for the most restrictive of all applicable designated uses.

In addition to describing designated uses, the rules also define parameters and criteria levels necessary to protect a waterbody for its designated uses. Part 4 of the rules describes Michigan's specific water quality standards, which set forth minimum and maximum levels for certain water quality parameters (Table III-1).

Toxic substances are controlled by the rules under the general standard that they shall not be present in Michigan waters at concentrations that are, or may become, injurious to the public health, safety or welfare; plant and animal life; or the designated uses of those waters. The toxic substances covered are the 236 chemicals and classes of chemicals listed on the 1984 Michigan critical materials register (the most recent version); the priority pollutants and hazardous chemicals in the Code of Federal Regulations (Appendix D, 1983); and any other toxic substances determined by the WRC to be of concern at a specific site. Criteria based on endpoints such as carcinogenesis are obtained from the MDNR and the Michigan Department of Public Health (MDPH). These criteria are compared to chronic criteria for aquatic life protection and the most restrictive value is recommended as the chronic criterion for effluent concentration calculations. The MDNR has developed water quality-based guideline levels for several toxic substances under Rule 57(2) (Table III-2).

Table III-1. Summary of Michigan Surface Water Quality Standards (from Part 4 of P.A. 245 of 1929, as amended in 1986).

Parameter	Limit
Turbidity Color Oil films Solids (floating, suspended or settleable) Foams Deposits	Waters of the state shall not have any of these unnatural physical properties in quantities which are or may become injurious to any designated use.
Total dissolved solids (TDS)	The addition of any dissolved solids shall not exceed concentrations which are or may become injurious to any designated use. In no instance shall they exceed 500 mg/l monthly average or 750 mg/l maximum for any waters of the state.
Chlorides	A maximum of 125 mg/l monthly average is allowed for waters of the state designated as public water supply sources, except for the Great Lakes and their connecting waters where chlorides shall not exceed a 50 mg/l monthly average.
Hydrogen Ion Concentration (pH)	6.5-9.0 in all waters of the state. Any artificially induced variation in natural pH shall remain within this range and shall not exceed 0.5 units of pH.
Taste and Odor	Waters of the state shall contain no taste-producing or odor-producing substances in concentrations which impair or may impair their use for a public, industrial or agricultural water supply source or which impair the palatability of fish.
Toxic Substances	Substance specific as determined by Rule 57 guidelines (see Table III-2).
Radioactive Substances	Standards prescribed by the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency.
Phosphorus	1.0 mg/l as a maximum monthly average for effluent discharges.

Table III-1. Continued.

Parameter	Limit
Nutrients	In addition to the maximum phosphorus discharge levels allowed, nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended and floating plants, fungi or bacteria, which are or may become injurious to the designated uses of the waters of the state.
Fecal Coliform	All waters of the state shall contain not more than 200 fecal coliform per 100 milliliters. This concentration may be exceeded if such concentration is due to uncontrollable nonpoint sources. The WRC may suspend this limit from November 1 through April 30 upon determining that designated uses will be protected.
Dissolved Oxygen (DO)	7 mg/l in all Great Lakes and connecting waterways and designated coldwater lakes and streams. In all other waters a minimum of 5 mg/l shall be maintained.
Temperature	No heat load which would warm receiving waters at the edge of the mixing zone more than 3 degrees Fahrenheit above existing natural water temperature for the Great Lakes and their connecting waters; 2 degrees Fahrenheit for coldwater streams; and 5 degrees Fahrenheit for warmwater streams.

Table III-2. Ambient Water Criteria (ug/l) for Selected Toxic Organic Substances.

Parameter	Michigan Rule 57(2) Guideline Levels (1988) Hardness (mg/l) 200	250	300	350	400	USEPA Ambient Water Quality Criteria (1985)	IJC WQA of 1978 Objectives (1978)
INORGANICS							
Arsenic			150.0[a]			190.0	50.0
Cadmium	0.64	0.77	0.90	1.02	1.14	---	0.2
Chromium	92.6	111.5	129.7	147.4	164.7	---	50.0
VI			6.0[a]			11.0[b]	---
III			---			230.43[b]	---
Copper	39.7	48.9	58.1	67.1	76.1	13.2[b]	5.0
Cyanide			5.0[a]			5.2	---
Iron			---			---	300.0
Lead	8.9	12.5	16.6	21.0	25.7	3.76[b]	20.0[c]
Mercury			0.0006[a]			0.012	0.2
Nickel	147.6	181.2	214.3	247.0	279.3	105.6[d]	25.0
Selenium			13.0[a]			35.0[e]	10
Silver			0.35[a]			5.08[d]	---
Zinc	176.5	213.4	249.2	284.1	318.2	118.4[b]	30.0
ORGANICS							
Aldrin/Dieldrin			---			---	0.001
Chlordane			---			---	0.06
DDT			0.00013[a]			---	---
+ metabolites			---			---	0.003
PCB			0.00002[a]			---	0.1
Phenol			230.0[a]			---	1.0
2,3,7,8-TCDD			1.0×10^{-7} ug/l[f]			"no safe level"	---

[a]Value is the same at all hardness levels.

[b]Four day average concentration not to be exceeded more than once every three years on the average; calculated at hardness equal to 114 mg/l CaCO3 based on 1986 Saginaw River water sample, Midland St. (MDNR, unpublished data).

[c]Lake Huron.

[d]USEPA, 1980 criteria; 24 hour average not to be exceeded at any time; calculated at hardness of 114 mg/l CaCO3 based on 1986 Saginaw River water sample, Midland St. (MDNR, unpublished data).

[e]USEPA, 1980 criteria; 4 day average not to be exceeded at any time.

[f]MDNR, 1987.

Portions of waterbodies can be designated as mixing zones within which water quality standards do not apply. The mixing zone is defined as the area where a point source discharge is diluted by the receiving water. This rule specifies that for a stream, the size of the mixing zone shall be minimized, and the final acute value shall not be exceeded anywhere within the mixing zone unless it is demonstrated to the WRC that a higher level is acceptable. Exposures in mixing zones shall not cause deleterious effects to populations of aquatic life or wildlife, and the mixing zone shall not prevent the passage of fish or fish food organisms in a manner which would result in adverse impacts on their immediate or future populations.

The water quality standards do not apply where dredging authorized by the U.S. Army Corps of Engineers (USACOE) or the MDNR takes place. In some cases, if the WRC determines that dredging will have unacceptable adverse impacts on designated uses, water quality standards may be applied. The water quality standards do apply to nonconfined waters that are used to dispose of dredge spoils.

The water quality standards are minimally acceptable water quality conditions. Ambient water quality should be equal to or better than the water quality standards 95% of the time. Antidegradation requirements exist for waters that have better water quality than the established water quality standards. This includes all Michigan waters of the Great Lakes, except as these waters may be affected by discharges to the connecting waters and tributaries. These waters cannot be lowered in quality unless it is determined by the WRC that degradation of these waters will not impair designated uses. Exceptions to the antidegradation rule will be allowed if: (1) an applicant demonstrates to the WRC that a lowering in water quality will not be unreasonable, (2) it is in the public interest in view of existing conditions, (3) it is necessary to accommodate important social or economic development, and (4) there are no prudent and feasible alternatives to lowering the water quality.

The rules also declare that Michigan waters which do not meet the water quality standards shall be improved to meet those standards. Where the water quality of certain waters does not meet the water quality standards as a result of natural causes or conditions, further reduction of water quality is prohibited.

b. U.S. Environmental Protection Agency

Pursuant to section 304 of the federal Clean Water Act, the U.S. Environmental Protection Agency (EPA) has developed water quality criteria guidelines to assist states in the development of their own criteria for toxic pollutants (Table III-2). The EPA guidelines summarize the relevant scientific literature and develop a criterion for each toxic substance. Criteria have been established for all 65 priority toxic pollutants (45 Fed. Reg. 79318, November 28, 1980, and 50 Fed. Reg. 30784, July 29, 1985). Generally, Rule 57(2) guidelines developed by MDNR are more stringent than U.S. EPA criterion and are enforceable by Michigan law. Therefore, only Rule 57(2) guidelines are discussed in this report, with respect to the water quality status of Saginaw Bay basin waters.

c. Great Lakes Water Quality Agreement of 1978

As part of the 1978 U.S.-Canada Great Lakes Water Quality Agreement (WQA), as amended in 1987, to restore and maintain the chemical, physical and biological integrity of the Great Lakes ecosystem, the United States and Canada agreed to specific objectives to serve as minimum levels of water quality desired in the boundary waters (Table III-2). The objectives are intended to protect the most sensitive use in all Great Lakes waters based on available information on cause/effect relationships between pollutants and receptors. These objectives apply only to the Great Lakes and their connecting channels; they do not apply to basin tributaries.

2. Drinking Water

Primary maximum contaminant levels (MCLs) were established by the U.S. EPA under the federal Safe Drinking Water Act and adopted by reference in Michigan Public Act 399 of 1976 (Michigan's Safe Drinking Water Act; Table III-3). The primary MCLs are enforceable in Michigan for all public water supplies.

3. Groundwater

The Michigan Water Resources Commission Act also protects groundwaters of the state. Proposed discharges to groundwater are reviewed by MDNR staff to determine if the discharge will cause groundwater degradation. The determination of degradation involves a substance-specific review of the amount of change that would take place in groundwater quality based on knowledge of treatment technologies, engineering, geology and hydrology. Limits are established that will protect human health, groundwater uses, and allow non-degradation of the aquifer. The groundwater rules are currently being revised.

Table III-3. Maximum Contaminant Levels for Drinking Water Supplies in Michigan (from P.A. 399, 1976).

Parameter	Maximum Contaminant Level (mg/l)
INORGANICS	
Arsenic	0.050
Barium	1.0
Cadmium	0.010
Chromium	0.050
Fluoride	2.4
Lead	0.050
Mercury	0.002
Selenium	0.010
Silver	0.050
ORGANICS	
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.0005
2,4-Dichlorophenoxyacetic Acid (2,4-D)	0.1
2,4,5-Trichlorophenoxy -proprionic Acid (2,4,5-TP)	0.01
Trihalomethanes	0.1

B. IMPAIRED USES

Two designated uses, as defined by Michigan's water quality standards, are presently considered to be impaired in the Saginaw River/Bay Area of Concern: the human consumption of fish; and, the suitability of the aquatic environment for use by indigenous wildlife populations.

Public health fish consumption advisories issued by the MDPH are currently in effect for several species because of elevated levels of polychlorinated biphenyls (PCBs) in fish tissue. However, these advisories are restricted to bottom feeding fish and fish with relatively high levels of body fat. People are advised not to eat any carp or catfish from either the Saginaw River or Saginaw Bay. Additionally, for Saginaw Bay, it is suggested that people restrict their consumption of lake trout, rainbow trout, and brown trout to no more than one meal per week. There are no advisories for yellow perch or walleye, the principle sport fish of Saginaw Bay.

Various biota populations have been negatively impacted by eutrophic water quality conditions in the Saginaw River/Bay Area of Concern. Eutrophic conditions directly impair some indigenous populations and create environmental characteristics favorable for many nuisance species, such as blue-green algae, that compete for food and habitat with the more desirable species.

C. PHYSICAL WATER QUALITY

1. Temperature

a. Saginaw Bay

Average annual water temperatures in Saginaw Bay are affected by circulation patterns and are warmest in the inshore waters of Wildfowl Bay (Smith et al., 1977). The lowest mean temperatures are found along the northwest shore where Lake Huron waters enter the bay. Area weighted mean temperatures for Saginaw Bay were 6.7°C in the spring of 1984 and more than 20.0°C in the summer of 1985 (Neilson et al., 1986). These temperatures were the highest of any stations sampled in Lake Huron during these periods (Neilson et al., 1986).

Consistent thermal structures are apparent only in the deeper water of the outer bay, where a thermocline is present from May to October (Smith et al., 1977). Brief periods of thermal stratification occur in the inner bay during spring calms, but wind and wave action generally cause complete mixing in all areas except those that are protected or deep (Schelske and Roth, 1973; Smith et al., 1977). Thermal inversions have occurred in the past at the mouth of the Saginaw River caused by chloride concentrations in the river sufficient to overcome normal temperature/density relationships (Smith et al., 1977).

Ice forms in shallow, protected areas of Saginaw Bay as early as late November and may persist until late April (Figure III-1). Ice thickness and the degree to which it has consolidated generally decreases from inner to outer portions of the bay.

Average monthly water temperatures at the mouth of the Saginaw River for the period 1974-1987 varied between 0.7°C in January to 24.7°C in July (Figure III-2). Temperatures increased most rapidly between April and May with a rise of over 8°C. Average summer temperatures during the months of June, July and August were 22°C or higher. Yearly peak temperatures in the Saginaw River between 1974 and 1987 often reached 26°C or higher (Figure III-3).

2. Dissolved oxygen

a. Saginaw River and Tributaries

Dissolved oxygen concentrations in the Saginaw River were measured monthly at the Midland Street Bridge, approximately five miles upstream of Saginaw Bay, and the Center Street Bridge, approximately 20 miles upstream of Saginaw Bay by MDNR from 1977 to 1987. Dissolved oxygen concentrations at the Midland Street Bridge dropped below Michigan's water quality standard of 5.0 mg/l eleven times during this period, but only two of these occurrences were between 1981 and 1987 (Figure III-4). Dissolved oxygen concentrations at the Center Street Bridge dropped below 5.0 mg/l three times from 1977 to 1987 and all three occurrences were between 1985 and 1987 (Figure III-5).

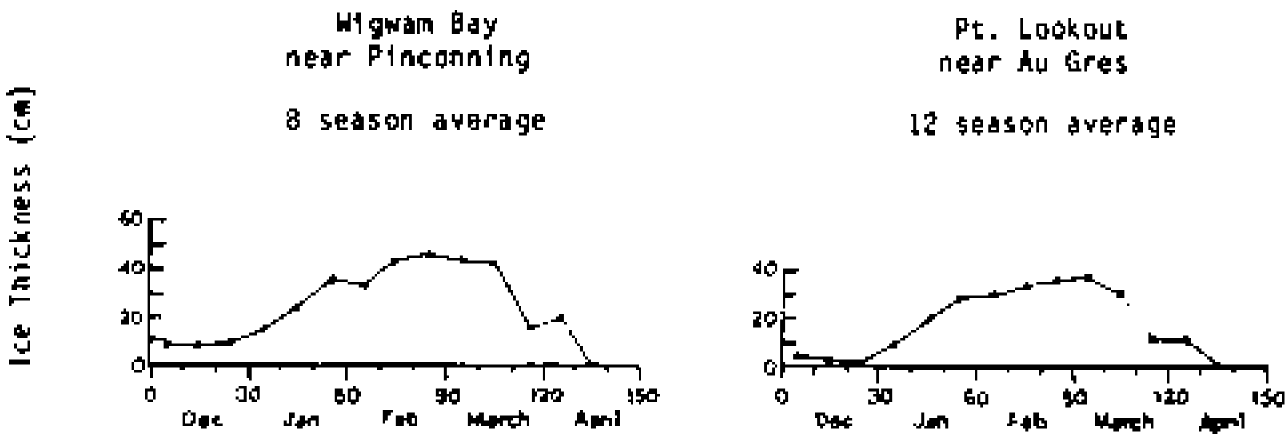


Figure III-1. Mean ice thickness over time at Wigwam Bay and Pt. Lookout, Saginaw Bay (NOAA, 1983).

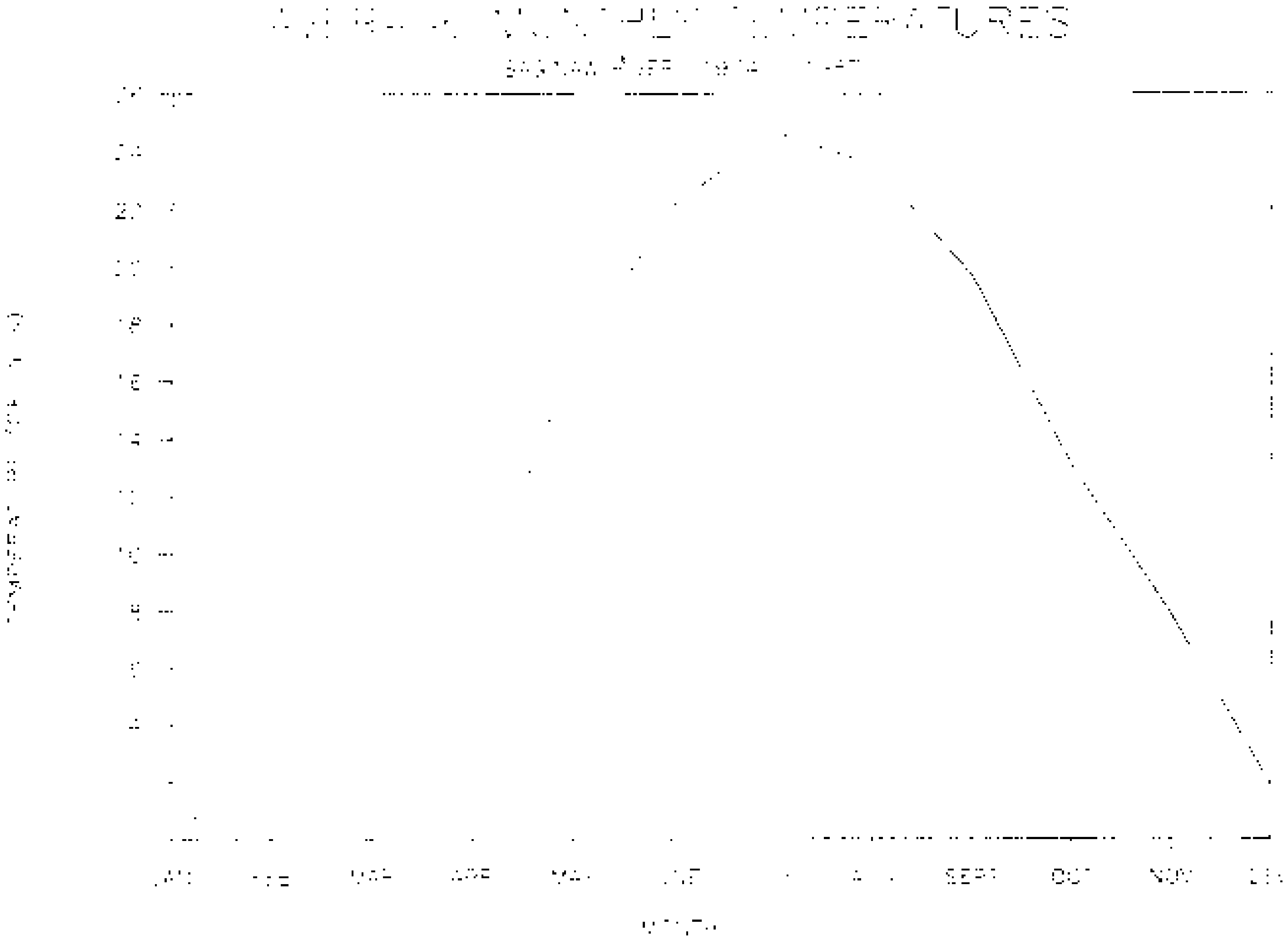


Figure III-2. Average monthly water temperatures in the Saginaw River, 1974-1987.

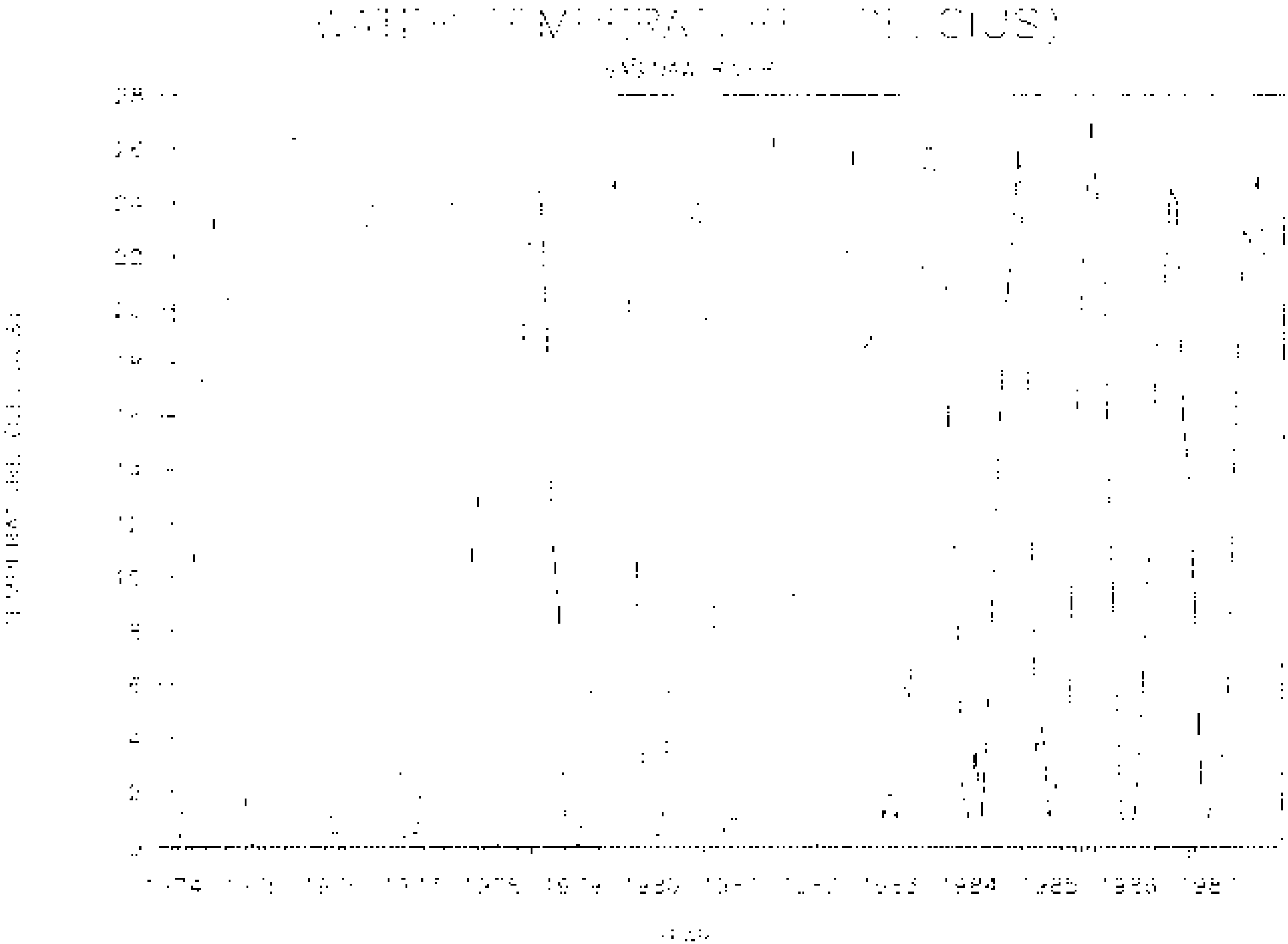


Figure III-3. Monthly water temperatures in the Saginaw River, 1974-1987.

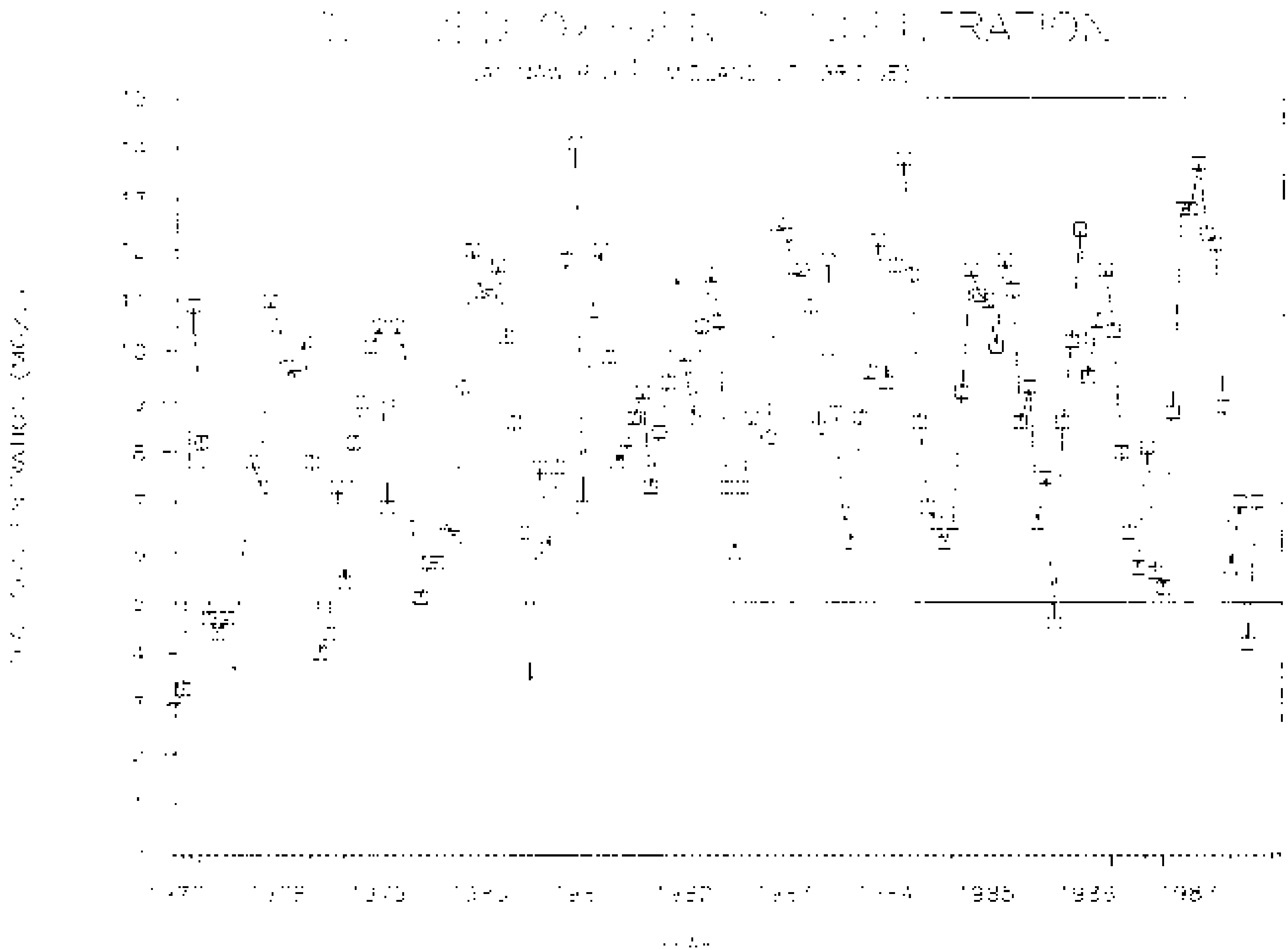


Figure III-4. Monthly dissolved oxygen concentrations in the Saginaw River at the Midland Street bridge, 1977-1987.

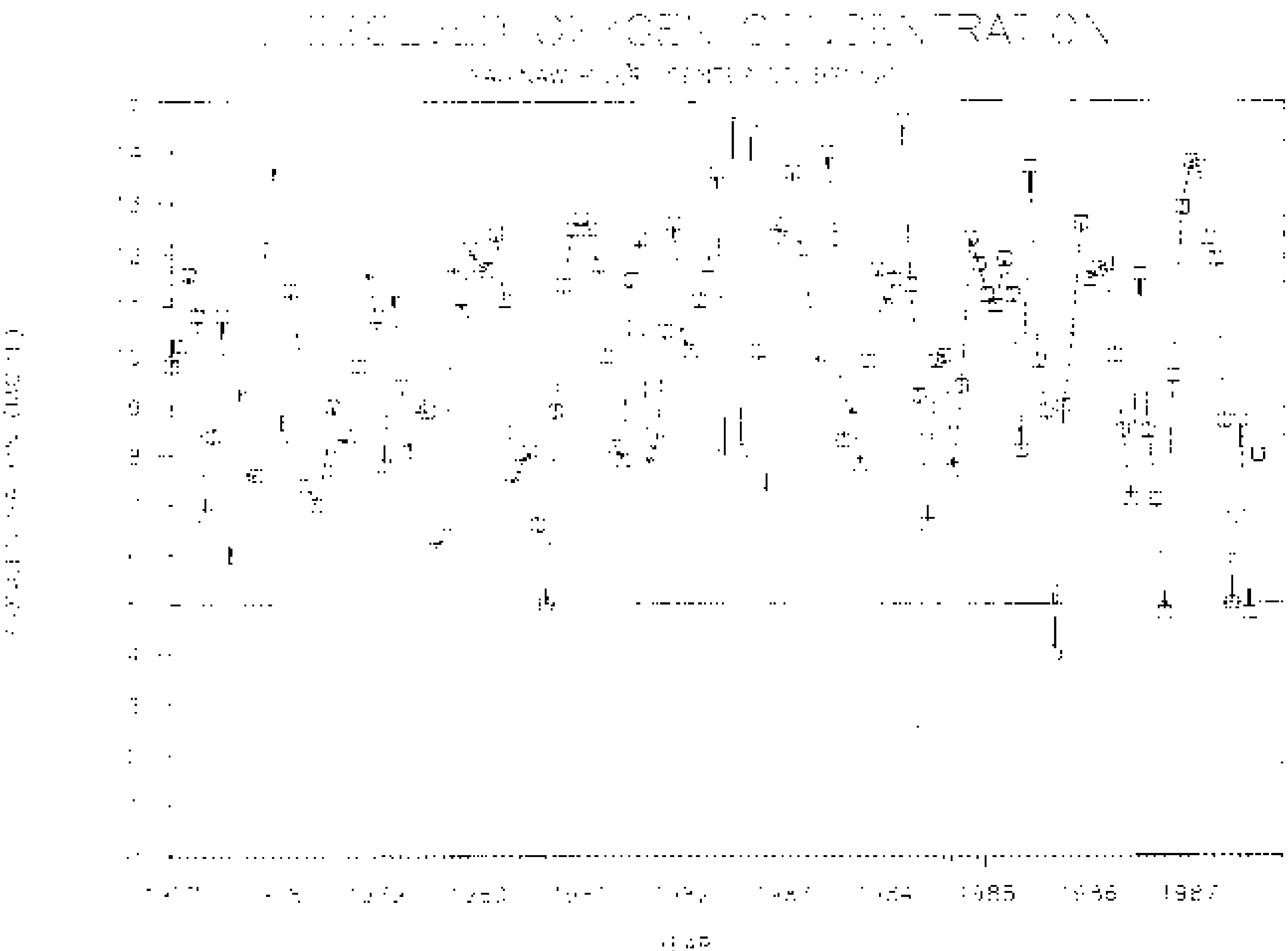


Figure III-5. Monthly dissolved oxygen concentrations in the Saginaw River (at the Center Street bridge, 1977-1987).

During this 10-year period, the average monthly dissolved oxygen concentrations were highest in December for both Center Street (12.3 mg/l) and Midland Street (12.0 mg/l). The lowest monthly average from Center Street samples was 7.9 mg/l in September while July samples were lowest at Midland Street and averaged 6.2 mg/l.

Monthly dissolved oxygen concentrations were also measured periodically in the four major tributaries to the Saginaw River from 1980 through 1986. Samples were taken from the Cass River at M-13, the Flint River at Elms Road, the Shiawassee River at Fergus Road, and the Tittabawassee River at Gordonville Road (Table III-4; Figure II-7). All dissolved oxygen concentrations were above 5.0 mg/l.

b. Saginaw Bay Tributaries

Dissolved oxygen levels were also monitored in 10 Saginaw Bay coastal tributaries between 1980 and 1986 including Sebewaing River at the C&O railroad bridge, Pigeon River at Kinde Road, Pinnebog River at M-25, Taft Drain at M-25, Tawas River at U.S. 23, Au Gres River at U.S. 23, Rifle River at State Road, Pine River at State Road, Pinconning River at the mouth, and Kawkawlin River at the mouth (Table III-4; Figure II-7). All tributaries had dissolved oxygen concentrations above 5.0 mg/l except for the Pigeon River in August 1985 (4.8 mg/l) and the Kawkawlin River in September 1985 (3.3 mg/l) and February 1986 (4.8 mg/l).

c. Saginaw Bay

Dissolved oxygen generally remains near saturation levels throughout the bay and variation in the concentration is primarily due to temperature gradients (Smith et al., 1977).

3. Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) was determined in water samples collected monthly by the MDNR from the Midland Street and Center Street bridge sites on the Saginaw River from 1974 to 1986. The annual average BOD ranged from a high of 5.80 mg/l at Center Street in 1982 to a low of 3.11 mg/l at Midland Street in 1985 (Figure III-6). Annual average BOD values have been below 4.0 mg/l since 1983.

Samples were also periodically collected for BOD analysis from the four major Saginaw River tributaries. The annual average BOD in the tributaries ranged from a high of 9.95 mg/l in the Flint River in 1978 to a low of 2.07 mg/l in the Shiawassee River in 1974 (Figure III-7). Biological oxygen demand in the Flint and Tittabawassee rivers has been below 4.0 mg/l since 1982. Among west coastal basin tributaries to Saginaw Bay, the annual average BOD ranged from a high of 6.05 m/gl in the Kawkawlin River in 1963 to 0.98 mg/l in the Rifle River in 1984 (Figure III-8). The highest annual average BOD reported for east coastal basin tributaries was 14.39 mg/l in the Sebewaing River in 1963 while the lowest was 1.22 mg/l in the Pigeon River in 1984 (Figure III-9).

Table III-4. Water Sampling Sites on Saginaw Bay Basin Tributaries.

Tributary	Location	Description
Saginaw River	Mouth	Downstream of Bay City
Saginaw River	Midland Street	Approx. RM 5.0 in Bay City
Saginaw River	Center Street	Approx. RM 20.0 upstream of Saginaw
Tittabawassee River	Gordonville Rd.	Downstream of Midland
Shiawassee River	Fergus Road	Near Mouth
Flint River	Elms Road	Downstream of Flint
Cass River	Dixie Highway	Near Mouth
Tawas River	U.S. 23	Near Mouth
Whitney Drain	U.S. 23	Near Mouth
Au Gres River	U.S. 23	Near Mouth
Rifle River	State Road	Near Mouth
Pine River	State Road	Near Mouth
Pinconning River	Mouth	Mouth
Kawkawlin River	Mouth	Mouth
Sebewaing River	C&O RR Bridge	Near Mouth
Pigeon River	Kinde Road	Near Mouth
Pinnebog River	M-25	Near Mouth
Taft Drain	M-25	Near Mouth

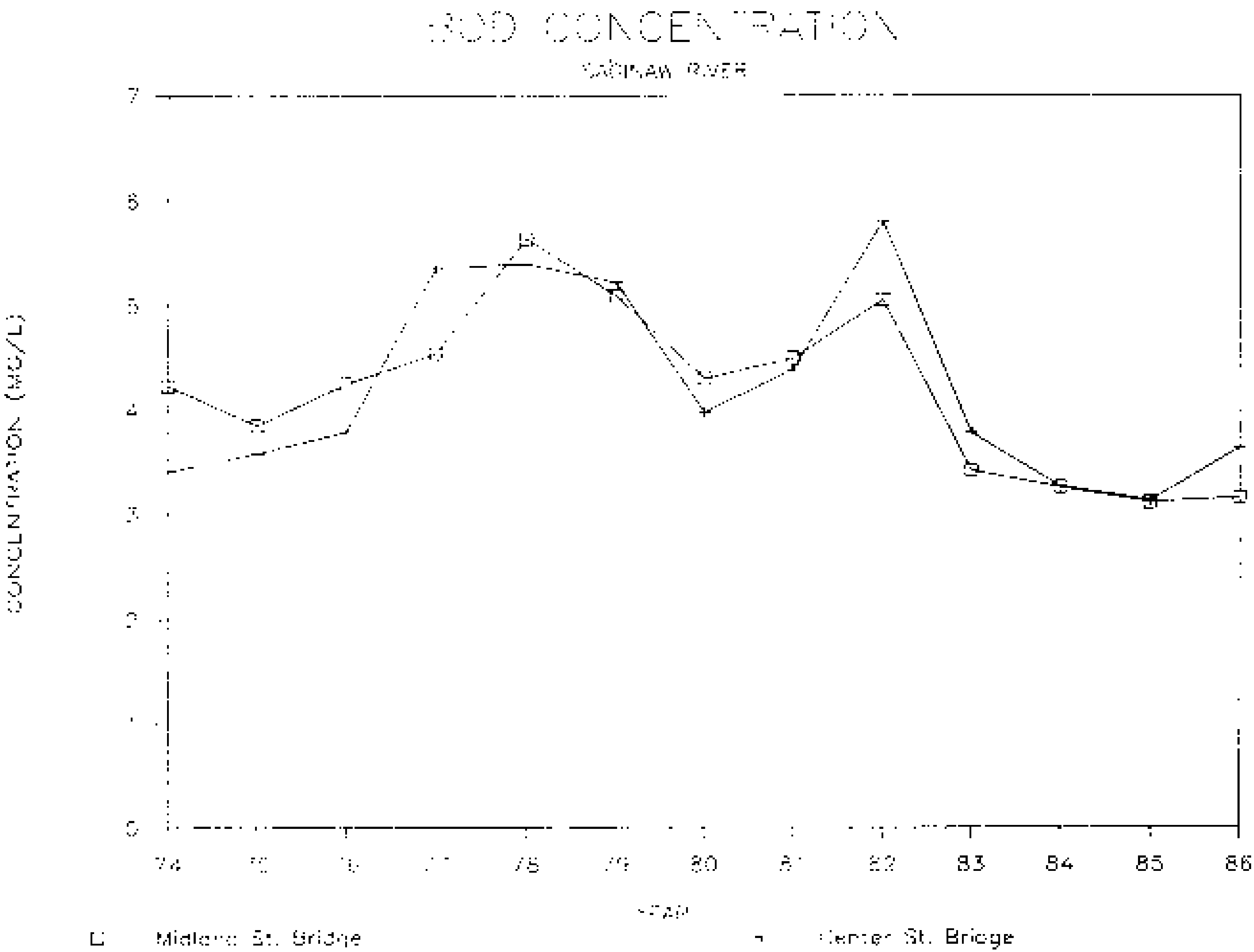


Figure III-6. Annual average biochemical oxygen demand in the Saginaw River, 1974–1986.

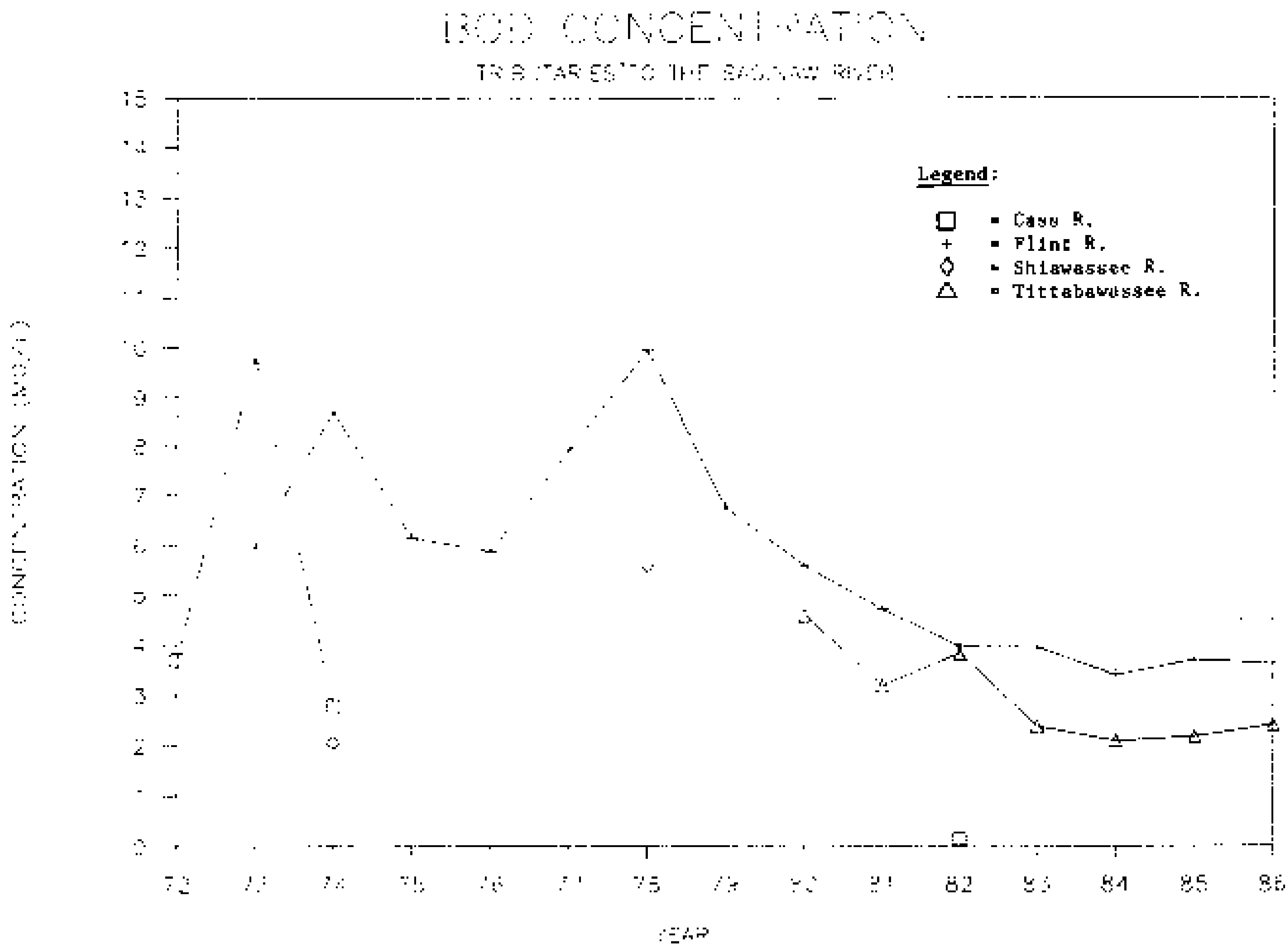


Figure III-7. Annual average biochemical oxygen demand in Saginaw River tributaries, 1972-1986.

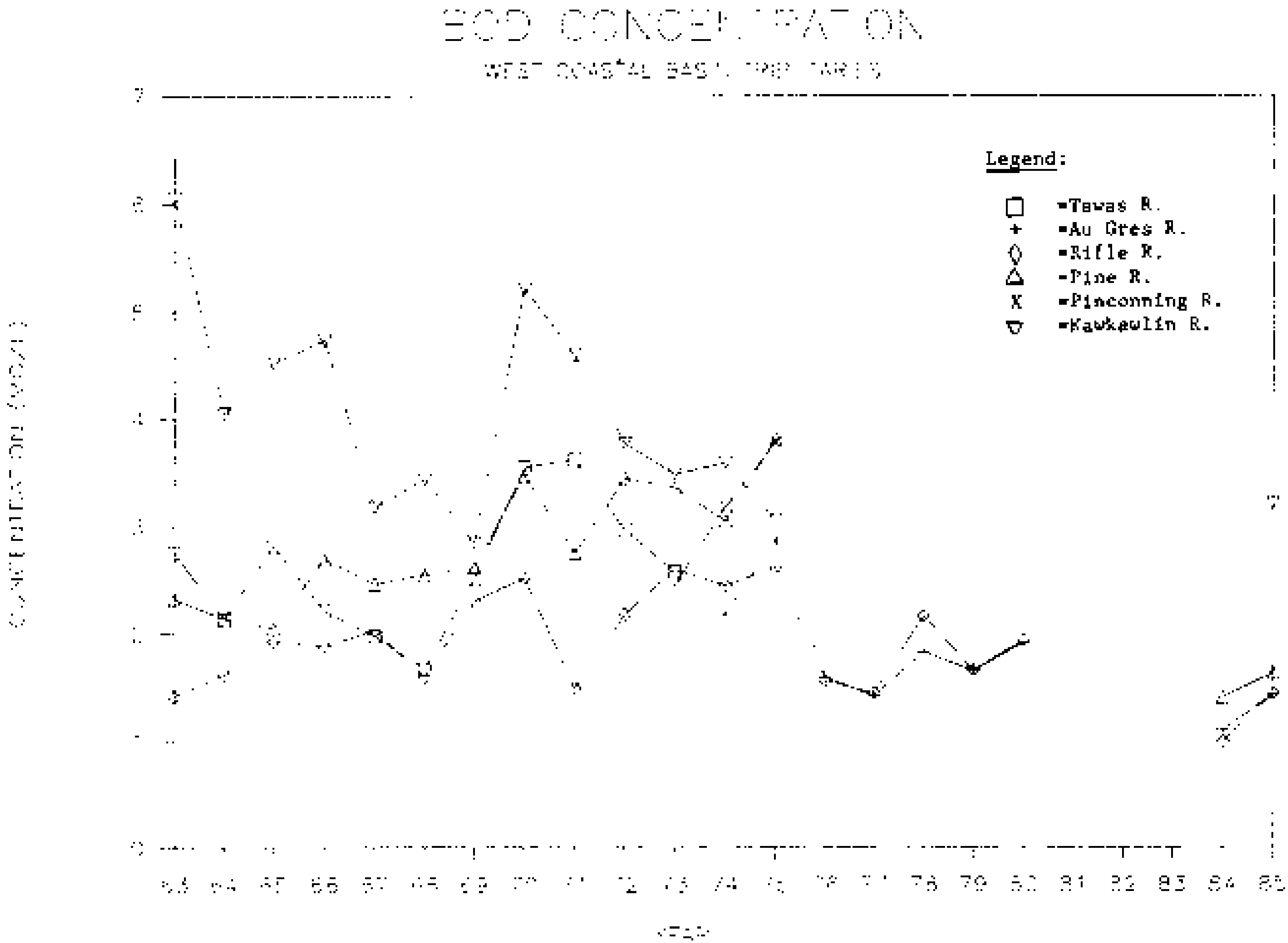


Figure III-8. Annual average biochemical oxygen demand in west coastal basin tributaries, 1963-1989.

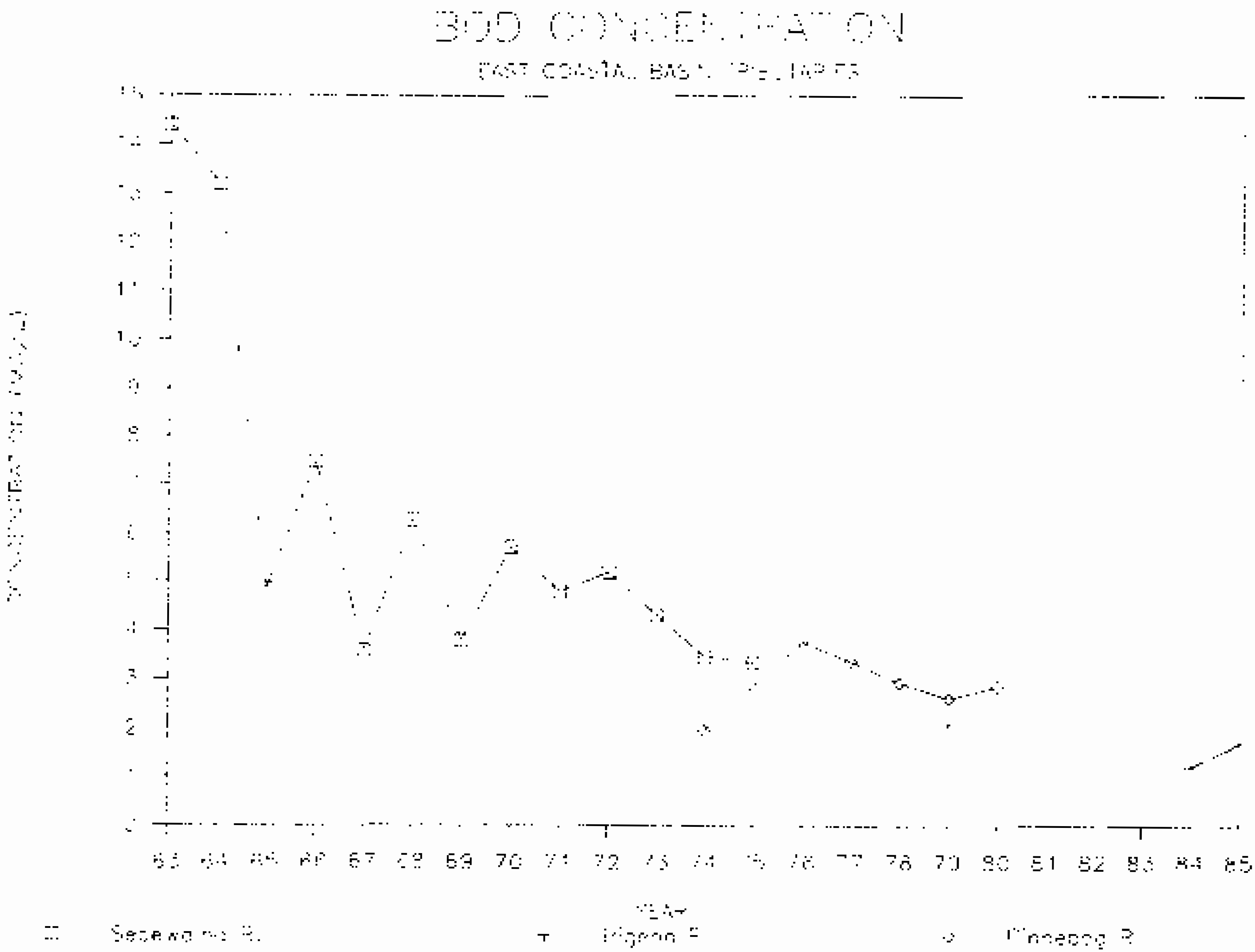


Figure III-9. Annual average biochemical oxygen demand in east coastal basin tributaries, 1963-1985.

4. Taste and Odor

a. Definition

Taste and odor in municipal water supplies drawn from Saginaw Bay have been one of the principal water quality issues for Saginaw Bay (Dolan et al., 1986). Odor is generally caused by blue-green algae, actinomycetes (aquatic fungi), and blue-green algae decomposition (Bratzel et al., 1977). Water treatment plant operators monitor taste and odor qualitatively by periodically tasting and smelling water samples and describing the odor as musty, grassy, fishy or in other similar terms. This odor analysis is subjective, depending on the opinion and perception of the operator working a particular shift, and is not considered to be a particularly reliable means of assessing odor problems (Peters, pers. comm., 1987). A more quantitative method for monitoring odor is to determine the amount of dilution necessary so that taste and odor are just detectable (Rogalski, pers. comm., 1987; Dolan et al., 1986). The water is then ranked on a scale from one to 10 based on the amount of dilution necessary with three being the U.S. Public Health Service (USPHS) standard threshold value.

b. Saginaw-Midland Water Intake

Though it is only one of three public drinking water intakes on Saginaw Bay, the Saginaw-Midland water intake at Whitestone Point accounts for 85% of the water drawn from Saginaw Bay for human use. The intake is located 2 miles out from shore in 50 feet of water (Peters, pers. comm., 1987; Figure III-10). Water drawn from this site had taste and odor problems, and exceeded the USPHS standard threshold odor value of 3, for a total of 56 days in 1974, and for shorter periods in 1975, 1976, 1978 and 1979 (Figure III-11). The threshold odor did not exceed the USPHS standard value in 1977 or 1980. Odor values for the Saginaw-Midland site did not go above 2 during 1985 (DPU, 1985).

The decrease in taste and odor problems from 1974 to 1980 correspond with biomass reductions of blue-green algae communities in segment 2 (Figure III-12) of Saginaw Bay (Table III-5). The apparent decrease and/or elimination of Aphanizomenon flos-aquae, a blue-green algae species, in the outer Saginaw Bay region by 1980 may be the major factor contributing to reduced taste and odor days for the Saginaw-Midland water intake (Dolan, personal communication). Blue-green algal dry weight biomass in the inner bay may be a good indicator of taste and odor conditions in the municipal water supply (Bierman et al., 1984).

c. Bay City Water Intake

The Bay City intake extends three and one half miles out into Saginaw Bay near the mouth of the Saginaw River (Figure III-10). Daily analysis of intake water is conducted, including taste and odor evaluation (De Kam, pers. comm., 1987). Raw water samples have historically had severe taste and odor problems, and even though raw water quality has improved over the last several years and taste and odor problems have diminished, ozone is still used to treat the water.

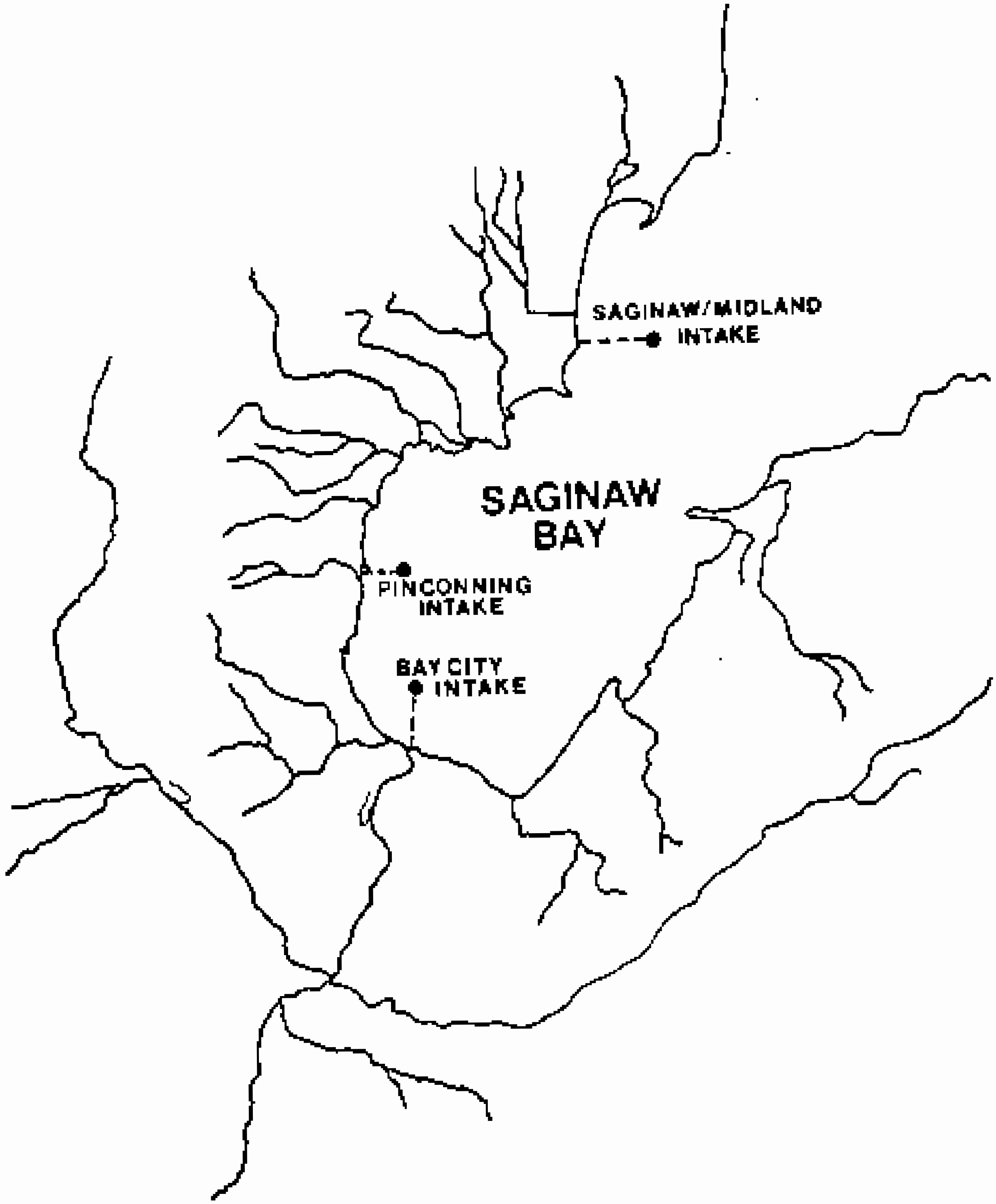


Figure III-10. Public drinking water supply intakes, Saginaw Bay, Lake Huron (USEPA, 1985).

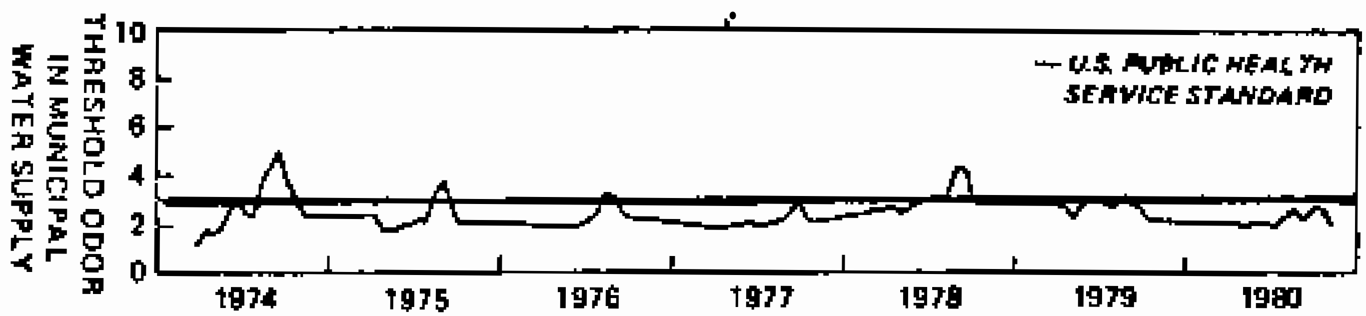


Figure III-11. Taste and odor in water from the Saginaw-Midland water intake, 1974-1980 (Dolan, et al., 1986).

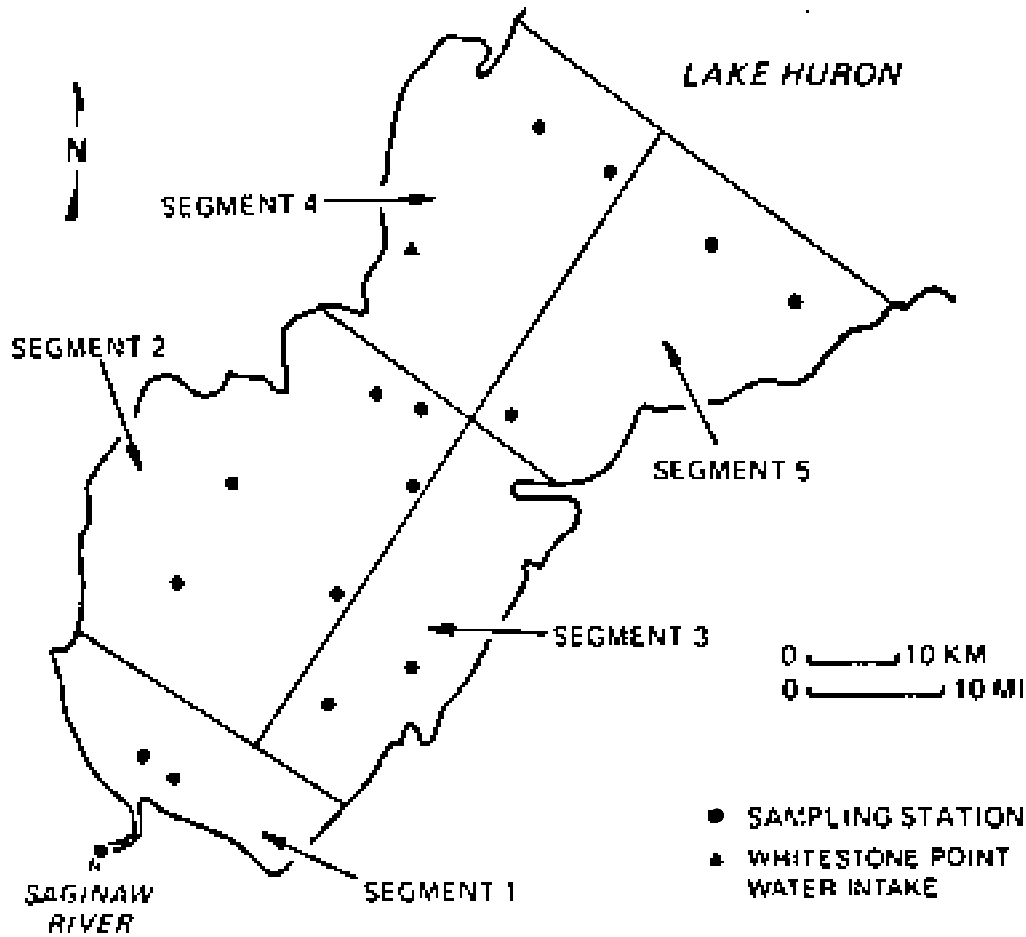


Figure III-12. Segments and sampling stations in Saginaw Bay (Dolan, et al., 1986).

Table III-5. Seasonal Phytoplankton Concentrations (mg/l dry weight) in Saginaw Bay Segment 2, and Number of Annual Odor Days and Maximum Odor Value, 1974-1976 and 1980 (Dolan et al., 1986).

	Year							
	1974		1975		1976		1980	
Parameter	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Peak Total Algal	8.0	2.47	9.87	4.42	19.6	3.32	0.630	1.39
Peak Diatom	7.62	0.921	9.64	3.66	19.1	1.97	0.541	1.30
Peak Total Bluegreen	0.217	1.29	0.387	0.863	0.066	0.59	0.043	0.027
Percent Bluegreen During Bluegreen Peak	15.0	63.4	25.4	27.9	0.49	19.7	8.04	5.46
Ratio of Bluegreen Peak to Total Algal Peak (%)	2.71	52.2	3.93	19.5	0.34	17.7	6.82	1.94
Number of Annual Odor Days (Odor >3)	56		22		9		0	

(De Kam, pers. comm., 1987). Current taste and odor data are not readily available.

d. Pinconning Water Intake

The Pinconning water treatment plant draws water from the western shore of Saginaw Bay half way between the Bay City and Whitestone Point sites (Figure III-10). Carbon treatment is used and is increased only when strong taste and odor problems persist for several days (Gies, pers. comm., 1987). Trend data are not readily accessible since no annual or monthly reports are compiled from the daily sampling data.

5. Saginaw Bay Turbidity

From 1974 to 1980, water clarity was consistently poor in inner Saginaw Bay during the spring and fall as indicated by secchi disk measurements. Secchi depth was lowest (poorest clarity) during this period in the spring of 1976 and the fall of 1977, reaching only 0.78 m (Table III-6). Water clarity improved between 1978-1980, as secchi depth values increased to 1.16 m for both the spring and fall of 1980. Clarity in the inner bay is probably affected by wave-resuspension of sediments in shallow water (Smith et al., 1977; Bierman et al., 1983).

There has been great variation in water clarity in outer Saginaw Bay, probably due to the mixing of clear Lake Huron water and turbid bay water. Mean secchi depths in outer bay segments 4 and 5 (Figure III-12) in 1974 and 1975, were considerably greater than mean depths for the inner bay segments (Table III-7).

6. Suspended Solids

Annual average suspended solids concentrations at the Saginaw River Midland Street station during the period 1974 to 1986 ranged from a high of 46.6 mg/l in 1985 to a low of 23.8 mg/l in 1981 (Figure III-13). Concentrations at the Saginaw River Center Street station ranged from a 46.4 mg/l high in 1975 to a 23.3 mg/l low in 1986 (Figure III-13). The four major tributaries to the Saginaw River were also sampled monthly for suspended solids periodically from 1972 to 1986. The highest annual average suspended solids concentration reported for all tributaries was 59.4 mg/l from the Flint River in 1977 and the lowest concentration was 13.6 mg/l in the Tittabawassee River in 1986 (Figure III-14).

Monthly suspended solids samples were collected from nine Saginaw Bay tributaries periodically from 1963 to 1985. The highest annual average suspended solid concentration reported for a west coastal basin tributary was 64.3 mg/l for the Rifle River in 1965 and the lowest concentration was 8.1 mg/l for the Tawas River in 1969 (Figure III-15). The highest concentration reported for an east coastal basin tributary was 95.6 mg/l in the Sebewaing River in 1967 and the lowest value was 9.9 mg/l in the Pigeon River in 1984 (Figure III-16).

Table III-6. Secchi Depth (m) by Season for Inner Saginaw Bay, 1974-1980 (Bierman et al., 1983).

Year	Season	
	Spring	Fall
1974	1.09	0.95
1975	1.30	1.12
1976	0.78	0.84
1977	1.39	0.78
1978	0.98	0.93
1979	1.09	0.95
1980	1.16	1.16

Table III-7. Mean Secchi Disc Depth (m) by Segment in Saginaw Bay, 1974 and 1975 (Smith et al., 1977).

Segment	Year	
	1974	1975
1	0.87	0.9
2	1.3	1.5
3	1.0	1.4
4	3.4	3.6
5	2.7	3.0

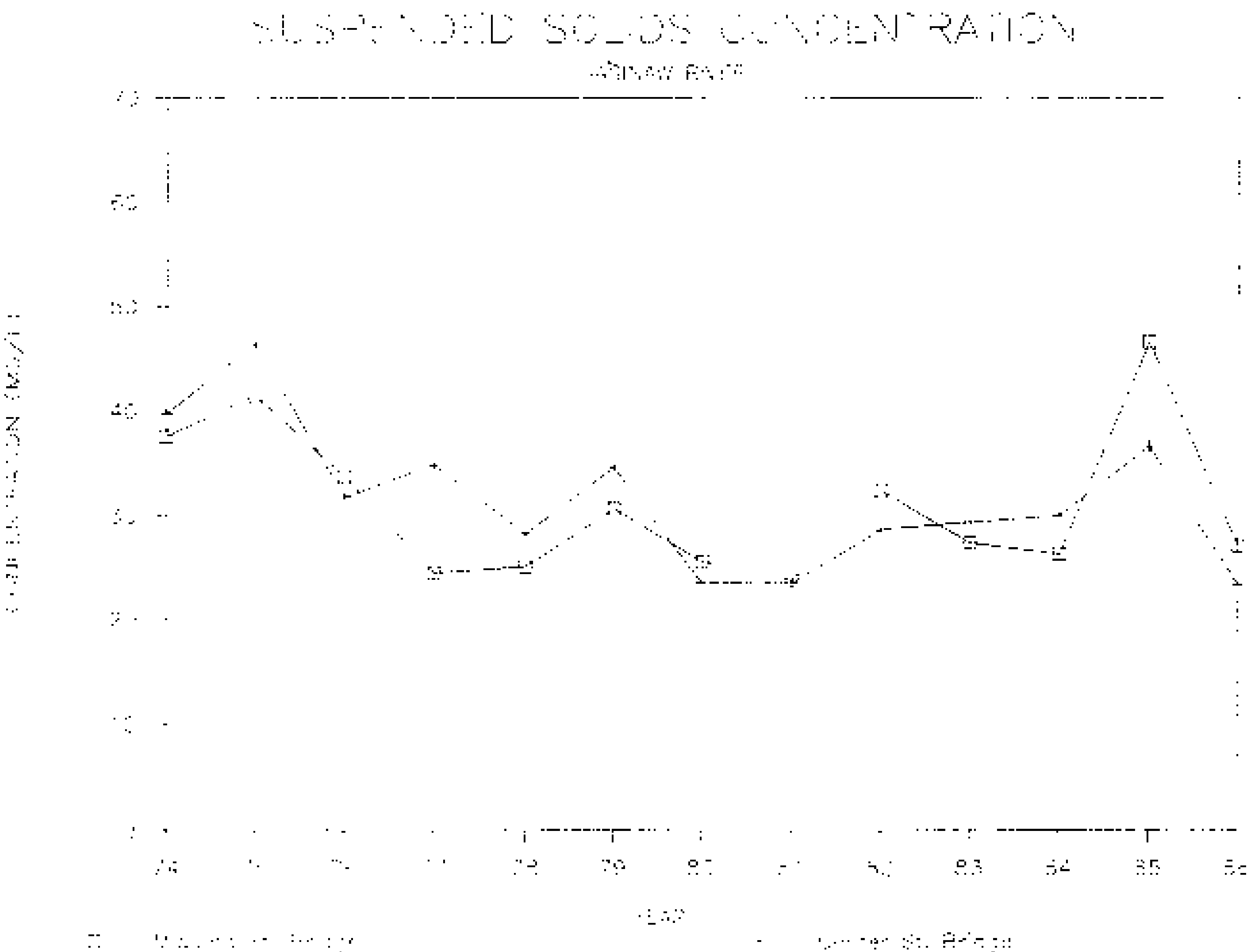


Figure III-13.   Annual average suspended solids concentrations in Saginaw River water samples, 1974-1986.

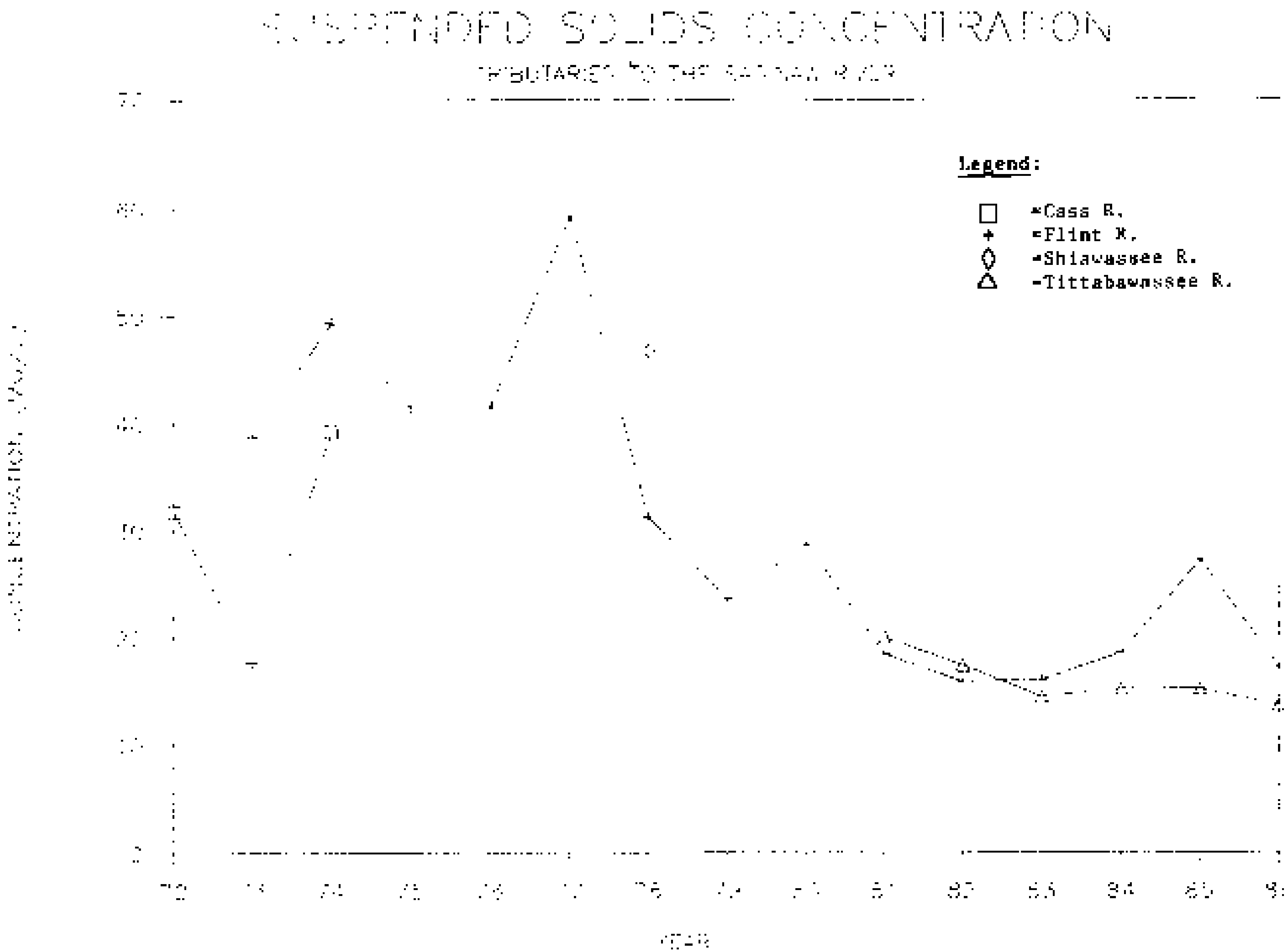


Figure III-14. Annual average suspended solids concentrations in Saginaw River tributaries, 1972-1986.

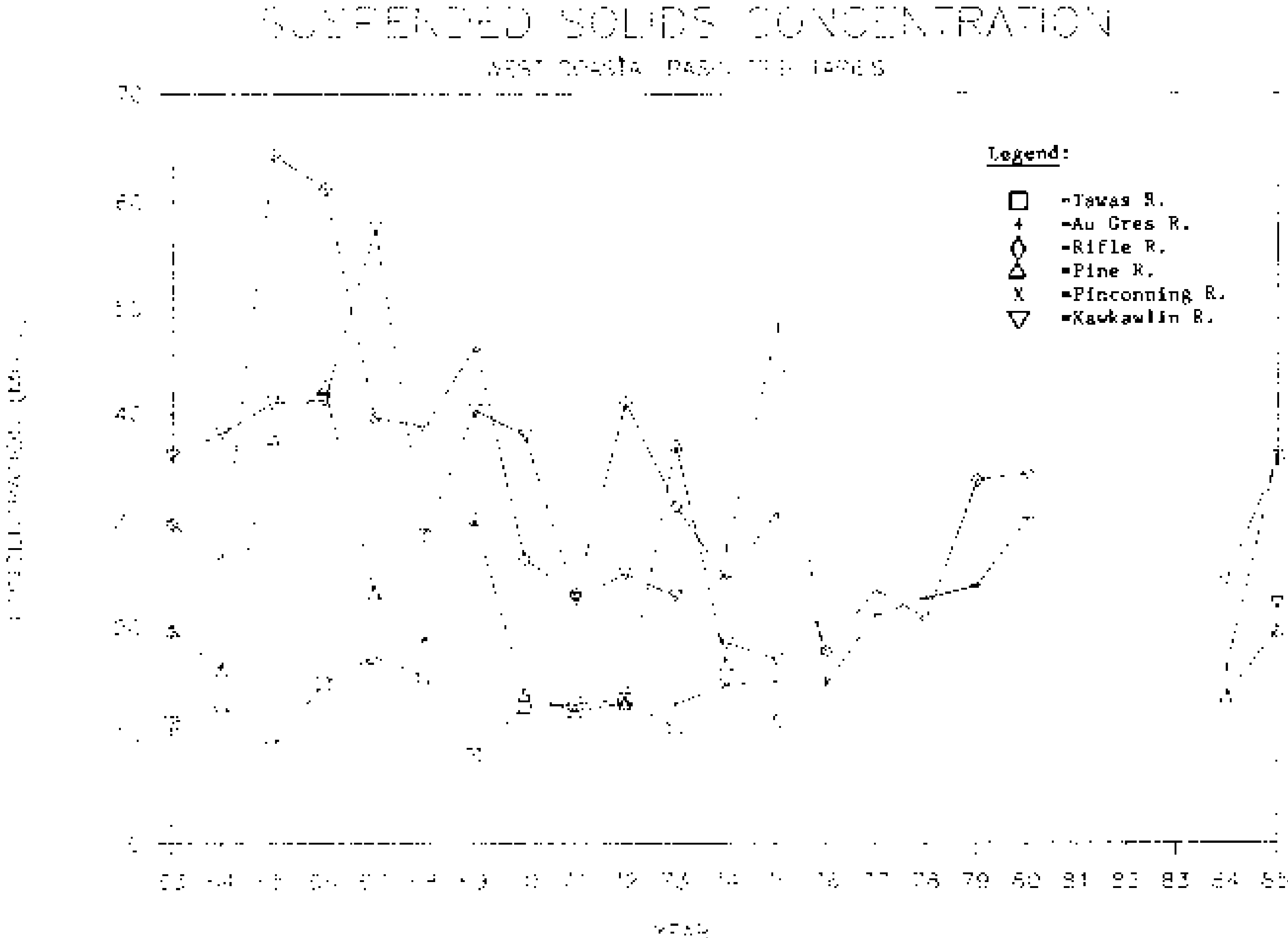


Figure III-15. Annual average suspended solids concentrations in Saginaw Bay west coastal basin tributaries, 1963-1985.

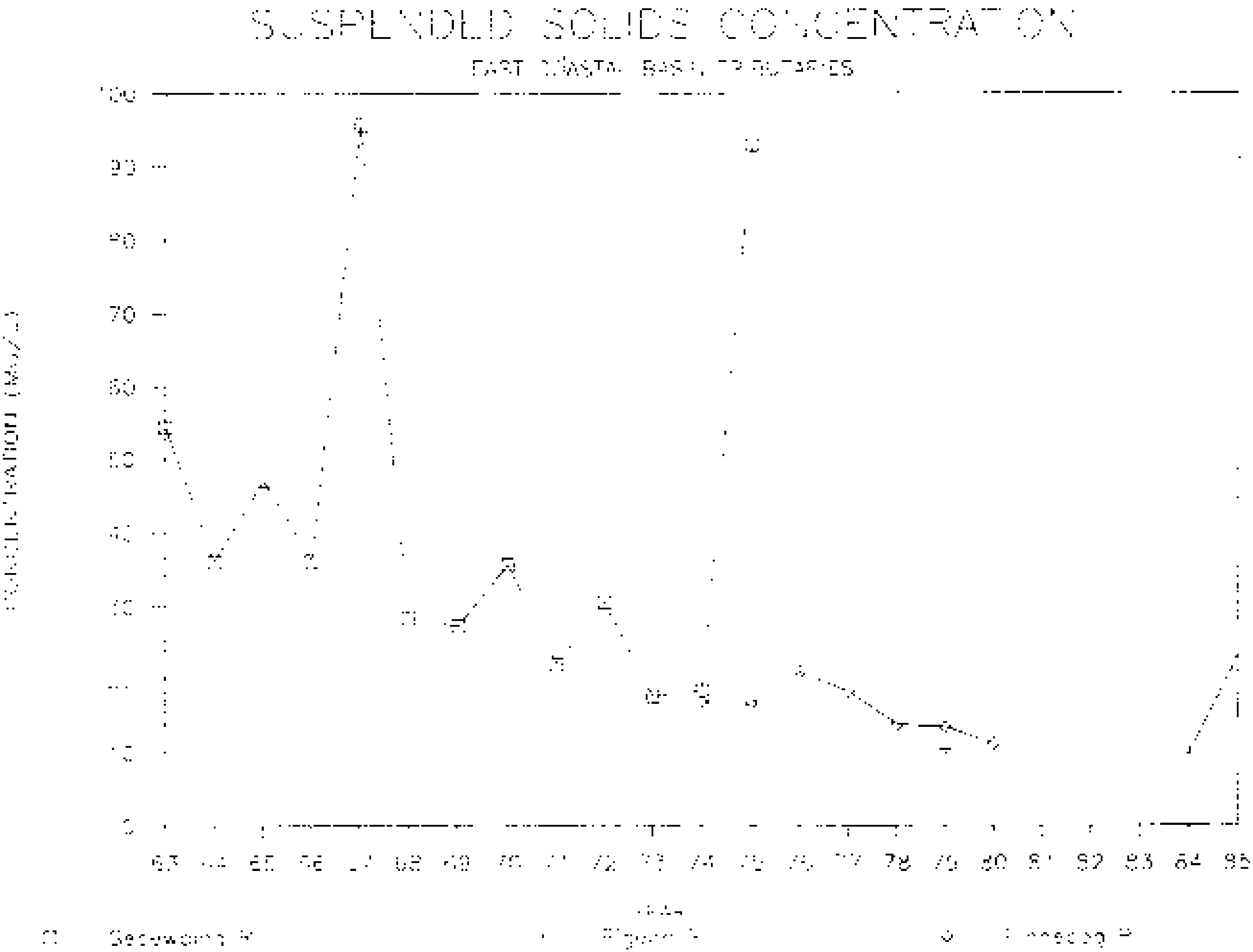


Figure III-16. Annual average suspended solids concentrations in Saginaw Bay east coastal basin tributaries, 1963-1985.

7. Total Solids

Total solids (filterable suspended solids plus non-filterable dissolved solids) were collected monthly during 1974 to 1986 from the Saginaw River at Midland Street and Center Street. The highest annual average total solids concentrations in the Saginaw River was 552 mg/l at Center Street in 1978 while the lowest concnetration was 408 mg/l at Midland Street (Figure III-17). Total solids decreased at both sites from 1982 to 1986. The highest total solids concentration among the four major Saginaw River tributaries was 548 mg/l in the Tittabawassee River in 1982 and the lowest concentration was 388 mg/l in the Tittabawassee River in 1986 (Figure III-18). Total solids concentrations decreased during 1982 to 1986 in the Tittabawassee River and from 1979 to 1986 in the Flint River.

The highest annual average total solids concentrations measured for Saginaw Bay coastal tributaries from 1967 to 1985 were 622 mg/l and 611 mg/l in the Pinconning River during 1973 and 1974, respectively. The lowest annual average of about 200 mg/l occurred consistently in the Tawas River (Figures III-19 and III-20).

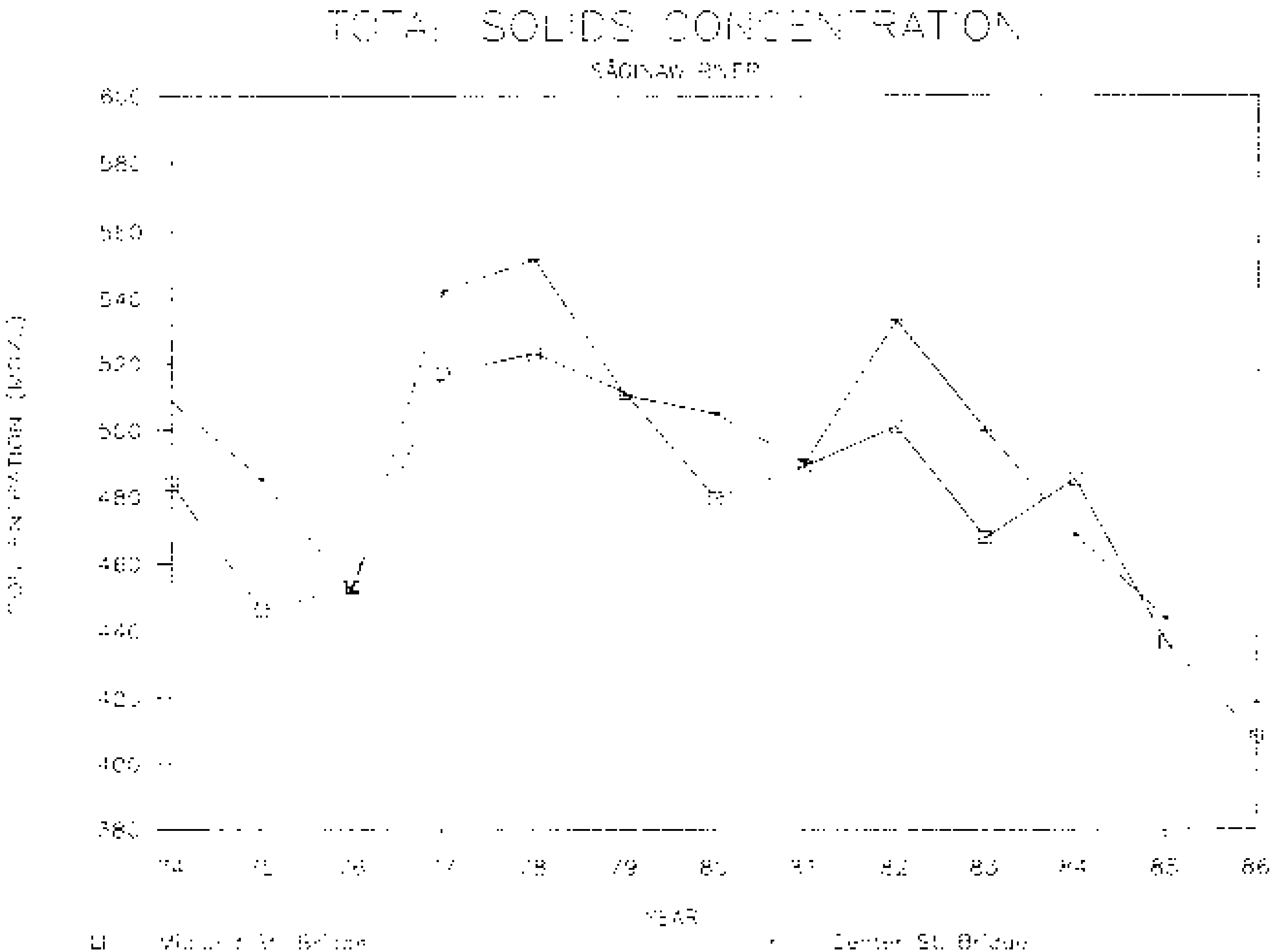


Figure III-17. Annual average total solids concentrations in Saginaw River water samples, 1974–1986.

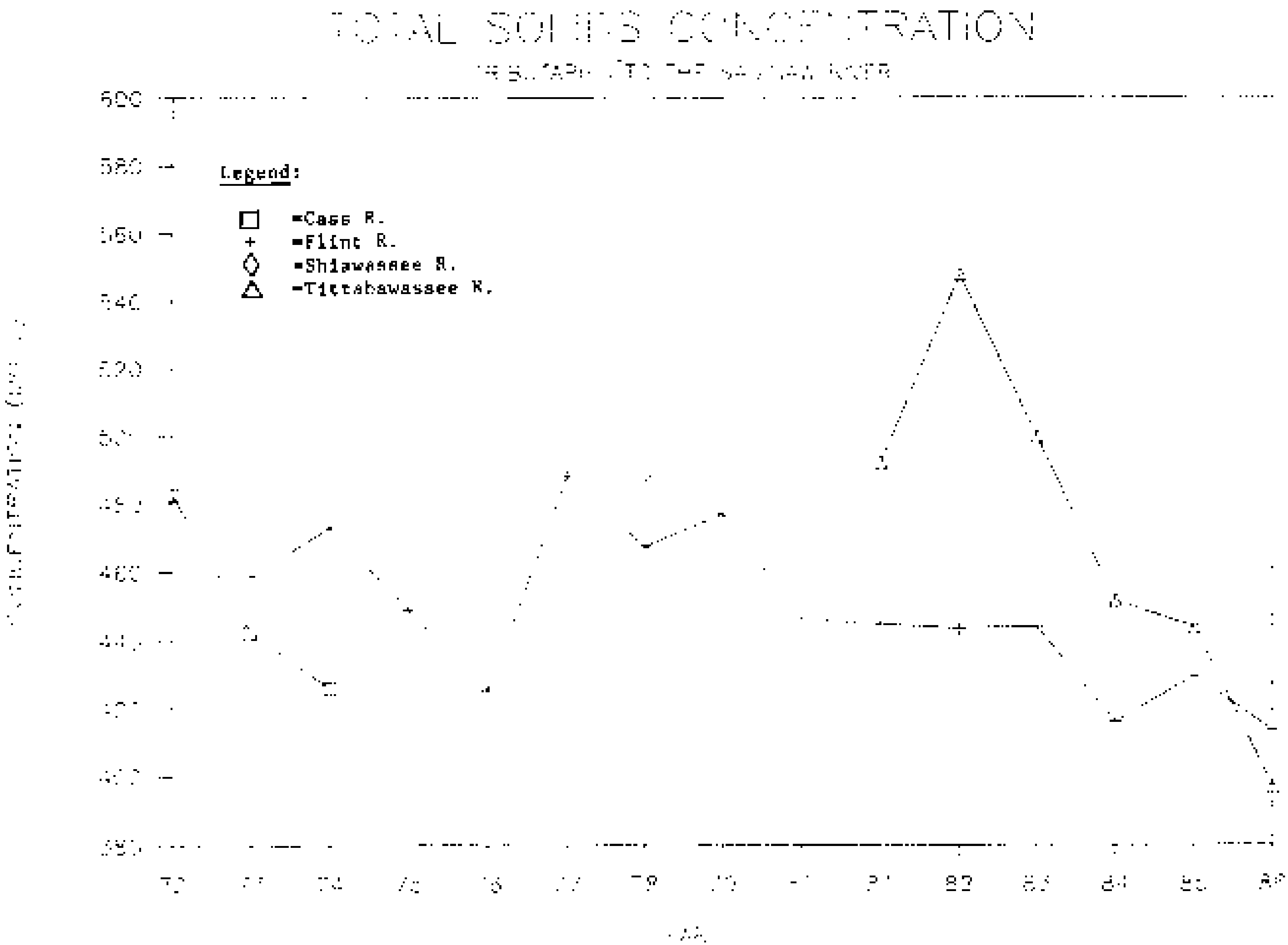


Figure III-18. Annual average total solids concentrations in Saginaw River tributaries, 1972-1986.

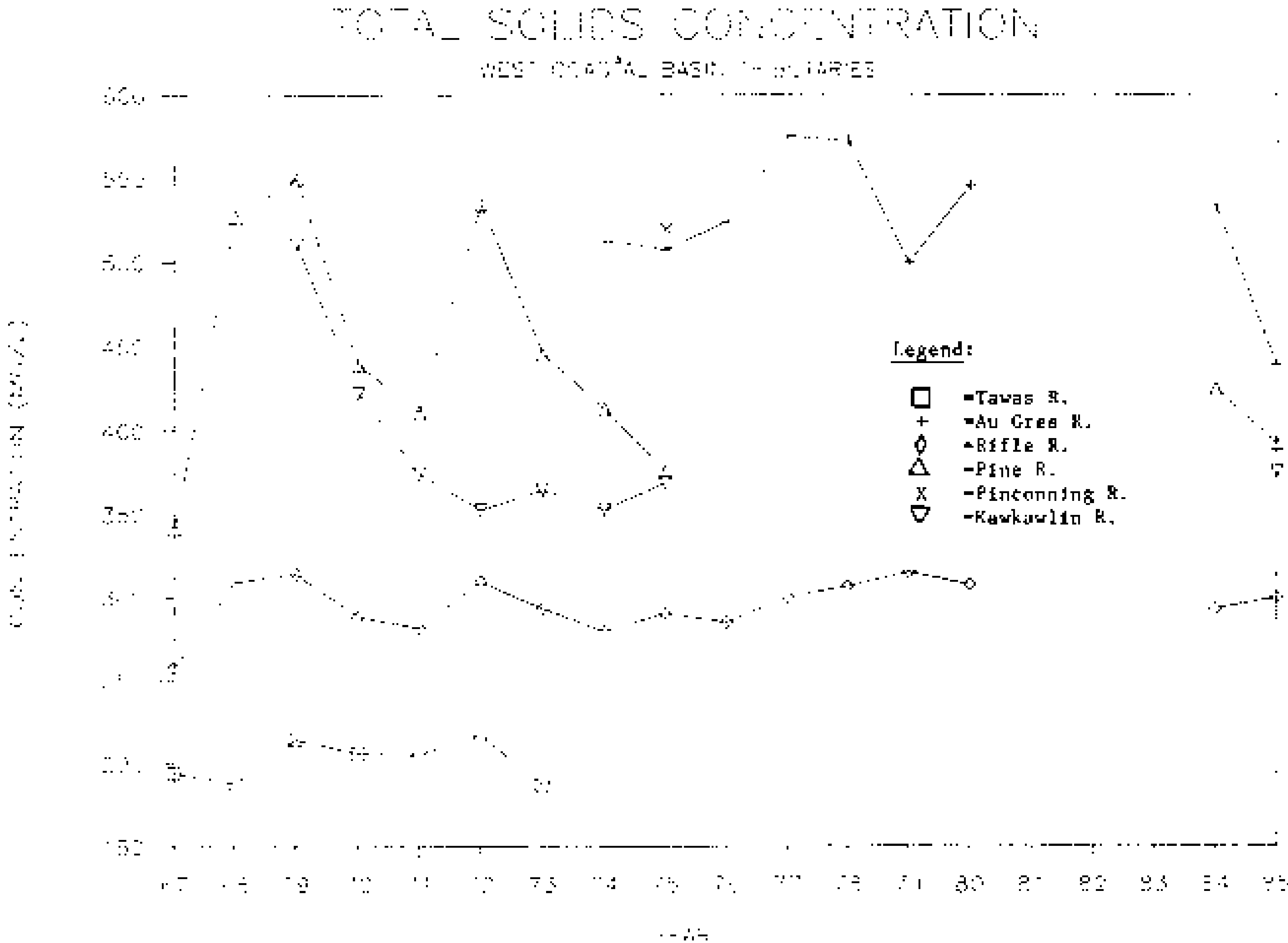


Figure III-19. Annual average total solids concentrations in Saginaw Bay west coastal basin tributaries, 1967-1985.

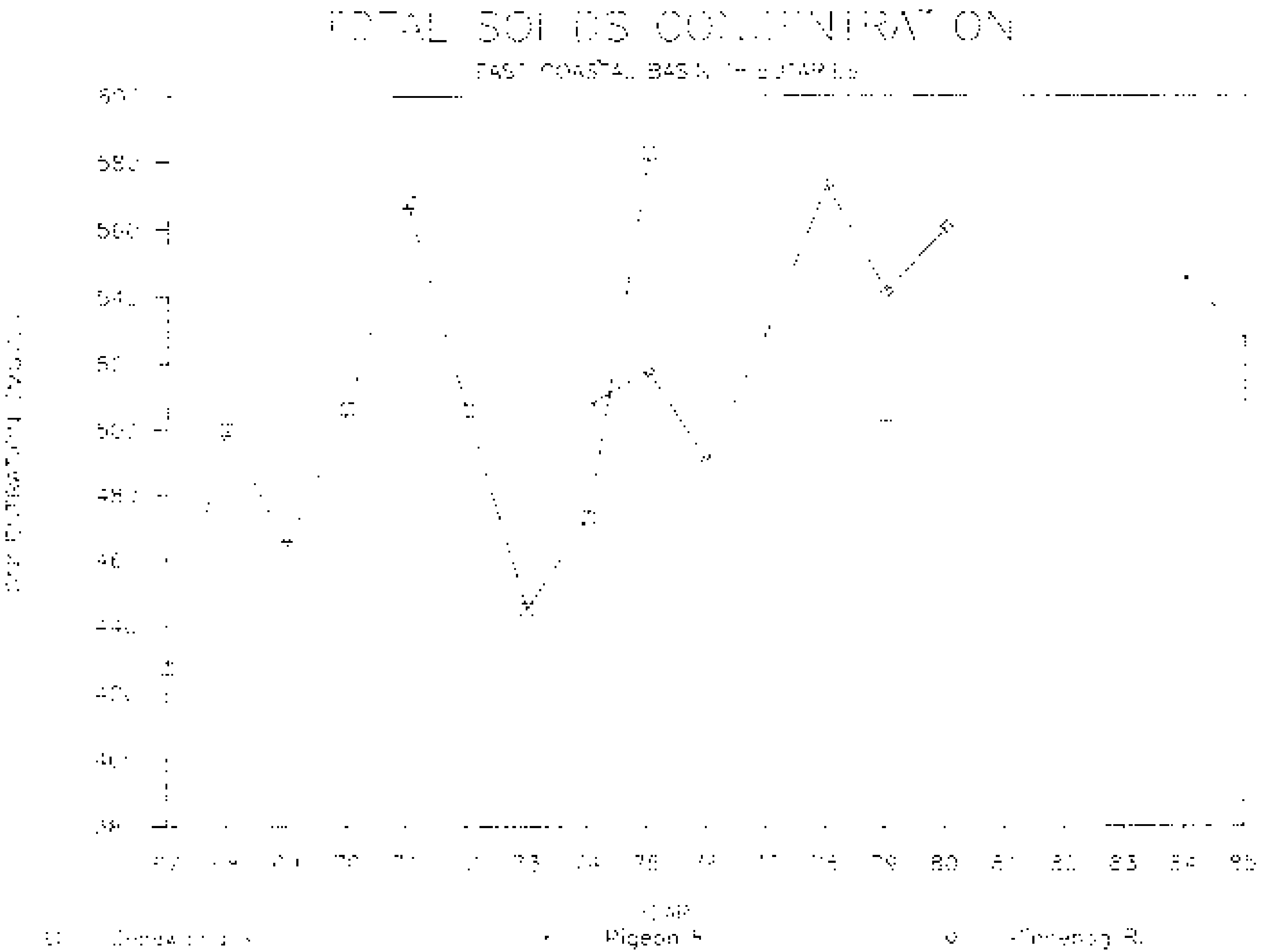


Figure III-20. Annual average total solids concentrations in Saginaw Bay east coastal basin tributaries, 1967-1985.

D. CHEMICAL WATER QUALITY

1. Data Introduction

Little water quality information is available for Saginaw Bay prior to 1974. Several cooperating agencies conducted a comprehensive survey of the chemical, physical and biological parameters in Saginaw Bay during 1974-1975 to establish baseline water quality data. Less intensive monitoring continued from 1976 to 1979, and another series of intensive studies was conducted in 1980.

For many of the major monitoring studies of Saginaw Bay, the bay has been divided into five spatial segments based on observed gradients in water quality (Figure III-12). The following discussions of Saginaw Bay refer to this common segmentation. Segments one through three correspond to the inner bay; segments four and five make up the outer bay.

The chemical water quality data for rivers discussed in this section is from monthly samples collected at each station (Table III-4) by the MDNR. The time period over which samples were collected varied with each station dependent upon data needs and the budget for monitoring activities.

2. Phosphorus

a. Saginaw Bay

Eutrophication is presently a water quality problem in Saginaw Bay. Eutrophic waters are high in organic or nutrient matter that promote biological growth and reduce dissolved oxygen in the hypolimnion (Likens, 1972; Bierman et al., 1984). Accelerated eutrophication can lead to turbidity, taste and odor problems, growth of nuisance blue-green algae, filter clogging in water intakes, aesthetic impairments, and fish kills. Nutrients may accumulate in the inner bay water column due to wind driven current patterns that may inhibit the mixing of inner and outer bay water (Danek & Saylor, 1975). The two nutrients that have a major role in eutrophication are phosphorus and nitrogen. Since phosphorus is usually the limiting nutrient for algal growth in lakes and rivers, it is the nutrient of greatest concern for the control of eutrophication.

Phosphorus analysis usually includes a determination of both total phosphorus (TP) and orthophosphate concentrations. Total phosphorus is a measure of both the organic and inorganic phosphorus. Orthophosphate is considered the most important form of inorganic phosphorus and is a measure of the phosphate available for use by photosynthetic micro and macro organisms in a system (Wetzel, 1983).

Seasonal average values of total phosphorus concentrations measured in the inner bay during fall and spring periods between 1974-1980 reached the highest levels for each season in 1976 and 1978 (Table III-8). Total phosphorus concentrations reached their overall highest level of 47.3 ug/l during the spring of 1978. Concentrations in the inner bay declined

Table III-8. Average Total Phosphorus Concentrations (ug/l) in Water for Inner Saginaw Bay, during Spring and Fall 1974-1980 (Bierman et al., 1984).

Year	Season	
	Spring	Fall
1974	30.5	29.3
1975	35.4	27.3
1976	41.2	40.9
1977	-	-
1978	47.3	34.8
1979	37.3	27.7
1980	26.8	24.8

from 1978 levels to 26.8 ug/l and 24.8 ug/l in the spring and fall of 1980, respectively.

The most recent measurements of total phosphorus concentrations in Saginaw Bay were taken by Environment Canada in 1985 as part of their annual surveillance program for Lake Huron. Samples were collected at seven stations in Saginaw Bay during two cruises, one in spring to coincide with peak runoff (May), and a second during the stratified period (August). The area weighted mean TP concentration for Saginaw Bay was 17.5 ug/l in the spring of 1985 (Neilson et al., 1986). This value was the highest recorded for any area sampled in Lake Huron during the spring sample period. Saginaw Bay also had the highest summer 1985 concentrations of TP, with little reduction in TP relative to the spring sampling (Neilson et al., 1986).

Both the 1980 spring and fall TP concentrations for the inner bay (26.8 ug/l and 24.8 ug/l, respectively) fell within the eutrophic range when using either Carlson (1977) or USEPA (1981) trophic status criteria (Table III-9). The spring 1985 TP concentration of 17.5 ug/l for the entire bay fell into the mesotrophic range using either the Carlson (1977) or the USEPA (1981) criteria.

No orthophosphorus data were available for Saginaw Bay.

b. Rivers

Annual average total phosphorus concentrations at the mouth of Saginaw River have generally declined from 1977 levels near 0.31 mg/l to 0.12 mg/l in 1986 (Figure III-21). Orthophosphorus values declined to an even greater extent from an annual average of about 0.15 mg/l in 1977 to less than 0.04 mg/l in 1986 (Figure III-22). There was little difference in concentrations of total phosphorus or orthophosphorus between the upstream and downstream stations.

Both total phosphorus and orthophosphorus concentrations were substantially higher in the Flint River during the 1970s than in any other tributaries to the Saginaw River that were sampled at that time (Figure III-23 and III-24). Total phosphorus levels in the Flint River declined from an annual average of over 1.14 mg/l in 1977 to less than 0.15 mg/l in 1980 and remained at that general level through 1986. Orthophosphorus concentrations also dropped in the Flint River from over 0.72 mg/l in 1977 to levels around 0.50 mg/l from 1980 through 1986. This decrease in Flint River phosphorus concentrations was reflected in the Saginaw River, which also showed corresponding substantial declines as just discussed.

Among Saginaw Bay coastal tributaries, the highest total phosphorus concentrations were measured in the Pinconning River with values of 2.84 mg/l and 1.36 mg/l in 1973 and 1974, respectively. Corresponding orthophosphorus measurements were 1.88 mg/l and 1.09 mg/l. These measurements were approximately an order of magnitude higher than values reported for any other Saginaw Bay tributary (Figures III-25, III-26, III-27 and III-28). However, Pinconning River phosphorus concentrations

Table III-9. Trophic Condition Classification Criteria for Total Phosphorus (LTI, 1983).

Trophic Condition	Total Phosphorus Concentration (ug/l)	
	Carlson (1977)	USEPA (1981)
Eutrophic	>24	>20
Mesotrophic	12 - 24	10 - 20
Oligotrophic	<12	<10

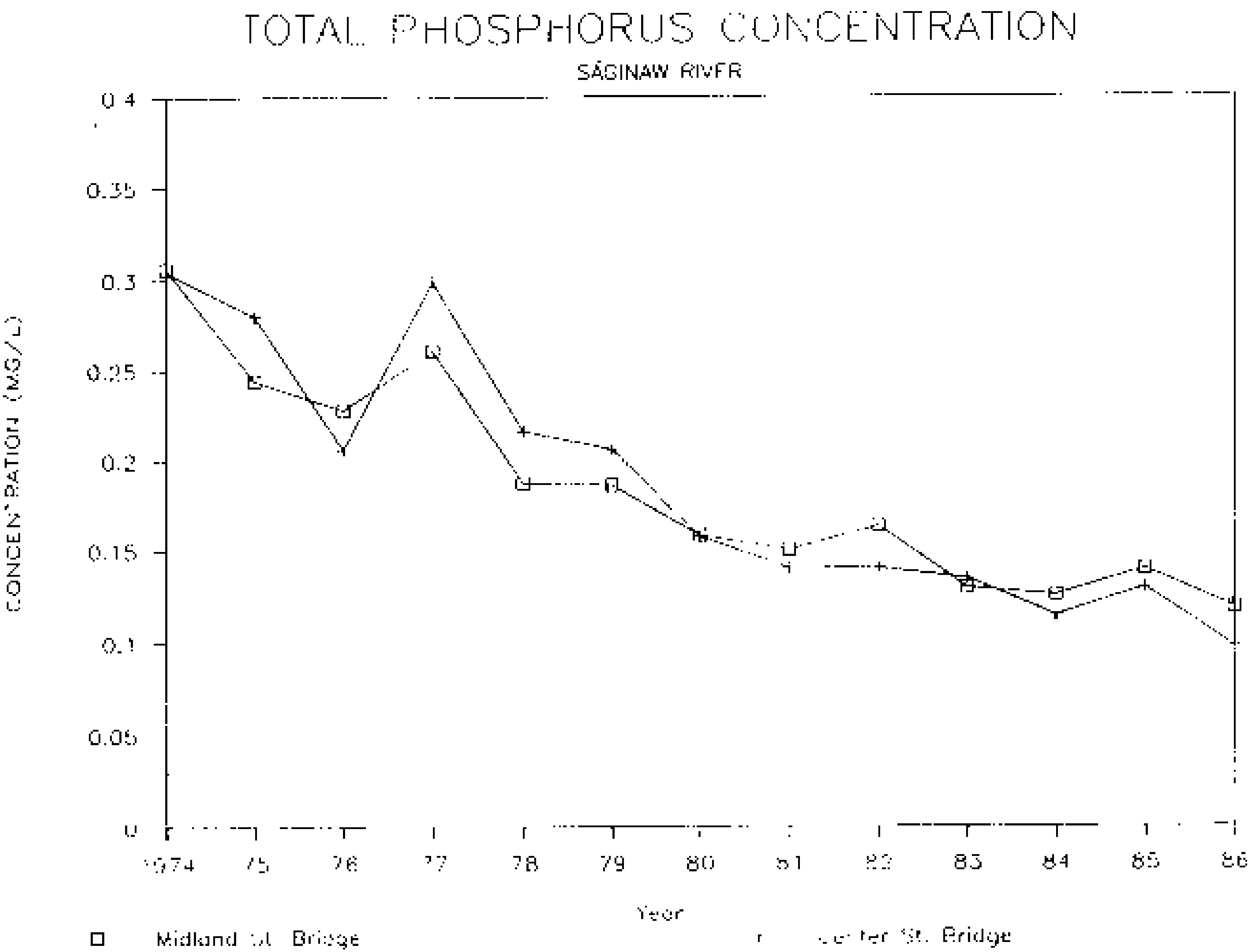


Figure III-21. Annual average total phosphorus concentrations in Saginaw River water samples, 1974-1986.

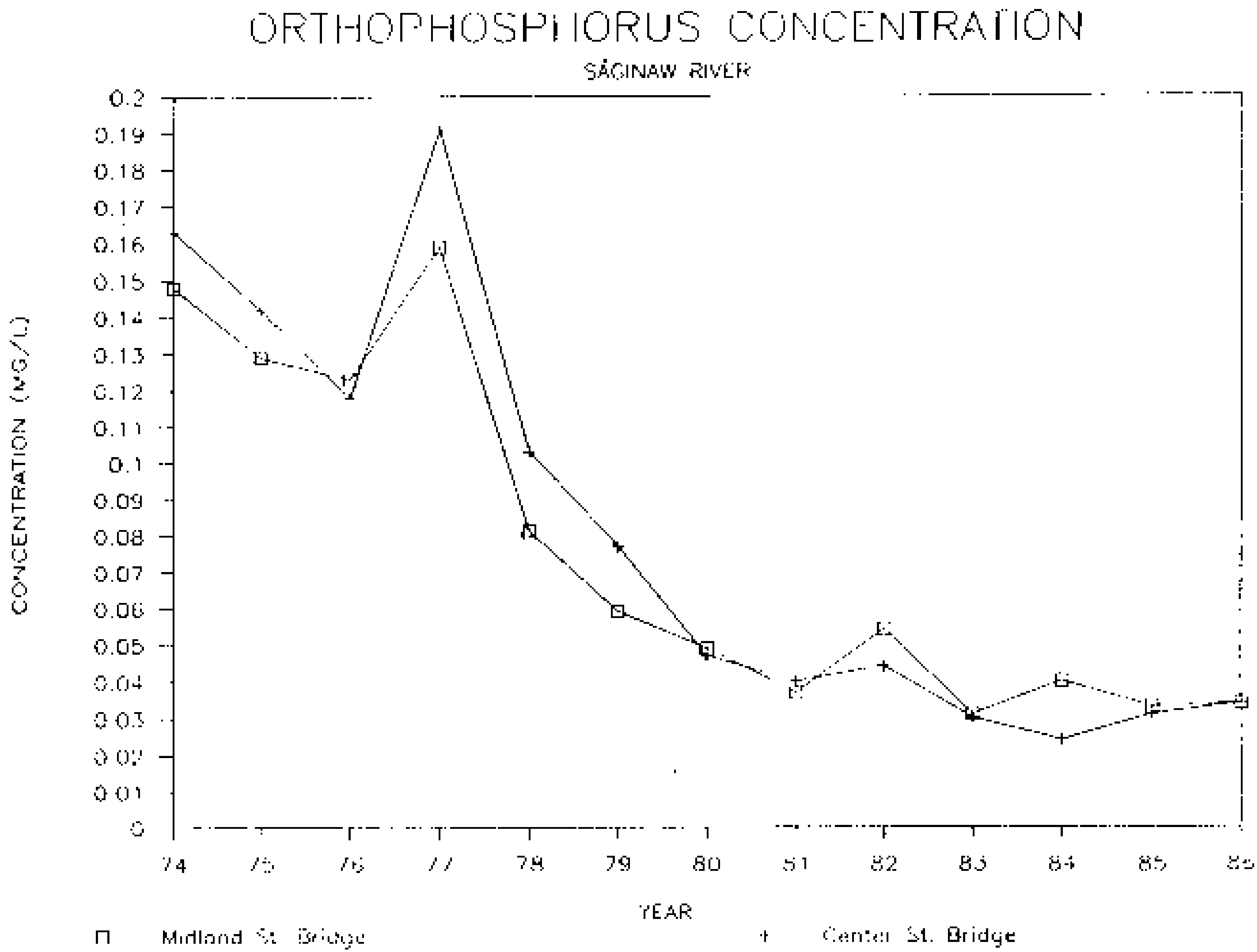


Figure III-22. Annual average orthophosphorus concentrations in Saginaw River water samples, 1974-1986.

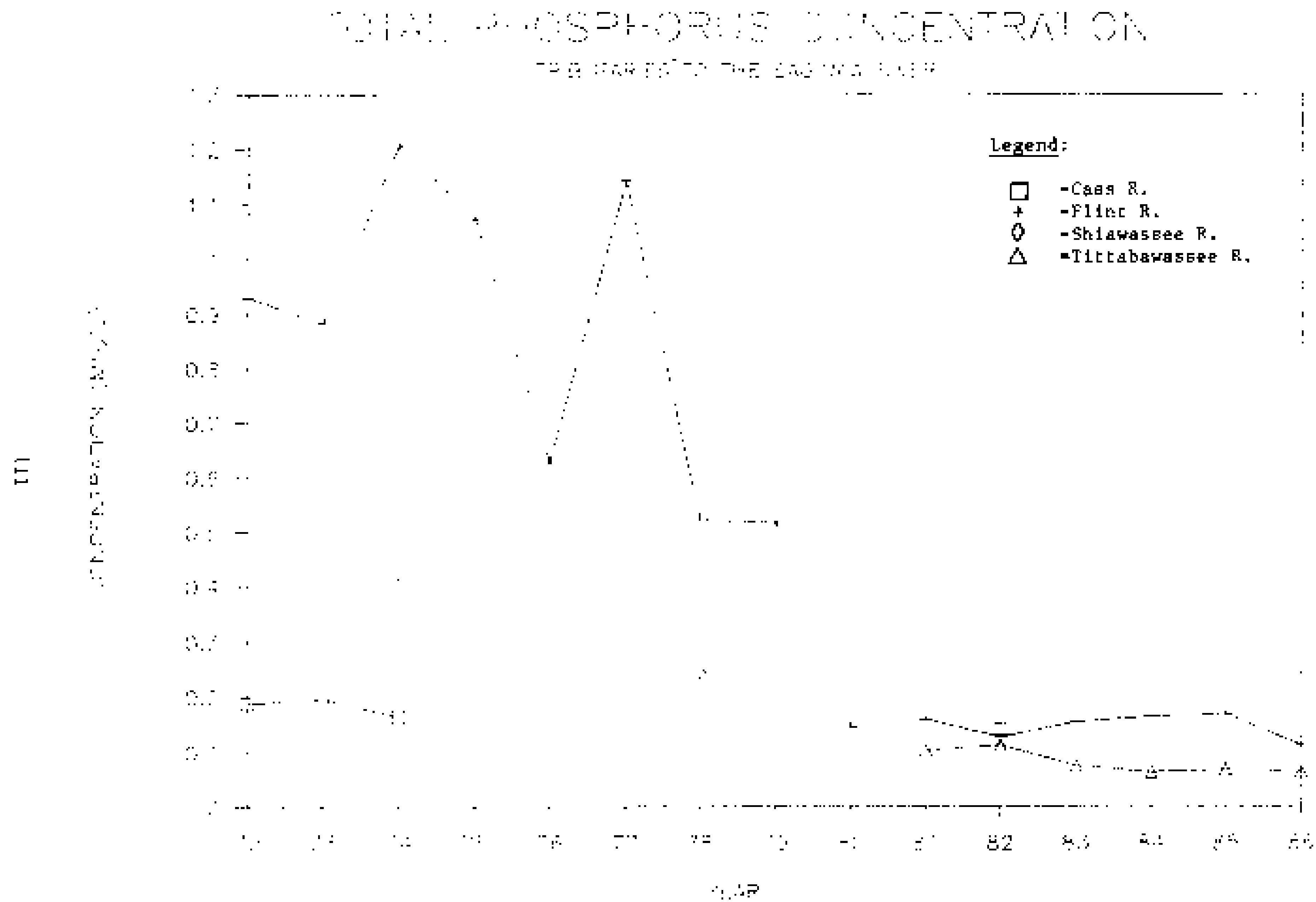


Figure III-23. Annual average total phosphorus concentrations in Saginaw River tributaries, 1972-1986.

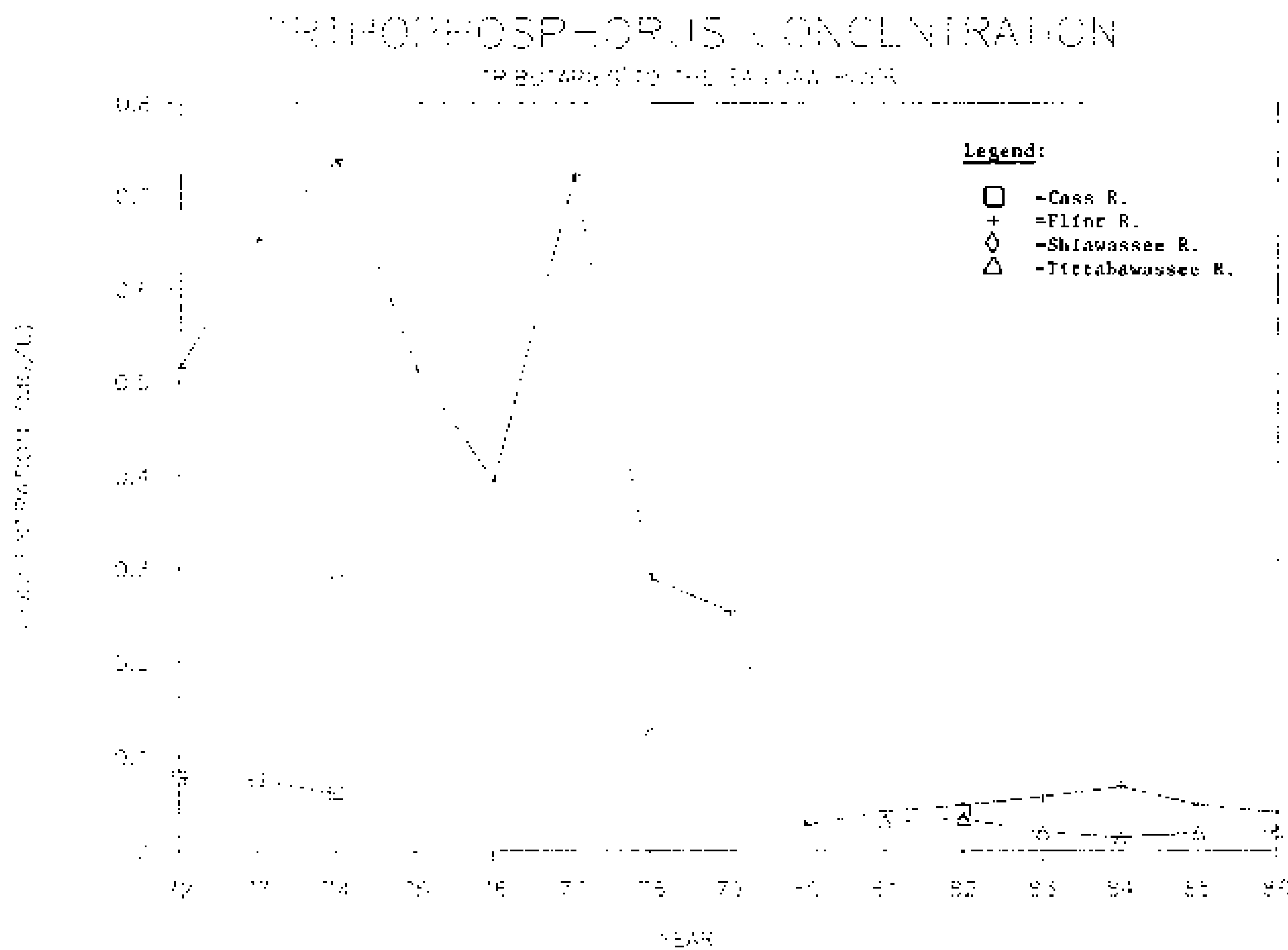


Figure III-24. Annual average orthophosphorus concentrations in Saginaw River tributaries, 1972-1986.

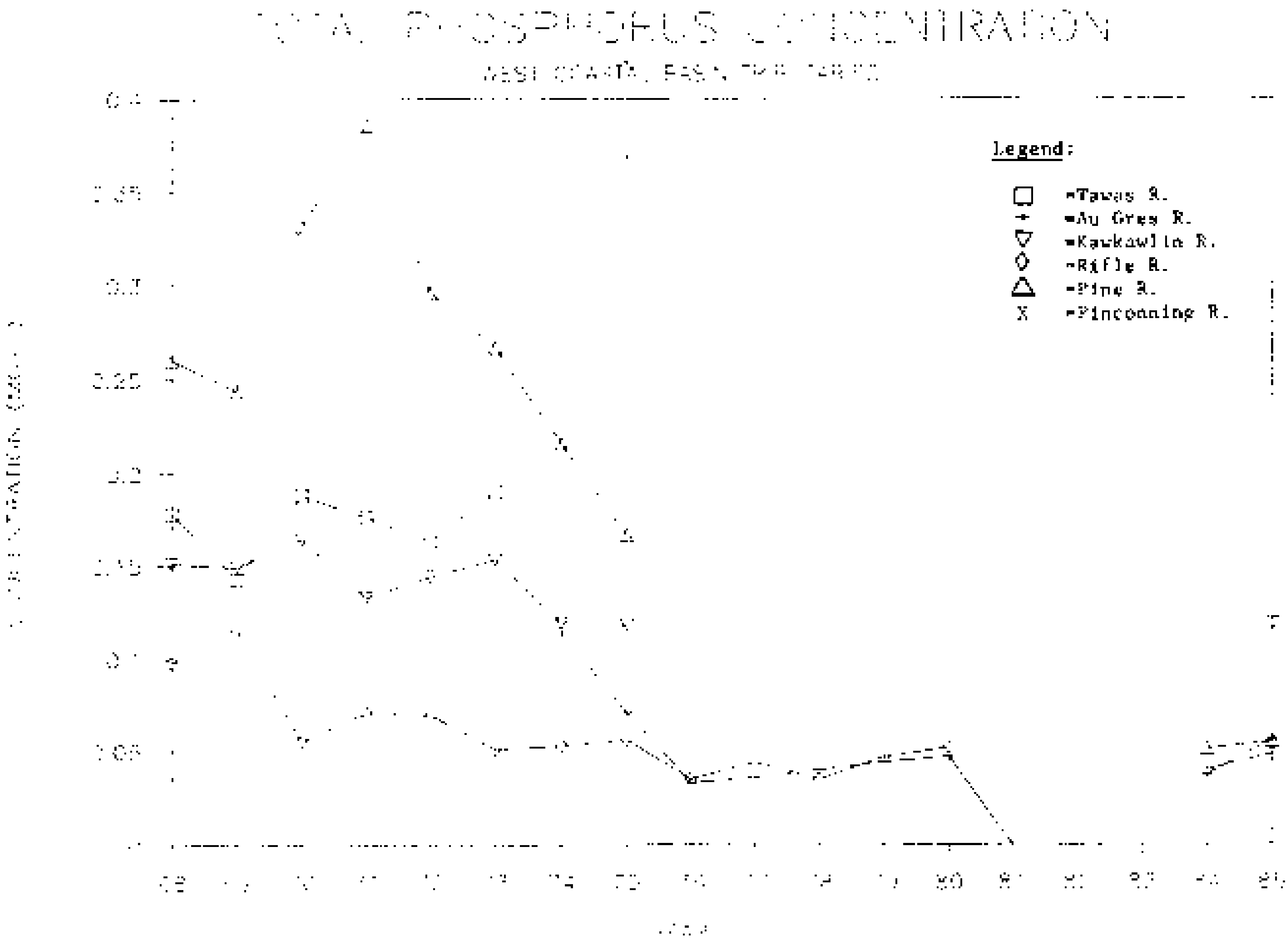


Figure III-25. Annual average total phosphorus concentrations in Saginaw Bay west coastal basin tributaries, 1968-1985.

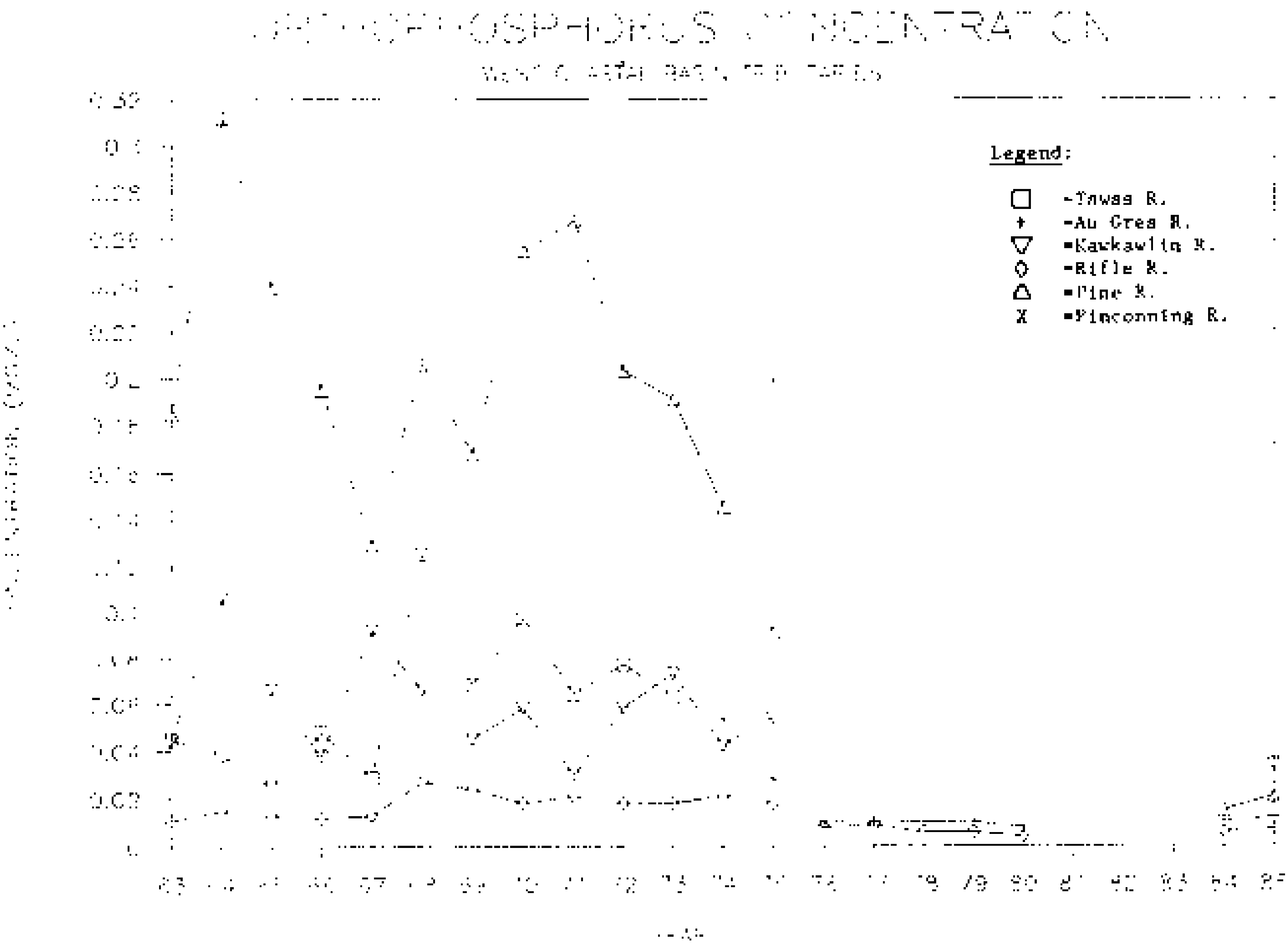


Figure III-26. Annual average orthophosphorus concentrations in Saginaw Bay west coastal basin tributaries, 1963-1985.

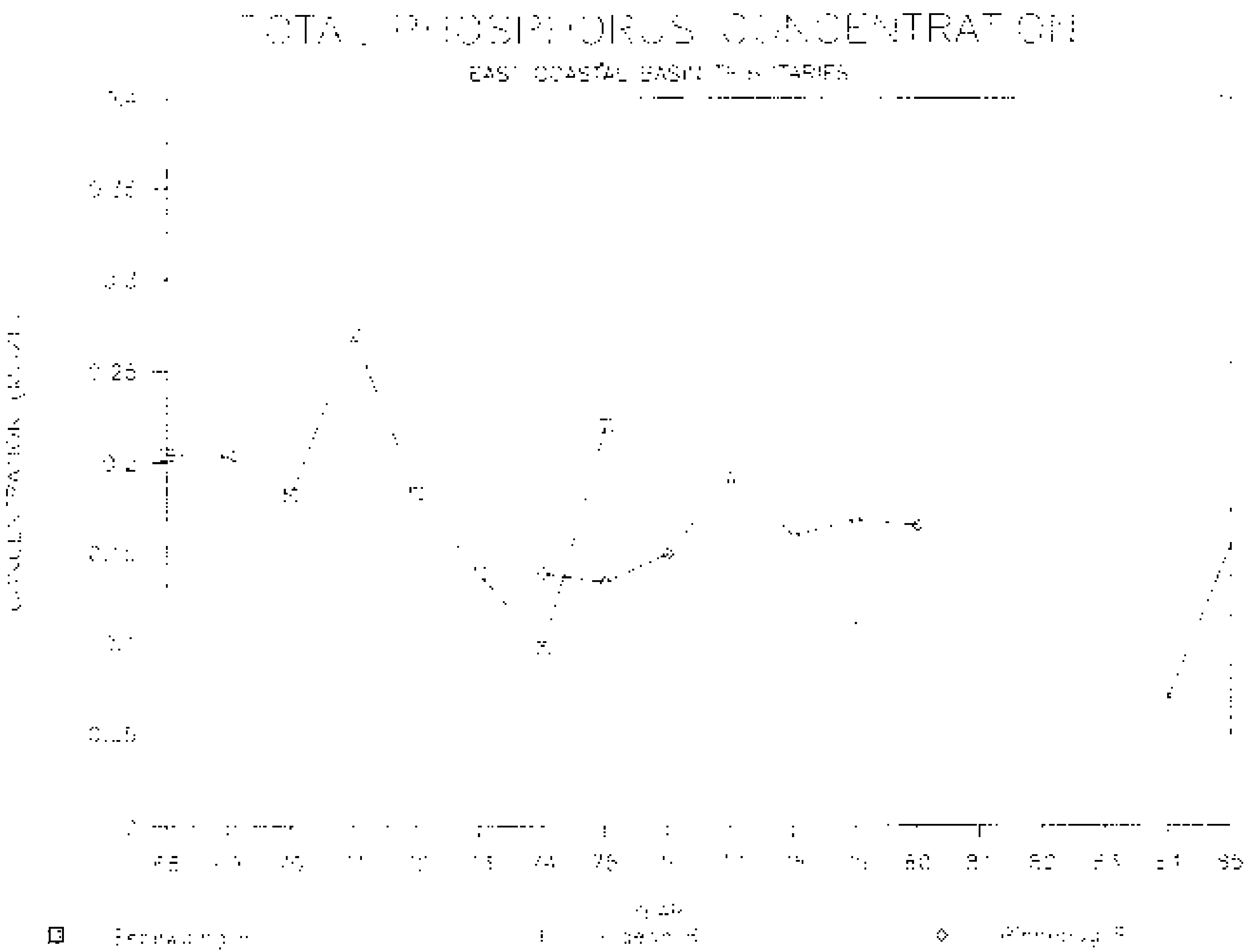


Figure III-27. **Annual average total phosphorus concentrations in Saginaw Bay east coastal basin tributaries, 1968-1985.**

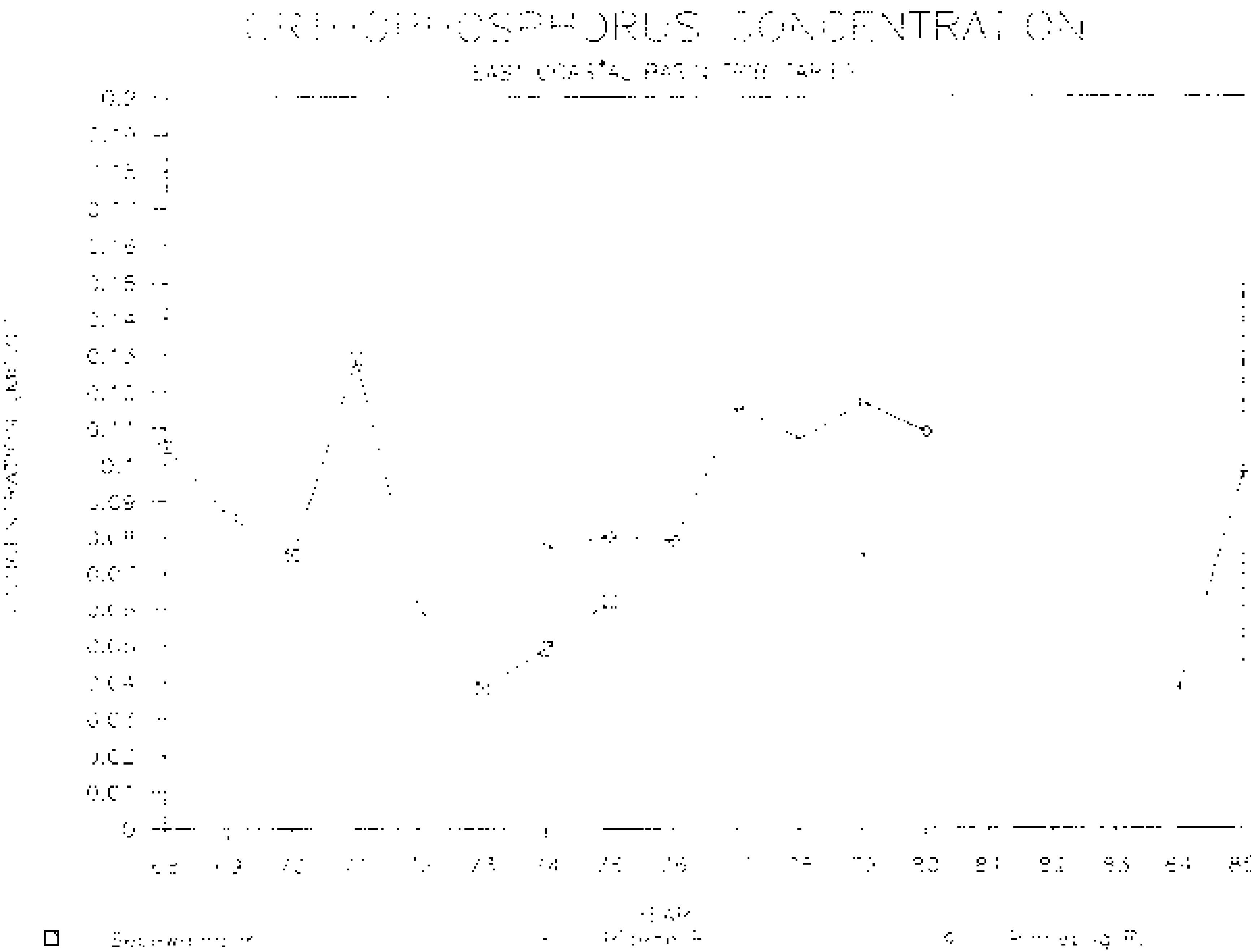


Figure III-26. Annual average orthophosphorus concentrations in Saginaw Bay east coastal basin tributaries, 1968-1985.

were substantially less in 1975, dropping to 0.37 mg/l of phosphorus and 0.20 mg/l of orthophosphorus.

The next highest phosphorus concentrations for a Saginaw Bay tributary were in the Pine River where total phosphorus concentrations were 0.39 mg/l in 1971 but had fallen to 0.06 mg/l in 1985 (Figures III-25 and III-27). Phosphorus values in the other tributaries varied throughout the sample period but appeared to have decreased somewhat since the early 1970s.

3. Nitrogen

a. Saginaw Bay

Nitrogen can also promote eutrophication in the Great Lakes when phosphorus is not limiting, although to a lesser extent than phosphorus when nitrogen is limiting (Likens, 1972; Wetzel, 1983). The nitrate-nitrite (NO_3+NO_2) concentration in Saginaw Bay segment 2 (Figure III-12) had a seasonal (March-April) peak of 1.1 mg/l in 1974 (data are not available for the remaining segments; Figure III-29). A peak NO_3+NO_2 seasonal value of less than 0.500 mg/l was reached in 1980 during May and June. Both nitrogen-fixing and other blue-green algae were almost entirely absent from Saginaw Bay in 1980 (Dolan et al., 1986). This contributed to the bay becoming severely, but not entirely, depleted of NO_3+NO_2 in the 1980 summer/fall period (Figure III-29).

Environment Canada measured NO_3+NO_2 concentrations for the bay during their 1984-1985 cruises. The area weighted mean for nitrates (NO_3) in Saginaw Bay during spring 1984 was 46.5 mg/l (Neilson et al., 1986). The mean NO_3 concentration for spring 1985 was 62.4 mg/l, with concentrations at some stations exceeding 80.0 mg/l. These NO_3 concentrations were among the highest found at any stations sampled in Lake Huron during these cruises.

The ratio of available nitrogen to phosphorus (N:P) in segment 2 of Saginaw Bay increased between 1974 and 1980 (Figure III-30). The N:P ratio increased from 20.2:1 in 1974 to 26.2:1 in 1976 to 28.3:1 in 1980 (Dolan et al., 1986; Limno-Tech, 1983). Although nitrogen levels decreased from 1974 to 1980, the decrease in phosphorus levels was much greater and resulted in an increase in the N:P ratio (Dolan et al., 1986). When the N:P ratio goes above 29:1, conditions are no longer favorable for blue-green algae (Smith, 1983). The N:P ratio of 28.3:1 in 1980 for Saginaw Bay may account for the decreases in blue-green algae which occurred between 1974 and 1980 (Dolan et al., 1986). More recent N:P ratios are not available.

b. Rivers

Annual average nitrate-nitrite concentrations in the Saginaw River during 1974-1986 ranged from a low of 0.95 mg/l in 1976 to a high of 1.97 mg/l in 1980 (Figure III-31). Though concentrations fluctuated throughout the period, the highest values occurred in the 1980s. There

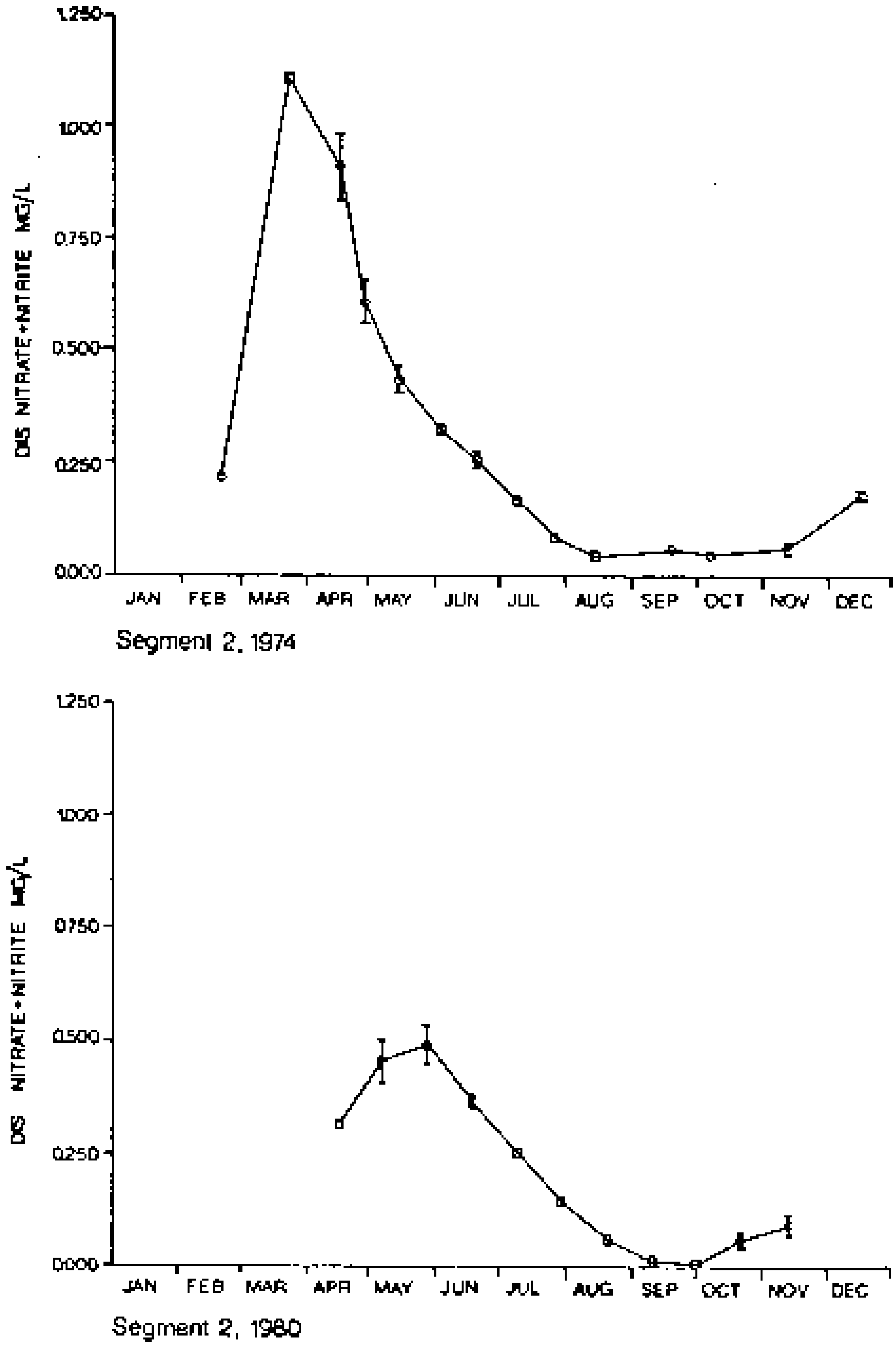


Figure III-29. Nitrate-nitrite concentrations (mg/l) in Saginaw Bay, 1974 and 1980 (Dolan, et al., 1986).

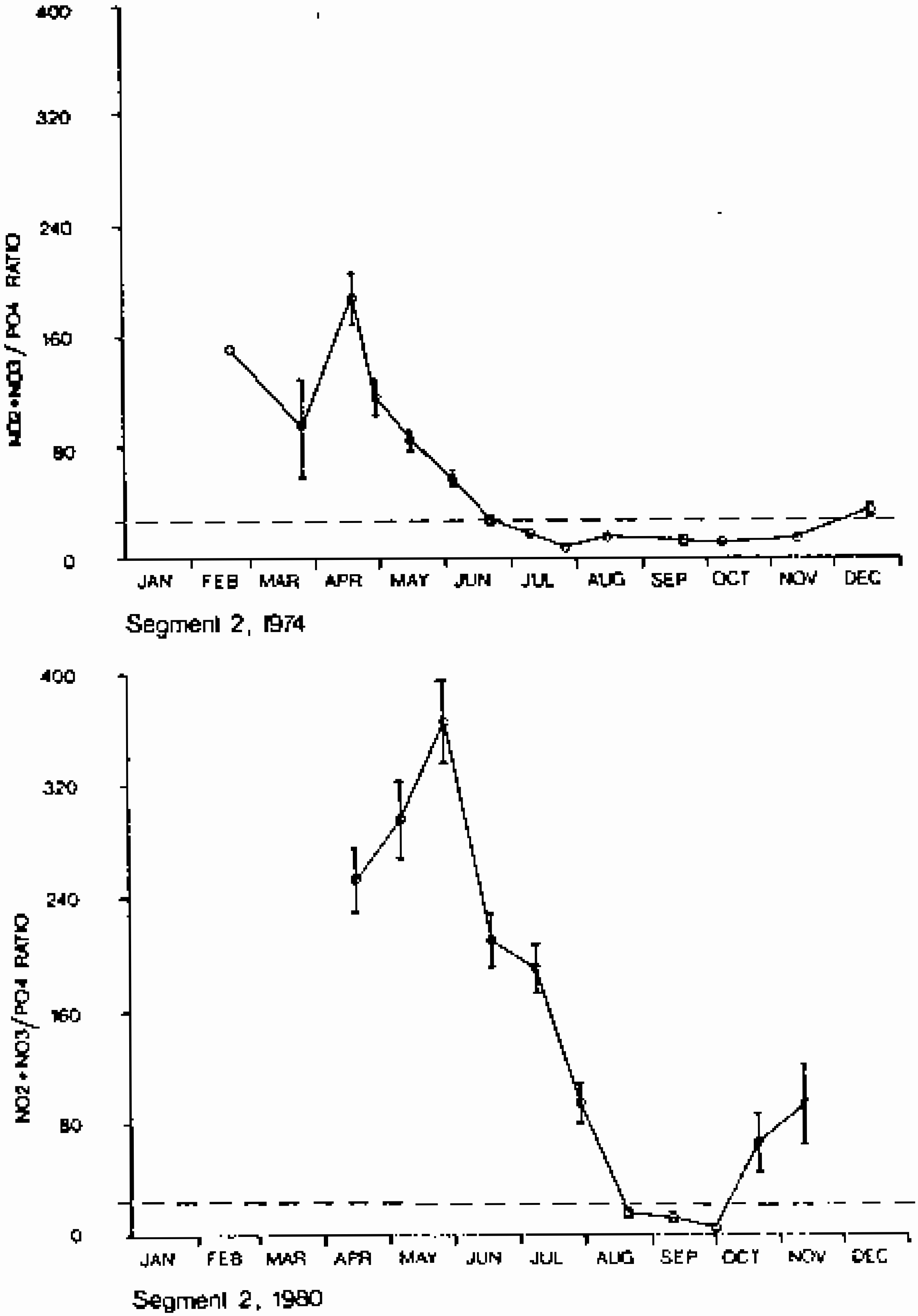


Figure III-30. Nitrogen/phosphorus ratios in Saginaw Bay, 1974 and 1980 (Dolan, et al., 1986).

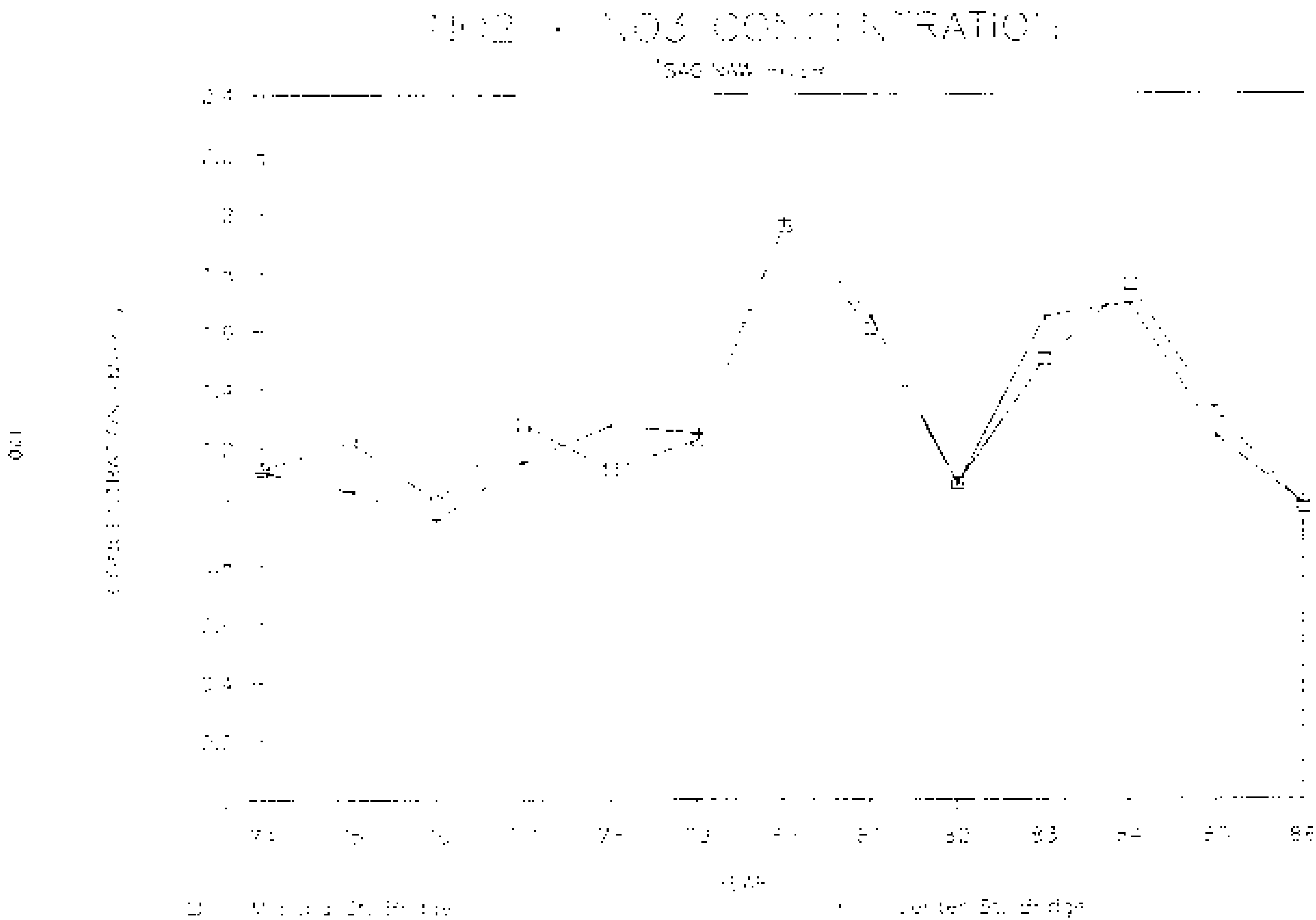


Figure III-31. Annual average nitrate-nitrite concentrations in Saginaw River water samples, 1974-1986.

was little difference in concentrations between the upstream and downstream sampling stations.

Nitrate-nitrite concentrations were highest in the Flint River for Saginaw River tributaries and increased from a low of 0.64 mg/l in 1978 up to 2.27 mg/l in 1984 (Figure III-32). Concentrations had decreased to 1.42 mg/l in 1986 but remained higher than during the late 1970s.

Limited data is available for nitrate-nitrite concentrations in coastal tributaries to Saginaw Bay during 1973-1989 and no trends could be discerned. However, the Sebewaing and Pigeon rivers appeared to have the highest concentrations, reaching levels of 7.23 mg/l and 5.22 mg/l, respectively (Tables III-33 and III-34). These levels were substantially higher than those measured in the Saginaw River or its tributaries.

4. Silica

Silica concentrations can also be used as an indicator of the trophic state of Saginaw Bay. Diatoms, which use silica as a nutrient, could not compete with blue-green algae during much of 1974 when blue-green algae were numerous, and consequently did not use much of the available silica (Dolan et al, 1984). In response to reductions in phosphorus loading to the bay, the blue-green population decreased substantially in 1980, and fall diatoms increased and depleted the reactive silica concentrations in Saginaw Bay (Figure III-35).

5. Chloride

The chloride ion, which is highly soluble, is commonly present in most natural waters. It is involved in very few natural removal reactions and is thus considered to be a conservative ion. Chloride sources include mineral solutions, agriculatural runoff, groundwater, and industrial and municipal discharges. Although chloride levels as low as 100 mg/l may give water a salty taste, the usual taste threshold is 400 mg/l.

Annual average chloride concentrations in the Saginaw River have decreased from 229.7 mg/l in 1963 to 53.1 mg/l in 1986 (Figure III-36). Chloride concentrations in Saginaw River tributaries were greatest in the Tittabawassee River but decreased from 141.1 mg/l in 1982 to 68.6 mg/l in 1986 (Figure III-37). Chloride concentrations in coastal basin tributaries appear to be somewhat less than in the past with 1986 values ranging between 63.6 mg/l and 17.3 mg/l (Figures III-38 and III-39).

6. Metals

a. Introduction

The following discussion on metal concentrations in rivers is based on relatively few samples. In many cases, metals were only sampled once per year.

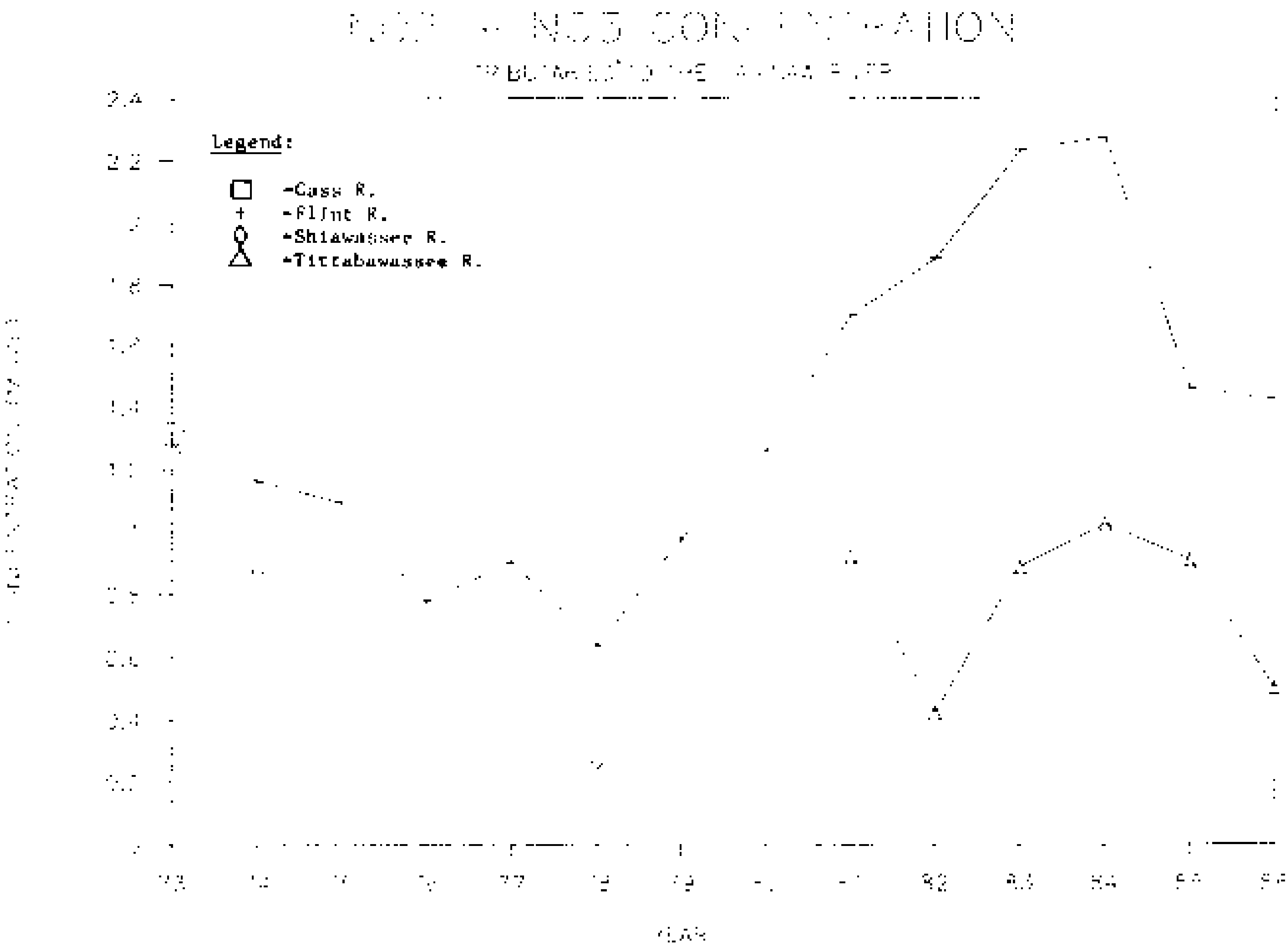


Figure III-32. Annual average nitrate-nitrite concentrations in Saginaw River tributaries, 1973-1986.

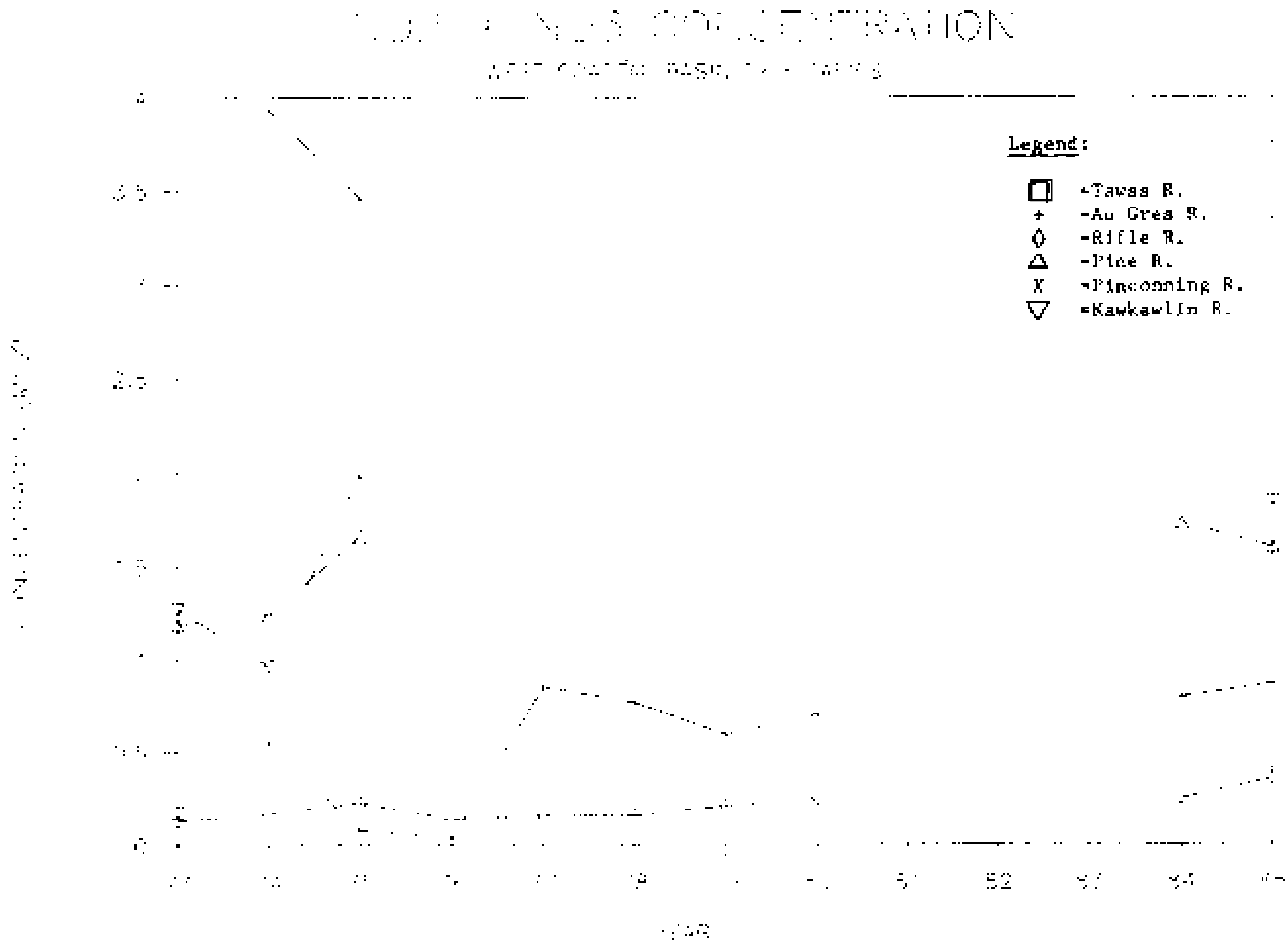


Figure III-55. Annual average nitrate-nitrite concentrations in Saginaw Bay west coastal basin tributaries, 1973-1985.

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Figure III-34. Annual average nitrate-nitrite concentrations in Saginaw Bay east coastal basin tributaries, 1973-1985.

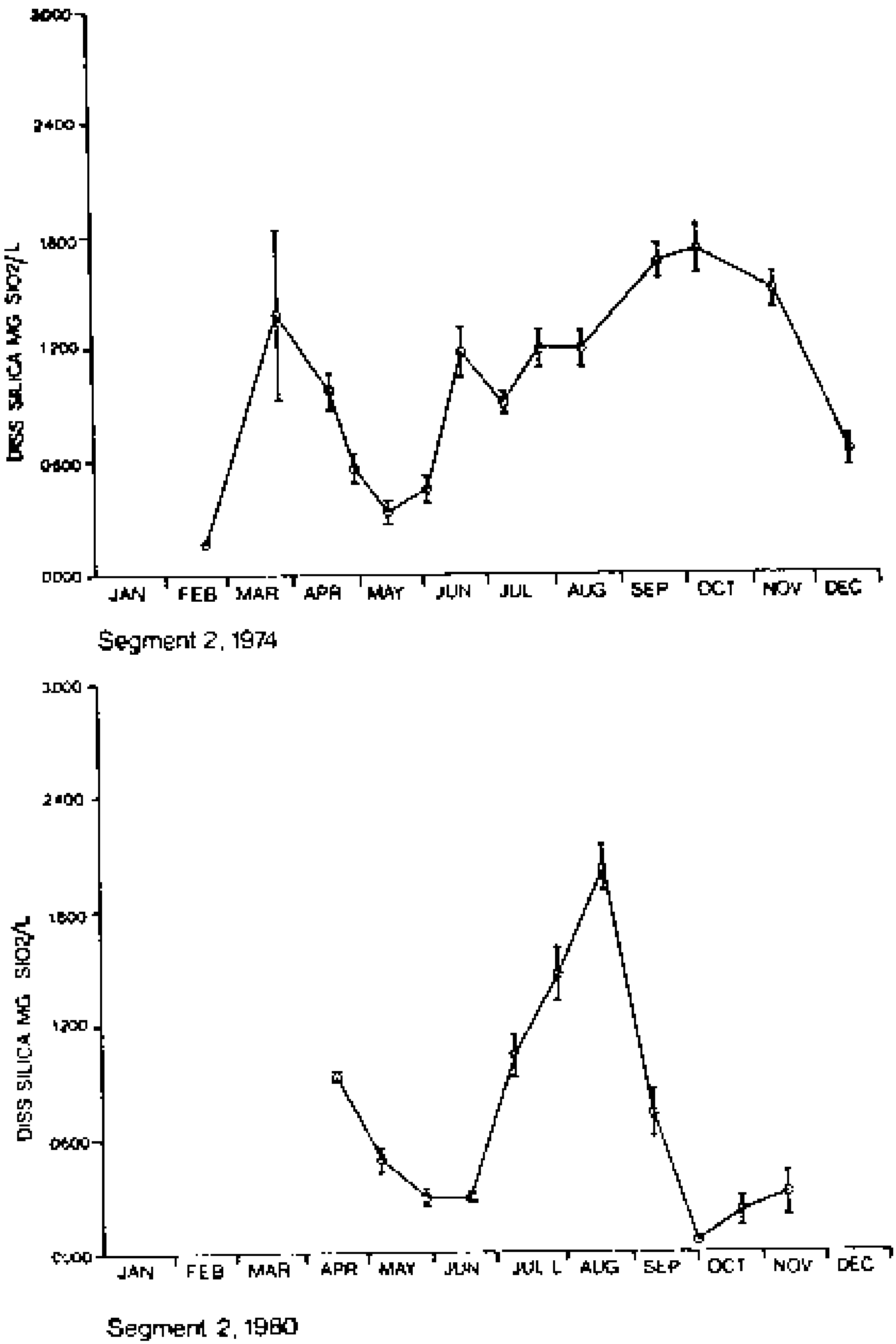

Figure III-35. Dissolved silica concentrations (mg/l) in Saginaw Bay, 1974 and 1980 (Dolan, et al., 1986).

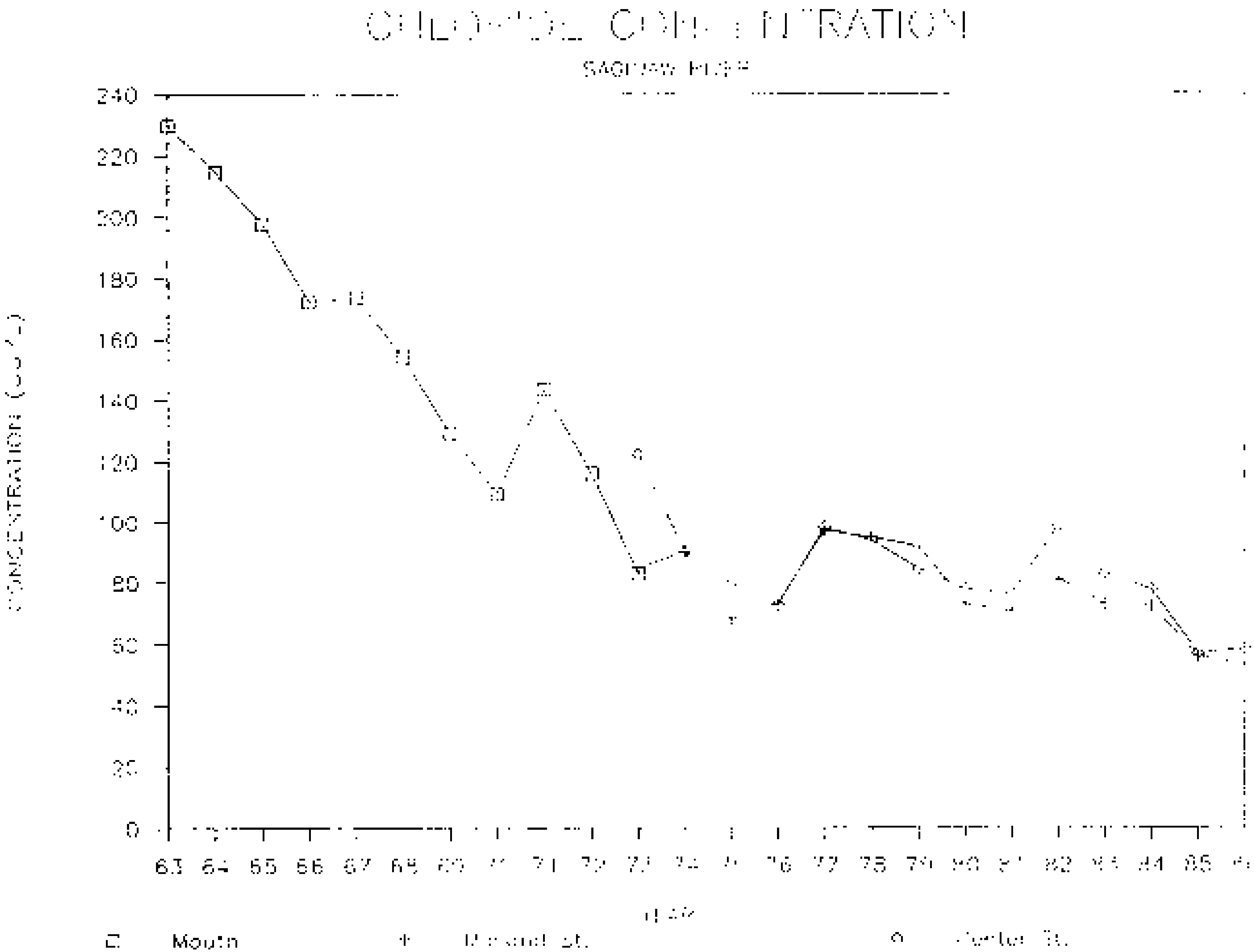

Figure III-36. Annual average chloride concentrations in Saginaw River water samples, 1963–1986.

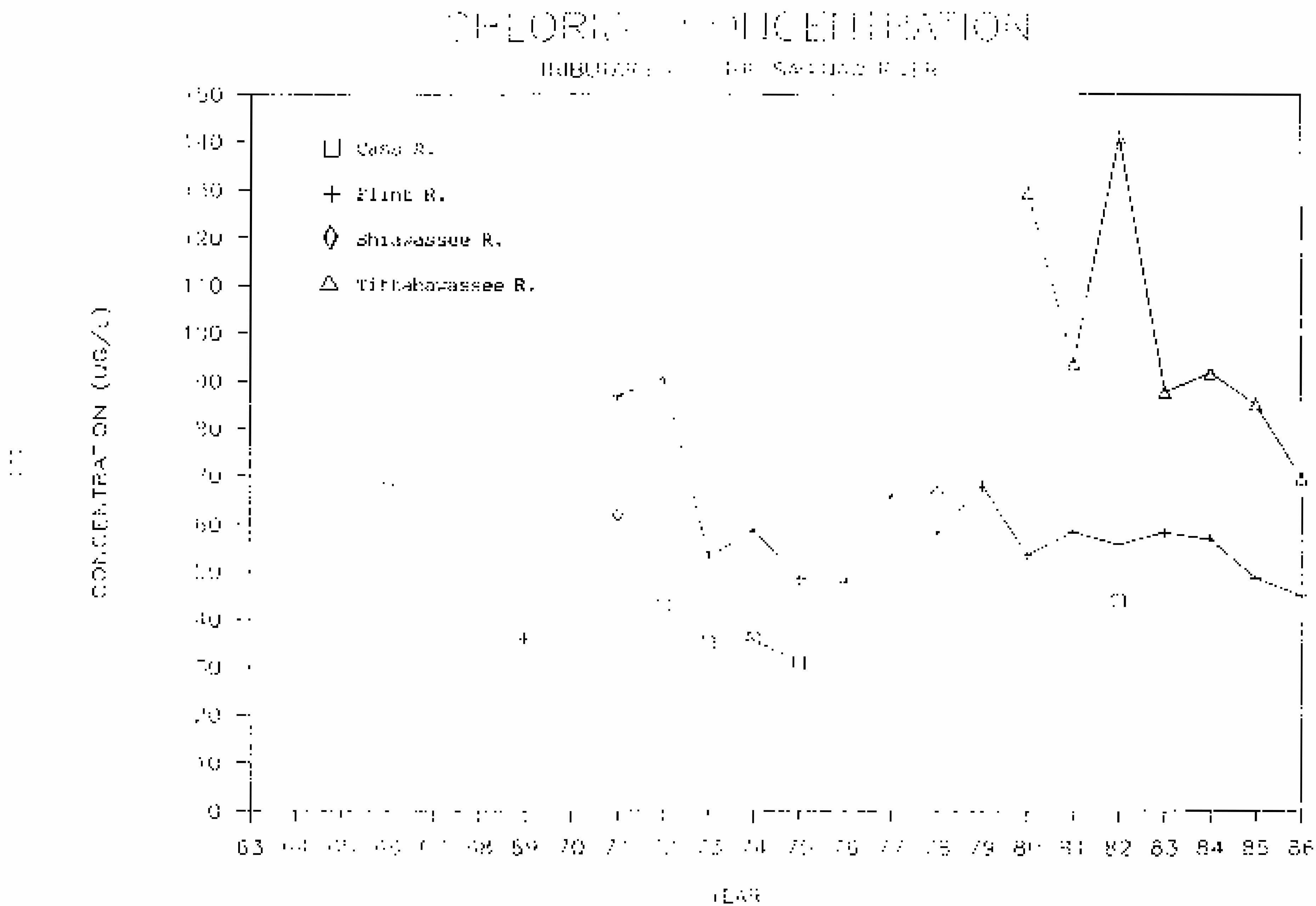

Figure III-37. Annual average chloride concentrations in Saginaw River tributaries, 1963-1986.

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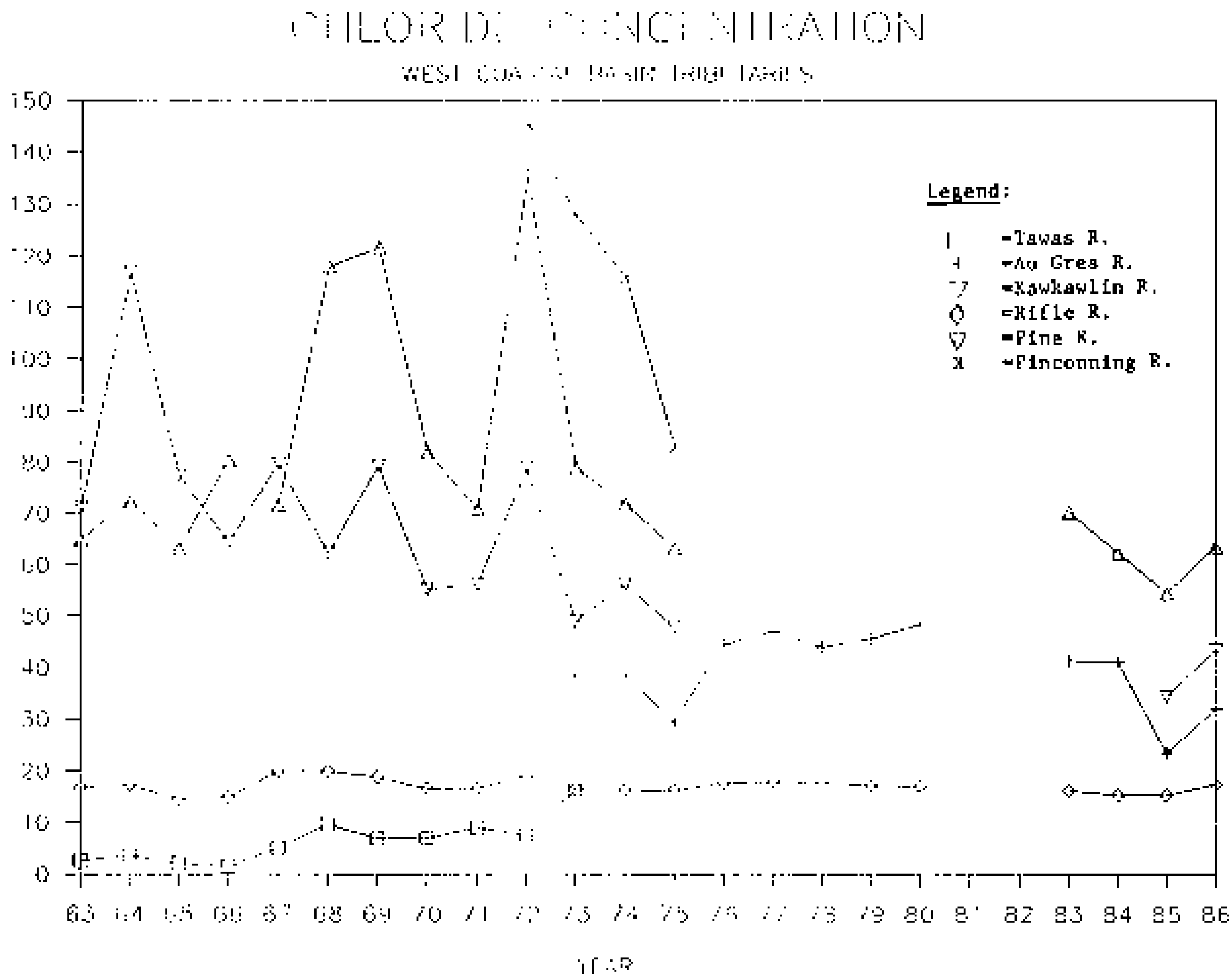

Figure III-38. Annual average chloride concentrations in Saginaw Bay west coastal basin tributaries, 1963-1986.

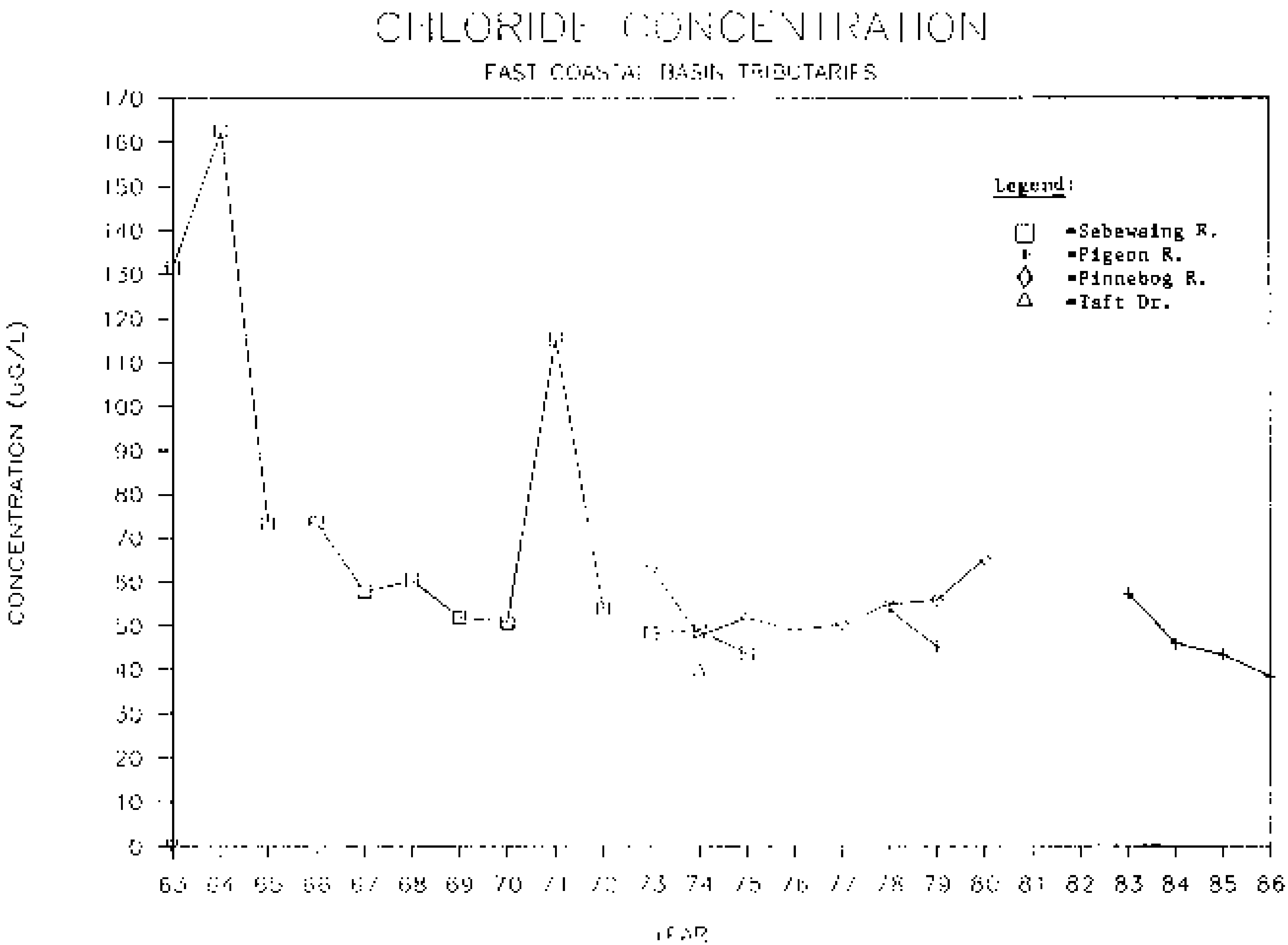

Figure III-39. Annual average chloride concentrations in Saginaw Bay east coastal basin tributaries, 1963-1986.

Metal concentrations were compared to Michigan's water quality standards for metals, which are defined by Rule 57(2) guideline levels implemented in January 1985. These levels are applicable under state law only at the end of a point source mixing zone; however, given that no ambient water criteria have been defined for metals by Michigan, Rule 57(2) guideline levels have been designated as ambient water criteria for the purposes of this Remedial Action Plan. In many cases, the Rule 57(2) guideline levels for metals vary with water hardness and are not the same for each river (Table III-10).

Generally, Rule 57(2) guideline levels are more stringent than U.S. EPA criterion (Table III-2). International Joint Commission objectives are not applicable to Great Lakes tributaries, except for the connecting channels, and therefore are not discussed with respect to river concentrations.

b. Saginaw Bay

Few studies have been conducted on metals in the Saginaw Bay water column. Data on the metal concentrations in Saginaw Bay before 1976 are limited but indicate that cadmium, copper, lead and zinc were present in the bay in measurable quantities (Bratzel et al., 1977).

Rygwelski et al., (1984) found that from 1976 to 1979 concentrations of Cd, Cu, Pb and Zn (both dissolved and total) decreased from the inner to the outer bay. A relationship was noted between the size of suspended particles in Saginaw Bay and the concentration of the Cu, Pb and Zn on particles (Table III-11). In 1978, particles in the 10-74 um size range contained the majority of the metal mass in the water, with mean concentrations of 410 ug/l, 240 ug/l and 390 ug/l for Cu, Pb and Zn, respectively.

c. Tributaries

i. Arsenic

Concentrations of arsenic (Ar) were at or below 10.0 ug/l at all tributary sites sampled during 1976-1986 and did not exceed the Michigan Rule 57(2) guideline level for arsenic concentrations in water of 150.0 ug/l.

Arsenic concentrations in the Saginaw River ranged from 2.0 ug/l to 8.0 ug/l. Tittabawassee River Ar samples ranged from not detectable up to 3.0 ug/l. Only one sample was collected in the Cass and Shiawassee rivers with Ar values of not detectable (1971) and 4.0 ug/l (1978), respectively. The Flint River had the highest Ar concentrations of all rivers sampled with values between 3.0 ug/l and 10.0 ug/l.

Concentrations of Ar were also measured in the Au Gres, Rifle, Pine, Kawkawlin, Pigeon and Pinnebog rivers. Values varied from not detectable up to 5.0 ug/l.

Table III-10. Water Hardness Values and Associated Michigan Rule 57(2) Metal Guideline Levels for Selected Saginaw Bay Tributaries.

Tributary	Hardness	Metals					
		Cadmium	Chromium	Copper	Lead	Nickel	Zinc
Saginaw River	249	0.77	111.1	48.7	12.4	180.6	212.7
Cass River	312	0.93	134.0	60.2	17.6	222.2	257.6
Flint River	200	0.64	92.6	39.7	8.9	181.2	176.5
Shiawassee River	278	0.84	121.8	54.1	14.7	199.8	233.6
Tittabawassee River	250	0.77	111.5	48.9	12.5	147.6	213.4
Tawas River	152	0.51	73.8	30.6	5.9	114.7	139.8
Au Gres River	402	1.15	165.3	76.5	25.9	280.5	319.6
Rifle River	214	0.68	98.0	42.3	9.9	157.1	187.0
Pine River	258	0.79	114.4	50.4	13.1	186.6	219.2
Pinconning River	341	1.00	144.2	65.9	20.1	241.1	277.9
Kawkawlin River	234	0.73	105.5	46.0	11.3	170.5	201.7
Sebewaing River	325	0.96	138.6	62.6	18.7	230.7	266.7
Pigeon River	339	1.00	143.5	65.1	20.0	239.8	276.5
Pinnebog River	371	1.07	154.7	70.9	22.9	260.6	298.5
Taft Drive	352	1.03	148.1	67.5	21.1	248.3	385.5

Table III-11. Concentrations (ug/l) of Metals on Suspended Particulate Size Fractions, Saginaw Bay, 1978 (Rygwelski, et al., 1984).

	Particulate Size (um)		
Metal	10-74	74-210	210-1000
Copper			
N	95	101	97
Mean	410	70	95
Median	300	22	31
Minimum	3.7	4.8	3.5
Maximum	1300	610	430
Lead			
N	100	101	85
Mean	240	46	100
Median	50	32	53
Minimum	23.0	20.0	4.6
Maximum	3300	210	540
Zinc			
N	98	101	102
Mean	390	170	220
Median	330	130	160
Minimum	6.3	95	20
Maximum	870	430	650

ii. Cadmium

Cadmium (Cd) concentrations did not exceed Rule 57(2) guideline levels in any Saginaw Bay basin river sampled during 1981-1986 except in the Rifle and Pine rivers. The Rifle River Cd concentrations exceeded the Rule 57(2) guideline of 0.68 ug/l in 1983 (0.70 ug/l), 1985 (1.20 ug/l), and 1986 (0.95 ug/l). The Pine River Rule 57(2) level for Cd is 0.79 ug/l and was exceeded in 1986 (0.95 ug/l).

Cadmium was not detected in the Saginaw, Flint or Tittabawassee rivers during 1981-1983 at detection limits of 1.0 ug/l and 2.0 ug/l. From 1984 to 1986, cadmium concentrations in these rivers ranged from non-detect at 0.20 ug/l to 0.40 ug/l in both the Saginaw and Flint rivers, and 0.60 ug/l in the Tittabawassee River. No samples were collected from the Cass or Shiawassee rivers during this period.

Cadmium was also detected in the remaining three rivers sampled during 1983-1986, which included the Au Gres, Kawkawlin and Pigeon rivers. Concentration ranges for cadmium were 0.20-0.70 ug/l in both the Kawkawlin and Pigeon rivers, and 0.30-0.60 ug/l in the Au Gres River.

iii. Chromium

Chromium concentrations in all Saginaw Bay basin rivers sampled during 1976-1986 were substantially below Rule 57(2) guideline levels. The highest chromium level was 32.0 ug/l in the Flint River in 1976. This level declined to 16.0 ug/l in 1977, 11.0 ug/l in 1978, to non-detectable levels in 1984, 1985 and 1986. Saginaw River chromium concentrations showed a similar decrease falling from 13.0 ug/l at Midland Street in 1976 to non-detectable levels in 1986. Chromium concentrations in other basin rivers ranged from 12.0 ug/l to non-detectable levels, with a generally decreasing trend from 1976 to 1986.

iv. Copper

Copper concentrations in all Saginaw Bay basin rivers sampled during 1976-1986 were well below Rule 57(2) guideline levels. The highest copper level was 28.0 ug/l in the Flint River in 1976. This level declined to 19.0 ug/l in 1977, 16.5 ug/l in 1978 and continued to drop to 3.6 ug/l in 1986. Copper concentrations in all rivers sampled in 1986 ranged from 2.2 ug/l to 4.4 ug/l. These levels were lower or similar to concentrations measured in these rivers in previous years.

v. Iron

There is no Rule 57(2) guideline levels for iron in water. Annual mean iron concentrations in the Saginaw River averaged about 1,100 ug/l and fluctuated between 300 ug/l and 2,640 ug/l during 1974-1986, with no apparent trend. Only one iron sample each was collected from the Cass and Shiawassee rivers with values of 700 ug/l (1971) and 1,600 ug/l (1978), respectively. No trends were apparent in either the Flint or Tittabawassee. Annual average iron concentrations in the Flint River ranged from 270 ug/l to 5,200 ug/l and averaged 1,530 ug/l. Tittabawassee River concentrations fluctuated between 247 ug/l and 1,400 ug/l and averaged 714 ug/l.

Average concentrations of iron in Saginaw Bay coastal tributaries during 1963-1986 were as follows: Tawas 313 ug/l, Au Gres 611 ug/l, Rifle 602 ug/l, Pine 546 ug/l, Pinconning 370 ug/l, Kawkawlin 484 ug/l, Sebewaing 795 ug/l, Pigeon 331 ug/l, Pinnebog 335 ug/l, and Taft 541 ug/l. Again, no trends were apparent though there were often large fluctuations in annual average concentrations from year to year.

vi. Lead

Lead concentrations did not exceed Rule 57(2) guideline levels for any Saginaw Bay basin river sampled during 1981-1986 except the Flint River. The Rule 57(2) guideline level for lead in the Flint River is 8.9 ug/l. This value was exceeded in 1981 (13.0 ug/l), 1982 (20.0 ug/l) and 1984 (12.0 ug/l). Lead concentrations in the Flint River were below guideline levels in 1985 (6.2 ug/l) and 1986 (6.0 ug/l). Lead concentrations in all other rivers sampled ranged between non-detectable levels and 11.0 ug/l, all below guideline levels.

Concentrations of lead in basic rivers during 1976-1980 were often higher than later values and Rule 57(2) guidelines were exceeded in several rivers including the Saginaw, Flint, Au Gres, Rifle and Kawkawlin. The highest concentration was reached in the Flint River where a concentration of 110.0 ug/l was measured in 1979. Saginaw River values reached a high of 29.0 ug/l in 1977. The Au Gres, Rifle and Kawkawlin rivers also reached their period highs in 1977 of 27.0 ug/l, 16.0 ug/l and 19.0 ug/l, respectively.

vii. Mercury

The Rule 57(2) guideline levels for mercury in water is 0.0006 ug/l. This is below the level of detection used to analyze ambient water samples in the Saginaw Bay basin. Mercury was not detected from any tributaries sampled during 1978-1986 with laboratory detection limits ranging from 0.2 ug/l to 1.0 ug/l during 1978-1980, and a detection limit of 0.5 ug/l between 1981 and 1986. Mercury was detected occasionally in several rivers from 1973 to 1977, at levels ranging from 0.2 ug/l to 0.7 ug/l, including the Saginaw, Flint, Au Gres, Rifle, Pine, Pinconning, Kawkawlin, Sebewaing and Pinnebog rivers. However, these observations may be artifacts of older laboratory techniques and not actual mercury concentrations given their closeness to detection limits.

viii. Nickel

Nickel concentrations in all Saginaw Bay basin rivers sampled during 1976-1986 were far below Rule 57(2) guideline levels. In 1986, nickel was detected in only three rivers - the Saginaw (4.0 ug/l), Au Gres (5.0 ug/l) and Rifle (7.0 ug/l). Nickel was not detected (at 4.05 ug/l) in 1986 in the Flint, Tittabawassee, Pine, Kawkawlin or Pigeon rivers.

Lead concentrations were substantially higher from 1976 to 1979 for several streams. The highest nickel concentration was again in the Flint River where a level of 86.0 ug/l was reached in 1976. The largest value measured in the Saginaw River was 36.0 ug/l in 1977. All other rivers had high concentrations of less than 30.0 ug/l. Nickel values have remained near or below detection limits since 1980 in all rivers sampled.

ix. Selenium

Selenium was detected only three times in Saginaw Bay basin rivers during 1976-1986 at levels of 2.0 (1978) in the Saginaw River, 1.0 (1984) in the Pigeon River, and 2.0 (1978) in the Pinnebog River. These concentrations are close to the analytical level of detection used at the time and are below the 1985-1986 level of detection of 2.5 ug/l. Therefore, they may be artifacts of older laboratory techniques and not actual concentrations of selenium. In any case, these concentrations are all below the Rule 57(2) guideline level for selenium in water of 13.0 ug/l.

x. Silver

The Rule 57(2) guideline level for silver is 0.15 ug/l, which is below the 0.5 ug/l level of detection used to analyze ambient water samples in the Saginaw Bay basin in 1985-1986. Silver was not detected in any Saginaw Bay basin rivers during 1981-1986 at levels of detection ranging from 0.2 ug/l to 2.0 ug/l. Silver was detected in several rivers between 1978 and 1980 including the Saginaw, Flint, Shiawassee, Au Gres, Rifle, Pigeon and Pinnebog. However, these values ranged from 2.0 ug/l to 10.0 ug/l when the level of detection was 2.0 ug/l, so again these values may be artifacts of older laboratory techniques rather than actual silver concentrations. This seems particularly likely given that no silver was detected in any of these rivers during 1976 and 1977 when a 1.0 ug/l level of detection was used.

xi. Zinc

Zinc concentrations did not exceed Rule 57(2) guideline levels for any river sampled in the Saginaw Bay basin during 1971-1986 except the Flint River in 1976. The 1976 Flint River value of 220.0 ug/l exceeded the Flint River zinc guideline level of 176.5 ug/l. Flint River zinc values decreased to 130.0 ug/l in 1977, 99.5 ug/l in 1978, and 45.0 ug/l in 1979. In the 1980s they fluctuated between 14.0 ug/l and 43.0 ug/l.

Annual average zinc concentrations at the Saginaw River mouth (Midland Street station) ranged from 21.0 ug/l to 104.0 ug/l during 1973-1986. Tittabawassee River zinc values fluctuated between 5.0 ug/l and 29.0 ug/l. Single sample observations in the Cass (1971) and Shiawassee (1978) rivers were 10.0 ug/l and 21.0 ug/l, respectively.

Zinc concentrations in Saginaw Bay coastal basin tributaries ranged from 6.0 ug/l to 92.8 ug/l during 1976-1986 with no apparent trends.

7. Organic Contaminants

a. Saginaw Bay

Most of the studies involving organic contaminants in Saginaw Bay have focused on contaminant concentrations in biota and sediments. Few studies have examined levels in the water column. Dieldrin was detected in a 1974 study by the Michigan Water Resources Commission (WRC) at a concentration of 0.6 ng/l (Table III-12). Di (2-ethylhexyl) phthalate (DEHP) was detected at levels ranging from 1,000 to 2,250 ng/l (Table III-12).

Polychlorinated biphenyls were first reported in the Great Lakes basin at the mouth of the Saginaw River in 1971 at concentrations of 1,250 ng/l (MDNR, 1973), giving the Saginaw Bay area the distinction of being the only place in the Great Lakes where PCBs had been detected in the water at that time. The Rule 57(2) guideline level for PCBs in water is 0.02 ng/l. Total PCB concentrations in Saginaw Bay varied with location in 1979, declining from 43.1 ng/l in Section 1 (inner bay) to 16.2 ng/l in Section 5 (outer bay) (Figure III-40; Table III-13). Dissolved and particulate PCB concentrations were also lower in the outer bay than the inner bay (Figure III-40; Table III-13). The A-1242 mixture of PCB was dominant in the river (75%), while the concentrations of A-1242 and A-1260 were almost identical in the bay (Figure III-40; LTI, 1983; Richardson et al., 1983).

b. Tributaries

i. Phenols

Phenol concentrations in all Saginaw Bay basin tributaries sampled during 1971-1986 were far below the Rule 57(2) guideline level for phenols in water of 230 ug/l. The highest annual average phenol concentration among all rivers was 12.0 ug/l in the Flint River in 1977. The highest value measured in 1986 for all rivers was 3.4 ug/l in the Saginaw. All Saginaw Bay coastal tributaries had annual phenol concentrations of 1.0 ug/l or less in 1986. Phenol values for most rivers were highest during 1976-1979 and declined thereafter.

ii. Polychlorinated Biphenyls

Remedial dredging was conducted in 1982 in the South Branch of the Shiawassee River to remove sediments contaminated with PCBs discharged from the Cast Forge Company of Howell. Data were collected at the source of the contamination (Cast Forge) and at stations downstream of the Cast Forge site. Data indicate that the average PCB levels in the water column ranged from 47 to 1,100 ng/l before dredging, 29 to 4,670 ng/l during dredging and 37 to 1,110 ng/l one year after the dredging in 1983 (Table III-14). The composition of the PCB was predominantly Aroclor 1242 in the samples collected at the downstream sites, while the Cast Forge site had equal mixtures of A-1242 and A-1254 (Rice et al., 1984).

Table III-12. Mean Concentrations (ng/l) and Percent Residues of Several Organic Contaminants found in Saginaw Bay Water Samples, 1967-1979 (Kreis and Rice, 1985).

	Year						
Category	1967	1968	1974	1976	1976	1977	1979
Source	1	1	2	3	4	5	6
Nearshore or River	R	R	N	N	R	N	N
No. of samples	1	1		8			118
PCB							
Total			0-23			25.0	24.4
%1260			44.0				51.1
%1254			13.0				
%1242			44.0				48.7
DDT							
DDT-R	ND	ND	<3.0				
%p,p'DDD	ND	ND	33.3				
%p,p'DDE	ND	ND	33.3				
%p,p'DDT	ND	ND	33.3				
Dieldrin	T	ND	0.6				
Aldrin	ND	ND					
Chlordane	ND	ND					
Lindane	ND	ND					
Alpha BHC	7.0	ND					
"Apparent" Toxaphene	ND	ND					
DEHP			1300	2250	1000		
DBP			1000				

T - Trace
ND - Not Detected

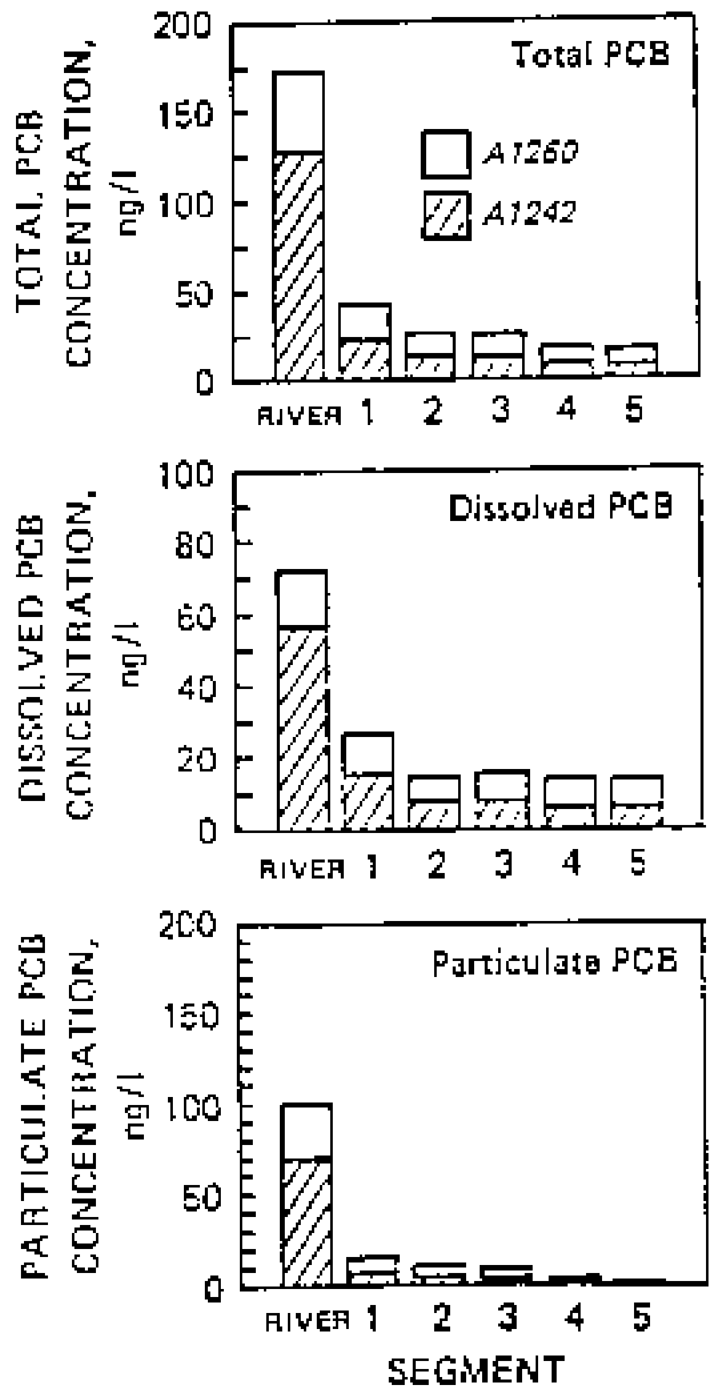

Figure III-40. Average of total PCB concentrations by particulate and dissolved fractions, Saginaw River and 5 segments of Saginaw Bay, 1979 (Richardson, et al., 1983).

Table III-13. Mean Concentrations of PCB (ug/l) and Suspended Solids (mg/l) in Saginaw Bay, 1979 (Richardson et al., 1983).

	Segment				
Parameter	1	2	3	4	5
Total PCB					
Total	43.1	26.4	25.6	18.1	16.2
Dissolved	27.0	14.8	15.7	14.1	13.7
Particulate	16.2	11.6	9.91	3.98	2.57
A-1242					
Total	23.0	13.4	12.7	7.66	6.87
Dissolved	15.67	8.09	8.13	5.95	5.83
Particulate	7.45	5.31	4.52	1.71	1.04
A-1260					
Total	20.1	13.0	12.8	10.4	9.36
Dissolved	11.4	6.68	7.45	8.13	7.83
Particulate	8.70	6.34	5.39	2.27	1.53
Suspended Solids	15.2	9.68	12.2	3.03	2.65

Table III-14. Total PCB (ng/l) Measured in Water Before, During and One Year After Dredging in the South Branch of the Shiawassee River, 1982-1983 (Rice et al., 1984).

Station	River Mile	Pre-Dredge	During Dredging	Post-Dredge
Cast Forge	0.0	47 ± 340	29 ± 15	37 ± 15
Bowen Road	1.0	1,100 ± 370	4,670 ± 3,760	1,110 ± 430
Marr Road	3.5	680	2,830	-
Chase Lake Road	6.8	650 ± 200	1,030 ± 260	522 ± 95

Polychlorinated biphenyls have also been detected in Saginaw River water. Concentrations of PCBs at the Saginaw River mouth appear to have decreased considerably over the past ten years, declining from an average of 1,250 ng/l in 1971 (MDNR, 1973) to 110 ng/l in 1979 (Smith et al, 1982), to 25 ng/l in 1981 (LTI, 1983). The 1979 Saginaw River data indicate that the PCB concentration follows an inverse relationship to flow (LTI, 1983). Therefore, low river flows are apparently associated with higher PCB concentrations, and vice versa, leading to higher PCB concentrations in the late summer and fall (LTI, 1983). This also suggests that the sediment release of PCB is independent of movement of the sediment into the water column (LTI, 1983).

iii. Polybrominated Biphenyls

Polybrominated biphenyl (PBB) contamination from the St. Louis Reservoir to the mouth of the Pine River was discovered by the MDNR in 1974 (Hesse, 1975). In the St. Louis Reservoir, PBB concentrations declined from an average of 710 ng/l in 1974 to 1 ng/l in 1980 (LTI, 1984). The concentrations of PBB were higher in the reservoir than downstream during the periods of major loading in 1974, whereas the downstream concentration levels were higher than within the reservoir in 1980 (LTI, 1984). Some PBB was detected in rainwater collected at St. Louis during 1981 at a concentration of 5.1 ng/l (LTI, 1983). Approximately 95% of the PBB in the water column was associated with suspended particles (LTI, 1984). No criteria for PBB concentrations in drinking water or for the protection of aquatic organisms have been established in Michigan. However, there are structural similarities between PBB and PCB, and PBBs are often treated similarly.

E. SEDIMENT QUALITY

1. Contaminant Levels in River Sediments

a. Shiawassee River

i. South Branch

The Shiawassee River was contaminated by PCB and heavy metals in the late 1960s and early 1970s along at least two river stretches. One stretch, the south branch near Howell, was contaminated by PCB, primarily Aroclor 1242. A 1974 MDNR survey found a PCB concentration of 530 mg/kg in surface sediments at Bowen Road (Table III-15), just downstream of the Cast Forge Company, which was the known discharger (Figure III-41). Concentrations of PCB were also quite high up to 10.5 river miles downstream: 97 mg/kg at Marr Road, 59 mg/kg at Chase Lake Road, and 16 mg/kg at Oak Grove Road.

The MDNR surveyed the surface sediments of the south branch of the Shiawassee River twice in 1977. In August, total PCB concentrations ranged from 0.8 mg/kg at the upstream control station at M-59 (CF-CON) to 85.1 mg/kg at Bowen Road (S-TR-2-S; Table III-16; Figure III-42). Concentrations greater than 60 mg/kg were detected at three other stations, and every station except the control had concentrations in excess of 19 mg/kg.

In October 1977, MDNR found a concentration of 43.7 mg/kg total PCB in surface sediments at Marr Road (station 1; Table III-17; Figure III-43). Total PCB was also high (20.2 mg/kg) at Chase Lake Road (station 2). Two other stations had concentrations exceeding 2.5 mg/kg: Oak Grove Road (station 3) at 4.1 mg/kg, and Byron Road (station 5) at 2.6 mg/kg.

A comparison of 1974 and 1977 data shows a decrease in total PCB concentrations in 1977 for the first 18 miles downstream from Cast Forge to Lillie Road (Figure III-43). Downstream of Lillie Road (station 4) total PCB levels in 1977 were about 0.9 mg/kg for a distance of 35 miles to Corunna (Figures III-43 and III-44). The detection of PCB beyond Durand Road (station 6) in 1977 is likely due to sediment transport downstream.

The following PCB concentrations in surface sediments of the south branch of the Shiawassee River were detected in a 1981 MDNR survey: averages of 533 mg/kg for RM 0 (the Cast Forge outfall) to RM 0.25; 24 mg/kg for RM 0.25 to 1.0 (Bowen Road); and 21 mg/kg from Bowen Road to approximately 2000 feet downstream (Rice et al., 1984). Additionally, PCB concentrations exceeding 500 mg/kg were found in a flood plain just upstream of Bowen Road as well. The average concentration at this location was 240 mg/kg. This PCB deposit was above the water level of the river during most flow conditions (Rice et al., 1984).

The MDNR's 1974 survey also found elevated concentrations of heavy metals, phthalates and oil in the surface sediments of the south branch

Table III-15. Organic Contaminant Concentrations (ug/kg dry weight) found in Sediments of the South Branch Shiawassee River below Howell, 1976 (MDNR, 1977).

Station	Station Location	PCB* 1242	PCB* 1254	PCB 1260	Phthalate DEHP	Phthalate DBP	Phthalate BBP	Oil (mg/kg)	Diel-drin	Chlor-dane	En-drin
Marion and Genoa Drain											
MAG-1	Fisk Road, Control	<600	<100	<50	900	<1,000	<100	850	<1	<10	<3
MAG-2	Above Howell WWTP	<200	560	<50	1,300	<1,000	310	6,000	<1	ND	<3
MAG-3	Below Howell WWTP	ND	[illegible]	<50	11,000	<1,000	203	9,900	<1	ND	<3
MAG-5	Mouth	<2,800	[illegible]	<50	51,000	<1,000	<100	6,000	<1	ND	<3
South Branch Shiawassee River											
SBS-1	Sexton Road, Control	<100	<100	<50	<500	<1,000	<100	1,400	<1	10	<3
SBS-2	Above Marion & Genoa Drain	<400	[illegible]	<50	[illegible]	<1,000	<100	4,900	<1	30	<3
SBS-3	Norton Road	<6,000	[illegible]	<50	20,000	80	350	2,300	ND	ND	<3
SBS-4	Grand River Road	<1,500	500	<50	11,000	<1,000	<200	5,000	<1	ND	<1
SBS-5	Bowen Road, Below Fort Forge	530,000	<11,000	<50	ND	ND	ND	20,000	ND	ND	<3
SBS-6	Marr Road	97,000	<5,000	<50	14,000	<1,000	<200	4,400	<1	ND	<3
SBS-7	Chase Lake Road	59,000	<600	<50	<200	<1,000	<200	2,300	<1	ND	<3
SBS-8	Oak Grove Road	16,800	<500	<50	1,200	<1,000	<100	660	<1	ND	<1
SBS-9	Cohoctah Road	2,900	200	<50	<200	<1,000	<200	<500	<1	ND	<3

ND: Not determined due to interference by other chemicals.

*Interfering chemicals resulted in less sensitivity at some stations.

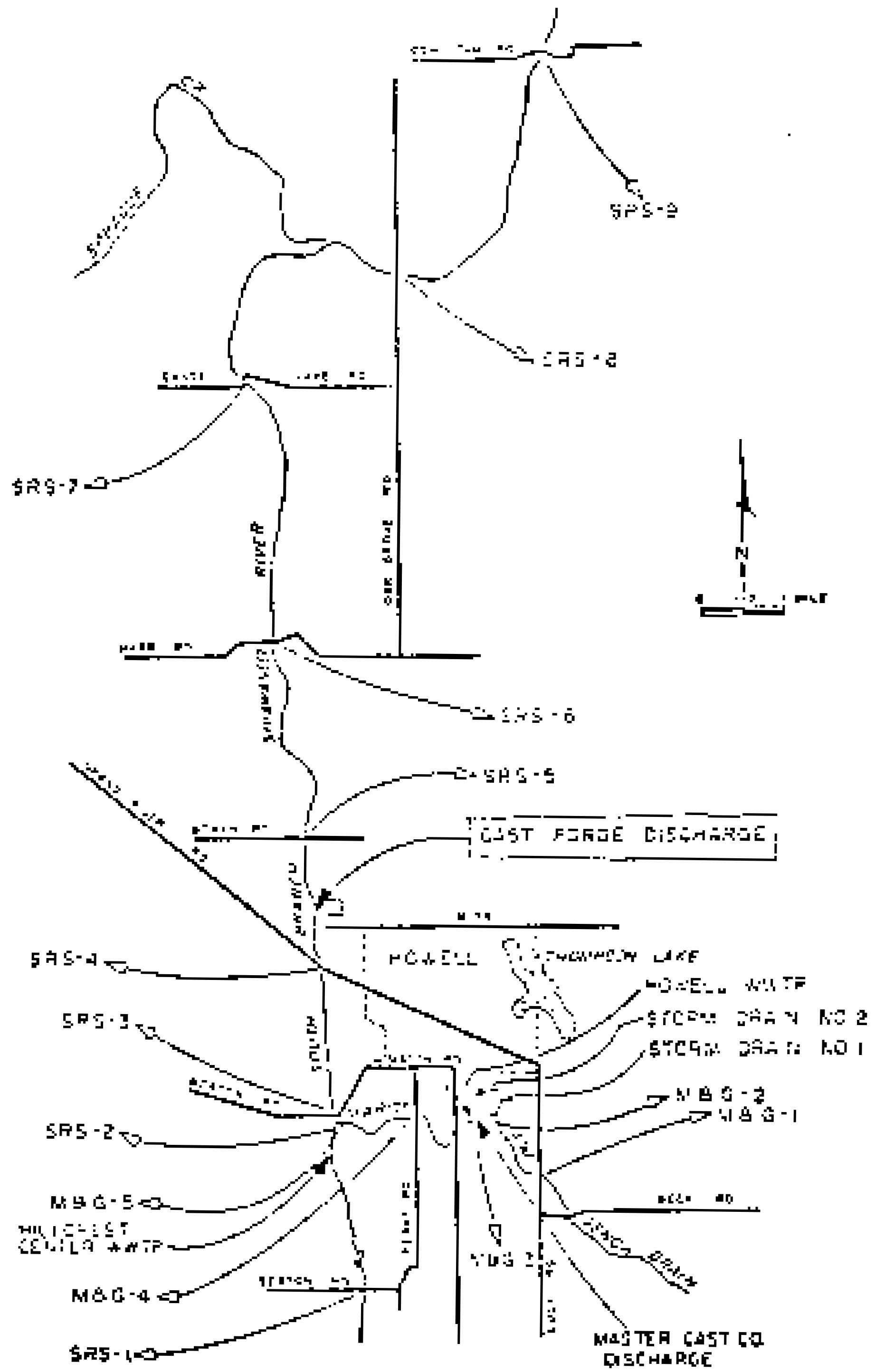

Figure III-41. South branch Shiawassee River 1974 sampling station locations and wastewater discharges (MDNR, 1979a).

Table III-16. Organic Contaminant Concentrations (mg/kg dry weight) found in Sediments of the South Branch Shiawassee River below Howell, August, 1977 (MDNR, 1979).

			Parameter			
Station*	PCB 1242	PCB 1254	PCB 1260	DEHP	DBP	Total PCB
1A	13.0	5.6	<5.0	<2.0	<2.0	19.5
5-TR-1-5	27.0	10.4	<5.0	<2.0	<2.0	37.4
5-TR-1-2	13.6	5.6	<5.0	<2.0	<2.0	19.2
5-TR-1-3	45.2	18.3	<5.0	<2.0	<2.0	63.5
5-TR-2-5 (Bowen Road)	64.8	20.3	<5.0	<2.0	<2.0	85.1
5-TR-2-2	16.2	15.4	<5.0	<2.0	<2.0	31.6
5-TR-2-3	23.8	9.0	<5.0	<2.0	<2.0	32.8
5-200	53.6	12.4	<5.0	<2.0	<2.0	66.0
5-400	64.0	15.7	<5.0	<2.0	<2.0	78.7
5-600	40.0	8.8	<5.0	<2.0	<2.0	49.4
5-800	20.3	<5.0	<5.0	<2.0	<2.0	20.3
5-1000	43.0	8.1	<5.0	<2.0	<2.0	51.1
CF-CON (M-59 Control Station)	0.5	0.8	<0.5	<2.0	<2.0	0.8
CF-DIS-1	23.0	8.7	<5.0	<2.0	<2.0	31.7
CF-DIS-2	35.3	6.7	<5.0	<2.0	<2.0	42.0
CF-DIS-3	31.0	7.8	<5.0	<2.0	<2.0	38.8

*Station 1A corresponds to Willson and Powers 1974 Survey; Station 5-TR-1 & 2 are core samples; 5-TR-200 & 1000 are sludge bed samples.
CF-CON is the control station immediately above M-59.
CF-DIS - 1, 2, 3 samples were taken 50, 100, and 150 yards downstream from Cast Forge old discharge channel.

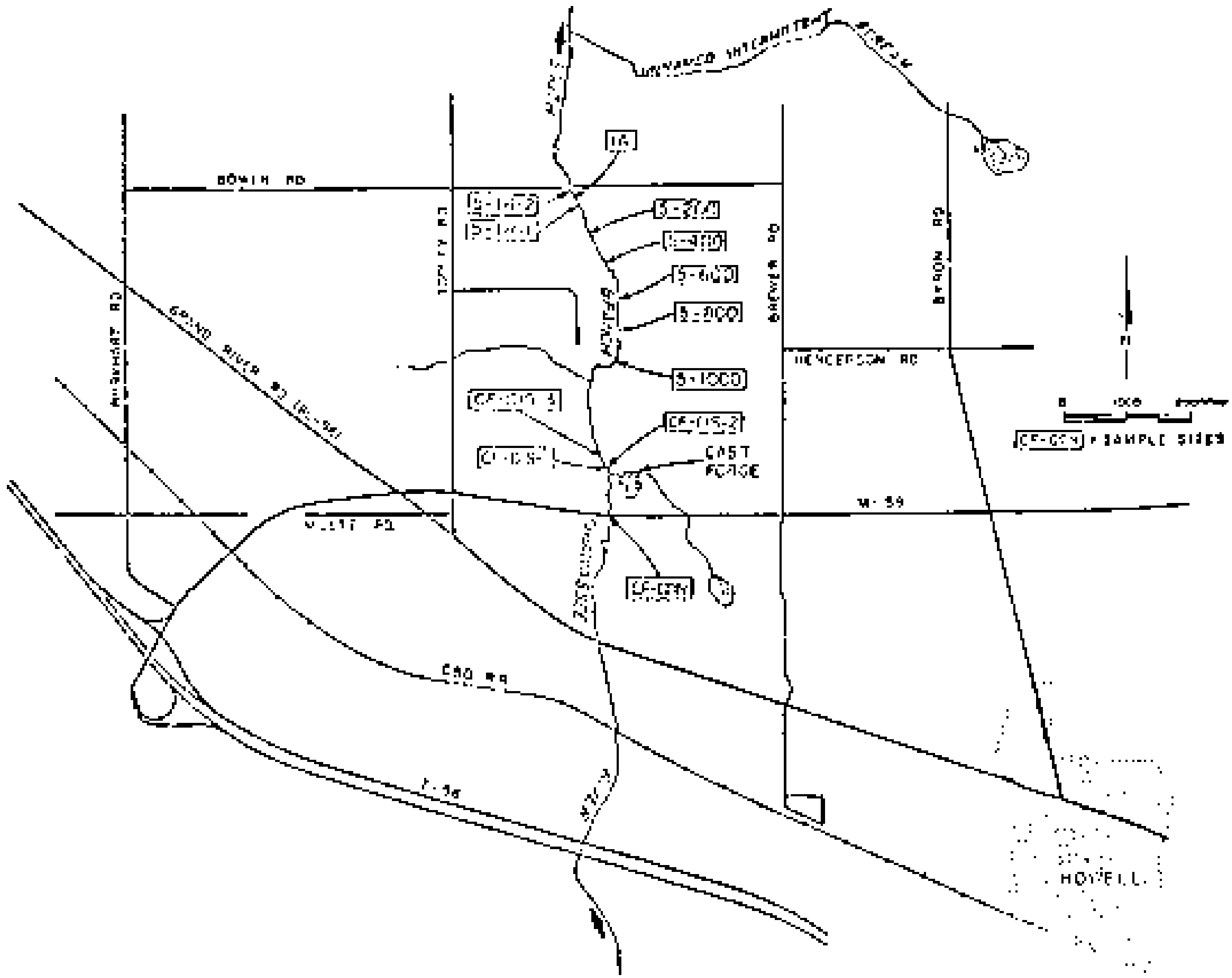

Figure III-42. South branch Shiawassee River sediment survey sampling locations, August, 1977 (MDNR, 1977).

Table III-17. PCB Concentrations (dry weight) in Sediments of the South Branch Shiawassee River from Howell to Corunna, October 1977 (MDNR, 1977).

Station Number	Station Location	PCB (mg/kg)			
		Aroclor			
		1242	1254	1260	Total
1	Marr Road	35.00	8.70	<0.50	43.70
2	Chase Lake Road	17.00	3.20	<0.50	20.20
3	Oak Grove Road	4.10	<0.50	<0.50	4.10
4	Lillie Road	0.96	<0.50	<0.50	0.96
5	Byron Road	2.60	<0.50	<0.50	2.60
6	Durand Road	0.54	<0.50	<0.50	0.54
7	Cole Road	0.50	<0.50	<0.50	0.50
8	Shiatown Res.	0.60	<0.50	<0.50	0.66
9	Corunna Imp.	0.50	<0.50	<0.50	0.50

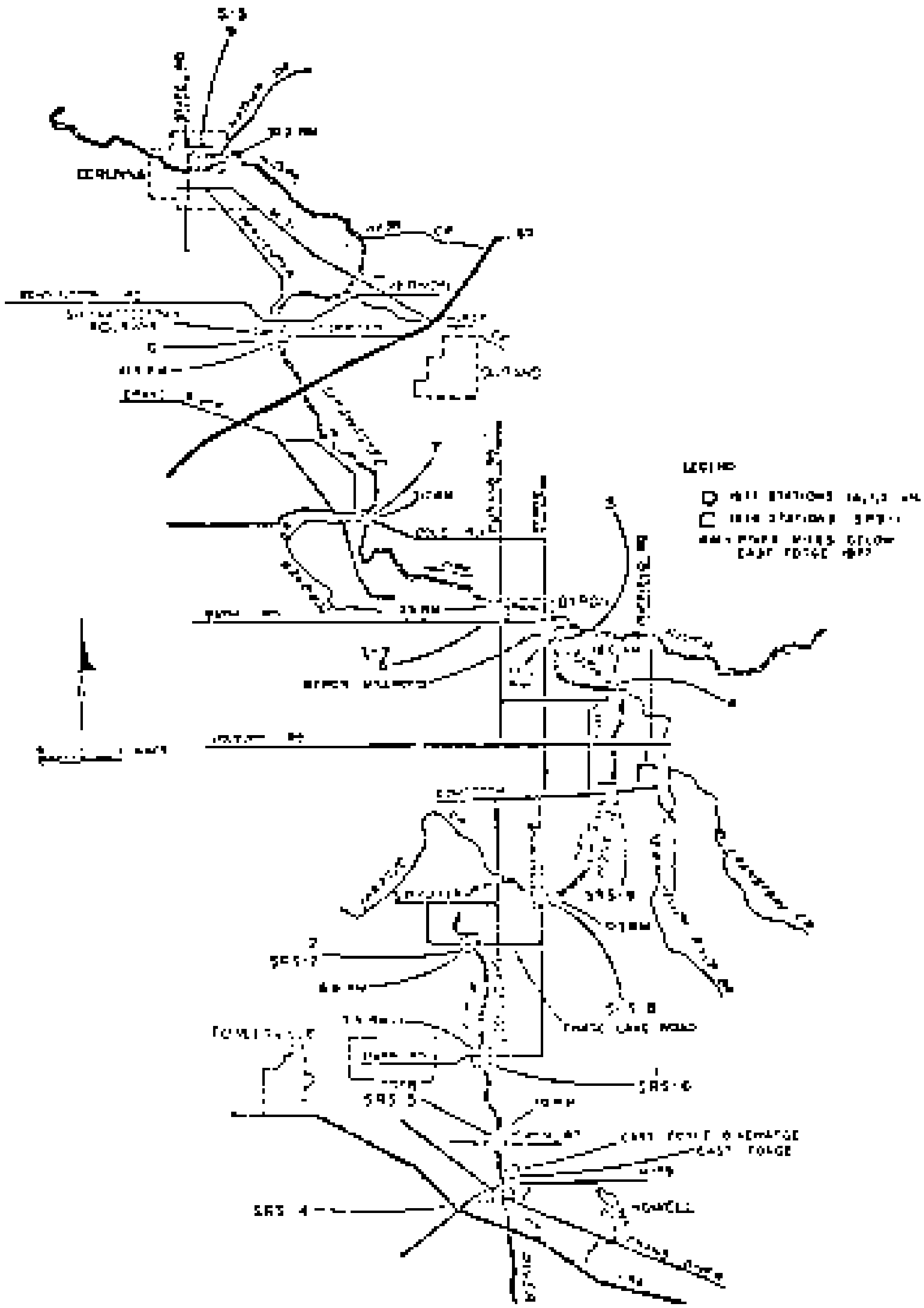

Figure III-43. 1974 and 1977 sampling locations for sediments, south branch Shiawassee River, Howell to Corunna (MDNR, 1977).

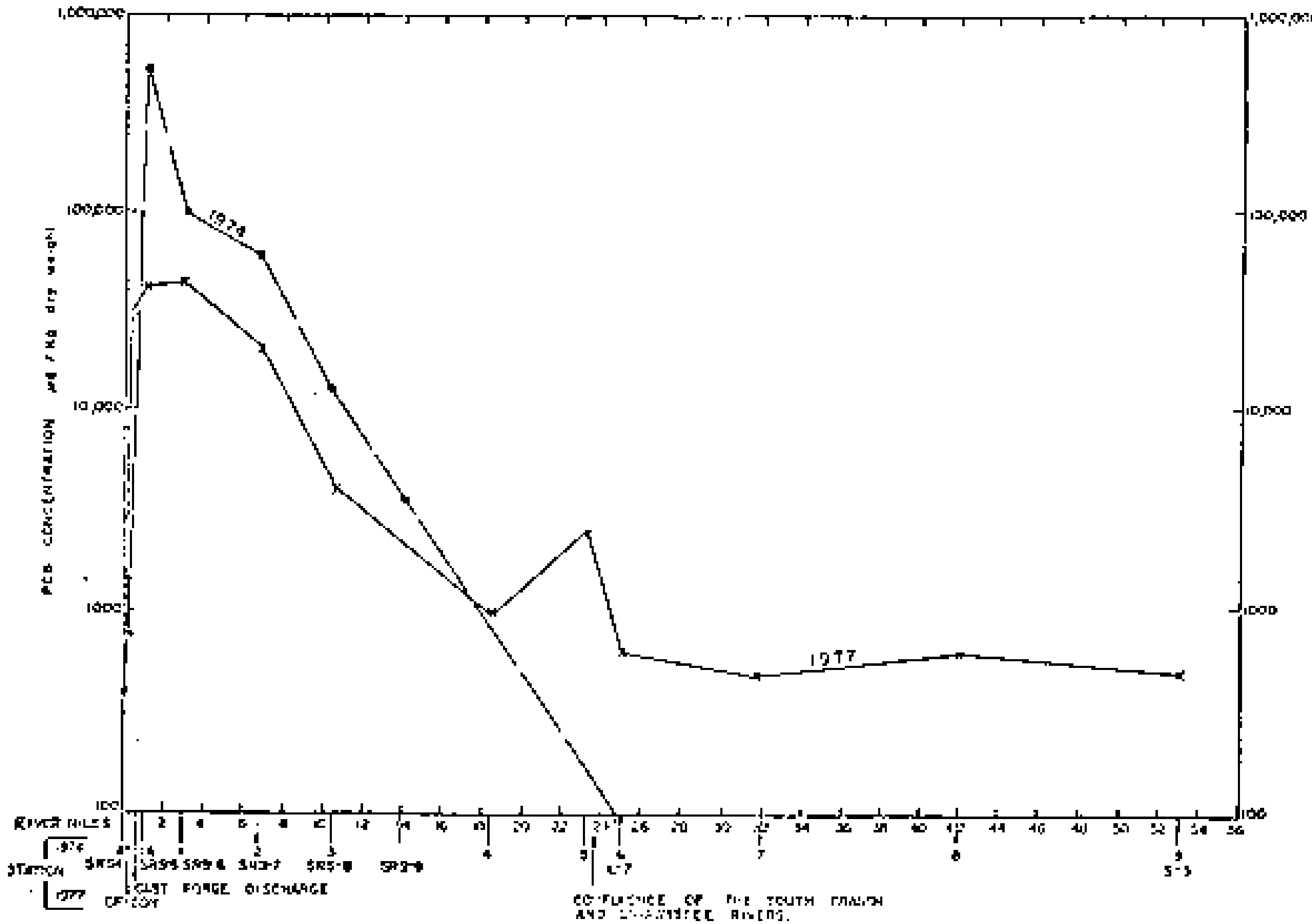

Figure III-44. 1974 and 1977 sediment PCB data for the south branch Shiawassee River below Howell to Corunna (MDNR, 1977).

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of the Shiawassee River. Concentrations of As ranged from 11 to 125 mg/kg, Cd from less than 1 to 6 mg/kg, total Cr from 17 to 4200 mg/kg, Cu from 14 to 180 mg/kg, Hg from less than 0.1 to 0.2 mg/kg, Ni from 16 to 54 mg/kg, Pb from 24 to 520 mg/kg, Zn from 100 to 1400 mg/kg, and CN from less than 0.2 to 4.6 mg/kg (Table III-18). The higher concentrations of As, Cr, Cu, Ni, Pb and Zn exceeded the EPA criteria for heavily polluted Great Lakes harbor sediments (Table III-19). The Norton Road station (SRS-3; Figure III-41) exhibited the highest concentrations of Cu, Cd, Cr, Zn, Pb and CN. The Grand River Road station (SRS-4) showed the second highest concentrations of metals.

Phthalate concentrations ranged from less than 0.1 mg/kg at SRS-7 and SRS-9 to 20 mg/kg at SRS-3 in the 1974 MDNR survey (Table III-15); the highest concentration found was 20 mg/kg at Norton Road (SRS-3). Other high concentrations occurred at Grand River Road (SRS-4; 11 mg/kg) and at Marr Road (SRS-6; 14 mg/kg). Oil was measured in concentrations from less than 500 mg/kg at Cohoctah Road (SRS-9) to 20,000 mg/kg at Bowen Road (SRS-5). The second highest concentration of oil was found at Norton Road (SRS-3; 7300 mg/kg).

A source of contaminants to the south branch of the Shiawassee River is the Marion and Genoa Drain (Figure III-41). A 1974 MDNR survey found a PCB Aroclor 1254 concentration of 1.6 mg/kg and a PCB Aroclor 1242 concentration of less than 1.8 mg/kg in surface sediments at the drain's mouth (M&G-5; Table III-15). The same station had a phthalate concentration of 33 mg/kg. Oil was detected at 9900 mg/kg below the Howell WWTP (M&G-3), and at 6000 mg/kg above the WWTP (M&G-2) and at the mouth of the Marion and Genoa Drain.

The following metal concentrations were measured in the Marion and Genoa Drain sediments in 1974: As, 20 to 43 mg/kg; Cd, less than 1 to 8 mg/kg; total Cr, 11 to 600 mg/kg; Cu, 32 to 230 mg/kg; Hg, 0.2 to 0.3 mg/kg; Ni, 36 to 52 mg/kg; Pb, 21 to 720 mg/kg; Zn, 140 to 1600 mg/kg; and CN, 0.2 to 2.2 mg/kg (Table III-18). Concentrations of As, Cr, Cu, Ni, Pb and Zn were all high enough to be classified as heavily polluted according to Great Lakes harbor sediment guidelines (Table III-19). Except for As and CN, all of the highest concentrations were found at the mouth of the drain (station M&G-5). Concentrations were also high upstream and downstream of the Howell WWTP.

The two major sources of contaminants in this area of the Saginaw River watershed are the Howell WWTP and the Cast Forge Company. Cast Forge manufactures aluminum cast products for the automobile industry, and uses lubricants during the molding process. Until 1976, these lubricants contained high levels of PCBs which, until 1973, were discharged directly to the river in the wastewater effluent. After 1973, wastewater was discharged to a lagoon on company property and to land adjacent to the lagoon. From 1975 to the present, PCB-contaminated waste has either been hauled to another disposal location or taken to an approved land disposal site (MDNR, 1979a).

Elevated PCB concentrations were discovered in surface sediments upstream of the Cast Forge property by MDNR in 1977 and were linked to

Table III-18. Metal and Nutrient Concentrations (mg/kg dry weight) found in Sediments from Marion and Genoa Drain and South Branch Shiawassee River, 1974 (MDNR 1979a).

Station	Location	As	Cu	Hg	Cd	Total Cr	Zn	Ni	Pb	CN	% Volatile Solids	Total Kjeld. N	PO_4-P
Marion and Genoa Drain													
M&G-1	Fisk Road Control	43	32	0.3	<1	11	140	36	21	0.3	19	6,200	80
M&G-2	Above Howell WWTP	31	150	0.2	5	1,200	1,200	40	600	1.1	12	8,600	80
M&G-3	Below Howell WWTP	29	160	0.2	5	1,800	1,300	40	720	2.2	4.2	6,400	170
M&G-5	Mouth	20	230	0.3	8	6,000	1,600	52	720	0.2	15	8,100	340
South Branch Shiawassee River													
SRS-1	Sexton Road, Control	125	24	<0.1	1	17	140	53	46	<0.7	12	19,000	170
SRS-2	Above Marion & Genoa Drain	36	30	<0.1	<1	36	200	34	46	<0.5	1.9	12,000	160
SRS-3	Norton Road	20	180	<0.1	6	4,200	1,400	48	520	4.6	12	8,600	400
SRS-4	Grand River Road	21	160	0.1	6	3,800	1,200	54	460	3.0	13	9,300	500
SRS-5	Bowen Road	11	84	<0.1	3	1,600	660	30	240	1.4	13	5,600	450
SRS-6	Marr Road	18	60	<0.1	3	1,700	740	38	260	1.4	9.5	5,700	220
SRS-7	Chase Lake Road	18	60	0.2	3	1,300	620	42	170	1.1	17	7,800	280
SRS-8	Oak Grove Road	12	34	0.2	1	420	240	28	100	0.3	7.9	5,800	200
SRS-9	Cohoctah Road	20	14	0.1	1	130	100	16	24	<0.2	4.5	3,200	68

Table III-19. USEPA Pollution Criteria (mg/kg dry wt.) for Great Lakes Harbor Sediments (modified from Rossmann et al., 1983).

Parameter	Classification		
	Non-Polluted	Moderately Polluted	Heavily Polluted
Volatile Solids (%)	<5	5-8	>8
COD	<40,000	40,000-80,000	>80,000
TKN	<1,000	1,000-2,000	>2,000
Oil & Grease (Hexane solubles	<1,000	1000-2000	>2,000
Ammonia	<75	75-200	>200
CN	<0.10	0.10-0.25	>0.25
Pb	<40	40-60	>60
Zn	<90	90 -200	>200
P	<420	420-650	>650
Fe	<17,000	17,000-25,000	>25,000
Ni	<20	20-50	>50
Mn	<300	300-500	>500
As	<3	3-8	>8
Cd	-	-	>6
Cr	<25	25-75	>75
Ba	<20	20-60	>60
Cu	<25	25-50	>50
Hg	-	-	≥1
PCBs (Total)	-	1≤10 (determined on case-by-case)	≥10 CDF (≥50 RWF)

the City of Howell WWTP discharge. The PCB concentrations found above M-59 were termed "typical" of those found below municipal wastewater treatment plants in Michigan (MDNR, 1977). The apparent source of these PCB compounds was industries that discharge effluent for treatment to the Howell WWTP.

ii. Corunna/Owosso Area

The second stretch of the Shiawassee River where contaminated sediments have been detected is in the Corunna/Owosso area. In 1972, MDNR found Pb concentrations to be above normal background levels (less than 40 mg/kg) at two locations at station 4 (Figure III-45): 136 mg/kg (4 Middle) and 378 mg/kg (4 South; Table III-20). Station 6 was the only other location where elevated concentrations of Pb were found.

The MDNR surveyed the Shiawassee River in 1977 in the vicinity of Globe Union, Inc., a manufacturer of automotive batteries. Globe Union discharges to the Seward No. 2 County Drain. Some PCBs were detected in drain sediments in the range of 0.5 to 17 mg/kg; several metals were also detected (Table III-21). Concentrations of some metals were elevated at Shiawassee River station 3, which is 50 feet below the Seward No. 2 County Drain.

A third MDNR survey in 1980 found extremely high concentrations of Cu and Pb (590 mg/kg and 14,000 mg/kg, respectively) in a sediment sample scraped from the inside of the county drain outfall pipe at station R-003-A (Table III-22; Figure III-46). Drain sediments were contaminated with PCBs and heavy metals, but appeared not to be contributing substantially to the river. Concentrations of PCBs and heavy metals downstream of the drain generally decreased with distance (MDNR, 1979a).

b. Cass River

No sediment data was found for the Cass River basin. The Cass flows through rural agricultural areas and several small towns and is less likely to be degraded by organic and metal contaminants than the more urbanized rivers in the Saginaw River basin. Any sediment contamination would be expected to be a result of either agricultural practices or small industries or local WWTPs discharging to the river. It is thought that no substantial sediment contamination problems exist in the Cass River.

c. Flint River

Surficial sediment samples were collected from the Flint River in 1974 by the MDNR. Sediments were heavily contaminated with lead (780 mg/kg), nickel (92 mg/kg), chromium (200 mg/kg) and copper (140 mg/kg; Table III-23). The highest concentrations were generally found at Elms Road downstream of Flint (Figure III-47) and were attributed to discharges from industrial sources in Flint as well as the Flint WWTP (MDNR, 1977). Sediments continued to show high levels of contaminants further downstream at Morris Road. The samples taken from both East Bart Road and M-13 had reduced contaminant levels. The highest

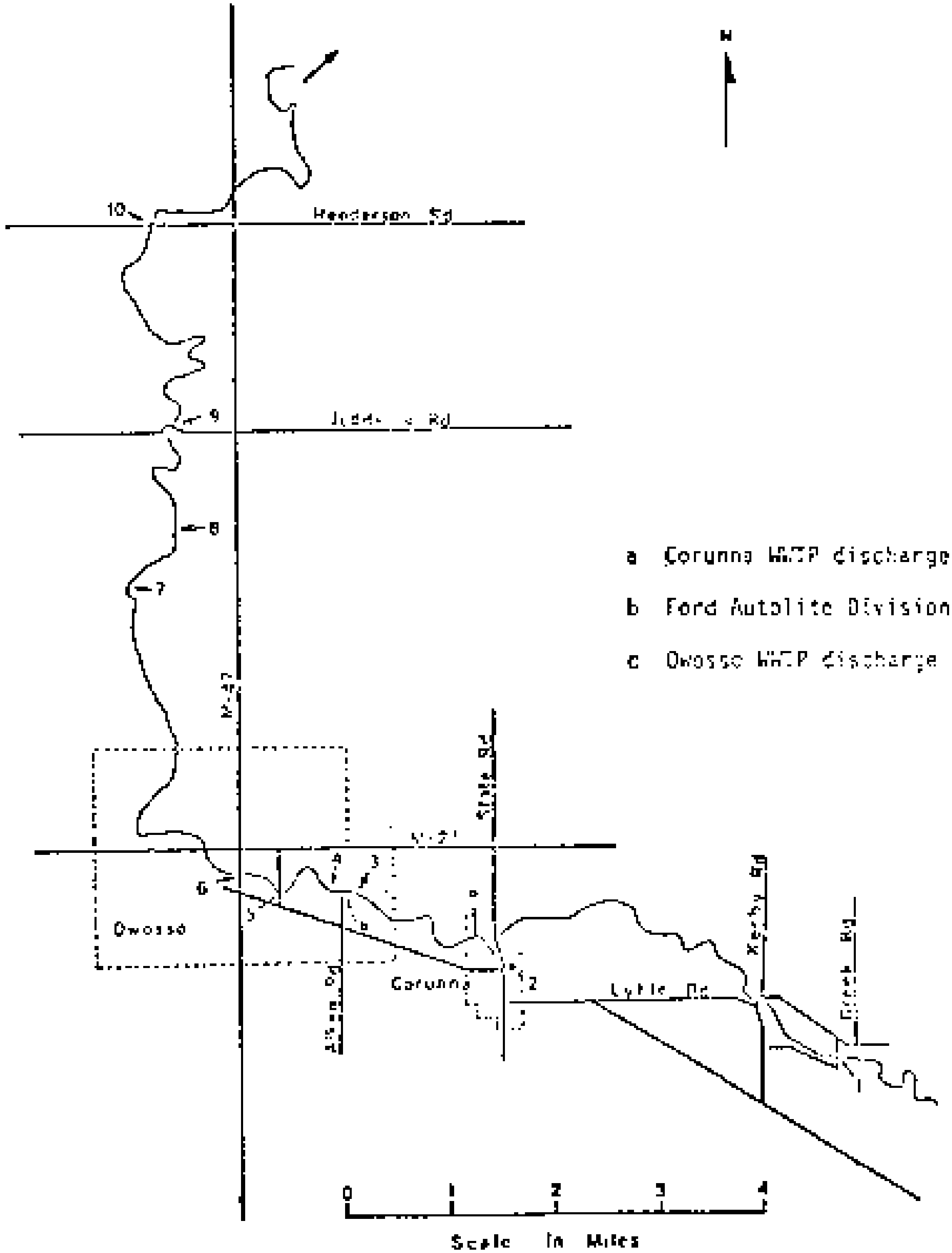


Figure III-45. Sediment sampling stations on the Shiawassee River, Owosso, 1972 (MDNR, 1972).

Table III-20. Metal Concentrations (mg/kg) in Shiawassee River Sediments Collected near Owosso, 1972 (MDNR, 1979a).

Metal	Station							
	2	3	4 North	4 Middle	4 South	5	6	7
Pb	36	27	18	136	378	26	136	40
Zn	25	15	26	18	26	17	44	33
Cu	7.2	4.6	5.4	3.4	4.8	2.6	6.6	6.2
Cr	12	13	7.2	9.0	7.6	7.4	11	10
Cd	2.2	2.8	1.0	1.0	1.0	1.0	2.4	1.8

Table III-21. Phosphorus, Nitrogen, Metal and PCB Concentrations (mg/kg dry weight) in Sediment Samples taken in the Vicinity of Globe Union, Owosso, 1978 (MDNR, 1979b).

	Station		
Parameter	1 Shiawassee River 50 ft. above Drain	2 In Drain	3 Shiawassee River 50 ft. above Drain
Total Kjeldahl nitrogen	12,000	25,000	16,000
Total phosphorus	1,600	4,800	2,700
Metals			
Cadmium	NS*	26	2.1
Copper	20	590	99
Chromium	NS	270	61
Iron	17,000	NS	NS
Nickel	9.5	99	21
Lead	80	14,000	9,800
Zinc	95	NS	NS
Arsenic	0.43	0.33	1.7
Antimony	<11**	<24	<11
Tin	<26	<61	<27
Chlorinated hydrocarbons			
1242 PCB	<0.2	17.0	<0.2
1254 PCB	<0.2	3.0	<0.2
1260 PCB	<0.2	<0.5	<0.2
Oil	920	2,000	2,000

* = not sampled

** = less than

Table III-22. Metal Concentrations (mg/kg) found in Shiawassee River Sediments, Owosso, 1980 (MDNR, 1980).

Site	Metal					
	Cadmium	Chromium	Copper	Nickel	Lead	Zinc
Shiawassee River at Lytle Rd., Shiawassee Co., Michigan	<2.0	12.0	6.0	6.0	10.0	50.0
Shiawassee River at Division St., City of Owosso	<2.0	23.0	13.0	10.0	28.0	70.0
Shiawassee River at Alkan St., City of Owosso - particulate matter scraped from inside of County Drain outfall pipe	80.0	170.0	15,000.0	1,500.0	100,000.0	740.0
Shiawassee River at Alkan St., approximately 10.0 m downstream from County Drain outfall	<2.0	<10.0	12.0	8.0	80.0	60.0
Shiawassee River at Alkan St., approximately 20.0 m downstream from County Drain outfall	<2.0	10.0	8.0	7.0	30.0	50.0
Shiawassee River at Alkan St., approximately 30.0 m downstream from County Drain outfall	<2.0	<10.0	7.0	7.0	20.0	50.0
Shiawassee River at Harmon - Partridge Park, City of Owosso	<2.0	10.0	8.0	5.0	40.0	60.0

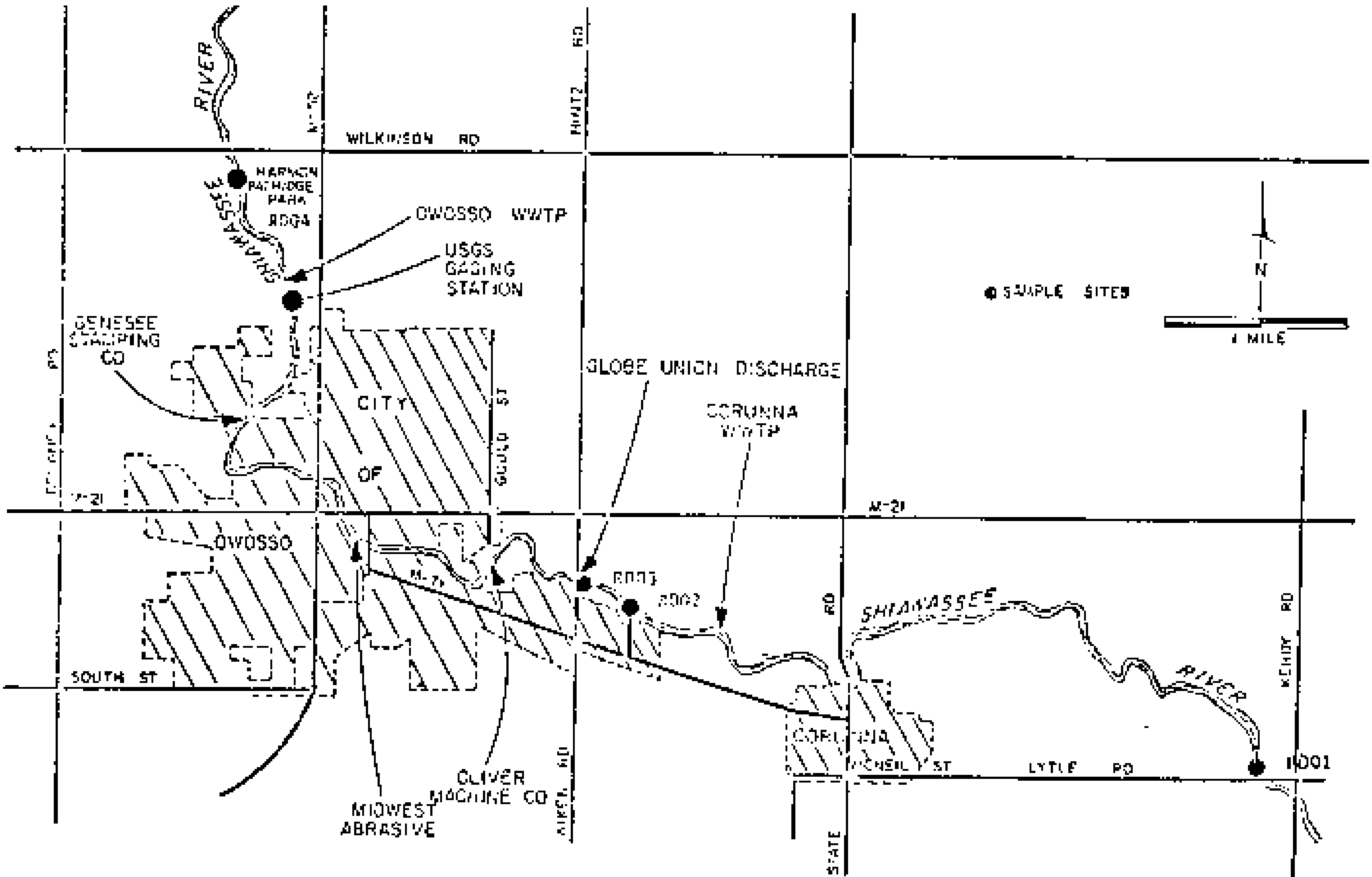


Figure III-46. Shiawassee River sediment sampling stations near Owosso, 1980 (MDNR, 1980).

Table III-23. Conventional, Metal and Organic Parameter Concentrations (mg/kg dry weight) in Flint River Sediments, 1974 (MDNR, 1977).

	Station			
	F-6 Elms Road	F-8 Mt. Morris Road	F-11 East Burt Road	F-13 Mich. 13
Arsenic	5.4	14.0	1.7	4.0
Copper	140.0	110.0	20.0	8.4
Mercury	0.4	0.3	0.2	0.2
Cadmium	6.0	4.0	<1.0	<1.0
Chromium	200.0	88.0	18.0	11.0
Zinc	1500.0	1100.0	130.0	54.0
Nickel	82.0	92.0	18.0	10.0
Lead	780.0	620.0	70.0	20.0
Total Solids (%)	29.0	29.0	76.0	71.0
Volatile Solids (%)	4.2	5.3	0.8	0.6
Total Kjeldahl-Nitrogen	6200.0	7000.0	770.0	830.0
Total Phosphorus	530.0	610.0	120.0	140.0
Dieldrin	<0.001	<0.001	<0.001	<0.001
Chlordane	<0.001	<0.001	<0.001	<0.003
DDD	ND	ND	ND	<0.003
DDE	ND	ND	ND	<0.001
o,p - DDT	ND	ND	ND	<0.003
p,p - DDT	ND	ND	ND	<0.003
Total DDT + Analogs	ND	ND	ND	<0.010
PCB 1242	ND	ND	ND	ND
PCB 1254	0.420	0.420	0.089	<0.003
PCB 1260	<0.003	<0.003	<0.003	<0.003
Total PCB	<0.423	<0.423	<0.092	<0.006
DEHP	18.000	18.000	0.840	2.400
DBP	<1.000	<1.000	<1.000	<1.000
Oil-Hexane (as %)	1.200	1.200	0.660	1.100
BBP	6.700	6.700	0.340	0.550

ND = Not determined due to presence of interfering chemicals.

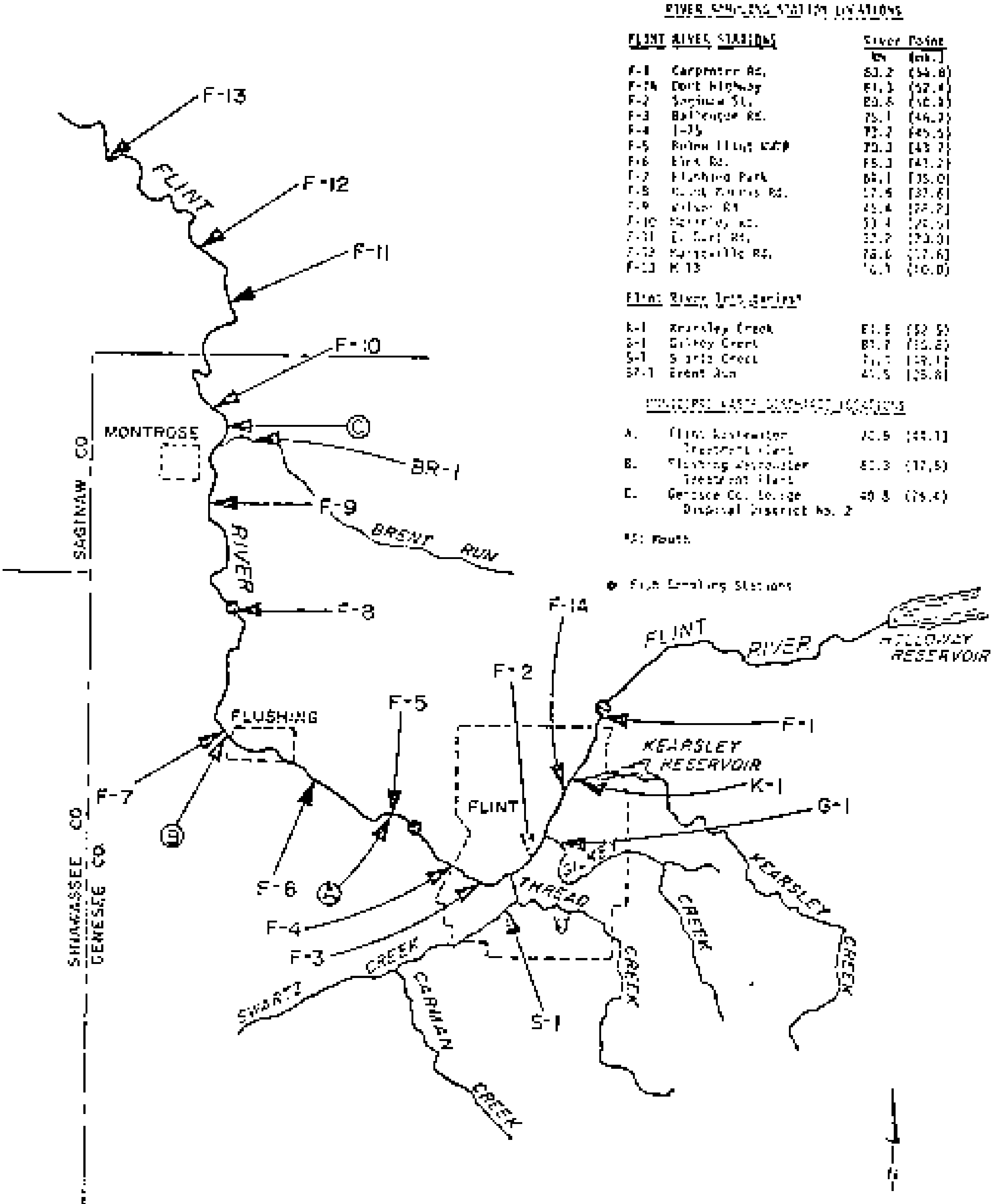


Figure III-47. Flint River sampling stations and municipal waste discharges, 1974.

PCB concentration measured at any station was less than 0.423 mg/kg, measured at both Elms and Mt. Morris roads.

d. Tittabawassee River

The Tittabawassee River is the largest tributary to the Saginaw River, contributing approximately 50% of the flow and draining 6786 square kilometers (Rossmann et al., 1983). The Tittabawassee and its major tributaries have been, and continue to be, heavily used by industry and municipalities. Industrial inputs include wastes from chemical, plastics and can manufacturers, and photographic industries (Rossmann et al., 1983). The Tittabawassee was sampled in 1974 by MDNR for contaminants in sediments. The USEPA conducted river sediment surveys in 1978, 1981 and 1985 (USEPA, 1986). The University of Michigan Great Lakes Research Division (GLRD) also conducted a river sediment survey in 1981 for heavy metals and trace organics (Rossmann et al., 1983).

In 1978, the Michigan Division of Dow Chemical Company in Midland informed the MDNR and the Michigan Department of Public Health (MDPH) that rainbow trout exposed to outfall effluent had accumulated up to 50 ng/kg 2,3,7,8-tetrachlordibenzo-p-dioxin (2,3,7,8-TCDD) . Consequently, in 1978, USEPA-Region V analyzed grab sediment samples from the Tittabawassee River upstream of the Dow Dam and downstream to Bay City on the Saginaw River (Figure III-48). Dioxins were not found in the Tittabawassee or Saginaw River sediments at detection limits of generally less than 50 ng/kg (USEPA, 1986).

In 1981, USEPA conducted a sediment survey of the Tittabawassee River from 0.5 miles upstream of M-20 downstream to Smith's Crossing Road (Figure III-48). Low levels of substituted benzenes and their derivatives were reported (USEPA, 1986). More than 90% of the compounds detected were downstream of Dow Chemical Plant discharges. Concentrations were generally detected in the low parts per million (mg/kg) range. One compound, di-n-octylphlate was identified upstream of the Dow Dam (USEPA, 1986).

The 1981 GLRD sediment survey of the Tittabawassee river is the most comprehensive to date (Rossmann et al., 1983). A comparison of USEPA Great Lakes Harbor sediment pollution guidelines (Table III-19) with the findings of Rossmann et al. (1983), suggest that the river is contaminated with the following metals: Fe, Pb, Cu, Mn, Ni, As, Ba and Cr (Table III-24). The incidence of parameters in the moderate to heavily polluted range is highest for stations 6 and 7, which are located downstream of Ames Drain and the Tittabawassee Township WWTP (Figure III-49). The region of the Tittabawassee River having the highest contamination was located between river miles (RM) 13 and 14.8, except for Ba, which was elevated along the entire sampled length of the river, and PAHs. The highest concentration of Ba was 80 mg/kg at RM 15.

Rossmann et al. (1983) compared their 1981 findings with a 1974 survey by the MDNR. The 1974 samples were collected during a period of low flow compared to the 1981 samples. Arsenic was generally lower in 1981 than in 1974, except for station 6 where concentrations were five times greater than in 1974 (Tables III-24 and III-25). The nearest

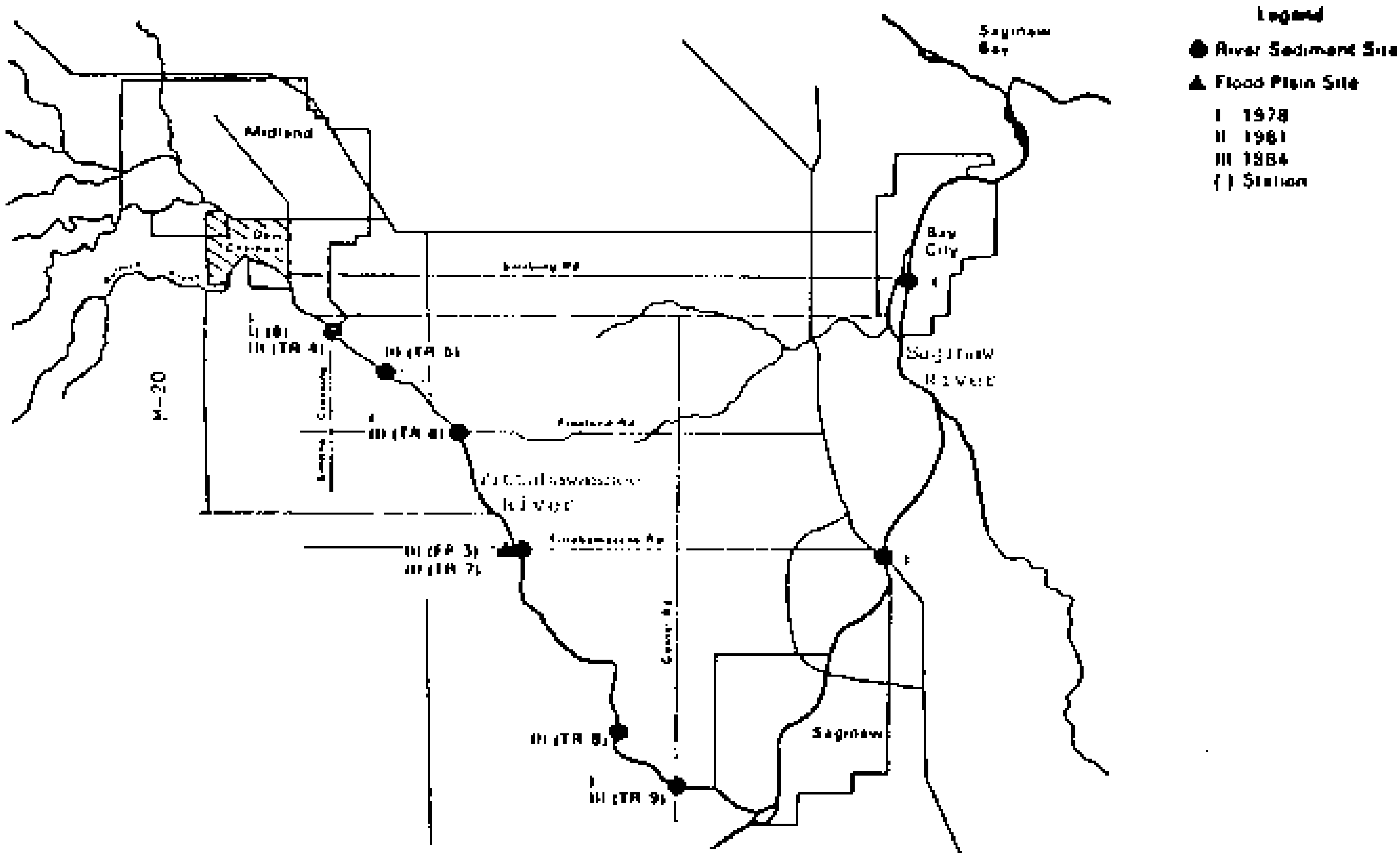


Figure III-46. Tittabawassee River and Saginaw River sediment sampling stations, 1978-1984 (USEPA, 1986).

Table III-24. Metal and Phosphorus Concentrations (mg/kg) in Tittabawassee River Sediments, 1981 (Rossmann et al., 1983).

		Metal								
Station	River Mile	As	Cu	Hg	Cd	Cr	Zn	Ni	Pb	Total P
1	25	0.614	1.59	.106[2]	.0378	6.65	14.6	4.10	3.97[2]	158
2	23.5	0.793	5.82	.186	.0555	13.5	20.3	5.76	10.0	235
3	20.9	1.81	3.26	.0109[2]	.0202	8.59	19.1	3.56	4.99	163
4	18.9	2.41	4.04	.0165	.0210	13.4	21.8	6.56	3.86[2]	292
5	17	4.15	5.79	.199[2]	.0320	20.5	36.8	11.6	10.8	257
6	14.8	37.4	6.52	.280	.189	117.0	48.6	15.0	40.8	510
7	13	6.49	18.6	.0516[2]	.147	31.6	43.9	15.2	19.5	191
8	12.4	3.12	8.79	.0209[2]	.0193	26.4	42.7	6.92	6.71	148
9	6.6	0.672	7.22	.0164[2]	.0212	8.96	21.9	3.58[1]	4.20[2]	106
10	4	1.78	7.48	.0250	.0398	9.91	32.7	5.64	6.89[2]	114
Mean		5.9	6.9	.091	.058	26	30	7.8	11	217
Standard Deviation		11.2	4.6	.097	.060	33	12	4.5	11	119

[1] Sylvester (1974).

[2] One or more samples from core below limit of detection.

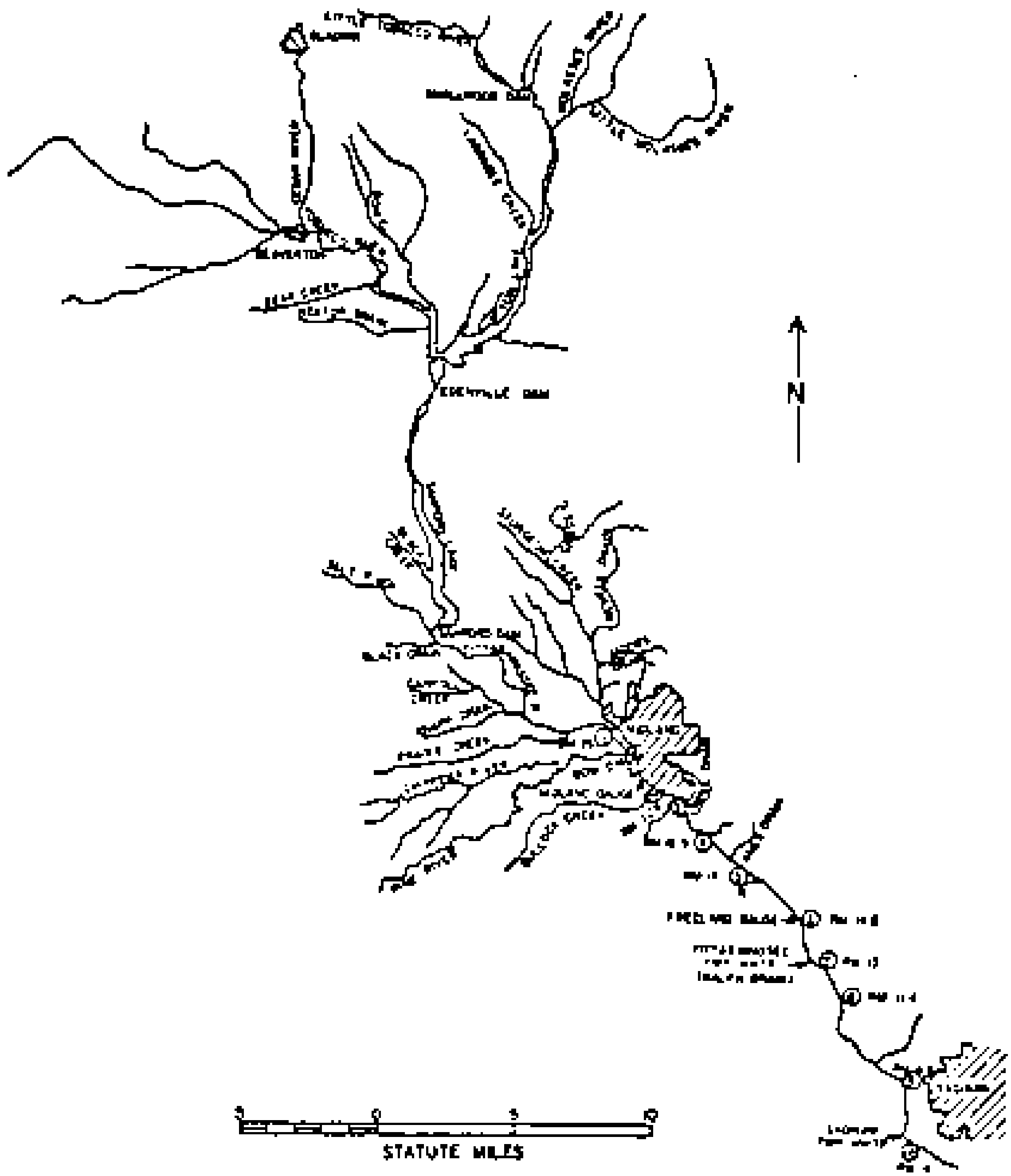


Figure III-49. Tittabawassee River sediment sampling sites for 1981 (Rossman, et al., 1983).

Table III-25. Metal and Phosphorus Concentrations (mg/kg) in Tittabawassee River Sediments, 1974 (Rossmann et al., 1983).

Station	River Mile	Metal								Total P
		As	Cu	Hg	Cd	Cr	Zn	Ni	Pb	
T1	26.5	2.5	2.4	0.1	0.1	2.8	9.6	3.8	2	45
T8	18.9	5.7	17.0	0.1	0.1	12	160	13	84	48
T9	14.8	6.4	14.0	0.1	0.1	9.6	210	11	9	58
T10	11.4	4.4	15.0	0.1	0.1	9.2	180	7.2	7	150
T11	6.6	4.4	22	0.1	0.1	10	190	9.4	9	74
T13	2.9	7.6	10	0.1	0.1	13	50	24	3	18
Mean		5.2	13	0.10	0.1	9.4	130	11.0	19	72
Standard Deviation		1.8	6.7	0.0	0.0	3.6	83	6.9	32	60

possible source of As to the Tittabawassee River upstream of station 6 was the Ames Drain.

Copper concentrations were lower in Tittabawassee River sediments in 1981 than in 1974 (Tables III-24 and III-25). The highest Cu concentration in 1981 was 18.6 mg/kg at RM 11.4 which is located downstream from the Tittabawassee WWTP.

The mean concentration of Zn in Tittabawassee River sediments in 1981 was considerably lower than that of 1974. Zinc concentrations ranged from 14.6 to 48.8 mg/kg with a mean of 30 mg/kg in 1981 compared to a range of 9.6 to 210 mg/kg with a mean of 130 mg/kg in 1974.

The mean Pb concentration was also lower in 1981 than in 1974. This was due primarily to a high concentration of Pb (84 mg/kg) at RM 18.9 in 1974. In 1981, the maximum Pb concentration of 40.0 mg/kg occurred further downstream than in 1974, at RM 14.8.

The concentration of Ni in sediments were very similar for 1974 and 1981. Nickel concentrations ranged from 3.8 to 24.0 mg/kg with a mean of 11 mg/kg in 1974 compared to a range of 4.1 to 15.2 mg/kg and a mean of 7.8 mg/kg in 1981.

Mercury concentrations in Tittabawassee River sediments were consistently at or below 0.1 mg/kg, except at stations 1, 2, 5 and 6 in 1981. The maximum mercury concentration found in 1981 sampling was 0.28 mg/kg at station 6 (Rossmann et al., 1983).

Cadmium was not detected in 1974 with a detection limit of 0.1 mg/kg. In 1981, concentrations of Cd were greater than 0.1 mg/kg at stations 6 and 7; these stations are located downstream from the Ames and Ralph drains (Figure III-49).

The mean Cr concentration for 1981 was higher than that for 1974. Elevated concentrations ranging from 26.4 to 117 mg/kg were found at stations 5, 6, 7 and 8; all of these stations are located downstream from the Ames and Ralph drains.

Total phosphorus was considerably higher in 1981 than in 1974, ranging from 119 to 510 mg/kg in 1981 compared to 18 to 190 mg/kg in 1974.

The 1981 sediment samples collected by GLRD were analyzed for the following organic contaminants: PBBs, PCBs, monochlorobiphenyl, chlorophenols, hexachlorobenzene, 2,4,5-Trichlorophenoxy acid herbicide, DDT family compounds, dieldrin, chlordane, endrin, ethylbenzene, xylene and other major pollutants identifiable by GC/MS organic scans (Rossmann et al., 1983).

The highest concentrations of chlorinated hydrocarbons observed were for the chlorobenzene group of compounds with an average concentration of 5.8 mg/kg average for a core (Rossmann et al., 1983). This group had an average concentration of 0.2-0.5 mg/kg for the total of the six chlorobenzenes measured. Highest concentrations were found at RMs 14.8 and 17.

Concentrations of the Aroclors (PCB compounds) ranged from 0.1 to 0.3 mg/kg. Concentrations of PCB aroclors 1242 and 1254 were 0.27 mg/kg and 0.051 mg/kg, respectively at RM 11.4.

Most of the phenols detected were at trace levels (detection limits of 0.01 to 0.05 mg/kg), but 4-chloro-3 methylphenol and 2,4,6-trichlorophenol were found to be about 0.02 mg/kg (detection limits of 0.1 mg/kg) in the sediment samples from station 1 and station 8, respectively (Rossmann et al., 1983).

Polyaromatic hydrocarbons (PAHs) were found in the sediments from stations 1, 7, 8 and 10. Concentrations of PAHs ranged from 0.005 to 0.015 mg/kg in these samples (Rossmann et al., 1983). The long chain aliphatic hydrocarbons were present at all stations, suggesting nonpoint discharges from oil and gas fields (Rossmann et al., 1983). The Dow Chemical plant had operated 70 brine production wells in the area and was required by the MDNR to shut down the entire brine system by 1986 (USEPA, 1986). The Dow Chemical brines are similar in composition to other oil and gas brines in Michigan and include low levels of benzene, toluene, phenol and various PAHs. Dow Chemical spent brines may also contain trace levels of PCDDs and PCDFs (USEPA, 1986).

Phthalates were detected at concentrations as high as 0.03 mg/kg during the 1981 GLRD sediment survey (Rossmann et al., 1983). Phthalates entering the basin could be the result of site-specific nonpoint sources from several landfills and from deep-well injection of hazardous wastes in the river drainage basin (Rossmann et al., 1983) The black silt/clay type of sediments contained higher concentrations of organic compounds than the sandy type sediments.

A number of other organic compounds were detected in Tittabawassee River sediments in the 0.05-0.1 mg/kg range: 3,5-dichlorophenols, total DDT residues, and 2,4-dichlorophenoxy acetic acid. The remainder of the compounds generally averaged below 0.05 mg/kg, with certain sites exceeding these amounts.

A 1984 USEPA Tittabawassee River sediment and flood plain sediment survey analyzed samples for PCDDs, PCDFs and other toxic organic pollutants (USEPA, 1986). Relatively few organic pollutants were found in any of the sediment or flood plain samples collected. Three pesticide compounds were found (4,4' DDT, 4,4'-DDE, and 4,4'-DDD) in four river sediment samples and each of the three flood plain samples (Table III-26). All three compounds were found at sampling stations TR-1 and TR-2 upstream of the Dow Chemical Plant outfall (Table III-26; Figure III-50).

Data for PCDD and PCDF distinguish the Dow Chemical Plant as the primary source of these compounds to the Tittabawassee system. The highest levels of PCDDs and PCDFs were found in the sediment and flood plain samples near and immediately downstream of the Dow Plant (Figures III-51 and III-52). Sediment contamination extends from the Dow Chemical

Table III-26. Organic Concentrations (ug/kg) in Tittabawassee River Sediments and Flood Plain Samples, 1984. (USEPA, 1986).

	Station											
	TR-1 Above Ash Pond	TR-2 Below Ash Pond	TR-3 Above Lingle Drain	FP-1 Flood Plain @ T. Pond	TR-4 Smith's Crossing Bridge	FP-2 Flood Plain at White and Debolt	TR-5 Up-stream of Brown Mills	TR-6 Free-land	TR-7 Ti. Road	FP-3 Flood Plain at T. Road	TR-8 Gratiot Road	TR-9 Center Road
Benzene	-	-	-	-	-	-	-	-	-	5	-	-
Methylene chloride*	2400	32	29	85	17	-	46	16	57	9500	40	99
Toluene	5.2	-	-	-	-	-	-	-	-	-	-	-
Xylenes	-	-	-	-	-	-	-	-	-	5	-	-
Bis(2-ethylhexyl)phthalate*	870	-	-	-	-	-	-	-	-	10	-	10
Di-n-butyl phthalate*	10	-	-	-	-	-	-	-	-	-	-	-
Di-n-octyl phthalate*	-	-	840	450	-	3100	-	-	-	-	-	-
Diethyl phthalate*	-	-	-	-	-	-	-	-	10	-	-	10
4,4'-DDT	14	17	8.3	6.6	-	-	-	-	-	31	-	-
4,4'-DDE	20	19	19	-	12	88	-	-	-	43	-	-
4,4'-DDD	15	14	-	7.3	-	-	-	-	-	13	-	-

-Not detected
All other organic priority pollutants not detected
*Presence may be due to laboratory or field contamination

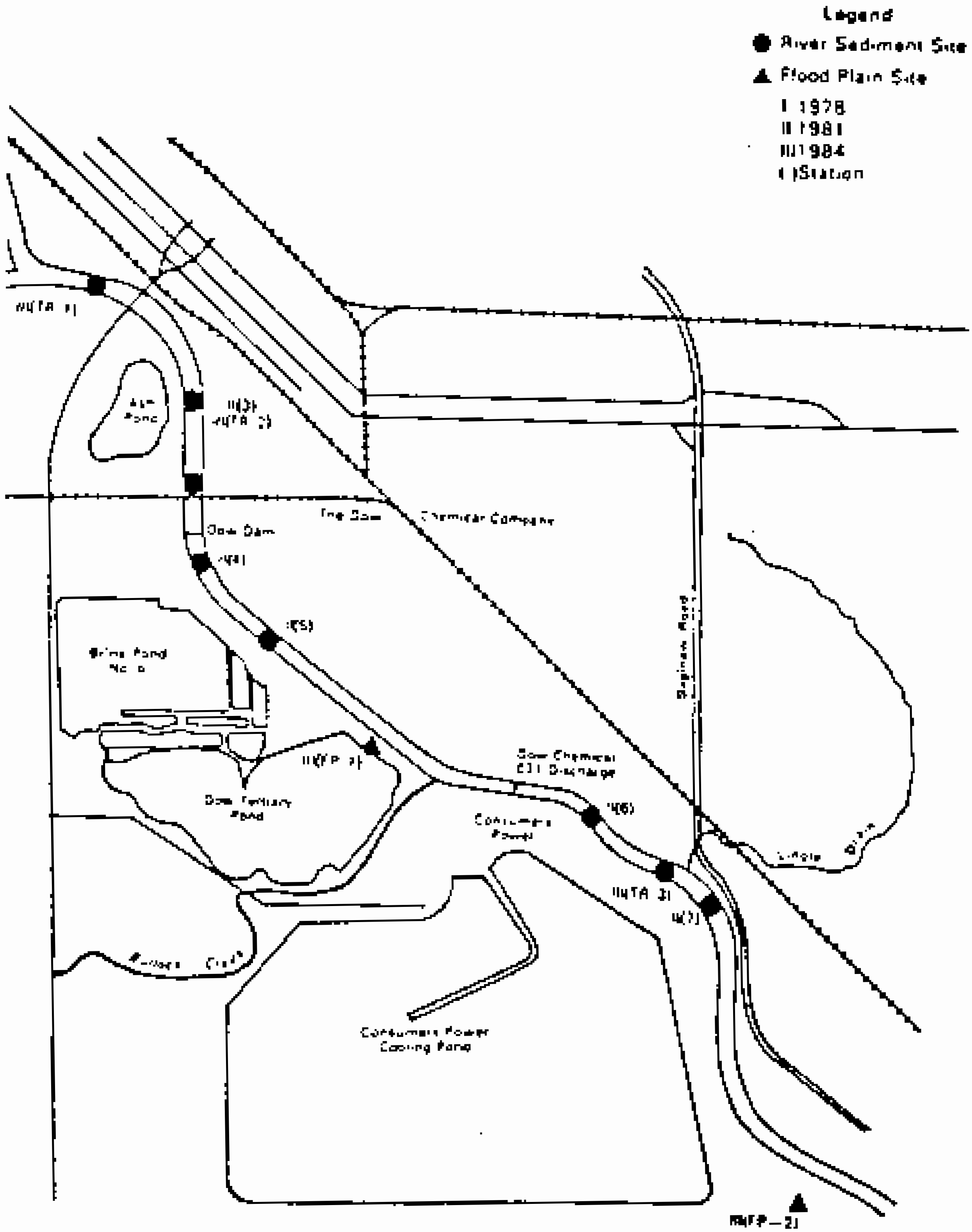


Figure III-90. Tittabawassee River sediment sampling sites, 1981 (Rossman, et al., 1983).

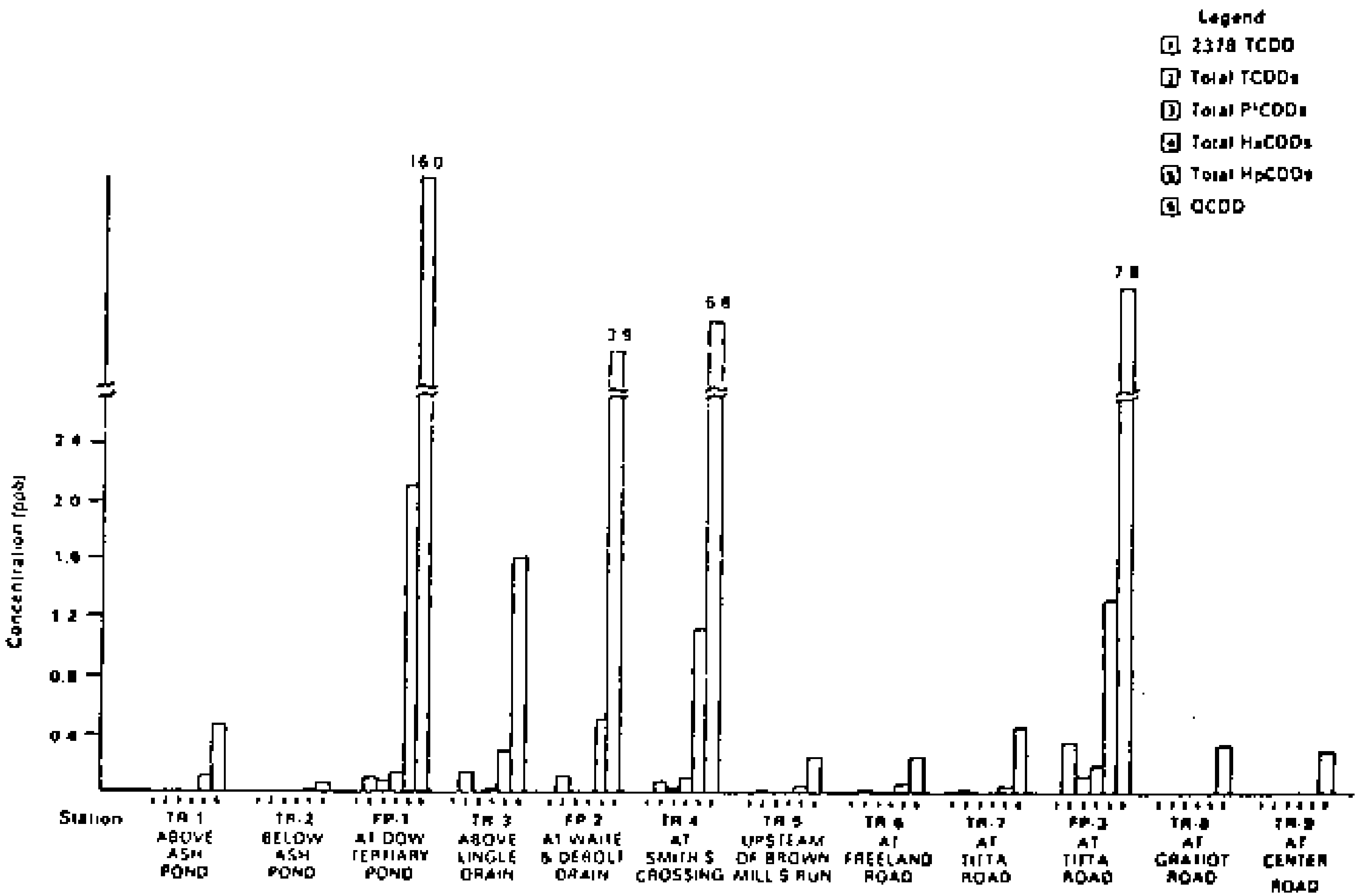


Figure III-51. PCDDs (ug/kg) in Tittabawasee River sediment and flood plain samples, July 1984 (USEPA, 1986).

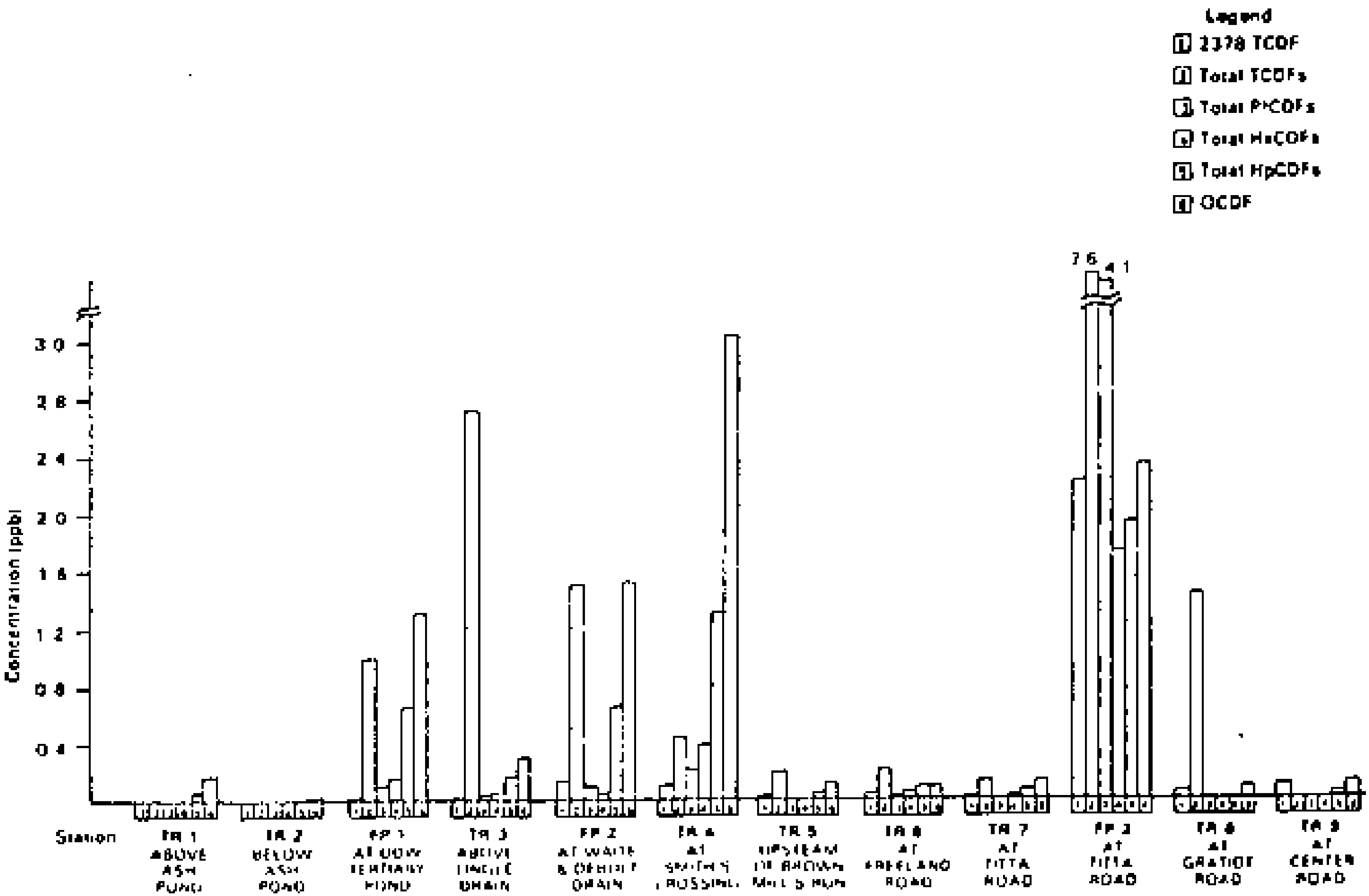


Figure III-52. PCDFs (ug/kg) in Tittabawassee River sediment and flood plain samples, July 1984 (USEPA, 1986).

Plant outfall downstream to Center Road reach (17.1 to 19.5 miles). No 2,3,7,8-TCDD was detected in any of the river sediment and flood plain samples at a detection level of 0.0001 to 0.00032 mg/kg (USEPA, 1986).

Comparisons of metals detected in sediments collected upstream and downstream of the Dow Chemical Plant do not indicate any significant contribution of metals to the river from the plant (USEPA, 1986).

e. Pine River

The Pine River in Gratiot and Midland counties was contaminated by the fire retardant polybrominated biphenyl (PBB) and other hazardous compounds in the late 1960s and early 1970s. In 1974, MDNR found that the concentration of PBB in river sediments immediately downstream from the St. Louis Reservoir (Figure III-53) was 6.2 mg/kg (Table III-27). The PBB concentrations downstream from the reservoir ranged from a high of 1.6 mg/kg two miles below the reservoir to less than 0.1 mg/kg nineteen miles below the reservoir (Figure III-53). The concentration of PBB in sediments immediately below the Velsicol Chemical Corporation (formerly Michigan Chemical) outfall above the dam was 4.8 mg/kg. Concentrations of PBB above Velsicol were less than 0.1 mg/kg.

Michigan Chemical was the state's only commercial manufacturer of PBB. The firm discharged PBB-tainted wastewater to the Pine River from 1971 to 1977 (LTI, 1984). Chronic problems relating to discharges forced the revocation of the facility's NPDES permit, and the company ceased operations and discharges on September 30, 1978 (Rice et al., 1980).

Some PBB concentrations as high as 77.0 mg/kg were detected in near-shore surface sediments just below the Velsicol outfall in 1975 (Rice et al., 1980). MDNR's second sediment survey in 1976 found a PBB concentration of 1.2 mg/kg immediately downstream of the St. Louis Reservoir (Table III-27). Downstream concentrations ranged from 0.2 mg/kg two miles from the dam to less than 0.1 mg/kg at all other sampling points (Figure III-53). The concentration immediately below the Velsicol outfall was 1.1 mg/kg, while both up stream stations registered less than 0.1 mg/kg.

The MDNR's third sediment survey in 1977 found a PBB concentration of 0.5 mg/kg immediately downstream of the St. Louis Reservoir (Table III-27). PBB concentrations further downstream of the reservoir ranged from 0.4 mg/kg two miles below the dam to less than 0.1 mg/kg nineteen miles below the dam (Figure III-53). The concentration immediately below the Velsicol outfall in 1977 was 7.1 mg/kg, while the station one-quarter mile upstream of Velsicol registered 0.35 mg/kg.

During 1980-1981 sampling, the highest measured PBB concentration was 8.06 mg/kg in a grab sample from the St. Louis Reservoir at station 11 (Figure III-54; Table III-28). Surficial sediments from stations 9 through 16 in the lower portion of the upper reservoir all had PBB concentrations in excess of 1.1 mg/kg. Sediment core sampling of the reservoir in 1980 and 1981 found PBB most heavily concentrated in the upper 45 cm of sediment at station 14 (Figure III-55) in the lower portion of the reservoir, above the dam (Figure III-54). The highest

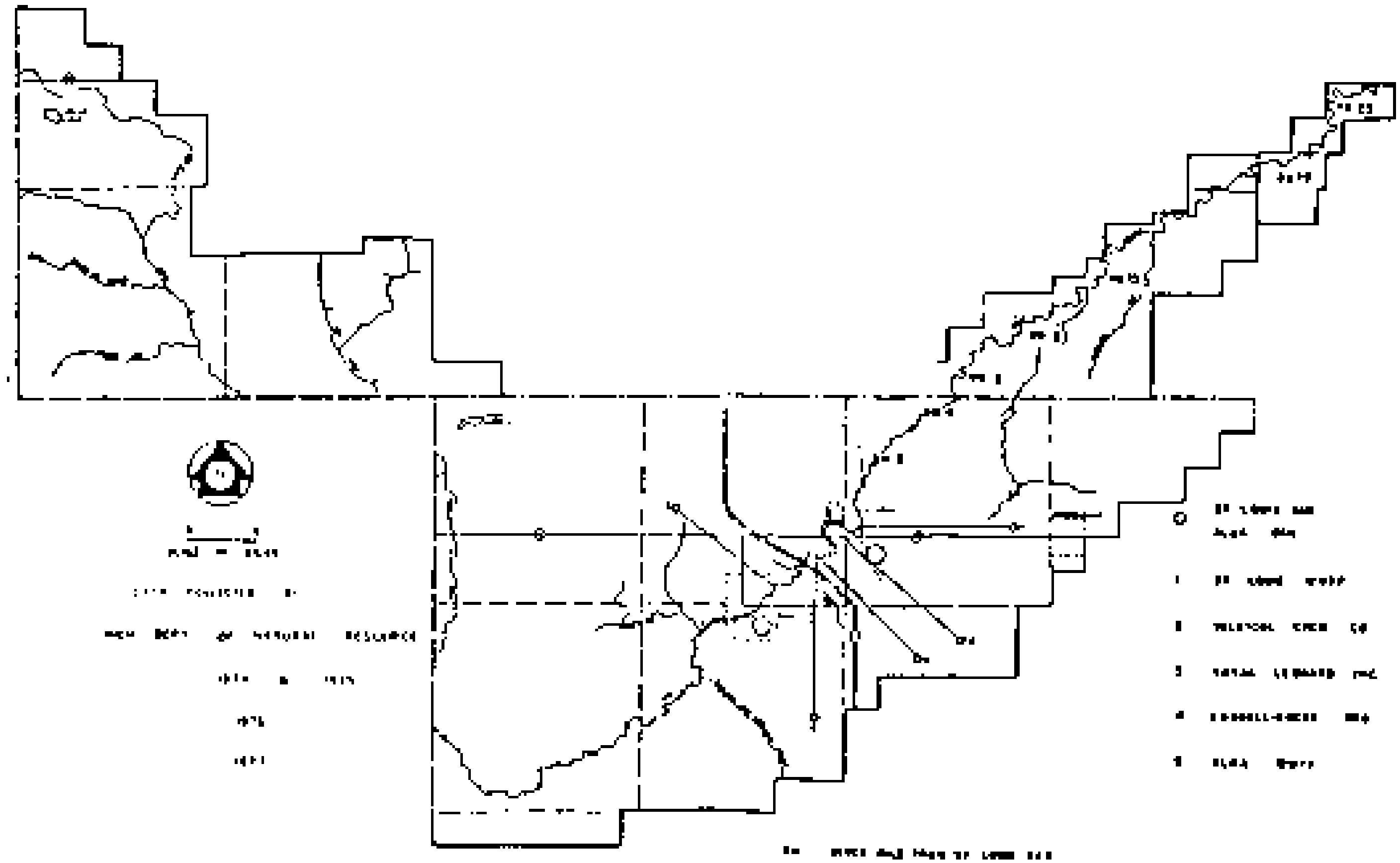


Figure III-53. Sediment sampling stations in the Pine River, 1974-1977 (ECMPDR, 1983).

Table III-27. PBB Concentrations (ug/kg dry weight) in Pine River Sediments, 1974, 1976 and 1977 (Rice et al., 1980).

	Year		
Station	1974	1976	1977
Downstream from Alma reservoir	<100	<100	-
M-46 1/4 mile upstream from Michigan Chemical Corporation	<100	<100	350
St. Louis reservoir immediately downstream from Velsicol Chemical Corporation	4800	1100	7100
Immediately downstream from St. Louis reservoir	6200	1200	500
Miles below St. Louis Dam – 2	1600	200	400
– 4	480	<100 (trace)	260
– 9	270	<100	180
– 19	<100	<100	<100
– 25	100	<100	150

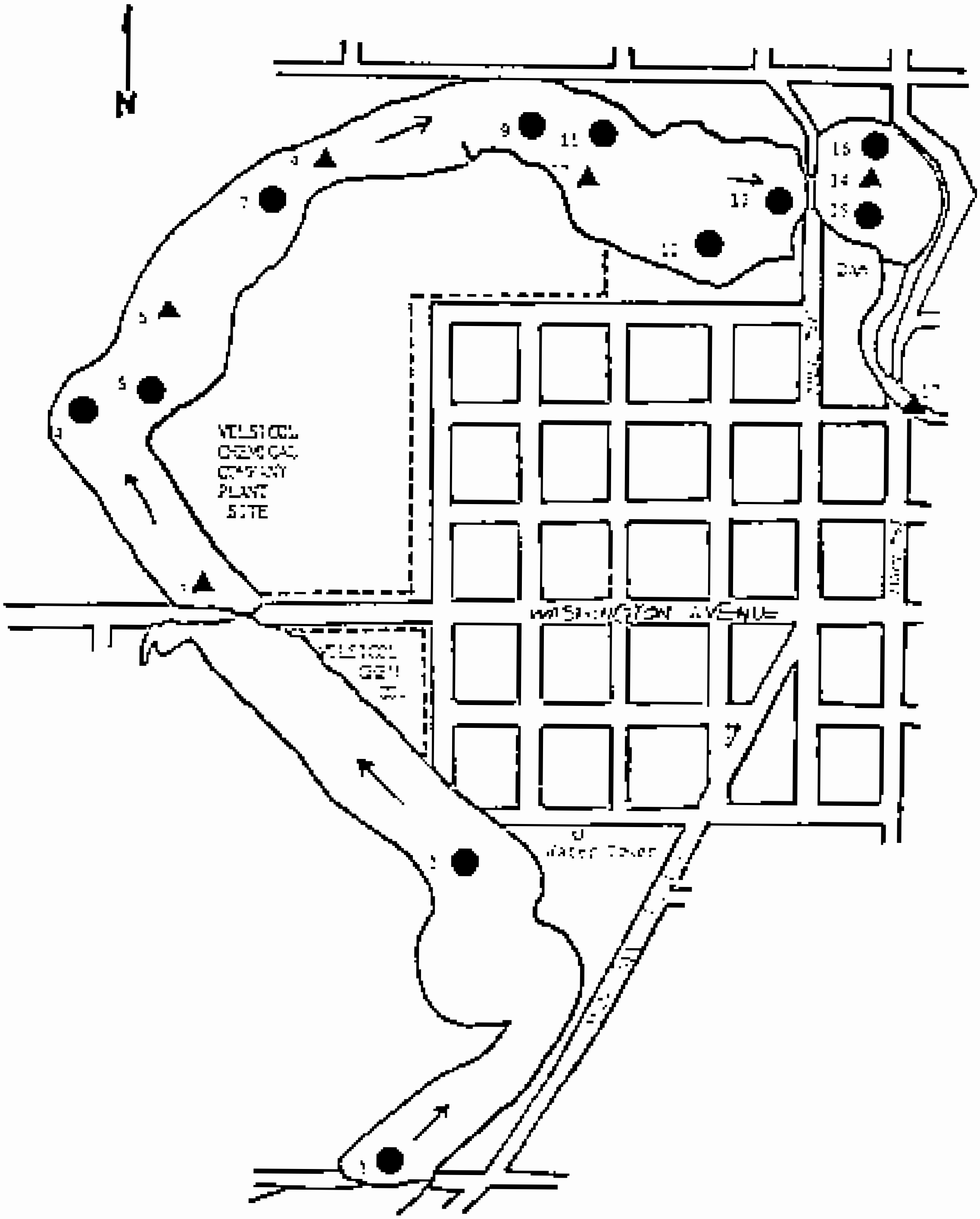


Figure III-54. St. Louis Reservoir sediment sampling locations, 1960-1981 (ECMPOR, 1983).

Table III-26. PBB Concentrations (ug/kg dry weight) in Sediment Grab Samples, St. Louis Reservoir, Pine River, 1980 and 1981 (Rice et al., 1982).

Station	PBB
1	23
2	16
4	248
4	106
4	86
5	173
7	496
9	1,350
11	8,064
12	4,586
13	1,140
15	1,340
16	1,108

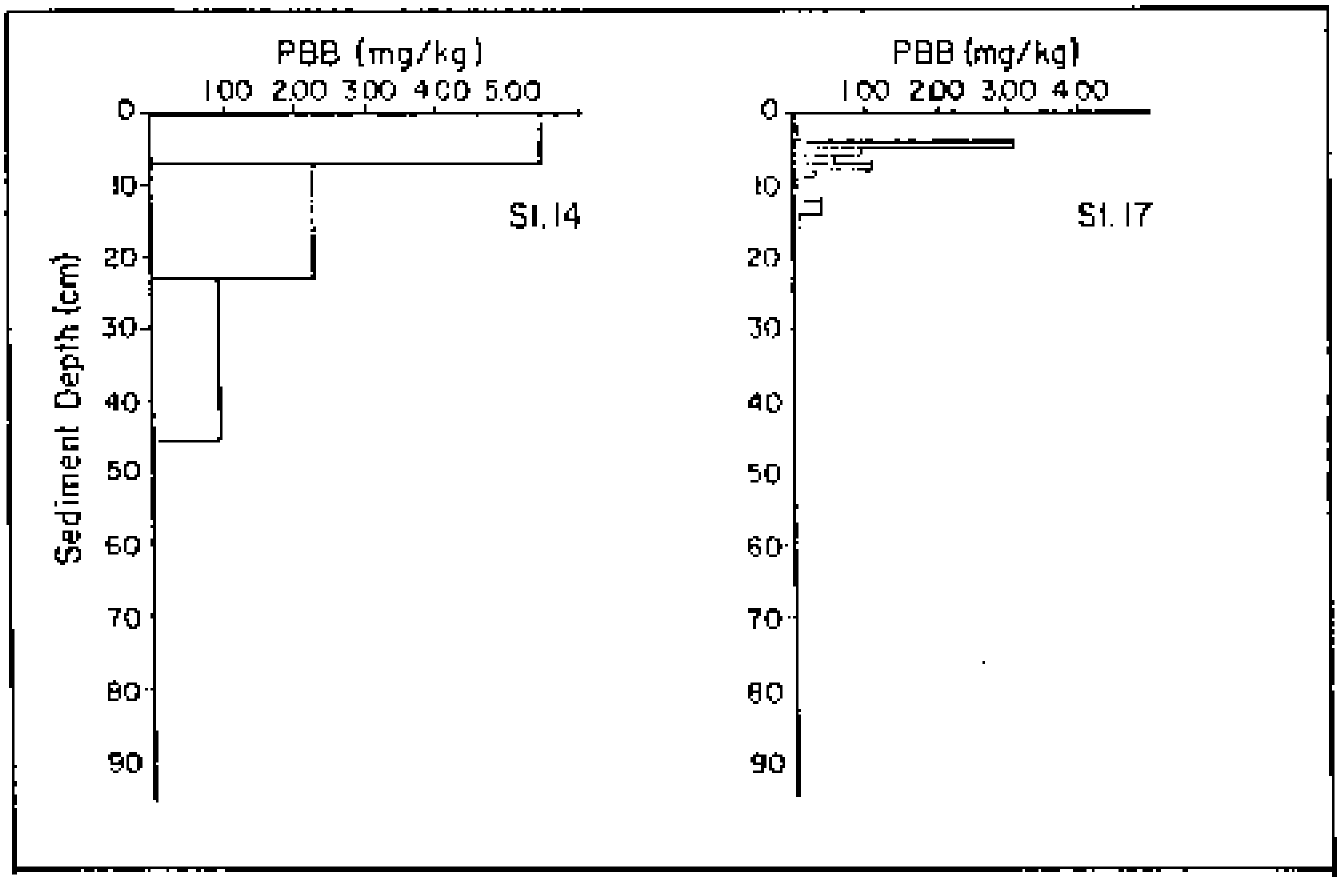


Figure III-55. Vertical PBB distribution in St. Louis Reservoir sediments from Station 14 lower reservoir and Station 17 immediately below the dam (171, 1984).

concentration of PBB at station 14 was 5.45 mg/kg dry weight found at the 7 cm slice of the core (Table III-29).

The PBB levels in the surface sediments of the middle reservoir at stations 4, 5, and 7, adjacent to the plant site but upstream of the major discharge points, ranged from 0.086 to 0.496 mg/kg. The highest PBB concentration in a sediment core taken at station 6 in the middle reservoir was 0.07 mg/kg in the upper 4.2 cm.

Below the dam, peak PBB concentrations in surficial sediments ranged from 0.01-0.20 mg/kg in the first 12 miles and were less than 0.10 mg/kg from RM 32 to the Pine River's confluence with the Chippewa River (Figure III-56; LTI, 1984). A sediment core taken at Station 17, below the dam, had PBB concentrations of 3.14 mg/kg at 5 cm and 1.13 mg/kg at 8 cm (Table III-29).

Surface sediment concentrations of PBB below the St. Louis Dam and five miles downstream of St. Louis declined between 1974 and 1980-81 (Figure III-57). The decline was probably due to sediment transport further downstream (LTI, 1984). The absence of a similar decline in sediment PBB concentrations in the lower portion of the St. Louis Reservoir may be an artifact of different sampling points, the variability in PBB distribution, and the limited number of samples collected in 1974 (3), 1976 (1), and 1977 (1) (LTI, 1984).

In addition to PBB, Michigan Chemical produced several other halogenated hydrocarbons including DDT, chlordane, and another bromine -based fire retardant, TRIS. The DDT and chlordane were detected in St. Louis impoundment sediments in 1980-81 (LTI, 1984). DDT concentrations ranged from 0.039 mg/kg (Table III-30) at station 1 (Figure III-54) to 8.935 mg/kg at station 12. The distribution of DDT in river sediments was similar to the distribution of PBB in the Pine River at St. Louis. Both DDT and PBB were found to be concentrated at levels exceeding 1.1 mg/kg at Stations 9, 11, 12, 15 and 16. The DDT concentrations exceeded 1.1 mg/kg at stations 18 and 19 as well. The highest concentration of PBB (8.064 mg/kg) was at station 11, while the highest concentration of DDT (8.935 mg/kg) was at station 12. The DDT concentrations in surface sediments downstream of the dam were more than an order of magnitude higher than PBB concentrations, but DDT was measured only 0.7 miles below the dam (Rice et al., 1982).

The highest DDT concentrations in Pine River sediment cores in 1980-81 were below a depth of 10 cm, and concentrations generally in creased with depth up to 80 cm (Table III-31; Figure III-58). The stratification of PBB in the upper 45 cm, and DDT from 10 to 80 cm reflects the periods when these compounds were in production at Michigan Chemical/Velsicol: DDT was manufactured in St. Louis until its ban in 1971, at which time PBB production commenced.

Chlordane has been detected in the deepest sections of core samples at stations 8 and 10 (Table III-31). The highest concentration of 2.813 mg/kg was found at a depth of 68 cm at station 10. The proportions of cis- and trans-chlordane at stations 8 and 10 were unequal, indicating

Table III-29. PBB Concentrations in Sediment Cores Collected from the Pine River, 1980-1981 (Rice et al., 1984).

Station	Slice Depth (cm)	PBB (ug/kg dry wt.)
Upper St. Louis Reservoir		
#3	10.0	316
	20.0	353
	30.0	368
	47.0	<5.0
Mid St. Louis Reservoir		
#6	4.3	70
	14.3	<5.0
	29.3	<5.0
	43.3	<1.0
#8	10.0	126
	21.0	437
	39.5	72
	56.5	17
	59.5	2
	70.5	2
	78.0	<1.0
Lower St. Louis Reservoir		
#10	5.0	449
	15.0	233
	32.0	277
	50.0	58
	68.0	30
#14	7.0	5,452
	23.5	2,265
	45.5	96
	62.0	<5.0
	78.5	<5.0

Table III-29. Continued.

Station	Slice Depth (cm)	PBB (ug/kg dry wt.)
Below Dam/St. Louis Reservoir		
#17	1.0	16
	2.0	39
	3.0	34
	4.0	81
	5.0	3,138
	6.0	951
	7.0	554
	8.0	1,131
	9.0	296
	10.0	26
	12.0	50
	14.0	390
	16.0	10
	18.0	11
	20.0	<4.0
	25.0	<4.0
	30.0	7
	32.0	1
#17 (Replicate Collection)	0-16	176

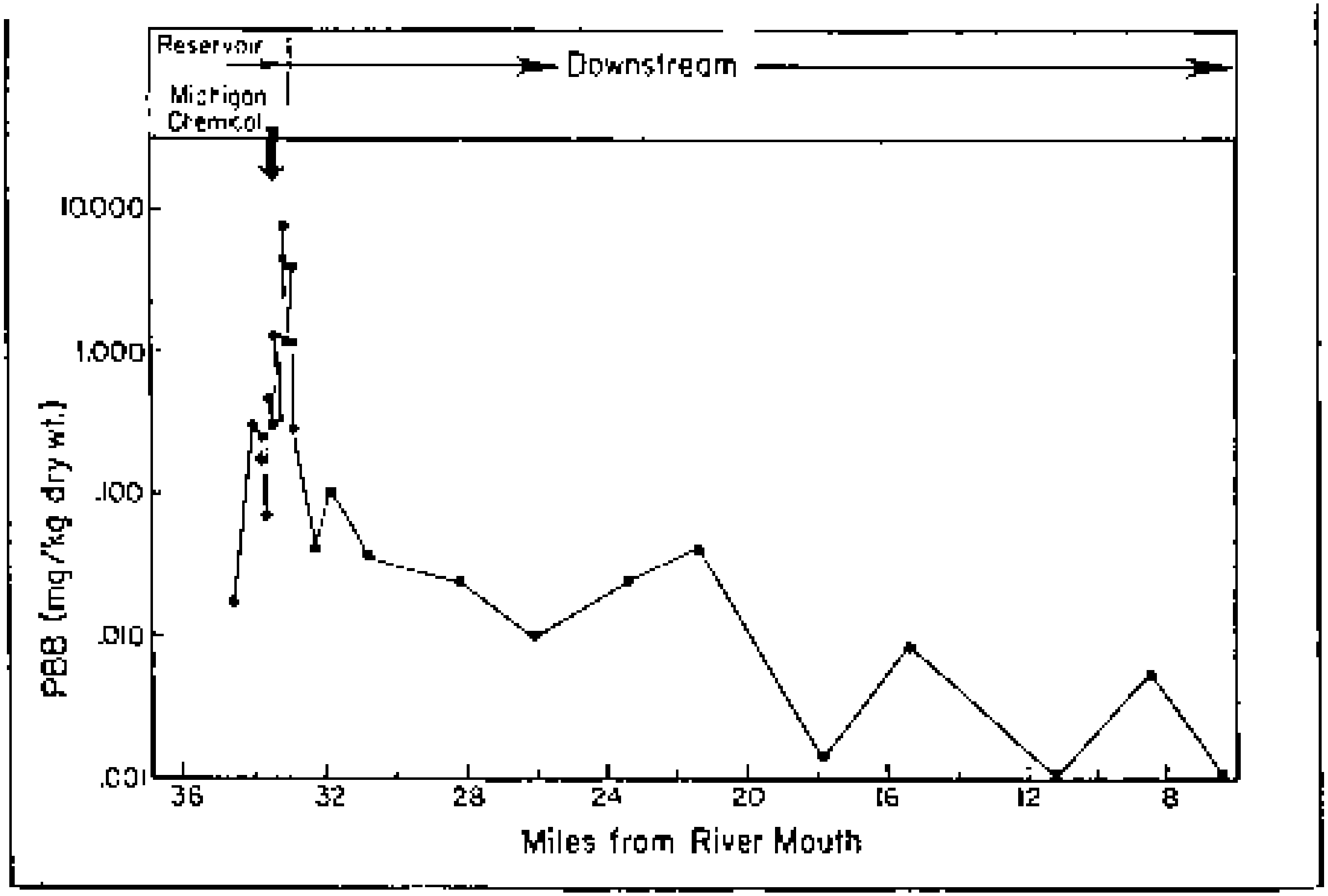


Figure III-56. Spatial distribution of PBB concentrations in surficial sediments of the Pine River, 1980-1981 (TTI, 1984).

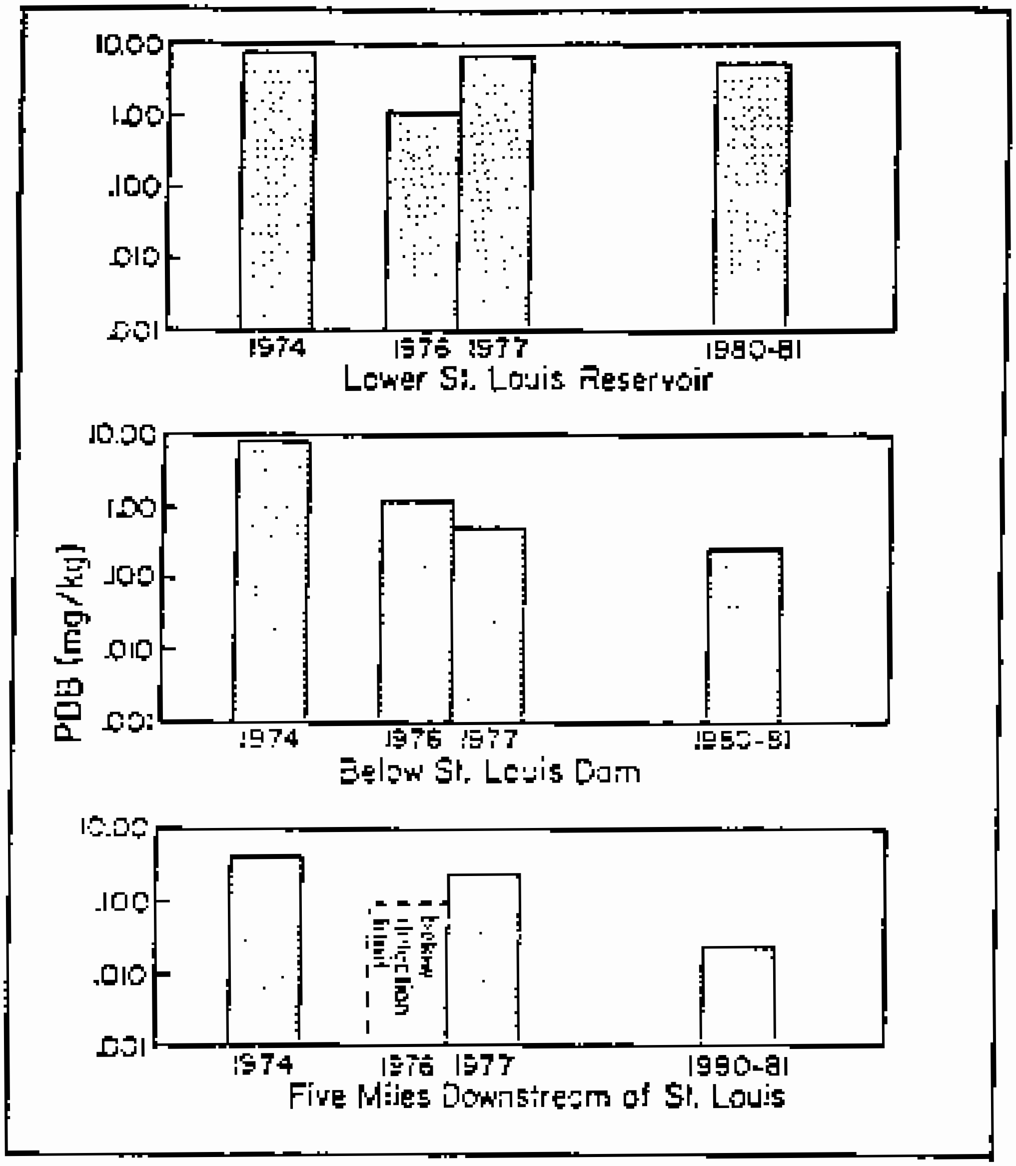


Figure III-57. Historical comparison of PCB concentrations in Pine River sediments, lower St. Louis Reservoir, below St. Louis dam, and five miles downstream ([illegible], 1983).

Table III-30. PBB, DDT and Chlordane Residue Concentrations in Pine River Sediment Grab Samples, 1980-1981, (Rice et al., 1982).

Station	PBB Conc. (ug/kg)	Total DDT Residue (ug/kg)	Percent Composition of DDT Residue			Total Chlordane (cis+trans) (ug/kg)
			% DDE	% DDD	% DDT	
1	23	39	26.65	71.69	1.65	3.2
4	268	69	40.50	20.13	39.37	5.6
5	173	160	4.94	82.88	12.19	8.6
7	496	179	18.88	78.91	2.22	<0.4
9	1,350	5,412	2.55	19.91	77.54	<0.3
11	8,064	1,530	.04	74.35	25.61	<0.7
12	4,586	8,935	.03	71.72	28.31	<0.4
15	1,341	3,746	4.43	84.93	10.64	<0.3
16	1,308	5,451	1.50	93.61	4.89	<0.6
18	41	1,103	1.28	83.43	15.30	<0.1
19	106	3,193	.63	26.90	72.47	0.0

Table III-31. PBB, DDT and Chlordane Residue Concentrations in Pine River Core Samples, 1980-1981, (Rice et al., 1982).

Station	Core Depth (cm)	PBB Conc. (ug/kg)	Total DDT Residue (ug/kg)	Percent Composition of DDT Residue			Total Chlordane (cis+trans) (ug/kg)
				% DDE	% DDD	% DDT	
3	20.00	353	126	6.66	84.09	9.25	12.6
3	30.00	367	313	29.08	36.66	34.26	11.6
3	47.00	0.0	546	27.75	50.84	21.41	21.2
8	10.00	126	359	8.72	24.89	66.39	<0.4
8	21.00	437	337	34.73	41.35	23.92	2.0
8	39.50	72	396	59.07	25.06	15.87	7.2
8	56.50	17	845	25.39	10.36	64.25	<0.1
8	59.50	2	310	73.70	12.96	13.34	20.3
8	70.50	2	861	29.51	6.65	63.84	<0.6
8	78.00	<0.1	209,316	1.89	73.28	24.84	1,513.2
10	15.00	233	4,608	18.42	39.06	42.52	0.0
10	32.00	277	89,005	8.59	32.70	58.71	2,757.6
10	50.00	30	99,119	5.28	30.50	64.21	1,946.0
10	68.00	58	3,570,109	0.37	0.35	99.28	2,813.0
14	23.50	2,265	4,696	11.57	81.76	6.67	120.3
14	45.50	96	107,343	99	83.96	15.05	<0.2

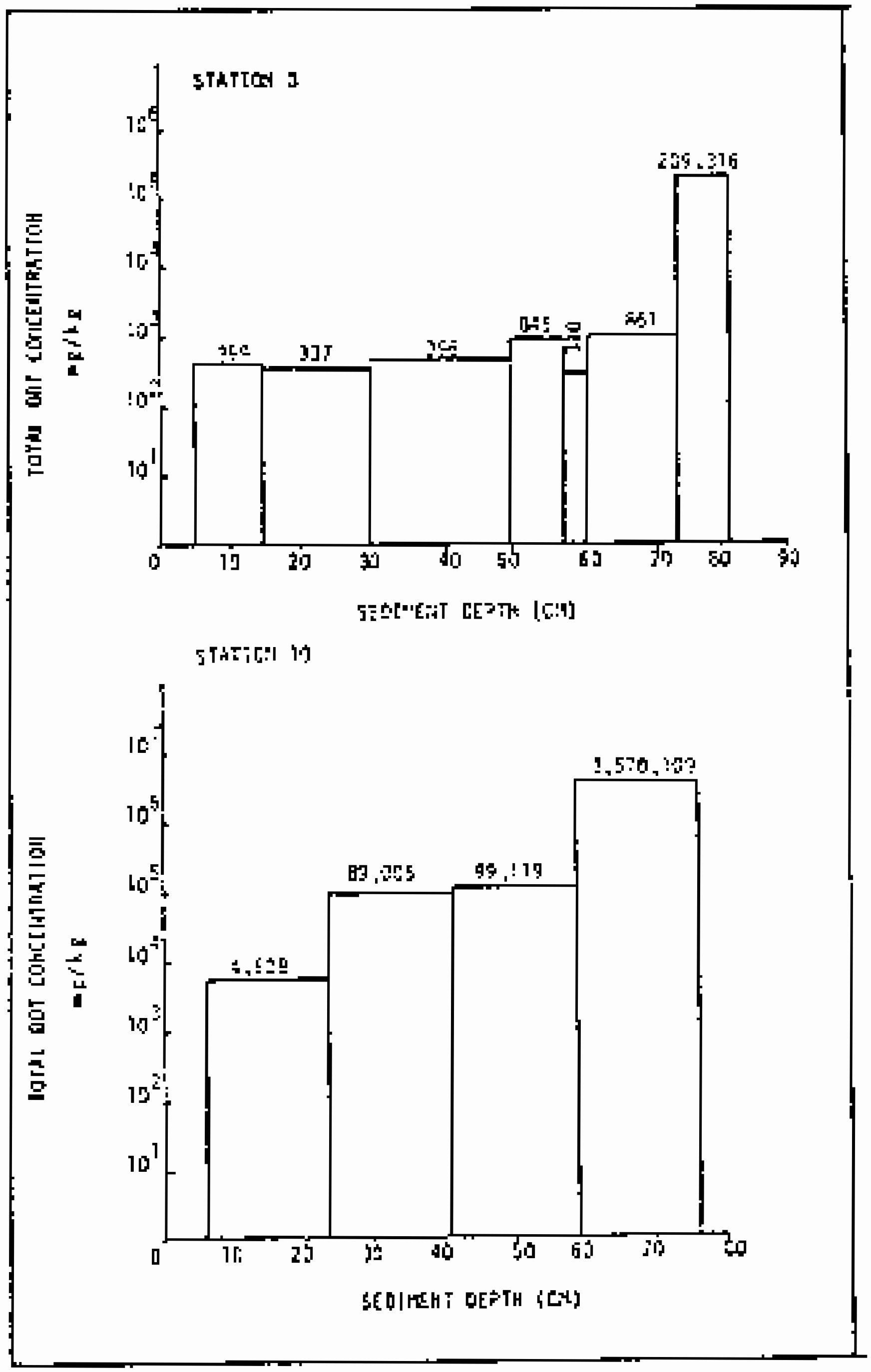


Figure III-58. Vertical DDT distribution, plotted on a log scale, in St. Louis Reservoir sediments offshore of the Michigan Chemical Corporation (ECMPDR, 1983).

that the source was likely the Michigan Chemical plant (Rice et al., 1982).

f. Saginaw River

Saginaw River sediments have been contaminated by PCBs from industrial and municipal discharges. The MDNR first sampled the Saginaw River for PCBs in 1971 and found concentrations ranging from 0.65 to 5.36 mg/kg in settleable solids from a station 1.5 miles upstream of the river mouth (Rice et al., 1980). Sediment samples were not taken at that time.

An August 1976 MDNR survey of Saginaw River surficial sediments found PCB concentrations in samples from above the Saginaw WWTP at RM 15.2 (Figure III-59) and below the General Motors Chevrolet facility at Bay City at RM 3.8 (Figure III-60) of 1.25 mg/kg and 23 mg/kg, respectively. Additional sampling of sediments from the Saginaw River navigation channel in October 1976 was conducted by the U.S. Army Corps of Engineers (USACOE). Sediments from 48 stations (37 river, 11 bay) located in the Saginaw River federal navigation channel were analyzed. Four samples exceeded the USEPA standard for open water disposal of polluted sediments of 10 mg/kg PCB dry weight by 1.8 to 12.9 mg/kg (Rice et al., 1980). Three of these heavily contaminated sites were located near the City of Saginaw between RMs 15 and 16 and the fourth was located near Bay City just below RM 3. The highest PCB concentration measured during the October 1976 sediment sampling was 22.9 mg/kg at RM 15.5 between the Zilwaukee Bridge and the Saginaw WWTP.

PCB contamination is not limited to the federal navigation channel. A study by Edmands Engineering in 1978 of two stations at RM 3.5 produced data indicating a greater concentration of total PCB adjacent to the navigation channel than within it; the concentration of PCBs in sediments from areas adjacent to the navigation channel reached 5.9 mg/kg while the concentration in the navigation channel was 1.4 mg/kg (Figure III-61; Rice et al., 1980).

A MDNR survey later in 1978 examined samples from four transects at RMs 2.5, 4.5 (Figure III-60), 15.5, and 18.0 (Figure III-59). At RM 18.0, upstream of the General Motors plants at Saginaw, all samples fell below the detection limit of 0.2 mg/kg. At RM 15.5, downstream of the Saginaw WWTP, two stations had total PCB concentrations at or in excess of 1.0 mg/kg, with the highest at 6.1 mg/kg (Figure III-61). At RM 4.5, upstream of the General Motors plant at Bay City, two stations had total PCB concentrations greater than 1.0 mg/kg, with the highest at 7.2 mg/kg. At RM 2.5, all five stations had total PCB concentrations at or exceeding 2.5 mg/kg, and two stations had high levels of 14.4 and 25.1 mg/kg.

In a 1978 USACOE survey of sediments in the Saginaw River, the three highest surface sediment PCB concentrations were found at stations SR-4, SR-5, and SR-7 (Table III-32). Stations SR-4 and SR-5 were just upstream of the MDNR's station 2 and SR-7 was just downstream of station 2 (Figure III-61). The only other station to have a concentration in excess of 10 mg/kg total PCB was SR-26 at 11.8 mg/kg which was located just downstream of the MDNR's Station 4.

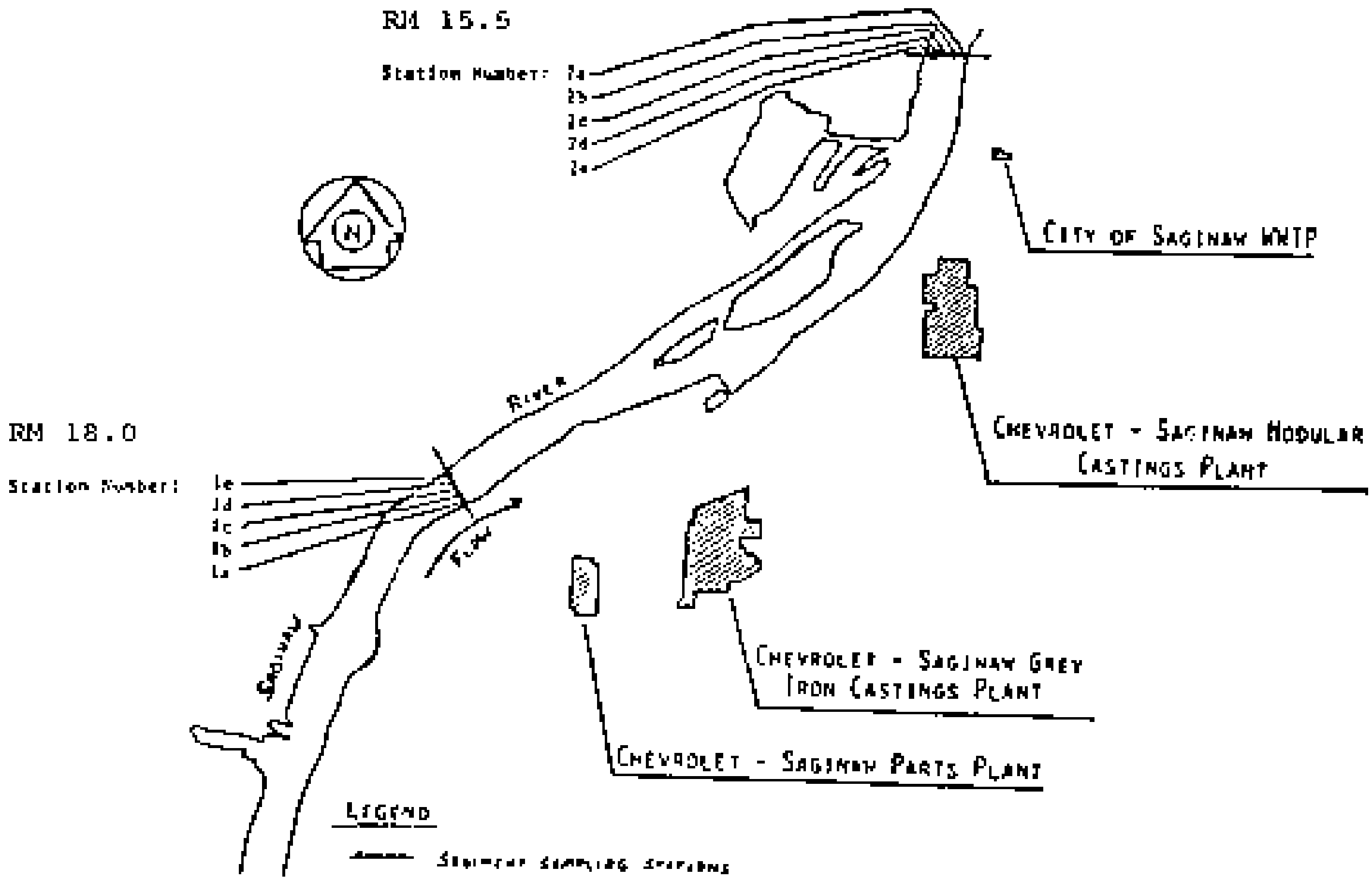


Figure III-59. MDNR sediment sampling locations in the Saginaw River at river miles 15.5 and 18.0 near Saginaw, 1978 (MDNR, 1978).

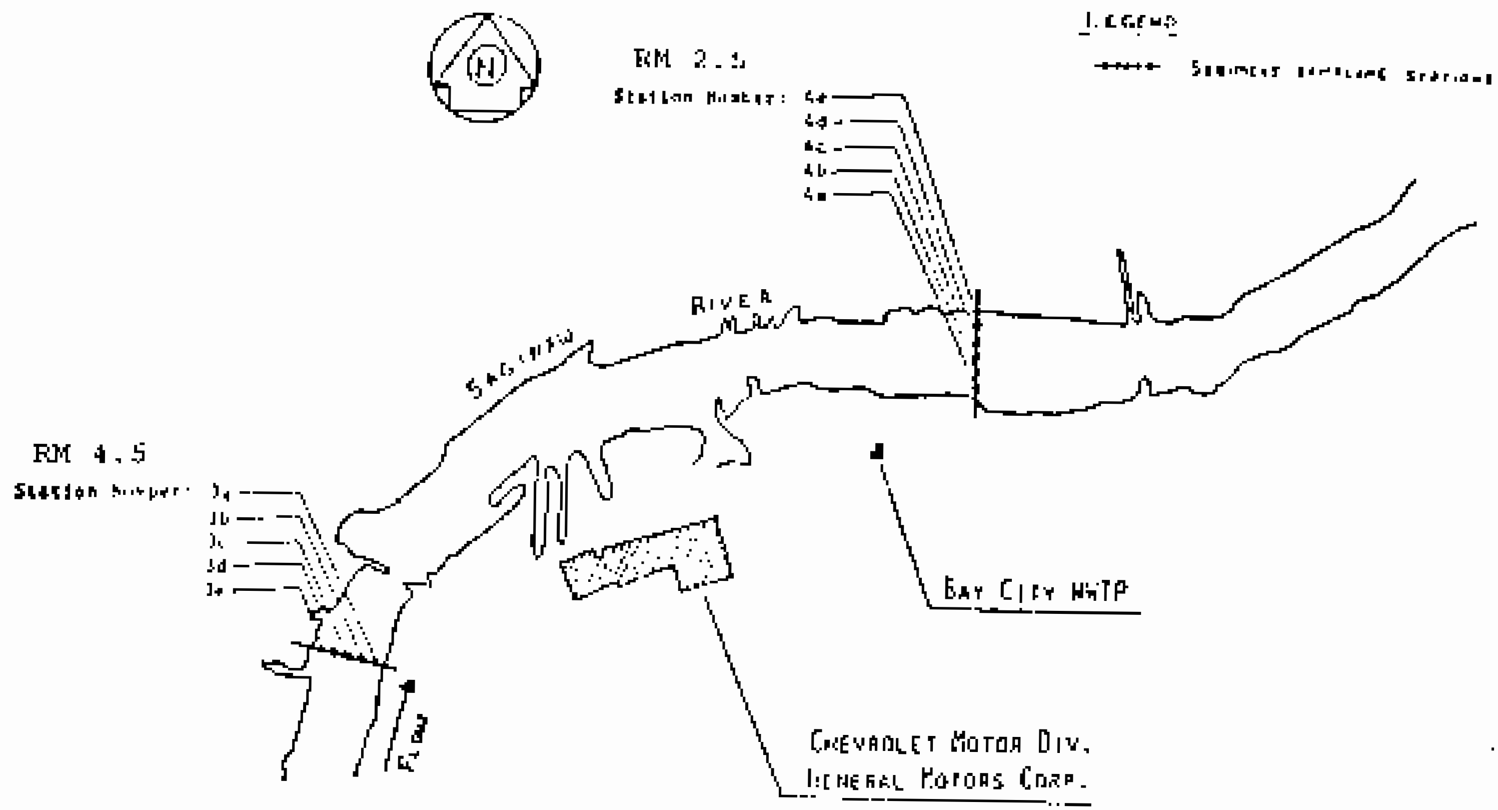


Figure III-60. MDNR sediment sampling locations in the Saginaw River at river miles 2.5 and 4.5 near Bay City, 1978 (MDNR, 1979).

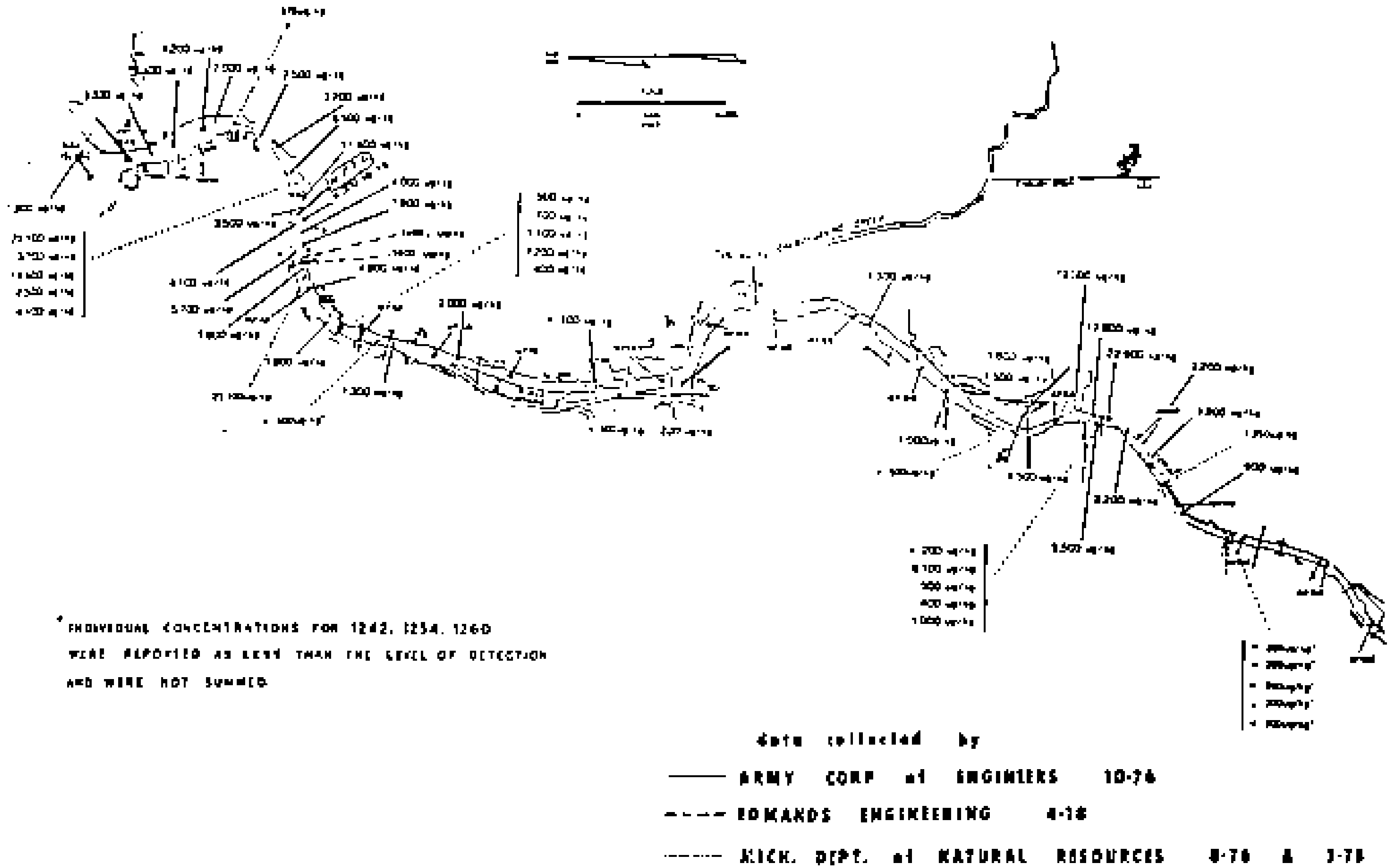


Figure III-61. Sediment sampling locations and PCB concentrations, Saginaw River (Rice, et al., 1980).

Table III-32. PCB, Dibenzofuran and Dibenzodioxin Concentrations in Saginaw River Sediments, 1978, 1980 and 1983 (USFWS, 1983).

Station	1978 Total PCB (mg/kg)	1980 Total PCB (mg/kg)	1983 PCB 1016, 1221 1232, 1242 1248[2]; 1254 1260; (mg/kg)		1983 2,3, 7,8-TCDF (ng/kg)	1983 2,3, 7,8-TCDF (ng/kg)
SR-1	0.9	<0.015	ND[3]		85	NA[4]
SR-2	1.2	-	ND		-	-
SR-3	2.2	1.1	2.0	(1248)	-	-
SR-3A	2.2	2.8[5]	ND		-	-
SR-4	22.9	0.11[5]	0.46	(1248)	-	-
SR-5	12.8	0.745	2.1	(1242)	35	ND
SR-6	5.5	-	7.6	(1242)	-	-
			1.7	(1254)		
SR-7	12.3	4.565	6.9	(1248)	-	-
SR-7A	1.8	<0.02	0.35	(1248)	-	-
SR-8	1.5	-	1.4	(1248)	-	-
SR-9	4.5	0.12	0.12	(1248)	-	-
SR-10	1.0	1.1	1.0	(1248)	-	-
SR-11	1.3	-	0.47	(1248)	-	-
SR-12	0.1	1.42	0.63	(1248)	-	-
SR-13	0.2	0.605	0.94	(1248)	-	-
SR-14	<0.1	1.2	0.93	(1248)	-	-
SR-14A	-	0.46	-		-	-
SR-15	2.0	0.11	ND		390	NA
SR-16	1.3	-	0.27	(1248)	-	-
SR-16A	-	1.28[5]	-		-	-
SR-17	1.9	1.9	0.22	(1248)	-	-
SR-18	4.8	<0.1	0.62	(1248)	-	-
SR-19	7.6	2.75	1.2	(1248)	-	-
SR-20	5.7	7.6	2.1	(1248)	-	-
SR-21	7.9	9.9	2.1	(1248)	-	-
SR-22	4.0	-	4.1	(1248)	-	-
SR-23	4.0	-	4.0	(1248)	95	ND
SR-24	4.1	0.42	4.9	(1248)	-	-
SR-25	3.5	6.3	22	(1248)	-	-
SR-26	11.8	2.0	27	(1248)	15	NA
SR-27	6.5	0.315	0.84	(1248)	-	-
SR-28	3.2	5.8	12	(1248)	-	-
SR-29	2.5	0.46	1.5	(1248)	-	-
SR-30	2.0	2.0	1.1	(1248)	-	-
SR-31	1.2	-	0.53	(1242)	-	-
SR-32	5.4	-	1.2	(1248)	-	-
SR-33	3.3	-	13	(1248)	220	ND
SR-34	2.1	-	2.5	(1248)	-	-
Site [6][6]	-	-	-		3000 (1981)	1000 (1981)
SR-35	1.9	-	0.62	(1242)		

The USACOE conducted a sediment survey of 23 stations in the navigation channel in 1980. The surface sediment sample from SR-21, just upstream of MDNR Station 4, had the highest concentration of total PCB at 9.9 mg/kg (Table III-32). The PCB concentrations at SR-4, SR-5, and SR-7, the locations of the highest concentrations in 1978, decreased at least an order of magnitude by 1980.

A 1980 sediment survey by MDNR found the most heavily PCB contaminated surface sediments from RMs 5.0 to 1.0 in the Bay City area (Figure III-62). Individual samples at RMs 3.0 and 1.0 surpassed the USEPA standard of 10 mg/kg for open water disposal of polluted sediments. Sediments outside the navigation channel between RMs 1-3 were found to be highly contaminated in the shallow areas closer to the shoreline. The highest measured surface concentration of PCB was 33 mg/kg at RM 3.2 (ECMPDR, 1983). Surface sediment PCB concentrations in the navigation channel at Bay City changed little from 1976 to 1980-81 (Figures III-63 and III-64). However, a substantial decrease occurred near the City of Saginaw (RMs 16-14), which may be at least in part due to maintenance dredging by USACOE (ECMPDR, 1983).

In a 1983 USACOE survey of surface sediments, several stations were frequently among those with the highest concentrations of conventional, metal and organic pollutants. Station SR-3, located near the Chevrolet Nodular Castings Plant (Figure III-65), had high levels of PAHs, As, Cu, Cr and Pb (Tables III-33 and III-34). Site SR-7, downstream of the Saginaw WWTP, had the highest concentrations of PAHs, total P and As, as well as elevated concentrations of Cu, Cr, Pb, Ni and Zn. Location SR-26, downstream of the General Motors Chevrolet facility and the WWTP in Bay City (Figure III-66), exhibited the highest concentrations of Cu, Cr, Fe, Pb and Ni. Station SR-26 was also the site of the highest total PCB concentration, 27 mg/kg (Table III-32). Other high PCB concentrations were found at SR-25, SR-28, and SR-33.

High levels of contaminants were found in sediment cores collected in the Saginaw River (Figure III-67) in 1980 - 1981 by Rice et al. (1983) at two stations near and below the Bay City WWTP outfall. The PCB contamination exceeded 100 mg/kg between the 10 and 15 cm depths at station 32 and between 20 and 30 cm at station 33 (Figure III-68). The PCB contamination was found as deep as 80 cm and many cores did not reach uncontaminated sediments despite efforts to obtain deep cores (ECMPDR, 1983). Concentrations of PCB exceeding 500 mg/kg were detected between 25 and 30 cm at station 32. Sediments at Station 32 were also heavily polluted, based on the USEPA Great Lakes harbor sediment classification for open water disposal of dredge spoils with As, Cd, Cr, Cu, Fe, Pb, Mn, Zn and PAHs (ECMPDR, 1983). Concentration profiles in other cores from the Bay City area show similar depth patterns, but have lower maxima, ranging from 5 to 114 mg/kg PCB (ECMPDR, 1983).

At the City of Saginaw, core analyses show significantly lower PCB concentrations (maxima less than 2 mg/kg) and less vertical change (maxima between 20 and 35 cm), with no consistent contamination pattern present (Figure III-69). At station 70, below the City of Saginaw, sediments were also moderately to heavily contaminated with As, Cr, Cu, Fe, Pb, Mn, Zn and PAHs (ECMPDR, 1983). In channel border areas at both

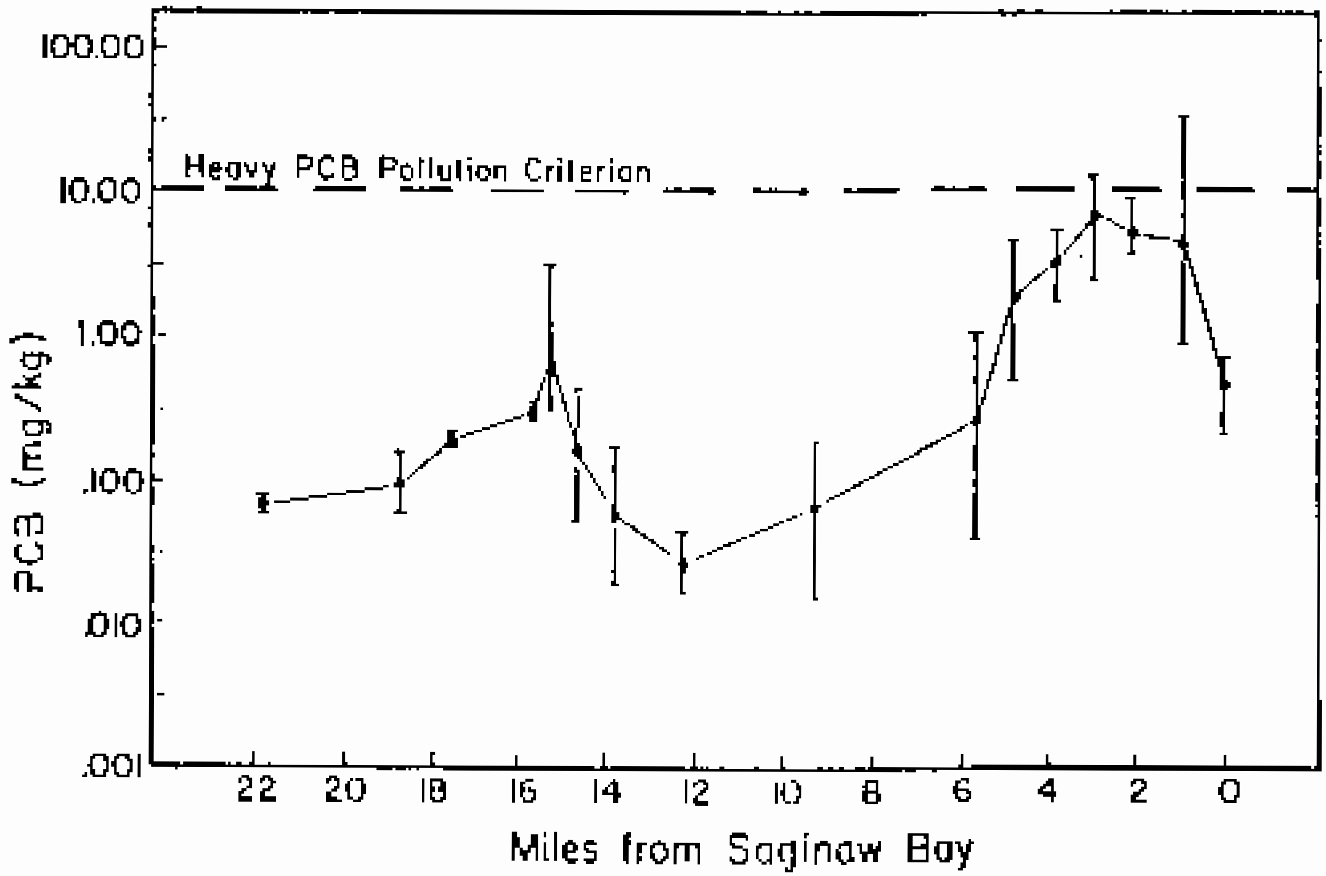


Figure III-62. PCB distribution in surficial sediments of the Saginaw River, transect means and ranges, 1980-1981 ([illegible], 1984).

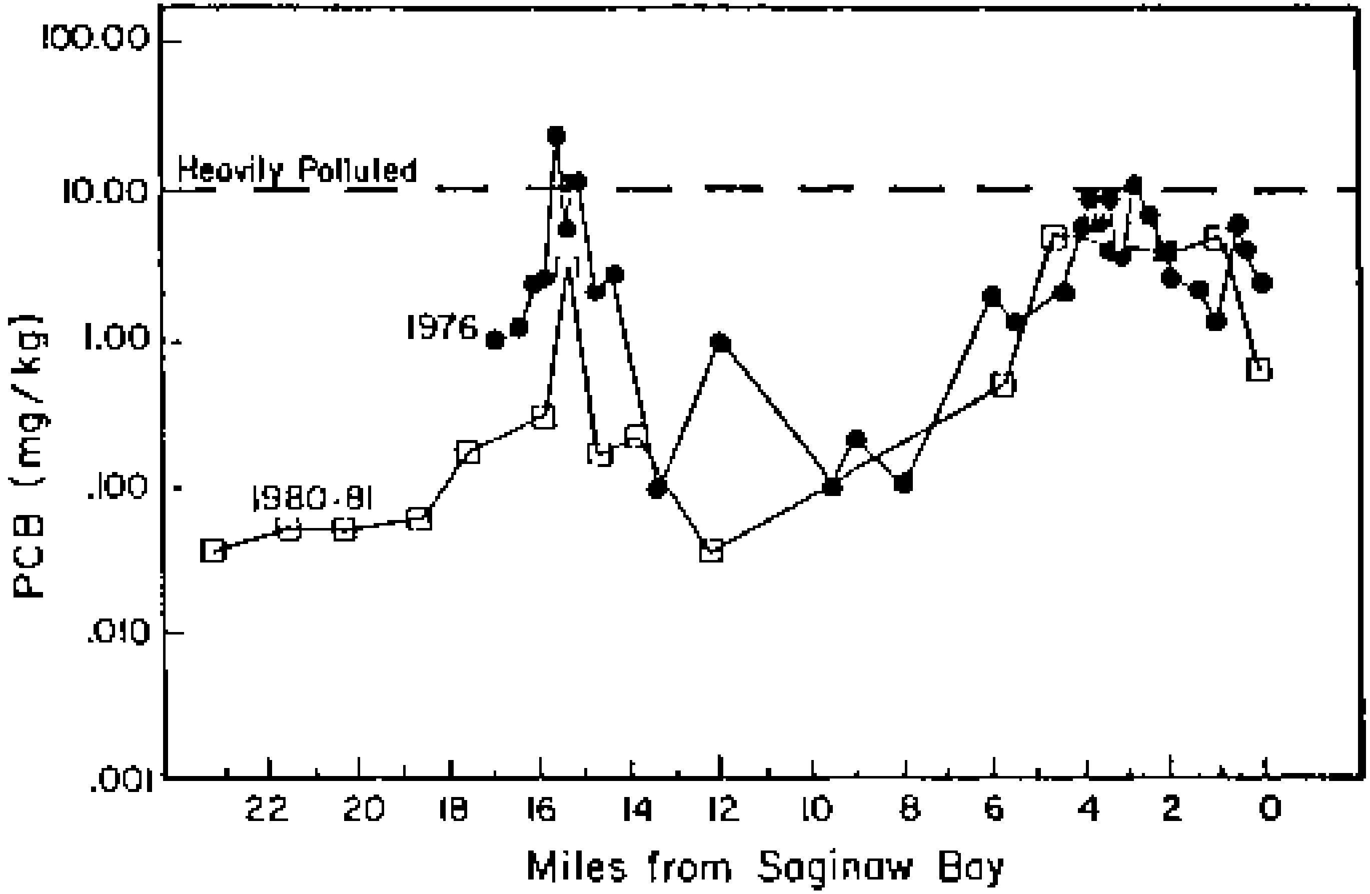


Figure III-63. Comparison of PCB distributions in 1976 USACOE sediment survey and 1980-1981 surficial sediment survey, Saginaw River navigation channel (LTI, 1981).

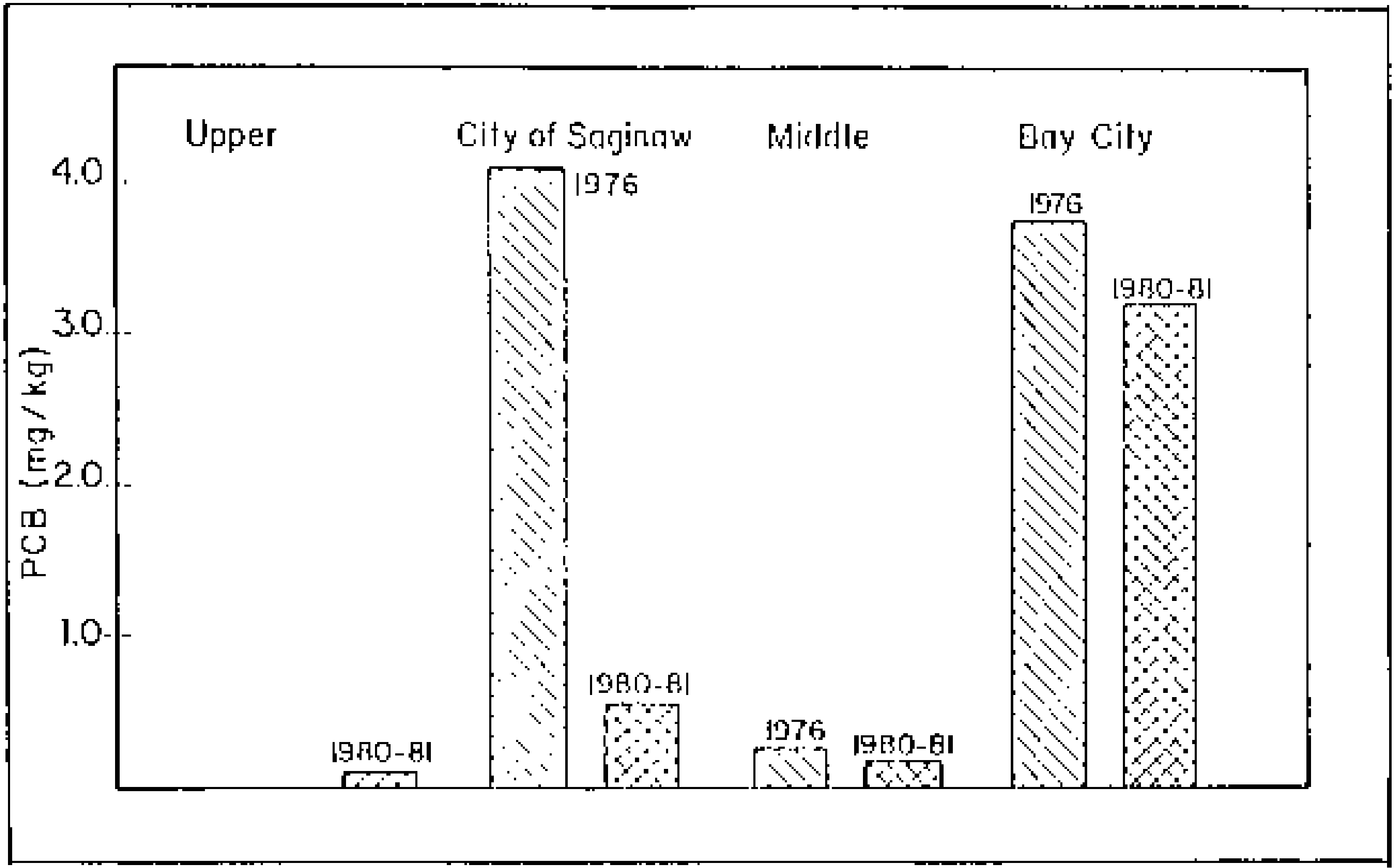


Figure III-64. Comparison of geometric mean PCB concentrations in surficial sediments of the Saginaw River navigation channel, 1976 USACOE survey and 1980-1981 (ETI, 1983).

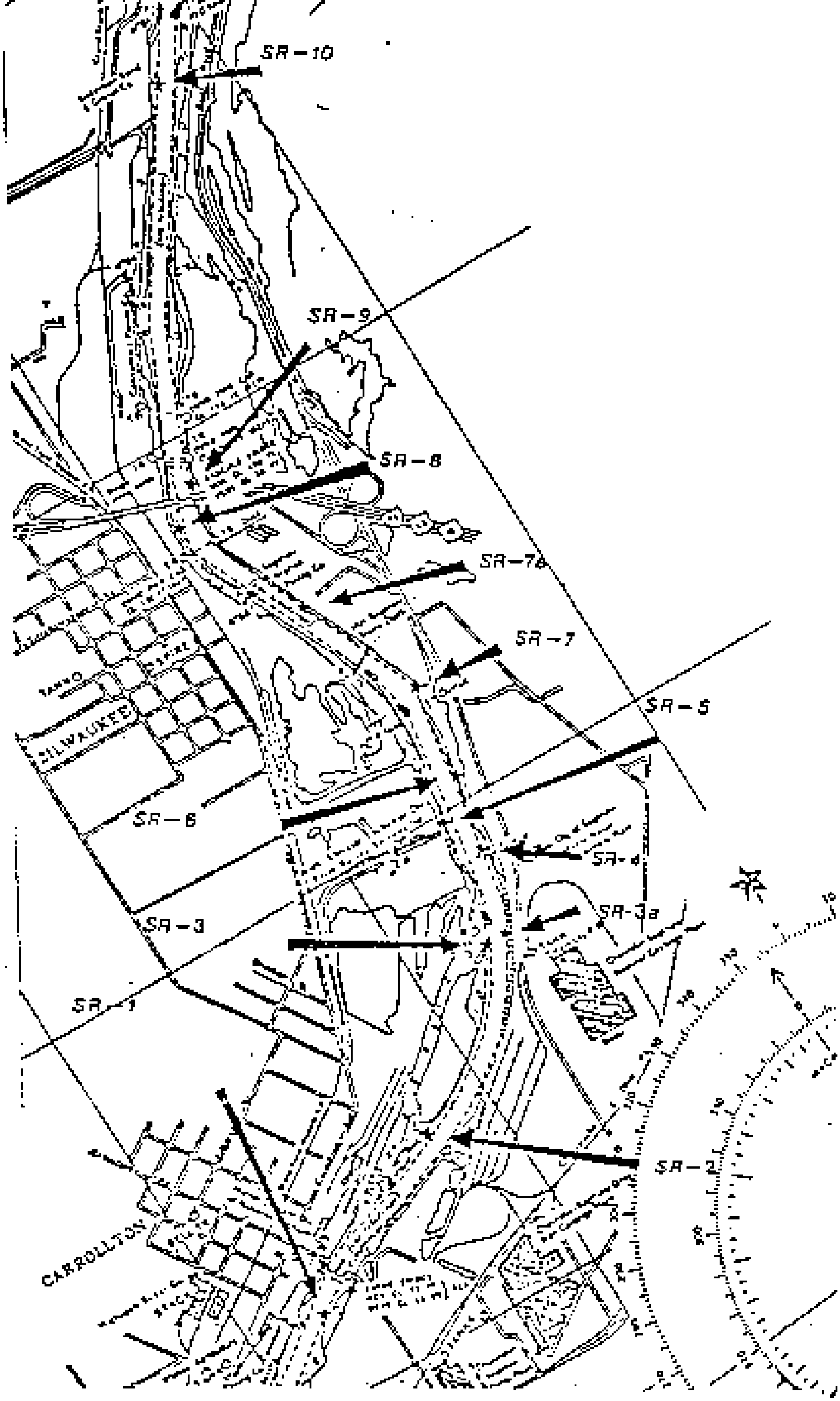


Figure III-65. Saginaw River sediment sampling stations, near the City of Saginaw, 1983 (USACOE, 1983).

Table III-33. Saginaw River Navigation Channel Sediment Concentrations (mg/kg) of Selected Metal Parameters, 1983, (USACOE, 1983).

Station	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
1	6.7	0.8	23	39	9,900	-	250	12	21	100
2	3.4	0.9	13	12	6,100	-	100	5	10	65
3	18	2.2	90	99	26,000	0.2	520	36	65	250
3A	9	<0.8	29	10	21,000	-	1,000	23	4	64
4	9.1	1.2	28	30	14,000	0.2	370	18	34	220
5	8.9	0.8	32	35	17,000	0.2	670	17	13	110
6	12	2.2	96	82	26,000	0.3	620	36	55	260
7	20	2.7	110	130	21,000	0.2	520	38	71	340
7A	8.1	1.2	44	37	16,000	-	420	22	45	310
8	12	1.5	53	61	15,000	0.1	410	27	48	260
9	5.7	1.0	22	16	11,000	0.2	310	14	26	340
10	20	1.8	67	71	21,000	0.3	490	32	54	330
11	6.9	1.2	54	22	8,600	-	190	15	20	150
12	12	2.0	56	60	22,000	0.1	550	33	64	520
13	9.1	1.7	56	45	15,000	-	350	25	33	270
14	7.7	-	41	52	13,000	0.1	310	23	29	140
15	9.4	-	16	11	15,000	-	420	18	11	150
16	5.4	-	15	15	8,100	-	180	14	11	110
17	4.4	-	12	8	7,700	-	150	12	12	130
18	5.0	-	18	-	9,300	-	210	14	16	170
19	8.5	-	30	-	14,000	-	350	25	32	280
20	5.0	-	37	-	8,600	0.2	200	18	21	150
21	4.2	-	29	19	9,900	-	200	22	23	180
22	7.5	-	10	9	12,000	-	310	18	8	74
23	8.4	-	35	28	14,000	-	310	26	33	260
24	10	-	54	44	20,000	-	470	35	72	380
25	12	-	110	75	20,000	0.2	460	52	61	310
26	17	3.5	180	150	34,000	0.2	680	87	96	500
27	9.7	-	30	32	16,000	-	380	29	33	230
28	9.6	1.7	75	66	12,000	-	310	40	44	260
29	12	2	76	64	17,000	-	540	45	72	550
30	14	1.2	57	49	20,000	-	500	31	58	490
31	18	1.2	60	56	24,000	-	730	40	63	560
32	20	1.8	67	71	21,000	0.3	490	32	54	330
33	6.9	1.2	54	22	8,600	-	190	15	20	150
34	12	2.0	56	60	22,000	0.1	550	33	64	520
35	9.1	1.7	56	45	15,000	-	350	25	33	270
36	7.7	-	41	52	13,000	0.1	310	23	29	140

Table III-34. Saginaw River Navigation Channel Sediment Concentrations (mg/kg) of Selected Conventional and Organic Parameters, 1983 (USACOE, 1983).

Station	Total P	TKN	PAH	Phenols
1	410	1,500	690	–
2	190	1,000	440	0.32
3	690	1,900	3,200	0.21
3A	330	2,400	430	–
4	540	980	3,100	–
5	710	2,800	2,300	–
6	790	970	2,700	–
7	1,500	2,600	12,000	–
7A	580	1,200	910	–
8	570	1,100	2,800	–
9	360	120	490	–
10	610	1,800	3,300	–
11	460	1,000	1,600	–
12	600	5,800	2,600	–
13	410	4,100	2,000	–
14	590	3,400	1,900	1
15	240	4,800	–	–
16	280	4,400	–	–
17	220	3,200	–	–
18	280	3,400	–	–
19	590	4,500	–	–
20	380	1,200	–	–
21	350	760	–	–
22	530	1,600	–	–
23	530	820	–	–
24	1,000	2,200	–	–
25	1,400	3,000	–	–
26	760	1,600	–	–
27	810	3,300	–	–
28	960	3,700	–	–
29	940	5,100	–	–
30	1,200	4,600	–	–
31	910	4,800	–	–
32	610	1,800	3,300	–
33	460	1,000	1,600	–
34	600	5,800	2,600	–
35	410	4,100	2,000	–
36	590	3,400	1,900	1

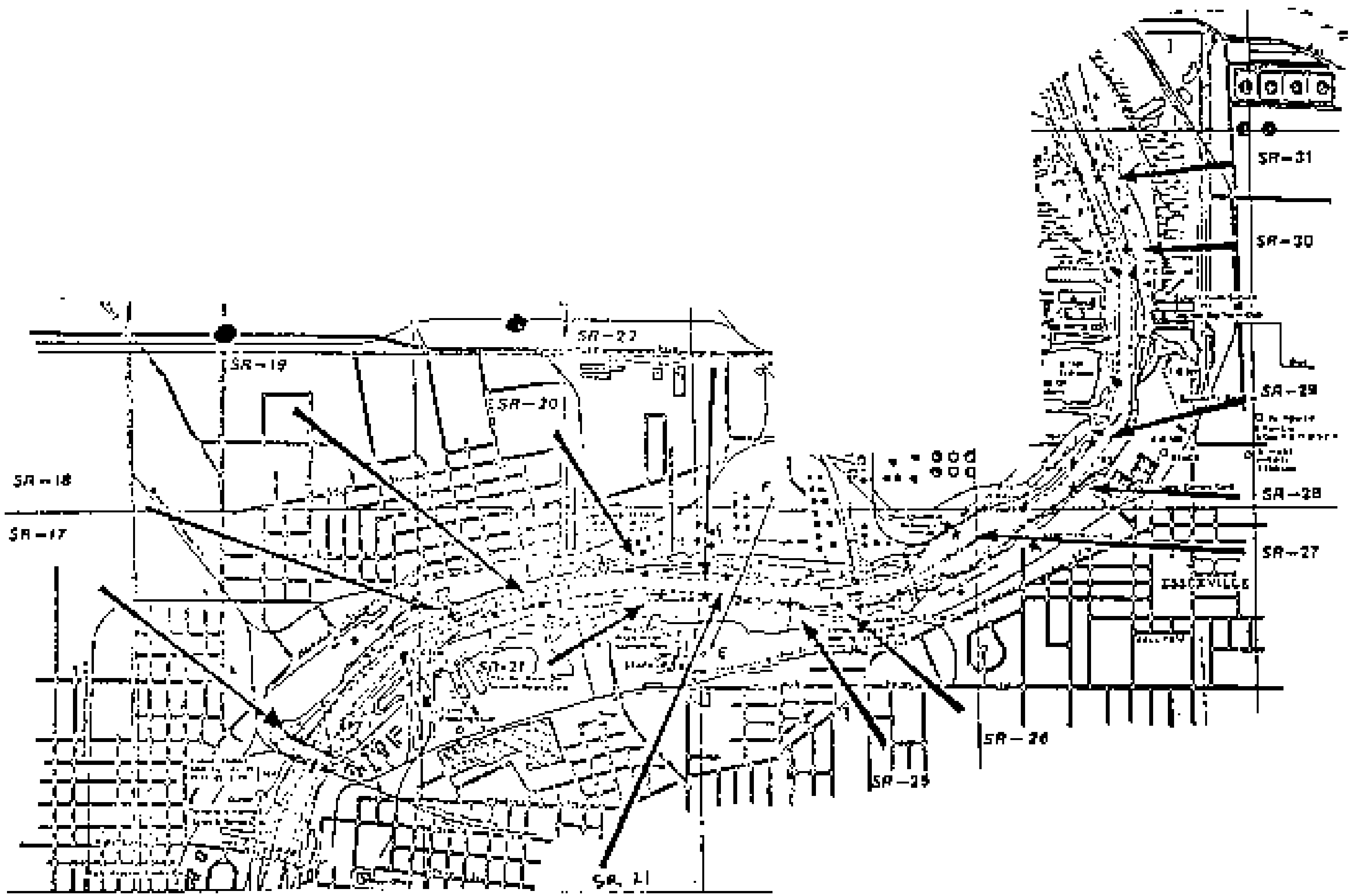


Figure III-66. Saginaw River sediment sampling stations, near Bay City, 1983 (USACOE, 1983).

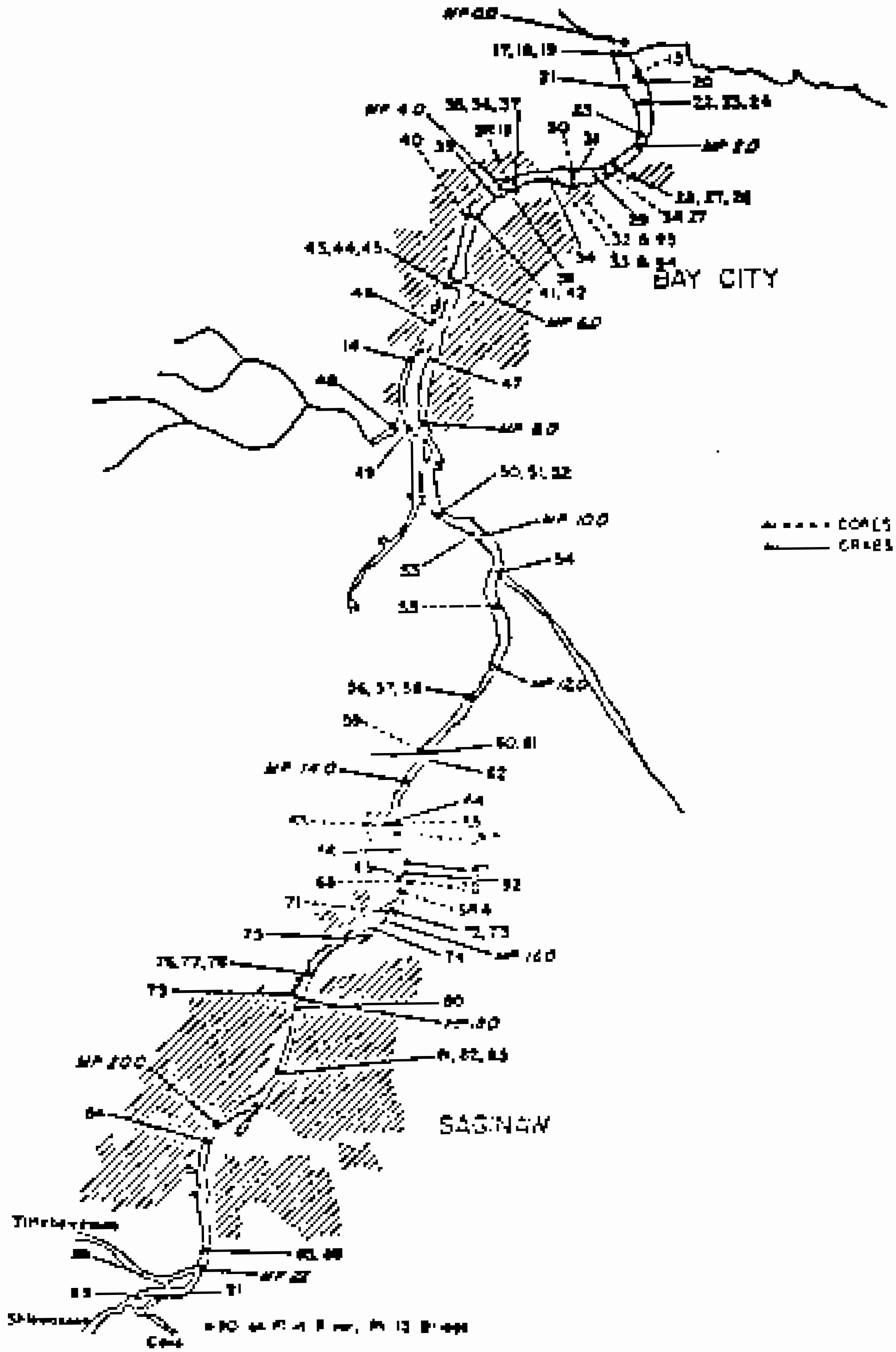


Figure III-67. Saginaw River sediment sampling stations of Rice, et al., 1980-1981 (ECMPDR, 1983).

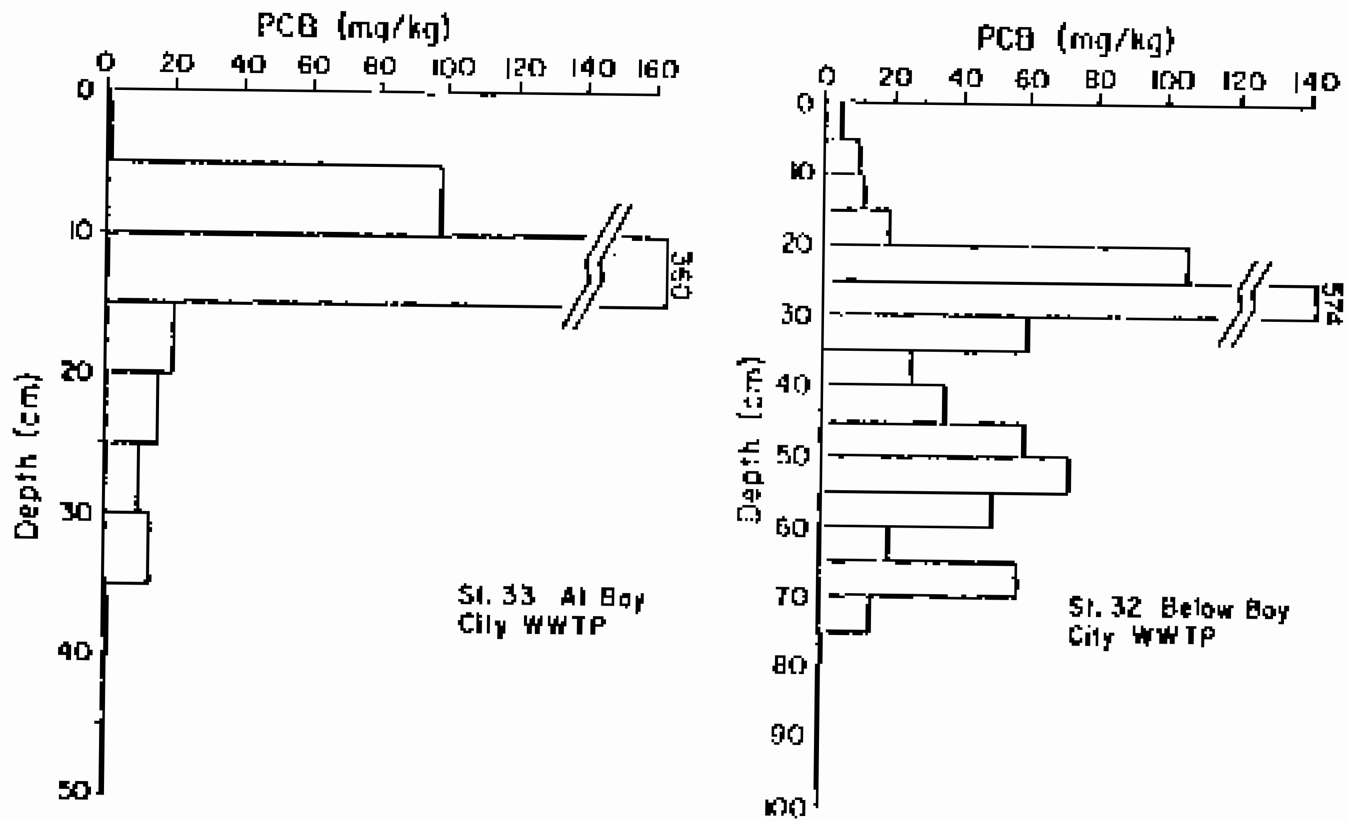


Figure III-68. Vertical PCB distribution in Saginaw River sediments near Bay City WWTP, 1980-1981 (LTI, 1983).

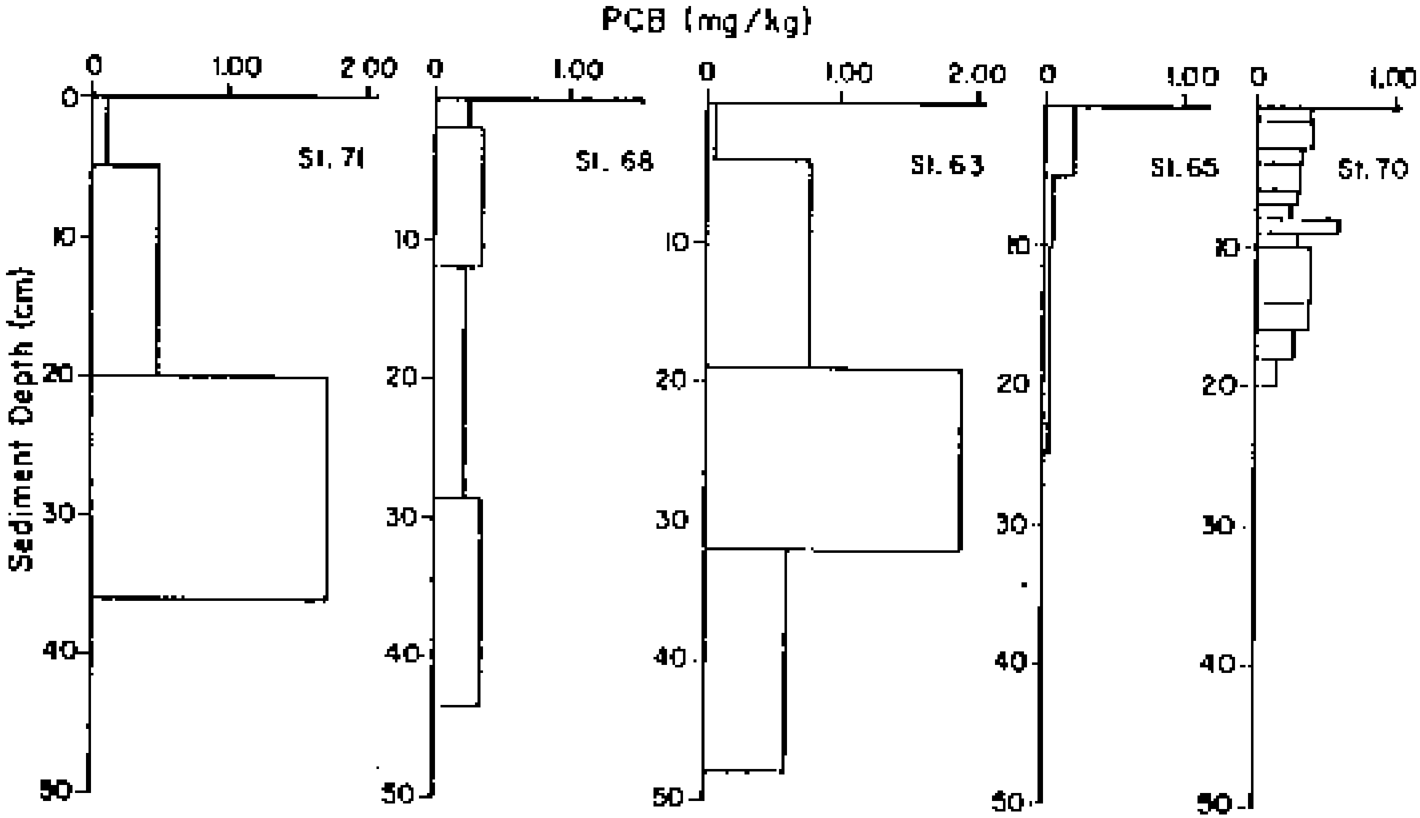


Figure III-69. Vertical PCB distribution in Saginaw River sediments at Saginaw, 1980-1981 (LTI, 1983).

the City of Saginaw and Bay City, the greatest PCB concentrations were below a depth of 10 cm and were therefore not in the active sediment layer, which should render them immobile (Rice et al., 1980). However, navigational dredging in the channel and scouring effects by the river itself in the border areas could potentially re-expose these contaminated sediments.

High levels of PCB are present near the outfalls of two industrial facilities that discharged contaminated wastes to the river: the General Motors Central Foundry in Saginaw, and the General Motors-CPC plant in Bay City (Figure III-70). In addition to discharging directly to the river, these establishments also sent contaminated wastewater to their respective WWTPs. Like most WWTPs, the City of Saginaw and Bay City facilities were not designed to treat halogenated hydrocarbons or high concentrations of heavy metals, and contaminated wastes were subsequently discharged to the river from these sources as well. Although the highest concentrations of PCB were near the discharge outfalls, mixing across the channel and upstream of the outfalls also occurred.

2. Saginaw Bay Sediments

a. Deposition Rates

During the period 1975 to 1978, sediment cores and grab samples were obtained from over 100 sites in inner Saginaw Bay where fine-grained sediment deposits occur (Figure III-71). Sediments were not collected from the outer bay because outer bay sediments consist primarily of coarser materials, such as sand, that tend to not adsorb contaminant materials (Robbins, 1986).

There is an extensive mud deposit, covering approximately 400 km^2, in the inner bay. The deposit is in the deeper waters following bathymetric contours, and is skewed toward the western side of the bay in shallower waters. Mud deposition coincides with bay current patterns, which are influenced by the Saginaw River and wind direction (Robbins, 1986). Toward the center of this deposit, the clay content exceeds 50% (Figure III-72), with the mean grain size increasing toward the margins of the deposit (Figure III-73).

Vertical distributions of radionuclides reveal a zone of constant mixing activity that extends from the sediment-water interface to depths ranging from 10 to 25 cm. Maximum deposition of ^{137}Cs occurred in 1963-64 and, due to its short residence time in the water column of approximately one year (Barry, 1973; Edgington and Robbins, 1975), should be observable as a distinct peak in cores where sedimentation rates are moderate to high (Robbins, 1982). Vertical ^{137}Cs activity profiles in Saginaw Bay cores were uniformly high in the top few centimeters and then decreased to near detection levels (Robbins, 1980), a pattern closely related to macrozoobenthos vertical distributions (Figure III-74). When the values for the depth to which 90% of the macrozoobenthos occurred (Z_{90}benthos) were regressed against the values for the depth to which 90% of the ^{137}Cs occurred (Z_{90}Cs), defined as the mixed layer by Robbins (1982), there was a nearly linear relationship (Figure III-75). This

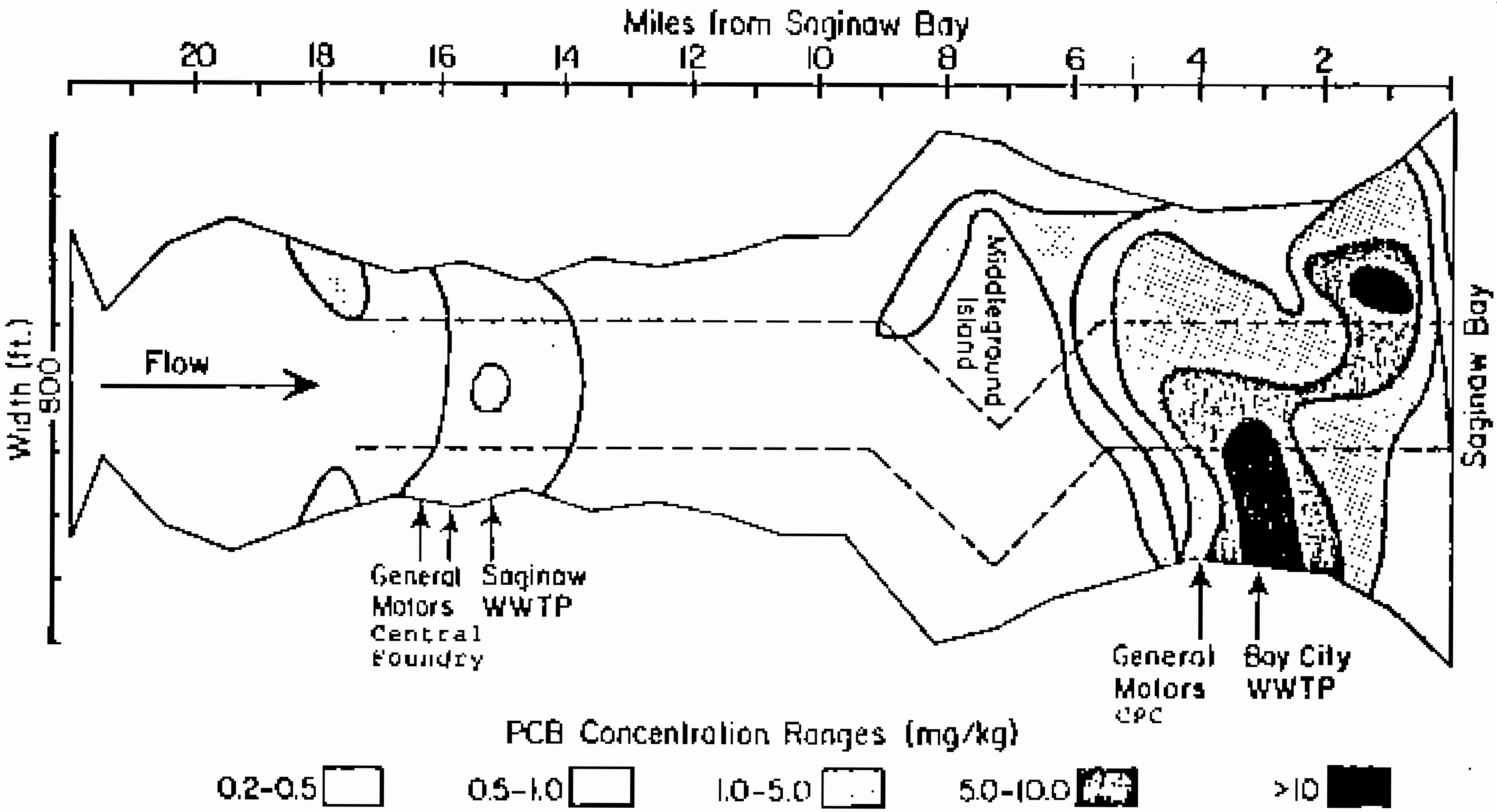


Figure III-70. Spatial distribution of PCB in surficial sediments of the Saginaw River, 1980-1981 (LTI, 1983).

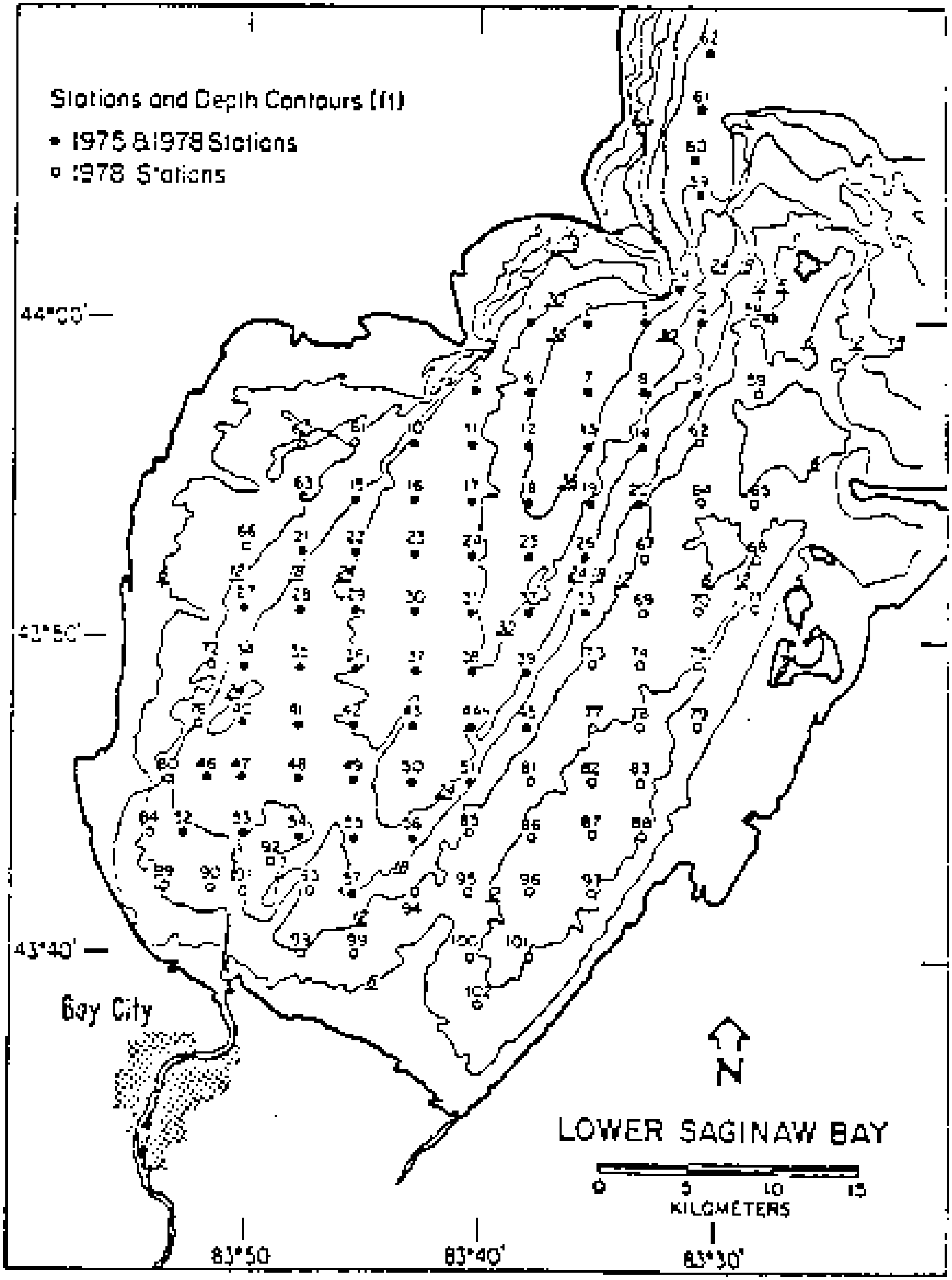


Figure III-71. Saginaw Bay sediment sampling stations, 1975-1978 (Robbins, 1986).

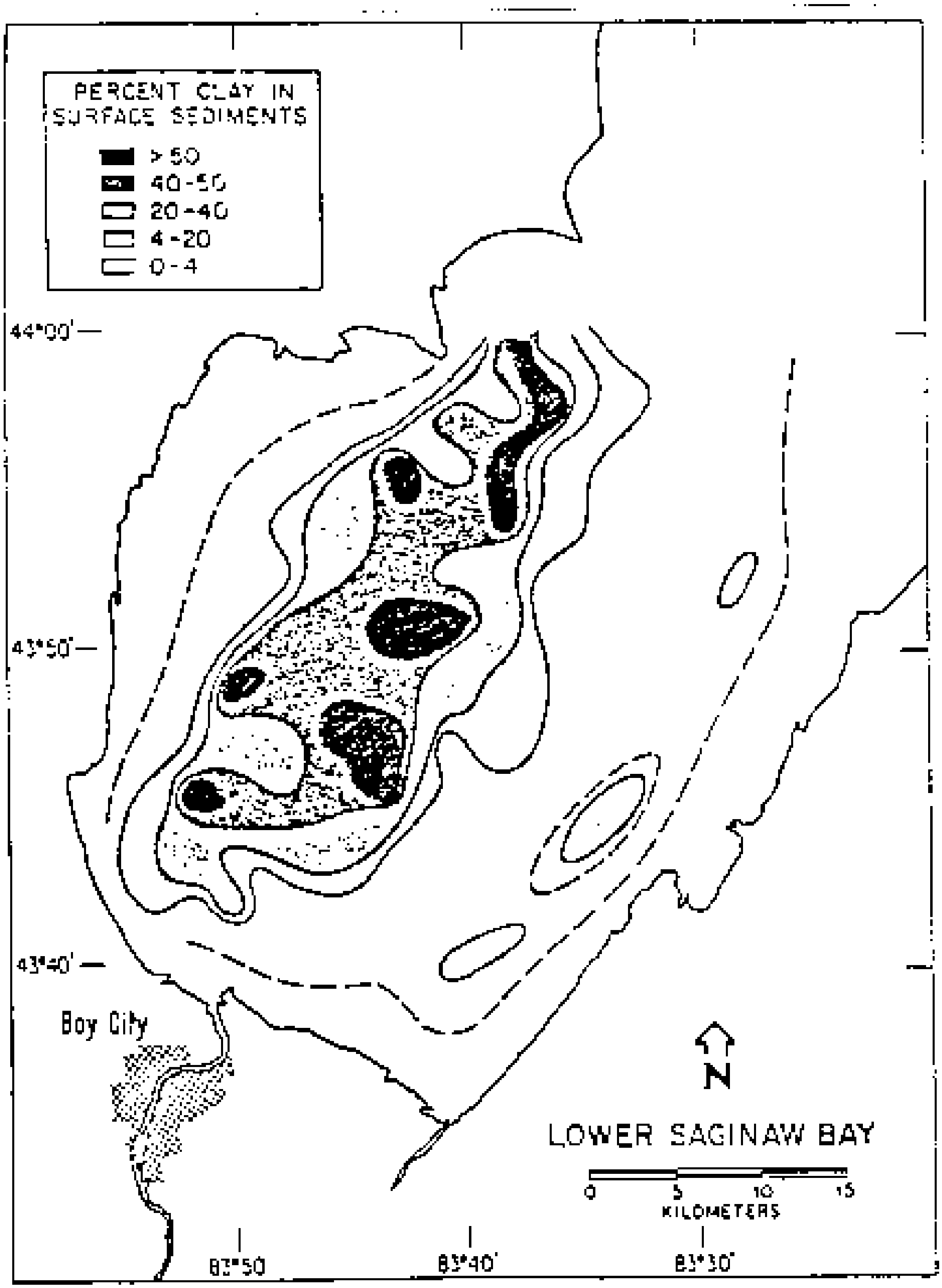


Figure III-72. Percent clay in surface sediments (1-2 cm) of inner Saginaw Bay, 1978 (Robbins, 1986).

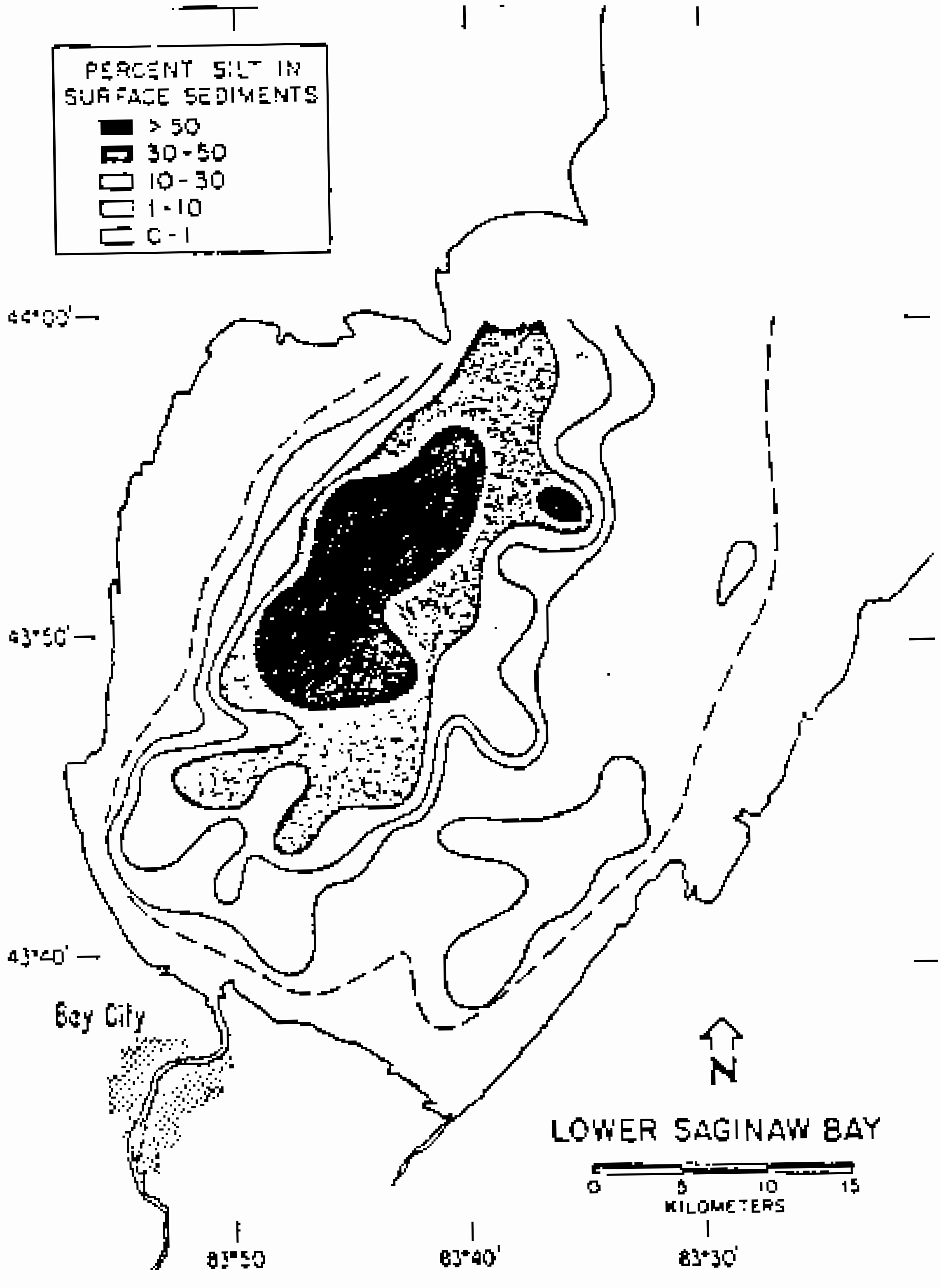


Figure III-73. Percent silt in surface sediments (0-1 cm) of inner Saginaw Bay, 1978 (Robbins, 1986).

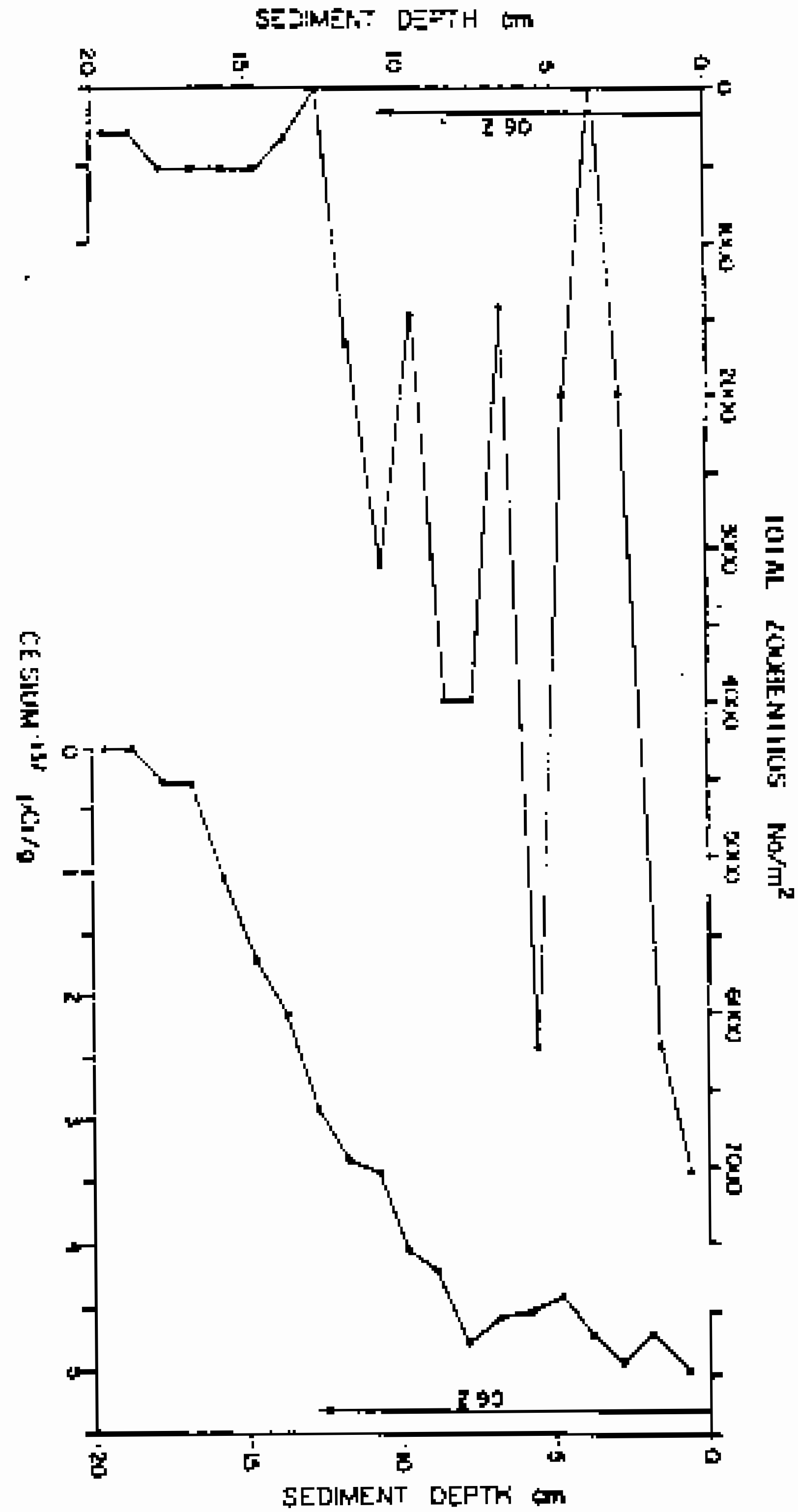


Figure III-74. Distribution of total zoobenthos in the sediment column, Saginaw Bay (White et al., unpublished).

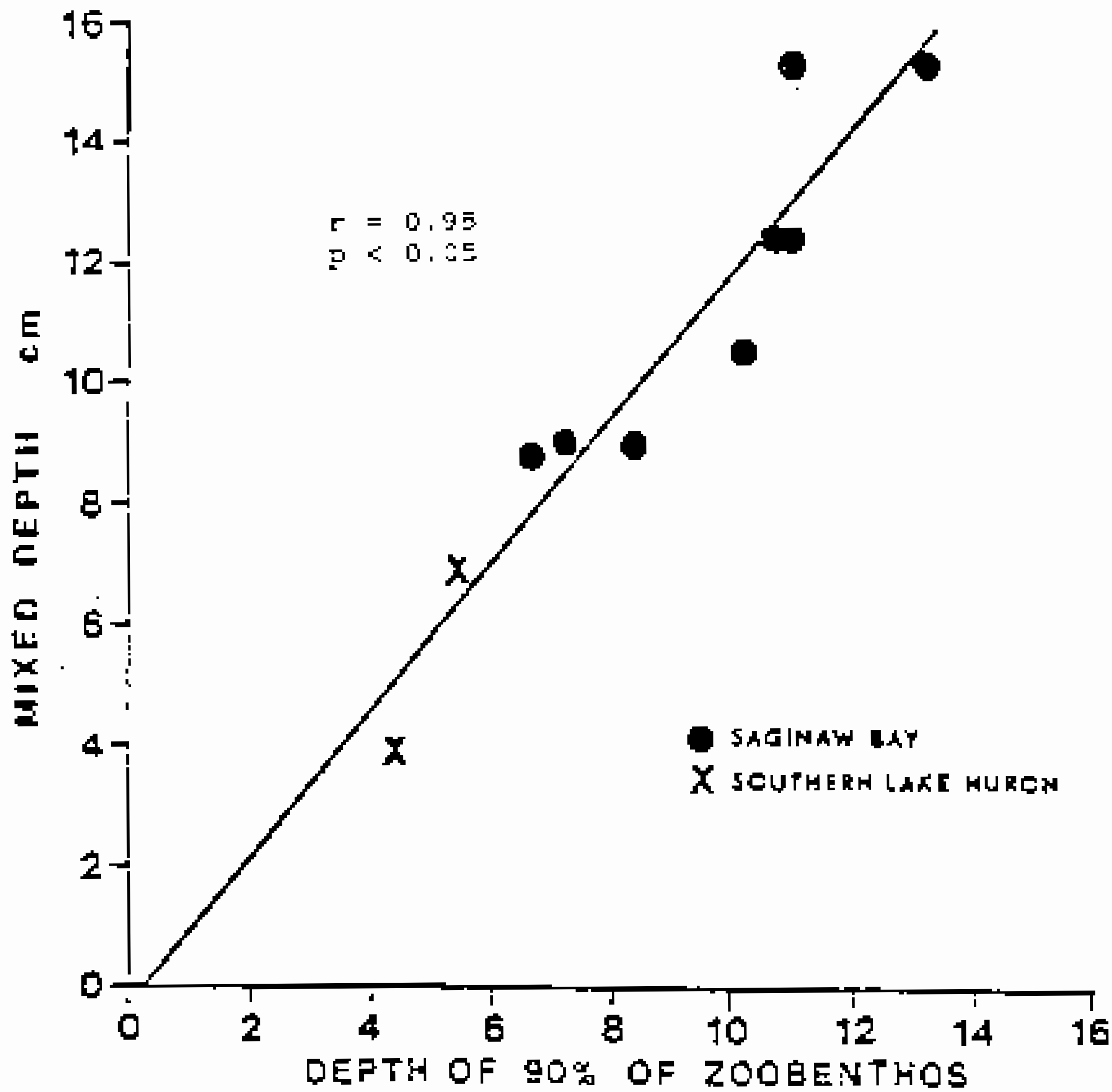


Figure III-73. Depth of 90% of zoobenthos in sediment column, Saginaw Bay and southern Lake Huron (White et al., unpublished).

relationship led White et al. (unpublished) to conclude that the vertical distribution of the ^{137}Cs peak could be ascribed almost entirely to bioturbation processes. Robbins et al. (1984) and Krezoski et al. (1984) have demonstrated similar redistribution of ^{137}Cs layers in laboratory microcosms.

Data of White et al. (unpublished) show that tubificids are a prime agent in mixing the surficial layers of muddy deposits. Many of the heavy metal vertical profiles for Saginaw Bay (Robbins, 1980) followed the same pattern as the ^{137}Cs profiles, strongly suggesting a common factor of bioturbation (Robbins et al., 1977). While fine-grained sediments of the inner bay function as a sink for contaminants, bioturbation processes of tubificids and other macrozoobenthos may release once-deposited materials back into the overlying waters.

Lead-210 dating suggests sedimentation rates in Saginaw Bay ranging from about 0.07 to 0.24 $g/cm^2/yr$ (Robbins, 1986). This estimate of sedimentation rates was based on the assumption that no diffusive mixing occurs below the mixed zone. Highest rates occur toward the southwestern end of the deposit and decrease with distance from the mouth of the Saginaw River (Figure III-76). The residence time of a particle within the mixed layer of sediment is approximated by the ratio of the mixed depth (g/cm^2) to the sedimentation rate ($g/cm^2/yr$; Robbins, 1986). This varies within the mud deposits of the inner bay and ranges from 11-60 years, with a mean value for the cores examined of 30 years (Robbins, 1986).

b. PCBs

Approximately 3.7 metric tons of PCB remain in the active sediment in inner Saginaw Bay (Richardson et al, 1983). The Saginaw River and atmospheric deposition contribute about 1.4 kg/day of PCB to Saginaw Bay (Richardson et al., 1983). The highest PCB concentrations (0.825 to 0.968 mg/kg) were found in the southwestern end of the inner bay mud deposit (Figure III-77). The USACOE analyzed sediment samples from the navigation channel in Saginaw Bay off the mouth of the Saginaw River in 1978, 1980 and 1983 and found maximum PCB concentrations decreasing from 4.2 mg/kg in 1978 to 2.9 mg/kg in 1980 to 1.4 mg/kg in 1983 (Figure III-78). The USACOE sediment samples were composite samples collected to a depth of approximately 10 cm. Both the USEPA and USACOE data suggest there has been a decrease in loads of PCB to Saginaw Bay.

c. Metals

Surface concentrations of metals were found to be consistently lower in Saginaw Bay mud deposits than in open Lake Huron deposits (Robbins, 1986). This is due both to the constant downward reworking of surface materials by zoobenthos, and to dilution by inert materials. Relative to underlying sediments, the contaminant metals are highly enriched in surface materials and far exceed the excess element accumulation in deposits of open Lake Huron.

Using USEPA criteria for polluted Great Lakes harbor sediments (Table III-19), sediments in the inner bay with average concentrations of

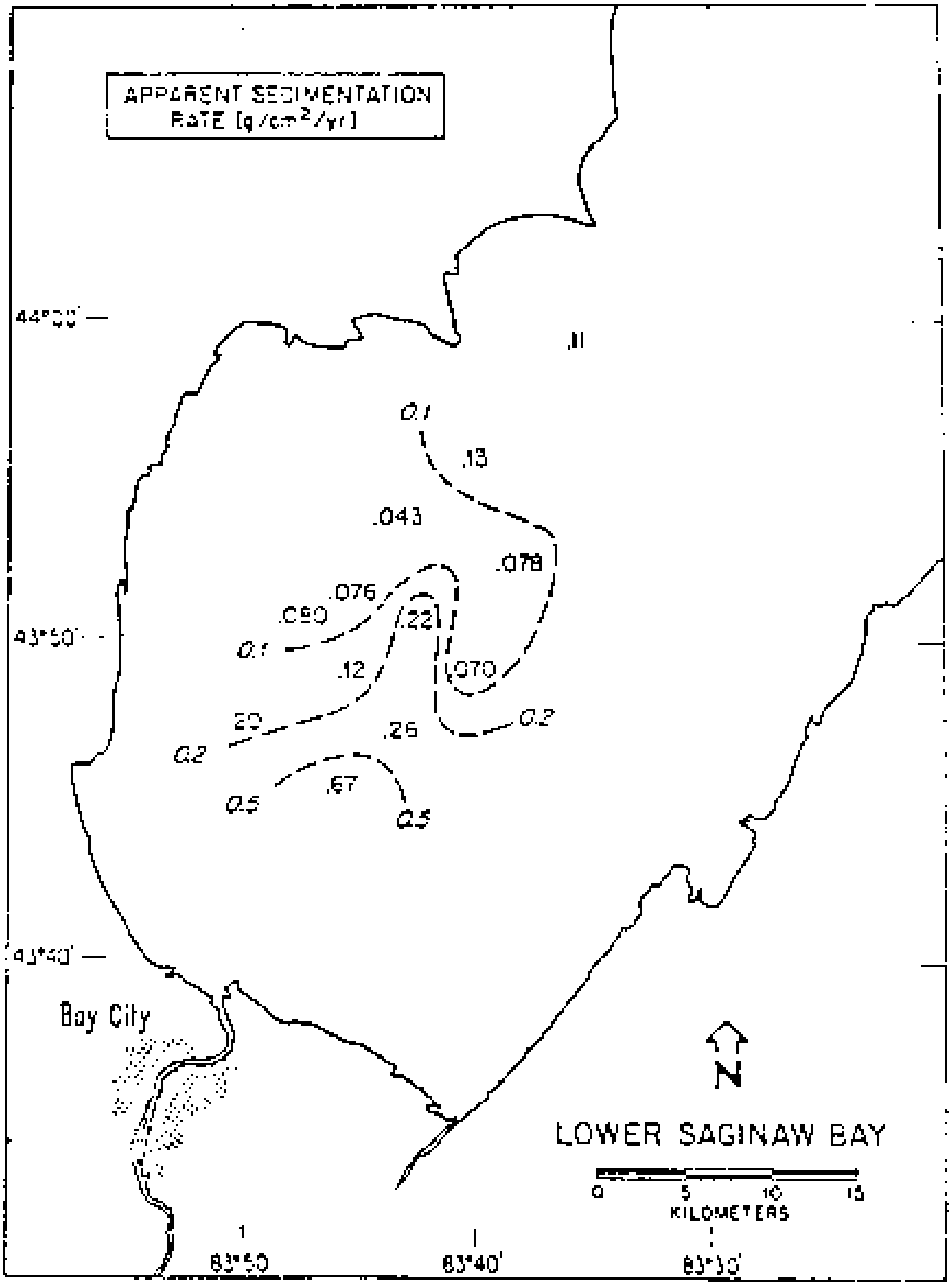


Figure III-76. Apparent sedimentation rates in inner Saginaw Bay (Robbins, 1980).

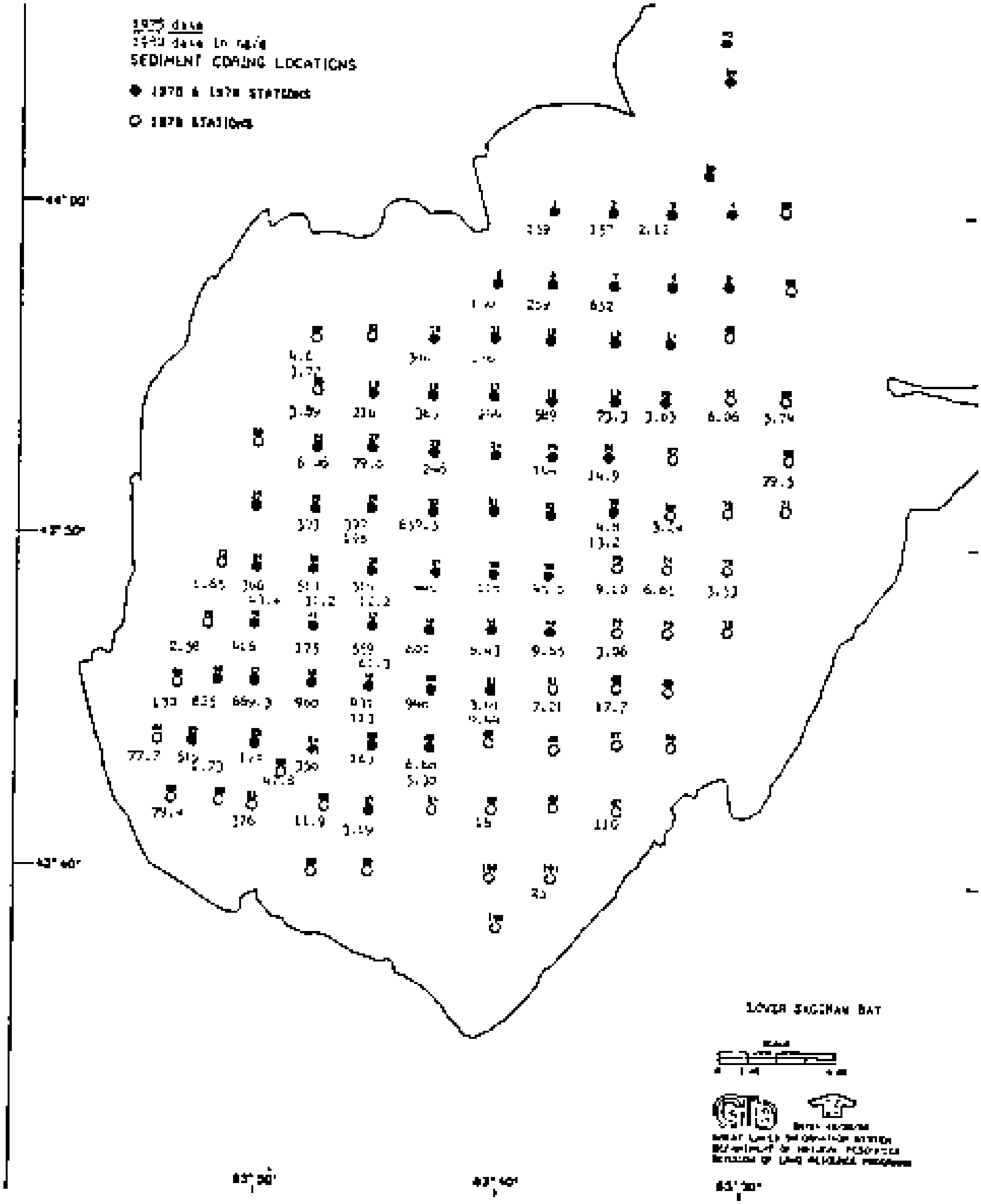
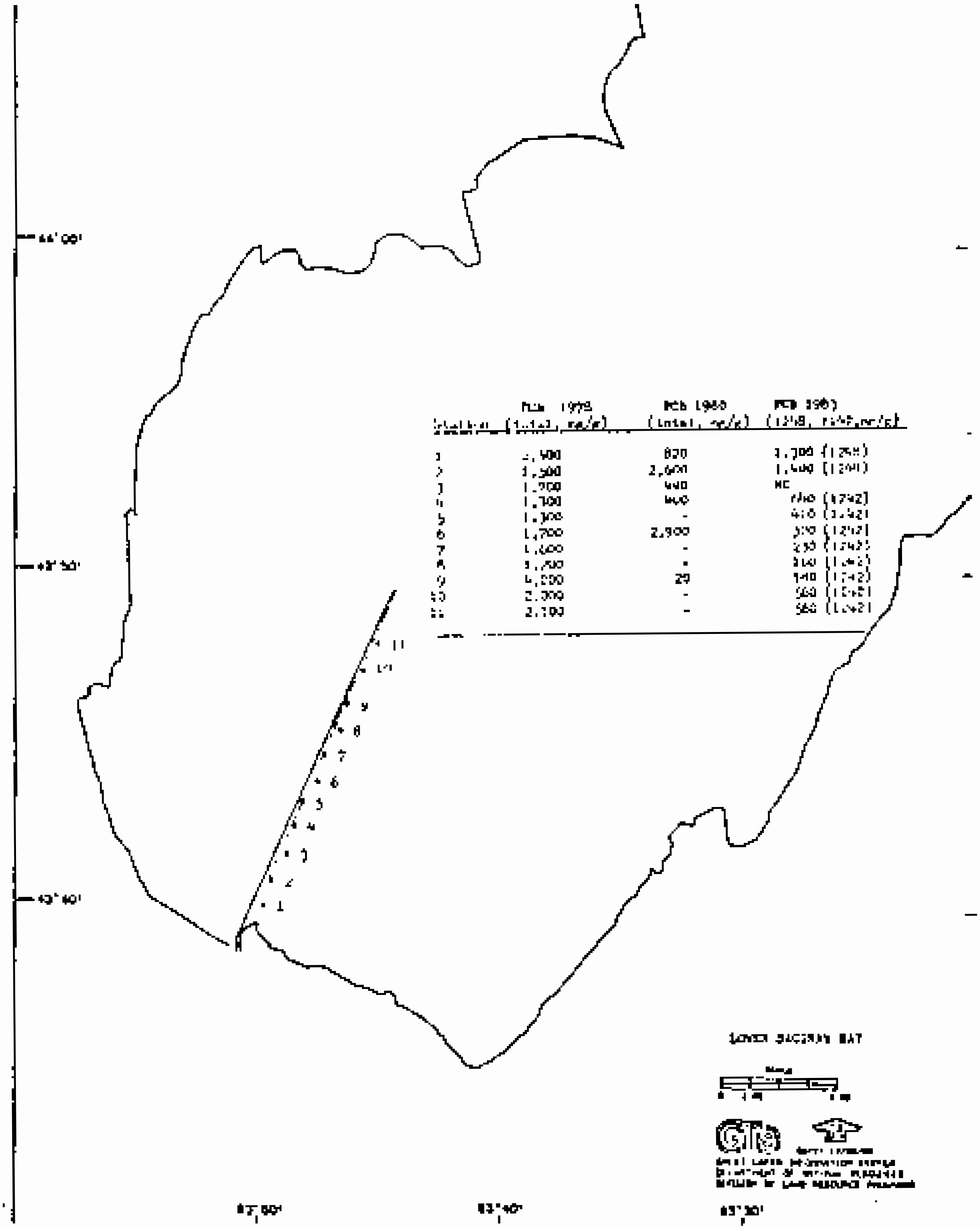


Figure III-77. Spatial distribution of PCB concentrations in surface sediments (1-2 cm) of Inner Saginaw Bay, 1976 and 1980 (USEPA, unpublished).



Station	PCB 1978 (total, ng/g)	PCB 1980 (total, ng/g)	PCB 1983 (1248, 1242, ng/g)
1	2,400	820	1,700 (1254)
2	1,500	2,600	1,400 (1248)
3	1,700	440	NC
4	1,700	460	740 (1242)
5	1,300	-	410 (1242)
6	1,700	2,900	370 (1242)
7	1,600	-	230 (1242)
8	1,500	-	310 (1242)
9	4,200	29	140 (1242)
10	2,300	-	560 (1242)
11	2,100	-	560 (1242)

Figure III-78. PCB concentrations in sediments of inner Saginaw Bay collected from the navigation channel at the mouth of the Saginaw River 1978, 1980 and 1983 (USACOE, unpublished).

As of 16 mg/kg and Ba of 422 mg/kg (Table III-35) would be categorized as heavily polluted. Sediments with average concentrations of Cr of 63 mg/kg, Cu of 25 mg/kg, Ni of 32 mg/kg, Pb of 45 mg/kg, and Zn of 96 mg/kg would be classified as moderately polluted. Cadmium (2.4 mg/kg) and Mn (0.05 mg/kg) would be considered to be at non-polluted levels.

The spatial distribution of Cd, Cr, Cu, Ni, Pb and Zn in inner Saginaw Bay are presented in Figures III-79 through III-84. The areas of inner Saginaw Bay that have the highest concentrations of metals are associated with sediments that have the highest content of clay-size particles. Chromium and Pb are the two most abundant metals in Saginaw Bay (Table III-35), followed by Ni, Cu and Zn (Robbins, 1986).

Table III-35. Average Concentrations (mg/kg) of Metals in Surface Sediments of Inner Saginaw Bay and Southern Lake Huron, 1980 (Robbins, 1986).

Metal	Location: Saginaw Bay	Location: Lake Huron
As	16	27
Ba	433	432
Cd	2.4	2.97
Cr	63	66
Cu	25	37
Mn	0.050	0.13
Ni	31.9	50.6
Pb	45.3	73.6
Zn	96.3	116.3

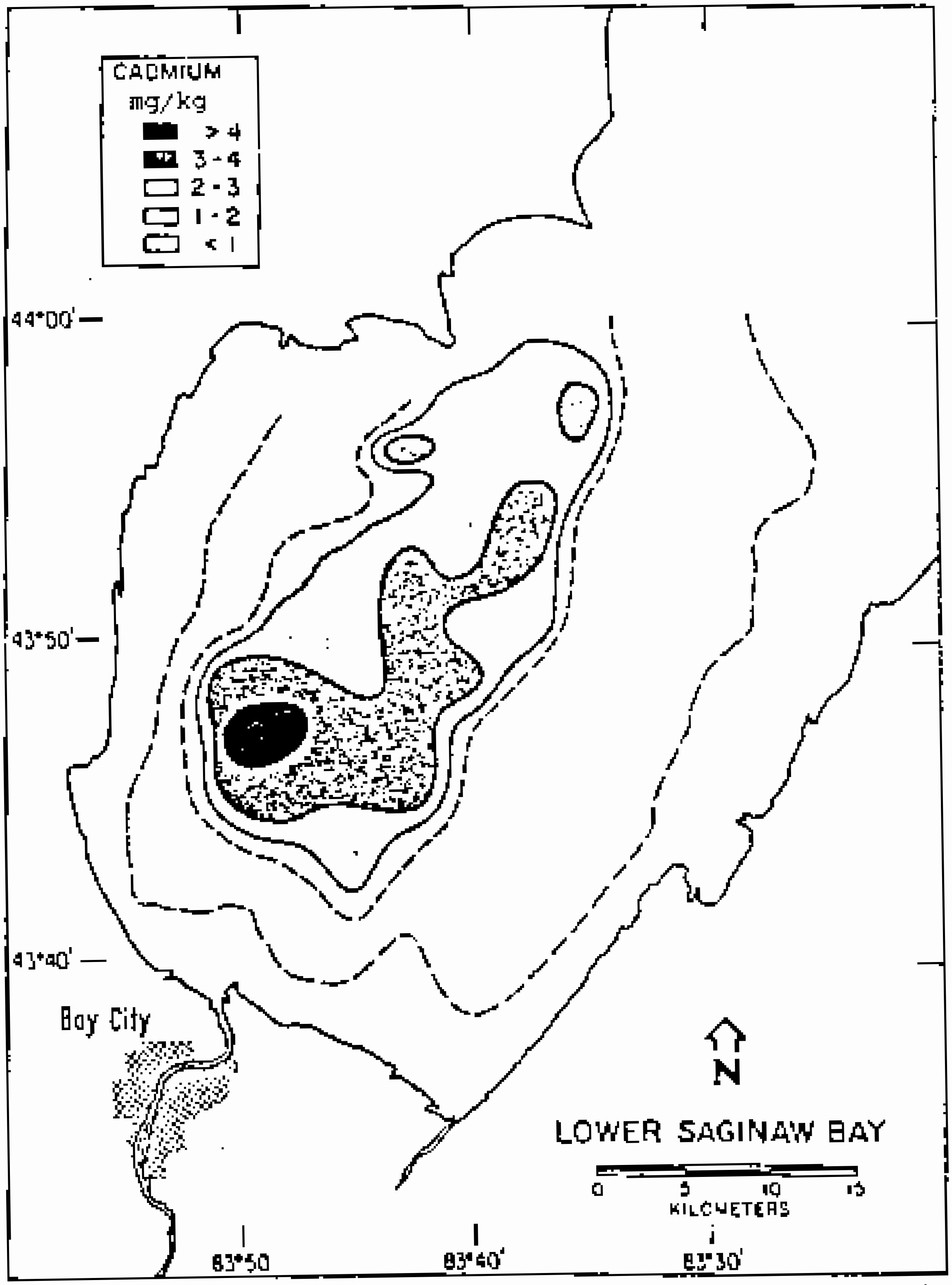


Figure III-79. Spatial distribution of cadmium in surface sediments (1-2 cm) of inner Saginaw Bay, 1978 (Robbins, 1986).

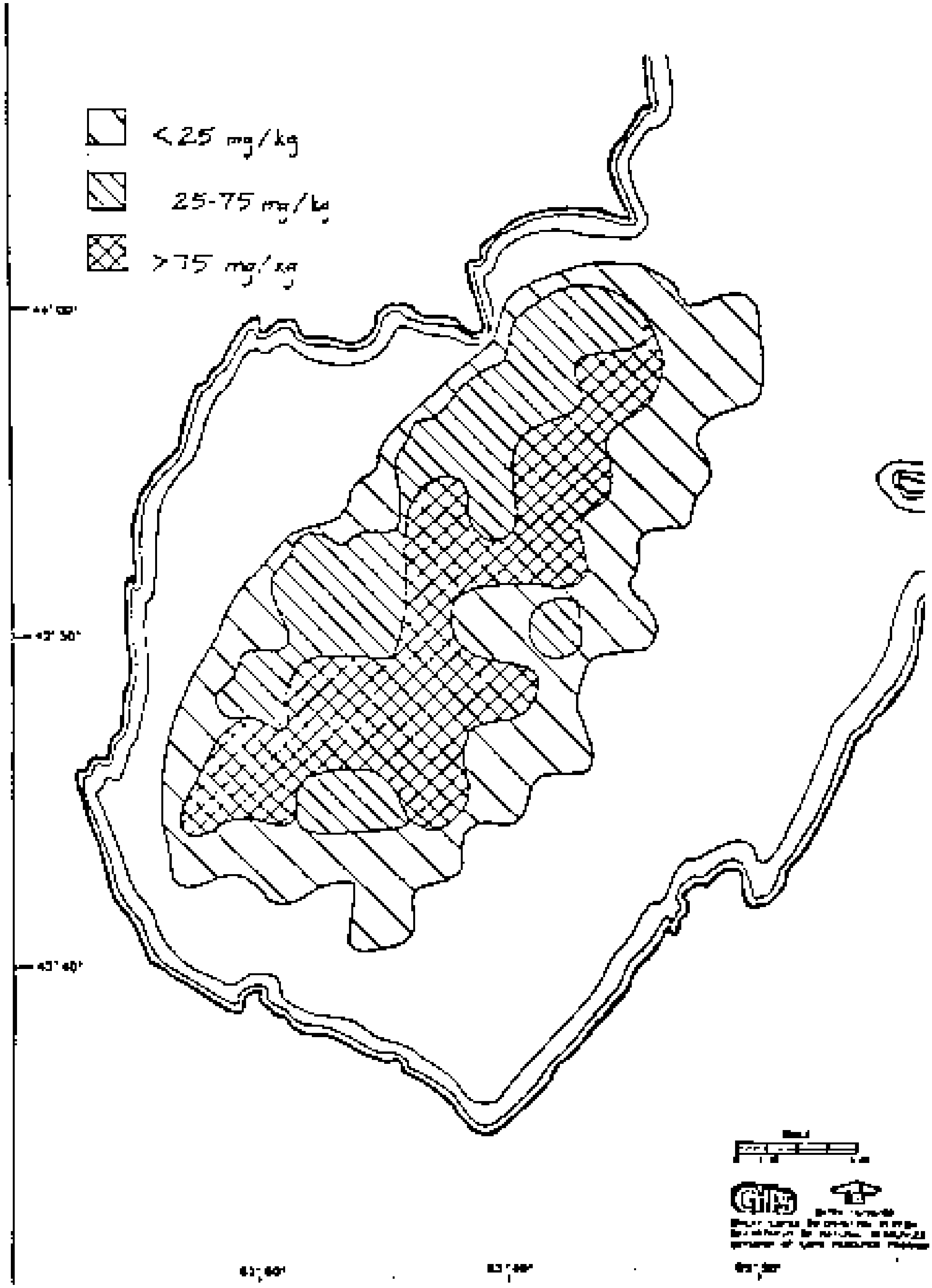


Figure III-80. Spatial distribution of chromium in surface sediments (1-2 cm) of Inner Saginaw Bay, 1978 (Robbins, 1986).

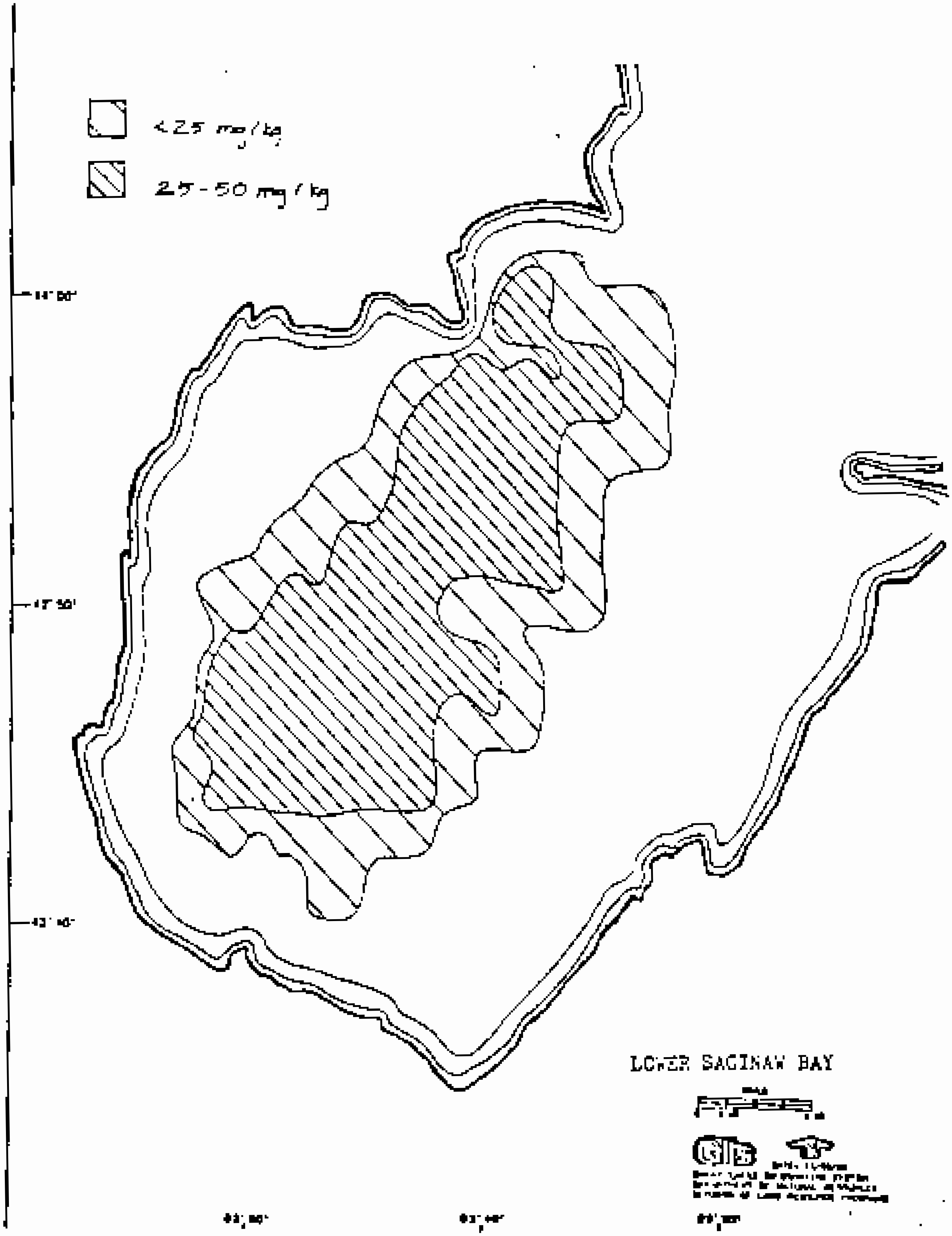


Figure III-81. Spatial distribution of copper in surface sediments (1-2 cm) of inner Saginaw Bay, 1978 (Robbins, 1986).

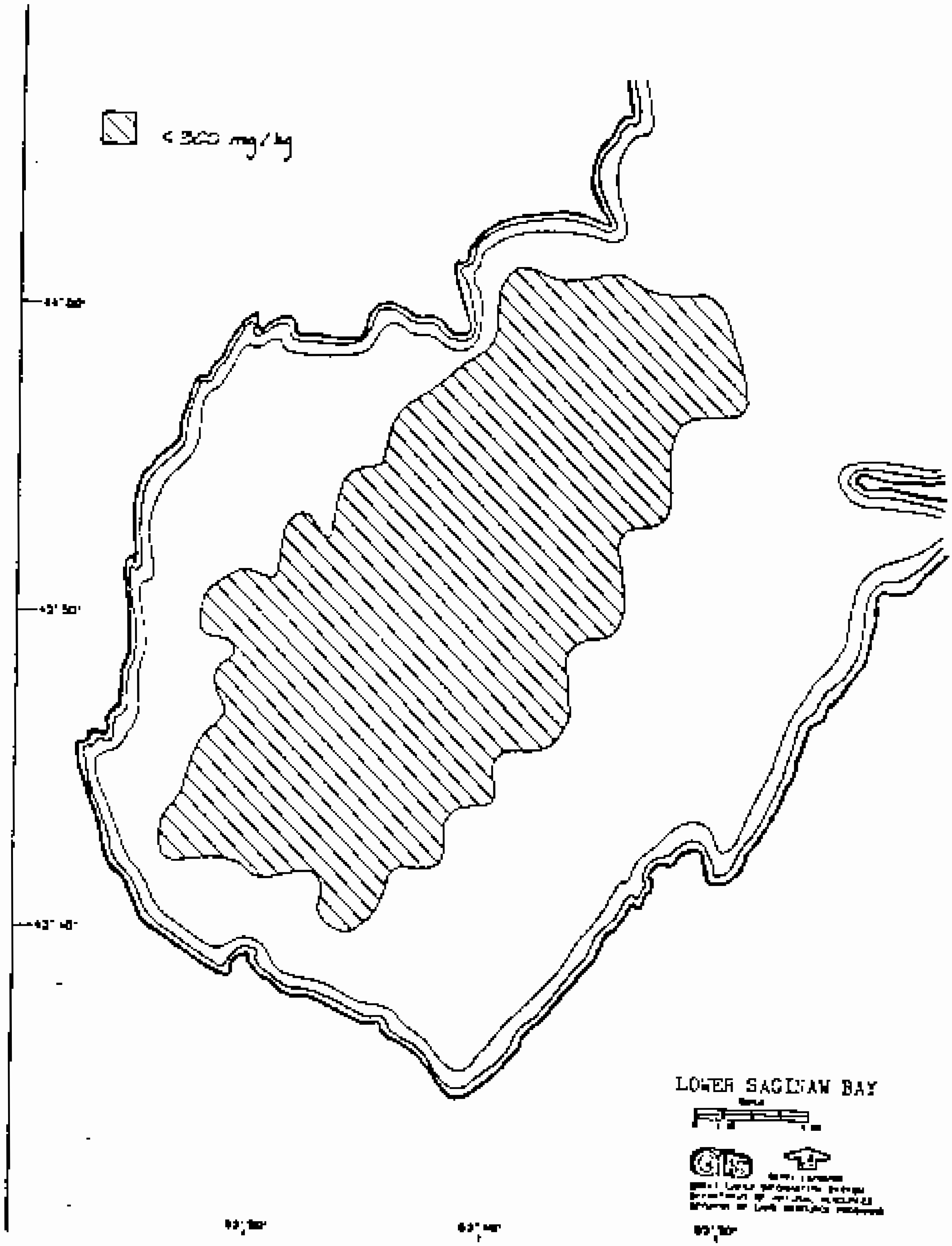


Figure III-82. Spatial distribution of nickel in surface sediments (1-2 cm) of inner Saginaw Bay, 1978 (Robbins, 1986).

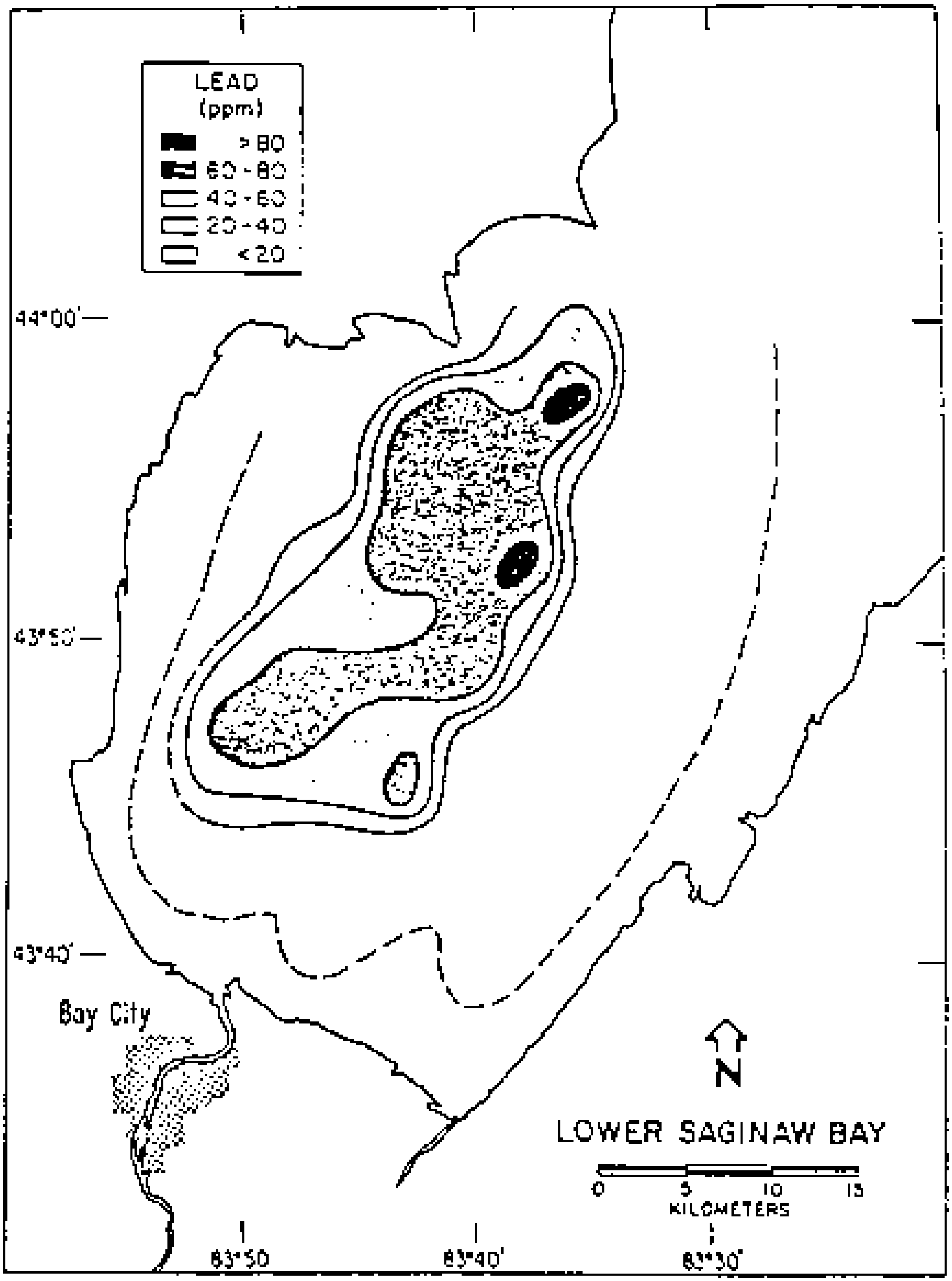


Figure III-83. Spatial distribution of lead in surface sediments (0-2 cm) of inner Saginaw Bay, 1978 (Robbins, 1980).

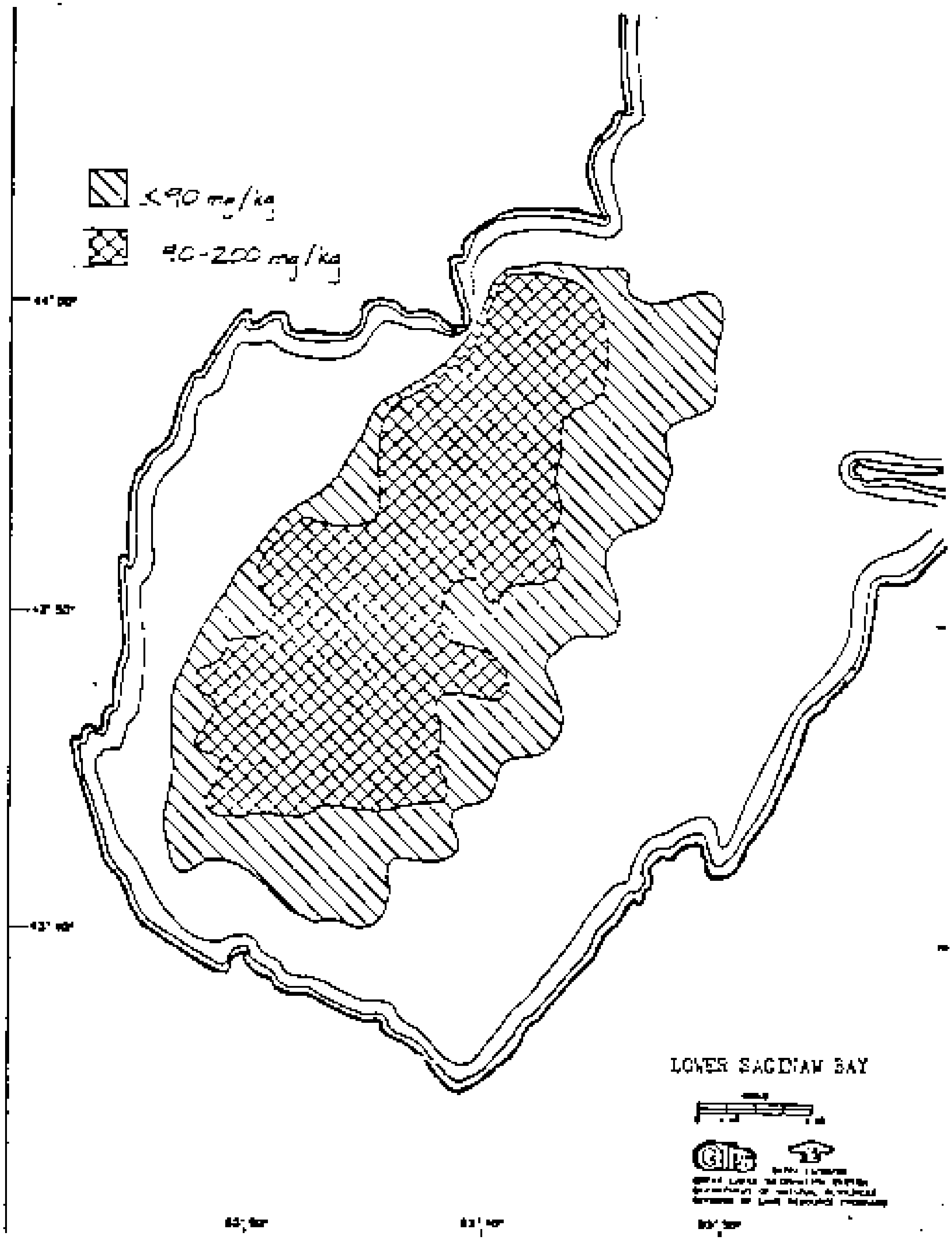


Figure III-44. Spatial distribution of zinc in surface sediments (1-2 cm) of inner Saginaw Bay, 1978 (Robbins, 1986).

F. BIOLOGICAL COMMUNITIES

1. Phytoplankton and Chlorophyll a

a. Phytoplankton

Southern Lake Huron contains a wide variety of phytoplankton assemblages, ranging from those associated with oligotrophic waters to those characteristic of highly eutrophic waters (Stoermer and Kreis, 1980). The offshore waters of Lake Huron are generally classified as oligotrophic, while the interface waters of Saginaw Bay have been classified as eutrophic (Kreis et al., 1985).

Fifty percent reductions in fluvial phosphorus inputs to Saginaw Bay between 1975 and 1978 produced qualitative changes in the phytoplankton flora of the bay (Stoermer and Theriot, 1983; McNaught et al., 1983). By 1980, reduction in fluvial inputs resulted in a 24% decrease in available orthophosphate for phytoplankton growth (McNaught et al., 1983). The most noticeable consequence of these reductions was a decline in the abundance and range of distribution of many species of nuisance blue-green algae in 1980, when compared to populations from 1974-1976. During the early 1970s, these populations were associated with taste and odor problems at water filtration facilities that drew their supplies from Saginaw Bay (Bratzel et al., 1977).

Certain eutrophic-tolerant diatom populations that had been a dominant element of phytoplankton biomass in the bay from 1974-1976 were also virtually eliminated as a result of reduced phosphorus concentrations in 1980 (Stoermer and Theriot, 1983). For example , *Actinocyclus normanni* fo. *subsalsa* was found at a limited number of stations and always at low abundance in 1980, yet it had been a subdominant species from 1974-76 (Stoermer and Theriot, 1983). This species has high population levels in areas of the Great Lakes that are very eutrophic, and it is thought to be an indicator of eutrophication in the Great Lakes system (Hohn, 1969). Similar species reductions were noted in the abundance and distribution of other diatom species that also occur under grossly polluted conditions, such as *Skeletonema* spp., *Thalassiosira* spp., *Stephanodiscus binderanus*, and *S. tenuis*.

From 1974-1976 there was an abundance of many large-sized, normally benthic, diatom species in the plankton of the bay (Stoermer and Theriot, 1983). This group of diatoms included several species of *Surirella*, *Cymatopleura*, and large benthic species of *Nitzschia*. The levels of nutrient enrichment in Saginaw Bay from 1974-1976 allowed these diatom populations, which are usually restricted to the nutrient-rich environment of the sediment-water interface, to thrive in plankton assemblages (Stoermer and Theriot, 1983). These diatom populations contributed substantially to the total cell volume of plankton communities in Saginaw Bay from 1974-1976 even though they were not present in great numerical abundance (Stoermer and Theriot, 1983). The invasion of plankton assemblages by benthic diatom populations under conditions of high nutrient loading seems to be unique to the Great Lakes (Stoermer et al., 1974; Holland and Claflin, 1975; Stoermer and Stevenson, 1980). These large populations were a very minor component of the phytoplankton assemblages sampled in 1980 (Stoermer and Theriot, 1983).

Not all phytoplankton populations have decreased in abundance in Saginaw Bay. The greatest relative change in abundance was found in some of the smaller species of Cyclotella, which typically are components of the summer flora of undisturbed regions of the Great Lakes (Stoermer, 1978). In 1980, these species became more widely distributed and increased in abundance in Saginaw Bay (Stoermer and Theriot, 1983). Within this group, C. comensis is numerically most important. This species has only recently become a major constituent of the phytoplankton flora in the Great Lakes (Stoermer and Theriot, 1983). Before 1970 it was occasionally found in samples from offshore stations in the upper lakes, but seldom in significant abundance (Stoermer and Theriot, 1983). Since then it has become dominant in the offshore flora of Lake Huron (Kreis et al., 1985). In Lake Huron, it is particularly efficient at silica uptake and is found most often at stations having relatively high nitrate concentrations (Stoermer and Kreis, 1980). Although it was previously excluded from Saginaw Bay, it was an important element in 1980 assemblages (Stoermer and Theriot, 1983).

This shift to an increased abundance of small-celled species of diatoms indicates a trend toward cells of smaller volume dominating the flora of the bay (Stoermer and Theriot, 1983). Even a small reduction in principle dimensions results in a large reduction in biovolume. The reduction in biovolume of phytoplankton communities in the bay in 1980 decreased more dramatically than did phytoplankton numbers (Stoermer and Theriot, 1983). This marked change to smaller species probably indicates a quicker cycling of nutrient pools in the bay by large numbers of pico-planktonic organisms (Stoermer and Theriot, 1983). Parts of the Great Lakes are rich in prokaryotic and eukaryotic photosynthetic organisms which are less than 1 micron in size. Although this component of the biota has not been well studied in the Great Lakes, limited observations suggest that they are most abundant during transitional periods between one nutrient cycling regime and another.

The absence of a spring diatom bloom was noted in 1980 samples and was a major departure from 1974-1976 conditions (Stoermer and Theriot, 1983). During studies from 1974-1976, there was a large spring bloom dominated by large species of Stephanodiscus and populations of Fragilaria capucina (Stoermer and Theriot, 1983). The biomass contribution by the large species of Stephanodiscus was lacking during 1980 since the spring diatom bloom did not develop (Stoermer and Theriot, 1983). All major phytoplankton groups, including diatoms, continued to increase to a seasonal maximum relatively late in the year, and then declined during the late fall (Stoermer and Theriot, 1983). There was no apparent explanation for this drastic change in successional pattern in 1980 (Stoermer and Theriot, 1983).

Grazing pressure in the early spring could have depressed population levels of those diatom species early in the spring and consequently, recycled nutrients were sequestered by the less efficiently grazed green and blue-green species as the season progressed (Stoermer and Theriot, 1983). Alternatively, late-season diatom populations could have been supported by nutrients released by the sediments during the summer (Stoermer and Theriot, 1983). Both of these mechanisms could have been operating in 1980 and it is possible that there will be a long period of instability before the ecosystem of the bay adjusts to its new nutrient load regime (Stoermer and Theriot, 1983).

The results of Stoermer and Theriot (1983; 1985) indicate that the direct effects of phosphorus induced phytoplankton overproduction in Saginaw Bay on the rest of the Lake Huron ecosystem has been considerably reduced. Cases still exist where populations generated in Saginaw Bay are transferred out of the bay proper, but it appears that the extensive transport of eutrophication tolerant populations, which occurred in 1974 and 1976 (Schelske et al., 1974; Kreis et. al, 1985), does not occur today (Stoermer and Theriot, 1983; 1985).

Certain aspects of the flora of Wildfowl Bay and Oak Point (stations 34 and 44 respectively, Figure III-85) were highly unusual because these stations supported large blooms of the prokaryote Pelonema sp. (Stoermer and Theriot, 1983). This organism is achlorotic and most of its relatives are found in highly organically enriched and oxygen depleted environments (Stoermer and Theriot, 1983). The unique flora of this eastern region of the Saginaw Bay coast led Stoermer and Theriot (1983) to conclude that the combination of restricted circulation, loads transported from the southern part of the bay, and local sources of both nutrient and organic loadings severely affected this region.

Despite the fact that the results of Stoermer and Theriot (1983; 1985) show that there has been substantial water quality improvement in Saginaw Bay, some major problems remain. The phytoplankton flora of the bay still contains large populations of diatoms, green and blue-green algae that indicate eutrophic or disturbed conditions (Stoermer and Theriot, 1983). The seasonal cycle of phytoplankton abundance (Figure III-86) and major group dominance (Figure III-87) during 1980 remained more typical of a hypereutrophic system than of one that was balanced and efficiently productive (Stoermer and Theriot, 1983).

b. Chlorophyll a

Chlorophyll a has traditionally been used as an indicator of phytoplankton production in natural waters. However, examination of 1974 field data from Saginaw Bay indicated that chlorophyll a concentrations were inconsistent with phytoplankton cell volumes (Dolan et al., 1978). The chlorophyll a to biomass ratio for Saginaw Bay was not constant throughout the year in 1974, but rather was analogous to the species succession in many eutrophic waters, first diatoms dominate, then blue-greens predominate, finally diatoms return (Dolan et al., 1978). Therefore, chlorophyll a and phytoplankton cell volume concentrations (biomass) cannot be considered equivalent estimators of phytoplankton abundance in the bay (Dolan et al., 1978).

Chlorophyll a concentrations in Saginaw Bay have historically been nine times higher than levels in Lake Huron (Schelske and Roth, 1973), a relationship that still existed in 1984 (Neilson et al., 1986). Chlorophyll a concentrations measured in Saginaw Bay in the spring and

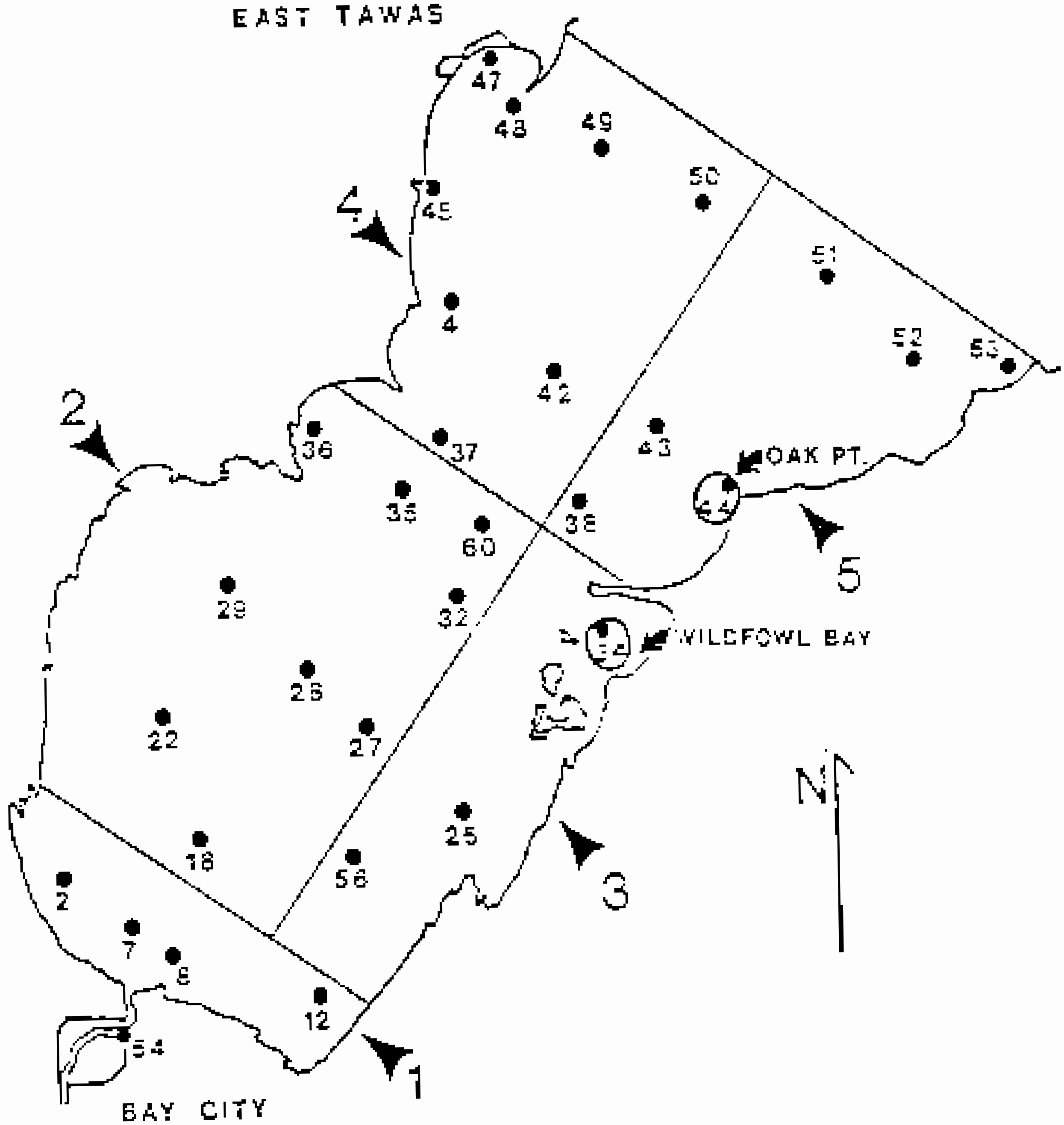


Figure III-85. Plankton station locations in Saginaw Bay, 1980 (Stoermer and Theriot, 1983).

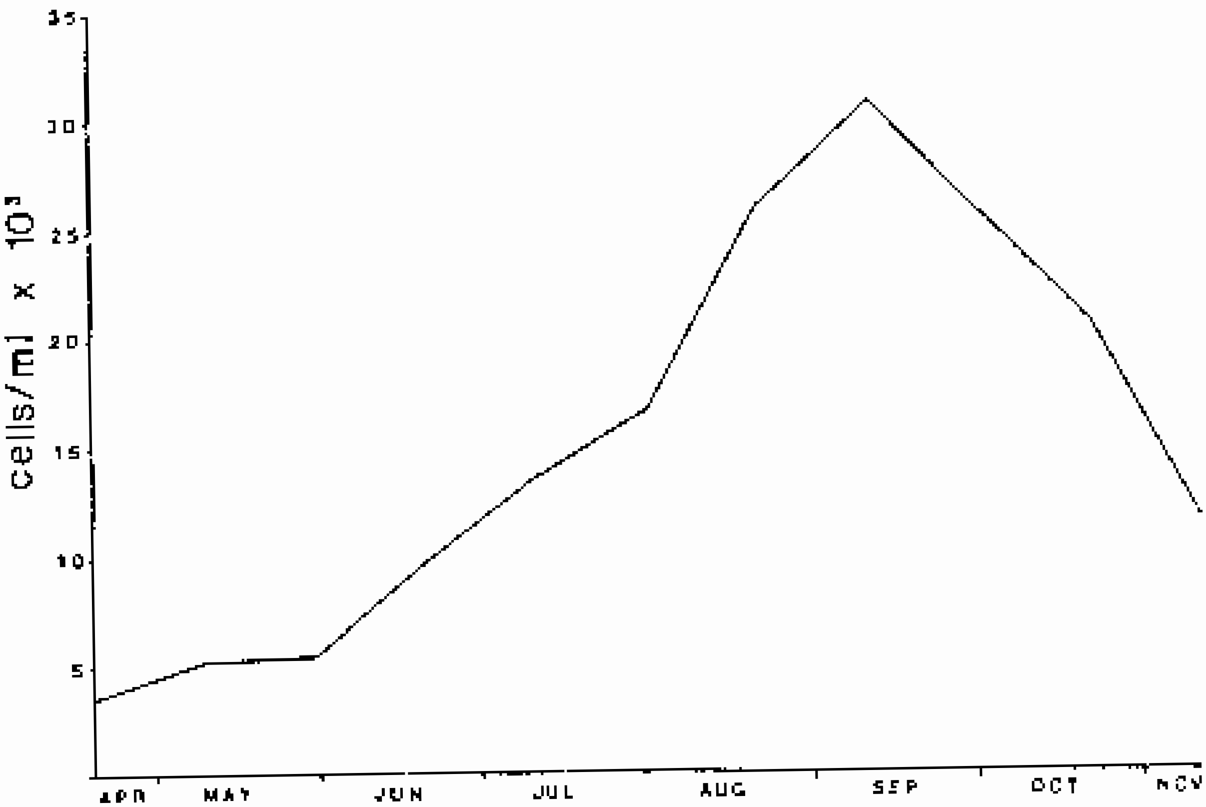


Figure III-86. Seasonal variation of mean total phytoplankton cell abundance in Saginaw Bay, April-November, 1980 (Stoermer and Theriot, 1983).

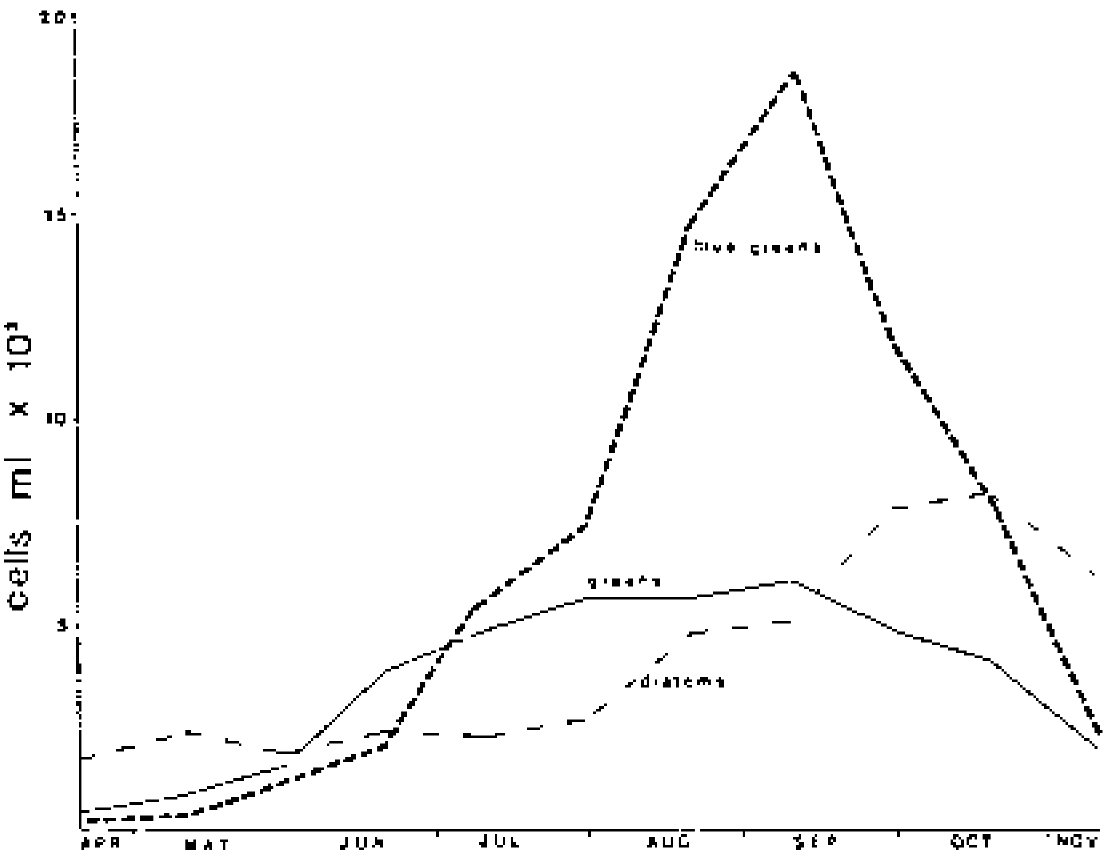


Figure III-87. Seasonal variation of abundance of the three dominant algal divisions in Saginaw Bay, April-November, 1980 (Stoermer and Theriot, 1983).

fall of 1974 through 1980 decreased significantly in both the inner and outer portions (Bierman et al., 1984). Decreases in spring and fall chlorophyll a concentrations over this period were 53% and 61% for the inner bay, and 26% and 0% for the outer bay, respectively (Bierman et al., 1984).

Chlorophyll a concentrations were generally higher and more variable in the inner bay than in the outer. Spring and fall chlorophyll a concentrations in the inner bay between 1974 and 1980 were highest in 1974 at 20.6 and 29.1 ug/l, respectively (Table III-36). The lowest chlorophyll a level measured in the inner bay, 8.1 ug/l, occurred during the spring of 1979. The most recent data available for chlorophyll a concentrations are from 1984 for Saginaw Bay, and 1985 for the Saginaw Bay-Lake Huron interface (Neilson et al., 1986). The area weighted mean chlorophyll a concentration for the bay was 10.1 ug/l in the spring of 1984 (Neilson et al., 1986). Based on 1984 spring measurements, concentrations of chlorophyll a dramatically increased from the mouth of the bay southward toward the Saginaw River (Figure III-88). Summer 1985 chlorophyll a data are available only for the Saginaw Bay-Lake Huron interface, where levels reached 2.0 ug/l (Neilson et al., 1986).

c. Trophic Status

Chlorophyll a concentrations have been used an indicator of trophic status and criteria for evaluating trophic status based on chlorophyll have been developed (Table III-37). The 1980 chlorophyll a concentration for inner Saginaw Bay of 12.2 ug/l (Bierman et al., 1984) fell within the eutrophic range of all classification schemes. The spring 1984 area weighted mean chlorophyll a concentration of 10.1 ug/l for the entire bay (Neilson et al., 1986) fell within the eutrophic range of three of the five sets of criteria (NAS/NAE, 1972; Dobson et al., 1974; and Carlson, 1977); and within mesotrophic range for two sets of criteria (Sakamoto, 1966; USEPA, 1981).

2. Zooplankton

a. Rotifers

Rotifer species in Saginaw Bay have been analyzed using cluster analysis to identify stations with similar assemblages; stations with similar assemblages were then grouped into four major sub-regions which define major water masses (Stemberger and Gannon, 1977; Gannon, 1981). Rotifer species assemblages associated with eutrophic environments were found predominantly in groups I and II (Saginaw River drainage basin and the shores of Saginaw Bay; Figure III-89) in 1974 (Table III-38). The species composition in group III (offshore inner regions of Saginaw Bay) reflected factors associated with the mixing and dilution of inshore waters with Lake Huron (Stemberger and Gannon, 1977). Group IV (beyond Alabaster off the eastern shore of the bay and beyond Pt. Aux Barques extending into the deep open waters of Lake Huron off the western shore of the bay) was composed of some coldwater stenotherms and was reflective of communities in the oligotrophic areas of the lake (Stemberger and Gannon, 1977).

Table III-36. Seasonal Average Chlorophyll a Concentrations (ug/l) for Inner Saginaw Bay, 1974-1980 (Bierman et al., 1983).

Year	Season: Spring	Season: Fall
1974	20.6	29.1
1975	119.5	19.9
1976	18.6	26.4
1977	-	-
1978	14.0	14.1
1979	8.1	12.4
1980	12.2	12.2

Table III-37. Chlorophyll a Trophic Status Criteria (LTI, 1983).

	Chlorophyll a Concentration (ug/l)				
Trophic Condition	Sakamoto (1966)	NAS/NAE (1972)	Dobson (1974)	Carlson (1977)	USEPA (1981)
Eutrophic	15-140	>10	8.8	>6.8	>12
Mesotrophic	1-15	4-10	4.3-8.8	2.4-6.8	7-12
Oligotrophic	0.3-2.5	0-4	0-4.3	<2.4	<7

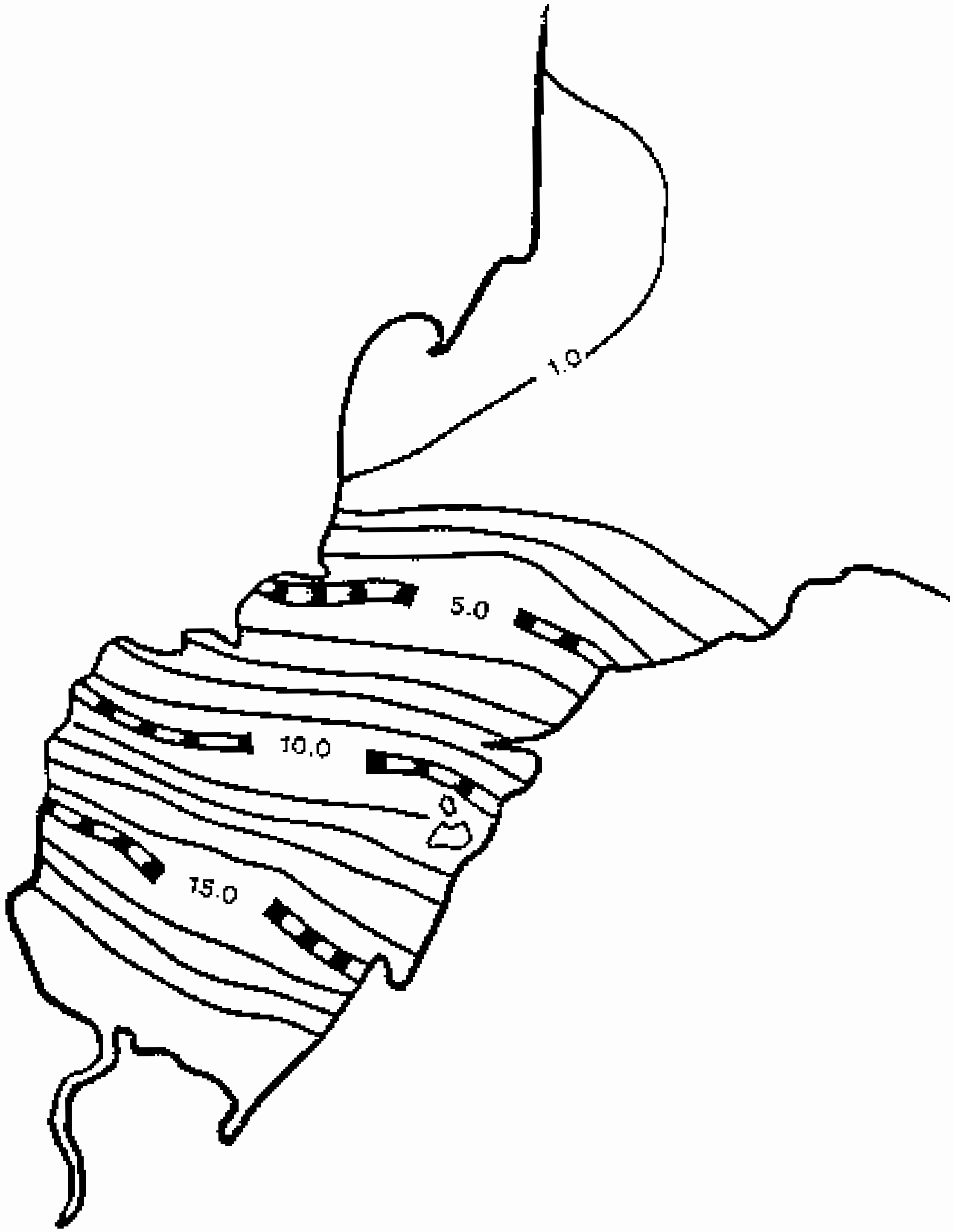


Figure III-89. Integrated (0-20 m) chlorophyll *a* levels (ug/l) in Saginaw Bay, May, 1984 (Neilson et al., 1986).

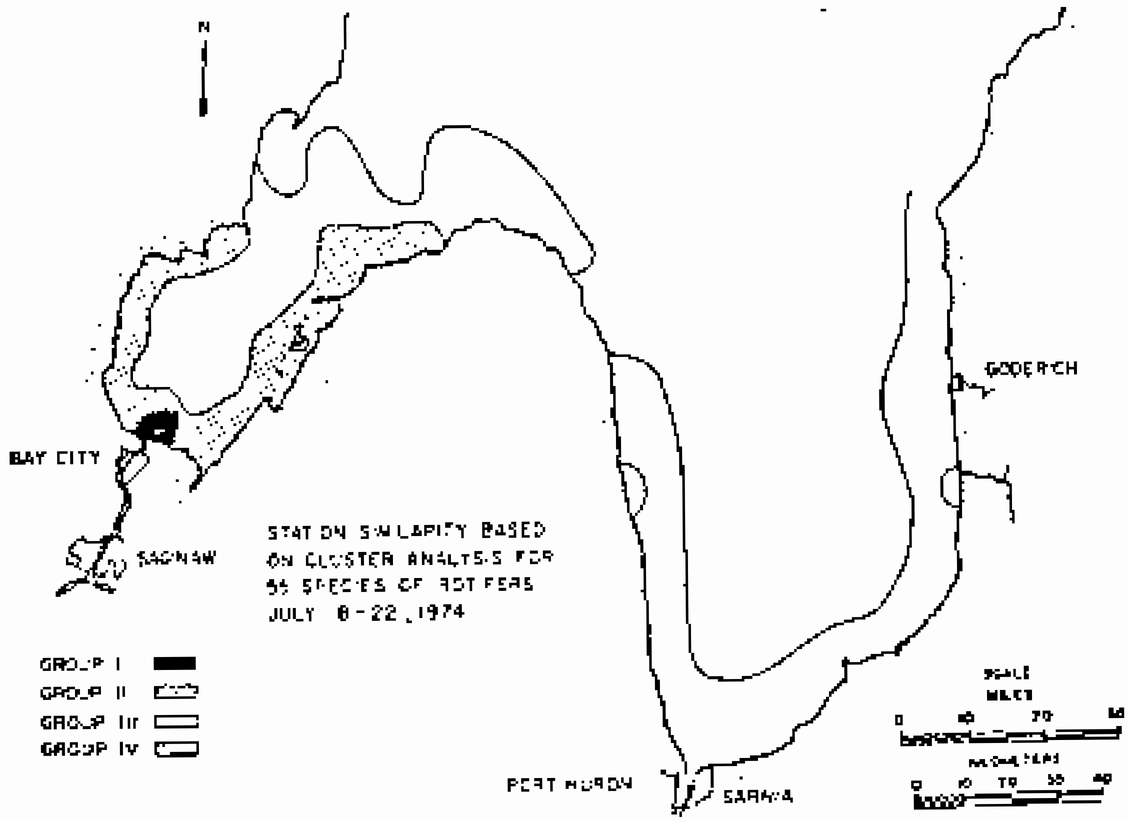


Figure III-89. Grouping of 72 stations determined by cluster analysis of rotifer data for Saginaw Bay and southern Lake Huron during July 1974 (Stemberger and Gannon, 1977).

Table III-38. Abundance (mean number of individuals/liter) of Selected Rotifers and Mean Surface Values of Selected Physiochemical Variables in Groups of Stations Identified by Cluster Analysis, 1974 (Gannon, 1981).

Topic	Groups I	II	III	IV
Species				
Brachionus spp.*	140	20	<1	<1
*Keratella cochlearis f. tecta**	170	13	1	<1
Conochiloides dossuarius	150	4	0	0
*Filinia longiseta**	34	273	70	12
*Pompholyx sulcata**	11	126	14	7
Polyartra vulgaris	294	528	132	51
Keratella cochlearis	193	154	102	51
Conochilus unicornis	<1	19	17	27
Kellicottia longispina	0	2	11	25
Notholca spp.**	0	0	<1	2
Total rotifers	1,144	1,972	626	312
Physicochemical Variables				
Secchi disc (m)	0.4	1.2	4.1	8.3
Temperature (°C)	23.5	23.3	20.7	19.0
Chlorophyll *a* (ug/l)	57.1	18.8	2.4	0.6
Specific conductance (umhos/cm)	636.0	277.0	228.0	210.0
Dissolved phosphorus (ug/l)	58.5	6.2	5.7	5.2
Ammonia-nitrogen (ug/l)	121.0	53.0	41.0	10.0
Chloride (ug/l)	119.0	24.4	11.9	6.3
No. Stations/Group	4	17	30	27

* Eutrophic indicator species

** Cold water stenothermic species

Differences in rotifer species composition and abundance within each group were reflected in differences in the measurements of the physiochemical environment (Table III-38). Group I (Saginaw River drainage basin) had the lowest secchi disk depth (0.4 m), the highest temperature (23.5 C), the highest concentration of chlorophyll a (57.1 ug/l), the highest specific conductance (636.0 umhos/cm), the highest dissolved phosphorus concentration (58.5 ug/l), the highest ammonia-nitrogen concentration (121.0 ug/l), and the highest chloride concentration (119.0 ug/l) of all groups measured for these physiochemical variables in 1974. These measurements reflect the eutrophic conditions that were present in the bay in 1974. Group I also had the highest densities (no. individual rotifers/l) for three of the five rotifers listed as eutrophic indicator species. Measurements of group II (shores of Saginaw Bay) physiochemical parameters also reflected eutrophic conditions in 1974. Group II had the highest rotifer densities for two of the five rotifers listed as eutrophic indicator species. Notholca spp., a coldwater stenothermic rotifer, was only found in groups III and IV where measurements of physiochemical variables in 1974 indicated more oligotrophic conditions.

Station clusters that resulted from the use of physiochemical variables (Figure III-90), revealed station groups bearing strong similarities to ones obtained from rotifer data (Figure III-89). Results may have revealed a tight coupling of rotifers to their physiochemical environment and indicated the importance of these organisms as indicators of water quality (Stemberger and Gannon, 1977).

Data collected in 1974 revealed distinct differences in the composition and abundance of rotifers between Saginaw Bay and southern Lake Huron stations (Stemberger and Gannon, 1977; Stemberger et al., 1979). These differences were qualitatively related to differences in trophic conditions, suggesting a strong relationship between rotifer community composition and the environment (Stemberger et al., 1979).

In 1974, based on rotifer data alone, the greatest impact of Saginaw Bay waters on Lake Huron occurred along the western shore of southern Lake Huron immediately below the mouth of the bay (Stemberger et al., 1979). Several species, such as Anuraeopsis fissa, Brachionus spp., Conochiloides dossuarius, and Keratella cochlearis f. tecta, that occurred only at stations in or near Saginaw River, are potentially valuable eutrophic indicators (Stemberger et al., 1979). Also, certain coldwater stenothermal species, such as Notholca laurentiae and Synchaeta asymmetrica, are useful as oligotrophic indicators, but only during periods of thermal stratification (Stemberger et al., 1979).

Rotiferan zooplankton responded dramatically to nutrient diversion in the bay with substantial decreases in total rotifers and predatory rotifers between 1974 and 1980 (McNaught et al., 1983). Total numbers of rotifers decreased 3-fold between 1974 and 1980 (Figure III-91; McNaught et al., 1983). Predatory rotifers also decreased substantially, which indicated that a lower predatory organism had responded as predicted to nutrient limitation (McNaught et al., 1983). Predatory rotifers provided substantial evidence that Saginaw Bay is rapidly responding to decreased nutrient levels (McNaught et al., 1983).

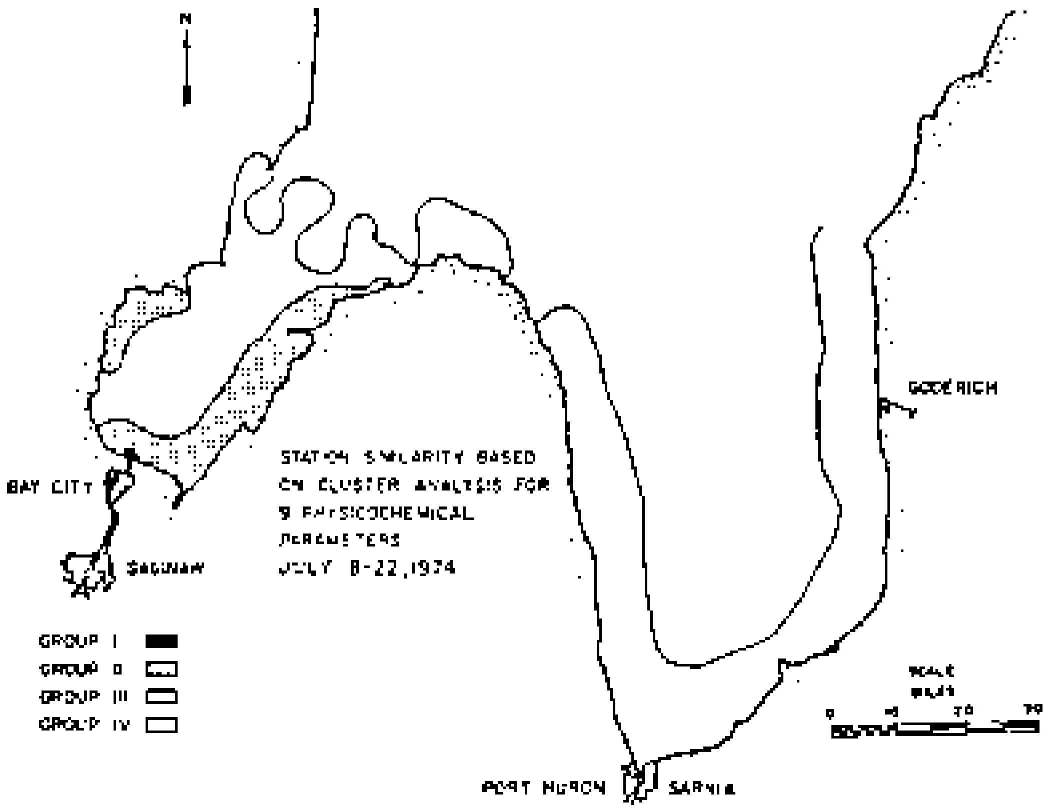


Figure III-90. Grouping of 99 stations determined by cluster analysis of physiochemical data for Saginaw Bay and southern Lake Huron during July, 1974 (Stemberger and Gannon, 1977).

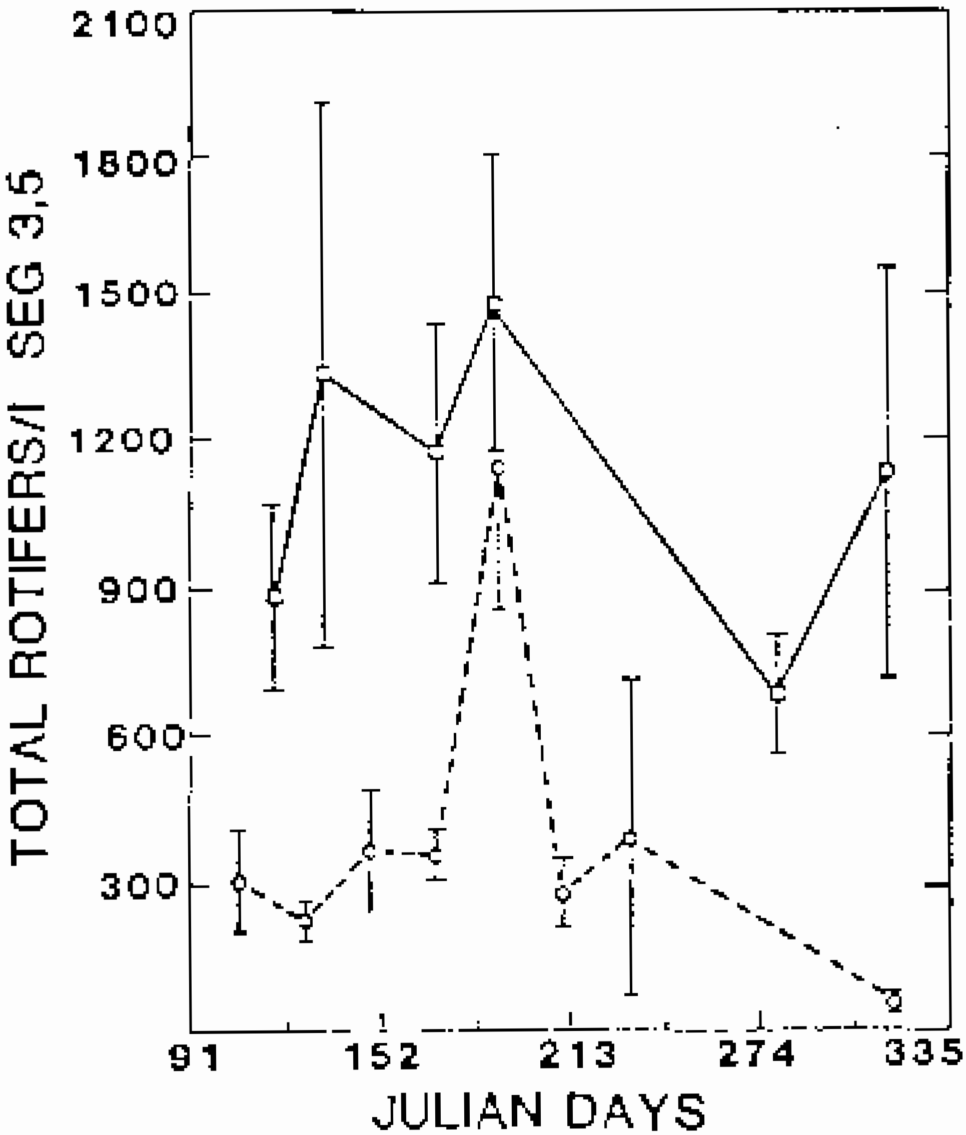


Figure III-91. Numbers of rotifers (#/l) found in segments 3 and 5 in 1974 (□) contrasted to 1980 (○) (McNaught et al., 1983).

Rotifers of the genus Brachionus (8 spp. in Saginaw Bay, along with the rare genus Anuraeopsis, which was absent during 1980), have been used as eutrophic indicators (McNaught et al., 1983). These eutrophic indicating rotifers were expected to be more common during 1974 than during 1980, yet no significant differences were evident, within one standard error, between 1974 and 1980 populations of eutrophic rotifers in segments 3 and 5. The eutrophic indicator Brachionus (Anuraeopsis did not appear in 1980) did not respond to either the reduced nutrient levels that occurred during this period, or to changes in phytoplankton populations (McNaught et al., 1983). Thus, Brachionus did not respond to what was clearly reduced eutrophy, probably because its food resources (including detritus) had not decreased substantially in the bay (McNaught et al., 1983).

b. Crustacean Zooplankton

Eutrophic waters are characterized by communities of crustacean zooplankton associated with warm waters, and related assemblages of algae and groups of predatory fishes (McNaught et al., 1980). Certain species of cyclopoid copepods and cladocerans are typically considered eutrophic indicators and were found in abundance in the inshore waters of Lake Huron and particularly in the mouth of Saginaw Bay in 1974 (McNaught et al., 1980). Calanoid copepods are thought to be more oligotrophic organisms than the cyclopoid copepods (McNaught et al., 1980). All calanoids were found offshore and the most oligotrophic calanoid, Diaptomus sicilis, was most abundant in the midlake region in 1974 (McNaught et al., 1980). The calanoid Diaptomus sicilis and calanoid copepods have generally been used as oligotrophic indicator species, yet Diaptomus siciloides has been identified as an eutrophic indicator species and has been found in the bay (McNaught et al., 1980). This evidence suggests that, whenever possible, the use of zooplankton as biomonitoring tools should be carried out on a species-specific basis.

From 1974 to 1980, Crustacean zooplankton were moderately reduced in abundance, and fell from a yearly mean of 155,708/m^3 in 1974 to 96,460/m^3 in 1980 (Figure III-92; McNaught et al., 1983). The percentage composition of the eutrophic indicator Bosmina longirostris remained somewhat constant, comprising 38% of total crustaceans in 1974 and 33.4% of total crustaceans in 1980. However, the magnitude of the spring bloom is evidence of decreased eutrophication. There were also some indications that populations of the oligotrophic indicator Diaptomus sicilis were increasing in 1980.

Planktonic ratios (calanoids/cyclopoids and cladocerans) and indicator species were the water quality indicators used to delineate eight management segments of southern Lake Huron (McNaught et al, 1980). Inshore segments (4, 5, 7, 8) and segment 6 offshore of Saginaw Bay demonstrated consistently lower water quality than segment 10 (northern open waters; Figure III-93). Sizable increases in pollution-indicating crustaceans were not apparent among samples collected by the Canadian Center for Inland Waters (CCIW) in 1971, and McNaught et al., in 1974.

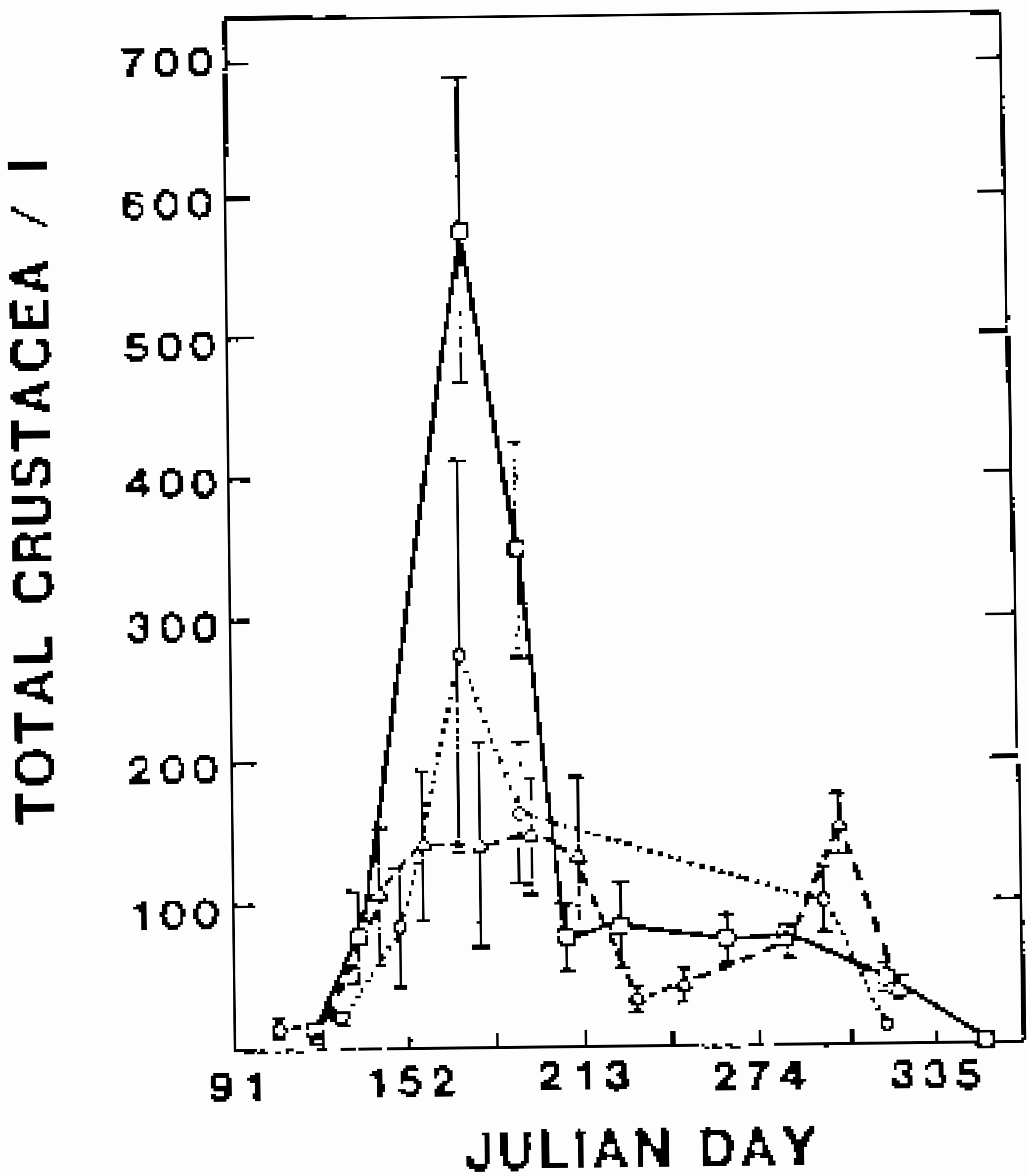


Figure III-92. Numbers of crustacean zooplankton (#/l) found in segments 3 and 5 during 1974, 1975, and 1980 (McNaught et al., 1983).

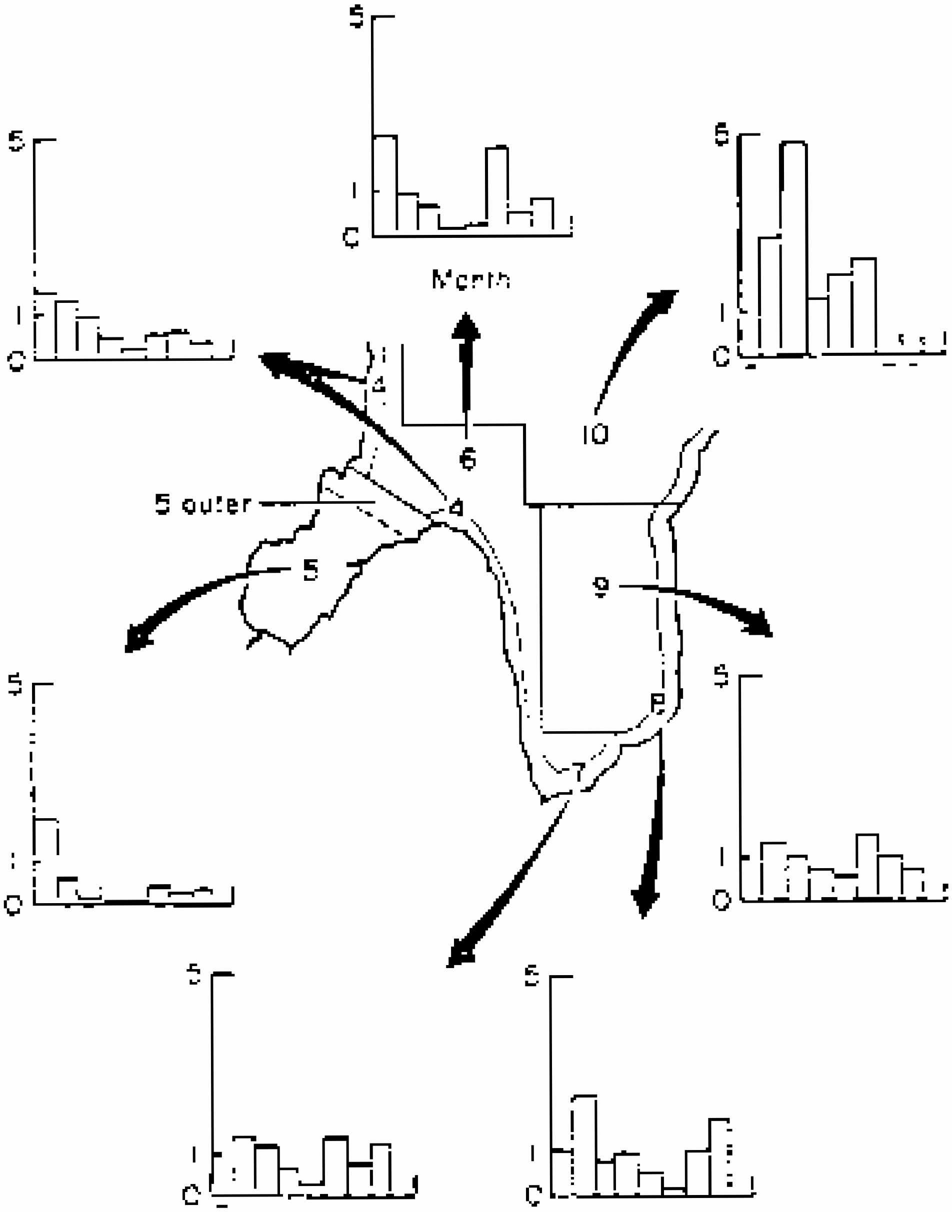


Figure III-93. The ratio of calanoids to cyclopoids (adults and copepods) plus cladocerans for April through October 1974 in southern Lake Huron (McNaught et al., 1980).

c. Rotiferan and Crustacean Zooplankton Comparisons

Although phosphorus inputs to the bay were reduced by 50% between 1975 and 1978, the resulting 7.6 ug/l change in phosphorus concentration in the water led to only small changes in crustacean zooplankton populations (Figure III-92). There were, however, significant decreases in total rotifers (Figure III-91) and total predatory rotifers during this period; the total density of rotiters in the bay decreased from 1,114,500/m^3 in 1974 to 352,000/m^3 in 1980 (McNaught et al., 1983).

Crustacean zooplankton and rotifers were five and 40 times, respectively, more abundant near the mouth of the Saginaw River than elsewhere in the bay in October of 1974, corresponding to high phosphorus levels during 1974 (Gannon, 1981). Rotifer and crustacean zooplankton analyses revealed major water masses interacting with Saginaw River water, impinging primarily on the eastern shore of the bay and Lake Huron water entering the outer western shore (Figure III-94 and Figure III-95).

Rotifer and crustacean zooplankton in each group were associated with specific trophic conditions (Table III-38 and Table III-39). Brachionus spp., a rotifer associated with eutrophic conditions, was found in 1974 only in groups I and II (Figure III-94; Table III-38). Keratella cochlearis f. tecta, another rotifer found in eutrophic environments, had a higher percent composition in groups I and II (8.7 and 5.1%, respectively) than in any of the other groups sampled in 1974 (Table III-38). Groups I and II had the highest levels of all three limnological variables and were the most eutrophic of all groups sampled (Table III-38). Bosmina longirostris, a crustacean zooplankton associated with eutrophic conditions, had a higher percent composition in group I (6.2%) than in any of the other groups sampled (Table III-39; Figure III-95). Group I had the highest levels of all three limnological variables measured and was the most eutrophic of all groups sampled (Table III-39).

Generally, rotifer data provided better resolution of trophic conditions than crustacean zooplankton data (Gannon, 1981). Eutrophic, mesotrophic and oligotrophic assemblages of rotifers in the different groups of stations were more distinct than for crustaceans (Table III-38 and Table III-39). Since rotifers have higher population turnover rates than crustacean zooplankton, they can respond more rapidly to environmental changes (Gannon, 1981). As a result, these data indicate that rotifers may often be more sensitive indicators of water quality than crustacean zooplankton (Gannon, 1981).

3. Macrozoobenthos

a. Saginaw River

Benthic macroinvertebrate samples were collected from the Saginaw River in July 1983. Environmental Research Group, Inc. (ERG) conducted the sampling for the U.S. Army Corps of Engineers (USACOE, 1984). Samples were collected from a total of 37 Saginaw River stations in the navigation channel from Carrollton to the mouth (Figures III-65 and III-66).

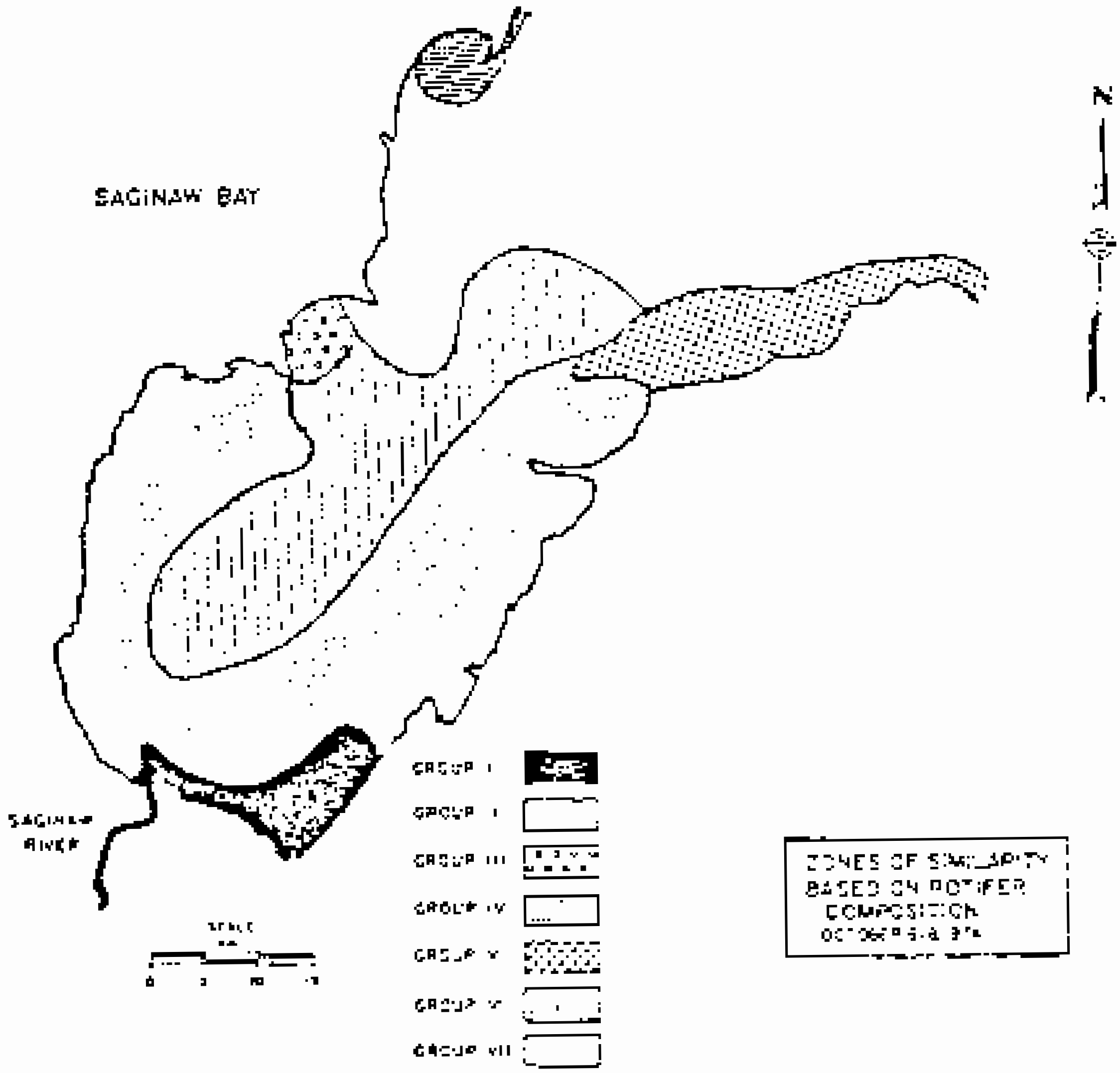


Figure III-94. Grouping of 38 stations determined by cluster analysis of rotifer data for Saginaw Bay during October, 1974 (Gannon, 1981).

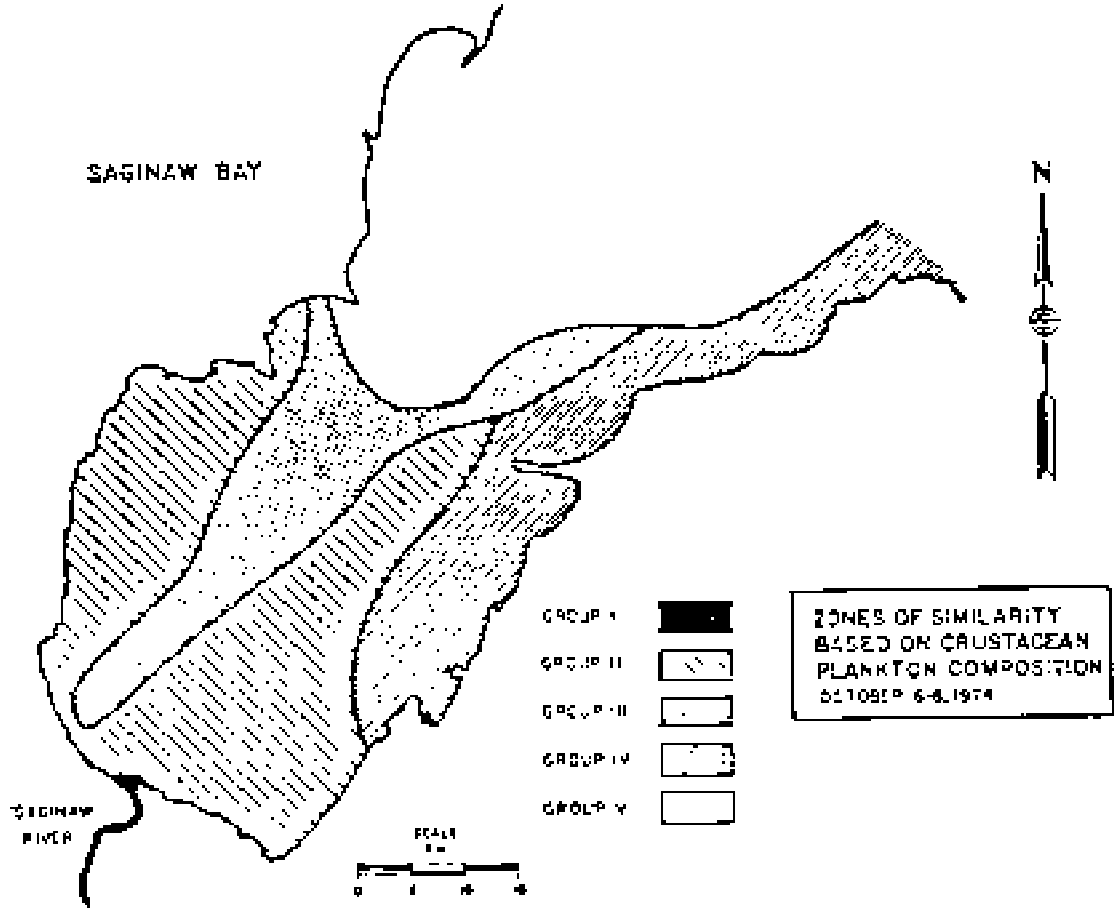


Figure III-95. Grouping of 38 stations determined by cluster analysis of crustacean plankton data for Saginaw Bay during October, 1974 (Gannon, 1981).

Table III-39. Abundance (percent composition) of Selected Crustacean Plankters and Mean Surface Values of Selected Limnological Variables in Groups of Saginaw Bay Stations Identified by Cluster Analysis, October 6-8, 1974 (Gannon, 1981).

Topic	I	II	III	IV	V
Taxon					
Acanthocyclops vernalis	4.7	0.7	3.8	0.3	2.1
Diacyclops bicuspidatus thomasi	0.4	0.2	0.4	0.1	2.4
Bosmina longirostris	6.2	2.2	0.8	4.1	4.1
Eubosmina coregoni	32.5	53.1	63.1	44.7	30.2
Daphnia retrocurva	2	2.7	9.1	2.4	5.0
Eurytemora affinis	0.5	1.6	0.9	2.4	0.5
Diaptomid copepodids	1.2	0.5	1.1	1.3	13
Limnological Variables					
Chlorophyll *a* (ug/l)	34.1	31.3	33.0	26.2	6.8
Spec. cond. (umhos/cm)	846	270	273	225	206
Total phosphorus (ug/l)	235	40	34	30	13
No. Stations/Group	2	9	4	5	6

Collections in the Saginaw River yielded eight species of tubificids, two species of naidids, and five genera of chironomids (Table III-40). Other taxa found in 1983 in Saginaw River samples include nematodes, the cladoceran Leptodor kindti, the coleopteran Dubiraphia sp., a single isopod specimen (Asellus sp.), and a single pelecypod specimen (Sphaeridum sp.).

All taxa collected from the Saginaw River are classified as pollution tolerant (Table III-41). Tubificids, including Limnodrilus hoffmeisteri, L. cervix, and L. maumeensis, were present at all stations. Mature tubificids contributed 100% of the total at station SR-3A and 13% to 68% of the total macrozoobenthos at the remaining stations in the river. Immature Tubificidae with and without hair chaetae comprised between 23% and 80% of the totals at each station. Chironomids were present at 81% of the stations and comprised between 1% and 20% of the totals at those stations.

b. Saginaw Bay

i. Navigation Channel

Benthic macroinvertebrate samples were collected from the navigation channel to the Saginaw River in Saginaw Bay in July 1983 by ERC for the U.S. Army Corps of Engineers. Samples were collected from 11 stations in the Saginaw Bay navigation channel.

Five tubificid species and six chironomid genera were found in samples from the channel (Table III-42). Other taxa present included nematodes, the cladoceran Leptodora kindti, the coleopteran Dubiraphia sp., and a single pelecypod specimen (Pisidium sp.).

Collections in the channel yielded only taxa classified as pollution tolerant, primarily chironomids and tubificids (Table III-43). Chironomids were present at all stations and comprised between 10% and 84% of the totals. Immature Tubificidae with and without hair chaetae comprised between 4% and 59% of the total macrozoobenthos at each station in the channel. Limnodrilus hoffmeisteri and L. cervix were the dominant identifiable tubificids, contributing 1% to 17% and 3% to 22% of the totals at each station, respectively.

ii. Saginaw Bay Proper

The offshore macrozoobenthic community in Saginaw Bay has been studied periodically since the mid-1950s (Surber, 1957; Brinkhurst, 1967; Schneider et al. 1969; Schelske and Roth, 1973; Shrivastava, 1974; and White et al., unpublished). More recently, Cole et al. (1983) have described the littoral macrozoobenthic populations of Sebewaing Harbor (east Saginaw Bay) and their relationship to particle size and organic matter in sediments.

Saginaw Bay is a shallow region that once supported a rich riverine invertebrate bottom fauna, but it underwent drastic changes in response to increased inputs of pollutants (Schelske and Roth, 1973). High sediment oxygen demands eliminated many species of invertebrates, and

Table III-40. Benthic Macroinvertebrate Taxa Collected from the Saginaw River, July 1983 (USACOE, 1984).

Taxon	Family	Species
Nematoda		
Oligochaeta	Tubificidae	_Aulodrilus_ _piqueti_
		Ilyodrilus _templetoni_
		Limnodrilus _cervix_
		Limnodrilus _hoffmeisteri_
		Limnodrilus _maumeensis_
		Limnodrilus _udekemianus_
		Quistadrilus _multisetosus_
		Spirosperma _ferox_
	Naididae	_Arcteonais_ _lomondi_
		Dero _digitata_
Diptera	Chironomidae	_Chironomus_ sp.
		Cricotopus sp.
		Cryptochironomus sp.
		Glyptotendipes sp.
		Procladius sp.
	Chaoboridae	_Chaoborus_ sp.
	Ceratopogonidae	
Cladocera	Leptodoridae	_Leptodora_ _kindti_
Coleoptera	Elmidae	_Dubiraphia_ sp.
Isopoda	Asellidae	_Asellus_ sp.
Pelecypoda	Sphaeriidae	_Sphaerium_ sp.

Table III-41. Benthic Macroinvertebrates Collected in the Saginaw River and their Pollution Tolerance Classification (USACOE, 1984).

Station	Taxa	Common Name	Count	Pollution Tolerance
SR-1	*Procladius* sp.	midge	2	tolerant
	Dero digitata	worm	2	tolerant
	Limnodrilus hoffmeisteri	worm	8	tolerant
	Limnodrilus cervix	worm	6	tolerant
	Limnodrilus maumeensis	worm	6	tolerant
	Limnodrilus udekemianus	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	30	tolerant
	Immat. Tubificidae w cap. chaetae	worm	3	tolerant
SR-2	*Procladius* sp.	midge	1	tolerant
	Dero digitata	worm	2	tolerant
	Quistadrilus multisetosus	worm	1	tolerant
	Limnodrilus maumeensis	worm	8	tolerant
	Limnodrilus hoffmeisteri	worm	6	tolerant
	Limnodrilus cervix	worm	16	tolerant
	Ilyodrilus templetoni	worm	4	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	17	tolerant
	Immat. Tubificidae w cap. chaetae	worm	1	tolerant
SR-3A	*Limnodrilus hoffmeisteri*	worm	3	tolerant
	Limnodrilus cervix	worm	6	tolerant
SR-3	*Procladius* sp.	midge	1	tolerant
	Cricotopus sp.	midge	1	tolerant
	Chaoborus sp.	phantom midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	12	tolerant
	Limnodrilus maumeensis	worm	9	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	7	tolerant
SR-4	*Limnodrilus hoffmeisteri*	worm	7	tolerant
	Limnodrilus cervix	worm	5	tolerant
	Limnodrilus maumeensis	worm	10	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	24	tolerant
	Immat. Tubificidae w cap. chaetae	worm	1	tolerant
SR-5	*Cricotopus* sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	9	tolerant
	Limnodrilus cervix	worm	6	tolerant
	Limnodrilus maumeensis	worm	5	tolerant
	Ilyodrilus templetoni	worm	3	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	21	tolerant

Table III-41. Continued.

Station	Taxa	Common Name	Count	Pollution Tolerance
SR-6	Glyptotendipes sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	2	tolerant
	Limnodrilus cervix	worm	5	tolerant
	Limnodrilus maumeensis	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	8	tolerant
	Immat. Tubificidae w cap. chaetae	worm	1	tolerant
SR-7A	Limnodrilus hoffmeisteri	worm	3	tolerant
	Limnodrilus cervix	worm	7	tolerant
	Limnodrilus maumeensis	worm	13	tolerant
	Ilyodrilus templetoni	worm	2	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	37	tolerant
SR-7	Chaoborus sp.	phantom midge	2	tolerant
	Procladius sp.	midge	1	tolerant
	Quistadrilus multisetosus	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	4	tolerant
	Limnodrilus cervix	worm	3	tolerant
	Limnodrilus maumeensis	worm	2	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	25	tolerant
SR-8	Dero digitata	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	5	tolerant
	Limnodrilus cervix	worm	1	tolerant
	Limnodrilus maumeensis	worm	3	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	6	tolerant
SR-9	Limnodrilus hoffmeisteri	worm	1	tolerant
	Aulodrilus pigueti	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	6	tolerant
SR-10	Procladius sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	2	tolerant
	Limnodrilus cervix	worm	3	tolerant
	Limnodrilus maumeensis	worm	2	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	11	tolerant
SR-11	Procladius sp.	midge	4	tolerant
	Chironomus sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	1	tolerant
	Limnodrilus cervix	worm	2	tolerant
	Limnodrilus maumeensis	worm	3	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	14	tolerant

Table III-41. Continued.

Station	Taxa	Common Name	Count	Pollution Tolerance
SR-12	*Procladius* sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	4	tolerant
	Limnodrilus cervix	worm	3	tolerant
	Limnodrilus maumeensis	worm	8	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/p cap. chaetae	worm	15	tolerant
SR-13	*Leptodora kindti*	water flea	1	tolerant
	Ceratopogonidae	biting midge	3	tolerant
	Procladius sp.	midge	2	tolerant
	Limnodrilus hoffmeisteri	worm	3	tolerant
	Limnodrilus cervix	worm	4	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	20	tolerant
SR-14	*Procladius* sp.	midge	4	tolerant
	Limnodrilus hoffmeisteri	worm	9	tolerant
	Limnodrilus cervix	worm	2	tolerant
	Limnodrilus maumeensis	worm	1	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	22	tolerant
SR-15	*Sphaerium* sp.	pill clam	1	tolerant
	Leptodora kindti	water flea	1	tolerant
	Ceratopogonidae	biting midge	1	tolerant
	Procladius sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	11	tolerant
	Limnodrilus cervix	worm	17	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/p cap. chaetae	worm	35	tolerant
SR-16	*Leptodora kindti*	water flea	1	tolerant
	Procladius sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	2	tolerant
	Limnodrilus cervix	worm	9	tolerant
	Limnodrilus maumeensis	worm	2	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	42	tolerant
SR-17	*Asellus* sp.	sow bug	1	tolerant
	Procladius sp.	midge	6	tolerant
	Dero digitata	worm	7	tolerant
	Limnodrilus hoffmeisteri	worm	2	tolerant
	Limnodrilus cervix	worm	3	tolerant
	Limnodrilus maumeensis	worm	4	tolerant
	Ilyodrilus templetoni	worm	3	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	29	tolerant
	Immat. Tubificidae w cap. chaetae	worm	2	tolerant

Table III-41. Continued.

Station	Taxa	Common Name	Count	Pollution Tolerance
SR-18	Ceratopogonidae	biting midge	1	tolerant
	Procladius sp.	midge	1	tolerant
	Cricotopus sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	1	tolerant
	Limnodrilus cervix	worm	11	tolerant
	Limnodrilus maumeensis	worm	6	tolerant
	Limnodrilus udekemianus	worm	2	tolerant
	Ilyodrilus templetoni	worm	2	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	64	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SR-19	Asellus sp.	sow bug	2	tolerant
	Procladius sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	2	tolerant
	Limnodrilus cervix	worm	18	tolerant
	Limnodrilus maumeensis	worm	7	tolerant
	Limnodrilus udekemianus	worm	1	tolerant
	Ilyodrilus templetoni	worm	2	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	63	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SR-20	Procladius sp.	midge	4	tolerant
	Dero digitata	worm	2	tolerant
	Limnodrilus hoffmeisteri	worm	5	tolerant
	Limnodrilus cervix	worm	6	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	65	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SR-21	Limnodrilus cervix	worm	5	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	10	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SR-22	Leptodora kindti	water flea	1	tolerant
	Procladius sp.	midge	2	tolerant
	Limnodrilus hoffmeisteri	worm	4	tolerant
	Limnodrilus cervix	worm	13	tolerant
	Limnodrilus maumeensis	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	21	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SR-23	Nematoda	roundworm	1	tolerant
	Procladius sp.	midge	3	tolerant
	Limnodrilus hoffmeisteri	worm	8	tolerant
	Limnodrilus cervix	worm	13	tolerant

Table III-41. Continued.

Station	Taxa	Common Name	Count	Pollution Tolerance
SR-23 Cont.	Limnodrilus maumeensis	worm	15	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	48	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	4	tolerant
SR-24	Dero digitata	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	3	tolerant
	Limnodrilus cervix	worm	16	tolerant
	Limnodrilus maumeensis	worm	5	tolerant
	Ilyodrilus templetoni	worm	2	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	10	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SR-25	Ceratopogonidae	biting midge	1	tolerant
	Procladius sp.	midge	4	tolerant
	Dero digitata	worm	3	tolerant
	Quistadrilus multisetosus	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	9	tolerant
	Limnodrilus cervix	worm	8	tolerant
	Limnodrilus maumeensis	worm	7	tolerant
	Ilyodrilus templetoni	worm	5	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	33	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SR-26	Nematoda	roundworm	1	tolerant
	Procladius sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	8	tolerant
	Limnodrilus cervix	worm	7	tolerant
	Limnodrilus maumeensis	worm	5	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	21	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SR-27	Procladius sp.	midge	7	tolerant
	Limnodrilus hoffmeisteri	worm	11	tolerant
	Limnodrilus cervix	worm	12	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	30	tolerant
	Immat Tubificidae w/cap. chaetae	worm	4	tolerant
SR-28	Asellus sp.	sow bug	1	tolerant
	Dero digitata	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	10	tolerant
	Limnodrilus cervix	worm	45	tolerant
	Limnodrilus maumeensis	worm	4	tolerant
	Ilyodrilus templetoni	worm	3	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	29	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	2	tolerant

Table III-4. Continued.

Station	Taxa	Common Name	Count	Pollution Tolerance
SR-29	Asellus sp.	sowbug	1	tolerant
	Procladius sp.	midge	2	tolerant
	Dero digitata	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	6	tolerant
	Limnodrilus cervix	worm	13	tolerant
	Limnodrilus maumeensis	worm	4	tolerant
	Immat. Tubificidae w/o cap. chaetae	wrom	68	tolerant
SR-30	Dubiraphia sp.	riffle beetle	2	tolerant
	Procladius sp.	midge	3	tolerant
	Dero digitata	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	12	tolerant
	Limnodrilus cervix	worm	21	tolerant
	Limnodrilus maumeensis	worm	3	tolerant
	Ilyodrilus templetoni	worm	9	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	32	tolerant
SR-31	Cryptochironomus sp.	midge	1	tolerant
	Procladius sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	1	tolerant
	Limnodrilus cervix	worm	8	tolerant
	Limnodrilus maumeensis	worm	6	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	16	tolerant
SR-32	Ceratopogonidae	biting midge	2	tolerant
	Procladius sp.	midge	2	tolerant
	Dero digitata	worm	4	tolerant
	Limnodrilus claparadianus	worm	1	tolerant
	Limnodrilus cervix	worm	3	tolerant
	Limnodrilus maumeensis	worm	2	tolerant
	Limnodrilus hoffmeisteri	worm	4	tolerant
	Ilyodrilus templetoni	worm	2	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	5	tolerant
	Immat. Tubificidae w cap. chaetae	worm	1	tolerant
SR-33	Hyalella azteca	scud	1	tolerant
	Procladius sp.	midge	3	tolerant
	Quistadrilus multisetosus	worm	2	tolerant
	Limnodrilus hoffmeisteri	worm	6	tolerant
	Limnodrilus cervix	worm	15	tolerant
	Limnodrilus maumeensis	worm	4	tolerant
	Ilyodrilus templetoni	worm	4	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	31	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant

Table III-41. Continued.

Station	Taxa	Common Name	Count	Pollution Tolerance
SR-34	*Leptodora kindti*	water flea	1	tolerant
	Ceratopogonidae	biting midge	2	tolerant
	Procladius sp.	midge	2	tolerant
	Chironomus sp.	midge	1	tolerant
	Spirosperma ferox	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	9	tolerant
	Limnodrilus cervix	worm	8	tolerant
	Limnodrilus maumeensis	worm	2	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	27	tolerant
SR-35	*Leptodora kindti*	water flea	5	tolerant
	Procladius sp.	midge	8	tolerant
	Arcteonais lomondi	worm	1	tolerant
	Dero digitata	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	11	tolerant
	Limnodrilus cervix	worm	17	tolerant
	Limnodrilus udekemianus	worm	2	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	98	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	2	tolerant

Table III-42. Benthic Macroinvertebrate Taxa Collected from the Saginaw Bay Navigation Approach Channel to the Saginaw River, July 1983 (USACOE, 1984).

Taxon	Family	Species
Nematoda		
Oligochaeta	Tubificidae	*Ilyodrilus templetoni*
		Isochaetides freyi
		Limnodrilus cervix
		Limnodrilus hoffmeisteri
		Limnodrilus maumeensis
Diptera	Chironomidae	*Chironomus* sp.
		Cryptochironomus sp.
		Paracladopelma sp.
		Procladius sp.
		Psectrotanypus sp.
		Tanytarsus sp.
	Ceratopogonidae	
Cladocera	Leptodoridae	*Leptodora kindti*
Coleoptera	Elmidae	*Dubiraphia* sp.
Pelecypoda	Sphaeriidae	*Pisidium* sp.

Table III-43. Benthic Macroinvertebrates Collected in the Saginaw Bay Navigation Approach Channel and Their Pollution Tolerance Classification (USACOE, 1984).

Station	Taxa	Common Name	Count	Pollution Tolerance
SB-1	*Tanytarsus* sp.	midge	1	tolerant
	Procladius sp.	midge	6	tolerant
	Chironomus sp.	midge	3	tolerant
	Ceratopogonidae	biting midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	13	tolerant
	Limnodrilus cervix	worm	20	tolerant
	Limnodrilus maumeensis	worm	7	tolerant
	Ilyodrilus templetoni	worm	5	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	34	tolerant
SB-2	*Chironomus* sp.	midge	9	tolerant
	Limnodrilus hoffmeisteri	worm	4	tolerant
	Limnodrilus cervix	worm	9	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	14	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	4	tolerant
SB-3	*Procladius* sp.	midge	8	tolerant
	Chironomus sp.	midge	12	tolerant
	Limnodrilus hoffmeisteri	worm	7	tolerant
	Limnodrilus cervix	worm	2	tolerant
	Limnodrilus maumeensis	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	11	tolerant
SB-4	*Leptodora kindti*	water flea	1	tolerant
	Chironomus sp.	midge	26	tolerant
	Procladius sp.	midge	10	tolerant
	Limnodrilus udekemianus	worm	1	tolerant
	Limnodrilus hoffmeisteri	worm	10	tolerant
	Limnodrilus cervix	worm	2	tolerant
	Limnodrilus maumeensis	worm	2	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	9	tolerant
SB-5	Nematoda	roundworm	1	tolerant
	Dubiraphia	riffle beetle	1	tolerant
	Chironomus sp.	midge	79	tolerant
	Procladius sp.	midge	2	tolerant
	Limnodrilus hoffmeisteri	worm	2	tolerant
	Limnodrilus cervix	worm	7	tolerant
	Limnodrilus maumeensis	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	4	tolerant

Table III-43. Continued.

Station	Taxa	Common Name	Count	Pollution Tolerance
SB-6	Nematoda	roundworm	2	tolerant
	Leptodora kindti	water flea	2	tolerant
	Paracladopelma sp.	midge	2	tolerant
	Cryptochironomus sp.	midge	1	tolerant
	Chironomus sp.	midge	24	tolerant
	Procladius sp.	midge	1	tolerant
	Tanytarsus sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	4	tolerant
	Isochaetides freyi	worm	3	tolerant
	Limnodrilus cervix	worm	7	tolerant
	Limnodrilus udekemianus	worm	1	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	22	tolerant
SB-7	Chironomus sp.	midge	53	tolerant
	Limnodrilus hoffmeisteri	worm	4	tolerant
	Limnodrilus maumeensis	worm	15	tolerant
	Limnodrilus cervix	worm	13	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	66	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SB-8	Chironomus sp.	midge	55	tolerant
	Procladius sp.	midge	1	tolerant
	Limnodrilus hoffmeisteri	worm	3	tolerant
	Limnodrilus maumeensis	worm	5	tolerant
	Limnodrilus cervix	worm	6	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	65	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	1	tolerant
SB-9	Nematoda	roundworm	2	tolerant
	Leptodora kindti	water flea	1	tolerant
	Chironomus sp.	midge	63	tolerant
	Limnodrilus hoffmeisteri	worm	7	tolerant
	Limnodrilus cervix	worm	7	tolerant
	Limnodrilus maumeensis	worm	7	tolerant
	Ilyodrilus templetoni	worm	2	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	98	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	10	tolerant
SB-10	Nematoda	roundworm	3	tolerant
	Pisidium sp.	pill clam	2	tolerant
	Chironomus sp.	midge	108	tolerant
	Limnodrilus hoffmeisteri	worm	4	tolerant
	Limnodrilus cervix	worm	10	tolerant
	Limnodrilus maumeensis	worm	5	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	161	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	30	tolerant

Table III-43. Continued.

Station	Taxa	Common Name	Count	Pollution Tolerance
SB-11	Nematoda	roundworm	3	tolerant
	Leptodora kindti	water flea	[illegible]	tolerant
	Chironomus sp.	midge	69	tolerant
	Limnodrilus hoffmeisteri	worm	3	tolerant
	Limnodrilus cervix	worm	14	tolerant
	Limnodrilus maumeensis	worm	7	tolerant
	Ilyodrilus templetoni	worm	1	tolerant
	Immat. Tubificidae w/o cap. chaetae	worm	58	tolerant
	Immat. Tubificidae w/ cap. chaetae	worm	9	tolerant

these were replaced by pollution-tolerant forms such as aquatic worms Limnodrilus spp. and lakeflies or midges Chironomus spp. (Schelske and Roth, 1973). Eight species of aquatic worms in the family Naididae were found in 1956, including Paranais litoralis, a species ordinarily restricted to salt or brackish-water (Brinkhurst, 1967). The presence of Paranais litoralis at three offshore stations deep in the bay was due to the exceptionally high salinity of the Saginaw River; water analyses at that time occasionally revealed concentrations of chloride greater than 500 mg/l (Brinkhurst, 1967). Eighteen species of aquatic worms in the family Tubificidae, the dominant being the pollution tolerant Limnodrilus hoffmeisteri, were also found in the bay in 1956 (Brinkhurst, 1967). White et al. (unpublished) found similar aquatic worm species (13 Tubificidae, 12 Naididae), and species of midges (5 Chironomidae) in 1978.

Total densities of macrozoobenthos in 1978 were an order of magnitude higher than those reported for 1956 or 1971 collections, and seasonal patterns showed the greatest densities in April (White et al., unpublished). The aquatic worm Vejdovskyella intermedia, not previously reported from Saginaw Bay or Lake Huron, was the dominant naidid reaching densities greater than $10,000/m^2$ in early spring but declining to less than $50/m^2$ in late summer indicating a one year life cycle (White et al., unpublished). Between 1956 and 1978, the species composition changed from a mesotrophic to a eutrophic assemblage, and many less tolerant taxa disappeared demonstrating probable organic enrichment (White et al., unpublished).

Burrowing mayfly nymphs (mostly family Ephemeridae, genus Hexagenia), once common members of the Saginaw Bay fauna, decreased in the open bay from $63/m^2$ in 1955, to $9/m^2$ in 1956, to $1/m^2$ in 1965 (Schneider et al., 1969), to $0/m^2$ in 1970 (Schelske and Roth, 1973). Mayfly nymphs are common in silt bottoms of larger streams and lakes and have been typically identified as clean water, pollution-intolerant species. Their decrease to $1/m^2$ in 1965 and disappearance in 1970 indicate a severe reduction in water quality in the bay between 1955 and 1970. Degraded environmental conditions in Saginaw Bay were further reflected in the bottom fauna at all three inner bay stations in 1970. When crustaceans were totally absent and the fauna consisted entirely of pollution tolerant species of aquatic worms (80-94% oligochaetes) and midge (chironomid) larvae (Schelske and Roth, 1973).

Mean macrozoobenthos densities in inner Saginaw Bay in 1978 ranged from $19,354/m^2$ at station 31 to $35,675/m^2$ at station 47 (Figure III-96). Oligochaetes comprised between 96% and 98% of the totals (White et al., unpublished). These densities were distinctly higher than previously reported for Saginaw Bay: $1,756/m^2$ in 1956 (Brinkhurst, 1967), and $3,500/m^2$ in 1971 (Shrivastava, 1974), suggesting increased pollution and decreased water quality in the bay (White et al., unpublished). Some of the density differences between the Saginaw Bay studies may have been due, in part, to the screen mesh sizes used in sorting zoobenthos from the sediments (0.565 mm in Brinkhurst, 1967; 0.500 mm in Shrivastava, 1974; and, 0.350 mm in White et al., unpublished).

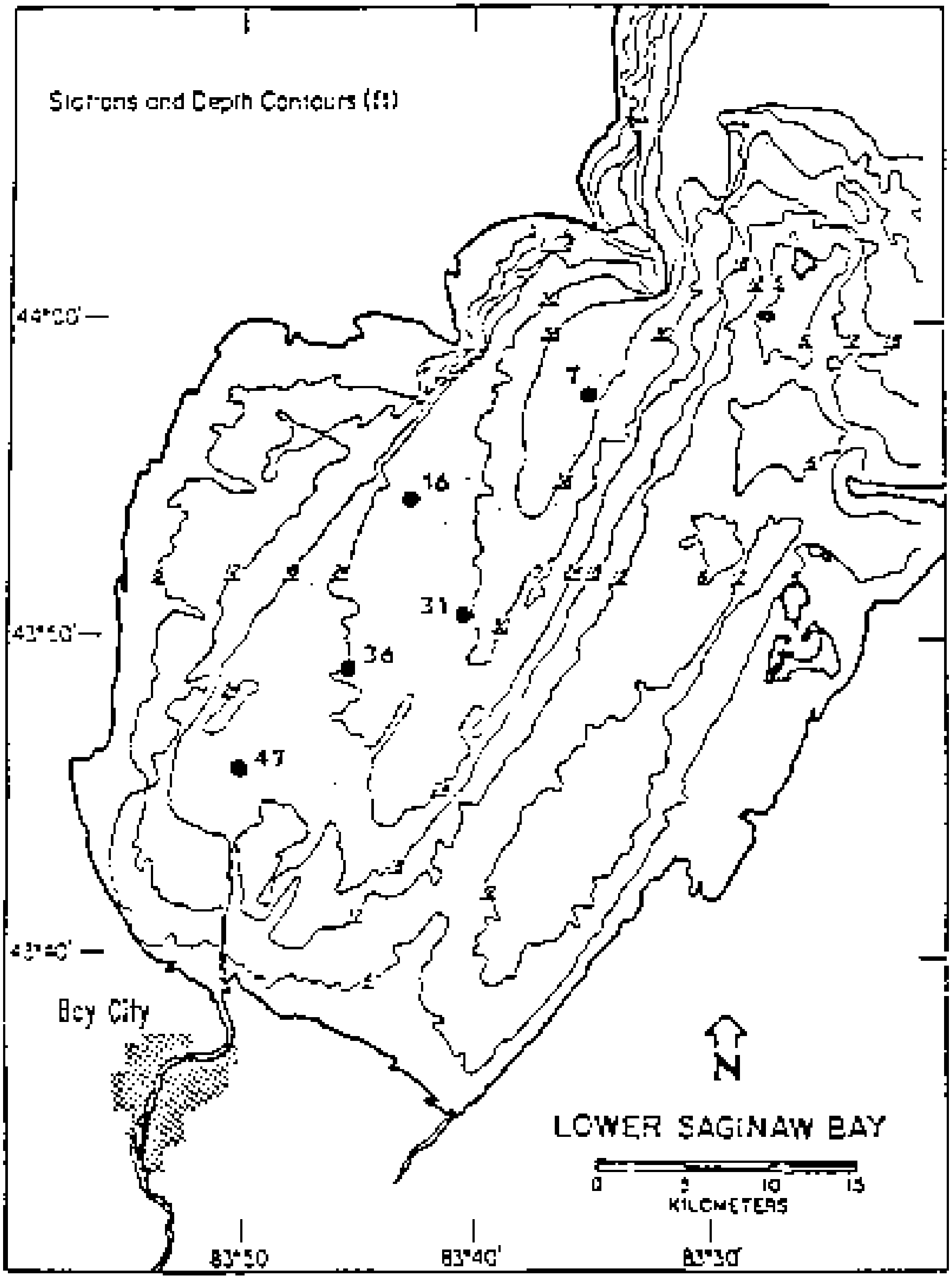


Figure III-96. Saginaw Bay sampling stations; shaded area depicts region of fine-grained sediments after Wood (1964) (White et al., unpublished).

The pollution-tolerant Limnodrilus hoffmeisteri, L. claparedeianus, and Chironomus spp. were the most abundant zoobenthic taxa collected in 146 samples from Sebewaing Harbor, during fall 1976, with mean densities of 1,208.3/m², 508.0/m², and 258.1/m² respectively (Cole and Weigmann, 1983). Biomass and mean individual weight of zoobenthos were significantly higher in the fine sediments, consisting of organically rich silts and clays, than in coarse sediments, consisting of organically poor sands (Cole and Weigmann, 1983).

In addition to density increases, there were macrozoobenthos species composition changes between 1956 and 1978 (Table III-44). Of the 18 tubificid taxa recorded for 1956 (Brinkhurst, 1967), seven were not found in 1978, 12 were common to both collections, and one taxon was only found in 1978 (White et al., unpublished). Three of the eight naidid species collected in 1956 were not found in 1978, four species were found in both 1956 and 1978, and eight were new in 1978 (White et al., unpublished). Schneider et al. (1969) listed the amphipod Gammarus and mayflies, including Hexagenia, as being present in the open bay, and Schelske and Roth (1973) collected both amphipods and pisidiids in the offshore waters of the outer bay (White et al., unpublished). None of these taxa were found in the 1978 samples of White et al. (unpublished). The disappearance of amphipods, mayflies and pisidium clams reflects environmental degradation and reduced water quality in the bay from 1956 to 1978. These changes in the benthic community have limited productivity of valubale fish species such as yellow perch (Haas, personal communication).

In summary, the density of macrozoobenthos in the mud deposits of inner Saginaw Bay increased dramatically between 1956 and 1978 (White et al., unpublished). Most of these increases were related to increased densities of tubificids associated with eutrophic conditions and to high densities of the naidid Vejdovskyella intermedia, which had not been previously reported for Saginaw Bay or Lake Huron (White et al., unpublished). Several mesotrophic tubificid species found in the bay in the mid-1950s were not collected again in 1978 (White et al., unpublished). High sediment oxygen demands eliminated many species of invertebrates, including mayflies (esp. Hexagenia spp.), that were replaced by pollution-tolerant forms such as Limnodrilus and Chironomus (Schelske and Roth, 1973). These data point to decreasing water and sediment quality in inner Saginaw Bay.

c. Changes in Trophic Status

Both oligochaetes and chironomids have been used as indicators of water and sediment quality in the Great Lakes (Kalepa and Thomas, 1976; Lauritsen et al. 1985; Winnell and White, 1985). While uncertainties remain in assigning tubificid species to a particular trophic status (oligotrophic, mesotrophic or eutrophic), trophic indices based on tubificids have proven valuable in documenting water and sediment quality changes in any one area over time (Winnell and White, 1985). Based on the index ranges in Winnell and White (1985), the sediments of inner Saginaw Bay would be classified as mesotrophic in 1956, becoming strongly eutrophic by 1971, and even more so by 1978 (White et al., unpublished).

Table III-44. Benthic Macroinvertebrate Taxa Collected from Saginaw Bay in 1956 (Brinkhurst, 1967) and 1978 (White et al., unpublished).

Order Family Species	Year 1956	Year 1978
Oligochaeta		
Tubificidae		
Aulodrilus americanus	X	
Aulodrilus limnobius	X	
Aulodrilus piqueti	X	X
Aulodrilus pluriseta	X	X
Ilyodrilus templentoni	X	X
Isochaetides freyi	X	
Limnodrilus angustipenis	X	
Limnodrilus cervix	X	X
Limnodrilus claparedeianus	X	X
Limnodrilus hoffmeisteri	X	X
Limnodrilus maumeensis	X	X
Limnodrilus udekemianus	X	
Potamothrix bedoti		X
Potamothrix moldaviensis	X	X
Potamothrix vejdovski	X	X
Quistadrilus multisetosus longidentus	X	X
Quistadrilus multisetosus multisetosus	X	X
Spirosperma ferox	X	
Rhyacodrilus montana	X	
Tubifex tubifex	X	X
Naididae		
Amphichaeta leydigi		X
Arcteonais lomondi	X	X
Cheatogaster diaphanus		X
Cheatogaster setosus		X
Dero digitata	X	X
Nais communis		X
Nais elinguis	X	
Nais simplex		X
Ophidonais serpentina	X	X
Paranais litoralis	X	
Piguetiella michiganensis		X
Specaria josinae		X
Stylaria lacustris	X	
Uncinais uncinata	X	X
Vejdovskyella intermedia		X
Diptera		
Chironomidae		
Chironomus anthracinus		X
Chironomus plumosus semireductus		X
Cryptochironomus fulvus		X
Procladius sp.		X
Psectrocanypus sp.		X

d. Vertical Distribution of Benthic Macroinvertebrates

Results from the vertical distributions of macrozoobenthos in Saginaw Bay cores were similar to results from studies of macrozoobenthos in southeastern Lake Huron (Krezoski et al., 1978) and Lake Michigan (Nalepa and Robertson, 1981). The upper 2 cm of each core contained only naidids and chironomids, both naidids and tubificids were present in the 2-3 cm layer, and only tubificids occurred below 3 cm deep (White et al., unpublished). The presence of only tubificids below 3 cm suggests an unsuitable environment even for pollution tolerant naidids and chironomids, and suggests high sediment-oxygen demands and contamination of surface sediments in the bay as well as contamination in bay sediments below 3 cm.

The depth to which 90% of the macrozoobenthos occurred (7-14 cm) was much deeper than reported for previous studies of the open Great Lakes (e.g., 4-6 cm in southern Lake Huron; Krezoski et al., 1978; and 1-5 cm in Lake Michigan; Conley, 1987) but was similar to depths listed for parts of Green Bay, up to 9.5 cm, and Grand Traverse Bay, up to 8 cm (Conley, 1987; White et al., unpublished). The occurrence of macroinvertebrates below 3 cm in Saginaw Bay sediments suggests a greater biological reworking of sediments than in other areas increasing the amount of sediment brought to the surficial interface with overlying waters.

G. BIOTA CONTAMINATION AND IMPACTS

1. Contaminant Levels in Biota

a. Phytoplankton

Algae are primary producers and provide the foundation of the aquatic animal trophic system. Algae are grazed by zooplankton and other invertebrates which in turn are consumed by fish and birds. Thus, algae that have picked up metal or organic contaminants may introduce contaminants to organisms higher in the food chain and may serve as environmental indicators of the conditions and quality of the water column.

Unfortunately, few data are available for contaminant levels in Saginaw River/Bay net plankton and filamentous algae (Kreis and Rice, 1985). However, McNaught et al. (1984) conducted in situ experiments on the inhibitory effects of PCBs on the growth of natural Saginaw Bay phytoplankton communities, and culture studies have revealed various effects of specific contaminants on phytoplankton growth in Saginaw Bay (Lederman and Rhee, 1981a, 1981b; Gotham and Rhee, 1982). Organic contaminant effects are compound and species-specific, and can serve to stimulate or inhibit algal growth (Kreis and Rice, 1985).

In 1974 and 1979, PCBs were detected in Lake Huron net plankton and ranged from 1.0 to 6.4 mg/g (Table III-45). The highest concentrations were found in the southern basin of the lake in 1974, while the next highest concentrations were found in Georgian Bay (Kreis and Rice, 1985). When considering the distribution and sources of PCBs into this region, Kreis and Rice (1985) found these concentrations perplexing. High concentrations of greater than 6.0 mg/g were found in southern Lake Huron plankton in 1974 but not in Saginaw Bay or Harbor Beach plankton, where known discharges of PCBs were occurring or where PCB ambient concentrations were high. The results of Kreis and Rice (1985) may indicate new or additional sources of PCBs.

Trace amounts of dieldrin were detected in all 1974 plankton samples (Table III-45). Trace levels of p,p'-DDE were found in 1974 but were recorded as less than 0.005 mg/g in 1979 (Kreis and Rice, 1985).

b. Macrozoobenthos

i. Pine River

Plankton, periphyton and benthic invertebrates were collected in the St. Louis Reservoir and at two locations downstream in the Pine River in 1980 and 1981 (ECMPDR, 1983). The PBB levels in plankton, periphyton and benthic invertebrates were determined from a single mean of all station measurements added together since samples from individual stations were too few to make valid comparisons. The data showed that PBB levels in plankton (detritus, filamentous algae and zooplankton), periphyton (detritus, diatoms and filamentous algae) and benthic invertebrates (oligochaetes and chironomids) were comparable to each other, averaging

Table III-45. Mean concentrations (ug/kg dry weight) of Organic Contaminants Detected in Lake Huron Net Plankton, 1974 and 1979 (Kreis and Rice, 1985).

Year/Location	n	Location	PCB Total	PCB %1254	PCB %1242	p,p' DDE	Diel-drin	Source
1974 SLH	4	O	6,366			T	T	1
1974 SB	1	O	1,000			ND	T	1
1974 NLH	4	O	1,000			T	T	1
1974 GB	5	O(N)	3,340			T	T	1
1974 NC	1	N	1,000			ND	T	1
1979 HB	4	N	1,651	37.3	62.7	5.0		2

Source Legend:

1. Glooschenko et al. (1976).
2. Anderson et al. (1982).

Key:

SLH = southern Lake Huron
SB = Saginaw Bay
NLH = northern Lake Huron
GB = Georgian Bay
NC = North Channel
HB = Harbor Beach, Michigan
N = nearshore
O = offshore
Blank = no data
ND = not detected

0.230 mg/kg (Figure III-97). This may have been because both plankton and periphyton samples contained detritus particle and filamentous algae, which may have masked any differences.

On a wet weight basis, PBB levels in plankton, periphyton and benthic invertebrates were approximately half the average concentration in fish (ECMPDR, 1983). The PBB concentrations in plankton and periphyton were on the order of 103-104 times greater than water concentrations (maximum water concentrations at all sites were 10 ng/l or less). Benthic invertebrate PBB levels were approximately five times greater than associated sediment concentrations with the highest PBB sediment concentration observed being 8.06 mg/kg (ECMPDR, 1983).

The PBB levels in plankton and benthos were highest immediately downstream of the St. Louis Reservoir (Figure III-98). The highest PBB levels, of greater than 0.600 mg/kg, were found immediately downstream of the St. Louis Reservoir.

ii. Saginaw River

The average PCB concentration in plankton, periphyton and benthic invertebrates collected from the upper, middle and lower Saginaw River in 1980-1981 averaged 0.264 mg/kg dry weight (ECMPDR, 1983). On a wet weight basis, concentrations were on the order of five times lower than average fish concentrations. A comparison of average PCB concentrations at all locations for different types of organisms showed that PCB concentrations in invertebrates were lower than plankton and higher than periphyton (Figure III-99). There was large variation of PCB in plankton samples that was related to concentrations of particulate matter. Suspended particulates inseparable from the plankton may have been responsible for the high PCB concentrations, since PCB compounds adsorb tightly to fine-grained particles.

The PCB concentrations in both plankton and periphyton were on the order of 10^2-10^3 times greater than water concentrations. Limited numbers of water samples taken under moderate flow conditions in 1981 had an average PCB concentration of 10 ng/l in upstream and minor tributaries (LTI, 1983). Concentration factors for benthos were hard to determine but appeared to be on the order of two times greater than sediment concentrations as sediment concentrations ranged from 0.01 mg/kg to 33.0 mg/kg (ECMPDR, 1983).

The PCB concentrations in plankton, periphyton and benthic invertebrates were most concentrated in the lower Saginaw River near Bay City (mouth of the river to six miles upstream), paralleling more concentrated PCB levels in sediments and water there (ECMPDR, 1983). Upstream PCB levels, both at the City of Saginaw and at the uppermost portion of the Saginaw River (head of river to about 14 miles upstream of the mouth), were comparable and less concentrated than levels found at Bay City (Figure III-100).

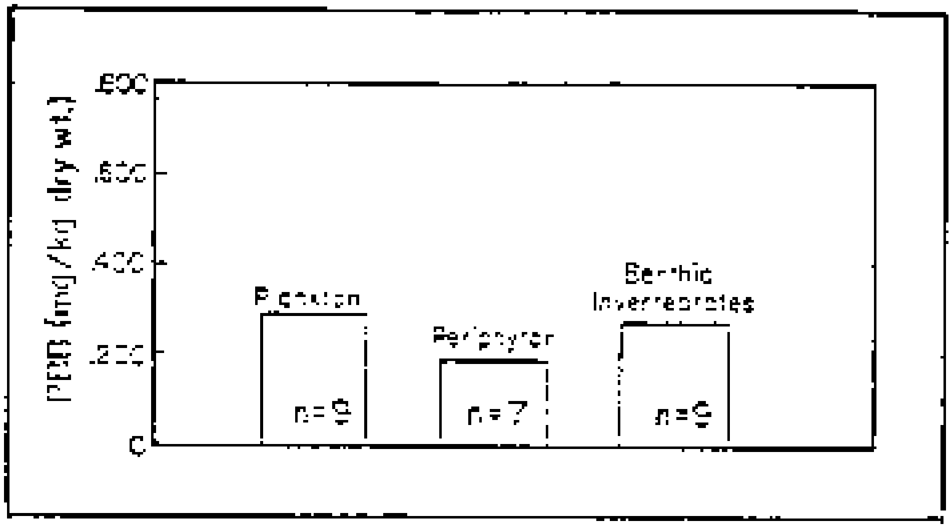


Figure III-97. Average PBB concentrations (mg/kg dry weight) in Pine River plankton, periphyton and benthic invertebrates [illegible].

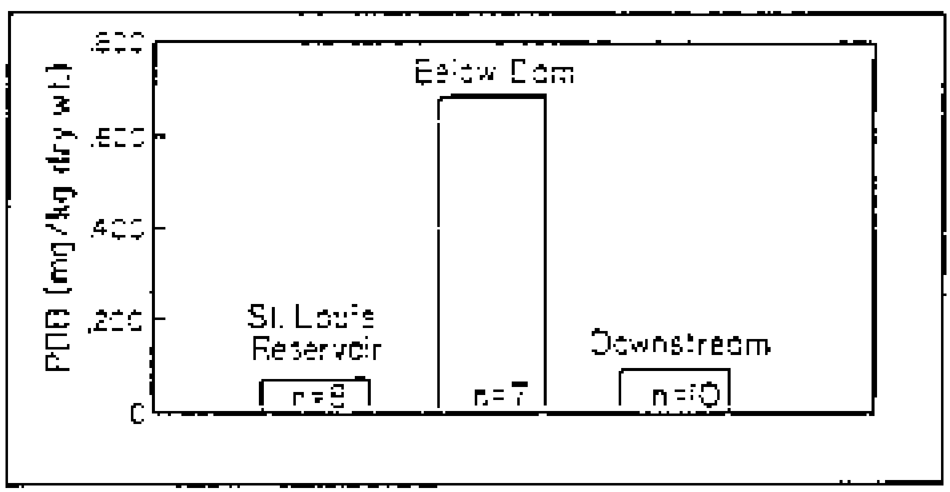


Figure III-98. Average PBB concentrations (mg/kg dry weight) in plankton, periphyton and benthic invertebrates collected in the Pine River from the St. Louis Reservoir, below the dam, and downstream from the dam ([illegible], 1983).

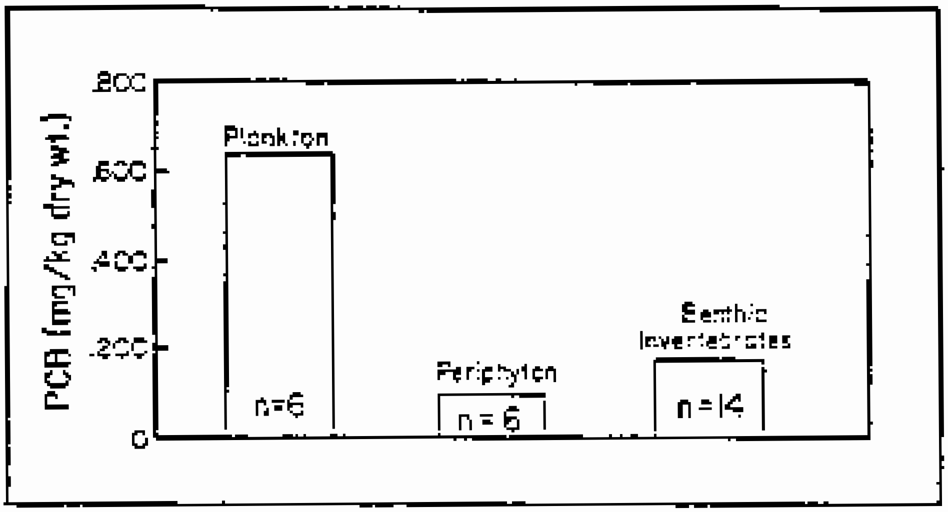


Figure III-99. Average PCB concentrations (mg/kg dry weight) in Saginaw River plankton, periphyton and benthic invertebrates (figure from LTI, 1983).

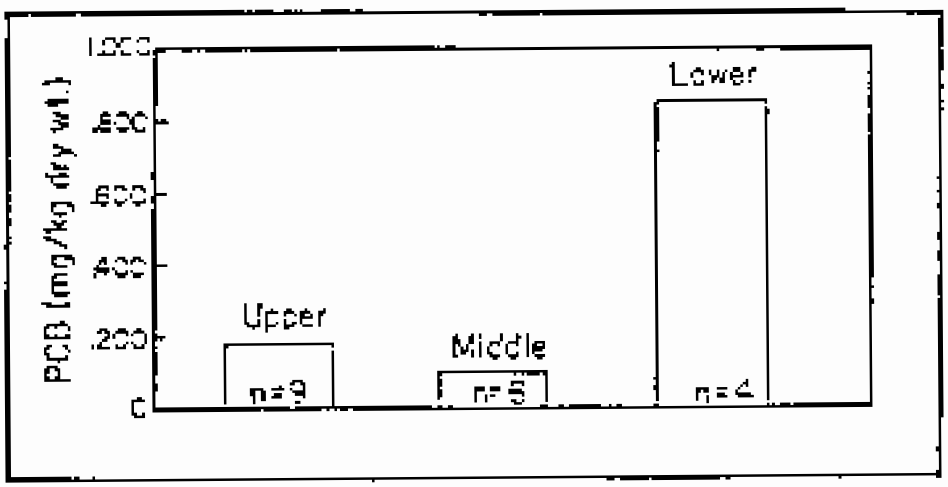


Figure III-100. Average PCB concentrations (mg/kg dry weight) in plankton, periphyton and benthic invertebrates collected from the upper, middle and lower Saginaw River.

c. Macrophytes

Wells et al. (1980) conducted a study of macrophytes in the Saginaw River and Saginaw Bay in which a total of 71 plant collections, representing 22 species of macrophytes, were analyzed for heavy metal concentrations. The highest concentrations of metals tended to occur in plants collected near the mouth of the Saginaw River. Zinc concentrations in 70 samples from Saginaw Bay averaged about 45 ug/g. The highest level of 458 ug/g was found in a pondweed (Potamogeton pectinatus) sample, and the next highest level of 158 ug/g was from a sample of crack-willow (Salix fragilis) leaves. Both submersed and emergent species, a green alga (Cladophora spp.) and narrow-leaved cattail (Typha angustifolia), respectively, were noteworthy in their high heavy metal concentrations. Different organs of the same species, or of the same plant, varied widely in concentrations of the same element. Additionally, plants such as common bulrush (Scirpus acutus) growing in Saginaw Bay contained lower levels of certain elements (Ba, Cr, Rb) than did the same species collected from small lakes in a wilderness area in Michigan's upper peninsula.

d. Fish

i. Consumption Advisories

The Michigan Department of Public Health's (MDPH) Center for Environmental Health Sciences (CEHS) has established criteria for issuing public health fish consumption advisories for certain sport fish caught in Michigan waters. Advisories are issued when contaminant levels in fish exceed state or federal health guidelines or "trigger levels" (Table III-46).

The MDPH issued a no consumption, or "do not eat", advisory in 1988 for any fish species for which 50% or more of the specimens in a particular size class exceeded one or more trigger levels, or for which the mean concentration exceeded the trigger level for any contaminant detected. A "restrict consumption advisory," which suggests limiting consumption to no more than one meal per week, was issued for any species for which 10-49% of the samples exceeded one or more of the trigger levels, but for which the mean concentration did not exceed a trigger level. The purpose of the advisories is to prevent human exposure to significant quantities of chemical agents potentially harmful to human health.

The MDPH, in conjunction with the Michigan Department of Agriculture (MDA) and the Michigan Department of Natural Resources (MDNR), in 1988 issued fish consumption advisories for a variety of fish species in the Saginaw Bay basin (Table III-47).

ii. Shiawassee River

The MDPH 1988 fish consumption advisories warn against eating any fish taken from the Shiawassee River between M-59 and Byron Road, and carp caught between Byron Road and Owosso (Table III-47).

Mean PCB concentrations for carp samples taken at Byron Road in 1985 exceeded the MDPH trigger level of 2.0 mg/kg (Table III-48). The mean

Table III-46. Contaminant Trigger Levels (mg/kg) Currently used in Establishment of Public Health Fish Consumption Advisories (Kreis and Rice, 1985; Humphrey Hesse, 1986).

Chemical	FDA	MDPH	IJC
Chlordane	0.3	0.3	
DDT	5.0	5.0	0.1
DDT metabolites (DDE, DDD)	5.0	5.0	
Dieldrin	0.3	0.3	0.1
Dioxin (2,3,7,8-TCDD)	No formal tolerance	0.00001	
Endrin	0.3	0.3	
Heptachlor	0.3	0.3	
Mercury	1.0	1.5	0.1
Mirex	0.3	0.3	
PCB	2.0	2.0	0.1
Toxaphene	5.0	5.0	

Table III-47. Fish consumption Advisories for 1988 in the Saginaw Bay Watershed (MDNR, 1988; MDPH 1988).

	Advisory		
Location	Restrict*	Do Not Eat	Contaminant of Concern
Saginaw Bay	Lake Trout Rainbow Trout Brown Trout	Carp or Catfish	PCB
Pine River Downstream of St. Louis		All species	PBB, DDT
Shiawassee River			
M-59 to Byron Rd.		All species	PCB
Byron Rd to Owosso		Carp	
Tittabawassee River Downstream of Midland		Carp or Catfish	Dioxin
Saginaw River		Carp or Catfish	PCB
Cass River Downstream of Bridgeport	Carp	Catfish	PCB

*The MDPH advises restricting consumption to no more than one meal per week.

Table III-68. Contaminant Concentrations (mg/kg) in Fish Samples from the Shiawassee River, 1985 (MDNR, unpublished data).

Species	PCB A-1254	PCB A-1248	PCB A-1260	Dieldrin	Toxaphene	DDD+DDE+DDT	Hg	As	Zn	Pb	Ni	Cu	Cr	Cd
BYRON ROAD														
Carp														
n	5			5	5	[illegible]								
value	5.90			<0.001	<0.050	[illegible]								
Rock Bass														
n		1		1	1									
value		0.18		<0.001	<0.050	[illegible]								
Smallmouth Bass														
n		6		6	6	6	2	2	2	2	2	2	2	2
value		0.27		<0.001	<0.05	[illegible]	0.2	<0.5	8.3	<1.0	<1.0	0.6	<1.0	<0.4
Sucker														
n	6	6		10	10	10	9	9	9	9	9	9	9	9
value	0.54	0.16		<0.001	<0.050	[illegible]	0.2	<0.5	11.0	<1.0	<1.0	0.6	<1.0	<0.4
LOTHROP ROAD														
Carp														
n		6		6	6	6	6	6	6	6	6	6	6	6
value		7.37		0.004	<0.050	[illegible]	0.2	<0.5	6.8	<1.0	1.1	1.4	<1.0	<0.4
Crappie														
n		1		1	1	1								
value		0.210		<0.001	<0.050	[illegible]								
Rock Bass														
n		6		6	6	6								
value		0.012		0.001	0.050	[illegible]								

PCB concentration in four carp samples of 2.32 mg/kg taken at New Lothrop Road also exceeded the MDPH levels. The PCB concentrations in rock bass, smallmouth bass, crappie and sucker were below the trigger level at Byron or Lothrop roads. Mean concentrations of other organic or metal parameters in individual samples of carp, rock bass, crappie, smallmouth bass and sucker samples taken at Byron or Lothrop roads in 1985 were below MDPH trigger levels (Table III-48).

iii. Cass River

The MDPH 1988 fish advisory for the Cass River suggests that people not eat catfish and restrict consumption of carp caught downstream of Bridgeport (Table III-47). The mean A-1254 PCB concentration for carp of 1.25 mg/kg in 1985 (Table III-49) did not exceed the MPDH level, but the advisory is in place because of the potential movement of contaminated carp from the Saginaw River into the Cass River.

iv. Tittabawassee River

The MDPH 1988 fish advisories warn against eating carp or catfish caught downstream of Midland on the Tittabawassee River because of dioxin contamination (Table III-47). Catfish collected from four sites downstream of the Dow complex in 1976 had TCDD levels ranging from 70 to 230 ng/kg (Forney, 1983); the current MDPH trigger level for dioxin is 10 ng/kg (Table III-46). Various species collected at Smith's Crossing showed levels ranging from non-detectable to 170 ng/kg (Forney, 1983). Single sample levels of 190 ng/kg (Duling, 1984) and 93 ng/kg (Fehringer, 1985) have also been reported. Analysis of three samples for dioxins other than 2,3,7,8-TCDD suggested that the Tittabawassee samples were dominated by Penta (Penta CDD) and Octachlorodibenzo-p-dioxin respectively (Octa CDD; Devault, 1984).

The mean concentration of 2,3,7,8-TCDD in 14 walleye samples collected from the Tittabawassee in 1985 was 4.0 ng/kg (Table III-50). Mean concentrations for other species tested ranged from 3.9 ng/kg for crappie to 9.5 ng/kg for northern pike. The 1985 means for white bass of 8.2 ng/kg and for northern pike of 9.5 ng/kg were below the MDPH trigger level; however, one pike had a TCDD concentration of 15.0 ng/kg. A whole carp sample taken below Dow on the Tittabawassee contained 37 mg/kg 2,3,7,8-TCDF and 290 ng/kg of PCDF (DeVault, 1984).

The mean PCB concentration of 2.66 mg/kg in carp collected from the Tittabawassee River in 1984 exceeded the MDPH trigger level of 2.0 mg/kg. Mean concentrations of PCB in crappie, northern pike, smallmouth bass, walleye and white bass samples taken in 1985 did not exceed the MDPH trigger level. Analysis of fish samples for dieldrin, DDT and toxaphene yielded mean concentrations below MDPH trigger levels (Table III-50).

v. Chippewa River

The Chippewa River was removed from the MDPH fish advisory list in 1986. The mean PCB concentration in all fish samples collected in 1985 were lower than the MDPH trigger level of 2.0 mg/kg (Table III-51). DDT mean concentrations in crappie of 0.296 mg/kg and sucker of 0.534 mg/kg

Table III-49. Contaminant Concentrations (mg/kg) in Fish Samples from the Cass River, 1984-1985 (MDNR, unpublished data).

		Parameter					
		PCB					
Species	Year	A-1254	A-1260	Dieldrin	Toxaphene	DDD,DDE DDT	Hg
Carp	1984						
n		9		9		9	
value		1.25		0.008		0.192	
Smallmouth Bass	1984						
n		17		17		17	
value		0.75		0.001		0.023	
Bullhead	1984						
n			4	4	4		2
value			0.06	0.001	0.050	0.019	0.4
Channel Catfish	1985						
n		4		4	4		4
value		0.72		0.010	0.050		0.2

Table III-50. Contaminant Concentrations in Fish Samples from the Tittabawassee River at Smith's Crossing, 1984-1985 (MDNR, unpublished data).

Species	Year	2,3,7,8-TCDD (ng/kg) (Dow)	2,3,7,8-TCDD (ng/kg) (FDA)	PCB A-1254 (mg/kg)	Dieldrin (mg/kg)	Total Chlordane (mg/kg)	Toxaphene (mg/kg)	DDD,DDE DDT (mg/kg)
Carp	1984							
n				9	8		9	9
value				2.66	0.01		0.01	2.66
Walleye	1984							
n				9	9		9	9
value				0.37	0.012		0.100	0.077
Crappie	1985							
n		3[a]	1	3[a]	3[a]	1[a]	3[a]	3[a]
value		3.9	5.4	0.13	0.002	0.019	0.023	0.088
Northern Pike	1985							
n		3[a]	1[a]	3[a]	3[a]	1[a]	3[a]	3[a]
value		9.5	16.5	0.382	0.003	0.055	0.068	0.386
Smallmouth Bass	1985							
n		3	1	3	3	1	3	3
value		5.00	8.00	0.045	0.001	0.010	0.042	0.048
Walleye	1985							
n		14	4	14	14	4	14	14
value		4.0	2.7	0.683	0.002	0.041	0.101	0.163
White Bass	1985							
n		4[b]	1[a]	4[b]	4[b]	1[a]	4[b]	4[b]
value		8.2	15.9	1.330	0.014	0.074	0.089	0.324

[a]"n" is the number of composit samples of three fish each.

[b]Three composites of three fish each and one composite of four fish.

Table III-51. Contaminant Concentrations (mg/kg) in Fish Samples from the Chippewa River, 1984-1985 (MDNR, unpublished data).

Species Year	PCB A-1254	PCB A-1260	Dieldrin	Toxaphene	DDD,DDE DDT	Hg	As	Zn	Pb	Ni	Cu	Cr	Cd
Crappie													
1984													
n	5		5		5								
value	0.064		0.001		0.296								
Sucker													
1984													
n	8		8		8								
value	0.090		0.002		0.534								
Carp													
1985													
n		8	8	8	8	8	8	8	8	8	8	8	8
value		0.126	0.002	0.050	0.240	0.4	0.5	14.4	1.1	1.8	13.2	1.0	0.4

collected in 1984, and in carp of 0.240 mg/kg collected in 1985 did not exceed the MDPH trigger level. Dieldrin, DDT and Toxaphene concentrations were below MDPH levels in 1984 and 1985.

vi. Pine River

Michigan Department of Public Health 1988 fish advisory warns against consuming any fish taken from downstream of St. Louis on the Pine River. The mean concentration in 10 carp samples taken from the Pine River in 1985 yielded a mean DDT concentration of 10.03 mg/kg, exceeding the MDPH trigger level of 2.0 mg/kg (Table III-52). Concentrations in all individual carp samples also exceeded the MDPH trigger level in 1985.

vii. Saginaw River

The Michigan Department of Public Health's 1988 fish advisory warns against the consumption of carp or catfish caught in the Saginaw River (Table III-47). No recent data on dioxin concentrations in fish from the Saginaw River are available. The mean concentration in five skin-off filleted samples of carp collected from the Saginaw River in 1986 was 12.47 mg/kg, a value above the MDPH trigger level (Table III-53). The mean concentration of PCB in skin-on filleted samples of three walleye collected from the Saginaw River in 1986 was 0.48 mg/kg, below the MDPH trigger level.

In a 1980-1981 study, ECMPDR (1983) found no significant differences in PCB levels, averaging 1.51 mg/kg, among bottom feeders, mid-level feeders, planktivores or piscivores. Comparisons may be complicated by the proximity of lower concentrations in Saginaw Bay and Lake Huron, as well as by fish mobility (ECMPDR, 1983). Aroclor 1242 comprised only 41% of the total PCB found despite its predominance in sediments and river water (ECMPDR, 1983).

Concentrations of DDT, dieldrin and toxaphene in 1986 samples of carp and walleye were all below the MDPH trigger levels for those materials.

viii. Saginaw Bay

The MDPH 1988 fish consumption advisory for Saginaw Bay restricts consumption of lake trout, rainbow trout and brown trout, and advises against eating carp or catfish. Edible portions of catfish collected from Saginaw Bay in 1978 contained 14 ng/kg TCDD (USEPA, 1981). A TCDD level of 4 ng/kg was found in skinless fillets of two suckers (USEPA, 1981). No TCDD levels above detection limits of 10 to 16 ng/kg were found in the edible portions of yellow perch, bowfin, walleye, whitefish and buffalo collected in the bay between 1978 and 1981 (Table III-54). Devault (1984) concluded that grid 1509 near Bay Port was the area of Saginaw Bay most seriously contaminated with TCDD where concentrations in 80% of catfish and 60% of carp analyzed exceeded 10 ng/kg TCDD.

Concentrations of TCDD were detected in edible fillet portions of carp and catfish collected in 1979-1981, but not in perch, sucker, walleye, whitefish or bullhead (Table III-55). Edible portions of carp

Table III-52. Contaminant Concentrations (mg/kg) in Fish Samples from the Pine River, 1984-1985 (MDNR, unpublished data).

Species Year	Parameter Dieldrin	DDD, DDE DDT	Hg	As	Zn	Pb	Ni	Cu	Cr	Cd
Smallmouth Bass										
1984										
n	2	2								
value	0.002	4.391								
Sucker										
1984										
n	4	4								
value	0.001	2.229								
Carp										
1985										
n	10	10	10	10	10	10	10	10	10	10
value	0.004	10.033	0.2	<0.5	12.6	<0.1	1.0	1.8	<0.1	<0.4

Table III-53. Contaminant Concentrations (mg/kg) in Fish Samples from the Saginaw River, 1986 (MDNR, unpublished data).

	Parameter									
Species	PCB A-1254	Dieldrin	Toxa-phene	DDE,DDD DDT	Hg	Pb	Ni	Cu	Cr	Cd
Carp										
n	2	2	2	2	2	1	2	2	2	2
value	15.2	0.04	1.4	1.5	ND*	0.11*	ND*	1.5*	ND*	0.03
n	5	5	5	5	5	5	5	5	5	5
value	12.74[b]	0.10	1.77	1.5	0.04	ND**	ND**	0.36**	ND**	0.002
Walleye										
n	2	2	2	2	2	2	2	2	2	2
value	4.05	0.028	0.053	0.605	ND[a]	ND[a]	ND[a]	ND[a]	0.6[a]	ND[a]
n	3	3	3	3	9	3	3	3	3	5
value	0.48[b]	0.004	0.12	0.077	0.2	ND[b]	ND[b]	0.017[b]	0.17[b]	ND[b]

* composited whole samples of five fish

** skin off fillet

[a] composited whole samples of three fish

[b] skin on fillet

Table III-54. Concentrations (ng/kg) of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Fish Samples from the Saginaw Bay Watershed (Devault, 1984).

Location	Species	Sample Type	# Samples/ # Fish per Sample	2,3,7,8-TCDD	Total TCDD	Total PCDD	Source
Saginaw River							
Saginaw WWTP	Carp	E	1/U	319	NA	NA	MSU 1979
Wickes Park	Carp	E	1/1	62	NA	NA	USEPA 1978
	Yellow Perch	E	1/2	<11	NA	NA	USEPA 1978
Wickes Park	Carp	E	1/U	35	NA	NA	MSU 1979
Blocks Marina	Channel Catfish	E	1/1	105	NA	NA	USEPA 1978
	Channel Catfish	E	1/1	52	NA	NA	USEPA 1978
	Carp	E	1/1	28	NA	NA	USEPA 1978
Mouth	Channel Catfish	E	1/1	30	NA	NA	USEPA 1978
	Carp	E	1/1	153	NA	NA	USEPA 1978
	Yellow Perch	E	1/2	11	NA	NA	USEPA 1978
Mouth	Carp	E	1/U	288	NA	NA	MSU 1979
Consumers Power	Carp	E	1/U	301	NA	NA	MSU 1979
Plant	Carp	E	1/U	129	NA	NA	MSU 1979
Below Saginaw	White Sucker	E	1/U	64	NA	NA	MSU 1979
WWTP	Carp	E	1/U	126	NA	NA	MSU 1979
	Carp	E	1/U	135	NA	NA	MSU 1979
Chippewa River							
10 miles upstream of Dow	Carp	E	1/U	136	NA	NA	MSU 1979
Pine River							
Below St. Louis	Carp	E	1/U	322	NA	NA	MSU 1979
	White Sucker	E	1/U	85	NA	NA	MSU 1979
Alma	Carp	E	1/U	<10	NA	NA	USFDA 1983
Cass River							
Frankenmuth	Redhorse Sucker	E	5/U	<60	NA	NA	MSU 1979
	Carp	E	1/U	<9	NA	NA	MSU 1979

Table III-54. Continued.

Location	Species	Sample Type	# Samples/ # Fish per Sample	2,3,7,8-TCDD	Total TCDD	Total PCDD	Source
Flint River							
Below Flint	Carp	E	1/2	<100	NA	NA	MSU 1979
	Carp	E	1/8	<10	NA	NA	USFDA 1983
Holloway Reservoir	White Sucker	E	1/U	<24	NA	NA	MSU 1979
Shiawassee River							
Chesaning	Carp	E	1/8	<10	NA	NA	USFDA 1983
Tittabawasse River							
5 Miles Upstream	White Sucker	E	1/U	287	NA	NA	MSU 1979
of Dow	Carp	E	1/U	20	NA	NA	MSU 1979
	White Sucker	E	1/[illegible]	<63	NA	NA	MSU 1979
Tittabawassee Rd.	Carp	E	1/1	52	NA	NA	USEPA 1978
	Yellow Perch	E	1/1	20	NA	NA	USEPA 1978
	Carp	E	1/1	93	NA	NA	USEPA 1978
Freeland Rd.	Carp	E	1/1	32	NA	NA	USEPA 1978
	Yellow Perch	E	1/1	10	NA	NA	USEPA 1978
	Carp	E	1/U	66	NA	NA	MSU 1979
Smith's Crossing Rd	Channel Catfish	E	1/1	273	NA	NA	USEPA 1978
	Carp	E	1/1	695	NA	NA	USEPA 1978
	Channel Catfish	E	1/1	49	NA	NA	USEPA 1978
	Carp	E	1/1	49	NA	NA	USEPA 1978
	Sucker	E	1/1	8	NA	NA	USEPA 1978
	Sucker	E	1/1	21	NA	NA	USEPA 1978
State Street	Yellow Perch	E	1/2	20	NA	NA	USEPA 1978
	Carp	E	1/1	93	NA	NA	USEPA 1978
Above Dow Dam	Channel Catfish	E	1/1	42	NA	NA	USEPA 1978
	Carp	E	1/1	<5	NA	NA	USEPA 1978
	Carp	E	1/1	<9	NA	NA	USEPA 1978
	Channel Catfish	E	1/1	28	NA	NA	USEPA 1978
	Yellow Perch	E	1/1	<4	NA	NA	USEPA 1978

Table III-54. Continued.

Location	Species	Sample Type	# Samples/ # Fish Per Sample	2,3,7,8-TCDD	Total TCDD	Total PCDD	Source
Dublin Rd	Carp	E	1/1	<9	NA	NA	USEPA 1978
Below Dow	Carp	W	1/1-2	NA	81	233	USFWS 1979
	Carp	E	1/U	17	NA	NA	MSU 1979
	Carp	E	1/C	39	NA	NA	MSU 1979
	Carp	E	1/U	83	NA	NA	MSU 1979
	Carp	E	1/U	<54	NA	NA	MSU 1979
Saginaw Bay							
Sebewaing	Yellow Perch	E	1/1	<16	NA	NA	MSU 1979
Au Gres	Yellow Perch	E	1/1	<15	NA	NA	MSU 1979
Sand Point	Carp	E	1/C	<14	NA	NA	MSU 1979
	Carp	E	1/8	<10	NA	NA	WFDA 1983
Near Saginaw River	Carp	E	1/C	43	NA	NA	MSU 1979
Near Saginaw River	Carp	E	1/U	173	NA	NA	MSU 1979
Near Saginaw River	Carp	E	1/U	28	NA	NA	MSU 1979
Near Saginaw River	Carp	E	1/C	<50	NA	NA	MSU 1979
Bay City	Carp	W	1/1	NA	94	385	USFWS 1981
Grid 1509*	Yellow Perch	E	1/24	<10	NA	NA	USFDA 1978
Grid 1507	Yellow Perch	E	1/24	<10	NA	NA	USFDA 1978
	Bowfin	E	1/1	<10	NA	NA	USFDA 1979
	Walleye	E	1/1	<10	NA	NA	USFDA 1984
Grid 1509	Yellow Perch	E	1/24	<10	NA	NA	USFDA 1978
Grid 1509	Yellow Perch	E	1/5	<10	NA	NA	USFDA 1979
	Whitefish	E	1/1	<10	NA	NA	USFDA 1979
	Buffalo	E	1/1	<10	NA	NA	USFDA 1979
Grid 1506	Sucker	E	1/12	<10	NA	NA	USFDA 1978
Grid 1506	Sucker	E	1/13	<10	NA	NA	USFDA 1978
Grid 1506	Catfish	E	1/7	<10	NA	NA	USFDA 1978
Grid 1506	Catfish	E	1/14	14/15	NA	NA	USFDA 1978
Grid 1506	Carp	E	1/2	<10	NA	NA	USFDA 1980
Grid 1506	Carp	E	1/2	<10	NA	NA	USFDA 1980
Grid 1507	Sucker	E	1/10	<10	NA	NA	USFDA 1978
Grid 1507	Carp	E	1/7	<10	NA	NA	USFDA 1978

Table III-54. Continued.

Location	Species	Sample Type	# Samples/ # Fish Per Sample	2,3,7,8-TCDD	Total TCDD	Total PCDD	Source
Grid 1507	Carp	E	1/2	16/20	NA	NA	USFDA 1978
Grid 1507	Catfish	E	1/1	35/45	NA	NA	USFDA 1979
Grid 1507	Carp	E	1/1	17/45	NA	NA	USFDA 1979
Grid 1507	Carp	E	1/1	<10	NA	NA	USFDA 1979
Grid 1507	Sucker	E	1/2	<10	NA	NA	USFDA 1979
Grid 1507	Crappie	E	1/1	<10	NA	NA	USFDA 1979
Grid 1507	Rockbass	E	1/1	<10	NA	NA	USFDA 1979
Grid 1507	Bullhead	E	1/1	<10	NA	NA	USFDA 1979
Grid 1507	Bullhead	E	1/1	<10	NA	NA	USFDA 1979
Grid 1509	Sucker	E	1/12	<10	NA	NA	USFDA 1978
Grid 1509	Carp	E	1/1	<10	NA	NA	USFDA 1978
Grid 1509	Carp	W	1/3-5	NA	27	111	USFDA 1979
Grid 1509	Catfish	E	1/1	29/32	NA	NA	USFDA 1979
Grid 1509	Catfish	E	1/1	26/34	NA	NA	USFDA 1979
Grid 1509	Catfish	E	1/3	<10	NA	NA	USFDA 1979
Grid 1509	Carp	E	1/3	<10	NA	NA	USFDA 1979
Grid 1509	Sucker	E	1/2	<10	NA	NA	USFDA 1979
Grid 1509	Bullhead	E	1/1	<10	NA	NA	USFDA 1979
Grid 1509	Bullhead	E	1/1	<10	NA	NA	USFDA 1979
Grid 1509	Catfish	E	1/10	13/12	NA	NA	USFDA 1980
Grid 1509	Catfish	E	1/10	13/14	NA	NA	USFDA 1980
Grid 1509	Carp	E	1/3	68/62	NA	NA	USFDA 1981

NA Not Analyzed
ND Not Dected
U Unknown
E Edible Portion
W Whole Fish

Table III-55. Concentrations (ng/kg) of TCDD in Commercial Fish Samples from Saginaw Bay, 1979–1982 (Firestone and Nieman, 1986).

Year	Species	Number of Samples	2,3,7,8-TCDD
1979	Sucker	9	ND
	Perch	8	ND
	Bullhead	2	ND
	Whitefish	1	ND
	Carp	6	ND
	Carp	1	21
	Carp	1	57
	Catfish	21	ND
	Catfish	1	60
	Catfish	1	19
	Catfish	1	52
	Catfish	1	43
	Catfish	1	34
1980	Carp	1	ND
	Carp	1	35
	Catfish	1	18
	Catfish	1	18
1981	Perch	1	ND
	Carp	1	ND
	Carp	1	28
	Carp	1	37
	Catfish	1	28
	Catfish	1	44
	Catfish	1	50
	Catfish	1	57
1982	Sucker	1	ND
	Walleye	1	ND
	Whitefish	1	14
	Whitefish	1	20
	Carp	3	ND
	Carp	1	15
	Carp	1	16
	Carp	1	18
	Carp	1	20
	Carp	1	30
	Catfish	4	ND
	Catfish	1	7
	Catfish	1	13

ND = Not quantified or confirmed; if 2,3,7,8-TCDD is present, it is present at a level below 10 ng/kg.

Values are corrected for reagent blank (ca 3 ng/kg and recovery).

and catfish samples contained up to 60 ng/kg 2,3,7,8-TCDD. Levels less than or equal to 30 ng/kg were found in carp, catfish, whitefish, walleye and sucker samples in 1982. The decline in TCDD concentrations in carp and catfish may have been related to the stop in production of 2,3,7,8-TCDD at Dow (Firestone et al., 1986).

Mean PCB concentrations in common carp in Saginaw Bay were relatively high in the early 1970s, then increased between 1977 and 1980 (Figure III-101). This trend was also apparent for channel catfish. Concentrations of PCB in carp samples collected in 1984 from grids 1607 and 1608 of 6.78 mg/kg and 4.03 mg/kg, respectively (Table III-56), exceeded the MDPH trigger level of 2.0 mg/kg.

The mean PCB concentration for ten skin-on walleye fillets obtain from Saginaw Bay at Caseville in 1986 was 0.67 mg/kg, a level well below the MDPH trigger level of 2.0 mg/kg (Table III-56).

Mean DDT concentrations for channel catfish fillets show a downward trend from 1974 to 1977, and a slight increase from 1977 to 1980 (Figure III-102). Mean DDT concentrations in whole yellow perch samples appear to have declined from 1967-1979 (Figure III-103).

e. Birds

i. Herring Gulls

Herring gulls have been monitored extensively in the Great Lakes since 1978 as part of the surveillance and monitoring activities conducted in response to the U.S.-Canada Great Lakes Water Quality Agreement. Herring gulls were selected as the subject of the monitoring program because (1) unlike most piscivorous birds in the Great Lakes, gulls are year-round residents after reaching breeding age, and (2) as top predators that feed primarily on fish, gulls readily bioaccumulate organochlorines (Struger et al., 1985). In addition, herring gulls are easily monitored: their ground nests can be observed, and eggs and chicks can be easily collected (Gilman et al., 1977). The herring gull is widely distributed in the Great Lakes, making it a good species for comparative studies.

Two gull colonies in Saginaw Bay have been monitored periodically since 1978: one on Channel/Shelter Island (a confined disposal facility for dredge spoils from the Saginaw River/Saginaw Bay) and one on Little Charity Island (Figure III-104). Several organic compounds have been detected in the eggs of herring gulls at Channel/Shelter Island, including DDT and its metabolites (DDE and DDD), dieldrin, mirex, PCB and 2,3,7,8-TCDD. Mean concentrations of DDE in herring gull eggs fluctuated from 1980 to 1982; the mean concentration of DDE was 8.9 mg/kg in 1980, 7.3 mg/kg in 1981, and 8.1 mg/kg in 1982 (Table III-57). The mean concentration of mirex was 0.23 mg/kg in 1982 and the mean concentration of dieldrin was 0.32 mg/kg in that year; levels of both these compounds increased significantly from 1981 to 1982. The mean concentration of PCB in eggs was 72 mg/kg in 1982 (Struger et al., 1985). Concentrations of PCBs, DDE and some chlorobenzenes in herring gull eggs from Channel/Shelter Island in Saginaw Bay persisted and did not decline

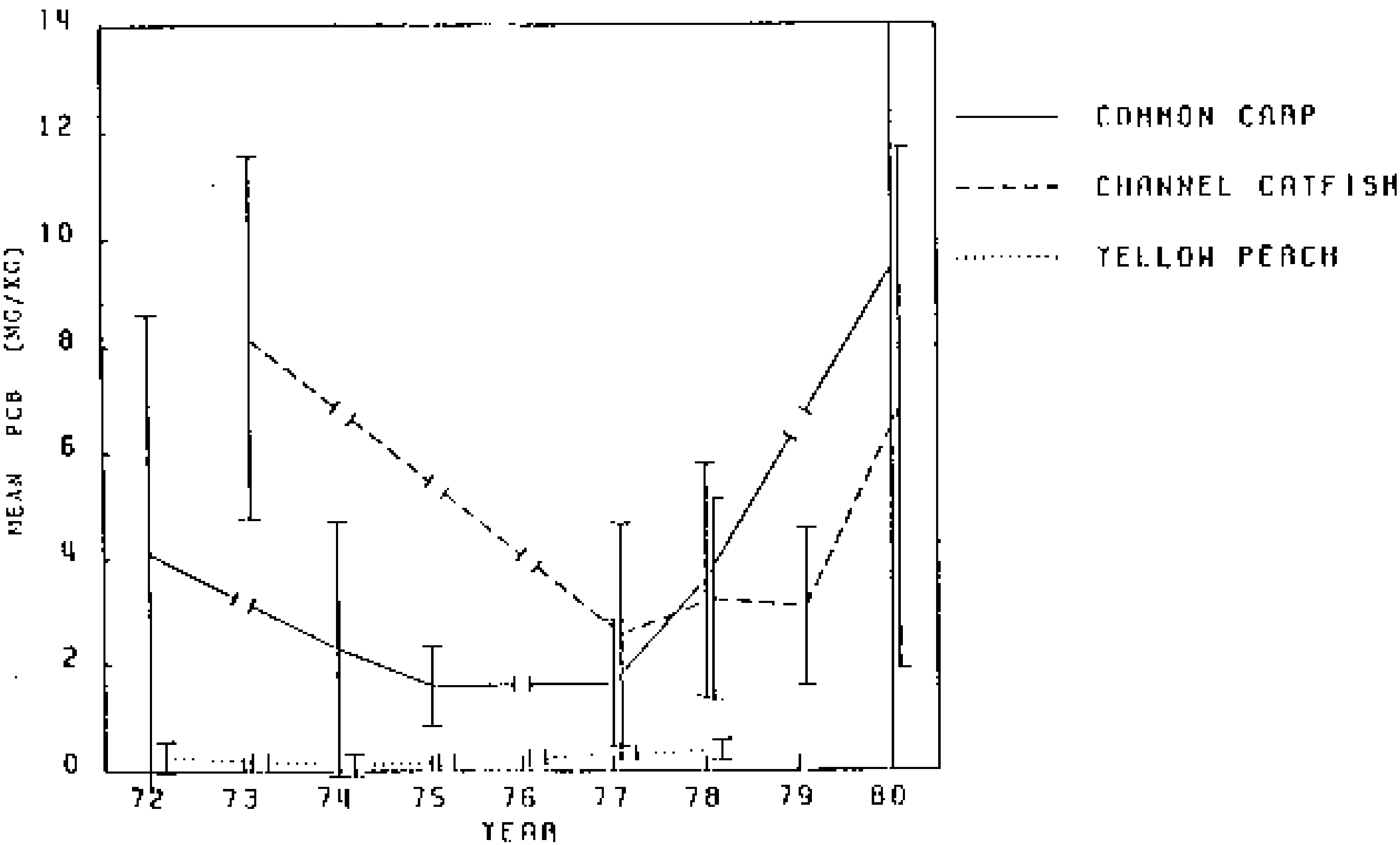


Figure III-101. Yearly mean PCB concentrations for common carp, channel catfish and yellow perch fillets from Saginaw Bay, 1972-1980. (Kreis and Rice, 1985).

Table III-56. Contaminant Concentrations (mg/kg) in Carp, Catfish and Walleye Samples from Saginaw Bay, 1982-1986 (MDA and FDA, unpublished data).

Species	Year	Location[a]	PCB	DDT	Dieldrin	Chlordane
			Parameter			
Carp	1984	Unknown				
		n	24	24	24	24
		value	2.32	0.76	0.03	0.17
		1506				
		n	1			
		value	1.25			
		1507				
		n	1			
		value	1.18			
		1509				
		n	1			
		value	ND			
		1607				
		n	1			
		value	6.78			
		1608				
		n	2			
		value	4.03			
	1985	1509				
		n	9		9	9
		value	1.92		0.01	0.01
		1607				
		n	9[b]	9		
		value	1.28	0.26		
		Bayport				
		n	4[c]			
		value	1.56			
Carp	1986	1506				
		n	4	4	4	4
		value	0.22	0.10	ND	0.04

Table III-56. Continued.

Species	Year	Location[a]	PCB	DDT	Dieldrin	Chlordane
		Unknown				
		n	3			
		value	2.97			
Catfish	1982	Bayport				
		n	2			
		value	1.84			
	1984	1507				
		n	6		4	
		value	3.42		0.02	
		1509				
		n	4		1	
		value	3.00		0.04	
		1608				
		n	1			
		value	2.09			
		Unknown				
		n	6	6	6	6
		value	1.55	0.36	0.05	0.08
	1985	1506				
		n	4			
		value	0.32			
		1509				
		n	9[b]			
		value	1.92			
Catfish	1985	1607				
		n	9	9	9	
		value	1.70	0.28	0.03	
		Unknown				
		n	6			
		value	2.76			
		Bayport				
		n	9			
		value	1.92			

Table III-56. Continued.

Species	Year	Location[a]	PCB	DDT	Dieldrin	Chlordane
			Parameter			
	1986	1506				
		n	4	4	4	4
		value	0.32	0.16	0.01	0.09
		1609				
		n	[illegible]	1	1	
		value	7.30	0.99	0.03	
		Unknown				
		n	6			
		value	2.76			
		Caseville				
		n	10	10	10	10
		value	1.61	0.28	0.02	0.03
Walleye	1986	Caseville				
		n	10	10	10	10
		value	0.67	0.11	0.01	0.02

[a]Grid location

[b]Composited skin-off fillets

[c]Composited samples of 6,6,5 and 2 fish

ND = Not detected

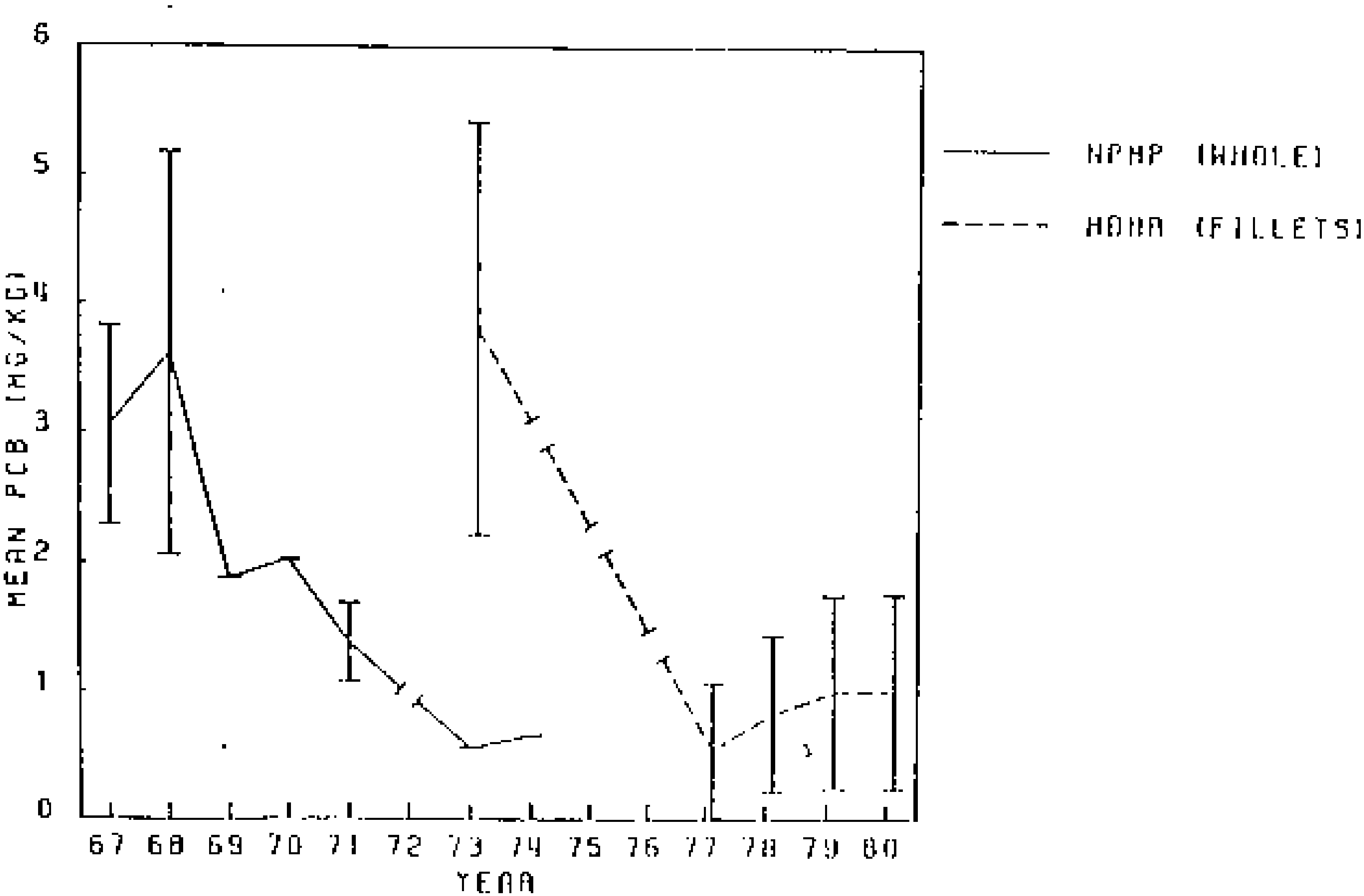


Figure III-102. Yearly mean PCB-[illegible] concentrations for channel catfish from Saginaw Bay, 1967-1980 ([illegible] Rice, 1985).

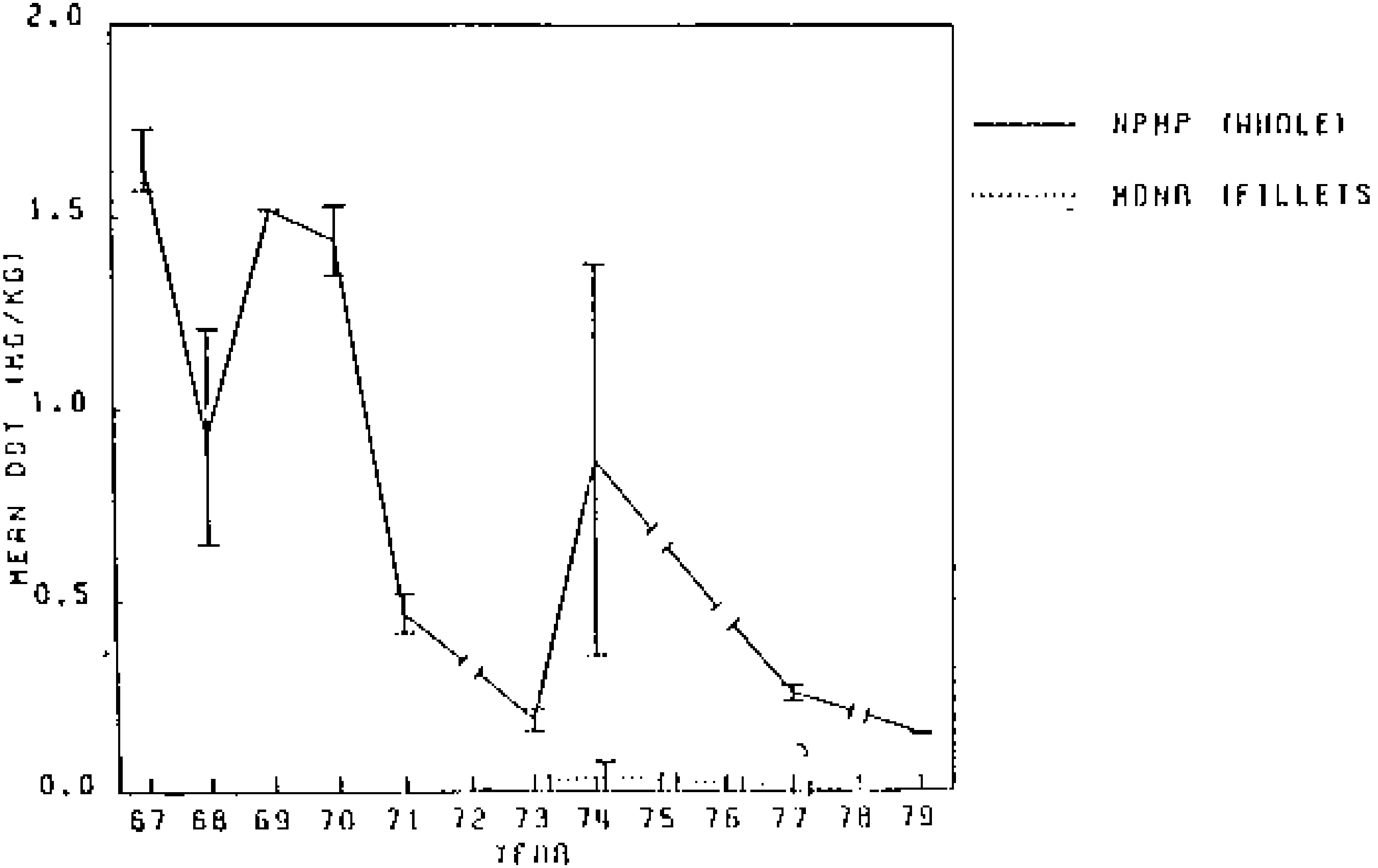


Figure III-103. Yearly mean DDT-R concentrations for yellow perch from Saginaw Bay, 1967-1979 (Kreis and Rice, 1985).

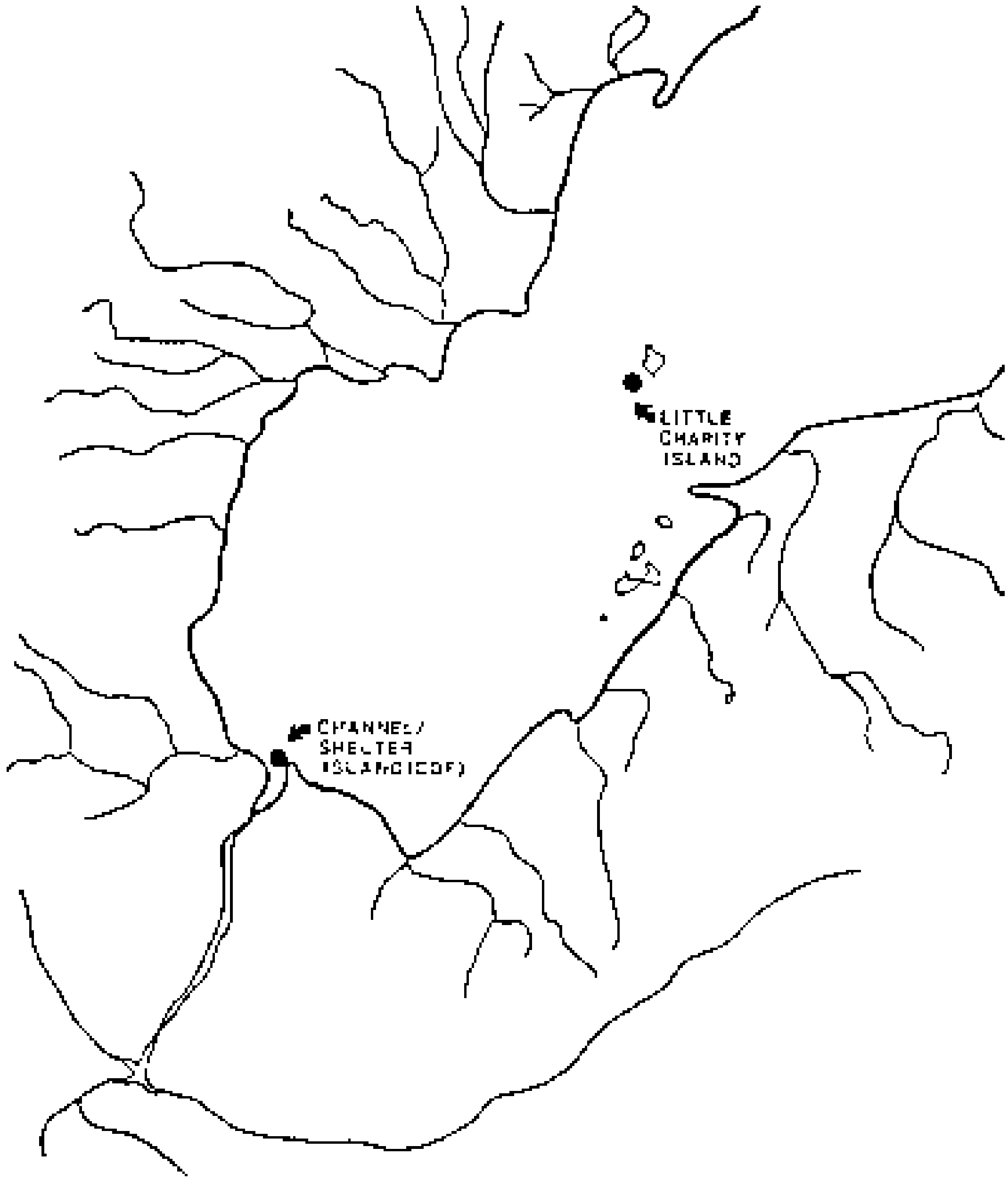


Figure III-.04. Locations of two herring gull colonies in Saginaw Bay monitored for organochlorine and other toxic organic contamination.

Table III-57. Organochlorine Residue Levels (mg/kg) in Herring Gull Eggs, Channel/Shelter Island, 1980-1982, and Little Charity Island, 1980, Saginaw Bay (Struger et al., 1985)

	Channel/Shelter Island			Little Charity Island
Compound	1980	1981	1982	1980
2,3,7,8-TCDD*				
egg	86[a] 86.0[c]	141[b]		43[c]
muscle	80.0[a]			
PCB	70 69.6[c]	65 64.1[a,c]	72	41.9[c]
DDE	8.9 8.9[c]	7.3 7.18[d]	8.1	6.4[c]
DDD		0.22	0.08	
DDT		0.05	0.04	
Dieldrin		0.18 0.17[d]	0.32	
Mirex	0.20 0.19[c]	0.06 0.08[d]	0.23	0.08[c]
Photomirex		0.03[d]		
Chlordane		0.14[d]		
Oxychlordane		0.12 0.12[d]	0.24	
Alpha-Chlordane		0.16	0.02	
Gamma-Chlordane		0.05	0.04	

*(ng/kg)

[a]Norstrom et al., 1982.

[b]Stalling et al., 1985.

[c]Kreis and Rice, 1985.

[d]Ellenton et al., 1985.

significantly between 1980 and 1982 (Struger et al., 1985). Dioxin (2,3,7,8-TCDD) reached 141 ng/kg in herring gull eggs in 1982. Mean concentrations of DDT, DDD and alpha-chlordane decreased significantly in herring gull eggs between 1981 and 1982 (Struger et al., 1985).

Caution is warranted in interpreting these data because Channel/Shelter Island is a confined disposal facility (CDF) for contaminated dredge spoils from the Saginaw River and highly contaminated fish have been found living within the CDF (ECMPDR, 1986). Thus, it is possible that if these gulls are eating fish from within the CDF, they are being exposed to higher levels of contamination than exist in the open waters of the bay.

In contrast to Channel/Shelter Island, Little Charity Island is a natural island located at the boundary between the inner and outer segments of Saginaw Bay (Figure III-104). Detectable levels of PCB, DDE, 2,3,7,8-TCDD and mirex have been found in herring gull eggs from this island (Table III-57). The concentration of PCB at Little Charity Island in 1980 was 41.9 mg/kg. The mean concentrations for DDE, 2,3,7,8-TCDD, and mirex were 6.4 mg/kg, 43.0 ng/kg, and 0.08 mg/kg, respectively. Even though Little Charity Island, located approximately 35 miles from the mouth of the Saginaw River, is a natural island and not a confined disposal facility for contaminated sediments, levels of contaminants in herring gull eggs collected from the island are elevated.

The levels of PCB in the eggs from both Little Charity Island and Channel/Shelter Island colonies were found to be 2-4 times higher than the levels for all but one of nine Lake Huron colonies from which eggs were collected in 1980 (Kreis and Rice, 1985). Moreover, analyses of eggs from the Channel/Shelter Island colony show some of the highest levels of dibenzo-p-dioxins, at 141 ng/kg for a 10 egg homogenate, of any Great Lakes colony.

ii. Common Terns

In 1984, the USFWS collected common tern eggs from three subcolonies nesting in the CDF at Channel/Shelter Island in Saginaw Bay. More than 50% of the samples had residues above the lower level of detection for DDE, dieldrin, PCBs, mercury and selenium (Table III-58). Concentrations of dieldrin ranged from an average of 0.08 mg/kg to 0.15 mg/kg. Concentrations of PCB (Aroclor 1260) were found ranging from an average of 9.5 mg/kg to 10.9 mg/kg. Average DDE concentrations ranged from 1.7 mg/kg to 2.1 mg/kg. Mercury had mean concentrations ranging from 0.30 mg/kg to 0.40 mg/kg.

iii. Double-crested Cormorants

In 1986, a new colony of double-crested cormorants, consisting of nine nests, was discovered on Little Charity Island in Saginaw Bay (Ludwig and Ludwig, 1986). All nine of the nests were abandoned early in the season for unknown reasons, so no data exist on contaminant levels in these birds or their eggs.

Table III-58. Geometric Means, Ranges and Numbers of Eggs with Quantifiable Residues of Organic and Inorganic Contaminants (mg/kg) in Common Tern Eggs Collected from Three Subcolonies Nesting in Saginaw Bay, 1984 (USFWS, unpublished, 1985).

Compound	SB-1 (N = 12)			SB-2 (N = 15)[a]			SB-3 (N = 12)		
	$\bar{x}$	range	n	$\bar{x}$	range	n	$\bar{x}$	range	n
p,p'-DDE	2.1	1.4 - 3.3	12	1.7	0.6 - 3.4	15	1.7	1.1 - 3.6	12
p,p'-DDD	nq	nq - 0.14	1	nq	nq - 0.17	4	nq	nq - 0.23	1
p,p'-DDT	nq	nq	0	nq	nq	0	nq	nq	0
Dieldrin	0.15	0.10- 0.29	12	0.10	nq - 0.38	10	0.08	nq - 0.19	6
Heptachlor epoxide	nq	nq	0	nq	nq - 0.11	1	nq	nq	0
Oxychlordane	nq	nq - 0.11	3	nq	nq - 0.17	6	nq	nq - 0.15	2
cis-Chlordane	nq	nq	0	nq	nq - 0.17	2	nq	nq - 0.15	3
trans-Nonachlor	nq	nq - 0.11	1	nq	nq - 0.17	2	nq	nq - 0.35	2
cis-Nonachlor	nq	nq	0	nq	nq - 0.11	2	nq	nq - 0.11	2
Endrin	nq	nq	0	nq	nq	0	nq	nq	0
Toxaphene (estimated)	0.08	nq - 0.24	6	0.08	nq - 0.25	7	nq	nq - 0.44	4
PCBs (estimated/1260)	9.8	5.0 -14.2	12	10.9	5.4 -23.9	15	9.5	5.8 -23.3	12
Mercury	0.40	0.25- 0.66	12	0.30	0.14- 0.47	14	0.33	0.12- 1.87	12
Selenium	0.72	0.46- 0.85	12	0.65	0.37- 1.87	15	0.71	0.40- 0.93	12

[a]Total of 14 samples analyzed for mercury

nq = not quantifiable

iv. Black-crowned Night Heron

Two colonies of black-crowned night herons were found in Saginaw Bay on Channel/Shelter Island and Little Charity Island. Two-hundred eighty-five nests were observed at Channel/Shelter Island and 76 nests at Little Charity Island in 1986. No data on contaminant levels in these herons were collected (Ludwig and Ludwig, 1986).

v. Ducks

Although no studies have been conducted on the body burdens of toxic materials carried by migratory or over-wintering ducks in the Saginaw Bay basin, a study of organochlorine contaminant levels in diving ducks over-wintering on the Detroit River suggests that diving ducks can accumulate substantial loads of organic material (Smith et al., 1985). The PCB levels in lesser scaup, greater scaup, and common goldeneye from the Detroit River ranged from 2.7 mg/kg to 20 mg/kg (Smith et al., 1985). Ducks feeding in the Saginaw Bay watershed would be exposed to levels of contaminants less than those in the Detroit River. Benthic invertebrates (oligochaetes and chironomids) in some parts of the Saginaw River watershed have PCB levels about one-half as high as those in the Detroit River (Detroit River oligochaetes 0.44 mg/kg; Saginaw River oligochaetes and chironomids approximately 0.2 mg/kg).

Carcasses of ducks released on the Channel/Shelter Island CDF were analyzed by the USFWS for organochlorine contaminants. The carcasses showed measurable residues of DDE and PCBs after 10 to 86 days exposure on the CDF. Concentrations of PCBs in mallard carcasses after ten days of exposure ranged from 0.17 mg/kg to 0.44 mg/kg (mean = 0.34 mg/kg); after 44 days exposure, PCB concentrations ranged from 2.5 mg/kg to 4.2 mg/kg (mean = 3.3 mg/kg; Table III-59). Concentrations of DDE were detected in low quantities in control ducks with no exposure on the CDF (range: 0.01 mg/kg to 0.02 mg/kg; mean = 0.01 mg/kg). After 10 days exposure, DDE concentrations in Mallard carcasses ranged from 0.01 mg/kg to 0.03 mg/kg (mean = 0.02 mg/kg); after 44 days exposure, DDE concentrations ranged from 0.11 mg/kg to 0.19 mg/kg (mean = 0.15 mg/kg).

2. Contaminant Impacts on Biota

a. Phytoplankton

Levels of PCBs occurring in Saginaw Bay were found to inhibit nannoplankton productivity (McNaught et al., 1984). Certain PCBs have also been shown to be more toxic to diatoms and green algae than to blue-green algae (McNaught et al., 1984). Further, hexachlorobiphenyl (PCB metabolite) inhibited algal photosynthesis from as much as 2% to 93%. However, these contaminants were also shown to stimulate algal productivity under some circumstances (McNaught et al., 1984).

Dichlorobiphenyl has been shown to be selectively more toxic to nannoplankton than netplankton, and dichlorobiphenyl metabolites are more toxic to phytoplankton than the parent isomer (McNaught et al., 1984). Though PCBs must be held below 5 ng/l to avoid adverse impacts on Saginaw Bay algae, after storms, when PCB-rich sediments were resuspended,

Table III-59. Total PCB and DDE Concentrations (mg/kg) in Mallard Carcasses after 0, 10, 25, 44, 84 and 86 Days of Exposure on the Channel/Shelter Island Confined Disposal Facility, Saginaw Bay (USFWS, unpublished, 1987).

Parameter		Days of Exposure					
		Control	10	25	44	84	86
n		4	4	3	4	3	4
PCB		ND	0.17	1.4	2.6	2.0	1.7
		ND	0.35	1.1	4.2	1.76	6.11
		ND	0.38	0.75	2.5	0.62	1.9
		ND	0.44	–	3.9	–	3.31
	mean	–	0.34	1.08	3.3	1.44	3.25
DDE		0.01	0.02	0.06	0.11	0.15	0.27
		0.02	0.03	0.10	0.19	0.14	0.60[a]
		0.01	0.01	0.08	0.13	0.05	0.18
		0.01	0.03	–	0.16	–	0.34
	mean	0.01	0.02	0.08	0.15	0.11	0.35

[a]Confirmed by GC/Mass Spectrometry

ND = None Detected

waterborne PCBs reach levels up to 316 ng/l and consequently inhibited productivity by more than 30% (McNaught et al., 1984).

b. Zooplankton

Since the complex food webs of Lake Huron involve hundreds of phytoplankton taxa and tens of zooplankton taxa, McNaught et al. (1984) used and developed two ecosystem functional indices to measure contaminant inhibition from 1976-1979. One of these was a measure of zooplankton grazing. Grazing in western Lake Erie was compared to that in Saginaw Bay (McNaught et al., 1984). Grazing as a control on algal populations in Lake Erie was almost as effective as in oligotrophic Lake Huron; grazing, however, was greatly depressed in Saginaw Bay (McNaught et al., 1984). This information suggests that the Lake Erie ecosystem is in better condition (less eutrophic) than Saginaw Bay (McNaught et al., 1984). Functional ecosystem inhibition by PCBs is a serious problem, and results indicate that PCB levels must be held below 5 ng/l (McNaught et al., 1984). The lack of zooplankton grazing in an ecosystem like Saginaw Bay may be related to unknown inhibitory compounds with a mode of action either similar or identical to PCBs (McNaught et al., 1984).

The lack of zooplankton grazing in Saginaw Bay could also be due, in part, to a greater abundance of large, unpalatable filamentous blue-green and green algae in the bay than in outer Lake Huron and western Lake Erie. When grazing cladocera and copepods were increased experimentally among natural phytoplankton populations, small algae such as cryptamonads, certain diatoms, and other nannoplankton decreased, whereas gelatinous green algae such as Sphaerocystis increased, and the blue-green Anabaena remained unchanged (Porter, 1973). Additionally, the ingestion, assimilation, survivorship, and reproduction rates of Daphnia that were fed blue-green algae were lower than those fed green algae (Arnold, 1971). Thus, the lack of zooplankton grazing in Saginaw Bay during the late 1970s may be due not to unknown inhibitory compounds with a mode of action similar or identical to PCBs, but to an abundance of large, unpalatable algal species.

c. Fish

Toxic materials, conventional pollutants and siltation influence the viability of fish populations directly by altering physiology and behavior, and indirectly by modifying habitat. Although mechanisms are not well understood, a number of explanations for the reduction of populations of desired species in the Saginaw Bay fishery have been offered.

Toxic substances may limit reproductive success by increasing the mortality of fry and eggs (Hendrix and Yocum, 1984). Lake trout fry exposed for 6 months to 10.0 ng/L PCB (A-1254) and 1.0 ng/L DDE in water, and 1.0 ug/g PCB and 0.1 ug/g DDE in food, experienced a cumulative mortality nearly twice that of control fry (Willford et al. 1981). Contaminated sediments also reduce survival of fry (Hesselberg, 1983). A change in preferred temperature by lake trout exposed to PCB and DDE was noted by Mac (1981) and was hypothesized to be possibly detrimental to growth and survival by causing the selection of inferior habitat.

Changes in water quality may affect foraging behavior of some species because nutrient loads can alter zooplankton and phytoplankton availability and benthic communities can be disturbed (Hendrix and Yocum, 1984).

The acceleration in production of plankton and benthic algae due to nutrient loading, followed by their settling out and decomposition in interstitial waters of spawning grounds, may limit production of lake trout by prohibiting egg development. This mechanism may be limiting reproduction of lake trout in Saginaw Bay (Great Lakes Fishery Laboratory, 1982). Sedimentation may make the substrate of spawning beds unsuitable for spawning, or smother eggs (Hendrix and Yocum, 1984).

d. Birds

i. Herring Gulls

Chick-edema syndrome, egg-shell thinning, teratogenic effects, and porphyrinogenic effects are caused in birds by the types of organic residues found in gull eggs from the Saginaw Bay colonies (Gilbertson, 1974; Gilbertson et al., 1976). There have been no studies documenting these effects on gulls in Saginaw Bay. Reproduction levels in Saginaw Bay herring gulls, however, were normal in the early 1980s (Mineau et al., 1984).

Some gull embryos from the colonies in the bay have shown significantly higher levels of the enzyme aryl hydrocarbon hydroxylase (AHH) in their livers than eggs from other less contaminated colonies (Ellenton et al., 1985). Those elevated levels were correlated with 2,3,7,8-TCDD levels measured in pooled homogenated egg samples (Ellenton et al., 1985). Many chemicals, such as chlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and polyaromatic hydrocarbons, enhance the activity of AHH, and elevated levels of AHH may serve as an monitor of biotic exposure to environmental contaminants (Ellenton et al., 1985).

Another effect of contamination on herring gulls may be thyroid dysfunction. Moccia et al. (1986) tested gulls at seven colonies in the Great lakes and found the highest incidence of epithelial hyperplasia, a disease of the thyroid, at the Channel/Shelter Island colony. The authors suggest that there is a correlation between the prevalence of epithelial hyperplasia and elevated environmental levels of PCBs and polyhalogenated aromatic hydrocarbons (Ellenton and McPherson, 1983; Mineau et al., 1984).

ii. Common Terns

Common terns are fish-eating birds and as such they tend to accumulate organic contaminants. Terns are quite sensitive to environmental contaminants. They have congenital anomalies more often than any other fish-eating bird studied (Gilbertson et al., 1976; Hays and Risebrough, 1972; Gochfeld, 1975). No studies that address the effects of environmental contamination on common terns in Saginaw Bay have been published, but the USFWS has been conducting studies of common tern colonies in the Great Lakes, including colonies in Saginaw Bay. The

USFWS examined 474 live tern chicks in the Great Lakes in 1984. Of these, two, both collected from a colony on Channel/Shelter Island, appeared to have axial skeletal abnormalities (USFWS, unpublished, 1984). In addition, three embryos with crossed bills were found among ten eggs.

Artificial incubation studies conducted on tern eggs from five Great Lakes colonies in 1985 showed high egg fertility for all colonies. Hatching success varied among colonies, however, with a low of 24% for eggs from a subcolony on Channel/Shelter Island (USFWS, unpublished, 1985).

iii. Caspian Terns

A 1986 study of caspian tern productivity at colonies in northern Lake Michigan and western Lake Huron found no evidence of congenital deformities at the colony on Channel/Shelter Island (Ludwig and Ludwig, 1986). However, Ludwig and Ludwig (1986) found that second-attempt nests at Channel/Shelter Island had the lowest hatch rate and lowest fledge rate of all colonies monitored. They suggest that the failure of the later nests may be associated with accumulated toxic materials, but no evidence supporting this hypothesis is presented in the study.

iv. Double-crested Cormorants

In 1986, a new colony of double-crested cormorants, consisting of nine nests, was discovered on Little Charity Island in Saginaw Bay (Ludwig and Ludwig, 1986). All nine of the nests were abandoned early in the season for unknown reasons (Ludwig and Ludwig, 1986), so no data exist on reproductive problems related to toxic substances for cormorants in the bay.

Cormorants nesting in the Great Lakes have a high rate of congenital deformities (Wesloh et al., 1985; Ludwig and Ludwig, 1986). Double-crested cormorants are also well known to be highly sensitive to shell thinning, an effect associated with DDT contamination in some species (Mineau et al., 1984). Cormorants are listed as a threatened species in Michigan since their numbers plummeted in the 1960s (Wesloh and Steeple, 1983), but cormorant numbers have been increasing since 1977 (Wesloh et al., 1985).

v. Black-Crowned Night Herons

In field work done in 1986, two-hundred eighty-five black-crowned night heron nests were observed at Channel/Shelter Island and 76 nests at Little Charity Island. No evidence of gross deformities was found (Ludwig and Ludwig, 1986).

e. Mammals

A reduction of the range of some mammals, including mink and river otter, has occurred in the Saginaw Bay watershed (Burt, 1957). The range of mink in Michigan in 1957 included the entire lower peninsula; the range of the river otter in Michigan in 1957 extended down the lower peninsula to just south of the mouth of the Saginaw River (Burt, 1957).

But, 1982-1983 trapping data for river otter (MDNR, 1983) show that no otter were trapped in the counties that border the inner bay (Arenac, Bay, Tuscola and Huron).

Habitat loss due to urbanization of the watershed may account for this absence of otter in the Saginaw River watershed, but it is possible that toxic contamination of the watershed's rivers, streams and bays may have contributed to these declines. Two studies indicate that organochlorine contamination of river otters may result in population declines (Henny et al., 1981; Mason et al., 1986). No studies to assess the impact of contaminants on river otter in the Saginaw Bay area have been published.

Mink are sensitive to the effects of PCBs with fetotoxicity occurring at dietary concentrations below 5 mg/kg and reproductive failure at 2 mg/kg (Aulerich and Ringer, 1977). Mink have shown even greater toxic effects from PCBs derived from Great Lakes fish than from technical-grade PCBs fed to mink (Hornshaw et al., 1983). In addition, mink can accumulate high residues of PCBs from feeding on contaminated fish in the wild; six of nine wild mink from along the lower Columbia River in Oregon showed PCB residue in their livers in concentrations that were as high as those which caused reproductive failure in mink in feeding studies (Henny et al., 1981). The lagrescale sucker in the Columbia River contained PCBs in the range of 0.24-2.8 mg/kg and a smallmouth bass had 0.6 mg/kg (Henny et al., 1981). Suckers in the Pine River had a mean PCB concentration of 2.29 mg/kg with a range of 0.506 mg/kg to 3.884 mg/kg and smallmouth bass had a mean concentration of 4.39 with a range of 2.350 mg/kg to 6.432 mg/kg (Section III).

H. HUMAN HEALTH CONCERNS

1. Exposure to Toxicants

a. Chemicals of Concern

Concern for human health is one of the motivating factors in initiating the Remedial Action Plan process. One of the serious human health concerns is the presence of toxic chemicals in the environment. The IJC has identified nearly 1,000 chemicals in the Great Lakes aquatic environment (IJC, 1983). In its Inventory of Chemical Substances Identified in the Great Lakes Ecosystem, the IJC identified 49 chemicals that may impact human health in the event of high local contamination (Table III-60). Many of these contaminants, including aldrin, dieldrin, 2,3,7,8-TCDD, toxaphene, and 1,1,2-Trichloroethane are present in the Saginaw Bay ecosystem.

Some of the chemicals of primary concern for human health reasons, which have been found in the bay, include the following:

FISH
- Chlordane
- DDT and its metabolites
- Dieldrin (aldrin)
- Dioxin (2,3,7,8,-TCDD)
- Mercury
- Mirex
- PCB
- Toxaphene

WATER
- Endrin
- Lindane
- Methoxychlor
- Toxaphene
- Trihalomethanes

b. Fish Consumption

The major route of human exposure to the organochlorine contaminants of greatest concern in the AOC is through the consumption of contaminated fish. The State of Michigan Sport Caught Fish Consumption Advisories: Philosophy, Procedures, and Process Draft Procedural Statement (Humphrey and Hesse, 1986) is the document representing the official policy of the Michigan Departments of Public Health, Agriculture, and Natural Resources on the problem of human exposure to environmental contaminants in Michigan through the consumption of fish. The following paragraph describes the problem of human exposure to contaminants from consuming fish as summarized in that document.

Some persistent contaminants have such a long half-life in humans that each succeeding exposure results in a net increase in total body burden (Humphrey, 1976; Kreis et al., 1982). It is known that many of the contaminants found in fish have acute or chronic toxicological properties as shown by studies of animals exposed to high levels in laboratory tests (IJC, 1981). We do not know, however, whether there is a critical level above which toxic effects are triggered or whether consumption of sport caught fish over a lifetime would cause such a level to be reached. Epidemiological studies have shown that fat soluble contaminants appear in breast milk and cross the placental barrier in

Table III-60. Chemicals found in the Great Lakes which may have Adverse Impacts on Human Health in the Event of High Local Contamination* (IJC, 1983).

Extremely toxic chemicals (LD_{50} 50 mg/kg)
- Aldrin
- Carbofuran
- Dieldrin
- 2,3,7,8-Tetrachlorodibenzodioxin (2,3,7,8-TCDD)
- Endosulfan
- Endrin
- Ethion
- Methyl mercury (chloride)
- Oxychlordane
- Toxaphene
- 1,1,2-Trichloro- 1,2,2-trifloroethane

Very toxic chemicals (LD_{50} 50-500 mg oral/kg)
- aniline
- Bromochloroethane
- Carbon disulphide
- Chlordane
- 2-Chloroaniline
- 4-Chloroaniline
- O-Cresol
- DDT
- Diazinon
- 1,2-Dibromoethane
- 1,2-Dichlorobutadiene
- 2,4-Dichlorophenoxyacetic acid (2,4-d)
- 1,3-Dichloropropene
- 2,3-Dichloroprpoene
- Diphenylamine
- N-Ethylaniline
- Furfural
- a-Hexachlorocyclohexzne
- y-Hexachlorocyclocyclohexane (Lindane)
- Hexchlorobutadiene
- Mirex
- Pentachlorophenol
- Phenol
- Photomirex
- Tetrachloroethane**
- 1,1,2,3-Tetrachloropropene
- 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)
- Vinyl Bromide
- Vinyl Chloride

Table III-60. Continued.

Elements which form toxic compounds (LD_{50} 500 mg oral/kg)	
Arsenic	(trioxide^{3+})
Cadmium	(chloride)
Cobalt	(cobaltous^{2+})
Lead	(alkyl^{4+})
Mercury	(elemental^{0})
Nickel	(acetate^{2+})
Silver	(nitrate^{3+})
Vanadium	(trioxide^{3+})

* Based on acute oral exposure in rats. Principal data base: NIOSH Registry of Toxic Effects of Chemical Substances, 1979, USDHS.

** Unspecified isomer(s)

women (Humphrey, 1983; Eyster et al., 1983; Kimbrough, 1980). However, the significance of such exposure to the fetus and infant has not been fully evaluated.

The effects of long-term chronic exposure to environmental toxins are not well known. There is, however, some evidence from studies conducted in Michigan that chronic prenatal exposure to low levels of PCBs may result in lowered birth weight and smaller head circumferences (Fein et al., in press). In addition, some subtle behavioral deficits may be correlated with intrauterine PCB exposure (Jacobson et al., 1984). There is also one study that suggests that PCB and its congeners have a major impact on reduction of sperm production and motility in males (Dougherty et al., 1983).

The PCB compound is commonly found in the blood serum of Americans, but it is present in substantially higher levels in persons who consume Great Lakes fish (Humphrey, 1983). A 1974 study of some Michigan residents showed that persons consuming greater than 10.91 kg of fish from the Great Lakes per year had higher PCB blood serum levels than people from the same communities who rarely ate such fish (Humphrey, 1983). This study found that contaminated Great Lakes fish are a source of exposure which contributes to elevated human PCB levels that are significantly greater than background PCB levels (Humphrey, 1983).

Given the fish contamination data presented in this document, people eating large amounts of fish from the Saginaw Bay area may be being exposed to high levels of organochlorine contaminants. While the existence of fish consumption health advisories is intended to provide anglers with adequate data on which to base well-informed decisions regarding fish consumption, research has shown that health advisories in Michigan have had little influence on sport angler behavior (Udd and Fridgen, 1985).

c. Drinking Water

Little monitoring of drinking water for priority pollutants has been conducted in the watershed. Endrin, lindane, methoxychlor, toxaphene, 2,4-D and 2,4,5-TP are regulated under the Safe Drinking Water Act. These substances must be monitored annually in municipal supplies and there have been no reports of standards being exceeded in the region.

In 1985, a study of public drinking water supplies from the Saginaw River and Saginaw Bay was conducted as part of a series of multi-media studies of dioxin and other pollutants associated with the Dow Chemical Plant at Midland (USEPA, 1985). Four communities use Saginaw Bay for their raw water supplies: Saginaw/Midland, Bay City, and Pinconning. Water samples were taken at each of the intakes along with samples from the Saginaw River standby intake for the City of Saginaw and from Midland City finished water. Chloroform, methyl chloride, bromodichloromethane, benzoic acid, and di-n-butyl phthalate were detected at very low levels. The study found dioxin was not present in detectable levels in any of the samples (USEPA, 1985). The USEPA reports that primary drinking water standards were not exceeded for the raw water supplies and the Midland City tap water also met primary and secondary drinking water regulations.

d. Contaminated Waterfowl

While there are currently no standards for the consumption of waterfowl, and little work has been done to quantify contaminant levels in waterfowl in Saginaw Bay, it is possible that consumption of waterfowl may result in exposure to contaminants.

2. Bacterial Contamination

a. Saginaw River

The highest fecal coliform value measured in the Saginaw River by the USGS during water years 1983 to 1985 occurred in 1983 at 920 cols/100 ml (Table III-61). The annual maximum fecal coliform count decreased from 920 to 470 cols/100 ml in 1984. The maximum then increased to 760 cols/100 ml in 1985, a value greater than the maximum at either the Pigeon or Rifle rivers for that sample year. This 1985 maximum was 3.8 times greater than the Michigan surface water quality standard of 200 cols/100 ml.

Fecal streptococci count increased in the Saginaw River between 1983 and 1985 to a high of 580 cols/100 ml in 1985. Overall, maximum fecal streptococci values for the Saginaw River were substantially lower than maximum fecal streptococci values for the Pigeon and Rifle rivers between 1983 and 1985.

b. Pigeon River

The highest fecal coliform level measured in the Pigeon River between 1983 and 1985 occurred in 1984 at 4500 cols/100 ml (Table III-61). This value was the highest fecal coliform level measured in the Saginaw Bay watershed between 1983 and 1985. The minimum fecal coliform level of 440 cols/100 ml measured in 1984 is 2.2 times higher than the Michigan surface water quality standard of 200 cols/100 ml.

Maximum fecal streptococci measured in the Pigeon River during 1983 to 1985 decreased from 9400 cols/100 ml in 1983 to 2800 cols/100 ml in 1984. Minimum fecal streptococci for the Pigeon River in 1985 was greater than the 1985 maxima for either the Saginaw or Rifle rivers.

c. Rifle River

The highest fecal coliform value for the Rifle River between 1983 and 1985 was reported in 1984 at 760 cols/100 ml (Table III-61). This annual maximum fecal coliform value decreased to 690 cols/100 ml in 1985, a value that is still 2.4 times greater than the Michigan surface water quality standard for fecal coliforms.

Maximum fecal streptococci levels in the Rifle River fluctuated widely between 1983 and 1985, dropping from 9500 cols/100 ml in 1983 to 370 cols/100 ml in 1984, then rising to 1600 cols/100 ml in 1985.

Table III-61. Fecal Coliform and Fecal Streptococci Values in Surface Waters of the Saginaw Bay Watershed Measured by USGS in 1983, 1984 and 1985 (USGS 1983, 1984 and 1985).

		Water Year		
River		1983	1984	1985
Saginaw[a]				
fecal coliform	min	410	110	220
	max	920	470	760
fecal streptococci	min	220	180	210
	max	320	570	580
Pigeon[b]				
fecal coliform	min	200	560	440*
	max	2200	4500	-
fecal streptococci	min	200	320	4300*
	max	9400	2800	-
Rifle[c]				
fecal coliform	min	410*	-	250
	max	-	760*	690
fecal streptococci	min	760	190	11
	max	9500	370	1600

[a]RM 20.3 (Rust Ave.)

[b]RM 3.1 (Kinde Rd.)

[c]RM 20.0 (Old M-70)

*not all four samples represented

d. Saginaw Bay

Each of the five counties that border Saginaw Bay (Iosco, Arenac, Huron, Bay and Tuscola counties) was contacted during 1987 and asked about their procedures for monitoring county beaches for coliforms. Arenac, Bay and Huron counties have four, two and 17 public beaches, respectively, bordering Saginaw Bay. Only Huron and Bay counties perform somewhat regular beach monitoring and compile their data into annual reports (Bendes, pers. comm., 1987; Mathews, pers. comm., 1987). Iosco and Arenac counties both have beach access within their boundaries that are monitored for bacterial contamination randomly and upon request (Hasty, pers. comm., 1987; Yocum, pers. comm., 1987). There are no beach areas for suitable for swimming in Tuscola County, therefore the county does no regular monitoring for bacterial contamination (Kimmell, pers. comm., 1987).

The MDNR contacts all local health departments in Michigan biennially to summarize official closings of public swimming areas. No public beaches on Saginaw Bay were closed during water years 1984-1987, the most recent reporting period (MDNR, 1988).

SECTION IV -- POLLUTION SOURCES

A. POINT SOURCES

1. Municipal and Industrial Dischargers

a. Distribution

There are 127 wastewater treatment facilities and 87 industries that discharge directly to surface waters in the Saginaw Bay watershed (Table IV-1; Appendix 5). These are divided into major and minor dischargers. Major municipal systems are generally defined as plants that treat one million gallons of wastewater per day or more. Major industrial systems are those that score 80 points or more in EPA's facility rating system, which considers such factors as the potential for the pollutants to be toxic, the size and type of the waste stream, potential public health impacts, and whether the effluent limits are water quality or technology based.

There are 12 major industrial dischargers in the Saginaw Bay watershed (Table IV-2); five of these are located on the Saginaw River (Table IV-3). The 12 major industrial dischargers are distributed among the following category types: primary metals industries (2), electronic manufacturing (1), transportation equipment manufacturing (1), chemical manufacturing (1), power utility (1), battery manufacturing (1), petroleum refining (1), and sugar beet processing (4). Industrial categories of the 75 minor dischargers to the Saginaw Bay watershed include transportation equipment manufacturing, primary metals manufacturing, fabricated metals products, machinery manufacturing, rubber and plastics manufacturing, chemicals manufacturing, cement manufacturing, food and kindred products, petroleum and coal products, gypsum extraction, and photographic equipment and supplies.

There are 18 major municipal WWTPs in the Saginaw Bay watershed (Table IV-2). Of these, five major facilities and five minor facilities discharge directly to the Saginaw River (Table IV-3). The 18 major municipal WWTPs in the Saginaw Bay watershed discharged an average of 155.5 million gallons per day of treated effluent in 1986 (Table IV-4).

b. Discharge Permits

Permits regulating direct industrial and municipal discharges to Michigan surface waters are issued under the National Pollutant Discharge Elimination System (NPDES) by the MDNR (Section VI). As of March, 1988, there was a backlog of expired NPDES permits for dischargers in the Saginaw Bay watershed. However, no major industrial dischargers or municipal wastewater treatment plants were operating under an expired NPDES permit. Sixty of the 109 minor municipal wastewater treatment plants and 17 of the 75 minor industrial dischargers had expired permits. Because current staffing levels prohibit processing of all permits scheduled for a given year, new permits and reissuances of permits for major discharges receive the highest priority.

Table IV-1. Number of Direct Industrial and Municipal Dischargers to the Saginaw Bay Watershed by Drainage Basin.

Drainage Basin		Facility Type Major	Minor	Total
Au Gres River	Industrial	0	7	7
	Municipal	0	4	4
Rifle River	Industrial	0	2	2
	Municipal	0	4	4
Kawkawlin River	Industrial	0	3	3
	Municipal	0	8	8
Saginaw River	Industrial	11	57	68
	Municipal	18	74	92
Wiscoggin Drain	Industrial	0	1	1
	Municipal	0	5	5
Pigeon River	Industrial	1	5	6
	Municipal	0	14	14
Saginaw Bay	Industrial	12	75	87
	Municipal	18	109	127
TOTAL		30	184	214

Table IV-2. Major Industrial and Municipal Dischargers to Surface Water in the Saginaw Bay Watershed by Receiving Water.

Receiving Water	Facility
Chippewa River	Mt. Pleasant Wastewater Treatment Plant
Pine River (Gratiot Co.)	Total Petroleum Inc. (Alma) Alma Wastewater Treatment Plant Hitachi Magnetics Corp. (Edmore)
Cass River	Michigan Sugar Company (Caro) Frankenmuth Wastewater Treatment Plant Bridgeport Township Wastewater Treatment Plant
Flint River	General Motors Corp. Fisher Guide (Flint) City of Flint Wastewater Treatment Plant Lapeer Wastewater Treatment Plant Genesee County Ragnone Wastewater Treatment Plant Flushing Wastewater Treatment Plant
Shiawassee River	Johnson Controls Inc. Owosso Mid-Shiawassee County Wastewater Treatment Plant Genesee County Wastewater Treatment Plant No. 3 Howell Wastewater Treatment Plant
Tittabawassee River	Dow Chemical Company (Midland) Midland Wastewater Treatment Plant Saginaw Township Wastewater Treatment Plant
Saginaw River	General Motors Corp. Chevrolet-Pontiac-Canada Group (Bay City) Monitor Sugar Company (Bay City) General Motors Corp. Central Foundry (Saginaw) Michigan Sugar Company (Carrollton) Bay City Wastewater Treatment Plant Saginaw Wastewater Treatment Plant

Table IV-2. Continued.

Receiving Water	Facility
Saginaw River (Cont.)	Zilwaukee-Carrollton-Saginaw Wastewater Treatment Plant
	West Bay County Regional Wastewater Treatment Plant
	Buena Vista Township Wastewater Treatment Plant
Saginaw Bay	Consumers Power Co. (Karn and Weadock Plants)[1]
	Michigan Sugar Co. (Sebewaing)[2]

[1]In the Saginaw River drainage basin.

[2]In the Pigeon River drainage basin.

Table IV-3. Major and Minor Industrial and Municipal Point Source Dischargers to the Saginaw River, 1987.

NPDES Permit No.	Facility Name (Expiration Date)
INDUSTRIAL	
* 655	Dow Chemical, Bay City Plants (10/1/90)
4138	Lake Ontario Cement-Aetna Cement Corporation (1/31/91)
4201	PVS Chem-Bay Chemical Company (2/28/90)
26026	Union Oil Company of California (12/31/85)
* 1121	GMC Chevrolet-Pontiac-Canada Group (3/31/90)
2232	Prestolite Motor of Eltra (7/31/90)
* 1091	Monitor Sugar Co. Bay City Plant (9/31/91)
* 1139	General Motors Corp. - Central Foundry (10/01/90)
* 2224	Michigan Sugar Company Carrollton Plant (3/31/87)
MUNICIPAL	
22918	Essexville Wastewater Treatment Plant (10/1/90)
*22284	Bay City Wastewater Treatment Plant (5/31/89)
*42439	West Bay County Regional WWTP (10/1/90)
*23981	Zilwaukee-Carrollton-Saginaw WWTP (3/31/90)
*22497	Buena Vista Township WWTP (1/31/90)
*25577	Saginaw Wastewater Treatment Plant (8/31/89)
44016	Carrollton Twp. Storm Water Overflow (6/30/88)
NON-MUNICIPAL	
28371	Bay City Country Club (8/31/79)
24236	Tri-City Airport (12/31/78)
25828	Riverview Estates (6/30/79)

*Major discharger

Table IV-4. Average Total Flow of Treated Wastewater to the Saginaw River and its Tributaries from Major Municipal Dischargers, 1986.

Facility	Average Daily Flow (MGD)
Alma	2.4
Bay City	8.7
Bridgeport	2.7
Buena Vista	1.7
Flint	42.5
Flushing	1.7
Frankenmuth	1.5
Genesee Co. Ragnone	25.2
Genesee Co. No. 3	9.41[a]
Howell	1.3
Lapeer	1.8
Midland	7.3
Mount Pleasant	3.7
Owosso	4.4
Saginaw	30.2
Saginaw Twp.	4.5
West Bay Co. Reg.	4.0
Zilwaukee-Carrollton-Saginaw Twp.	3.5
TOTAL	155.5

[a]During discharge.

The MDNR is in the process of converting NPDES data storage from the Water Information System for Enforcement, Revised (WISER) computer system to the USEPA Permit Compliance System (PCS). Data entry of NPDES permit information to WISER was discontinued in May, 1986, and the transition to the PCS system is taking longer than originally planned. However, all major dischargers have been entered into the system as of October 1, 1987, and are updated monthly as permits are reissued. All dischargers to the Saginaw River or its tributaries are coded in the PCS as discharging to the Saginaw River; PCS does not list the specific receiving stream for each discharger.

Surface water discharge permit holders are required to submit monthly Discharge Monitoring Reports (formerly called Monthly Operating Reports or MORs) to MDNR. Summarized Discharge Monitoring Report (DMR) information for 1987 are available on the PCS. The most recent WISER DMR summaries are for 1986. The PCS database can provide an inventory of the parameters being monitored by dischargers and is suitable for loading calculations. MDNR also inputs DMR reporting information to the EPA STORET computer system. Data regarding special effluent monitoring surveys for heavy metals and organics are stored in the files of the Great Lakes and Environmental Assessment Section, Surface Water Quality Division, MDNR.

In addition to MDNR records, information on dischargers in the Saginaw Bay watershed can be obtained from the USEPA Industrial File Index System (IFIS). The IFIS lists the receiving water and Standard Industrial Code (SIC) for dischargers with NPDES permits. The IFIS list of dischargers is not as current as the PCS list.

c. Phosphorus and Suspended Solids

The following conventional parameters are generally regulated in each of the 18 major municipal and 12 major industrial dischargers' NPDES permits: biochemical oxygen demand (BOD), suspended solids (SS), and total phosphorus (TP). Total phosphorus and suspended solids loads from these major facilities to the Saginaw River and its tributaries were estimated by summing the products of the average monthly flow and the average monthly mean concentrations. The load estimates are rough approximations as settling and degradation rates were not considered in the calculations and loads from minor dischargers were not included.

Municipal phosphorus loads to surface water in the Saginaw Bay watershed were estimated to be 169.2 metric tons in 1986 (Table IV-5). Phosphorus loads to surface water in the Saginaw Bay watershed from major municipal wastewater treatment plants have decreased substantially since 1974 (Table IV-6). It is estimated that more than half of the total decrease in phosphorus loads to Saginaw Bay between 1974 and 1979 was due to phosphorus removal efforts by WWTPs in the Saginaw River basin and to the 1977 phosphate detergent ban in Michigan (IJC, 1983). The slight increase in municipal phosphorus loads from 1979 to 1981 may be due to differences in the number of facilities that reported an increase in the total flow treated, and poor performance by one or more of the municipal facilities (IJC, 1983). In 1982, 88.2% by volume of all municipal point source effluent was treated for phosphorus removal (LTI, 1983).

Table IV-5. Phosphorus and Suspended Solids Loads to the Saginaw River and its Tributaries from Major Municipal Dischargers, 1986.

Facility	Total Phosphorus (mt/yr)	Total Suspended Solids (mt/yr)
Alma	2.1	27
Bay City	6.6	266
Bridgeport	2.7	34
Buena Vista	1.8	50
Flint	45.0	430
Flushing	1.0	29
Frankenmuth	1.2	48
Genesee Co. Ragnone	20.4	884
Genesee Co. No. 3	1.9	105
Howell	1.0	18
Lapeer	2.1	11
Midland	2.5	72
Mount Pleasant	3.4	36
Owosso	1.7	73
Saginaw	22.7	261
Saginaw Twp.	48.6	410
West Bay Co. Reg.	2.6	67
Zilwaukee-Carrollton-Saginaw Twp.	1.9	87
TOTAL	169.2	2,908

Table IV-6. Phosphorus Loads from Municipal Wastewater Treatment Plants to Surface Waters in the Saginaw Bay Watershed, 1974, 1979-1981 (IJC, 1983), and 1983-1986.

Year	Load (metric tons/yr)
1974	800
1979	211
1980	220
1981	232
1983	141[a]
1984	125[a]
1985	114[b]
1986	169[c]

[a] Data not available for Saginaw Twp. WWTP or Mt. Pleasant WWTP.

[b] Includes phosphorus load from Mt. Pleasant WWTP (3 mt); data not available for Saginaw Twp. WWTP.

[c] Includes phosphorus loads from Mt. Pleasant WWTP (3 mt) and Saginaw Twp. WWTP (49 mt).

The total discharge of phosphorus to surface waters of the Saginaw Bay watershed in 1986, from the six major industrial dischargers with permit requirements for phosphorus, was approximately 68 metric tons (Table IV-7). In 1981, discharge from the Dow Chemical Company plant in Midland was the largest point source of phosphorus to the Saginaw Bay drainage basin (EPA, 1986). The 1981 annual discharge was estimated to be 44 metric tons. The total annual discharge of phosphorus in 1986, based on data from the DMRs, was approximately 13 metric tons. The reduction in phosphorus load is attributed to a decrease in discharge flows and to the construction of a sand filtration treatment system at Dow (EPA, 1986). Improvements in treatment capabilities at the Pinconning WWTP, a minor municipal facility, have reduced the average total phosphorus concentration in this discharge from 5.07 mg/l in 1983 to 0.39 mg/l in 1986.

Most of the major WWTPs and industrial dischargers in the Saginaw River basin are meeting the 1.0 mg/l Michigan water quality standard for phosphorus in wastewater, although five of the plants exceeded the standard for at least one month in 1986. Those plants were Bridgeport, Buena Vista, Howell, Lapeer, and Saginaw Township. Five of the 12 major industrial dischargers in the Saginaw Bay watershed have monitoring requirements or limits for phosphorus in their NPDES permits. Only Hitachi Magnetics, Incorporated has a numerical limit for phosphorus of 1.0 mg/l, which was met consistently in 1986. Dow Chemical Company has reduced their average annual total phosphorus concentration from 1.7 mg/l in 1982 to 0.84 mg/l in 1986 (EPA, 1986).

d. Metals and Organics

The discharge of toxic materials from point sources to surface water is regulated under the NPDES program. In the Saginaw Bay watershed during 1987, four of the 12 major industrial dischargers had NPDES permit requirements for metals and six had permit requirements for toxic organic substances. Nine of the 18 major municipal WWTPs have NPDES permit requirements for metals or organics. Table IV-8 summarizes the number of industrial and municipal facilities discharging selected parameters to the river basins in the Saginaw Bay watershed.

The NPDES permit requirements for metals and organics may be specific numerical limits regulating the concentration and/or mass of material a facility may discharge, or they may include monitoring requirements for certain parameters. Facilities with permit limits and/or long-term monitoring requirements must submit monthly reports of wastewater discharge monitoring data to the MDNR. The results of these monthly Discharge Monitoring Reports (DMRs) are summarized by MDNR district office staff and compared to the requirements contained in the facility's permit to determine compliance.

Annual loads of metals and toxic organic substances to surface waters in the Saginaw Bay basin were estimated using 1987 data from the DMR summaries. Total annual loads based on the DMR summaries were calculated by summing the products of the twelve average monthly flows and the average monthly concentrations of each parameter for each surface

Table IV-7. Total Phosphorus Loads to the Saginaw River and its Tributaries from Major Industrial Dischargers with NPDES Permit Requirements for Phosphorus, 1986.

Facility	Total Phosphorus (mt/yr)
Dow Chemical USA	13.4
Hitachi Magnetics Corp.	0.3
Michigan Sugar - Caro	21.8
Michigan Sugar - Carrollton	14.6
Michigan Sugar - Sebewaing	17.9
Monitor Sugar - Bay City	0.4[a]
TOTAL	68.4

[a]Monitoring data for October and November, 1986 only.

Table IV-8. Number of Industrial and Municipal Facilities in the Saginaw Bay Watershed Requested for Selected Parameters by Basin, 1988.

PARAMETER	RIVER BASIN					
	Saginaw	Pigeon	Wiscog.	Au Gres	Rifle	Kawkawlin
Total SS	112	15	5	8	4	10
Total P	59	13	5	3	2	6
Total CN	3					
Total Cd	2			1		
Total Cr	5	1		1		
Total Co	1					
Total Cu	13			1		
Total Fe	6				1	
Total Pb	4					
Total Hg	5					
Total Ni	4			1		
Total Ag	4			1		
Total Zn	11	1		1	1	
Carbon-tetrachloride	1					
Chloroform	1					
Total Recoverable Phenolics	3					
Benzene	2					
Acrylonitrile	2					
2,3,7,8-TCDD	1					
Total Phenol	1					
Polychlorinated Biphenyls	3					
Total toxic organics	2					
Styrene	1					

outfall. These are gross loadings and include the background levels of these parameters in intake waters.

i. Cadmium

A total of three facilities have permits regulating the discharge of cadmium (Cd) to the Saginaw Bay watershed. Among these, two are major wastewater treatment plants, the City of Alma and the City of Flint. The total discharge of Cd from these two facilities to the Pine River, in Gratiot County, and the Flint River, based on data from their DMRs was 164 kg in 1987 (Table IV-9). Ambient water concentrations of Cd did not exceed the Michigan Rule 57(2) guideline level in 1986 for any waters in the basin where facilities report discharging Cd (Section III).

ii. Chromium

Seven facilities in the Saginaw Bay watershed have NPDES permit requirements for chromium (Cr). Two major industrial facilities and one major municipal WWTP are in the Saginaw River Basin. In addition, two minor facilities in the Saginaw River basin and two minor facilities in the Au Gres River basin have NPDES permit limits for Cr. Data from the DMRs for these facilities indicate that the Saginaw WWTP had the greatest contribution of chromium to the surface waters. The total load of Cr discharged by the Saginaw WWTP in 1987 was 1,273 kg (Table IV-9).

Ambient surface water concentrations of Cr in the Saginaw Bay watershed did not exceed the Rule 57(2) guideline level in 1986 (Section III).

iii. Copper

Fourteen facilities in the Saginaw Bay watershed have NPDES permits with requirements for copper (Table IV-8). Thirteen of these are in the Saginaw River watershed, including five major industrial dischargers and five major municipal dischargers. The remaining facility discharges to the Au Gres River. Based on the DMR summaries for the major facilities, approximately 11,400 kg of copper was discharged to surface waters of the Saginaw River watershed in 1987 (Table IV-9).

None of the rivers examined in this report had copper concentrations exceeding Michigan Rule 57(2) guideline levels in 1986 (Section III).

iv. Lead

Four facilities in the Saginaw Bay watershed have NPDES permits regulating the discharge of lead (Table IV-8), including two major industrial dischargers (Johnson Controls, Inc. and GMC-Central Foundry) and two major municipal wastewater treatment plants (Bay City WWTP and Lapeer WWTP), all of which are in the Saginaw River basin. Based on the 1987 DMR summaries, the major discharge of lead was from the GMC-Central Foundry (7,300 kg). However, this estimate was based on only two samples and may not be representative of actual loading. Ambient water concentrations of lead did not exceed Rule 57(2) guideline levels in 1986 for any river assessed for this report (Section III).

Table IV-9. Estimated 1987 Loads (kg) of Selected Metals to Surface Waters in the Saginaw Bay Watershed from Major Point Source Dischargers with NPDES Permit Requirments for those Parameters (data from MDNR DMR Summaries).[a]

NPDES Permit Number	Facility	Metal							
		Ag	Cd	Cr	Cu	Hg	Ni	Pb	Zn
INDUSTRIAL									
868	General Motors Central Foundry				5200[b]			7300[b]	203000[b]
25194	General Motors Fisher Guide				1.7[e]		9.9[e]		1.2[e]
27812	Hitachi Magnetics Corp.				6.6	0.3	5.3		14.2
3484	Johnson Controls Inc.							0.4	
MUNICIPAL									
20265	City of Alma WWTP	19.8	22.5						
22284	Bay City WWTP				932			287	
22926	City of Flint WWTP	383	141		4584	27.1			
23655	Mt. Pleasant WWTP	7.4[c]							
25577	City of Saginaw WWTP			1273	724		1810		2633
23981	Zilwaukee-Carrollton-Saginaw Twp WWTP	d			d				d
22918	Essexville WWTP					0.7[c]			

[a] When loads were estimated, a data point of less than a level of detection was factored into the loading equation as one-half the level of detection.

[b] These loadings are based on only two data points. GM-Central Foundry began sampling for these parameters in November, 1987. These estimates may not be representative of actual annual loadings.

[c] These loadings are based on only six data points.

[d] Monitoring had not begun until 1988.

[e] These loadings represent discharge from January through June, 1987. Subsequent discharges were routed to the municipal WWTP.

v. Mercury

The discharge of mercury (Hg) is regulated in the permits of five facilities in the Saginaw Bay watershed. Three are major dischargers Hitachi Magnetics Corporation (Pine River), Johnson Controls (Shiawassee River), and the Flint WWTP (Flint River). The total load of Hg to surface waters in the Saginaw Bay watershed from these three major facilities in 1987 was estimated to be 28.1 kg (Table IV-9).

Mercury was not detected by the MDNR ambient monitoring program in any waters of the Saginaw Bay basin in 1986 (Section III).

vi. Nickel

Five facilities in the Saginaw Bay watershed have NPDES permits regulating the discharge of nickel (Ni). The total estimated load of Ni discharged to surface waters of the Saginaw Bay basin in 1987 by three major dischargers was 1,825 kg (Table IV-9). The Saginaw WWTP alone was estimated to discharge 1,810 kg into the Saginaw River during 1987.

The measured concentrations of Ni in the waters of Saginaw Bay basin rivers did not exceed Rule 57(2) guideline levels in 1986 (Section III).

vii. Silver

The NPDES permits of five municipal facilities in the Saginaw Bay watershed contain regulations for silver. The total estimated load of silver (Ag) from the City of Flint WWTP in 1987 was 383 kg based on data from their DMR (Table IV-9). However, the MDNR ambient monitoring program did not detect silver in any waters of the Saginaw Bay basin in 1986 (Section III).

viii. Zinc

Fourteen facilities in the Saginaw Bay watershed have NPDES permits which contain regulations for zinc (Zn). The GMC-Central Foundry was estimated to have the greatest contribution of zinc (203,000 kg) in 1987. However, this estimate was based on only two samples and may not represent actual annual loadings.

Ambient water concentrations of zinc in the Saginaw Bay basin did not exceed Michigan Rule 57(2) guideline levels in 1986 (Section III).

ix. Organics

Six of the 12 major industrial dischargers in the Saginaw Bay watershed and four of the 18 major wastewater treatment plants have permit requirements for certain organic chemicals. Of these organic chemicals, only PCB and TCDD have been found to impair designated uses in the Saginaw Bay watershed. Dow Chemical Company at Midland has the most organic chemical discharge requirements with monitoring required for 23 organic parameters.

Two major industrial dischargers and four major municipal dischargers have permit requirements for cyanide (CN). The total estimated load of free CN into surface waters of the Saginaw Bay watershed in 1987 was 2,376 kg (Table IV-10). The major contributors of cyanide to the Saginaw Bay watershed were GMC-Central Foundry, Flint WWTP, and Saginaw WWTP. The CN monitoring data for Hitachi Magnetics was consistently less than the level of detection.

Total phenolics are regulated in the permits of three major industrial facilities and one major wastewater treatment plant. The 1987 total estimated load of phenolics to surface waters of the Saginaw Bay watershed was 14,648 kg excluding Total Petroleum Inc., for which DMR discharge data were not available.

PCBs are listed in the permits of three facilities in the Saginaw River basin of which two are major industrial dischargers, the GMC Chevrolet-Pontiac-Canada Group (CPC) plant in Bay City and GMC-Central Foundry plant in Saginaw, and one is a major municipal wastewater treatment plant, the City of Flint. The total load of PCBs to the Saginaw River watershed from these three plants in 1987 was estimated to be 4.4 kg (Table IV-10).

e. Saginaw River Dischargers

Seven municipal, three non-municipal and nine industrial facilities have NPDES permitted discharges to the Saginaw River (Table IV-3). Ten of these facilities, are considered to be relatively insignificant dischargers. For example, Prestolite Electric, Incorporated, a minor industrial facility, discharges only non-contact cooling water into the river. The three non-municipal facilities, which discharge from wastewater sewage lagoons, were considered in 1977 to be insignificant sources of pollutants (The Chester Engineers, 1977). No new information warrants changing that assessment. Intermittent discharges from the Carrollton Township Overflow Treatment Facility (four days discharge in 1986) and the CnoCal storm water discharge (no reported discharge in 1986) are also insignificant pollutant sources. Of the remaining minor facilities, Aetna Cement Corporation discharged only cooling water between April and November 1986 at average flows of less than 0.2 MGD, and Bay Chemical discharged an average of less than 1 MGD cooling water in 1986. Dow Chemical, Bay City had no reported discharge of process wastes to the Saginaw River in 1986 according to DMR summaries. The remaining ten facilities are considered to be more significant dischargers.

i. Bay City WWTP

The Bay City WWTP discharged an estimated 10,141 kg of phosphorus and 268 metric tons (mt) of TSS to the Saginaw River in 1987 according to the Discharge Monitoring Reports (Table IV-11). However, during this period, phosphorus concentrations in the plant's effluent never exceeded the 30-day average limit of 1.0 mg/l.

In 1987, the Bay City WWTP exceeded its maximum daily Cu limit of 0.215 mg/l in June, October, and November, and in 1986 this limit was

Table IV-10. Estimated Total 1987 Loads (kg) of Selected Organics to Surface Waters in the Saginaw Bay Watershed from Major Point Source Dischargers with NPDES Permit Requirements for those Parameters.

NPDES Number	Facility	CN*	Total Phenolics	PCBs
INDUSTRIAL				
1121	General Motors C-P-C Group			2.4
1139	General Motors Central Foundry	842	13693	2.0
27812	Hitachi Magnetics Corp.	**		
1066	Total Petroleum Inc.			
MUNICIPAL				
20265	City of Alma WWTP	**		
22926	City of Flint WWTP	934	***	
25577	City of Saginaw WWTP	600	955	

* Amenable

** Monitoring data consistently less than detection.

*** Too few data points to estimate loading.

Table IV-11. Estimated Total 1987 Loads (kg) of Phosphorus and Total Suspended Solids (TSS) to the Saginaw River from Selected Point Source Dischargers.

NPDES #	Facility	Parameter	
		Phosphorus	TSS (mt/yr)
INDUSTRIAL			
1121	General Motors C-P-C Group	-	56
1139	General Motors Central Foundry	-	144
2224	Michigan Sugar-Carrollton Plant	647[a]	64
1091	Monitor Sugar-Bay City Plant	334[b]	25[b]
MUNICIPAL			
22284	Bay City WWTP	10141	268
22918	Essexville WWTP	304	22
22497	Buena Vista WWTP	1392	32
25577	City of Saginaw WWTP	20184	178
42439	West Bay County Regional WWTP	2750	49
23981	Zilwaukee-Carrollton-Saginaw Twp. WWTP	1762	79

[a]Average for eight months discharge.

[b]Total for five months discharge.

exceeded in January and May. The plant did not exceed either its daily maximum or 30-day average permit limits for Pb (1.0 mg/l and 0.34 mg/l, respectively) during 1987 or 1986.

ii. Essexville WWTP

The Essexville WWTP is a minor municipal facility discharging just under 1.0 MGD of treated wastewater to the Saginaw River. The plant contributed relatively minor loads of phosphorus and TSS to the Saginaw River in 1987 (Table IV-11). Thirty-day average concentrations of phosphorus in the plant's effluent did not exceed their NPDES permit limit of 1.0 mg/l in 1987.

Essexville WWTP has no monitoring requirements or permit limits for organics. However, this facility does have a long-term Water Quality Based Effluent Limit (WQBEL) for mercury in their current NPDES permit. There is one categorical discharger serviced by the Essexville WWTP and the municipality is in the process of developing an Industrial Pretreatment Program (IPP; Brouillet, personal communication, 1987).

iii. West Bay County Regional WWTP

The West Bay County Regional WWTP discharged an estimated 2,750 kg of phosphorus and 49 mt of TSS to the Saginaw River in 1987 (Table IV-11). The plant did not exceed its 30-day average phosphorus limit of 1.0 mg/l in 1987 or 1986. West Bay County Regional WWTP had occasional difficulty meeting the 1.0 mg/l limit in both 1984 and 1985 when the limit was exceeded once, and in 1983 when the limit was exceeded three times. However, improvements in the pretreatment of discharge from Monitor Sugar enabled the West Bay County WWTP to operate without upset and within its NPDES permit limits in 1986 and 1987.

West Bay County Regional WWTP has not identified any categorical dischargers to its facility. However, this facility currently has a long-term water quality based effluent limit for mercury in their NPDES permit.

iv. Buena Vista Township

Buena Vista Township WWTP discharge an estimated 1,392 kg of phosphorus and 32 mt of TSS to the Saginaw River in 1987 (Table IV-11). The plant exceeded the 30-day average phosphorus limit of 1.0 mg/l contained in their NPDES permit on six occasions in 1985 but only once in 1986. However, the phosphorus limit was not exceeded during 1987.

Buena Vista Township has no permit limits for metals or organic substances. The township has an IPP, but currently no categorical or significant non-categorical facilities discharge to the plant (Hern, personal communication, 1987).

v. Saginaw WWTP

Large loads of total phosphorus and TSS have been discharged by the Saginaw WWTP to the Saginaw River relative to other dischargers. Saginaw

WWTP discharged an estimated 20,184 kg of total phosphorus and 178 mt of TSS to the river in 1987. However, the Saginaw WWTP did not exceed its 30-day average limit of 1.0 mg/l phosphorus in 1987.

The Saginaw WWTP has biweekly monitoring requirements for Cr, Fe, CN, total phenolics, Zn, Cu and Ni. The plant's estimated loads of Cr, Cu, Ni, and Zn in 1987 were 1,273 kg/yr, 724 kg/yr, 1,810 kg/yr, and 2,633 kg/yr, respectively. However, permit limits for these parameters were not exceeded during 1987.

Saginaw WWTP receives wastewater from five categorical industrial dischargers, including General Motors' Central Foundry and Steering Gear Plant, and two significant non-categorical dischargers. The City of Saginaw has an IPP program for the regulation of industrial discharges to the WWTP.

vi. Zilwaukee-Carrollton-Saginaw WWTP

The Zilwaukee-Carrollton-Saginaw WWTP (Z-C-S) discharged an estimated 1,762 kg of total phosphorus and 79 mt of TSS to the Saginaw River in 1987. The plant did not exceed its 30-day average maximum phosphorus limit of 1.0 mg/l in 1987.

The Z-C-S plant currently has quarterly monitoring requirements for Ag, Zn and Cu, as well as methylene chloride. However, there were not adequate data to estimate loads of these parameters. As of March 1987, one categorical discharger and two significant non-categorical dischargers to the plant had been identified and the wastewater treatment plant is developing an IPP.

vii. General Motors Corporation Chevrolet-Pontiac-Canada Group, Bay City (GMC-CPC)

The GMC-CPC plant in Bay City discharged an estimated 56 mt of TSS to the Saginaw River in 1987. The plant has no permit requirements for phosphorus.

The plant discharged an estimated 2.4 kg of PCB to the Saginaw River in 1987. Most of this PCB can be attributed to ambient concentrations in the plant's water intake. However, it has not been determined where the PCB in the water intake is originating. Water samples collected in the Saginaw River upstream of GMC-CPC by MDNR in 1987 did not detect PCB at an analytical detection limit of 10 ng/l. No other metals or organics are discharged in sufficient quantities to require monitoring.

viii. General Motors Corporation - Central Foundry, Saginaw

The GMC-Central Foundry plant in Saginaw discharged an estimated 144 mt of TSS to the Saginaw River in 1987 (Table IV-11). The plant has no permit requirements for phosphorus.

The plant discharged an estimated 13,693 kg of phenolics to the Saginaw River in 1987. In addition, the Central Foundry plant was responsible for 45% of the total load of PCB, discharging an estimated 2.0 kg in 1987.

A new permit for GMC-Central Foundry requiring discharge limits for Zn, Pb, Cu and some organic materials, which were previously not limited, was issued in August 1987. This permit also contains long-term water quality based effluent limits for PCBs and mercury. Monitoring for these parameters was initiated in November, 1987.

ix. Monitor Sugar - Bay City Plant

The Monitor Sugar Plant in Bay City is an intermittent source of pollutants to the Saginaw River. In 1987, the plant reported discharging condensor cooling water in January, February, October, November and December. During those periods the plant discharged an estimated total annual load of 25 mt of TSS to the Saginaw River. Monitor Sugar discharged an estimated 334 kg of phosphorus to the Saginaw River during 1987. However, permit limits for these parameters were not exceeded during 1987.

x. Michigan Sugar - Carrollton

The Michigan Sugar Plant in Carrollton discharged treated process wastewater and cooling water to the Saginaw River in January through May and September through December, 1987. In those periods, the plant discharged an estimated of 334 kg of total phosphorus and 64 mt of TSS to the Saginaw River. However, permit limits for these parameters were not exceeded during 1987.

2. Intermittent Point Sources

a. Sewer Overflows and Urban Stormwater Discharges

Intermittent point sources (combined sewer overflows and separate storm sewers) have historically contributed a substantial percentage of pollutants to the Saginaw River/Bay system during high flow conditions (Chester Engineers, 1976). The majority of these sources are within the highly urbanized areas of Bay City, Saginaw, Midland and Flint, but sources occur throughout the watershed (Table IV-12). No data were available on the types or amounts of pollutants entering the Saginaw River/Bay system from combined sewer overflows (CSOs).

In Flint, there are separate sewers for sanitary and storm flows, and lagoons capture overflow stormwater prior to chlorination and discharge. This prevents the discharge of untreated effluent to the Flint River by the City of Flint (Hicks, personal communication).

The City of Flushing periodically discharges untreated sewage to the Flint River during some periods of wet weather. Flushing had until June 1988 to upgrade its wastewater treatment plant in order to meet effluent standards. A representative from the City of Davison stated that its lone sanitary sewer overflow had been eliminated (Hicks, personal

Table IV-12. Summary of Municipalities Suspected of Generating Intermittent Point Sources (The Chester Engineers, 1976).

MDNR Facility Number	Municipality	Reason for suspecting the existence of intermittent point sources (I/I: infiltration and inflow)
290014	Alma	Storm sewer and I/I problems
090028	Auburn	Suspected I/I problems
060022	Au Gres	Suspected I/I problems
320048	Bad Axe	Suspected I/I problems
090029	Bay City	Predominantly combined sewers
290046	Breckenridge	Storm sewers
730032	Bridgeport Twp.	Suspected I/I problems; storm sewers
760028	Brown City	Possible I/I problems
730029	Buena Vista Twp.	Suspected I/I problems; storm sewers
790006	Caro	Suspected I/I problems; storm sewers
730030	Carrollton Twp.	Combined sewer overflow
790007	Cass City	Suspected I/I problems; storm sewers
730019	Chesaning	Possible I/I problems; storm sewers
180009	Clare	Possible I/I problems; storm sewers
760029	Croswell	Combined system
760074	Deckerville	Storm sewers
350026	East Tawas	Suspected I/I problems; combined system
320069	Elkton	Possible I/I problems; storm sewers
090030	Essexville	Suspected I/I problems; combined system
730070	Frankenmuth	Storm sewers
260007	Gladwin	Possible I/I problems; partially combined
290017	Fulton Twp.	Storm sewers
320049	Harbor Beach	Possible I/I problems
290015	Ithaca	Suspected I/I problems; combined system
790066	Kingston	Storm sewer
760030	Lexington	Possible I/I problems; storm sewers
760031	Marlette	Suspected I/I problems; combined system
790023	Mayville	Combined system
730159	Merrill	Storm sewers
560009	Midland	Possible I/I problems; combined sewers
790022	Millington	Suspected I/I problems; cross connections
370011	Mount Pleasant	Suspected I/I problems; storm sewers
320087	Port Austin	Combined system
720068	Roscommon	Possible I/I problems; combined sewers
370052	Rose City	Possible I/I problems
730026	Saginaw	Combined system
730028	Saginaw Twp.	Partially combined sewers
730043	St. Charles	Suspected I/I problems; storm sewers
290019	St. Louis	Possible I/I problems; partially combined
760033	Sandusky	Possible I/I problems; partially combined
370010	Shepherd	Combined system
060018	Standish	Possible I/I problems; storm sewers
350028	Tawas City	Suspected I/I problems

Table 12. Continued.

MDNR Facility Number	Municipality	Reason for suspecting the existence of intermittent point sources (I/I: infiltration and inflow)
320134	Ubly	Combined system
790010	Vassar	Possible I/I problems; storm sewers
650003	West Branch	Possible I/I problems; partially combined
730031	Zilwaukee	Possible I/I problems; combined system

communication). No data on flows or concentrations were available for these sites.

Five CSOs exist on the Tittabawassee River, all of them in the City of Midland. The locations are at State, St. Nicholas, Hubbard, Gordon and Benson Streets (Young, personal communication). A recent (undated) report by the City of Midland indicated the following: (1) CSO control at Midland would not result in any significant change in suspended solids in the Tittabawassee River; (2) implementation of any of the CSO control alternatives proposed in the study should substantially reduce the fecal coliform concentration downstream of Midland; and, (3) the dissolved oxygen level downstream of Midland is seriously affected by combined sewer overflows during large storms when the river flow is very low.

Several combined sewer overflows also exist along the Saginaw River. Bay City utilizes five retention basins to control stormwater, but still has overflow during large storm events (Yusaf, personal communication). In Essexville, a combined sewer mixes with the main storm flow. Saginaw Township has a CSO facility at Center Road that is regulated through an NPDES permit. Carrollton Township also has an NPDES permit regulating the discharge of combined sewer overflow. No data are available on any of these locations (Yusaf, personal communication).

The worst stormwater-related problems occur in the City of Saginaw. A rain event on 7 July 1980, which produced 0.8 inches of precipitation, caused the observed instream dissolved oxygen to decrease from 6.0 mg/l to 3.6 mg/l and the bacterial levels to increase from 200 counts/100 ml to in excess of 60,000 counts/100 ml (LTI, 1981). Combined sewer overflows are a major contributor to this reduction in water quality, but factors such as continuous point source discharges and upstream nonpoint sources may play a substantial role as well (LTI, 1982).

The Weiss Street area (Weiss Street Pump Station and the Weiss Street gravity overflow from Saginaw Township) is the primary overflow in the system (Figure IV-1), with 33% of the annual discharge (EDP, 1981). A major bottleneck to flow occurs at the interceptor river crossing, causing the West Side interceptor to back up. An extensive study concluded that raising the weir height into the wet well, thereby increasing the flow across the river to the treatment plant, would be an important, cost-effective step to relieve the system of overflow at the Weiss Street location (EDP, 1981).

b. September 1986 Flood

i. Municipal Wastewater Treatment Plant Overflows

Over 15 inches of rain fell in Midland and 16 inches in Saginaw during September, 1986. Between September 9 and 11, more than a foot of rain fell in many places within a 32-36 hour period. The depth of the Tittabawassee River increased from 8 feet to over 33 feet and flow was greater than the 100-year record flow. Discharge data and overflow events were monitored by the MDNR and are summarized in several memoranda written between September 10, 1986 and September 24, 1986.

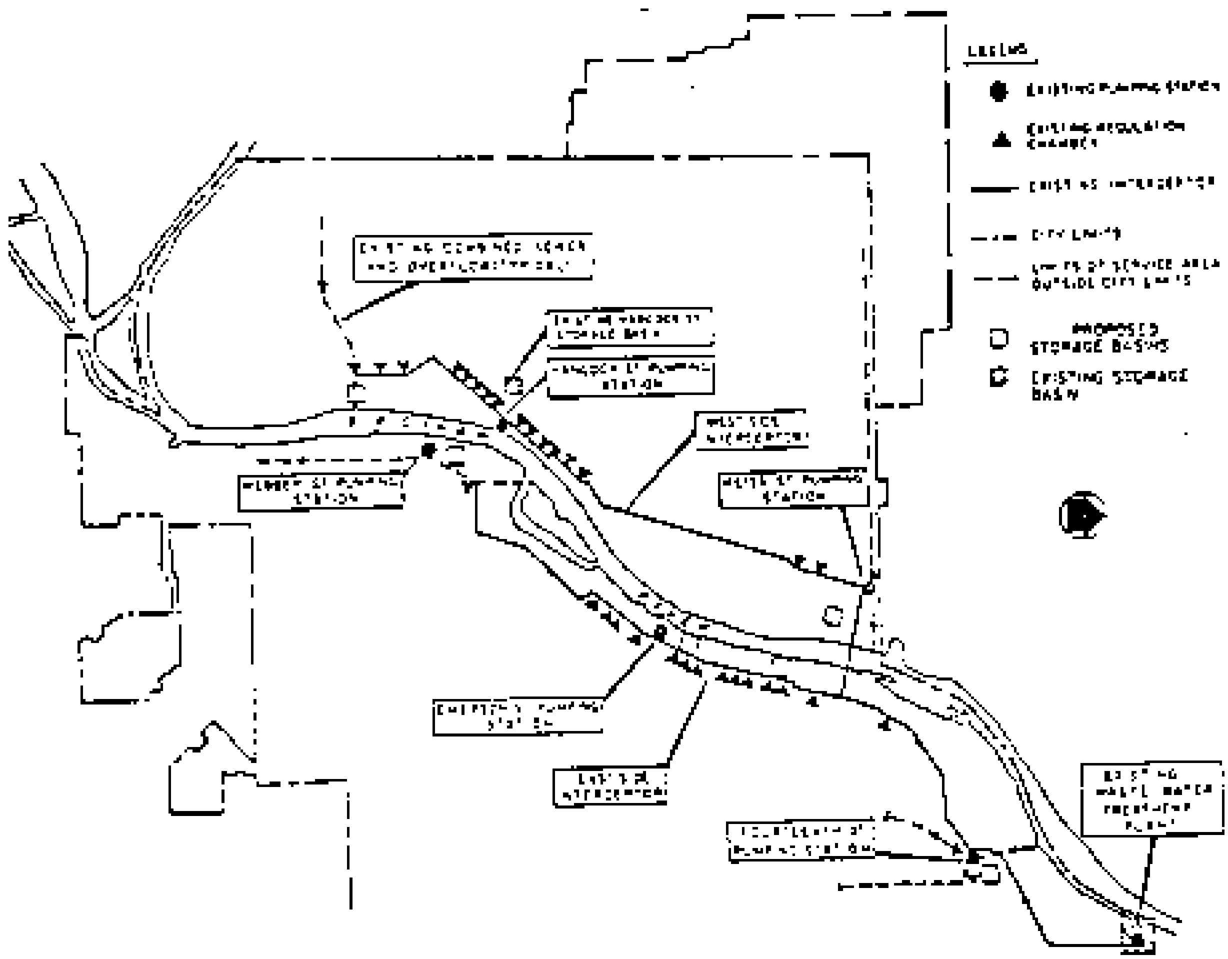


Figure IV-1. Combined sewer overflow storage and retention basins in the City of Saginaw (EDP, 1981).

Discharges of untreated sewage from combined sewer overflows, emergency bypass pumping, and plants which were out of service, flowed into Saginaw Bay tributary rivers including the Tittabawassee River below Midland, the Shiawassee River below Chesaning, the Cass River below Vassar, and the entire length of the Saginaw River. Impacts of the storms ranged from total plant site flooding and loss of treatment capability to flooding of pumping facilities and the bypassing of raw sewage.

A number of municipal WWTPs were affected by the flooding. The major public health concern was bacterial contamination of downstream waters. There was also concern for major plants discharging metals and/or organic compounds. However, information concerning the impact of the storms, the amount of time plants were not in service, and the materials and quantities discharged was limited or unavailable for many of those plants.

Information was not available for WWTPs in the cities of Flint, Howell, and Mt. Pleasant. The City of Alma WWTP was flooded and did not operate for an unspecified period of time. The plant was back in service by 8:00 p.m., September 16, 1986.

Although the Bay City WWTP remained operational during the flood period, raw sewage to storm sewers was bypassed at some locations on September 11, 1986. It is not clear how long this occurred.

The Saginaw WWTP never went out of operation during the flood period and all combined sewer overflows were running; however, two pump stations were flooded out for an unspecified period of time. The impacts due to the flooding were not available.

Although the Zilwaukee-Carrollton-Saginaw Twp. plant was not flooded, high flows into the plant required process modification to prevent bacterial washout. On September 24, 1986, the current status of the plant was reported as operational and meeting NPDES limits.

Remaining major WWTPs within the Saginaw Bay watershed were impacted by the September flooding, however, discharge of metals and/or organics were not quantified. The Bridgeport WWTP had increased flows through the plant, but effluent permit limits were never exceeded. Although the Frankenmuth and Buena Vista WWTPs were both operational throughout the flood period, two pump stations were flooded and some bypassing occurred at the Frankenmuth plant. There were two by-pass points during the flood at the Buena Vista plant. The West Bay County WWTP bypassed raw sewage to storm sewers at two locations on September 11, 1986. It is not clear from the report how long this occurred.

The Midland wastewater treatment plant bypassed raw sewage to storm sewers at up to eight different locations on September 11, 1986. Five CSOs were discharging flows of 8 MGD through the plant and 9 MGD through the retention basin (primary treatment). Wastewater did not undergo chlorination or phosphorus removal for a 24-hour period on September 12 and 13, 1986.

The Saginaw Township WWTP went out of service on September 13, 1986, at 3:30 am. At this time, the plant was completely flooded with river water and sewage. Thomas Township, which discharges to the Saginaw Township WWTP, bypassed raw sewage from September 13 to September 18, 1986. As of September 24, the Saginaw Township plant was still only partially operational with flows receiving settling and chlorination.

Information was not available for the remaining major WWTPs within the Saginaw Bay watershed.

ii. Industrial Point Source Overflows

Major industrial dischargers in the Saginaw Bay watershed were also impacted to varying degrees during the September flooding. Information was available for Dow Chemical Company, Total Petroleum, the GMC-CPC plant in Bay City, Consumers Power, and Monitor Sugar Company. Both GMC-CPC and Monitor Sugar were not affected by the storms since flooding did not occur at either plant. Although information is limited, some flooding occurred at Total Petroleum. The company, which reports discharging metals and organics, was forced to conduct an emergency discharge from a holding pond and their API separator and lagoons were not operational for an unknown period of time. Monitor Sugar had to drain floodwaters into Columbia Drain.

At the Dow Chemical Company in Midland approximately 220 million gallons of runoff resulted within a 2½ day period when eight inches of rain fell on 1000 acres of the 1500 acre complex. The rain entered the storm sewer collection system and flowed to the wastewater treatment plant. Flows in excess of what the WWTP could treat were pumped to the diversion basin ("shot pond") for storage and eventual treatment. Plant pumping capacities were eventually exceeded and the plant flooded. As a result, approximately 100 million gallons of essentially untreated wastewaters were discharged to the Tittabawassee River over a period of two and one half days. In addition, three open influent sewers that transport manufacturing waste to Dow's wastewater treatment plant filled with rainwater and overflowed into the surrounding area. The rainwater and untreated wastewater accumulated and eventually overflowed the dikes separating the plant and the river. The sewers are located in the area of the plant where manufacturing and production occur, which is on the north side of the Tittabawassee River. Stormwater also flowed into the brine pond and resulted in erosion of the dike between the pond and the river.

During September 12 and 13, 1986, discharges from Dow contained concentrations of phenol, pentachlorophenol, and 2,4,6-trichlorophenol that exceeded daily maximum loads by up to 210, 69 and 199 percent, respectively, at some time during the 2-day period. The discharge of 2,3,7,8-TCDD from Dow was diluted by the floodwaters resulting in an instream concentration of one-third of normal conditions.

The long-term impacts of the floodwaters have not been fully assessed. However, MDNR evaluations concluded that there were not any significant public health or environmental hazards created by the flood. The flood was of short duration and did not result in any acute toxicity to aquatic life or humans. The long-term effects on contaminant concentrations in in-place sediments needs to be determined.

B. NONPOINT SOURCES

1. Agriculture

a. Soils

Sediments deposited in rivers and the bay can cover fish eggs, degrade the spawning grounds of fish, fill in shipping channels, increase the frequency and magnitude of flooding, and lead to increased treatment costs for drinking water. Soils play a major role in the transport of nutrients and toxic materials to waterways. Contaminants can be adsorbed onto soil particles, particularly onto the finer silts and clays, and carried to rivers and lakes (Baker, 1985; Yocum et al., 1987). The extent to which different nutrients and toxicants are transported by soils varies, but can be substantial. For example, most agriculturally derived phosphorus reaching Lake Erie is adsorbed onto soil particles (Baker, 1985).

Estimates of total sediment loads to Saginaw Bay and its tributaries are limited. From 1973 to 1975, annual suspended solid loads to inner Saginaw Bay were approximately 415,000 metric tons (Canale et al., 1976). In 1980, the suspended solid loads to the inner bay were approximately 252,000 metric tons, with agricultural nonpoint sources contributing approximately 88% of the load (LTI, 1983). The portion of the bay receiving loads from the Saginaw River had the greatest agricultural nonpoint suspended solid load in Saginaw Bay in 1980 (124.9 metric tons) while the northern portion of the outer bay had the smallest load with (9.6 metric tons; Figure IV-2). Sediment loads by tributary in the Saginaw Bay drainage basin have not been calculated.

Wind and water erosion of agricultural land is the major source of sediment in the Saginaw River and Saginaw Bay (LTI, 1983). Erosion rates are influenced by a variety of factors such as soil type, land use, management techniques, and climate. Agricultural lands generally have higher erosion rates than pasture or forest lands and subsequently deliver a greater amount of eroded material to Saginaw Bay.

More than 8,700,000 metric tons of soil are eroded annually from agricultural lands in the Saginaw Bay drainage basin, according to county figures in the 1982 National Resources Inventory (NRI; Table IV-13). Water-induced sheet and rill erosion account for an estimated 3,200,000 metric tons (37%) of the annual erosion, while more than 5,400,000 metric tons (63%) of eroded soil are the result of wind erosion. Wind erosion causes more than 70% of the total erosion in Arenac, Gratiot, Huron, Isabella, Midland and Saginaw counties.

Recent efforts have been made to identify areas susceptible to erosion in the Saginaw Bay basin. Priority rankings were based on the percentage of the basin area covered by cropland on high clay, low infiltration rate, soils (Yocum et al, 1987). A substantial amount of this type of cropland exists within the Saginaw Bay drainage basin (Figure IV-3).

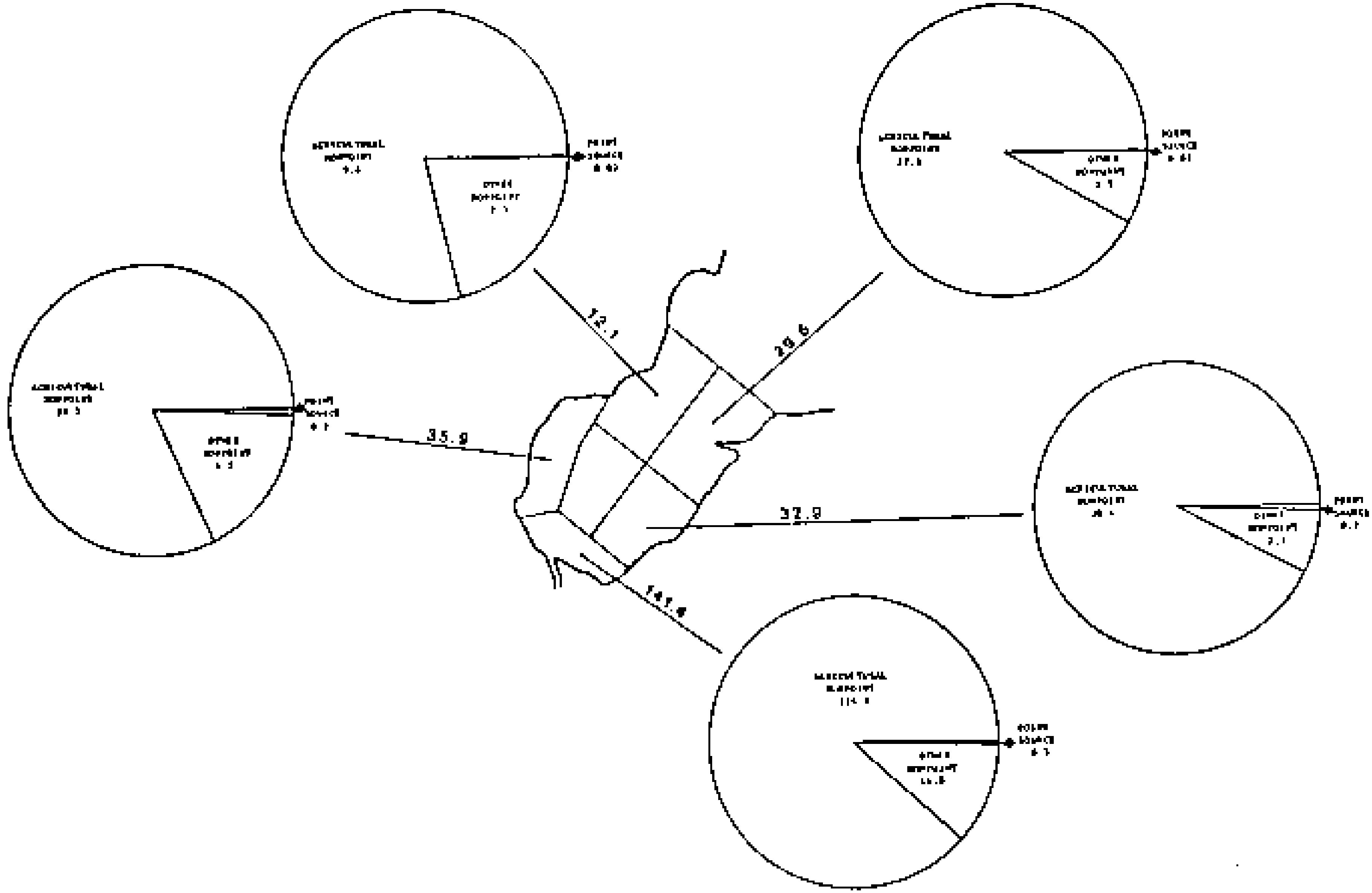


Figure IV-2. Distribution of annual suspended solid loads (1000 metric tons) to inner Saginaw Bay in 1980 (LTI, 1983).

Table IV-13. Average Erosion Rates (metric tons/acre) and Estimated Annual Sheet, Rill and Wind Erosion (metric tons/year) on Cropland for Selected Counties in the Saginaw Bay Drainage Basin in 1982 (USDA-SCS et al., 1987)

County	Average Rate of Erosion	Wind Erosion	Sheet & Rill Erosion	Total Erosion
Arenac	4.3	230,900	68,700	299,600
Bay	3.6	437,300	208,700	646,000
Clare	3.7	46,700	88,800	135,500
Genesee	2.0	108,800	229,500	338,300
Gladwin	3.4	69,300	56,100	125,400
Gratiot	3.1	573,500	236,400	809,900
Huron	3.0	944,900	312,600	1,257,500
Isabella	4.6	537,300	194,200	731,500
Lapeer	3.1	194,600	316,900	511,500
Livingston	2.6	51,600	251,100	302,700
Midland	2.9	179,000	62,400	241,400
Saginaw	4.5	1,003,900	437,100	1,441,000
Sanilac	1.6	415,700	237,300	653,000
Shiawassee	1.8	177,800	291,800	369,600
Tuscola	4.6	522,300	333,900	856,200
Total for Saginaw Bay Drainage Basin		5,493,600	3,325,500	8,719,100

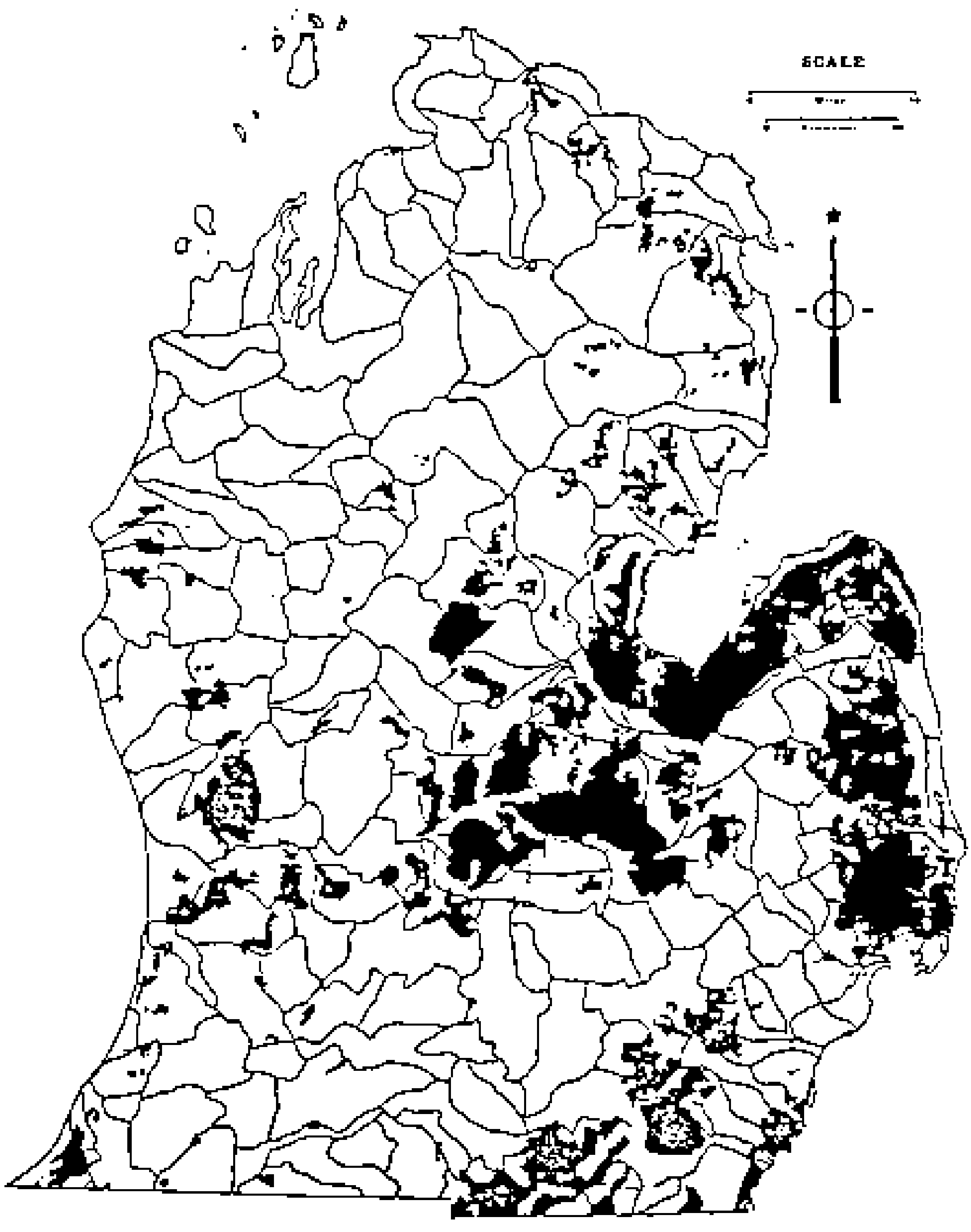


Figure IV-3. Cropland on high clay, low infiltration rate, soils in the Saginaw Bay drainage basin (Yocum et al., 1987).

A variety of soil management techniques can be used to reduce soil erosion from croplands. One of these, conservation tillage, involves leaving a large portion of the crop residue on the field surface than is the case with conventional moldboard plowing, which completely turns over the soil. Edge-of-field sediment losses were studied by Gold and Loudon (1986) at two side-by-side plots with different soil tillage practices in Tuscola County from 1981 to 1983. Soil losses were greater from the conventional tilled plot than from conservation tillage, with the conventional tillage field losing an average of 928-1003 kg suspended solids/ha while the conservation tillage field lost an average of 389 kg/ha.

Subsurface drainage tiles are used extensively in some areas of Saginaw Bay drainage basin with heavy soils. Generally, water discharged from a subsurface drainage tile carries less suspended sediments than surface water runoff (Baker and Johnson, 1977). In the side-by-side plots studied in Tuscola County, suspended solids were greater in the overland flow than in the tile drainage flow, with mean concentrations of 443 mg/l versus 69 mg/l on the conventional field, and 176 mg/l versus 63 mg/l on the field with conservation tillage.

h. Nutrients

i. Source Areas

There are many different nonpoint sources of phosphorus in the Saginaw Bay watershed including fertilizers, animal wastes, and septic tanks. Total phosphorus loads to Saginaw Bay averaged 1700 metric tons/year from 1973 through 1975, with nonpoint source accounting for nearly 60% of the total phosphorus load (Canale et al., 1976; Bierman and Dolan, 1980). Agricultural nonpoint sources contributed an estimated 59% of the 698 metric tons of total phosphorus loads to the inner Saginaw Bay in 1980 (LTI, 1983). Other nonpoint sources accounted for 18%, point sources contributed 20%, and atmospheric deposition generated 3%. The portion of the bay receiving water from the Saginaw River and its tributaries had the greatest nonpoint phosphorus load in 1980 totaling 724.4 metric tons of which 432.1 metric tons came from agricultural sources. Agricultural inputs of phosphorus were greatest in the southern and eastern portion of the bay (Figure IV-4).

The Great Lakes Phosphorus Task Force estimated the nonpoint source contribution of phosphorus to Saginaw Bay by major tributaries based on 1982 data. The Saginaw River, which accounts for approximately 75 to 85% of the total tributary flow to the bay contributed only half the total nonpoint phosphorus load to the bay, or 162.2 metric tons/year (Great Lakes Phosphorus Task Force, 1986). This estimate of the Saginaw River percent contribution to the total nonpoint phosphorus load was much smaller than previous data had indicated. The remainder of the nonpoint phosphorus load to Saginaw Bay was contributed by the Rifle-AuGres rivers area (72.9 metric tons), Kawkawlin River area (26.6 metric tons), and the thumb area complex (86.2 metric tons).

All river basins in the Saginaw Bay watershed have been evaluated for designation as nutrient critical areas (Yocum et al., 1987). An area

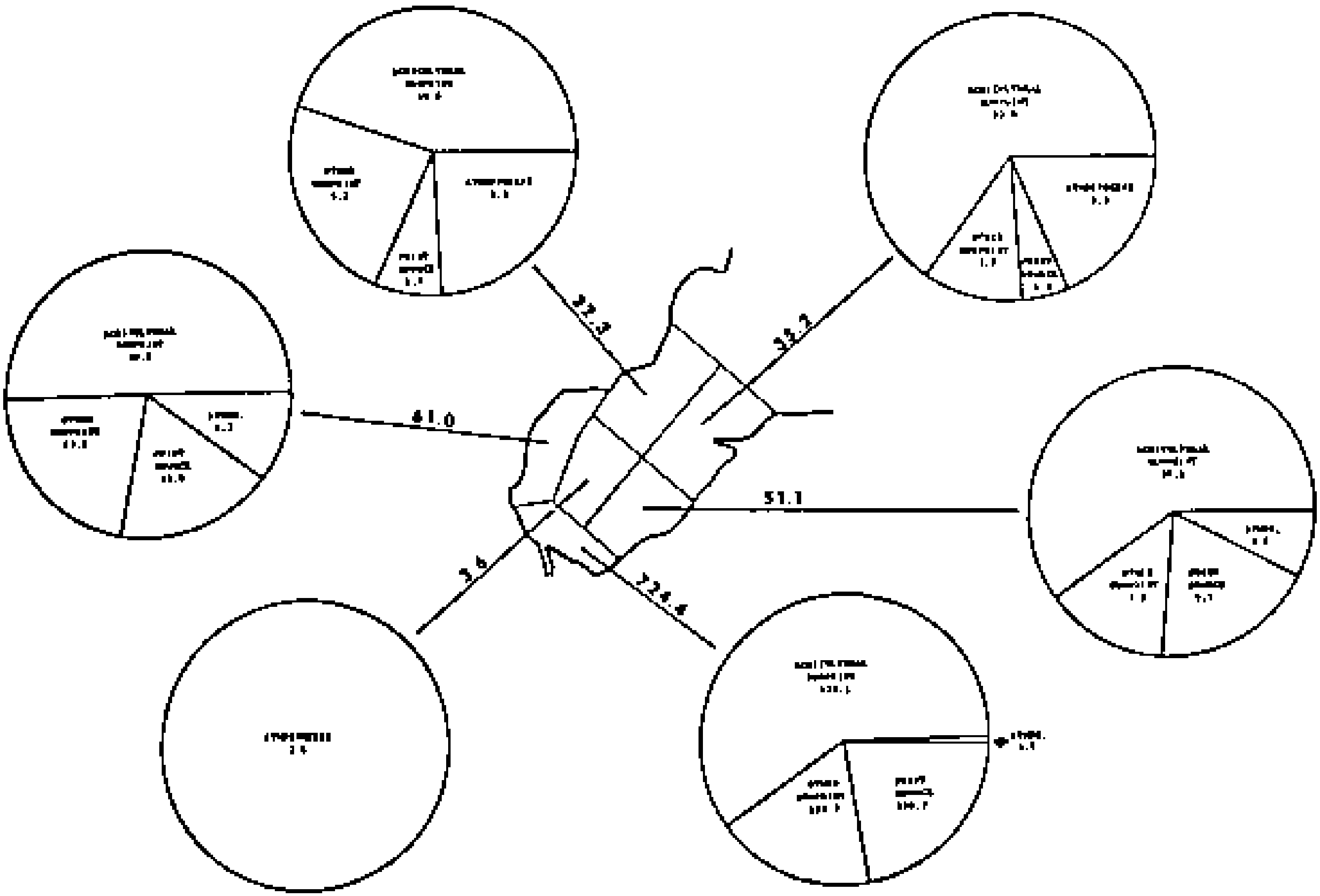


Figure IV-4. Source distribution of annual total phosphorus loads (metric tons) to inner Saginaw Bay in 1980 (LTI, 1983).

must meet one of the following criteria for selection as a critical basin: cropland with more than 13% clay in the surface layer; cropland with low infiltration rates; or inclusion in the river basin of counties ranked among the top 30 in Michigan for animal weight, unsewered residences or fertilizer sales per acre (Yocum et al., 1987). The entire Saginaw Bay drainage basin qualifies as a nutrient critical area.

ii. Fertilizers

Phosphorus and nitrogen fertilizers have been used to increase overall soil fertility and productivity over the past several decades, and have become an integral part of agriculture. Fertilizer sales in Michigan increased from over $131 million in 1974 to $242 million by 1982 (Bureau of Census, 1982). Not all of the fertilizer applied is utilized by the crops. Many agricultural soils have high residual phosphorus test values and are reaching saturation points, indicating that this increased application may not be necessary (MDNR, 1985; Yocum et al., 1987). The average of median phosphorus soil test levels for the counties in the Saginaw Bay drainage basin steadily increased from 25.8 kg/ha (23 lbs P/acre) in 1962 to 114.3 kg/ha (102 lbs P/acre) in 1984 and decreased to 101 kg/ha (90 lbs P/acre) in 1985 and 1986 (Table IV-14).

The Michigan Department of Agriculture (MDA) has estimated that the average phosphorus application in the Saginaw Bay watershed is more than twice what is needed for crops, with applications of 21,015 metric tons (23,116 tons) versus crop phosphorus needs of 9,214 metric tons (10,135 tons). Excess fertilizer is subject to surface water runoff or can percolate into groundwater. Ultimately, the fertilizer can be transported to the Saginaw River and/or Saginaw Bay, and contribute to eutrophication problems.

Fertilizer nutrient priority river basins have been identified in the coastal and Cass River watersheds of the Saginaw Bay drainage basin (Yocum et al., 1987). The priority basins are defined as those that are partially or totally included in a county ranked among the top five Michigan counties for fertilizer sales per cropland acre, and contain cropland on either low infiltration rate or high clay soils (Yocum et al., 1987). Bay, Huron, Saginaw and Tuscola counties are considered priority management counties and will receive greater consideration in the development of accelerated fertilizer and residue management programs (MDNR, 1985).

Nonpoint phosphorus loads to Saginaw Bay are influenced by many of the same factors that affect sediment delivery rates since much of the phosphorus moved off-site is bound to soil particles. Some of the factors that affect soil transport are soil type, water infiltration rates, vegetative cover, and management techniques such as conservation tillage and subsurface drainage tiles. Discharge from subsurface drainage tiles generally contains lower concentrations of total and soluble phosphorus than surface water runoff (Loudon et al., 1986). Conservation tillage has been found to reduce edge-of-field losses of total phosphorus, but has not proved as effective for reducing losses of soluble phosphorus. A study done in Tuscola County compared phosphorus losses from side-by-side conservation and conventional tilled fields.

Table IV-14. Median Phosphorus Soil Test Levels (pounds per acre) for Counties in the Saginaw Bay drainage basin, 1972-1986 (MDNR, 1985; Warncke, 1987).

County	Year								
	1962	1967	1972	1976-1977	1979-1980	1982-1983	1984	1985	1986
Arenac	19	21	46	88	130	102	119	108	90
Bay	27	51	74	88	130	147	194	182	222
Clare	--	--	--	41	66	76	66	61	60
Genesee	17	27	33	54	107	98	98	80	62
Gladwin	17	18	17	41	45	61	40	67	67
Gratiot	19	31	52	66	98	107	124	131	100
Huron	28	25	23	17	68	104	95	109	90
Iosco	--	31	27	38	77	67	85	57	78
Isabella	18	32	48	62	126	106	109	94	92
Lapeer	22	19	35	38	60	62	80	68	72
Livingston	44	32	36	62	98	96	98	114	80
Midland	26	30	45	51	111	128	165	130	99
Ogemaw	--	83	27	45	66	74	56	49	60
Shiawassee	16	25	36	41	82	97	90	100	63
Tuscola	18	29	38	56	82	93	112	97	117
Average	23	32	38	53	90	95	102	96	90

Reductions in both the total and soluble phosphorus edge-of-field losses were seen on the conservation tillage fields (Gold and Loudon, 1986).

iii. Animal Wastes

Animal wastes are a significant source of phosphorus to Saginaw Bay (MDNR, 1985). More than 1.7 million metric tons of animal waste is produced annually in the Saginaw Bay basin with almost a million metric tons potentially available to area waters (MDNR, 1985). In 1984 there were over 276,600 animals - including milk and beef cows, sheep and lamb, hogs and pigs - within the watershed (Cooperative Extension Service, 1984). Waste generated from livestock feeding and loafing delivers the highest percentage to watercourses followed by manure spreading and manure storage (Table IV-15). About 61 metric tons of phosphorus from animal waste is delivered to Saginaw Bay (MDNR, 1985). Several of the eastern coastal watersheds of Saginaw Bay are among the priority animal waste nutrient river basins (Yocum et al., 1987).

c. Organics/Pesticides

Pesticide is a general term used for a variety of chemical products, including herbicides, insecticides and fungicides. The current generation of pesticides has short persistence and little tendency for bioaccumulation relative to the chlorinated hydrocarbons of the past, many of which have been greatly restricted or banned (Baker, 1985). However, some of the less persistent chemicals developed to replace the chlorinated hydrocarbons can be more acutely toxic (Yocum et al., 1987). Safe drinking water standards have not been set for many of the currently used pesticides and the level of health risk associated with long-term exposure to these compounds has not been assessed.

Limited monitoring of pesticide concentrations is done in the Saginaw Bay basin. Endrin, lindane, methoxychlor, toxaphene, 2,4-D and 2,4,5-TP are regulated under the Safe Drinking Water Act and must be monitored annually in municipal water supplies. There have been no reports of any pesticide standards being exceeded in the Saginaw Bay region. The pesticides regulated under the Safe Drinking Water Act make up a small proportion of the current pesticide usage, however, and conventional water treatment removes only a small portion of the soluble pesticides from water (Baker, 1985).

Estimates of pesticide loads to the Saginaw River or Saginaw Bay are not available. No edge-of-field studies or modeling of pesticides has been done in the region. The potential magnitude of pesticide loads to Saginaw Bay can only be addressed indirectly, based on the amount of pesticides used in the watershed and delivery rates to waterways studied in other areas.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) classifies pesticides as restricted-use pesticide or general-use pesticides. Pesticides that could cause environmental damage, even when used as directed, are classified as restricted-use pesticides. Michigan's Pesticide Control Act (P.A. 171 of 1976) requires licenses for users of the restricted-use pesticides, and provides information on the

Table IV-15. Amount of Animal Waste Predicted to be Delivered to the the Saginaw Bay Watershed (MDNR, 1985).

Source	Amount of Waste (metric tons)	Delivery Percent to Water Course	Animal Waste Delivered to Water Course (metric tons)
Feeding/Loafing	33,315	40%	13,326
Spreading			
Winter	359,780	35%	125,924
Summer	239,855	10%	23,985
Manure Storage	33,325	35%	11,630
TOTAL	666,275	26%	174,865

sales of restricted-use pesticides in the region. About 400,000 pounds of restricted-use pesticides (manufacturer's finished product) were sold in the counties in the Saginaw Bay drainage basin in 1986 (MDA, 1987).

Only 1% to 2% of applied herbicides move off the fields in surface runoff under typical conditions. Under catastrophic conditions, where pesticide applications are closely followed by heavy rains, as much as 10% of the herbicides can be lost (Baker, 1985). The USEPA reported in 1984 that various studies have shown that less than 5% of the total amount of pesticides applied is lost through transport in surface runoff (Yocum et al., 1987).

2. Urban Runoff

Many pollutants can enter aquatic systems via urban runoff including nutrients, metals, organic comounds and road deicing materials. No data on pollutant loads from urban runoff specific to the Saginaw River/Bay watershed were available.

3. Specific Land Sites

a. Hazardous Waste Sites

Land waste disposal sites are regulated under the federal Resource Conservation and Recovery Act of 1976 (RCRA) and the state Hazardous Waste Management Act (PA 64 of 1979). The Michigan Environmental Response Act (MERA), Public Act 307, provides guidelines for the identification, risk assessment and ranking of contaminated sites in the state.

Two priority lists of contamination sites were compiled by the MDNR under Act 307 for 1988 to be used as a basis for recommendations to the Michigan legislature for funding site evaluation, interim response and final response activities (MDNR, 1988). Sites in Priority List One are ranked in order of relative risk to human health and the environment and require evaluation and interim response activities. Evaluation may include hydrogeologic studies, drinking water sampling, or air monitoring. Interim response often includes control of leaking or exposed wastes, removal or fencing of hazardous material, or provision of alternate drinking water supplies. List One sites are also broken down into two groups. Group One sites have been scored on a scale of 0-2000 by the Michigan Site Assessment System and have received a score of nine or more. Group Two sites have been screened but have not been scored by the detailed model. The screening process provides a score from one to fifteen and sites scoring nine or higher are subjected to the full risk assessment modeling process. Priority List Two identifies and ranks sites where the state will undertake response activities, which are the final remedies chosen to address the site problems.

There are current 178 Priority List One sites in the Saginaw Bay watershed (MDNR 1988). Eleven Group One sites and 36 Group Two sites which affect surface waters, and of these, six Group One and fourteen

Group Two sites also affect groundwater in the watershed (Appendix 6). In addition, 40 Group One and 91 Group Two sites in the watershed affect groundwater quality (Appendix 7). Also, there are 14 Act 307 Group One sites and 82 Group Two sites in the watershed that affect other resources such as soil or air (Appendix 8). Five Priority List Two sites are found within the Saginaw Bay watershed (Appendix 9). Three of the sites are dumps in Oakland County and the other two are landfills in Lapeer and Bay counties.

There are 13 federal Superfund sites within the Saginaw Bay watershed (Appendix 10). Eight of the sites are Act 307 Priority List One, Group 1 sites, three are Priority List Two sites and the other two are not on the Act 307 list. Superfund sites are chosen using a numerical scoring system to determine which sites throughout the country pose the greatest environmental or public health threat. Sites that score higher than a given minimum score are placed on the National Priorities List and become eligible for federal funding to pay for site investigation and cleanup.

The Saginaw River and Saginaw Bay are listed as a Group One site on the Act 307 Priority List One. A few of the other sites also affect, or potentially affect, the Saginaw River/Bay AOC and are discussed in Section V.

b. Landfills

Solid waste is regulated under the state Solid Waste Management Act, the state Liquid Industrial Wastes Act, and the federal Resource Recovery Act. No comprehensive list of landfills has been compiled for the Saginaw Bay watershed. Information on risks to surface water systems from existing landfills has also not been compiled. However, landfills are identified as the point of release for 10 of the 65 Act 307 Group 1 sites and 32 of the 209 Group 2 sites in the Saginaw Bay watershed (Appendices 6-8). Also, two of five Act 307 List Two sites are landfills (Appendix 9).

The locations of many landfills, on both public and private land, have never been recorded. County solid waste management plans list licensed landfills and a limited number of unlicensed landfills. Counties list deficiencies of existing landfills, including lack of hydrogeologic studies (monitoring wells), burning and failure of Open Dump Inventory standards (ECMPDR, 1982).

c. Underground Storage Tanks

Underground storage tanks are regulated under the Federal Resource Conservation and Recovery Act of 1976, the Michigan Water Resources Commission Act 245, and the state Fire Marshal Act 207. Underground tanks are the point of release for 11 of the 65 Group 1 hazardous waste sites in the watershed and 38 of the 209 Group 2 sites (Appendices 6-8). The MDNR is currently in the process of registering known underground tanks, but information on numbers and conditions of tanks is not yet available. Comprehensive information on risks to Saginaw Bay is also not available.

The U.S. EPA has estimated that 25% of the underground gasoline storage tanks in the United States are leaking. Underground tanks can lead to contamination of soils and groundwater by means of leaks, piping failures, and poor filling practices (MDNR, 1981). Contamination of surface water is possible if an unconfined aquifer discharges to streams or lakes (MDNR, 1981). Additives to petroleum fuels in underground tanks may include anti-knock compounds (tetraethyllead), dyes, antioxidants (N,N'Disalicylidene-1,2,-Diaminopropopane), metal deactivators (alkyl and amine phosphates), antirust agents (glycols), detergents, diesel fuel ignition accelerators (organic peroxides), and biostats/biocides (benzene, toluene; MDNR, 1981).

d. Injection Wells

Federal regulatory control for underground injection, or deep well injection, is provided in the Safe Drinking Water Act and RCRA. Additional control is provided under the state Mineral Wells Act. Current information on well sites, status and potential risks to ground and surface water systems is not available.

Class I underground wells are used to inject hazardous wastes from industrial or municipal sources. A nationwide study of hazardous waste deep well injection wells was conducted in 1985 (EPA, 1985). The study identified fourteen active Class I hazardous waste wells in Michigan. Two of the fourteen Class I wells in Michigan are operated in Gratiot County (MDNR, 1986b). Total Petroleum Company injected 28.6 million gallons of waste in 1983 and 27.8 million gallons in 1984. Velsicol injected 3.5 million gallons of waste in 1983 and 1.8 million gallons in 1984 (MDNR, 1986b). Data were unavailable for additional years.

Class II wells are used for oil and brine disposal and it has been suggested that oil brines may contain low levels of benzene, toluene, phenol and polynuclear aromatic hydrocarbons (EPA, 1986). Based on a numerical ranking of the potential for groundwater contamination from Class II wells by the Department of Geology at Western Michigan University, several areas subject to relatively high risks are located within the Saginaw Bay watershed (Western Michigan University, 1981).

Dow Chemical's brine system occupies portions of Midland, Saginaw, and Bay County. The system includes 70 brine production wells, 35 brine injection wells, seven solution mining wells and approximately 150 miles of 25 to 30 year old pipeline (EPA, 1986). In addition to the low levels of benzene, toluene, phenol and polynuclear aromatic hydrocarbons that may be present in Dow's brine, the plant's spent brine may also contain trace levels of PCDDs and PCDFs. A consent order with MDNR required Dow to begin a phase shutdown of the Dow brine system on December 31, 1986 (EPA, 1986), and this shutdown has been completed.

e. Spills

Spills of hazardous materials and conventional wastes are a potential source of pollutants to surface waters in the Saginaw Bay watershed. The MDNR maintains a Pollution Emergency Alerting System (PEAS) to receive reports of spills, accidental discharges, dumpings and related problems. The PEAS, established in 1974, receives reports from private citizens, and from governmental agencies who respond to reported spills and other environmental incidents.

The MDNR reviewed all PEAS reports from January 1984 to October 1986 for the Saginaw Bay watershed to identify spills that reached surface waters. The PEAS records show that the highest number of incidents (101) in the watershed occurred in the Flint River drainage basin. Chevy Manufacturing of Flint had the most reported discharges with 20 incidences of oil and other substances being released into the Flint River. Buick Motor Division, Genesee Wastewater Treatment Plant, and Flint Buick-Oldsmobile-Cadillac each had eight spills reported to PEAS. General Motors-CPC had six reported oil discharges into the Flint River and Fisher Guide had four reported oil discharges. The Anthony Ragone Wastewater Treatment Plant, which serves Flint, had two reported sewage releases to the Flint River and four to Brent Run Creek.

Overall, 43% of the reported spills and discharges to the Saginaw River and its tributaries were oil and fuel oil discharges. A minimum of 11.9 m^3 of petroleum were discharged. Twenty percent of the reports pertained to sewage discharges, and seven percent related to chemicals, including ethylene glycol, sodium phosphate, and calcium oxide. The remaining 30% of reports were for a variety of other substances or fish kills.

The PEAS records indicate that Saginaw Bay and its coastal tributaries had pollution-related emergencies from a variety of sources including industries, municipalities and individuals. Twenty-three separate incidents of discharges to Saginaw Bay were reported. Thirty-seven percent of the incidents reported involved fuel oil or other petroleum products. None of these spills had reported volumes above 8.0 m^3. Although spills of materials likely to increase biochemical oxygen demand (e.g., discharges of sugar or dairy by-products) were reported almost as frequently (30%), these spills were a small source of pollutant loads to the bay. Isolated incidents, however, have had negative impacts -- particularly fish kills -- and cumulative effects are difficult to estimate. Reported fish kills accounted for seven of the 27 reports (25%) received by PEAS for Saginaw Bay and its lesser tributaries.

4. In-place Pollutants

Sediments in the Saginaw River/Bay watershed have been contaminated by municipal and industrial discharges and by runoff from nonpoint sources. Contaminants often adhere to or mix with sediment particles, especially fine-grained silts and clays, components that are very common in the Saginaw system. Polychlorinated biphenyls for example are hydrophobic with very low water solubility and tend to adsorb onto suspended particulates upon entry into the aquatic environment. The extent of association depends in large measure on the nature and composition of the particulate, notably the size and organic content (Rice, et al., 1980).

Once deposited, contaminants are usually not stationary, but move with the sediments. There are several mechanisms by which disturbance of sediments occurs: wave action caused by wind, river flow, disturbance by animals or propellers and dredging activities. A fraction of sorbed PCBs may be desorbed and released into water where they are maintained in a dynamic equilibrium system (Rice, et al., 1980).

The Saginaw River/Bay area is one of the many navigational channels and harbors in the Great Lakes that are routinely dredged in order to maintain adequate depths for ship traffic. The U.S. Army Corps of Engineers (ACOE) performed the operation until 1984, when a Congressional mandate opened the work to private contractors. Using current methods, large amounts of sediments are resuspended in the water column during both dredging and disposal of dredged material (Seelye et al., 1982). The Corps conducted a Dredged Material Research Program and concluded in most cases the water quality concerns related to short-term release of contaminants to disposal site waters are unfounded (IJC, 1982). Dredging activities, however, frequently take place in harbors and river mouths that are important rearing grounds for fish. Since sediments in these areas are often contaminated with toxic substances, persistent chemicals can be accumulated by fish directly from resuspended sediments (Seelye, et al., 1982).

The Saginaw navigation channel ranked fourth of 97 Great Lakes locations for total quantities of sediment dredged from 1975-1979. Over one million cubic meters place material (CMPM) (i.e., in place in the channel) were removed during this five-year period as a result of seven separate projects. This figure was five times higher than the next largest quantity in the Lake Huron basin (Goderich, Ontario), and was two-thirds of the total amount dredged for the five-year period from the Lake Huron basin. The largest quantity was dredged in 1978, when over 600,000 CMPM were removed. During 1980-1986, approximately 3.6 million CMPM were removed (Table IV-36).

The type of vessel used to maintain the Saginaw navigation channel from 1975-1979 was an ACOE hopper dredge. The vessel's trailing arm drags along the bed of the area to be dredged and vacuums the material into hoppers located in the hull. Pumping normally continues until a substantial load has been accumulated in the hoppers. Excess water, which contains a proportion of the finer constituents, is returned to the waterbody (IJC, 1982). Hopper dredges have a single discharge point by which to expel the liquid and suspended matter that are not slated for disposal. This method returns suspended matter to the water column less conspicuously than the method used during 1984-1986, in which water and suspended materials spill over the side of the boat. There are no studies that compare the rates of sediment resuspension resulting from the use of various dredging methods for the Saginaw area. Since much of the dredging activity in the Saginaw navigation channel occurs in areas of moderate to high sediment contamination, sediment resuspension is a water quality concern.

Dredge spoils from the Saginaw navigation channel were disposed of in open lake waters in 1975 (IJC, 1982). No data prior to 1975 were acquired, but some spoils during that period were disposed of at

Table IV-16. Quantity of Material Dredged from the Saginaw Navigation Channel, 1979-1986 (USACOE, 1987).

Fiscal Year	Cubic Yards	Disposal Area	Contractor or Government
1979	237,464	Bay CDF	Govt/Markham
1979	102,392	Bay CDF	Govt/Hains
1979	41,251	Middleground	Govt/Hains
1979	12,538	Middleground	Govt/Lyman
1980	698,350	Bay CDF	Govt/Markham
1980	19,895	Middleground	Govt/Lyman
1980	13,391	Bay CDF	Govt/Hains
1980	159,730	Middleground	Govt/Hains
1981	425,410	Bay CDF	Govt/Markham
1981	21,555	Bay CDF	Govt/Lyman
1981	57,432	Middleground	Govt/Lyman
1981	19,393	Bay CDF	Govt/Hoffman
1981	36,711	Middleground	Govt/Hoffman
1981	68,554	Bay CDF	Govt/Hains
1981	48,229	Middleground	Govt/Hains
1982	565,828	Bay CDF	Govt/Markham
1982	60,835	Middleground	Cont/Leudtke
1982	16,181	Bay CDF	Govt/Markham
1983	85,931	Middleground	Govt/Hains
1983	823,819	Bay CDF	Govt/Markham
1984	745,277	Bay CDF	Cont/Natco
1984	153,471	Middleground	Cont/Natco
1985	365,275	Bay CDF	Cont/Natco
1986	344,000	Bay CDF	Cont/Natco

Middleground Island in the Saginaw River at Bay City. In 1977, the Saginaw Bay Confined Disposal Facility (CDF) became available to receive spoils from the most contaminated reaches of the river (downstream of the Detroit and Mackinac Railway Bridge at River Mile 3. Spoils disposed of in the Saginaw Bay CDF exceeded U.S. EPA classification for highly polluted sediments of Great Lake Harbors for a number of parameters, including metals and conventional pollutants (Section III).

By 1986, the Saginaw Bay CDF had been filled to almost half of its capacity (IJC, 1986). The facility is scheduled to be filled to capacity in 1990 and there is at present no plan concerning future disposal of dredge spoils.

The only other location in the Saginaw Bay drainage basin that has been dredged recently by the Corps is the harbor at Sebewaing, which was dredged in 1977. The project included dredging 0.58 km of the river near its mouth at the bay and using the spoils for beach nourishment. Several metals (As, Cu, Ni, Pb) were found to be at moderately polluted concentrations (IJC, 1982).

Dredging has been performed as a remedial action on stretches of three rivers in the Saginaw Bay watershed. In 1972, Michigan Chemical Corporation dredged about 70,000 cubic yards of material from the St. Louis reservoir on the Pine River (Rice, et al., 1980). The dredging was done to remove magnesium oxide deposits that were filling up the reservoir. The spoils were placed in a lagoon on the plant site. Although dredging was conducted upstream of the major areas of PBB contamination, the material removed still contained substantial amounts of PBB (LTI, 1984). Leaching from the disposal lagoon was a source of PBB and possibly other contaminants to the reservoir (Rice, et al., 1980). Dredging also occurred when the state Highway Department rebuilt the Mill Street bridge over the reservoir in 1978, probably causing some sediment disturbance in the process.

The USACOE regular maintenance dredging of the Saginaw navigation channel is not designed to remove contaminated sediments. However, one operation conducted between 1976 and 1981, was done specifically to remove PCB-contaminated sediments in the navigation channel. The impact was said to be small, as the operation was limited and did not remove highly-contaminated sediments near Bay City (Rice et al., 1980).

The south branch of the Shiawassee River from the Cast Forge property outfall to 600 meters downstream of Bowen Road was dredged by A-1 Disposal of Plainwell, Michigan in 1983. Vacuum dredging was used for most of the disposal, but there was some backhoeing as well. The dredging operation removed approximately 1,150 kg of PCBs contained in 1,380 m^3 of river sediment and 3,400 m^3 of liquid waste that was generated from the vacuuming (Rice et al., 1984).

A water and caged clam bioaccumulation study, which was conducted for one year following the termination of the Shiawassee River dredging operation, showed that the PCBs released did not move very far downstream and produced only local increases in concentration (Rice et al., 1984). There was, however, a noticeable increase in availability of PCBs at all downstream locations and in the area of the dredging during and approximately six months after the operation. At Bowen Road, for example, the PCB level in fish increased from 64.5 mg/kg dry weight to 87.95 mg/kg dry weight after dredging (Table IV-17). The PCB concentrations in clams at site A/B (Cast Forge to Bowen Road) increased from 13.82 mg/kg dry weight to 18.30 mg/kg dry weight after dredging and there was a substantial increase in PCBs in the water during dredging at all stations downriver of the Cast Forge station.

There are two unique features of this particular dredging operation. First, the south branch of the Shiawassee River at the Cast Forge property is approximately 2 meters wide, making dredging operations substantially easier to conduct than on a larger waterbody. Second, the contamination was not well integrated into the river sediment and much of the PCB existed as oily deposits layered into various-sized lenses in the sandy bottom of the river. Organic silt often occurred along with the concentrated PCB deposits and the sediments were generally low in clay content. This tended to make the PCBs more available than would be the case in the sand-silt-clay type of sediment typically found in most rivers (Rice et al., 1984). Nevertheless, this study showed that dredging of organic compounds can have a direct effect on biota and water quality for some distance downstream of the operation.

5. Atmosphere

a. Organics

Available data suggest that atmospheric deposition may be sizable, and perhaps the major source of inorganic and organic pollutants to the Great Lakes (Eisenreich et al., 1981). The long hydraulic retention times of the Great Lakes, coupled with their large surface areas, increase the impact of atmospheric pollutant inputs and prolongs recovery periods.

Atmospheric deposition of trace organics into Lake Huron over the past 10-15 years have been averaged into a single rate for each compound (Table IV-18). Values for Lake Huron are second only to Lake Superior for all the organics reported. The highest loading rates of organics into Lake Huron occurred for alpha-BHC (11.6 tons/year), total PAH (118 tons/year), DBP (12 tons/year) and DEHP (12 tons/year). Atmospheric loading rates of organics to Lake Huron are at least two times greater than rates for Lakes Erie and Ontario (Eisenreich et al., 1981). High atmospheric loadings into Lake Huron may be indicative of high atmospheric loadings into Saginaw Bay.

b. PCBs

Estimates of bulk atmospheric loading of PCBs to Lake Huron vary from 2325 kg/yr (Murphy et al., 1982) to 7200 kg/yr (Eisenreich et al., 1981). The average atmospheric deposition rate of PCBs to Saginaw Bay has been estimated at 18 $g/km^2/yr$ (Murphy et al., 1981). The estimated average annual total atmospheric load of PCBs to the bay based on its surface area of 2959 km^2, is then 53.26 kg/yr.

Table IV-17. Total PCB Measured in Water, Clams and Fish Before, During and Six Months After Dredging the South Branch of the Shiawassee River (Rice et al., 1984).

River Mile	Site	Pre-Dredge		During Dredging		Post-Dredge	
Water (ug/l)							
0.0	Cast Forge	0.047	(3)	0.029	(5)	0.037	(5)
1.0	Bowen Road	1.10	(6)	4.67	(9)	1.11	(5)
3.5	Marr Road	0.68	(1)	2.83	(1)	-	
6.8	Chase Lake Road	0.65	(5)	1.03	(5)	0.522	(5)
Clams (ug/g dry wt.)							
0.0	Cast Forge	0.78	(1)	1.18	(5)	1.36	(4)
0.25	Site A/B	13.82	(2)	59.08	(4)	18.30	(3)
1.0	Bowen Road	40.02	(1)	69.34	(4)	6.49*	(1)
3.5	Marr Road	44.27	(1)	43.54	(4)	-	
6.8	Chase Lake Road	13.21	(1)	12.55	(3)	15.26	(2)
Fish (ug/l dry wt.)							
0.0	Cast Forge	1.78	(3)	-		1.62	(2)
1.0	Bowen Road	64.54	(3)	-		87.95	(3)
6.8	Chase Lake Road	32.09	(3)	-		61.14	(2)

*These cages were silted over, therefore this result is unusually low.

Table IV-16. Total Deposition of Airborne Trace Organics to Lake Huron in Metric Tons per Year (Eisenreich et al., 1981).

Compound	Mass
Total PCB	7.2
Total DDT	0.43
alpha-BHC	2.4
gamma-BHC	11.6
Dieldrin	0.55
HCB	1.2
p,p'-Methoxychlor	6.1
alpha-Endosulfan	5.8
beta-Endosulfan	5.8
Total PAH	118.0
Anthracene	3.5
Phenanthrene	3.5
Pyrene	6.3
Benz (a) anthracene	3.0
Perylene	3.4
Benzo (a) pyrene	5.8
DBP	12.0
DEHP	32.0
Total organic carbon	1.5×10^5

Atmospheric deposition of PCBs into Saginaw Bay has been measured in terms of wet precipitation, dry deposition and bulk deposition (Murphy et al, 1981; Kreis & Rice, 1985). Loading of PCBs through wet precipitation for all sample sites ranged from 0-68 g/km^2/yr between 1977-1978 (Table IV-19). Pinconning had the highest loading rate of 39.0 g/km^2/yr and ranged from 26-68 g/km^2/yr. Loading at Tawas Point increased from 14.50 g/km^2/yr in 1977-1978 to 16.80 g/km^2/yr in 1979 but then decreased by half to 8.40 g/km^2/yr in 1980.

Pinconning also had the highest dry deposition loading rate of PCBs between 1977-1980 of 27.0 g/km^2/yr for 1977-1978 (Table IV-19). The loading value for Pinconning in another estimate was only 6.6 g/km^2/yr for that same time period. The 1979 dry deposition rate of 16.2 g/km^2/yr for Pinconning was almost double a 1978 Pinconning estimate of 8.16 gm/km^2/yr. The lowest PCB deposition rate occurred at Whitestone Point in 1977 where only 3.24 g/km^2/yr were reported. Dry deposition at Sebewaing increased slightly from 5.76 g/km^2/yr in 1978 to 6.00 g/km^2/yr in 1979.

Bulk atmospheric loading of PCBs during 1977-1978 was highest at Pinconning where 21 g/km^2/yr were reported. The lowest bulk deposition rate for 1977-1978 was 9 g/km^2/yr at Tawas Point (Table IV-19). Rates reported for the individual years from 1977-1980 fluctuated for each sample site. Bulk deposition decreased at Pinconning from 29.64 g/km^2/yr in 1977 to 19.92 g/km^2/yr in 1978 then increased to 30.24 g/km^2/yr by 1979. Tawas Point showed a similar trend, with a rate of 3.60 g/km^2/yr for 1978 and 1980, but a much higher value of 10.20 g/km^2/yr in 1979.

Inner Saginaw Bay is usually frozen for 8-12 weeks in the winter during which time the ice cover accumulates precipitation, dry deposition, and vapor along with the materials they contain. Materials such as PCBs are then deposited into the lake in the spring as the ice melts (Murphy and Schinsky, 1983). Measurements of the net atmospheric deposition of PCBs were made using ice cores collected from the surface of Saginaw Bay during the winter of 1978 and 1979 (Figure IV-5). The net deposition included wet, dry and vapor deposition, less any evaporation. The PCB deposition rate in the ice core samples decreased from 2.3 gm/km^2/mo (36 gm/km^2/yr) in January 1978 to 1.8 gm/km^2/mo (22 gm/km^2/yr) in February 1978 (Table IV-20). The February 1979 deposition rate of 1.7 gm/km^2/mo (25 gm/km^2/yr) was only slightly lower than the rate for February 1978. The volume weighted net flux of PCBs to the snow and ice surface was about 2.0 gm/km^2/mo (24 gm/km^2/yr). At this rate the total input to inner Saginaw Bay (1550 km^2) was 8 kg of PCBs in 1978 (83 total days of ice cover) and 6.5 kg in 1979 (64 total days of ice cover) when the ice melted (Murphy & Schinsky 1983).

Average PCB concentrations measured in precipitation in the City of Saginaw and Bay City during 1977-1982 was 21 ng/l (Murphy, 1979; LTI, 1983).

c. Nutrients

Atmospheric deposition accounted for an estimated 3% of the total phosphorus load to inner Saginaw Bay in 1980 (LTI, 1983). The relative

Table IV-19. Wet Precipitation, Dry Deposition and Bulk Atmospheric Loading of PCBs ($gm/km^2/yr$), Measured at Selected Sample Sites along the Saginaw Bay Shoreline (Murphy et al., 1981; Murphy et al., 1982).

Year/ Station	Wet Precipitation Avg[a]	Wet Precipitation Range[b]	Dry Deposition	Bulk Loading
1977-1978				
Whitestone Pt.	11.5	0-24		
Pinconning	39.0[b]	26-68	27.0[b] 6.6[a]	21
Tawas Point	14.5	6-24	16.0[b] 6.6[a]	9
Sebewaing			24.0[b] 6.2[a]	11
Saginaw Bay				12
1977[b]				
Whitestone Pt.			3.24	
Pinconning				29.64
1978[b]				
Pinconning			8.16	19.92
Tawas Point			10.2	3.6
Sebewaing			5.76	8.4
1979[b]				
Pinconning			16.2	30.24
Tawas Point	16.8			10.20
Sebewaing			6.0	12.00
1980[b]				
Tawas Point	6.4			3.60

[a]Murphy et al., 1981

[b]Murphy et al., 1982

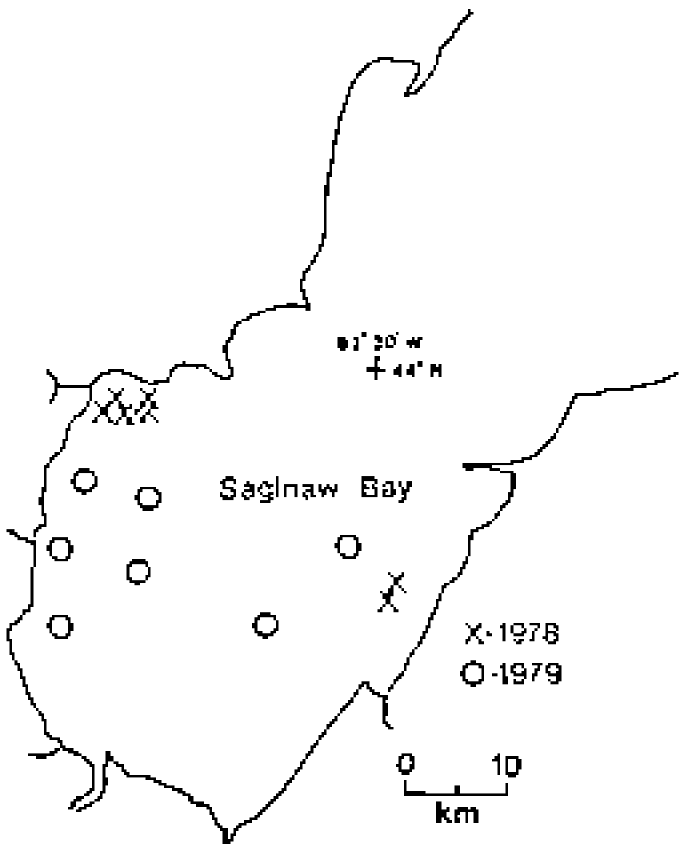


Figure IV-5. Location of ice core collection sites on Saginaw Bay, 1978-1979 (Murphy and Schinsky, 1983).

Table IV-20. PCB Accumulation on the Frozen Surface of Saginaw Bay, 1978-1979 (Murphy and Schinsky, 1983).

Category	January 1978	February 1978	February 1979
	Collection Times		
Number of Sites	3	4	5
Number of Cores	16	18	29
Total PCBs (ng)	110	318	306
Total Area of Cores (m^2)	0.073	0.091	0.132
Days of Ice Cover Before Sampling	19	61	43
Deposition Rate to Ice ($gm/km^2/mo$)	2.3±0.7	1.8±0.4	1.7±1.3

contributions of atmospheric deposition to the total phosphorus loads of different sections within the bay in 1980 ranged from 3.6 tons in the center of the inner bay to 6.5 tons in the northeastern portion (Figure IV-4).

Data on atmospheric deposition of total phosphorus and other nutrients were collected from 1982 to 1984 at Bay City, Port Austin and Tawas Point as part of the Great Lakes Atmospheric Deposition (GLAD) sampling network. Total phosphorus atmospheric deposition rates were highest at Tawas Point in 1982 (19.9 kg/km^2) and 1983 (20.6 kg/km^2) and at Port Austin in 1984 (13.0 kg/km^2; Table IV-21). Average annual atmospheric total phosphorus loads decreased from 37 tons in 1982 to 24 tons in 1984.

Nitrate levels were highest at Port Austin in 1982 (341 kg/km^2), at Tawas Point in 1983 (351 kg/km^2), and at Port Austin again in 1984 (488 kg/km^2; Table IV-21). The average annual atmospheric nitrate load to the bay increased from 925 tons in 1981 to 1170 tons in 1984.

Highest TKN concentrations were reported at Port Austin in 1982 (599 kg/km^2), at Tawas Point in 1983 (406 kg/km^2), and at Port Austin in 1984 (577 kg/km^2; Table IV-21). The average annual atmospheric loading of TKN decreased from 1336 tons 1982 to 987 tons in 1983, but then increased to 1387 tons in 1984.

The highest nitrate, TKN and total phosphorus loads in 1983 all occurred at Tawas Point. These three nutrients were all highest at Port Austin in 1984 (Table IV-21). Atmospheric loads of nitrate and TKN were highest in 1984, while total phosphorus loads were greatest in 1982.

d. Chloride

Data collected from the GLAD network during 1982-1984 showed that atmospheric deposition of chloride into Saginaw Bay was highest at Bay City in 1982 (327 kg/km^2), in 1983 (215 kg/km^2) and in 1984 (284 kg/km^2; Table IV-21). Average annual atmospheric loading of chloride into Saginaw Bay decreased from a high of 866 tons per year in 1982 to 555 tons per year in 1983. By 1984, the loading had increased to 621 tons.

e. Metals

Atmospheric deposition of heavy metals into Saginaw Bay during 1982-1984 was also analyzed through the GLAD sampling network. The highest mercury deposition rate of 146 $gm/km^2/yr$ was reported at Bay City in 1983 (Table IV-22). Average annual loading of Hg to the bay increased from 0.2 tons in 1982 to a high of 0.40 tons in 1983, followed by a decrease to 0.20 tons in 1984.

Deposition of cadmium was highest at Tawas Point where a rate of 1422 $gm/km^2/yr$ was reported in 1982 (Table IV-22). Average annual loading of Cd decreased from a high of 4.20 tons in 1982 to a low of 0.38 tons in 1984.

Table IV-21. Atmospheric Deposition Rates (kg/km^2/yr) of Nutrients and Chlorides at Bay City, Port Austin and Tawas Point Sample Stations, 1982-1984 (data from GLAD sampling network database).

Year/ Station	Parameter			
	Nitrate	TKN	Total Phosphorus	Chloride
1982				
Bay City	322	302	4.9	327
Port Austin	341	590	13.0	289
Tawas Point	275	454	19.9	262
Saginaw Bay Total (metric tons/yr)*	925	1336	37.0	866
1983				
Bay City	289	260	2.8	215
Port Austin	331	335	7.6	188
Tawas Point	351	406	20.6	160
Saginaw Bay Total (metric tons/yr)*	958	987	31.0	555
1984				
Bay City	358	356	3.5	284
Port Austin	488	577	13.0	177
Tawas Point	340	473	7.8	169
Saginaw Bay Total (metric tons/yr)*	1170	1387	24.0	621

*Station values summed, averaged, and multiplied by bay surface area

Table IV-22. Atmospheric Deposition rates (gm/km^2/yr) of Heavy Metals at Bay City, Port Austin and Tawas Point Sample Stations, 1982-1984 (data from GLAD sampling network database).

Year/ Station	Metal							
	Hg	Cd	Cu	Pb	Ni	As	Cr	Zn
1982								
Bay City	69		2982	31204	6241	172	5923	13279
Port Austin			4262	34290		191	5158	10634
Tawas Point		1422		1280	6096	251	9809	11199
Saginaw Bay Total (metric tons/year)*	0.2	4.2	10.7	65.9	18.3	0.6	20.6	34.63
1983								
Bay City	146	104		2872	347	248		5932
Port Austin	242	185	1273	3361	4046	224	6096	6926
Tawas Point	119	142	2987	3413	841	307	711	4991
Saginaw Bay Total (metric tons/year)*	0.4	0.42	6.3	9.5	5.2	0.8	10.1	17.6
1984								
Bay City	139	122	2420	2859	831	168	643	12792
Port Austin	8	150	3642	3286	609	219		20351
Tawas Point	71	112	3430	2339	498	316	711	18150
Saginaw Bay Total (metric tons/year)*	0.2	0.4	9.4	8.4	1.9	0.7	2.0	30.6

*Station values summed, averaged and multiplied by bay surface area.

Concentrations of copper were highest at Port Austin in 1982 (4262 gm/km^2/yr) and in 1984 (3642 gm/km^2/yr; Table IV-22). The corresponding average annual loads for Cu were 10.71 tons in 1982 and 9.36 tons in 1984.

Concentrations of lead decreased from the highest value of 34,290 gm/km^2/yr at Port Austin in 1982, to a 1984 value of 3286 gm/km^2/yr, also at Port Austin (Table IV-22). Average annual Pb loading decreased from 65.86 tons in 1982 to 8.37 tons in 1984.

Atmospheric deposition of nickel was highest at Bay City in 1982 (6241 gm/km^2/yr). Average annual loading of Ni decreased from the highest value of 18.25 tons in 1982 to 1.91 tons by 1984.

The highest arsenic deposition rate of 316 gm/km^2/yr was reported in 1984 at Tawas Point (Table IV-22). The average annual load of As decreased from 0.77 tons in 1983 to 0.70 tons in 1984.

The rate of chromium deposition decreased substantially between 1982 and 1984 (Table IV-22). The highest rate of 9809 gm/km^2/yr was reported at Tawas Point in 1982 while a much lower value of 711 gm/km^2/yr was reported for that station in 1984. The average annual Cr load decreased dramatically from 20.60 tons in 1982 to 2.00 tons in 1984.

The highest zinc deposition rate was 20,351 gm/km^2/yr and occurred in 1984 at Port Austin (Table IV-22). The total annual load of Zn decreased from 34.63 tons in 1982 to 17.60 tons in 1983 and then increased to the highest value of 50.59 tons in 1984.

Most of the total loads were lower, some substantially, in 1984 compared to 1982. Atmospheric loading of Zn into Saginaw Bay, however, was almost one and one half times larger in 1984. The greatest atmospheric deposition of Hg, Pb and Ni in 1984 occurred at Bay City. Deposition of Cd, Cu and Zn in 1984 were highest at Port Austin, and the greatest deposition of As and Cr in 1984 was reported at Tawas Point.

5. Acids

Acid precipitation has been known to kill fish eggs, salamander eggs, frog eggs, aquatic vegetation, and other aquatic life (USEPA, 1980). A pH value below 5 for a given waterbody increases its sensitivity to additional acidic input (DeGuire, 1986b) and a pH value below 5.6 is considered acidic (DeGuire, 1986a).

Saginaw Bay is among the waterbodies in the United States that receive the greatest amounts of acid rain and area precipitation has some of the lowest pH values (USEPA, 1980). However, the substantial buffering capacity of Saginaw Bay mitigates the effects of acid rain (DeGuire, 1986b). The lowest pH values for precipitation between 1981-1985 occurred at Tawas Point for each sample year except 1984, when a pH of 3.1 was reported at Port Austin (Table IV-23). This value was the lowest pH recorded overall for the five year sample period. High and low pH values at each site fluctuated during the sample period. Low pH

Table IV-23. Mean and Range of pH Values in Precipitation Samples at Bay City, Port Austin and Tawas Point, 1981-1985 (Deguire, 1986a).

	Bay City			Port Austin			Tawas Point			Summary		
Year	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
1981	4.4	4.0	5.4	4.4	3.9	6.7	4.1	3.7	4.7	4.3	3.7	6.7
1982	4.4	4.0	5.1	4.5	4.0	5.5	4.2	3.7	6.4	4.4	3.7	6.4
1983	4.3	4.0	5.1	4.2	3.7	5.7	4.1	3.7	4.5	4.2	3.7	5.7
1984	4.3	4.0	4.8	4.1	3.1	6.8	4.0	3.5	6.9	4.1	3.1	6.9
1985	4.5	4.1	7.0	4.2	3.8	7.6	3.9	3.5	4.6	4.1	3.5	7.6
Avg	4.4			4.3			4.1			4.2		

values at Port Austin and Tawas Point in 1985 were 0.1 and 0.2 units lower than their respective lowest 1981 values.

The lowest average pH value (calculated as average-log [H+]) of 3.9 was reported in 1985 at Tawas Point (Table IV-23). A higher average of 4.5 was also reported in 1985 at Bay City. Average pH values at each sampling site fluctuated between 1981 and 1985. Port Austin precipitation samples showed the greatest range of average pH values (4.1-4.5). Values at Port Austin and Tawas Point were both 0.2 units lower in 1985 than in 1981, while the value at Bay City was 0.3 units higher in 1985. The yearly average pH value increased from 4.3 in 1981 to 4.4 in 1982 and decreased to 4.1 in 1985.

SECTION V. HISTORICAL ACTIONS

A. INTRODUCTION

The impetus for the multitude of past remedial actions taken in the Saginaw Bay basin to improve water quality came from the enactment of a series of federal and state statutes (Figure V-1). The justification to implement and maintain the water quality programs authorized by these statutes was provided by numerous water quality and biological surveys. The surveys documented areas of severe water quality degradation in the 1960s and 1970s. Several comprehensive studies conducted in the early to middle 1970s focused on Saginaw Bay and the Saginaw River watershed, including its tributaries - the Cass, Shiawassee, Tittabawassee and Flint rivers. Later studies on these same areas documented water quality improvements from implemented state and federal programs and completed remedial actions.

1966 — State Municipal Grant Program enacted under Act 329 of Public Acts of 1966.

1970

1971 — PCB Source Control Program was instituted by the State of Michigan

1972 — Federal Clean Water Act passed: included NPDES permitting program and Municipal Grants Program

1973 — Michigan's Act 245 Water Quality Standards Part 4 Rules were promulgated

1974

1975

1976 — Federal Resource Conservation and Recovery Act (RCRA).

1977 — State ban on use of phosphate detergents.
Federal Clean Water Act Amendments enacted requiring EPA to develop nationwide Industrial Pretreatment Program.

1978 — Great Lakes Water Quality Agreement signed
MDNR begins complete chemical monitoring program on the Tittabawassee River watershed.

1979

1980 — National Water Quality Criteria for Toxic Pollutants published as guidance under Section 304(a) of the Clean Water Act (11-28-80)

1981 — Federal Municipal Wastewater Treatment Construction Grant Amendments of 1981.

1982 — Michigan's Environmental Response Act (1982 P.A. 307) enacted.

1983 — MDNR accepted delegated responsibility for the federal Industrial Pretreatment Program
EPA revised the Water Quality Standards regulations.
Great Lakes Phosphorus task force created through National Program Office, EPA

1984 — Federal Hazardous and Solid Waste Amendments (HSWA) enacted.

1985 — Michigan develops Phosphorus Reduction Strategy for the Michigan portion of Lake Erie and Saginaw Bay.

1986 — Rule 57(2) promulgated which sets forth an explicit process for limiting toxic substances in NPDES permits.
Federal Superfund Amendments and Reauthorization Act enacted.

1987 — Federal Water Quality Act of 1987 (CWA reauthorization)

Figure V-1. Enactment timeline of selected state and federal environmental protection acts and programs, 1966–1987.

B. HISTORICAL WATER QUALITY

1. Saginaw Bay

In the early 1970s Saginaw Bay was impacted by high concentrations of dissolved solids and nutrients. Nuisance growths of blue-green algae populations were extensive, contributing to taste and odor problems in municipal drinking water supplies drawn from the bay. The once common mayfly population had disappeared and the existing benthic fauna indicated stressed and pollution contaminated conditions. Commercial fishing had declined as lake trout, walleye, whitefish and lake herring became scarce. There was growing concern over thermal enrichment from power plants, municipal and industrial dischargers. At the time, limited information was available to document water quality trends or identify all sources of water quality impairment. Initial remedial strategies were designed to reduce nutrient loads, oxygen consuming substances and coliform bacteria. As toxic material regulations were strengthened and problems with conventional parameters improved, organic and heavy metal discharges were increasingly addressed.

2. Saginaw River

Saginaw River has been identified as the major contaminant source to Saginaw Bay. The five municipalities that discharged to the river did not begin to institute secondary treatment with phosphorus removal until 1972. Low dissolved oxygen levels and high BOD loads were major contributors to the Saginaw River's exceptionally poor water quality. Chloride levels were also found to be quite high and nutrient concentrations were elevated year round. High total fecal coliform concentrations were measured throughout most of the river and occurred throughout the year, even during times when contaminant wastewaters were chlorinated. Early surveys found high PCB levels in Saginaw River water, fish and sediments. Biological communities reflected these degraded conditions and were composed of pollution tolerant species, many at nuisance population levels.

3. Shiawassee River

In 1974, the entire lower half of the Shiawassee River suffered from excessive nutrient concentrations. Six reaches were identified in the lower river to have substandard water quality, three of which were from inadequately treated sewage. Other problems included dissolved oxygen depressions, high coliform densities, and high concentrations of total dissolved solids. High concentrations of PCBs in sediments downstream from the Cast Forge Company on the South Branch of the Shiawassee River were discovered in 1974. Subsequent surveys disclosed that the PCBs found in the sediments were mobile and appeared to have contaminated sediments at a distance of 22 kilometers downstream.

4. Tittabawassee River

The Tittabawassee River historically was degraded from Midland downstream to its mouth. A major problem was high concentrations of dissolved solids, especially chlorides. The Tittabawassee was described as the major chloride source to the Saginaw River and Saginaw Bay. Three reaches of the river were considered substandard by the Michigan Water Resources Commission in 1971. The cause was inadequate municipal sewage treatment that created high coliform and nutrient levels, and depressed dissolved oxygen. A 1972 MDNR study found that waste discharges to the Tittabawassee River from the Dow Chemical Company and the City of Midland had increased periphyton algae to nuisance levels, seriously altered the macroinvertebrate community for more than 26 kilometers and virtually eliminated downstream sport fish populations for approximately 35 kilometers. A scan for PCBs indicated a source of PCB contamination in the Midland area.

5. Cass River

The main problems identified in the Cass River were high nutrient concentrations, and high total and fecal coliforms, in the lower portion of the river. Dissolved oxygen levels were depressed and BOD levels were elevated downstream of the larger population centers. The primary nutrient load contributors during low flow periods were municipal wastewater treatment plants in Cass City, Caro, Vassar and Bridgeport. During the high flow period between November and May, the largest inputs of nutrients were attributed to nonpoint sources. Other contaminants found in 1974 included elevated levels of diethylhexyl phthalate (DEHP) and arsenic in water, and increased mercury levels in fish tissue.

6. Flint River

The Flint River makes up 25% of the Saginaw River flow, but accounted for over 40% of the annual phosphorus load in 1974. The worst water quality noted in the Saginaw River basin in 1974 by the U.S. EPA was below the Flint WWTP. The municipal treatment plant contributed to elevated levels of BOD, phenols, ammonia-nitrogen and phosphorus. The result was depressed dissolved oxygen concentrations, and excessive growths of algae and aquatic weeds.

C. POINT SOURCES

1. Municipal Facility Planning, Design and Construction

a. Program Description and Costs

The construction grants program was initiated with the promulgation of the federal Water Pollution Control Act of 1972 (Public Law 92-500). The act required that communities applying for federal funds follow a series of steps designed to insure that the best possible project resulted from the time, effort and money expended. After meeting applicant eligibility requirements, an applicant was funded through a series of three steps to final completion of the project. Step 1 funding was provided for the development of a facility plan where a consultant could be hired to evaluate the existing sewer system, study alternative treatment works, prepare an environmental assessment, and determine the most cost effective waste treatment management system that would meet water quality standards. Step 2 funding was disbursed to cover the costs of preparing the engineering designs and specifications for the alternative chosen. Step 3 funding was for construction costs. In some cases, Step 2 and Step 3 funds were combined in one allocation to the grant applicant and labeled Step 4 funding. Generally, federal funding was authorized for up to 75% of the project cost at each step level.

State funding for municipal grants was authorized under Public Act 329 of 1966. Up to 5% of the project cost was authorized for state funding at each step level.

The state reviewed the eligibility of each applicant and prioritized the funding allocations for each fiscal year. A scoring system was used to prioritize how federal and state funds would be distributed. Several municipalities have applied for, but not received funding for various step projects because they scored too low relative to the other applicants (Table V-1).

Total project costs in the Saginaw Bay basin for all step levels implemented during 1972-1988 amounted to over $500 million. State and federal grants covered almost $400 million of total project costs (Table V-2, V-3 and V-4).

There are 39 NPDES permitted municipal wastewater treatment plants (WWTPs) and 36 NPDES permitted municipal wastewater sewage lagoons (WWSLs) in the Saginaw Bay basin. Of the 39 WWTP, 28 received construction funding (Table V-4). Only six of the 36 municipal WWSLs obtained public funds for lagoon construction. Twenty grants were awarded to municipalities to install new sewers, and 19 grants awarded covered sewer improvement and rehabilitation costs. Finally, eight grants were disbursed towards new interceptor installation costs. Grant funding for construction was staggered over a 15-year period between 1972 and 1987 (Figure V-2). Over 80% of the projects funded were located in the Saginaw River basin (Table V-5).

Table V-1. Municipal WWTP Project Assistance Funding that has been Deferred in the Saginaw Bay Basin, 1988.

Municipality	County	Project Description	Step Number
Au Gres	Arenac	Collecting sewers and lagoon expansion	3
Beaverton	Gladwin	Land application	4
Chesaning	Saginaw	WWTP expansion	3
Hayes Township	Clare	Collecting sewer, sewage treatment plant	3
Clare	Clare	WWTP expansion, sewer rehab	4
Clifford	Lapeer		4
Cummings Township	Ogemaw		3
Goodrich	Genesee		3
Fenton	Genesee	Collecting sewers, interceptors	4
Flushing Township	Genesee	Sewers	3
Genesee County Metro	Genesee	Swartz Creek - seg. 01 forcemain (collection) seg. 02 Flushing - seg. 03	1
Otisville	Genesee	Treatment sewers	3
Swartz Creek	Genesee		3
Genoa Township	Livingston	Collecting sewers, land application facility	4
Genoa Township	Livingston	Land application facility	4
Gladwin	Gladwin	Sewer rehabilitation	4
Hill Township	Ogemaw		3
Ubly	Huron	WWTP	3
Kinde	Huron		3
Ithaca	Gratiot	WWTP expansion	4

Table V-1. Continued.

Municipality	County	Project Description	Step Number
Midland	Midland	WWTP	3
Midland Township	Midland	8 segments	1
Mt. Pleasant	Isabella		3
Holly	Oakland	Sludge disposal	4
Oakley	Saginaw	Treatment sewers	3
Pinconning	Bay	Interception/Infiltration collecting sewers	3
Plainfield Township	Iosco	WWTP expansion, sewers	3
Buena Vista	Saginaw		3
Zilwaukee	Saginaw		3
Merrill	Saginaw		3
Saginaw	Saginaw	Combined sewer overflows miscellaneous segments	3 1
Shepherd	Isabella	Lagoon expansion	3
Tawas City	Iosco	East Tawas Segment Tawas City Segment	1 1
Wheeler Township	Gratiot		3

Table V-2. Step I Wastewater Treatment Facility Planning Costs for Municipalities in the Saginaw Bay basin, 1972-1988.

Municipality	County	Project Cost	Federal Funds	State Funds	Funded to Date
Akron/Fairgrove	Tuscola	$6,300	$4,725	$315	$5,040
Alma	Gratiot	$59,525	$37,894	$2,526	$40,420
Argentine Twp	Genesee	$89,750	$67,540	$4,480	$70,774
Au Gres	Arenac	$51,159	$38,354	$2,557	$40,911
Bad Axe	Huron	$356,271	$267,203	$17,814	$285,017
Bay City	Bay	$617,800	$463,350	$30,890	$494,240
Beaverton	Gladwin	$73,174	$54,880	$3,659	$58,539
Birch Run	Saginaw	$14,515	$10,886	$756	$11,612
Caro	Tuscola	$90,893	$68,170	$4,545	$72,715
Caseville/Fairhaven	Huron	$74,495	$55,871	$3,725	$59,596
Cass City	Tuscola	$28,617	$21,463	$1,430	$22,893
Chesaning	Saginaw	$10,200	$7,650	$510	$8,160
Clare	Clare	$151,859	$113,894	$7,593	$121,486
Clifford	Lapeer	$28,952	$21,714	$1,448	$23,099
Cumming Twp	Ogemaw	$62,900	$47,175	$3,145	$49,815
Durand	Shiawassee	$46,462	$34,846	$2,333	$37,379
Fenton	Genesee	$485,991	$364,493	$24,300	$374,260
Flushing	Genesee	$312,098	$234,073	$15,605	$249,793
Genesee	Genesee	$34,644	$25,983	$1,732	$27,715
Genesee Co. -Metro	Genesee	$1,625,076	$1,218,807	$81,305	$1,299,856
Gladwin	Gladwin	$45,000	$33,750	$2,250	$36,000
Goodrich & Atlas Twps	Genesee	$16,171	$12,128	$814	$12,942
Harrison & Hayes Twps	Clare	$276,700	$207,532	$13,835	$221,367
Hill Twp	Ogemaw	$45,900	$34,425	$2,300	$36,725
Holly	Oakland	$127,970	$95,977	$6,399	$102,376
Howell	Livingston	$147,710	$110,780	$7,385	$118,175
Ithaca	Gratiot	$34,600	$25,950	$1,730	$27,680
Lapeer	Lapeer	$185,279	$138,959	$9,264	$148,223
Lennon, Clayton & Venice Twps	Genesee	$6,944	$5,208	$347	$5,555
Lincoln Twp	Clare	$39,000	$29,250	$1,950	$31,200
Marlette	Sanilac	$119,290	$89,445	$5,961	$95,316
Midland Twp	Midland	$336,304	$252,228	$16,815	$269,043
Oakley	Saginaw	$56,367	$42,275	$2,830	$45,049
Otisville	Genesee	$12,609	$9,457	$630	$10,087
Owendale	Huron	$6,200	$4,650	$310	$4,960
Pinconning	Bay	$46,111	$34,582	$2,306	$36,888
Plainfield Twp	Iosco	$11,600	$8,700	$580	$9,280
Port Austin	Huron	$24,500	$18,375	$1,225	$19,600
Richland Twp	Saginaw	$20,235	$15,176	$1,012	$16,076
Saginaw Twp - Saginaw Metro	Saginaw	$273,920	$205,440	$14,960	$219,136
St Louis	Gratiot	$25,130	$18,847	$1,256	$20,103
Standish	Arenac	$77,004	$57,753	$3,850	$61,603
Tawas City	Iosco	$429,900	$322,425	$21,495	$340,165
Tittabawassee Twp	Saginaw	$11,875	$8,906	$594	$9,500
Ubly	Huron	$10,600	$7,950	$530	$8,480
Union Twp	Isabella	$404,266	$303,206	$20,213	$323,414
Unionville	Tuscola	$10,351	$7,748	$517	$8,265
Vassar	Tuscola	$118,100	$88,575	$5,905	$94,480
Watertown Twp	Tuscola	$47,600	$35,700	$2,380	$38,080
West Branch	Ogemaw	$80,296	$60,222	$4,015	$64,237
Wheeler Twp	Gratiot	$20,142	$15,106	$1,007	$16,098
TOTALS		$7,279,517	$5,459,630	$365,363	$5,807,901

Table V-3. Step 2 Wastewater Treatment Facility Design Costs for Municipalities in the Saginaw basin, 1972-1988.

Municipality	County	Project Cost	Federal Funds	State Funds	Funded in [illegible]
Akron/Fairgrove	Tuscola	$82,872	$64,728	$4,040	$74,577
Alma	Gratiot	$24,413	$18,310	$1,221	$19,531
Argentine Twp.	Genesee	$354,132	$291,133	$17,707	$308,840
Bay City	Bay	$1,317,627	$988,220	$65,881	$1,054,101
Bay City	Bay	$437,240	$327,930	$21,867	$349,797
Bay City	Bay	$789,579	$592,184	$39,479	$631,663
Bay City	Bay	$28,800	$21,600	$1,440	$23,040
Bay County, [illegible] Area	Bay	$2,245,792	$1,537,148	$103,810	$1,840,958
Bridgeport Twp	Saginaw	$344,536	$261,707	$17,228	$278,935
Bridgeport Twp	Saginaw	$77,388	$65,953	$3,870	$69,811
Caro	Tuscola	$414,083	$317,508	$20,704	$339,843
Cass City	Tuscola	$177,524	$133,143	$8,876	$142,019
Chesaning	Saginaw	$2,000	$1,500	$100	$1,600
Durand	Shiawassee	$170,600	$127,950	$8,530	$136,480
Elba Twp	Lapeer	$292,977	$219,733	$14,649	$234,382
Essexville	Bay	$48,000	$36,000	$24,000	$38,400
Flint	Genesee	$1,878,812	$1,409,109	$93,941	$1,503,050
Goodrich & Atlas Twps	Genesee	$124,386	$93,289	$6,219	$99,034
Hampton Twp	Bay	$36,704	$27,532	$1,835	$29,367
Holly	Oakland	$240,164	$180,123	$12,008	$192,131
Howell	Livingston	$309,480	$232,110	$15,474	$247,582
Lapeer	Lapeer	$919,287	$689,480	$45,966	$735,416
Lapeer Twp.	Lapeer	$96,553	$72,415	$4,828	$77,243
Linden	Genesee	$101,349	$76,162	$5,077	$81,239
Mayfield Twp	Lapeer	$111,620	$83,715	$5,581	$89,296
Mt. Pleasant	Isabella	$329,360	$247,020	$16,468	$263,488
Mt. Pleasant	Isabella	$164,162	$123,121	$8,208	$131,330
Oakley	Saginaw	$99,100	$74,325	$4,955	$79,280
Otisville	Genesee	$135,881	$101,910	$6,794	$108,704
Port Austin	Huron	$241,900	$181,425	$12,095	$193,520
Portsmouth Twp	Bay	$172,899	$129,674	$8,645	$138,319
Richland Twp	Saginaw	$40,604	$30,453	$2,030	$32,483
Saginaw Twp., Saginaw Metro	Saginaw	$382,156	$290,908	$19,108	$310,016
St. Louis	Gratiot	$202,300	$151,875	$10,125	$162,000
Standish	Arenac	$161,500	$121,125	$8,075	$129,200
Unionville	Tuscola	$79,460	$59,595	$3,973	$63,568
West Branch	Ogemaw	$322,800	$242,100	$16,140	$258,240
TOTALS		$12,971,734	$9,842,172	$861,530	$10,377,281

Table V-4. Step 3 and 4 Wastewater Treatment Facility Construction Costs for Municipalities in the Saginaw Bay basin, 1972-1988.

Municipality	County	Step	Project Cost	Federal Funds	State Funds	Funded to Date	Project Purpose
Akron/Fairgrove	Tuscola	3	$3,440,372	$2,580,279	$172,467	$2,748,613	
Alma	Gratiot	3	$196,964	$147,723	$9,848	$157,571	S-REHAB
Alma, Arcada & Pine River Twps	Gratiot	3	$1,094,174	$820,030	$54,709	$875,339	NEW-S, INT
Argentine Twp	Genesee	3	$194,900	$165,665	$9,745	$175,410	
Argentine Twp	Genesee	3	$8,008,590	$5,611,306	$340,436	$5,779,882	NEW-S, NEW-WWTP
Bay City	Bay	3	$34,699,675	$26,024,756	$1,734,984	$27,759,740	WWTP-IMP
Bay City	Bay	3	$10,700,061	$8,025,046	$537,692	$8,549,292	WWTP-IMP
Bay City	Bay	3	$19,637,715	$14,743,286	$987,261	$15,709,702	WWTP-IMP
Bay City	Bay	3	$890,540	$674,655	$45,540	$719,632	NI
Bay City	Bay	3	$340,448	$260,586	$17,972	$287,558	S-IMP
Bay County, Westside Area	Bay	3	$59,677,000	$44,007,750	$3,022,020	$47,737,993	NEW-WWTP
Birch Run	Saginaw	4	$1,436,087	$1,077,065	$71,804	$1,148,869	NEW-WWSL, NEW-S
Bridgeport Twp	Saginaw	3	$7,154,000	$5,408,372	$357,700	$5,825,417	S-IMP, WWTP-IMP
Caro	Tuscola	3	$10,272,300	$7,704,225	$513,615	$7,890,322	NEW-S, S-REHAB, WWTP-IMP
Cass City	Tuscola	3	$6,055,590	$4,541,692	$302,780	$4,844,472	WWTP-IMP
Chesaning	Saginaw	3	$1,527,674	$1,145,756	$76,383	$1,222,139	WWTP-IMP, NEW-S
Chesaning	Saginaw	3	$24,810	$18,607	$1,240	$19,847	S-REHAB
Durand	Shiawassee	3	$3,799,084	$2,849,313	$190,892	$3,035,517	WWTP-IMP
Elba Twp	Lapeer	3	$11,374	$8,528	$569	$9,097	
Essexville	Bay	3	$981,750	$736,313	$49,332	$784,426	NEW-S, S-REHAB, WWTP-IMP
Essexville	Bay	4	$166,162	$124,621	$8,306	$132,636	S-REHAB
Fenton	Genesee	3	$243,156	$182,347	$12,157	$193,967	NEW-S
Flint	Genesee	3	$54,324,794	$40,743,595	$2,716,240	$43,422,780	WWTP-IMP, NEW-S, S-IMP
Flint	Genesee	3	$93,276,579	$69,957,434	$4,663,250	$73,091,497	NEW-S, WWTP-IMP, S-REHAB
Flushing	Genesee	4	$4,872,700	$444,900	$0	$145,899	WWTP-IMP, S-REHAB
Frankenmuth	Saginaw	3	$2,667,277	$519,297	$0	$519,297	WWTP-IMP
Gagetown	Tuscola	4	$1,705,215	$1,278,911	$85,261	$1,350,535	NEW-WWSL, NEW-S
Gaines	Genesee	4	$1,940,152	$1,456,614	$97,108	$1,353,722	NEW-S, INT
Genesee Co	Genesee	3	$17,445,503	$9,393,927	$0	$9,393,927	S-REHAB, INT
Genesee Co Regional WWTP	Genesee	3	$6,421,460	$4,816,095	$0	$4,816,095	WWTP-IMP
Genesee Co Regional WWTP #3	Genesee	3	$14,674,821	$11,006,115	$65,947	$11,072,067	WWTP-IMP
Gladwin	Gladwin	3	$1,712,659	$1,284,494	$85,633	$1,370,127	WWTP-IMP
Hampton Twp	Bay	3	$660,977	$495,732	$33,197	$528,189	
Hampton Twp	Bay	4	$99,075	$74,306	$4,035	$78,341	S-REHAB
Holly	Oakland	3	$9,364,663	$7,023,497	$470,413	$7,483,475	WWTP-IMP, S-REHAB
Howell	Livingston	3	$7,608,302	$5,706,229	$382,229	$6,088,457	WWTP-IMP, INT, NEW-S.
Lapeer	Lapeer	3	$10,674,787	$8,006,090	$533,339	$8,539,829	WWTP-IMP
Lapeer	Lapeer	3	$1,510,086	$1,132,564	$75,504	$1,208,068	S-REHAB
Lapeer Twp	Lapeer	3	$6,068	$4,551	$303	$4,854	NEW-S
Linden	Genesee	3	$6,113,821	$4,585,366	$307,225	$4,884,927	NI
Marlette	Sanilac	4	$1,906,381	$1,764,356	$0	$129,903	WWTP-IMP, NEW-S, S-REHAB
Mayfield Twp	Lapeer	3	$7,986	$5,989	$400	$6,389	NEW-S
Merrill	Saginaw	3	$156,994	$67,446	$39,549	$127,195	NEW-WWSL, NEW-S
Mt. Pleasant	Isabella	3	$12,275,020	$9,206,771	$613,651	$9,816,422	WWTP-IMP, S-REHAB
Otisville	Genesee	3	$2,473,938	$1,855,453	$123,697	$1,976,995	WWTP-IMP, NEW-S
Owendale	Huron	4	$1,481,272	$1,110,954	$74,064	$1,174,068	NEW-WWTP, NEW-S
Owosso	Shiawassee	3	$13,695,350	$10,271,512	$687,942	$10,959,525	WWTP-IMP
Owosso & Caledonia Twp	Shiawassee	3	$10,536,168	$7,902,176	$526,806	$8,419,786	NEW-S, INT
Port Austin	Huron	3	$5,154,300	$3,865,725	$257,715	$4,095,105	WWTP-IMP
Richland Twp	Saginaw	3	$442,359	$243,207	$0	$70,554	WWSL-EXP
Saginaw	Saginaw	3	$7,646,728	$5,735,046	$382,336	$6,117,382	WWTP-IMP
Saginaw Twp, Saginaw Metro	Saginaw	3	$6,041,780	$4,422,979	$0	$4,137,797	WWTP-IMP
St. Louis	Gratiot	3	$5,689,928	$4,267,446	$285,096	$4,553,142	WWTP-IMP, NEW-S, INT, S-IMP
Standish	Arenac	3	$3,429,200	$2,571,900	$171,460	$2,734,349	WWTP-IMP, S-REHAB
Tawas City	Iosco	4	$1,133,400	$623,370	$0	$505,090	WWTP-IMP
Tittabawassee Twp	Saginaw	4	$2,727,462	$2,045,596	$136,375	$2,128,321	WWSL-EXP, NEW-S, INT
Union Twp	Isabella	3	$4,869,562	$3,652,171	$244,039	$3,892,503	
Unionville	Tuscola	3	$1,543,860	$1,157,901	$77,195	$1,228,846	
Vassar	Tuscola	4	$10,511,900	$7,883,925	$0	$1,617,818	NEW-WWTP, S-REHAB
West Branch	Ogemaw	3	$8,484,655	$6,363,491	$424,233	$6,646,911	NEW-WWTP, INT, NEW-S
TOTALS			$506,877,599	$371,027,892	$22,762,460	$381,509,248	

Project Purpose Key:

- INT- New Interceptors
- NI- No Information
- NEW-S- New Collecting Sewers
- NEW-WWSL- New Wastewater Sewage Lagoons
- NEW-WWTP- New Wastewater Treatment Plant
- S-IMP- Sewer Improvements
- S-REHAB- Sewer Rehabilitation
- WWSL-EXP- Wastewater Sewage Lagoon Expansion
- WWTP-IMP- Wastewater Treatment Plant Improvements

1972	NPDES permitting program began
1973	Flint
1974	
1975	Bay City, Chesaning, Owosso, Owosso & Caledonia Twp.
1976	Gladwin, Merrill
1977	Alma, Bay City, Chesaning, Durand, Holly
1978	Akron/Fairgrove, Alma, Bay Co.-Westside, Essexville, Flint, Hampton Twp., Howell, Lennon, Mt. Pleasant, Port Austin, Union Twp.
1979	Cass City, Saginaw
1980	Bay City, Elba Twp., Fenton, Lapeer, Lapeer Twp., Mayfield Twp., Otisville, St. Louis, Standish, Unionville, West Branch, Birch Run, Tittabawassee Twp.
1981	Argentine Twp., Gagetown, Owendale, Gaines Twp., Hampton Twp.
1982	
1983	Argentine Twp., Bridgeport Twp., Caro
1984	Genesee Co.-Ragnone, Vassar
1985	Genesee Co.-Ragnone, Saginaw Twp.
1986	
1987	Frankenmuth, Genesee Co., Richland Twp., Flushing, Marlette, Tawas City

Figure V-2. Municipal grants timeline of WWTP construction starts in the Saginaw Bay basin, 1972-1987.

Table V-5. Municipal Wastewater Treatment Facility Construction Grants by River Basin in the Saginaw Bay Watershed, 1972-1988.

Basin/Municipality	County
Pigeon	
Port Austin	Huron
Gagetown	Tuscola
Owendale	Huron
Wiscoggin	
Akron/Fairgrove	Tuscola
Hampton Township	Bay
Unionville	Tuscola
Saginaw	
Alma	Gratiot
Alma, Arcada & Pine River Townships	Gratiot
Argentine Township	Genesee
Bay City	Bay
Bay County Westside Area	Bay
Birch Run	Saginaw
Bridgeport Township	Saginaw
Caro	Tuscola
Cass City	Tuscola
Chesaning	Saginaw
Durand	Shiawassee
Elba Township	Lapeer
Essexville	Bay
Fenton	Genesee
Flint	Genesee
Flushing	Genesee
Frankenmuth	Saginaw
Gaines	Genesee
Genesee County	Genesee
Genesee County-Ragnone WWTP	Genesee
Gladwin	Gladwin
Holly	Oakland
Howell	Livingston
Lapeer	Lapeer
Lapeer Township	Lapeer
Lennon	Genesee
Mayfield Township	Lapeer
Marlette	Sanilac
Merrill	Saginaw
Mt. Pleasant	Isabella
Otisville	Genesee
Owosso	Shiawassee
Owosso and Caledonia Township	Shiawassee
Richland Township	Saginaw

Table V-5. Continued.

Basin/Municipality	County
Saginaw (continued)	
Saginaw	Saginaw
Saginaw Township, Saginaw Metro	Saginaw
St. Louis	Gratiot
Tittabawassee Township	Saginaw
Union Township	Isabella
Vassar	Tuscola
Kawkawlin	
None	
Rifle	
Standish	Arenac
West Branch	Ogemaw
Au Gres	
Tawas City	Iosco

b. Construction Grant Project Descriptions

i. Completed Actions

Akron/Fairgrove - Specific information on construction outlays were not available.

Alma - The construction grant was received to install intercepting and collection sanitary sewer extensions in Alma and the townships of Arcada and Pine River. Other grant funding was used to rehabilitate established sewers in Alma.

Argentine Township (Genesee County) - Argentine Township used a portion of municipal grant money to acquire the land for its land treatment facility. The rest of the grant was used to construct the facility and put in a pressure-sewer collection system, gravity and forcemain interceptor and pump stations.

Bay City - Construction dollars were used for improvements and modifications to the Bay City sewer system. Three retention treatment structures were installed at the Bay City WWTP for treatment and disinfection. Additional processes added to the trickling filter WWTP included sludge dewatering and incineration equipment.

Birch Run - Construction grant funds were used to design and build two 6-acre lagoons, new collection sewers, a forcemain and a pump station.

Bridgeport - The improvement project was divided into two parts: 1) construction of an 18-inch relief sewer to a pumping station and a 14-inch forcemain that runs to the treatment plant; and 2) construction of two oxidation ditches to extend aeration during the activated sludge process. A 3.7 million gallon polishing pond was also built to provide dechlorination and tertiary effluent polishing prior to discharge to the Cass River. In addition, on-site sludge storage facilities (amounting to 150 days) were added and improvements to 8,000 square feet of sludge drying beds were made.

Caro - Construction included rehabilitating the existing sewage collection system adding six sewage lift stations, about 8 kilometers of forcemain and over 3 kilometers of sewer. In addition, the WWTP was expanded and upgraded to a 1.2 MGD facility.

Chesaning - The Chesaning WWTP was upgraded and expanded including the addition of a four stage bio-disc secondary treatment process. Grant money was also used to install new sanitary and storm sewers.

Durand - The Michigan Water Resources Commission issued a final order to the City of Durand outlining the steps to abate pollution of the Holly Drain and the Shiawassee River by August 1, 1973. The plant has been upgraded to a secondary treatment facility using a 2-stage trickling filter system. The sewer system includes both separated and combined sewer systems. In addition, the three lift stations can be bypassed to Three Mile Drain.

Essexville - The plans and specifications were developed for construction of sanitary sewers, conversion of existing combined sewers to storm sewers, a sewage pumping station, forcemains and improvements to the existing WWTP.

Flint - Improvements to the Flint facility include a 10 million gallon retention facility, a 40 MGD pump station, and modifications to the existing WWTP influent box. Existing pumping stations throughout the collection system were modified and a new 26 MGD peak flow pumping station was constructed. New trunk sanitary sewers providing 10 MG of in-line storage and sanitary relief sewers were also constructed.

Gagetown - In 1967, the Michigan Water Resources Commission informed the Village that raw or semi-treated sewage was being discharged to surface waters. In 1981 work began to construct a new sanitary sewer collection system within the village and two 3-hectare waste stabilization lagoons and other appurtenances.

Genesee County-Ragnone WWTP - This facility was required to upgrade and expand its operations to meet NPDES permit final limitations, including a stable nitrified plant effluent and a daily maximum residual chlorine limit. The final project was divided into two phases to expand the existing 20 MGD activated sludge treatment plant. The first phase included Brent Run pump station improvements that increased capacity from 60 MGD to 125 MGD. In addition, six new primary settling tanks, chlorination equipment and a 1.2 meter bypass from the primary settling tanks to the Flint River were added.

The second phase added an aeration basin for biological treatment and nitrification. Two new circular final clarifiers were installed for final sedimentation and removal of phosphate from sewage. In addition, two equalization basins, with a combined capacity of 1.6 MGD, and wet weather treatment tanks for chlorination of all the primary treated sewage, were constructed. Several other miscellaneous appurtenances, such as pumping facilities and instrumentation monitoring equipment were added making this an advanced secondary treatment facility.

The Ragnone WWTP experiences high WWTP flows (35 MGD) during wet weather, which previously resulted in sanitary sewage bypasses at the Brent Run pumping station up to 15% of the time in the spring. The addition of the wet weather treatment tanks (that can handle flows from 40 to 95 MGD) has eliminated the use of the Brent Run bypass.

Gladwin - The city's primary WWTP was upgraded and expanded to a secondary treatment facility that included aerated stabilization lagoons, phosphorus removal and sludge digestion, and laboratory improvements.

Holly - The Michigan Water Resources Commission ordered the Village of Holly to upgrade their existing level of wastewater treatment according to a schedule of compliance. After receiving grant funding the existing secondary treatment plant was upgraded to a tertiary plant (with a design average daily flow of 1.16 MGD and maximum flow of 4.0 MGD) providing ammonia and phosphorus removal, utilizing the Bio-disc process.

Money was also used to rehabilitate the Village sewers and complete interceptor and collector sewer projects.

Howell - The municipal grants program funded construction for expansion and modification of the existing WWTP to a 1.82 MGD activated sludge WWTP with effluent pressure sand filtration and the capacity for nitrification. Additional money was used to construct a new intercepting sewer, pump station, forcemain and collecting sewer, and to rehabilitate some existing sewers.

Lapeer - To meet the NPDES permit requirements, Lapeer abandoned its Oakdale Center WWTP (a secondary treatment facility) and built a 4.0 MGD regional activated sludge WWTP with tertiary treatment, including sand filtration. Collecting sewers were installed in the townships of Mayfield, Elba and Lapeer and the DeMille interceptor, pump station and forcemain were constructed to transport the wastewater to the new facility.

Lennon - Information on construction details was not available.

Merrill - Stabilization ponds covering six hectares were constructed on a 16 hectare site and designed to provide the equivalent of primary and secondary treatment. New sanitary sewers were also funded with a municipal grant.

Mt. Pleasant - The City demolished its old WWTP and replaced it with a new tertiary treatment facility incorporating an aerated grit chamber, five primary clarifiers (3 existing units, and 2 new units), rotating discs for biological contact, two new final clarifiers, two chlorine contact tanks, reaeration equipment, an upgraded anaerobic digestor plus a secondary digestor and a sludge centrifuge to dewater the sludge. The construction grant also covered construction of the facility's administration building, service building and digestor building; sewer rehabilitation, and pump station modification.

Otisville - In 1980 a municipal facility construction grant was awarded to the Village of Otisville to construct a stabilization lagoon spray irrigation waste treatment system and sanitary collection sewer system to serve Otisville and an adjacent portion of Forest Township.

Owendale - Owendale's municipal grant money funded the design and construction of a sanitary sewer collection system with one pump station and treatment at two 8 hectare waste stabilization ponds.

Owosso (and the Townships of Owosso & Caledonia) - Owosso constructed a new WWTP with an aerated grit chamber, two coagulation and sedimentation basins, high rate filtration, carbon adsorption and chlorination-dechlorination (for nitrogen removal) processes. Grant construction money was also used for a new intercepting sewer and sewer separation.

A second construction grant award was used to build intercepting sewers, collection sewers, two metering stations, eight pumping stations and appurtenances to service the townships of Owosso and Caledonia.

Port Austin - Construction grant funding was used for a sewage treatment works. No further information was available.

Saginaw - Information on construction details was not readily available.

Saginaw Township - The construction grant for the wastewater treatment plant expansion included site work, mechanical plant work, buildings, yard piping and outlet sewers. A 4.8 MGD extended aeration oxidation ditch was added to the primary treatment plant. Sludge handling processes were also included in the grant award.

Standish - The construction project consisted of the construction of stabilization ponds, and pumping station and forcemain, and sewer system rehabilitation.

St. Louis - The city upgraded and expanded the primary WWTP to a 0.83 MGD WWTP with grit removal, primary clarification, phosphorus removal, biological treatment including nitrification employing a rotating biological disc process. Digestors and sludge drying beds handle the solids produced in the wastewater treatment process.

Grant dollars also funded separation of the St. Louis combined sewer system. Storm sewers were constructed and the existing combined sewers were then used as sanitary sewers. Additional funding provided for the construction of an interceptor and collecting sewers to serve Bethany and Pine River Townships.

Tittabawassee Township - Municipal grant funding covered the design and construction of four additional waste stabilization lagoons, sanitary collection sewers, an interceptor across the Tittabawassee River consisting of a pump station and a forcemain, and a hydrogeologic investigation of the lagoon site.

Union Township - Specific information on construction outlays were not available.

Unionville - Specific information on construction outlays were not available.

Vassar - The Vassar project consisted of the design and construction of a 1.4 MGD rotating biological contractor WWTP, one pump station, about 1.5 kilometers of forcemain, and a sewer rehabilitation program including a new river crossing.

West Bay County Regional WWTP - This is a new secondary treatment plant with phosphorus removal. Funding also covered construction of the westside sewer system including collector and interceptor sewers, lift stations and forcemains.

West Branch - West Branch originally treated wastewater in its primary wastewater treatment facility. To meet NPDES permit requirements the City decided to abandon its existing treatment facility and construct a tertiary treatment facility with interceptor sewer construction from the existing site to the new site. The plant was designed to serve the City of West Branch and the three surrounding townships: West Branch, Ogemaw and Klacking. Construction grant money received was used to build the plant, interceptor sewer, pumping station, and collector sanitary sewers for West Branch Township and Ogemaw Township. Specific processes for the tertiary treatment plant include a grit chamber, primary settling tank, 2 sludge digestion tanks, 1,300 m^2 of sludge drying beds, four bio-discs, two final clarifiers, three tertiary sand filters, and a chlorine contact chamber.

ii. Actions Currently in Progress (begun in 1987)

Flushing - The project consists of design and construction of wastewater treatment plant improvements and sewer rehabilitation.

Frankenmuth - Final Order effluent limits required tertiary treatment processes be instituted at the city's WWTP. Improvements were made to Frankenmuth's WWTP consisting of raw sewage screening, primary tank revisions, addition of a new equalization basin, a new final clarifier, return and waste sludge pumping, UV disinfection, sludge thickening, and digested sludge storage with land disposal. Funds also went towards site improvements and yard piping and laboratory and building revisions. The project also included design and construction of tertiary filtration, however, grant funding for this process has been deferred.

Marlette - Identified as a state priority on March 29, 1987, the Marlette project consisted of modifications to the existing plant and replacement of the existing trickling filters with sequencing batch reactors. Other processes added included ultraviolet disinfection and methane gas recovery. Grant funding also covered sewer rehabilitation, pump station modifications, and new gravity collecting sewers.

Richland Township - A new 20 hectare wastewater stabilization lagoon was added to the two-cell lagoon treatment system.

Tawas City - A new secondary wastewater treatment plant was constructed at Tawas City including 28 hectares of aerated lagoons, followed by phosphorus removal, four final settling tanks, two sludge ponds, a chlorination chamber. Municipal grant funding also covered a new forcemain, the revamping of two pumping stations and other appurtenances.

2. Industrial Pretreatment Program

The NPDES permit system has been effective in reducing and controlling the pollutant concentrations discharged to surface waters of the state. However, before 1977, industrial discharges to municipal wastewater treatment plants were not regulated. Problems arose when industrial dischargers released toxic materials to municipal wastewater treatment sewer systems. Not only could these materials pass through the municipal system untreated, but some toxic materials actually interfered with the plant operations, reduced the treatment efficiency, or contaminated residual sludge materials, creating disposal problems.

The Clean Water Act amendments of 1977 addressed these problems by requiring the U.S. EPA to begin development of a nationwide Industrial Pretreatment Program (IPP). The responsibility to implement the program was delegated to the MDNR by the EPA in 1983. Two years later, in 1985, the Michigan Water Resources Commission promulgated rule revisions addressing pretreatment concerns.

Twenty-seven municipal wastewater treatment facilities in the Saginaw Bay basin are required by these rules to develop pretreatment programs (Table V-6) that will identify and control the discharge of toxic pollutants from nondomestic sources to assure that pollutants from these sources do not interfere with the treatment system or pass through the system and enter waters of the state at unacceptable levels. There are four types of pollutants regulated under the Industrial Pretreatment Program:

-- Pollutants limited by the federal categorical standards in the discharges from categorical sources. These are defined in federal regulations promulgated by the U.S. EPA.

-- Pollutants for which there are discharge limitations in the NPDES permit for the wastewater treatment facility. These are established by action of the Michigan Water Resources Commission.

-- Pollutants for which concentration limits are established in the Program for Effective Residuals Management (PERM) in order to allow safe sludge disposal. The PERM is proposed by the wastewater treatment facility and approved by the MDNR.

-- Pollutants which must be controlled in order to avoid operational problems in the wastewater treatment facility or its sewer system. This includes federal prohibited discharge criteria and other requirements established by the wastewater treatment facility.

3. Other Point Source Facility Improvements

Extensive wastewater treatment improvements have been made at other municipal and industrial facilities in the Saginaw Bay basin in recent years. Many of these improvements have been made under the facilities initiative. Others have been made as a result of stricter effluent discharge requirements under the NPDES permit program. And still others were made after enforcement actions were taken against facilities not complying with NPDES permit limits. The following discussion is based primarily on recent facility improvements made in the MDNR Saginaw District area and is meant to be representative of the type of actions taken - not an exhaustive list.

There are several different types of enforcement actions against NPDES permit holders that can be taken by the MDNR. In order of increasing importance these are: 1) Notice of Noncompliance, issued by

Table V-6. Municipal WWTPs and WWSLs in the Saginaw Bay Basin Required to have Approved Industrial Pretreatment Programs.

Municipal Facility	NPDES Permit Number
Alma WWTP	MI0020265
Au Gres WWSL	MI0022233
Bridgeport Township WWTP	MI0022446
Cass City WWTP	MI0022594
Clare WWTP	MI0020176
East Tawas WWTP	MI0021091
Essexville WWTP	MI0022918
Flint WWTP	MI0022926
Frankenmuth WWTP	MI0022942
Genesee County-No. 3 WWTP	MI0022993
Genesee County-Ragnone WWTP	MI0022977
Gladwin WWTP	MI0023001
Holly WWTP	MI0020184
Howell Township WWSL	MI0044903
Howell WWTP	MI0021113
Lapeer WWTP	MI0020460
Midland WWTP	MI0023582
Mt. Pleasant WWTP	MI0023655
Owosso Mid-Shiawassee Co. WWTP	MI0023752
Pinconning WWTP	MI0020711
Saginaw Township WWTP	MI0023973
Saginaw WWTP	MI0025577
Standish WWTP	MI0024139
Tawas City WWTP	MI0024210
Vassar WWTP	MI0024252
West Bay County Regional WWTP	MI0042439
Zilwaukee-Carrollton Township WWTP	MI0023981

the SWQD District Supervisor; 2) Notice of Violation, issued by the Surface Water Quality Division Chief and signed by the Michigan Attorney General; 3) Order and Stipulation issued by the MDNR Director; 4) Final Order, issued by the Michigan Water Resources Commission; and 5) Court Orders.

Bay City WWTP - The Bay City WWTP was issued a Notice of Noncompliance in August 1986, for failure to implement its Industrial Pretreatment Program.

Village of Caseville - A Final Order was issued in 1987 to the Village of Caseville by consent, to plan, design and build a collecting sewer and treatment system. The Village had identified problems by conducting sanitary surveys and was issued the Final Order so a higher funding priority could be achieved through the municipal grants process.

Cast Forge Company, Howell - The Cast Forge Company has operated a plant for the manufacture of aluminum cast products since 1969 on the South Branch of the Shiawassee River at Howell. Until 1973, wastewater contaminated by PCB-containing hydraulic fluids was discharged to the river. From 1973 to 1977, process wastewater was discharged to a 400,000 gallon lagoon on the plant property. Illegal discharges from this lagoon, as well as periodic overflows of the lagoon, led to the contamination of nearby wetlands and subsequently the Shiawassee River.

Results of sampling by MDNR in late 1978 showed high levels of PCB in soils around the site. Some PCB was also found in monitoring wells on the site in June 1979. High levels of PCB have been found in Shiawassee River sediment below the plant property.

The State of Michigan filed suit against Cast Forge on November 8, 1977, for PCB contamination of the environment. The case was settled through a Consent Judgment on June 19, 1981. Pursuant to that settlement, the company removed its wastewater lagoon, cleaned up PCB-contaminated soils and sediments from its property and provided \$750,000 for the restoration of the Shiawassee River. Approximately 1,380 m^3 of PCB contaminated sediment was dredged from the river in 1983.

Dow Chemical Company - The Dow Chemical Company, headquartered in Midland alongside the Tittabawassee River, is continually upgrading and optimizing its waste and wastewater treatment system (Gravey, 1986). These waste management systems are coordinated through a special Environmental Services Division which is responsible for two incinerator units (a rotary kiln and liquid injection incinerator), liquid waste storage tanks, container handling areas, and the Dow Chemical wastewater treatment plant (Goble, et al. 1987).

The wastewater treatment plant was originally built in the 1930s to provide primary wastewater treatment. It was upgraded to a secondary treatment plant in the 1950s with the addition of a biological treatment system. Tertiary ponds were added in the 1970s to equalize temperature and flow rate prior to effluent discharge.

In the 1970s groundwater contamination was discovered below Dow Chemical's complex. To protect the Tittabawassee River from contaminated groundwater inflows, Dow Chemical built an underground slurry wall (also called an underground revetment system) costing approximately $6 million. Up to 1 million gallons of groundwater are collected annually and treated at the WWTP which has a design capacity of approximately 26.5 million gallons per day.

The old trickling filter systems at Dow were originally manufactured and sold by Dow Chemical. As the wastewater treatment plant was upgraded, these trickling filters were used for additional treatment prior to primary treatment, but were finally taken out of service between 1985 and 1986.

In 1987 construction of three diversion tanks with a total 50 million gallon capacity to replace unlined surface impoundments was completed. The purpose of the tanks is two-fold. First, if there is a chemical spill within the Dow Complex, wastewater can be diverted to the tanks to prevent toxic chemicals from disrupting or passing through the wastewater treatment system. Second, the tanks serve as retention basins for stormwater runoff during storm events. All the sewers on site are interconnected and all stormwater runoff is collected and treated at the WWTP prior to discharge to the Tittabawassee River. The cost of the three diversion tanks totalled approximately $10 million.

In June 1983, the Dow Chemical Company announced a research initiatives program to address public concerns about dioxins in the environment and their potential health impacts in the Midland community. The results of the dioxin point source research study was published in November 1984. Four critical sources of TCDD were identified:

-- Dewatering wells located on a closed on-site landfill that is clay-capped and is surrounded by a clay wall extending to the natural clay bottom to prevent leakage and rainwater infiltration. These wells were deactivated.

-- A shallow sump near former chlorophenol production sites which formerly flowed into the sewer system. This sump has been deactivated.

-- A historical deposit of organic material containing TCDD was found to be entering the sewer.

-- The waste incinerator.

The rotary kiln incinerator (the liquid injection incinerator is rarely used) burns over 200 tons of solid and liquid waste and trash daily. To control particulate emissions a water slurry quenches the kiln ashes and combustion gases are scrubbed with water within the incinerator's emission control system. The ash is disposed at a licensed Class I landfill and the slurry and scrubbing waters are collected and treated at the company's WWTP. The WWTP can remove 98% of the TCDD it receives, however, a special multimedia filtration system was designed to further improve TCDD removal capabilities prior to discharge to the Tittabawassee River.

The sewer system serving the Midland plant site was also extensively analyzed to determine the TCDD contribution of each currently operating manufacturing unit. Results showed that none of the manufacturing facilities had a significant TCDD discharge.

Prior to the scheduled October 1988 reissuance of its NPDES permit, Dow Chemical was required to perform several actions to fulfill its Final Order of Abatement for dioxin. On August 27, 1987, Dow presented a Section 24 Demonstration Under Dioxin Order of Abatement to seek an extension for implementing the best available control technology economically achievable. Technologies to control 2,3,7,8-TCDD (e.g. dioxin) discharges are limited with Dow Chemical having the only wastewater effluent limit for dioxin in the nation. As part of the demonstration, Dow documented the actions taken thus far to comply with the Dioxin Minimization Program outlined in the Final Order of Abatement.

Dow installed a multimedia filtration system at a cost of about $4.4 million and annual operating costs of approximately $1 million. According to the Demonstration, the filtration system began operation in November 1985 and was successful in reducing dioxin in the discharge to less than 10 picograms/kg or parts per quadrillion (ppq) on a monthly average.

A clarification system has recently been added to pretreat the incinerator water effluent before it enters the WWTP. This system was added to increase removal of dioxin-bound particles because dioxin often attaches to the particles scrubbed from the incinerator's combustion gases. In addition, improved computer process controls have been instituted with the rotary kiln incinerator, resulting in a 98-99% reduction in dioxin air emissions. It is estimated that this also reduces the amount of dioxin collected by water from scrubbing and quenchin operations, although this has yet to be verified.

The shallow sump point-source of dioxin identified in Dow's 1984 dioxin investigation was in an area associated with the historical production of chlorophenolics. The sump and the dewatering wells in the closed landfill were both discontinued to reduce dioxin loading to the WWTP. The U.S. EPA has approved specific investigation plans that will cost Dow Chemical's Michigan Division $2.5 million to implement at these two source sites.

Another dixoin source; historical deposits of organic material, cost Dow $6 million to remediate. Dow replaced its open sewers with enclosed 1.4 meter diameter polyethylene pipe in 1987 for $3 million. Implementation of the U.S. EPA approved closure plans cost another $3 million.

As a part of the Final Order, Dow agreed to complete some dioxin-related special conditions including evaluation of other end-of-pipe control measures to reduce dioxin discharge levels. The technologies being evaluated include activated carbon adsorption, reverse osmosis, and an additional technology to be determined.

Dow has also agreed to survey the native fish population in the Tittabawassee River every other year. The 1985 fish survey resulted in the lifting of the fish consumption advisory in 1986. The fish consumption advisory was originally instituted in 1978 because of high levels of dioxins (600 ng/kg) found in carp and catfish. The 1985 Dow survey confirmed the low levels of dioxin in sport fish found by U.S. EPA's extensive survey in 1983.

A diffuser was laid three-fourths of the way across the bottom of the Tittabawassee River at a cost of about $200,000 in 1985. The perforated pipe was designed to increase the rapid mix rate of Dow's WWTP effluent discharge with the Tittabawassee River. Dow has conducted fish avoidance studies near the diffuser system and found no evidence of fish avoidance to the rapidly-mixed effluent.

Dow estimates that the company has spent over $12 million on the program for dioxin abatement, including the $4.4 million multimedia filtration system, the ditch enclosure project for about $6 million, and about $2 million on other miscellaneous dioxin abatement programs.

Two more multimedia filters have been added to the WWTP (the total is now 8 filters) since the Section 24 Demonstration at a cost of about $1 million. The cost of the biological studies performed for the dioxin abatement program, exclusive of the native fish monitoring studies, was estimated by Dow to cost over $1 million over a period of 4 to 5 years.

Dow has also incurred substantial costs for remediations on other property that it owns or leases. Dow recently added another slurry wall around a portion of one of the tertiary ponds at a cost of $1.7 million. The site was described as overlook park and the remediation was designed to stem leakage that has been detected.

In 1985 an agreement was signed between Dow and the MDNR to close down its entire brine well operation. Wells had been installed to access underground brine which was used to extract magnesium and other ions. After extraction, the brine was reinjected into the aquifer. The agreement required Dow to cap approximately 120 production wells and 39 reinjection wells. In addition, environmental assessment at 92 sites of known spills was required. Implementing this agreement was believed to have cost Dow Chemical millions of dollars.

Another remediation site was property along the Saginaw River that was leased by Dow Chemical for a period of time. The site, International Terminal, Incorporated (ITI) has been a fuel depot since World War II. The impacts to surface water have not yet been assessed, but Dow has willingly installed monitoring wells and performed a site investigation identifying chlorinated and non-chlorinated solvents. It is estimated that Dow has spent between $250,000 to $500,000 on the site thus far.

<u>City of Frankenmuth</u> - An Order and Stipulation was issued to the City of Frankenmuth in February 1986 requiring the city to plan, design

and construct WWTP improvements. A consent decree was entered in circuit court in April, 1987, requiring the city to complete the improvements according to a specified schedule. The July 1, 1988, deadline was not met and a $7,000 fine was assessed by the court. However, one-half of this fine was suspended and Frankenmuth paid the remaining $3,500 fine and was placed on probation for one year.

Johnston Contracting, Midland - Johnston Contracting is involved with oil and salt storage and under Part 5, Rules of Michigan P.A. 245 is required to prepare a Pollution Incident Prevention Plan (PIPP). In March 1988, MDNR filed suit against the company through a county prosecutor to carry out preparation of a PIPP because various spills on company property had resulted in surface water and groundwater contamination. A court rules in favor of the MDNR and fined the company $50,000. This was suspended to $5 and the company was placed on one year probation.

Lapeer WWTP - A Notice of Violation was issued to the Lapeer WWTP in October 1986, for not implementing their Industrial Pretreatment Program.

City of Midland - The City of Midland was issued a Notice of Noncompliance in October 1987, for raw sewage discharges from its sanitary sewer system. The city had developed a program to expand and upgrade its collecting sewer and treatment system at an estimated cost of $20 million. A bond issue to implement the program was passed in 1987 for $19.8 million.

Monitor Sugar Company, Bay City - Action was taken against the Monitor Sugar Company for pumping sugar beet processing sludge into the Columbia Drain leading to the Saginaw River. A court order required Monitor Sugar to pay a $10,000 fine and the plant operator was placed on probation. The company subsequently hired an environmental manager and built a pretreatment facility for sludge handling at a cost of several hundred thousand dollars.

Pinconning WWTP - In June 1984, a Final Order was issued to the Pinconning WWTP by the Michigan Water Resources Commission to comply with the conditions of its permit. Previously, a sludge spill from the WWTP had resulted in a fish kill. The facility was fined $10,000 and the enforcement action resulted in improvements in operation and development of an Industrial Pretreatment Program.

City of Saginaw and WWTP - A final order was issued to the City of Saginaw to institute sewer overflow improvements, that will cost the city $25 to $30 million over the next five years to implement.

City of Vassar - An Order and Stipulation was issued to the City of Vassar in May 1987 requiring the city to plan, design and construct WWTP improvements.

West Bay County Regional WWTP - In June 1984, a Notice of Violation was issued to the West Bay County Regional WWTP for failure to develop an IPP and also because the plant was in noncompliance with its effluent limits. This enforcement action resulted in the development of a very good Industrial Pretreatment Program. Now, Monitor Sugar Company discharges to the WWTP, which keeps very close track of their discharge.

4. Point Source Phosphorus Reduction Strategy

Michigan's point source phosphorus reduction strategy relies on reducing phosphorus discharges through the NPDES permit process. This permit system requires all major and minor municipal dischargers (except lagoon systems), and many industrial dischargers, to attain a level of 1.0 mg/l or less of phosphorus in their effluent discharge. Many dischargers have achieved this goal and many are discharging less than 1.0 mg/l of phosphorus. This has resulted in a net reduction in the amount of phosphorus annually discharged to Saginaw Bay from point sources of 9.3 metric tons, since the 1982 base year of the strategy (MDNR, 1987). Industrial facilities have achieved their target reduction of 6.9 metric tons. Municipal dischargers have decreased their annual load of phosphorus by 2.4 metric tons towards an objective of 4.5 metric tons. However, because only approximately 50% of the phosphorus load to Saginaw Bay is from point sources, the phosphorus goal for Saginaw Bay will not be met by point source controls alone, even if a discharge limit of 0.5 mg/l were imposed.

Combined sewers collect and convey both sanitary wastewater and stormwater to WWTPs and WWSLs. However, during storm events, or periods of wet weather, the combined sewer overflows (CSOs) release stormwater and untreated sewage directly to surface waters. It is estimated that up to 2.4 billion gallons per year overflow in the Saginaw Basin. Some municipal grant funding has allowed improvements to be made to combined sewers, such as sewer separation projects. However, because of the large expenditures to date for improvements to wastewater treatment processes, additional phosphorus reductions through improvements to combined sewers will only be required where feasible.

D. NONPOINT SOURCE REMEDIAL ACTIONS

1. Agricultural Best Management Practices

a. Management Practices

Agricultural management practices in the Saginaw Bay basin are undergoing changes designed to reduce the loss of top soil and the pollution of water resources by sediments, fertilizers and agricultural chemicals. Conservation tillage methods of all kinds accounted for up to 41% of the acreage planted in row crops, small grains and forage crops in some Saginaw Bay basin counties in 1986.

Agricultural best management practices (BMPs) are encouraged through a federally funded cost sharing and technical assistance program. The Agricultural Conservation Program (ACP) established in 1936, is administered by the USDA Agricultural Stabilization and Conservation Service (ASCS). The ASCS allocates funds among the 50 states for soil, water and forestry practices of long-term benefit. Technical assistance, including determinations of where conservation practices are practical and necessary, preparation of conservation plans, and design and lay-out of the practices is provided by the USDA Soil Conservation Service (SCS). Five percent of the total federal funds allocated goes to the SCS who also supervises and certifies proper installation of the practices.

Funding for Michigan fiscal year 1988 amounted to $4.325 million. Recent data on how this money was allocated among the best agricultural management practices for the Saginaw basin is not readily available. However, the ASCS did provide computer generated information on funding for 1980 and 1985 by county.

There are approximately 24 best agricultural management practices eligible to receive funds. Of these, 20 practices are designed to improve water quality (Table V-7). In 1980, total acreage under the ACP was 76,124 acres (Table V-7). In 1985, this increased to 79,210 acres. Although acreage increased in 1985, federal cost-share dollars decreased from $1,067,797 in 1980 to $1,026,701 in 1985.

The main reason for the decrease is the reduction in funding for animal waste control facilities. This agricultural practice is not directly tied to acreage values. In 1980, 63 animal waste control facilities were cost-shared versus only 13 facilities cost-share in 1985.

In 1980 and 1985, permanent vegetative cover establishment practices received the largest portion of cost share dollars. However, on an acreage basis, this practice ranked 4th for both years. Cropland protective cover practices ranked first by acres (34,141) in 1980, whereas reduced tillage systems ranked first by acres (29,396) in 1985 (Table V-7).

In 1980, Tuscola County received the highest funding ($236,320) compared to the other 22 counties in the Saginaw Bay basin (Table V-8). Gratiot County received the highest funding in 1985 ($93,230). Both

Table V-7. Areal Extent and Cost of Agricultural Best Management Practices Implemented in Saginaw Bay Basin Counties in 1980 and 1985.

Conservation Practice	1980 Acres	1980 $	1980 Rank Acres	1980 Rank $	1985 Acres	1985 $	1985 Rank Acres	1985 Rank $
Permanent Vegetative Cover Establishment	7,059	269,997	4	1	9,852	341,005	4	1
Permanent Vegetative Cover Improvement	143	2,085	10	11	133	3,086	9	11
Strip-cropping Systems	253	2,075	9	12	91	819	11	14
Terrace Systems	0	0			49	172	12	16
Diversions	1,102	20,624	7	7	1,558	51,350	6	7
Grazing Land Protection	20	248	11	13	0	0		
Windbreak Restoration or Establishment	2,162	17,349	5	8	331	7,817	8	9
Cropland Protective Cover	34,141	149,955	1	5	18,968	85,319	2	5
Farmsted and Feedlot Windbreak	0	0			96	6,097	10	10
Permanent Vegetative Cover on Critical Areas	297	4,288	8	9	15	2,357	15	12
Vegtative Row Barriers	0	0			23	213	14	15
Contour Farming	0	0			0	0		
Reduced Tillage Systems	20,611	189,632	2	3	29,396	150,859	1	3
Crop Residue Management	0	0			0	0		
No-Till Systems	0	0			10,493	115,961	3	4
Water Impoundment Reservoirs	0	0			0	0		
Sediment Retention, Erosion or Water Control Structures	8,855	161,221	3	4	7,077	150,997	5	2
Stream Protection	14	2,535	12	10	40	934	13	13
Sod Waterways	1,468	41,401	6	6	1,088	60,687	7	6
Animal Waste Control Facilities	63[a]	206,387		2	13[a]	49,028		8
Total Acres	76,124				79,210			
Total Dollars		$1,067,797				$1,026,701		

[a]Value refers to number of facilities funded, not acreage.

Table V-8. Areal Extent and Cost of Agricultural Best Management Practices Implemented in the Saginaw Bay Basin by County in 1980 and 1985.

	1980				1985				% of County
County	Acres	$	Rank Acres	Rank $	Acres	$	Rank Acres	Rank $	in Basin
Arenac	1,608	23,184	13	17	2,556	27,641	12	17	100
Bay	5,737	46,902	3	9	9,360	44,767	2	12	100
Clare	467	30,497	20	14	748	29,723	19	16	54
Genesee	678	26,978	18	15	3,674	33,818	7	14	100
Gladwin	487	15,670	19	20	917	14,315	18	21	100
Gratiot	2,375	36,109	7	11	15,010	93,230	1	1	63
Huron	11,384	146,855	2	2	7,657	79,531	3	3	63
Iosco	347	14,484	21	21	593	16,118	21	20	66
Isabella	2,150	41,595	9	10	1,950	50,984	15	10	100
Lapeer	1,157	51,020	15	6	3,143	66,705	10	5	71
Livingston	1,471	33,516	14	12	2,725	45,511	11	11	43
Mecosta	2,195	50,570	8	7	2,169	64,036	14	7	24
Midland	1,966	26,464	11	16	2,342	25,155	13	18	100
Montcalm	5,082	54,136	4	4	4,949	67,688	6	4	13
Oakland	1,060	16,667	16	18	1,061	24,520	17	19	18
Ogemaw	795	16,626	17	19	709	31,292	20	15	79
Osceola	2,050	63,486	11	3	1,690	51,755	16	9	5
Roscommon	49	1,629	22	22	49	3,474	22	22	11
Saginaw	3,889	33,510	5	13	3,380	37,296	8	13	100
Sanilac	3,441	53,028	6	5	3,332	90,254	9	2	32
Shiawassee	2,370	48,550	9	8	4,973	62,650	5	8	57
Tuscola	25,366	236,320	1	1	6,221	66,238	4	6	100

counties also had the highest number of acres devoted to these agricultural practices. Tuscola County had cost-shared agricultural BMPs on 25,366 acres in 1980 and BMPs were cost-shared on 15,010 acres in Gratiot County in 1985.

b. Animal Waste Control Facilities

Between 1983 and 1987, forty animal waste control facilities were constructed with cost-share dollars within Saginaw Bay basin counties (Table V-9). This has resulted in improved management of almost 70,000 tons of material, half of which is located in critical areas, that is those areas that are considered high priority for water quality management.

2. Nonpoint Source Phosphorus Reduction Strategy

a. Background

The Great Lakes Water Quality Agreement was signed in 1978 between the United States and Canada to reaffirm their intentions to restore and maintain the ecological integrity of the Great Lakes basin. In October 1983, Annex 3 of the 1978 agreement was expanded by agreement between the U.S. and Canada to confirm target phosphorus loads for the Great Lakes. Shortly thereafter, the U.S. created the Great Lakes Phosphorus Task Force through the Great Lakes National Program Office of the U.S. EPA. The purpose of the task force was to develop a phosphorus loading reduction plan, allocated on a state-by-state basis. The Michigan Department of Natural Resources is the lead state agency in development and implementation of Michigan's phosphorus reduction plan, with assistance from other agencies including the Michigan Department of Agriculture, Michigan State University Cooperative Extension Service and Agricultural Experiment Station, the USDA Soil Conservation Service, and USDA Agricultural Stabilization and Conservation Service. The focus of the phosphorus reduction strategy is Lake Erie and Saginaw Bay. Since Saginaw Bay is entirely within Michigan's jurisdictional boundaries, its entire target phosphorus load is allocated to Michigan.

The Michigan Phosphorus Reduction Strategy states that achievement of the target load for Saginaw Bay of 440 metric tons/year (from 1982 levels of 665 metric tons/year) will result in maintaining an in-bay phosphorus concentration of 15 ug/l and reduce other indicators of eutrophication (excessive algal growths, as well as taste and odor and filter clogging at water filtration plants). Because nonpoint phosphorus loads to Saginaw Bay are substantial, (approximately 50% of the total load), improvements in nonpoint source controls comprise a major portion of the strategy. There are several components to the nonpoint source strategy including fertilizer management, crop residue management and animal waste management.

b. Fertilizer Management

Agricultural soils are generally able to immobilize a certain amount of phosphorus through a process called adsorption. Adsorption involves a

Table V-9. Number and Cost of Animal Waste Control Facilities Constructed in Saginaw Bay Basin Counties, 1983-1987.

County	Number of Facilities	Cost-Shared Amount ($)
Arenac	9	30,041
Bay	3	9,934
Clare	6	16,948
Genesee	3	10,500
Gladwin	2	4,600
Gratiot	3	9,334
Huron	4	12,062
Iosco	-	-
Isabella	3	10,474
Lapeer	1	3,500
Livingston	0	0
Midland	0	0
Ogemaw	3	10,500
Saginaw	0	0
Shiawassee	1	3,500
Tuscola	-	-
Total	40	121,393

strong attraction between certain sites on a soil particle and phosphorus. When all the adsorbing sites on the soil particle are filled, further additions of phosphorus can result in direct phosphorus inputs to groundwater and surface water. In 1972, the average available phosphorus level in the Saginaw basin was 38 lbs/acre. Warncke (1987) found that this has increased to over 93 lbs/acre (Table IV-34). The maximum phosphorus adsorption capacity for Saginaw Bay basin soils ranges from 90 to 200 lbs/acre of phosphorus, depending on soil texture and organic matter content. It was found that agricultural producers are applying roughly twice the amount of phosphorus fertilizer that is necessary. The strategy recommends phosphorus fertilizer application be reduced to about 25 lbs/acre for cropland planted in corn. Based on a 1983 MDA estimate of corn production, this would significantly reduce annual phosphorus loads. The strategy also recommended more appropriate fertilizer application times and techniques and stressed soil conservation practices to reduce soil detachment and transport. Proper fertilizer management alone is expected to reduce phosphorus loads to Saginaw Bay by 30.8 metric tons/year (MDNR, 1987).

c. Residue/Resource Management

A 1982 National Resource Inventory disclosed that about 9.0 million tons of soil eroded from cropland in the Saginaw Bay watershed in 1982. Another survey in 1984 by SCS district conservationists reported that over 40 percent of the cropland in the Saginaw Bay drainage area is fall plowed, which contributes to surface erosion of exposed soils. However, progress to reduce erosion is being made.

In 1982, the base year for the phosphorus reduction strategy, residue management was conducted on 206,800 acres (MDNR, 1987). By 1986 this had increased to 405,389 acres with an estimated reduction in phosphorus load to Saginaw Bay of 42.2 metric tons/year (MDNR, 1987). Additional reductions of 34 metric tons/year were realized through the planning and installation of permanent and annual resource management systems. Combined, these two practices have accounted for an estimated phosphorus load reduction to Saginaw Bay of 76.2 metric tons/year, toward the strategy goal of 182.2 metric tons/year for these activities.

In the Saginaw Bay watershed, 7,280 hectares of critically eroding cropland has been taken out of crop production through the Conservation Reserve Program. The reductions in phosphorus loading, however, have not been determined at this time.

d. Animal Waste Management

A significant contribution of phosphorus to surface waters comes from animal wastes. Cattle, sheep and pigs total almost 500,000 animals within the Saginaw Bay and Lake Erie watersheds. Often, these animals are located near surface waters. Nonpoint sources of animal wastes include animal waste from pastures, confinement facilities and indiscriminate manure spreading. It has been estimated that over 3,700,000 metric tons of animal waste is produced in the Saginaw Bay and Lake Erie basins annually.

The 40 animal waste facilities that were cost-shared through the federal Agricultural Conservation Program between 1985 and 1987, are estimated to have helped reduce phosphorus loads to Saginaw Bay by as much as 9.15 metric tons/year, exceeding the phosphorus reduction strategy goal of 4.4 metric tons/year.

e. Future Phosphorus Reduction

A combination of residue and fertilizer management strategies are expected to be implemented in the Saginaw Bay watershed in the future. The impact is expected to double the amount of phosphorus reduction compared to residue management alone.

An additional 24 animal waste control facilities within the Saginaw Bay watershed are expected to be cost-shared through the Agricultural Conservation Program by 1990. Also by 1990, the compliance provisions of the 1985 Food Securities Act are to ensure that highly erodible cropland will be managed to reduce soil losses to tolerable levels.

To meet phosphorus goals by 1990, several additional programs are being proposed to accelerate nonpoint source efforts. These programs include technical assistance, cost-sharing (in addition to ASCS ACP program), and information/education programs. The counties of Bay, Huron, Saginaw and Tuscola have been identified as having numerous critical areas that contribute above average nonpoint source pollutant loads to surface waters. These counties have been prioritized to receive additional resources because they have the greatest potential for phosphorus reduction.

3. MDNR Nonpoint Source Pollution Management Strategy

The MDNR formalized its nonpoint source pollution initiatives in 1986 with the establishment of the Nonpoint Source Unit within the Surface Water Quality Division. The first major task of the unit was to fulfill the nonpoint pollution source assessment requirement of the federal Water Quality Act of 1987. The database created by the assessment will be used to develop and guide the Nonpoint Source Pollution Management Strategy and prioritize the future remedial actions needed to rectify water quality impairments. A draft of the strategy was completed in August 1988.

4. Michigan Act 307 Sites

a. River Sites

One hundred eighty-three sites of environmental contamination in the Saginaw Bay basin have been identified under the Michigan Environmental Response Act (PA 307 of 1982; Section IV). However, only 49 of these have documented impacts on surface water and of these, only a few affect, or potentially affect, the Saginaw River/Bay AOC.

Four rivers in the Saginaw Bay basin were listed in 1988 as Act 307 sites of environmental contamination including the Tittabawassee River downstream of Midland, the South Branch of the Shiawassee River downstream of Howell, the Pine River downstream of the St. Louis Reservoir, and the entire Saginaw River. Saginaw Bay itself is included in the Saginaw River site designation. Environmental impacts in the Pine River are defined under the Act 307 site designation as restricted to sediment contamination without effects on water quality. Action to address the Tittabawassee River site problems have been taken by Dow Chemical Company as described earlier in this section. The Saginaw River/Bay site is being addressed through a variety of MDNR evaluation actions and including an Act 307 funded 1988-1989 sediment contamination survey in the amount of $383,100. The Shiawassee River site is also a federal superfund site and an intensive multi-media assessment survey was conducted in fall 1987. The environmental contamination at the Shiawassee River site has not been found to affect water quality in the AOC. All these sites are discussed in Section III.

b. Sites With Documented Impact on the Area of Concern

C & O Railroad, Bay City - The C & O Railroad site was an old shipyard located on a peninsula that juts out into the Saginaw River. The facility is not longer in use, however, the company is willing to do the necessary cleanup. C & O Railroad has contracted with Marine Pollution Control (MPC) to investigate the materials remaining in approximately 40-100 barrels on site and eventually to remove the barrels. Barrels that were empty have been crushed and transported to a proper disposal facility. Of the remaining barrels, some are located directly in surface water and others pose a high risk for groundwater contamination. Soil contamination is apparent from observations that certain soil areas are black and shiney.

A MDNR December 1986 memo noted that this site received a low priority for U.S. EPA site inspection. The MDNR's major concern is identification of barrel contents and assessment of environmental transport. It has also noted that MPC seemed to be taking appropriate steps to address the situation.

General Motors CPC Plant, Bay City - The General Motors Chevrolet-Pontiac-Canada (CPC) Group Plant located in Bay City manufactures automotive transmission and engine parts. Prior to the mid-1970s, the plant used fire retardant hydraulic fluids in its die-cast hydraulic systems which were essentially 100% polychlorinated biphenyls (PCBs). Although the plant phased out usage of these fluids by the late-1970s, concern has remained about residual levels of contamination on the site, in the wastewater collection and treatment system and in the discharge to the Saginaw River. As a result, the NPDES permits issued to the Company in 1980 and 1985, contained a requirement that there be no net discharge of PCBs to the river. The 1985 permit also had a special condition that CPC submit a plant and schedule to eliminate or minimize the discharge of PCBs from any source actually or potentially capable of discharging through the permitted outfall.

In response to this permit requirement CPC submitted a PCB minimization and elimination plan in September, 1985. A Work Plan identifying known areas of PCB-contamination, areas requiring more investigation, and proposed remedial actions was submitted in February, 1986. The Work Plan identified silt in the stormwater retention pond as being contaminated with an average of 1,150 mg/kg PCBs, and a peninsula on the northwest corner of the site, known as the machine storage area, as being contaminated with an average of approximately 1,400 mg/kg PCBs (with a maximum sample result of 75,000 mg/kg). Recent actions have included the construction of a slurry wall to prevent PCBs in the machine storage area from reaching groundwater or the Saginaw River, plans to add a clay cap over the surface of the machine storage area, and a multi-media PCB monitoring program.

Prestolite, Bay City - This facility had high levels of PCBs and trichloroethylene contamination due to seepage from an old lagoon. Cleanup was handled by the U.S. EPA under RCRA and in 1987 the surface water discharge to the Saginaw River was rerouted to the Bay City WWTP.

Union Oil, Bay City - This oil storage area located alongside the Saginaw River has undergone a series of remediation actions. The majority of the crude oil sludges and contaminated soils were excavated, but a narrow slip of land immediately adjacent to the water could not be removed. Two sumps were placed adjacent to this strip of land to collect any contamination migrating from those soils. A groundwater monitoring program has also been implemented for the deeper aquifer. These systems will need to be monitored over a period of time to determine if there is any residual contamination and if further remedial action is needed. Contaminants that were identified at the site included cadmium, lead, benzene, toluene, xylene and several other organic chemicals.

c. Sites with Undocumented but Potential Impact on the Area of Concern

Bay City Middlegrounds, Bay City - Bay City Middlegrounds landfill was a municipal landfill located on an island in the Saginaw River. The landfill was never licensed and when contaminants were discovered on site (benzenes, toluene, xylene) the landfill became unlicensable under Michigan's Act 641. Bay City was unwilling to upgrade the landfill and in 1985 the facility was closed by mutual agreement between the MDNR and the municipality. Clean Michigan Fund money was used to properly install a leachate collection system, monitoring wells, and a landfill cap. Although no surface water contamination was ever documented, Saginaw MDNR district staff noted a definite hydraulic connection between groundwater below the site and the Saginaw River.

GMC Grey Iron Plant, Saginaw - The GMC Grey Iron Plan has one closed Type II landfill, one closed Type III landfill and one operating Type III landfill on site, alongside the Saginaw River. The closed Type II landfill is the primary area contributing to contamination at the site. Fluorides, heavy metals and PCBs have been identified as soil contaminants thus far. Monitoring wells were installed, and buried drums have been removed, by the company for a combined cost of well over $1.0 million. Surface water impacts have not been assessed, but are probable.

considering the site location along the river. Negotiation for further remedial actions by the company is being pursued by the MDNR.

Hartley & Hartley Landfill, Bangor Township - This site, owned by Wayne Hartley and sons was an old Type II landfill that operated in the 1960s and 1970s. Located in an isolated area near the Bangor Township Type II landfill and within the Tobico Marsh which drains into Saginaw Bay, the landfill was originally licensed under Michigan's Act 87. The site contained an area of sludge burning pits and several pits were dug in the marsh. The State of Michigan acquired 40 acres of the land as part of a late 1960's trespass suit settlement with Wayne Hartley. The landfill was never licensed under Michigan Act 641 and was therefore ordered to close.

Remediation at the site occurred after its purchase in the 1980s by SCA, now Waste Management, Inc. There were primarily three separate dump locations that were of concern to the state. Two small areas of concern along the site's west boundary were encapsulated by Waste Management at a cost of approximately $2½ million.

Prior to Waste Management's purchase of SCA, the company had spent approximately $5 million to encapsulate the large dumpsite along the eastern site border. In negotiating the 4 year consent agreement with SCA, the DNR gave up immediate remediation within the large dumpsite area, but was able to obtain a 30-year monitoring obligation from SCA.

The property obtained by the state has low level radioactive waste contamination. Act 307 funds totalling $246,000 have been spent so far for remedial investigation of this site by the state. The entire landfill site is not considered an imminent threat to public health due to its isolated location but is a potential source of low levels of contaminants to Saginaw Bay. This site has not scored very high under the Michigan Act 307 scoring system which prioritizes remedial action funding.

Hirschfields Salvage Yard, Bay City - Located adjacent to the Saginaw River and upstream from the GM-CPC Bay City Plant, this facility's PCB contamination was discovered by a federal Toxic Substances Control Act inspection in 1986. The extent of the surface water impact has not been determined, however the hydrogeology of the area indicates a groundwater/surface water hydraulic connection. Through negotiations with the MDNR, the company agreed to put in five to eight monitoring wells, although the MDNR feels many more are needed.

Sargent Docks and Terminal, Kochville Township - Sargent Docks is a CP gasification plant located along the Saginaw River just south of the Zilwaukee bridge. Polynuclear aromatics and oils have contaminated the soils along the banks of the river. Surface water impacts have not yet been documented, however surface water contamination from migrating oils is suspected. To date, the company has incurred remediation costs of approximately $200,000 to $400,000 for soil excavation and disposal.

Surath Bay City Scrap Yard, Bay City - Contamination at this site was discovered in 1985 and included volatile organic compounds and possibly PCB. Several drums were found on the property along the banks of the Saginaw River. In addition, extensive piles of metal shavings covered the site. At one time, the city spent approximately $100,000 to clean up the site for potential sale as part of a marina development nearby. The Saginaw MDNR district office was unsure of the extent of the cleanup, and to date, the marina development has not taken place.

SECTION VI - PROGRAMS AND PUBLIC PARTICIPATION

A. ADMINISTRATIVE AND REGULATORY PROGRAMS

1. Program Types

Programs for the management and regulation of water quality involve a multiplicity of agencies at virtually all levels of government. From township and village governments to federal agencies such as the U.S. Environmental Protection Agency (U.S. EPA) and the U.S. Department of Agriculture (USDA), there are literally dozens of programs, statutes, and ordinances that have the potential to measurably affect water quality. Further complicating the situation is the fact that responsibilities are often not clearly delineated among the various agencies involved, resulting in overlapping programs and duplication of effort in some cases. Within the Michigan state government, for example, there are over sixty programs that either directly or indirectly impact water resources (GLNRPC, 1987). These programs are spread out among six separate state departments, including the Departments of Natural Resources, Agriculture, Commerce, Public Health, Attorney General, and Transportation, and among numerous divisions within these departments. However, there are certain specific programs that are directly applicable to the goals and objectives of the Remedial Action Plan process, and it is those programs that will be discussed here. This discussion of regulatory and administrative programs relating to the RAP represents a preliminary assessment of programs with direct applicability to the advancement of possible remedial actions. Continual assessment of the range of potentially applicable programs may result in the expansion of this section in subsequent versions of this document.

There are three broad program categories including those that: 1) are primarily regulatory in nature, 2) provide financial assistance for water quality measures, and 3) provide technical assistance or technology transfer. With some degree of oversimplification, all public water quality programs can be attributed to one of these three areas.

2. Regulatory Programs

The primary regulatory program for the protection of water quality is the National Pollutant Discharge Elimination System (NPDES) permitting program. The legal authority for this program is drawn both from the federal Clean Water Act of 1972 (PL 92-500) and the Michigan Water Resources Commission Act (PA 245 of 1929, as amended). This program provides detailed standards and procedures for the issuance of NPDES permits in the Saginaw Bay drainage basin.

Under the provisions of the Clean Water Act, the State of Michigan has been delegated the authority to administer the NPDES permit process by EPA. The program is administered by MDNR's Surface Water Quality Division (SWQD), which provides extensive technical review and analysis of permit applications to the Michigan Water Resources Commission, which has the authority to grant permits. Permits, once granted, are in effect for a maximum of five years, after which they are reviewed and reissued or modified.

The water quality standards by which permit applications are judged are contained primarily in the administrative rules of the Water Resources Commission Act, which meet or exceed all applicable federal standards. These standards have been promulgated to protect the public health and welfare, to enhance and maintain the quality of water, and to protect the states natural resources (Section 323.1041, Michigan Complied Laws). Further, compatibility with the 1978 Great Lakes Water Quality Agreement is also stated as an objective. The water quality standards apply to all types of pollutant producing substances, including radioactive materials, dissolved solids, taste or odor producing substances, and others, but the provisions most directly applicable to the RAP process are those concerning toxic materials (Rule 57) and plant nutrients (Rule 60).

Rule 57 states that toxic substances may not be present in Michigan waters at levels that may be harmful to humans, plant and animal life, or any designated uses of those waters. The toxic substances to which Rule 57 applies are those listed on the Michigan Critical Materials Register, U.S. EPA designated priority pollutants, and any other toxic substance determined by the Water Resources Commission at any specific site.

The discharge of plant nutrients, primarily phosphorus, is governed by standards set forth in Rule 60, which establishes a maximum monthly average discharge of phosphorus of 1 milligram per liter, and allows for higher or lower monthly averages as deemed necessary by the Water Resources Commission. Provisions to prevent nuisance growths of aquatic weeds are also included.

It is important to note that the water quality standards reviewed here are to be regarded as minimum acceptable standards. As described in Rule 90, water quality must generally meet or exceed these standards at least 95 percent of the time, except in mixing zones, and as prescribed in Rules 50 and 82, which outline some of the deviations from the standards which are allowed by law. Rule 98 designates certain waters of the state as being under special antidegradation regulations, where no action of the WRC may result in a reduction of water quality in designated waters except when such degradation meets certain conditions. Great Lakes waters are designated for antidegradation protection, but the effects of discharges in connecting waters and tributaries are not to be considered. Thus, discharges directly to the waters of Saginaw Bay would come under the provisions of Rule 98, but discharges to the Saginaw River would not.

One of the more important aspects of the NPDES permitting process is the incorporation of industrial pretreatment requirements. The Industrial Pretreatment Program (IPP) was developed in recognition of the fact that some industrial operations, rather than maintain their own wastewater treatment facilities, route their wastewater through Publicly Owned Treatment Works (POTWs). This industrial wastewater may contain pollutants that the POTW does not have sufficient capabilities to adequately treat. To alleviate this problem, any Michigan municipality who operates a wastewater treatment plant that receives a discharge from an industrial categorical discharger must develop an industrial pretreatment plan that details how the problem will be addressed. Industrial users of POTWs are required to comply with national standards, developed by EPA, local requirements developed by the community operating the POTW, and reporting and self-monitoring requirements developed by the state. National standards have been developed for 26 basic industrial categories, and involve over 125 toxic pollutants commonly discharged by these industries. There are currently 18 major POTWs within the Saginaw Bay drainge basin that have been required to develop an industrial pretreatment plan.

The transport, storage and disposal of hazardous wastes are controlled by programs developed under the Hazardous Waste Management Act (PA 64 of 1979). Land waste disposal sites are also regulated under the federal Resource Conservation and Recovery (RCRA) Act of 1976. Responses to sites of contamination are part of two programs, the U.S. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; PL 96-510 of 1980), commonly referred to as "Superfund" and the Michigan Environmental Response Act (MERA; PA 307 of 1982), provide some mechanisms for assessing responsible parties for the clean-up of contaminated sites. Both of these programs, however, make their greatest contribution by financing the high cost of remedial measures when no responsible party is found to assume liability.

Air pollution is addressed through a permitting process similar to the NPDES process, under the authority of the federal Clean Air Act of 1970 (amended in 1977), and the Michigan Air Pollution Act (PA 348 of 1965). The regulation of air quality may have substantial impacts on water quality, particularly when pollutants that enter aquatic systems through atmospheric deposition are involved.

Soil erosion, primarily from construction sites, is regulated through the Soil Erosion and Sedimentation Control Act (PA 347 of 1972), which establishes performance standards, to be applied at sites falling under the purview of this act, regarding the use of suitable erosion control technologies. This program is administered by MDNR through local designated enforcement agencies.

The use of pesticides is addressed through the Michigan Pesticide Control Act (PA 171 of 1976), which has requirements for registration of pesticide products, certification and licensing of pesticide applicators, and investigations of suspected pesticide problems. Pesticide programs are under the jurisdiction of the Michigan Department of Agriculture, which also has programs for emergency response in cases where contaminants may enter food chains.

Dredge and fill activities are controlled on the federal level by sections 401 and 404 of the Clean Water Act, which regulates the discharge of dredged or other fill material into navigable waters and their adjacent wetlands. These activities are also covered under Section 10 of the federal Rivers and Habors Act of 1899.

Wetlands in Michigan are also protected from alteration under a variety of state laws. The most recent and comprehensive of these is the Wetland Protection and Management Act (PA 203 of 1979). Others are the Shorelands Protection and Management Act (PA 245 of 1970), which currently protects about 120 miles of designated shoreline along Saginaw Bay, the Great Lakes Submerged Lands Act (PA 247 of 1955), which regulates activities along the Great Lakes shorelines, the Inland Lakes and Streams Act (PA 346 of 1972), which regulates the physical alteration of adjoining lands, and the Michigan Environmental Protection Act (PA 127 of 1970).

There are some provisions of the federal Food Security Act of 1985 (PL 99-198), commonly referred to as the "farm bill", which could be regarded as regulatory in nature. These provisions employ a concept known as "cross-compliance" which ties the payment of price supports, storage facility loans, and disaster assistance, to the utilization of approved conservation practices on highly erodible lands. The provisions of this bill may reduce the contribution of agricultural sources to eutrophication problems in Saginaw Bay. These programs are administered primarily by agencies of USDA.

3. Financial Assistance Programs

The federal government, through EPA, bears a large portion of the financial burden for many of the programs discussed in the regulatory section above. According to Dean (1985), a substantial portion of the MDNR budget for administrating the NPDES permit program, hazardous waste programs, and air quality programs comes ultimately from EPA, particularly for those programs that EPA has delegated to the appropriate state agency. Much of the water quality planning activity conducted in Michigan is now funded by the federal government under Section 205(j) of the Clean Water Act. An extensive water quality planning effort was funded under Section 208 of the Clean Water Act in the period 1975-87, with expenditures in the East Central Michigan Planning and Development Region alone exceeding $1,000,000. In addition to these programs, several other federal financial assistance programs merit consideration here because they make substantial contributions to the advancement of RAP related objectives.

Section 188 of the Clean Water Act, a new section added by the 1987 amendments, authorizes funding for five years for study and demonstration projects relating to the control and removal of toxic pollutants in the Great Lakes ecosystem. This new program is to be administered by EPA's Great Lakes National Program Office (GLNPO) located in Chicago. In selecting projects to be funded under this new program, priority consideration is to be given to five particular locations in the Great Lakes, including Saginaw Bay. While it is not known precisely how this new program is to be administered at this time, it is anticipated that it will make a substantial contribution to the remediation of existing toxics problems in the Saginaw River/Saginaw Bay Area of Concern. Existing GLNPO programs, including research and interagency coordination functions, are also maintained by the 1987 amendments.

Since passage of the Clean Water Act in 1972, the federal government has made large contributions to improving the water quality of the Saginaw Bay drainage basin through grants for the construction of municipal wastewater treatment plants. This grant program supplied 75 percent or more of the total cost of plant construction to municipalities meeting the eligibility requirements, including consistency with the areawide 208 water quality plan. Current allocations under the 1987 amendments to the Clean Water Act for the State of Michigan total approxiamtely $104 million for fiscal years 1987 and 1988 (Copeland, 1986). Actual appropriations may be somewhat lower than this level.

Financial assistance is the major mechanism by which nonpoint source pollution problems are addressed, primarily those associated with agriculture. The USDA, through its state level offices and county level Soil Conservation Service (SCS) and Agricultural Stablization and Conservation Service (ASCS) offices, provides direct cost-share payments though the Agricultural Conservation Program (ACP). The ACP, which has been in existence, in various forms, since the early 1930s, provides partial reimbursement to farm operators who voluntarily install approved conservation practices on their lands. These practices may be structural in nature, such as grade control structures or terraces, or management related, like the various forms of conservation tillage. Since 1980, practices funded under ACP have been increasingly conservation/water quality related, as steps were taken to eliminate payments for production related activities incompatible with the intent of the program (Rasmussen, 1982). Many of the practices are implemented in the Saginaw Bay basin pursuant to the guidelines presented in the 1985 State of Michigan Phosphorus Reduction Strategy for the Michigan Portion of Lake Erie and Saginaw Bay.

The Clean Water Incentives Program (CWIP), jointly administered by MDNR and MDA, was modeled after the ACP, with several important variations. This program provided planning grants, in amounts not to exceed $50,000, to local units of government to develop detailed nonpoint abatement plans for individual watersheds. Planning grants were available for both rural and urban nonpoint projects, and were to be followed with three consecutive years of implementation grants not to exceed $100,000 annually to implement approved plans. Much of the implmentation grant monies were to be used for cost-share programs closely paralleling ACP, and required a minimum of 20 percent in non-CWIP matching funds. Continued funding for CWIP planning grants and for urban implementation grants has been deleted from the MDNR and MDA budgets for fiscal year 1988, leaving the future of this program very uncertain. Funding for rural implementation grants has remained in the MDA budget, but there have been no approved plans developed in the Saginaw Bay drainage basin, so the applicability of this program at present is negligible.

The remedial actions funded under Superfund and the Michigan Environmental Response Act (PA 307 of 1982) represent a major source of financial assistance. When no responsible party is available in a case of environmental contamination, these programs assume the financial responsibility for remedial actions.

4. Technical Assistance/Technology Transfer Programs

Technical assistance is a major factor in the control of nonpoint sources, particularly from agriculture. The primary vehicle for the provision of technical assistance is the county level Soil Conservation District, a program jointly administered by USDA, through SCS, and the individual counties. In general, SCS provides a District Conservationist and occasionally some additional staff, and counties provide support staff and some funding.

The Soil Conservation District (SCD) program is administered through the Michigan Soil Conservation Districts Act (PA 297 of 1937, as amended) by MDA and a state soil conservation committee consisting of the director of MDA (or a designee), the Dean of the College of Agriculture and Natural Resources at Michigan State University, the director of MDNR (or designee), and four farm operators appointed by the Governor from among the Boards of Directors of the individual conservation districts in the state. The committee serves in an oversight capacity, assisting the districts in their various functions, coordinating multi-district activities, and to act as a liaison with USDA.

SCDs are governed by a Board of Directors consisting of five members, three are elected by "land occupiers" within the district and two are appointed by the state soil conservation committee. The terms served by directors varies according to the provisions of the Act. The SCDs are an officially recognized governmental unit of the State of Michigan, and have broad powers to conduct research, acquire property and easements, enter into contracts, administer projects related to soil conservation and erosion control, and engage in other activities to promote soil conservation and resource management, so long as these activities are consistent with the intent of the Act.

The most important activity undertaken by the SCD in relation to the objectives of the RAP process is the detailed conservation planning, with assistance from MDA and SCS, done in cooperation with individual landowners. Individual conservation plans are developed for field scale farming operations designed to minimize soil erosion and water quality degradation from land use activities. Detailed conservation plans for highly erodible lands are mandated by the 1985 Farm Bill in order to maintain eligibility for price supports. These conservation plans must be completed by 1991.

A formal relationship exists between the SCDs and county level ASCS offices for the administration of the ACP. Five percent of the annual appropriations for ACP are transferred to the SCD by ASCS to cover the costs of technical reviews of cost-share requests, which are required under project guidelines.

The Cooperative Extension Service (CES), operated by Michigan State University under the Land Grant College Program, is a research and technology transfer organization that maintains offices in all Michigan counties. The CES is very active in the dissemination of new agricultural technologies to farm operators, many with substantial water quality ramifications. The primary vehicle for information dissemination is an extensive catalog of free or low cost bulletins, which give detailed treatment of specific topics. The current catalog of CES bulletins lists such topics as soil conservation policy, pesticide and fertilizer management, conservation tillage, manure management, and water quality. The Michigan Sea Grant College Program also maintains the Sea Grant Extension program, in conjunction with CES, which disseminates more specific water quality information, including bulletins on toxic contaminants in fish, fact sheets for the Great Lakes, and other related topics.

5. Administrative Programs

Phosphorus reduction efforts for Saginaw Bay are currently specifically addressed by two administrative programs. One is a multiagency program outlined by the 1985 State of Michigan Phosphorus Reduction Strategy for the Michigan Portion of Lake Erie and Saginaw Bay. The other is the MDNR Nonpoint Source Pollution Control Management Strategy, which was released in initial draft form in August 1988.

B. PUBLIC PARTICIPATION

1. Process

Because remedial action planning is a relatively new phenomenon, there was an absence of suitable models on which to base a structured public participation program for the Saginaw River/Bay RAP. However, all parties involved in the drafting of the plan were aware of the need for the development of suitable mechanisms for incorporating the public into the planning process. Recognizing this need, initial discussions were held among the East Central Michigan Planning and Development Region (ECMPDR), the Michigan Department of Natural Resources (MDNR), and the planning team from the University of Michigan and the National Wildlife Federation (UM/NWF). This resulted in a framework for public participation that included a series of general public meetings and a series of more narrowly focused meetings called "Key Group" meetings, where invitations were extended to pre-selected representatives of special interest groups to meet with ECMPDR staff. Subsequent discussions led to the decision to assemble a public review body, known as the Saginaw Basin Natural Resources Steering Committee, and also to include coverage of RAP related topics at "A New Way for the Bay: A Workshop for the Future of Saginaw Bay," a conference that was held at Delta College on March 5, 1987.

The rationale behind the selected course of action had three important elements: to provide an indication of public concerns related to Saginaw River and Saginaw Bay water quality, to expose the public to the goals and procedures of the Remedial Action Plan process, and to provide mechanisms to involve the public in developing the RAP. All activities were considered necessary to insure that appropriate opportunities for public input were available.

2. Initial Public Meetings

The initial opportunity for public participation in the RAP process came at a public meeting conducted by MDNR staff on September 16, 1987 in Bay City. At this meeting, MDNR staff described the Saginaw River/Bay RAP process, the major issues that would be addressed in the RAP, and invited the approximately 80 people in attendance to express their opinions about what water quality issues were of most concern to them in the Saginaw River/Bay system. Many comments received at this meeting have been addressed in the RAP and a written response to each question is presented in Appendix 1.

Great Lakes United, an international organization dedicated to the conservation and preservation of Great Lakes resources, conducted a public hearing in Auburn on September 25, 1986 to gather public comment on the U.S.-Canada Great Lakes Water Quality Agreement. While this hearing was not specifically connected with the RAP process, the comments received were reviewed and incorporated in the RAP when appropriate.

The second phase of public participation in the Saginaw River/Bay RAP was a series of five open informational meetings conducted by staff of ECMPDR and UM/NWF at selected locations around the bay basin. These meetings were informal in nature and consisted of a brief slide presentation introducing the Saginaw Bay drainage basin and some of the water quality issues to be addressed in the RAP, a general overview of the goals and procedures of the Remedial Action Plan process, and an extensive open discussion of the concerns of meeting attendees and how these concerns would be addressed in the RAP. This meeting format was very successful in initiating discussion and although attendance was somewhat low, the caliber of the public input supplied at the meetings was high.

To publicize the meetings, a general news release was sent to 36 local newspapers, radio stations, and television stations in late December - approximately three weeks prior to the first meetings. Direct contact with selected media representatives in the immediate area of each respective meeting was made approximately one or two weeks prior to the meeting date to remind the local press that the meetings were coming up and a press announcement would be appreciated. Additional information was supplied to media contacts when requested.

The five sites selected were Bay City (January 15, 1987), Au Gres (January 22), Caseville (January 29), Caro (February 5), and Midland (February 12). A total of 51 people completed the registration forms at the five meetings and actual attendance (including individuals who did not register) was approximately 60-65. Attendance was likely reduced at the Au Gres and Caseville meetings due to inclement weather.

Because the discussions at the meetings were informal in nature, discussion topics included many subjects that were not directly addressable within the scope of the RAP, including such issues as wetland preservation, fisheries and wildlife management, water level impacts, and flood control. However, several issues were raised that had relevance to RAP activities. At all meetings, participants felt that they lacked sufficient information on the nature and impacts of toxic materials in the environment to formulate valid and informed opinions on the subject. It was stated on several occasions that the only consistent source of such information was by the media. Suggestions for bridging this information gap included the development of school curricula on toxics issues, non-technical workshops for the general public, and the preparation and distribution of printed materials explaining toxic material transport and impacts in non-technical language.

A great deal of apprehension was expressed surrounding the issuance of fish consumption advisories in the waters of the Saginaw Bay region. Many meeting participants did not fully understand the procedures used to determine whether an advisory was warranted or precisely what the advisory means to the sport angler. Others perceived the advisories as scientifically unfounded and detrimental to the tourist industry in the area. Still others believed that the advisories were prematurely lifted or relaxed to enhance the tourist industry. The only point upon which general consensus was reached is that the current methods by which information regarding fish consumption advisory information is transmitted to the public - general news releases and a brief narrative provided to purchasers of sport anglers licenses - are inadequate.

Another topic that was raised several times was the lack of comprehensive basin-wide management. At both Au Gres and Caseville, meeting participants expressed dismay that the water quality of Saginaw Bay was affected by activities that take place in river basins tributary to the bay and that they had no influence on the management of those upstream areas. They felt that there should be a basin-wide authority that could address these concerns.

One final issue that was present, if not explicit, at all five public meetings was the general perception that the resource management agencies, whether they are regional, state or federal, are generally unresponsive to the needs and desires of the local citizens. Whether this perception is well founded or not, it undermines public support of RAP activities. Public support for the goals and objectives identified in the RAP process is an important element that may have a profound influence on the success of the program.

It is important to note that the opinions expressed at the five public meetings reflects only a general summary of the comments consistently expressed by meeting participants. It is not intended to be a comprehensive analysis of public opinion and should not be interpreted as such. All comments directed to the water quality issues that are addressed in the RAP were considered in the development of RAP recommendations.

3. Key Group Meetings

To supplement the comments obtained at the public meetings, ECMPDR staff conducted a series of key group meetings in the months of March and April, 1987. The rationale behind the key group meeting was to bring together a group of interested parties representing a single point of view, or several closely allied points of view, and allow them to comment on the RAP process and the issues addressed therein, assuming that the meeting participants might be more candid in the absence of substantially conflicting opinions. An organizational/public participation consultant was retained by ECMPDR to handle the arrangements for all key group meetings and there were limited press releases announcing the meetings. Over 500 individual invitations were mailed out to potential attendees. Initially, there were five key group meetings scheduled with the representatives of agriculture, local commerce, local government, conservation and educational organizations, and industry and manufacturing. Poor attendance at the agriculture, industry/manufacturing, and local commerce meetings caused these meetings to be rescheduled. A mail survey approximating the meeting format was included with the invitations for the rescheduled meetings. In all, via returned surveys and meeting participation, 57 individuals shared their views with ECMPDR staff.

All key group meetings employed the same format. Following a brief introduction to the RAP process, meeting participants were asked to first prioritize the five issues identified by the International Joint Commission as problems in the Saginaw River/Saginaw Bay Area of Concern (IJC, 1985): toxic organics, eutrophication, contaminated sediments, fish consumption advisories, and impacts on human and aquatic life. Participants were then asked to rank, in order of importance, the four pollutant sources identified by IJC as critical: in-place pollutants, industrial point sources, municipal point sources, and rural nonpoint sources. Some participants chose to add additional pollutant sources to the list and include them in the rankings. Finally, meeting attendees were asked to list up to five negative aspects of the five critical issues listed above. Meeting attendees either worked individually or in small working groups, depending upon the number of people attending the respective meetings. People at the key group meetings were frequently reminded that the ECMPDR staff was not assuming any level of technical expertise on their part, but were primarily interested in their opinions and perceptions of the problems under consideration.

The key group meeting for representatives of industry and manufacturing was held on the afternoon of March 30, 1987. Low attendance caused the meeting to be repeated on the evening of April 28. The total number of people representing industry and manufacturing, including those who responded to the mail survey, was seven. Members of this key group declined to rank the five issues identified by IJC, feeling that they did not have sufficient information to render supportable judgement. Among the pollutant sources, municipal point sources were ranked highest, followed by rural nonpoint sources, industrial point sources, and in-place pollutants, respectively. Because the listing of negative aspects of the five issues identified by IJC was rather open-ended, it is difficult to relate the responses in specific terms. However, several categories of statements were apparent. Most respondents indicated that the lack of technologically feasible and economically attractive options for remediation of existing water quality degradation, and the prevention of further degradation, was a serious problem. Nearly all recognized that the issues in question have very serious impacts on both human health and that of the aquatic organisms that inhabit the waters of the bay region. It was consistently stated that the water quality problems experienced in the Saginaw River and Saginaw Bay contributed to a negative image for tourism, particularly sport fishing, in the area.

Representatives of agriculture were gathered on March 31 and April 30 to discuss their views with the ECMPDR staff. Thirteen people attended the two meetings. Impacts on human and aquatic life was the issue selected as the highest priority among the five issues presented, followed by toxic organics and contaminated sediments. No priority was given to either eutrophication or fish consumption advisories. When ranking pollutant sources, the agriculture group chose to add two additional categories, municipal nonpoint sources and other nonpoint sources, to the original list of four. These new categories were ranked as the highest priority, with equal scores, followed in order by rural nonpoint sources, industrial point sources, and in-place pollutants. Municipal point sources, one of the four original categories, was unranked. Discussions of the negative aspects of the five critical issues followed generally along the same lines as the industry/manufacturing key group, with two notable exceptions. First, several respondents identified the inherent problems of resuspending contaminants during dredging operations, and the high cost of dredging operations, as high priority issues. Second, in their responses and during the discussions that followed the prioritization of negative aspects, many meeting participants indicated they felt that agriculture had unfairly been singled out as the primary uncontrolled pollutant source in the Saginaw Bay drainage basin. Some stated that they did not regard the contribution of agricultural operations to water quality degradation as in any way significant. This perception, if not addressed, could develop into a substantial barrier to the implementation of remedial measures to control rural nonpoint source pollution.

Meetings scheduled for representatives of the local commerce key group did not result in acceptable attendance. Despite the large numbers of invitations mailed out, only four people attended the first meeting held on the afternoon of April 6, one of whom was a reporter from a local radio station. No representatives of local commerce attended a subsequent meeting scheduled for the evening of April 27. Those who attended the first meeting ranked contaminated sediments as the highest priority critical issue, toxic organics was ranked second, and the remaining three were unranked. In the prioritization of pollutant sources, the additional category of other nonpoint sources was added to the original four, and was ranked highest, followed by industrial point sources. Municipal point sources, in-place pollutants, and rural nonpoint sources were unranked. The negative impacts that water quality problems had on the tourism industry was regarded as the highest priority critical issue, followed by the high cost of pollution abatement and remedial activities.

Representatives of conservation groups met with ECMPDR staff on April 13. Twenty people attended this meeting and a great diversity of opinion was expressed by the participants. Toxic organics was the issue ranked highest in priority followed closely by contaminated sediments, eutrophication, impacts on human and aquatic life, and fish consumption advisories. Industrial point sources were ranked as the most critical pollutant source followed by municipal point sources, in-place pollutants, rural nonpoint sources, and other nonpoint sources, respectively. Four primary themes emerged from the listing of negative aspects of the five key issues discussed. First and foremost was the cost of restoring degraded water quality and preventing further degradation. Second, the accuracy and reliability of fish consumption advisories was questioned, and their detrimental effect on the tourism industry was mentioned frequently. Several participants suggested that waterfowl also be tested for contaminants and similar advisories be issued if warranted. A third theme, which was common among participants, was a perceived lack of certainty surrounding the sources, transport and ultimate fate of many of the pollutants of concern. Finally, it was suggested that there was a glaring need for sound, understandable public information regarding the region's water quality problems, particularly the potential human health effects of the toxic pollutants present in the Saginaw Bay drainage basin.

Local government representatives constituted the fifth group that met with ECMPDR staff. Thirteen people attended a meeting held on April 15. Impacts on human health and aquatic life was the issue that was overwhelmingly selected as the highest priority, with toxic organics and contaminated sediments ranked equally as the second highest priority. Eutrophication and fish consumption advisories were unranked. Among pollutant sources, rural nonpoint sources was ranked first, again by a wide margin, followed by industrial point sources and in-place pollutants tied as second priority, and municipal point sources and other nonpoint sources tied as third priority. When listing negative aspects associated with the five critical issues, local government representatives indicated their most pressing concern was the potential health effects of toxics in the waters of the region, both from the perspective of domestic water supplies and the consumption of contaminated fish. The second issue emphasized was the negative effects of poor water quality on the economic well-being of the region, including not only the obvious effects on the tourism industry but also the more subtle effects that a poor image may have on overall quality of life and the area's potential for increased economic development. Finally, members of this key group were sensitive to the high costs of remedial actions and understandably concerned that the local units of government may be called upon to bear some of the financial burden. There was also some discussion of the negative impacts of increased regulation on the region's economic base. One of the working groups at this meeting offered, as a postscript to their prioritization of the negative aspects of toxic organic pollutants, the following caveat: "Stronger regulations on industry may likely be resisted due to high unemployment in (the) local area. Don't regulate for fear that industry will leave."

Summarizing the input from the five key group meetings is important not because the comments offer any specific recommendations for courses of action that the RAP may pursue, but rather because the key groups provide some indication of the status of knowledge and range of opinion surrounding the relevant issues addressed in the RAP. Though the opinions and concerns voiced by the various key groups may not be based upon a full and complete knowledge of RAP issues, they are real perceptions and must be carefully considered in order to develop and implement successful remedial actions in the RAP.

4. Saginaw Bay Workshop

Although the RAP and the "New Way for the Bay: A Workshop for the Future of Saginaw Bay" were originally conceived and developed as separate projects, a strong relationship developed between them while both were in the initial planning phases. The workshop was held at Delta College on March 5, 1987. Over 230 people attended the all-day information/issues exchange among the public and professionals in resource management, environmental protection and economic development. Because the workshop was coordinated in part by ECMPDR staff, it was natural that a strong RAP component developed within the workshop format.

Incorporation of the RAP program into the workshop was accomplished in three major ways. First, speakers and facilitators who participated in the workshop's many sessions were requested to relate material covered to the RAP whenever possible. This was very successful in the working sessions relating to Environmental Quality, one of the workshop's three main subject areas, and to a lesser extent in the remaining two; Resource Management and Economic Development. This approach generated a great deal of public interest in the RAP, some of which carried over into the series of key group meetings just discussed. The second RAP activity conducted at the workshop was a forty-five minute special session held in the afternoon, which was devoted entirely to the RAP process and the issues addressed in the Saginaw River/Bay Area of Concern. This session, jointly conducted by ECMPDR staff and members of IJC's Science Advisory Board, consisted of a slide presentation, an overview of the Saginaw River/Bay RAP, and a question and answer period. The RAP session was attended by approximately 60 workshop participants. Finally, a brief RAP update outlining the progress of the planning activities was prepared by ECMPDR staff and included in the information packets provided to all workshop participants. This update included the same basic information that was presented at the special session, enabling those unable to attend that session to come away from the workshop with a basic understanding of the RAP process and the problems it addresses.

5. Saginaw Basin Natural Resources Steering Committee

Throughout the implementation of the initial public participation phase of RAP activities, the process was hampered by the absence of any basin-wide public advisory or interest groups that could address the relevant issues in a comprehensive fashion. Clearly, the existence of such a group would facilitate public participation in the planning process, and to this end, at a February 1987 meeting among staff members of MDNR's Surface Water Quality Division, Office of the Great Lakes, and ECMPDR, preliminary plans for the development of such an organization were begun. The task of organizing this group, which eventually took the name Saginaw Basin Natural Resources Steering Committee (SBNRSC), was conducted by ECMPDR and its organizational/public participation consultant.

The responsibilities of the SBNRSC fall in four general areas; to provide organized public review of, and input to, the RAP; to act as a public advisory body to agencies that are responsible for the implementation of remedial measures outlined in the RAP; to provide a public forum for other resource management issues outside the scope of the RAP process; and, to conduct and promote public information and education activities on natural resource topics. Beginning with the initial organizational activities, it was stressed that the SBNRSC would, without interference from any regional or state agency, be free to address any and all natural resource issues it desired. Activities related to the development, review, and implementation of the RAP would constitute only a small part of the group's potential activities.

The structure selected for the SBNRSC was a 47 member committee composed of 37 representatives from the 22 counties in the Saginaw Bay drainage basin, and 10 at-large representatives of regional and statewide organizations. Counties received either one or two seats on the committee, depending on the percentage of their land area that fell within basin boundaries. Those counties with 50 percent or more of their land area within the basin were allowed two representatives, while those with less than 50 percent received one representative. The 10 at-large seats were allocated to representatives of organizations selected by ECMPDR staff, in consultation with MDNR, with the goal of providing a diversity of interests and perspectives.

The responsibility for selecting individuals to represent the various counties was given to the County Boards of Commissioners. The Board Chair in each county was contacted by mail by ECMPDR staff, with a request that the County Board seat the appropriate number of representatives on the SBNRSC. The request was accompanied by an information packet outlining the proposed goals and responsibilities of the committee and also a list of individuals who had volunteered to serve on the committee, if any such individuals from that particular county were known to ECMPDR staff. In the accompanying information, it was made clear to the county boards that certain special interests merited representation on the SBNRSC (ie., agriculture, industry, conservation groups, and others), and that they should consider which interests were appropriate for their particular county. County boards were then free to select anyone of their choosing to represent their interests, with the only restriction being that only one representative from any county could be an elected official. It was anticipated that by allowing the individual counties to select their own committee members, reflecting their own interests, balanced representation among the various interest groups would be achieved. The 10 at-large seats were used to offer representation to any groups omitted in the county selection process.

The SBNRSC began its RAP review activities in August 1987, following the initial organizational meeting held in July. The committee formed work groups to deal with the review of specific topic areas in the September 1987, RAP first draft. Participation in these work groups was available to the general public on request, which ensured that any individual or group that had expressed a desire to participate in the review process would have the opportunity to do so. Thus, the SBNRSC allowed for the broadest public participation possible, while still maintaining a manageable organizational structure.

The SBNRSC submitted a substantially expanded remedial actions section to MDNR in April 1988. The MDNR modified the new remedial actions section somewhat, based on comments received from other sources and knowledge of existing environmental programs, and returned the modified version to the SBNRSC for review. At a July 1988 SBNRSC meeting attended by MDNR staff, the remedial actions section was further modified, following which it was formally approved by the SBNRSC. At that same meeting, the committee began the process of implementing several of the RAP actions for which it was designated as being responsible for. These activities include the preparation of a non-technical lay summary of the RAP, the production of a quarterly newsletter, and the formation of a separate nonprofit corporation to seek donations and provide funding for some of the remedial actions.

Staff support for the SBNRSC is being temporarily provided by ECMPDR using both its funds and a grant from MDNR through August 1989. Future funding support for the committee is presently being sought to ensure the committee's continued viability throughout and beyond existing RAP activities.

6. Technical Work Group

A scientific group was also formed to provide both technical review of the RAP and formal input on the RAP process from agencies and organizations potentially affected by RAP activities. This group, known as the Saginaw River/Bay RAP Technical Work Group, is composed of approximately 30 representatives, with expertise in various subject areas, from local, state and federal agencies. The membership includes ECMPDR, SWF, MDNR, IJC, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, National Oceanographic and Atmospheric Administration, U.S. Geological Survey, U.S. Soil Conservation Service, U.S. Army Corps of Engineers, Michigan Department of Public Health, Michigan Department of Agriculture, University of Michigan, and several environmental consulting firms. The group first convened in November 1986 to discuss what environmental data was currently available for inclusion in the RAP. Since then, the Technical Work Group has reviewed the Environmental Setting, Problem Description, and Sources and Loads sections of the RAP during the development stage of these sections, and the July 1988 draft of the Remedial Actions Section. Substantial comment is still needed from this group following distribution of the RAP to work group members for review in September 1988.

7. Review of the RAP First Draft

The first draft of the Saginaw River/Bay Remedial Action Plan was distributed for review on September 1, 1987. It consisted primarily of data compilations, which formed the basis for beginning the process of developing specific remedial actions to address the eutrophication and toxic material problems in the Saginaw River and Saginaw Bay. The MDNR provided a complete copy of the RAP to each member of the Saginaw Basin Natural Resources Steering Committee and requested that the Steering Committee provide substantial input in designing and prioritizing remedial actions. Input was also requested from the general public and was solicited through a public meeting and general public participation in steering committee work groups. Complete copies of the RAP were sent to the county commission office of each of the 22 counties in the Saginaw Bay basin and were available for public review. The Executive Summary and Remedial Actions portions of the RAP were mailed to people who had attended previous public meetings, key group meetings and/or expressed interest in the RAP process.

Several generalized remedial actions were proposed in the first draft of the RAP. These actions were proposed on the basis of public input to date and review of the technical data. They formed a basis for discussions in the review process during which some activities were expanded, others modified, and many additional actions added.

In September 1987, the Michigan Water Resources Commission (WRC) allocated one full day (9/18) of their monthly meeting to the Saginaw River/Bay RAP. The day began with a morning boat tour of the Saginaw River by the WRC, local legislators, local press, MDNR staff, and invited public. In the afternoon, MDNR staff made a presentation to the WRC on the RAP and the WRC passed a resolution supporting the Saginaw River/Bay RAP process (Appendix 2). The meeting was then opened for public comment on the RAP for the remainder of the afternoon.

A second draft of the Remedial Actions section was prepared based on all comments received, and distributed for public review in July 1988. Both oral and written comments were solicited through direct mailings and an August 3, 1988, public meeting in Bay City. Comments received were incorporated into this most recent version of the RAP.

8. Additional Activities

Other efforts have been made to inform the general public in the Saginaw Bay basin about the RAP process and invite public comment and participation through a variety of methods including newspaper articles, radio broadcasts, television interviews, a television talk show session on the RAP, MDNR news releases, MDNR newsletters, the ECMPDR newsletter - which is sent to all units of local government within the 14-county ECMPDR planning area - and several ECMPDR standing committees.

Public participationin the RAP process to date has been beneficial and efforts should be made to continue and expand this participation. The Saginaw Basin Natural Resources Steering Committee provided many useful comments, suggestions and recommendations to the project following their review of the September 1, 1987, first draft of the RAP. Public comment at public meetings during development of, and following release of, the first draft has been useful in refining certain parts of the document, framing issues from the local perspective, and prioritizing remedial actions. Citizen awareness and knowledge of local water quality problems has generated local public support that helped to implement some new remedial actions begun in the past year.

SECTION VII - REMEDIAL ACTIONS

A. OVERVIEW

This section of the Saginaw River/Bay Remedial Action Plan (RAP) is the primary reason this document has been compiled - to develop a plan of action to further address the water quality problems of toxic materials and cultural eutrophication in the Saginaw River/Bay Area of Concern (AOC). The specific goals are to (1) reduce toxic material levels in fish tissue to the point where public health fish consumption advisories are no longer needed for any fish species in the AOC, (2) reduce toxic material levels in the AOC to those of Michigan's water quality standards, and (3) reduce eutrophication in Saginaw Bay to a level where the bay will support a balanced mesotrophic biological community.

The Michigan Department of Natural Resources (MDNR) has been designated as the state agency responsible for submitting this Remedial Action Plan to the International Joint Commission (IJC). Though this document is not legally binding on any agency or individual, it does outline the approach Michigan intends to take in applying expanded efforts, beyond existing programs and activities, to further address these two water quality issues in the Saginaw River/Bay AOC.

It is intended that this RAP be used by all agencies (federal, state, local), organizations and individuals concerned with, affected by, or impacting water quality in the Saginaw River or Saginaw Bay. Extensive efforts have been made, and continue to be made, to include all interested and/or affected parties in the development, review and implementation of this plan so that it fully addresses the issues from a variety of perspectives and is broadly supported. As the RAP project progresses, more groups are expressing interest in being involved in the process and mechanisms are generally implemented or modified to accommodate this interest. The Remedial Action Plan is an iterative, long-term effort and it is anticipated that the RAP will be periodically updated and revised as more data are acquired, remedial measures are implemented, and environmental conditions improve.

A wide range of activities need to be undertaken to further address the eutrophication and toxic material problems affecting the Saginaw River/Bay AOC at an estimated cost (excluding any contaminated site clean-ups) of $134-$139 million over the next ten years (a period of time used for cost projection purposes only). The activities outlined in this Remedial Action Plan are presented as initial perceptions of the needed actions. They will be used to plan and guide remedial efforts at this stage of the Remedial Action Plan process. Since the RAP process is iterative, these actions are subject to further evaluation and modification consistent with changing environmental conditions in the Area of Concern or the acquisition of data supporting adjustments in scope or approach. Additional discussion of the remedial actions is encouraged and comments are welcome at any time from any interested party.

This list of actions was developed by the Saginaw Basin Natural Resources Steering Committee (SBNRSC) and the MDNR following comments received during the developmental stages, and after public review, of the September 1, 1987, RAP first draft and the July 1988 second draft of this Remedial Action section. Input was received from the following sources:

-- a series of 18 public meetings held from September 1986 through August 1988 (described in Section VI);

-- periodic meetings of the Saginaw Basin Natural Resources Steering Committee (described in Section VI);

-- the East Central Michigan Planning and Development Region (ECMPDR) who compiled Sections II and VI of the RAP first draft;

-- the National Wildlife Federation and graduate students from the University of Michigan who compiled sections III and IV of the RAP first draft; and,

-- the Saginaw River/Bay RAP Technical Work Group (the Technical Work Group has only reviewed a spring 1987 pre-draft copy of the RAP, which did not include any proposed actions, and the July 1988 second draft of the Remedial Action Section. Therefore, substantial comment is still needed from this committee following distribution of the RAP to Work Group members for review in September 1988).

The remedial activities discussed on the following pages focus primarily on five topic areas: public participation and education, identifying impacted areas and the contaminants involved, assessing the magnitude of environmental degradation, identifying specific sources and source areas of pollutants, and reducing pollutant loads at the source. The activities are presented under four major subject headings: Public Information/Education; Pollutant Sources (Point Sources, Atmospheric Inputs, Terrestrial Nonpoint Sources, and In-Place Sediments); Pollutant Effects (Water and Biota); and, Recommendations on Existing Programs. Within each category is a general introduction ot the topic followed by a discussion of specific remedial actions. Though all the actions presented are important to achieving the RAP goals, the items marked by asterisks (*) are the most important in terms of the next step in the RAP process.

B. PUBLIC INFORMATION/EDUCATION

A public that is informed about, and active in, the Remedial Action Plan process is an important component that will affect the degree of success achieved by the RAP. Public support for remedial actions is necessary in order to achieve the political will to provide the funding, staff and time commitment levels required to carry out the proposed activities. This support would be fostered by greater public knowledge and understanding of the Saginaw basin's natural resources, environmental processes, water quality problems, resource uses, and Remedial Action Plan goals. Additionally, a diverse group of resource users exists in the basin and mutual understanding of each others needs and perspectives will enhance the process of achieving better water quality for all.

There are several difficulties to overcome in increasing both the general knowledge of local citizens on water quality issues affecting the Saginaw River/Bay system and the degree of public participation in the RAP process. One is access to information. Even among those of the general public who are versed in environmental principles, there is a feeling that information is not readily accessible to them on area water quality problems or the range of possible solutions to those problems. No single authority exists that the public can turn to for information about either the magnitude of the problems facing the Saginaw Bay system, or about how to participate in the development and implementation of remedial actions. Often, the information that is available is too technical to be readily understood by the layperson. Scientific acronyms such as PCB, DDT, and ppt are not meaningful to the average citizen. Along the same line, many people are uncertain about the impact of toxic material contamination within the basin and feel ill prepared to assess the levels of acceptable risk. Developing public understanding about the levels of acceptable risk, and about subsequent actions to reduce that risk, is important to the success of the RAP.

Another problem is the length of time involved in developing and implementing remedial actions. Because of the complex nature of the remaining environmental problems, and the financial costs of correcting them, a multifaceted and informed approach is needed. Consequently, a substantial amount of time often passes before observable remedial actions are implemented. This developmental time is often perceived by the public as a time of inaction since no results are apparent. Efforts need to be undertaken to explain this process to the public and provide appropriate progress updates.

A corollary problem is that individual remedial actions often do not result in substantial environmental improvements. As a result, their merit is sometimes questioned, even though the action may be a key factor in a series of remedial actions that ultimately provide significant improvements in the ecosystem. Accordingly, individual remedial actions should be presented to the public in context with a stepwise approach and the overall remedial process.

A variety of activities are therefore presented to (1) provide public information and education; (2) promote public involvement in the

Saginaw River/Bay RAP project, and (3) provide for coordination of public participation in the RAP process.

1. Continued public participation in the RAP process should be sought in order to provide for public input in the decision making process for RAP goals, implementation activity selection and action prioritization.

*a. The MDNR should work with the Saginaw Basin Natural Resources Steering Committee on RAP document updates, RAP implementation activities, and receiving general public comment on the RAP and implemented actions.

Status - ongoing and proposed in RAP for continuation
Schedule - continuous throughout project
Cost - $10,000/year for SBNRSC activities
Funding - local needed for continuation of SBNRSC activities

*b. The SBNRSC should be the lead organization in sponsoring RAP related public meetings and promoting public involvement in the RAP process. Other RAP associated organizations should conduct public meetings on RAP activities as necessary, but the meetings should be coordinated with the SBNRSC.

Status - ongoing and proposed in RAP for continuation
Schedule - continuous throughout project
Cost - $10,000/year
Funding - various

c. The MDNR should encourage local participation by supporting locally funded and implemented remedial action projects as outlined in the RAP.

Status - ongoing and proposed in RAP for continuation
Schedule - continuous throughout project
Cost - none

These activities promote public involvement/support for the RAP and provide the public with an active role in developing/revising the RAP and implementing remedial actions.

*2. The SBNRSC should oversee the development and creation of an independent, private non-profit corporation that would address natural resource issues in the Saginaw Bay watershed. The corporation should have among its objectives the following activities:

a. Solicit and distribute funds for RAP activities that are consistent with corporation goals.

b. Implement appropriate RAP actions as able.

c. Create a broader public interest in, and understanding of, natural resource issues in the basin.

d. Initiate a positive public movement encouraging environmental consciousness and promotion of clean air, land and water.

e. Foster a spirit of cooperation among the diverse interest groups present in the basin.

f. Establish and maintain lines of communication between itself and similar organizations in the U.S. and Canada. Efforts should be made toward sharing information and learning from the experiences of others.

Such a corporation would serve as a funding source and advocate for RAP activities as well as increase public knowledge and awareness.

Status - incorporation papers being filled out, no operation funds allocated
Schedule - incorporation by spring 1989, Board/staff membership in place by summer 1989
Cost - incorporation $5,000, operation $150,000/year
Funding - local needed for operation expenses

3. The SBNRSC should produce, publish and distribute a non-technical summary of the RAP. This document should be easily understandable and accessible to the general public. It should be brief but address the following issues.

a. Which toxic materials and nutrients are of concern in the basin and why.

b. What are the possible and observed impacts of toxic materials on the aquatic ecosystem and human health.

c. The location of known or suspected problem areas within the basin, particularly those areas with fish consumption advisories and areas containing major sources of the pollutants of concern.

d. The process by which fish consumption advisories are deemed necessary, including the level of risk that is considered acceptable by the relevant agencies.

e. The current status of remedial efforts including compliance of permitted dischargers, any litigation actions, efforts to obtain funds for remedial actions not currently under way, nonpoint source control measures, and research being conducted within the basin.

f. The changes in environmental quality over time including historical environmental quality data, current conditions, and future conditions that will be expected following the completion of the RAP activities.

g. An overview of the RAP process including the role of the SBNRSC in that process. Information should be provided on the committee's unique membership, oriented toward the whole basin rather than limited by traditional political boundaries. Also that a variety of interests are represented including business and industry, labor, conservation and environmental groups, agriculture and local government.

h. Examples of successful remedial actions already completed in the basin and current efforts on the part of basin citizens to improve the quality of the Saginaw basin.

i. The scientific and technical justification for instituting remedial measures, and the economic and social ramifications of various alternatives including the "no action" alternative. The problems of the basin should be assessed in terms of human health, ecological conditions, and economic impacts.

j. Any and all citizens, businesses and organizations should be encouraged in the document to provide comment and recommendations on the RAP.

k. The document should be packaged in segments designed to enable those interested to easily read and understand the information presented. Visual aids and graphics should be liberally used. Acronyms should be avoided or, if used, explained in detail.

This document would help educate the public, inform them of the RAP process and the SNBRSC, and promote public involvement.

Status - funds appropriated by MDNR (from federal funding source) and ECMPDR to support the project but funds have not yet been distributed
Schedule - to be completed one year after distribution of funds in approximately September 1988
Cost - $10,000
Funding - local and federal

4. Periodic dissemination of RAP information to the public should be conducted using a variety of methods.

*a. The SBNRSC should develop, and regularly distribute to the general public, an informational newsletter on RAP activities, SBNRSC actions, and related topics of interest. This newsletter should encourage public comment on the RAP process as well as newsletter articles, and provide a mechanism to receive these comments.

Status - proposed in RAP
Schedule - quarterly issues on an ongoing basis
Cost - $10,000/year
Funding - local

b. Regularly scheduled meetings of the SBNRSC should be employed as a public forum and a public education mechanism by widespread publicity of the meeting time, date and location. A specified portion of the meeting should be designated as a public comment period.

Status - proposed in RAP
Schedule - quarterly on an ongoing basis
Cost - SBNRSC operation $30,000/year
Funding - local

c. Any organization participating in the RAP project should be encouraged to distribute information on their RAP activities, and the RAP process in general, to the general public. The organization could do this itself or forward the information to another organization distributing RAP information.

Status - ongoing and proposed in RAP for continuation
Schedule - periodically as appropriate
Cost - incidental

d. Any organization participating in the RAP should identify a media spokesperson(s) for their activities on the RAP.

Status - ongoing and proposed in RAP for continuation
Schedule - continuous throughout project
Cost - none

e. All organizations distributing RAP information to the public should monitor the public's awareness and opinions on the issues addressed by the RAP and thereby partially assess the effect of public information/participation activities and implemented remedial actions. This feedback is important to the ongoing process of evaluating and potentially modifying remedial actions or their relative priorities. This response may be achieved through public meetings, comments received, questionnaires and public opinion surveys.

Status - ongoing and proposed in RAP for continuation
Schedule - continuous throughout project
Cost - dependent on survey method
Funding - various

Information supplied to the public through these activities should be objective and not reflect the beliefs or agenda of any one organization, agency or individual. Positive developments or programs in the basin that are currently underway should be identified and widely publicized, including information on which groups, individuals or businesses are working to improve environmental quality in the basin, what their efforts are, and how successful they have been. A good example of this would be the adoption of conservation tillage practices on the part of basin agricultural producers and its potential impact on nutrient loads to the bay.

Public information/education activities should also be coordinated among all relevant state and local organizations that express a desire to assist in these activities. These organizations should inform state and federal legislators and local government officials of their activities and include them in the RAP process to the greatest extent possible. Additionally, these organizations should work among themselves and the various resource users in the basin to promote a mutual understanding regarding the use and protection of the natural resources.

All public information/education activities should be reported to the MDNR RAP coordinator so that the activities can be tracked in the RAP process.

3. Environmental education efforts dealing specifically with the Saginaw Bay ecosystem should be greatly expanded.

   a. The SBNRSC should work directly with basin school systems, the Michigan Department of Education, and the Michigan Education Association to institute environmental education programs in area schools that include curricula dealing specifically with the Saginaw Bay watershed ecosystem. These programs should be developed or expanded for all education levels, but especially at the elementary and junior high school grade levels.

      Status - proposed in RAP
      Schedule - ongoing once implemented
      Cost - implementation in all basin public schools
      $1 million/year
      Funding - state and local

   b. The SBNRSC should sponsor a public education forum that meets periodically to present information on, and discuss, water quality issues of importance to area citizens. This could be part of, or separate from, SBNRSC business meetings, but in either case should include an educational presentation.

      Status - proposed in RAP

Schedule - quarterly
Cost - $5,000/year
Funding - local

These education efforts, combined with distribution of a non-technical RAP, would expand public knowledge of the issues affecting the Saginaw Bay ecosystem and promote interest in the RAP.

6. Information should be obtained on natural resource protection/enhancement/use activities in other areas and on associated efforts in the Saginaw Bay watershed such as economic development and tourism.

   a. The SBNRSC should establish and maintain lines of communication between itself and similar organizations in the U.S. and Canada. Efforts should be made toward sharing information and learning from the experiences of others involved in similar endeavors in other geographic areas.

      Status - proposed in RAP
      Schedule - ongoing once implemented
      Cost - incidental

   b. The ECMPDR should gather information on how counties within the Saginaw Bay basin are promoting tourism and economic development. This should be followed by a concerted effort to coordinate those activities to encourage a unified effort and incorporation of the RAP wherever feasible.

      Status - proposed in RAP
      Schedule - ongoing once implemented
      Cost - $5,000 for data gathering
      Funding - local

These activities will provide a broader information base for the RAP process, on environmentally associated projects and the efforts of other organizations.

C. POLLUTANT SOURCES

Point Sources

Wastewater discharges from municipal and industrial facilities continue to contribute pollutants to the Saginaw Bay system, though the amounts are substantially less than in the past. Efforts need to be continued to further reduce discharges of certain materials that exceed NPDES permit limits, such as PCBs from the remaining three point sources of PCB.

The meeting of NPDES permit limits should not, however, be construed as an endpoint. Dischargers should strive to further reduce discharges as feasible pursuant to the federal Clean Water Act goal of zero discharge. This is particularly true for phosphorus and toxic materials, both of which continue to impair designated uses in the AOC. Facilities currently discharging materials at levels that are less than permit limits should attempt to maintain these lower levels and work towards further reductions where possible.

*1. The MDNR needs to substantially expand the NPDES permit compliance monitoring efforts in the Saginaw Bay basin to verify if the discharge values reported by the facilities are accurate. This program has been seriously understaffed in recent years due to state budget constraints.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - $100,000/year
Funding - state or federal

2. The Michigan legislature should give the MDNR authority to assess administrative fines for violation of NPDES permit provisions rather than continue the current tedious practice of case-by-case settlements. This would streamline the process for levying fines on noncomplying facilities.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - dependent on complexity of system implemented
Funding - federal

3. The MDNR's PCS permit database should be modified to allow information to be retrieved by major watersheds of the Saginaw River to supplement those Saginaw Bay basin watersheds already available. This would facilitate data analysis by source area to the Saginaw River.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - dependent on complexity of making change
Funding - federal/state

4. The MDNR needs to expand efforts to enter information on minor dischargers into the PCS permit database system. This would enhance compliance tracking efforts and data analysis of discharges from minor facilities.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - dependent on level of detail
Funding - federal/state

5. The MDNR should review operating records of small WWTPs and lagoon systems to determine if the results of previous studies, which indicated that the contribution of these sources to tributary and bay loads were relatively insignificant, are still valid given recent reduction in loads to the bay.

Status - proposed in RAP
Schedule - to be determined
Cost - dependent on complexity of review process
Funding - federal/state

*6. Notwithstanding other reasonable options to reduce pollutant discharges, several local municipal wastewater treatment facilities need to be upgraded to meet effluent discharge requirements and a few additional facilities are needed. A partial list follows.

City of Saginaw WWTP - residual chlorine control to eliminate acute toxicity of the effluent	$1 million
Buena Vista, Zilwaukee, Essexville and Bay City WWTP - residual chlorine control to eliminate acute toxicity of the effluent	$3 million
Carrollton Township WWTP - facility upgrade to remove a wet weather primary treatment plant discharge to the Saginaw River, which contributes phosphorus and toxic materials	$5 million
Caseville septic system - build sewers and treatment lagoons to eliminate nonpoint sources of phosphorus to Saginaw Bay	$3 million
Portsmouth Township (Bay County) septic system - build sewers and either a WWTP or treatment lagoons to eliminate nonpoint sources of phosphorus to Saginaw Bay	$2 million
Fairhaven Township (Bay Port) septic system - build sewers and treatment lagoons to eliminate nonpoint sources of phosphorus to Saginaw Bay	$2 million

Status - proposed in RAP
Schedule - facility dependent
Cost - $16 million
Funding - local

*7. The MDNR should determine the present load of phosphorus to Saginaw Bay, by watershed, from point source discharges. This should be compared to nonpoint source phosphorus loads to determine if further point source reductions are needed pursuant to the intergovernmental/interagency State of Michigan Phosphorus Reduction Strategy for the Michigan portion of Lake Erie and Saginaw Bay.

Status - point source load determination implemented
Schedule - implemented activities to be completed fall 1988
Cost - $3,000 for implemented activities, $2,000 for comparison assessment when nonpoint data is available
Funding - State

*8. The remaining three known point sources of PCBs in the Saginaw Bay basin (GMC-CPC - Bay City, GMC Central Foundry - Saginaw and Flint WWTP) should make all effort practically possible to eliminate detectable discharges of PCBs in order to meet discharge permit limits and help ameliorate PCB concentrations in the water and biota of the AOC.

Status - implemented through the NPDES discharge permit program
Schedule - as soon as possible, facility dependent
Cost - unknown
Funding - private and local (Flint WWTP)

These actions will provide information on the individual point sources with remaining wastewater problems, determine the severity of these problems to the environment, and implement additional activities to resolve them. Other than municipal wastewater treatment facility upgrade costs of $16 million, costs are incidental to existing programs except for $200,000/year needed for increased MDNR compliance monitoring and effluent toxicity testing and $100,000/year for expanded efforts on reissuing minor permits.

Atmospheric Inputs

Atmospheric deposition is a documented source of large quantities of some pollutants to the Great Lakes. Air pollution regulations have been in force for conventional air pollutants for two decades and there has been a reduction of pollutants in the atmosphere during that period, but substantial amounts of toxic contaminants continue to appear in atmospheric deposition. Little is known of actual deposition rates of contaminants to the Saginaw Bay watershed or how rates vary annually, seasonally or with wet weather events versus dry weather settling. This lack of data also hampers efforts to relate the magnitude of atmospheric inputs of contaminants to Saginaw Bay with inputs from point sources and terrestrial nonpoint sources.

Actions are needed in two general areas, (1) assessment of the quantity, quality and deposition rate of contaminants to the Saginaw Bay watershed from atmospheric sources; and (2) further reductions of pollutant emissions to the atmosphere as indicated by general Great Lakes area deposition data. These actions should be taken consistent with the Great Lakes Toxics Substances Control Agreement and the Great Lakes Water Quality Agreement.

*1. The MDNR and U.S. EPA should expand existing monitoring efforts of wet atmospheric deposition of conventional and metal parameters to Saginaw Bay using the Great Lakes Atmospheric Deposition (GLAD) network stations and any additional stations that may be needed. This expansion should include additional conventional and organic parameters, particularly phosphorus and PCB, as well as dry deposition monitoring. Use of previously operated monitoring stations such as Tawas Point, should be considered. The monitoring objective should be to identify, quantify and determine the deposition rates of each contaminant on an annual basis to determine loads and trends.

Status - proposed in RAP
Schedule - sufficient to determine annual loads and trends on a long-term basis
Cost - $100,000/year
Funding - federal

2. The U.S. EPA and Environment Canada should jointly assess their atmospheric deposition data, obtained for the Great Lakes basin, to determine the source areas of atmospheric contaminants.

Status - proposed in RAP
Schedule - once every 5 years
Cost - dependent on sufficiency of data
Funding - federal

3. The Great Lakes state and provincial jurisdictions should identify the specific sources within these areas and the relative contribution from each source in order to prioritize areas and sources for emission reductions.

Status - proposed in RAP
Schedule - staff representatives of the air quality programs of the Great Lakes states have developed a proposed schedule to compile a computerized emission inventory database for air point sources of selected pollutants of concern for the Great Lakes basin
Cost - jurisdiction specific
Funding - efforts are being made to obtain adequate funding and staff levels within each of the states, including Michigan, in order to properly complete this effort

*4. Federal, state and provincial agencies with jurisdiction over air quality standards and/or stack emissions should make a concerted effort to reduce both toxic and conventional pollutant emissions to the air through adherence to, and enforcement of, regulatory laws and policies. Where air emissions remain at levels of concern, existing laws and regulations should be reviewed and modified as appropriate to reduce emissions.

Status - Current state and U.S. federal regulations require permit applicants to utilize best available control technology to reduce volatile organic compound emissions from new air pollution sources. Additional work is being done in Michigan to develop air toxics regulations to include review of both new and existing sources.
Schedule - ongoing once implemented
Cost - jurisdiction specific
Funding - state, provincial and federal

5. Federal, state and provincial agencies with jurisdiction over air quality standards should assess potential sources of atmospheric pollutants that are not currently regulated or monitored such as volatilization of materials from wastewater treatment plants and landfills, agricultural operations and transportation sources, as well as existing sources. These sources should be assessed in terms of their relative contributions to total pollutant loads to the atmosphere and subsequent deposition levels in order to determine if emission reductions are needed from these sources. Potential control strategies should also be compiled.

Status - proposed in RAP
Schedule - determined from initial assessment efforts
Cost - $100,000/year in Michigan
Funding - various

*6. The MDNR should seek rule changes in Michigan Public Act 348 of 1965, the Michigan Air Pollution Act, that would allow for existing permits for stack air emissions to be reviewed and reissued on a regular basis. This would enable the periodic incorporation of discharge restrictions on toxic organic and metal materials as needed. However, this would require substantial funding and staff increases as the MDNR Air Quality Division currently receives 1,500 permit applications a year for new emission sources.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - dependent on permit reissuance schedule
Funding - federal/state

*7. The SCS, ASCS, Cooperative Extension Service and MDNR should encourage the continued and expanded implementation of agricultural and construction site BMPs to reduce the amount of wind erosion from exposed soils in the Saginaw Bay basin. Additional efforts to reduce fugitive dust should be implemented.

Status - ongoing and proposed in RAP for expansion
Schedule - continuous throughout project
Cost - additional BMP implementation costs discussed in the following terrestrial non-point sources section

These activities will identify geographically, and by source, where reductions are needed in the discharge of pollutant materials to the atmosphere. They will also provide a more effective mechanism for reducing these emissions. Approximately $200,000/year are needed for emission source and atmospheric deposition monitoring. Substantial additional funds, and staff level increases, are required to implement needed program expansions.

Terrestrial Nonpoint Sources

The predominant land use activity in the Saginaw Bay drainage basin is agriculture and recent studies of nutrient loads to the Bay suggest that agricultural lands have supplanted point sources as the largest source of nutrients. However, other nonpoint sources, including construction sites, highway surfaces and urban runoff, are also contributors. These sources have also been identified as contributing toxic organic and metal contaminants.

The pollutant loads come from wind erosion and surface water runoff of land surfaces, which results in the delivery of sediments to area rivers and the subsequent deposition of these sediments on river substrates and in Saginaw Bay. This movement of sediments is the major pathway for the addition of nutrients and toxic materials, which are bound to sediment particles, to the AOC from nonpoint sources.

The following actions need to be taken to determine the magnitude of current pollutant inputs from these sources, define the geographic areas with the largest loads, and implement Best Management Practices.

*1. The SBNRSC should oversee the establishment of a permanent Nonpoint Source Pollution Control Committee (NSPCC) for the Saginaw Bay watershed. This committee would help focus programs from different agencies on common goals and foster interagency cooperation. The committee membership should include representatives from the following organizations:

-- USDA Soil Conservation Service

-- Soil Conservation Districts
-- USDA Agricultural Stabilization and Conservation Service
-- Michigan State University Cooperative Extension Service
-- Michigan Department of Natural Resources
-- Michigan Department of Agriculture
-- Michigan Department of Public Health
-- Michigan Department of Transportation
-- Michigan Farm Bureau
-- Regional Planning Agencies
-- Drain Commissioners
-- Conservation and Sportsperson groups
-- Other interested organizations as appropriate

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - formation $2,000
Funding - local

2. The NSPCC should develop a nonpoint source management plan specific to the Saginaw Bay watershed that draws from existing nonpoint source management plans, such as the MDNR state strategy and the phosphorus reduction plan for Saginaw Bay. The plan should include the assessment and ranking of individual tributary watersheds from both monitoring data and modelling results in order to determine geographical areas with high loads and thereby prioritize areas for the allocation of limited funds.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - dependent on detail of plan
Funding - various through participating organizations

3. The NSPCC should evaluate the hydrologic system of the basin to determine the potential benefits of returning some areas to an approximation of their natural state, in order to reduce nonpoint source contaminant inputs to Saginaw Bay, including the following:

-- areas with potential for reclaimed or artificial wetlands in river floodplains and along the bay shoreline

-- diked rivers and streams for potential broadening of existing floodways

-- tributary channels and floodways for enhancement of characteristics that moderate flood peaks and reduce sediment transport from source areas

-- agricultural drains that have been established along natural creek bottoms to determine the potential for reestablishing natural contours

-- areas with the potential for buffer strip development between highly erodible lands and the bay or its tributaries. This would include the development, and adoption by local government units, of zoning ordinances designed to protect highly erodible lands from disturbance.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - dependent on assessment effort
Funding - various through participating organizations

*4. All organizations in the NSPCC should encourage the continued and expanded use of Best Management Practices (BMPs), such as conservation tillage of agricultural land, planting of windbreaks, and streambank stabilization, to reduce sediment erosion.

Status - proposed in RAP
Schedule - ongoing
Cost - none for encouragement, for implementation of BMPs see next activity

*5. Agencies administering federal cost-sharing for BMPs should consider the use of cost-sharing funds for sub-surface tiling and fertilizer management. Additional programs for the adoption of BMPs should be pursued at both the state and federal level in order to reduce nonpoint source contaminant inputs to Saginaw Bay.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - $27.65 million over a 10-year period for implementation on 616,000 acres of cropland presently eroding at higher than tolerable (T value) levels
Funding - federal

6. The Michigan legislature should reinstate the Clean Water Incentives Program to facilitate implementation of additional nonpoint source control measures. Projects within the Saginaw Bay drainage basin meeting program requirements should receive priority consideration.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - $250,000/year
Funding - state

7. The NSPCC should work with member organizations to develop and implement a comprehensive plan to educate agricultural producers on how to employ currently available state and federal programs to reduce agricultural pollutant loads to Saginaw Bay, including the following:

-- The Conservation Reserve Program
-- Other conservation provisions of the Food Security Act of 1985
-- The Agricultural Conservation Program

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - dependent on degree of education effort
Funding - various through participating organizations

8. The agencies that oversee the implementation of BMPs should conduct additional studies in the Saginaw Bay watershed to quantify the effectiveness of various BMPs in reducing nonpoint source pollutant loads to Saginaw Bay and its tributaries. This should include research on the potential of new BMPs such as sub-irrigation and artificial wetland creation.

Status - proposed in RAP
Schedule - as needed
Cost - $100,000/year
Funding - federal

*9. The MDNR should collect suspended and bedload sediment samples from the mouth of rivers tributary to the Saginaw River and Saginaw Bay to identify watersheds with high sediment loads (water monitoring activity described in a later section on water). Samples should be collected during base-flow, high flow, and event conditions over a three-year period and once every five years thereafter. Parameter analyses should include particle grain size, toxic organics (particularly PCBs and organochlorine pesticides), heavy metals, and nutrients.

Status - One-year ECNFDR project funded by MDNR from a federal grant
Schedule - one-year project to begin fall 1988
Cost - Implemented project $96,000, additional needed $100,000 each assessment year
Funding - federal/state

10. The NSPCC should oversee the implementation of subwatershed water and sediment monitoring to address the following data needs:

-- Impacts of episodic events to the load from a given tributary at different stages of crop development under different storm events and snowmelt conditions.

-- Pollutant contribution from land uses other than agriculture present in predominantly agricultural watersheds.

-- Edge-of-field and tile flow nutrient and sediment loads for different crop and soil types under various storm event conditions.

-- Characterization of baseflow conditions.

Status - proposed in RAP
Schedule - intermittent once implemented
Cost - $100,000/year
Funding - federal and state

11. The NSPCC should oversee the development and implementation of agricultural stormwater management to slow stormwater flows from agricultural lands, consistent with guidelines and procedures of the U.S. SCS Farm Conservation Plan and other similar documents, as appropriate. Stormwater management should be conducted in such a way as to avoid impairing normal field drainage or crop development.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - $1,000,000/year
Funding - federal/state/local

12. The MDA should undertake a livestock census in the various basin tributaries and assess the contributions of animal generated wastes to basin nutrient, sediment and bacterial loads for each of the tributary basins where high concentrations of livestock are found. The livestock census should be sufficiently location specific to determine the density of livestock in relation to the drainage network of tributary streams and agricultural drains. This would enable the generation of an estimate of the relative contribution of these materials to watershed nonpoint source loads from livestock operations.

Status - proposed in RAP
Schedule - to be determined
Cost - $50,000
Funding - state

13. The NSPCC should organize efforts to determine the quantity of pollutants contributed by nonpoint sources such as urban stormwater runoff, runoff from fertilized lawns, leachate from defective or inadequate septic systems, and others to determine the relative contributions from these sources to area watershed nonpoint source loads.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - $250,000/year
Funding - state and federal

14. The MDNR or identified Private Responsible Parties (PRPs), whichever is appropriate at a given site, should expand the evaluation of contributions from known contaminated upland sites, that are in close proximity to basin surface waters, to contaminant loads to the Saginaw River and/or Saginaw Bay.

Status - proposed in RAP
Schedule - as needed
Cost - unknown
Funding - PRPs and state

*15. The MDNR should require municipalities to develop and implement plans for the control of CSOs and urban stormwater runoff, including the construction of retention structures to reduce overflows during periods of heavy runoff.

City of Saginaw -	
Construct a retention basin at Weiss St.	$13.5 million
Construct a retention basin and swirl concentrator at 14th Street	$ 8.2 million
Construct a swirl concentrator at Emerson Street	$ 3 million
Contruct a swirl concentrator at Weber St.	$ 3 million
Saginaw Township - construct a retention basin	$ 3 million

Status - proposed in RAP, partial implementation
Schedule - to be determined
Cost - $30.7 million for known needed correction in the Saginaw River
Funding - local

*16. Basin agricultural producers should reduce agricultural fertilizer application levels to those recommended by the Michigan State University Cooperative Extension Service in order to reduce soil phosphorus levels.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - net savings to producers

17. Basin drain commissioners should expand their traditional roles dealing with water quantity to include water quality issues. Drainage projects should take into account sound nonpoint source pollution abatement practices to reduce pollutant inputs to Saginaw Bay.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - dependent on water quality management practices used
Funding - local

These actions will identify and quantify nonpoint source pollution loads from specific sources and geographic areas. Mechanisms will also exist for overseeing and implementing procedures to reduce nonpoint inputs to the AOC. Costs in addition to incidental programs are estimated to be on the order of $7.5 million/year over the next 10 years.

In-Place Sediments

Bottom sediments in portions of the Saginaw River and Saginaw Bay are contaminated with toxic organic and metal compounds. These contaminated sediments are a suspected source of toxic materials to the aquatic biota and may have contributed to the issuance of fish consumption health advisories for certain species in the AOC. The general locations of the most contaminated sediments are known. However, the areal extent and volume of material has only been approximated. The most recent data on contaminant concentrations in surficial sediments were obtained from samples collected in the late 1970s and early 1980s. Additionally, it is not known if the high flows that occurred in the Saginaw River during the September 1986 flood affected surficial sediment concentrations by depositing additional sediment, exposing the most contaminated layers, or eroding the materials out into Saginaw Bay. Several actions need to be taken to address these contaminants which exist in different mixtures and concentrations in a variety of areas.

*1. The MDNR should collect surficial sediment samples from throughout the Saginaw River, and sediment cores from the Saginaw River in the identified PCB contaminated area downstream of the Grand Trunk Western railroad bridge in Bay City (River mile 5.0) to the mouth. Samples should be analyzed for metals, toxic organics, and nutrients to determine the areal extent of contamination and the concentration levels in sediments for comparison to historical data and trend analysis.

Status - partial implementation
Schedule - sampling in 1988
Cost - $145,000 implementation, $500,000 additional needed
Funding - implemented state, additional state or PRP as appropriate

*2. The MDNR and U.S. EPA should collect surficial and core sediment samples throughout Saginaw Bay to be analyzed for metals, toxic organics, and nutrients in order to determine the areal extent of contaminants and surficial sediment concentrations for comparison to historical data and trend analysis.

Status - partially implemented by MDNR
Schedule - sampling in 1988
Cost - $195,000 implementation, $500,000 additional needed
Funding - state implemented, federal additional

*3. The MDNR should collect surficial sediment samples from the mouths of rivers tributary to Saginaw River and Saginaw Bay. Samples should be analyzed for metals, toxic organics, and nutrients to help determine the source of any continuing inputs.

Status - partially implemented
Schedule - sampling in 1988
Cost - $75,000 implemented, $150,000 additional needed
Funding - state

*4. The U.S. Army Corps of Engineers should select and prepare a disposal location for dredge spoils from the lower Saginaw shipping channel to be used for contaminated sediments when the Saginaw Bay confined disposal facility is filled in order to allow continuation of lower Saginaw navigation channel dredging.

Status - proposed in RAP
Schedule - as soon as possible
Cost - $15-20 million for site selection and construction
Funding - undetermined, potentially local, state or federal

*5. In addition to the present ban on the use of overflow, clam shell and bucket dredging in the Saginaw River where PCBs are found in sediments at concentrations greater than 10 ppm, the MDNR should prohibit these methods anywhere in the Saginaw Bay basin where sediments are contaminated by toxic materials at levels that would prevent open lake disposal of the dredge spoils. This would prevent resuspension and movement of sediments and associated toxic materials.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - unknown but would be additional costs for dredging
Funding - federal

6. The MDNR should suspend overflow, clam shell, and bucket dredging anywhere in the AOC until such time that it is conclusively demonstrated that there are no adverse impacts from the resuspension of sediments.

Status - proposed in RAP
Schedule - issue presently being studied by U.S. ACOE, U.S. EPA, and MDNR
Cost - unknown but would be substantial additional dredging costs
Funding - federal

7. The U.S. Coast Guard should institute further navigational limits in the Saginaw navigation channel, such as no wake zones, in areas where resuspension of contaminated sediments occur.

Status - proposed in RAP

Schedule - ongoing once implemented
Cost - incidental

8. The MDNR should not allow hydrologic modifications to basin streams that would increase current velocities over any contaminated sediment sites.

Status - proposed in RAP
Schedule - undetermined
Cost - dependent on project impact assessment efforts
Funding - state

9. Any agency should, in analyzing initial sediment samples in an area, check for all substances on the Michigan Critical Materials Register (for which there are analytical methods) that might be expected to occur in sediments at levels of environmental concern as a result of upstream sources to determine whether any of these materials are present at levels of concern.

Status - proposed in RAP
Schedule - implement as possible
Cost - included in sediment collection costs
Funding - federal and state

*10. The MDNR should collect surficial sediment samples in and below urban areas on the Flint and Cass rivers for analysis of metals, toxic organics, and nutrients in order to obtain data lacking on these rivers with regard to their potential impact on the AOC.

Status - proposed in RAP
Schedule - undetermined
Cost - $100,000
Funding - state or federal

11. The MDNR should sample surficial sediments in the South Branch of the Shiawassee River downstream of Howell to evaluate the present PCB levels and the potential impacts on the AOC. This activity should not duplicate efforts recently undertaken between M-59 and Chaye Lake Road through the federal Superfund program.

Status - proposed in RAP
Schedule - undetermined
Cost - $50,000
Funding - state

12. The U.S. EPA should study the frequency of occurrence, seasonal distribution, duration, geographic distribution and magnitude of sediment resuspension events in Saginaw Bay to determine the potential magnitude of toxic material and nutrient resuspension.

Status - proposed in RAP
Schedule - undetermined
Cost - $250,000
Funding - federal

13. The U.S. EPA should study the toxicity and bioavailability of contaminants on AOC sediments during natural resuspension events and dredging activities to determine potential impacts on aquatic biota.

Status - proposed in RAP
Schedule - undetermined
Cost - $250,000
Funding - federal

*14. The MDNR should examine the extent of toxic material contamination in Saginaw Bay wetland areas which retain fine-grained sediments to determine if these areas are a potential source of contaminants to the open waters and if contaminants are present that could potentially inhibit macrophyte growth or impact resident biota.

Status - implemented
Schedule - surficial sediment sampling conducted in 1988
Cost - $10,000
Funding - state

15. Once U.S. EPA has established sediment quality criteria for contaminants, the MDNR should use them, along with information on site-specific sediment toxicity and the potential for sediment movement, to rank sites of sediment contamination in the AOC in order to prioritize the distribution of funds for remedial actions.

Status - proposed in RAP
Schedule - following development of sediment criteria
Cost - dependent on amount of data available
Funding - state

16. The U.S. EPA should consider the listing of sediment contaminated sites in the AOC as Superfund sites.

Status - proposed in RAP
Schedule - undetermined
Cost - incidental

*17. The U.S. EPA should fund demonstration projects in the Saginaw River/Bay AOC pursuant to Section 118 of the Water Quality Act of 1987.

Status - proposed in RAP
Schedule - undetermined

Cost - dependent on type and magnitude of implemented projects
Funding - federal

18. In cases where sediment contamination can be traced conclusively to a particular source, that source should be assessed the remediation costs by MDNR as is presently done. For areas where several sources are identified, each should be assessed a fair and equitable portion of remediation costs. Where sources cannot be determined, public funds should be used for remediation efforts.

Status - proposed in RAP
Schedule - as sources are identified
Cost - dependent on magnitude of contamination
Funding - PRPs, state and federal

19. The U.S. EPA should identify the range of economically and environmentally feasible remedial actions available to mitigate areas of contaminated sediments. This should include action merits, liabilities, costs and technological considerations.

Status - proposed in RAP
Schedule - as methods are developed
Cost - dependent on number of methods researched
Funding - federal

20. The MDNR and SENRSC should evaluate the potential actions available, as just described in action 19, for sites in the AOC with respect to the following in order to determine which remedial action to take.

-- local political sentiment for the different actions
-- available funds and their sources
-- the time frame involved in implementing and completing the actions
-- the geohydrologic future of the area
-- present and future uses of the area
-- site specific assessment of bioavailability/toxicity of contaminants in sediments

Status - proposed in RAP
Schedule - following definition of the problem area
Cost - dependent on number and extent of sites
Funding - state

These activities will identify potential pollutant source areas, the location and extent of contaminated sediments, and eventual remedial actions for contaminated sediment sites. Costs over a 10-year period are estimated to range between $22 and $33 million.

D. POLLUTANT EFFECTS

Water

Water quality parameters in Saginaw Bay are at levels below those that would cause concern for public drinking water supplies or body contact recreation, except for bacteria. In 1988, for the first time in many years, the Bay County Public Health Department closed some public bathing beaches on Saginaw Bay because of high fecal coliform counts. Fecal coliform counts in the Saginaw River were consistently high in 1988. Bacterial levels in the Saginaw River have also been high in previous years, particularly after storm events, but 1988's consistently low flows appeared to have compounded the problem.

Water is a major transportation medium for the movement of contaminant materials in the Saginaw Bay system as well as an exposure route of contaminants to aquatic biota. It is often the medium where pollutant problems are first detected and can be used to locate the source of contaminant materials. Accordingly, several water monitoring actions are described to track water quality trends in Saginaw Bay and its tributaries.

1. The MDNR should continue the development of a geographic mapping database of water quality values for Saginaw Bay and its tributaries that would be available for present and future reference to facilitate data analysis.

    Status - implemented
    Schedule - ongoing
    Cost - dependent on amount of data entered
    Funding - state

*2. The MDNR should maintain a minimum of six permanent water monitoring stations in the Saginaw River system to include one station at the mouth of each tributary to the Saginaw (Cass, Flint, Shiawassee and Tittabawassee) and an upstream and downstream station on the Saginaw. Monitoring should be for conventional, metal and organic parameters as determined by water quality conditions and the contaminant materials being discharged by upstream facilities or from nonpoint sources. Monitoring should be done periodically throughout the year and cover high flow, low flow, and event conditions with flow measured throughout the year. This activity is important for monitoring tributary water quality trends and contaminant inputs to Saginaw Bay.

    Status - implemented in Saginaw River, proposed for federal funding in FY 89 for other tributaries
    Schedule - once monthly sampling
    Cost - implemented $10,000/year, additional needed $20,000/year
    Funding - federal

*3. The MDNR should maintain from four to six permanent water monitoring stations at the mouths of tributaries to Saginaw Bay with an equal number on each side of the bay. Monitoring should be conducted as with the Saginaw River stations to track tributary water quality trends and contaminant loads to Saginaw Bay.

Status - proposed for federal funding for FY 89
Schedule - once monthly sampling
Cost - $30,000/year
Funding - federal

*4. The MDNR should periodically monitor all 28 tributaries to Saginaw Bay to track water quality trends and determine relative assessments of water quality and pollutant loads among tributaries.

Status - conducted in 1987, proposed for federal funding in FY 89
Schedule - once in 1987, quarterly in 1989
Cost - $25,000
Funding - federal

5. Where water quality parameters are measured at levels of concern, MDNR should monitor upstream stations to identify the source(s) of contaminants and the magnitude of the problem as appropriate.

Status - proposed in RAP
Schedule - as needed once implemented
Cost - $50,000/year
Funding - state

*6. The U.S. EPA should collect seasonal (spring and summer) water samples from a minimum of 75 open water Saginaw Bay stations (15 from each of the five cells identified previously in bay water mass studies) once every three years. Parameters analyzed should be as per the tributary stations to track bay water quality and parameter trends.

Status - proposed in RAP
Schedule - twice a year every three years
Cost - $250,000/year
Funding - federal

7. The U.S. EPA should collect water samples from near the Saginaw Bay confined disposal facility prior to and immediately following dredging, as well as a large wave-producing event, to check for leakage of organic and metal parameters from the CDF.

Status - implemented
Schedule - project sampling conducted in 1987 and 1988

Cost - dependent on scale of project
Funding - federal

8. The USGS should add a minimum of five flow gaging stations in the basin to help quantify annual pollutant loads.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - $35,000/year
Funding - federal/state/local

*9. The MDNR should conduct runoff event response sampling on selected tributaries to the Saginaw River and Saginaw Bay once every three years to monitor event loads to more accurately assess annual loads.

Status - proposed in RAP
Schedule - once every three years when implemented
Cost - $300,000/year
Funding - state

These activities would monitor water quality conditions, contaminant loads, track trends, and identify source areas in need of remedial actions. Most of these activities are monitoring activities requiring additional funds at an average rate of about $315,000/year.

Biota

The status of the biological community is the endpoint to which this RAP document is addressed. The goal is to restore conditions in Saginaw Bay to the point where a balanced mesotrophic biological community exists and no public health fish consumption advisories are needed for any fish species in the Saginaw River or Saginaw Bay. Consequently, monitoring of biological populations at various trophic levels is required to (1) detect geographic areas where problems exist, (2) define the magnitude of identified problems, (3) monitor the effectiveness of remedial actions, and (4) assess progress towards this goal.

*1. The MDNR should continue the collection of sport and commercial fish from the Saginaw River and Saginaw Bay for tissue analysis of toxic organic and metal compounds on a periodic basis to assess fish body burden levels and potential impact on human health through fish consumption.

Status - implemented
Schedule - ongoing
Cost - $80,000/year, repeat stations every 3 to 4 years
Funding - state

2. The MDPH should issue a public report that identifies the concentrations of contaminants of concern, and the criteria levels against which they are judged, so that progress towards the lifting of fish consumption advisories can be tracked by the public.

Status - proposed in RAP
Schedule - ongoing once implemented
Cost - $10,000/year
Funding - state

*3. The MDNR should conduct caged fish/clam bioassay contaminant uptake rate studies in the Saginaw River and the mouths of its four major tributaries (Cass, Flint, Shiawassee and Tittabawassee), Saginaw Bay, and the mouth of bay tributaries as needed to assess the biouptake rates of these fish in various areas of the AOC.

Status - implemented for 1988
Schedule - sampling in summer 1988
Cost - $35,000 implemented, $35,000 additional needed periodically
Funding - state

4. The U.S. EPA should conduct caged fish/clam bioassay contaminant uptake studies near the Saginaw Bay CDF to check for leakage of contaminants from the CDF.

Status - implemented
Schedule - sampling in fall 1987 and fall 1988
Cost - $80,000
Funding - federal

*5. The MDNR and/or U.S. EPA or NOAA should sample the Saginaw Bay benthic macroinvertebrate community seasonally for several consecutive years, and then once every five years, to evaluate the present benthic community structure and track historical trends.

Status - implemented by MDNR and NOAA for 86-88, no provisions for sampling beyond these dates
Schedule - MDNR samples collected 1986-88, NOAA samples collected 1987-88
Cost - $60,000/year/project
Funding - state and federal

6. The MDNR should sample the benthic macroinvertebrate community at the mouths of tributaries to Saginaw Bay to determine which tributaries carry pollutant loads in sufficient quantity to impair the benthic community.

Status - proposed in RAP
Schedule - once every 3-5 years once implemented

Cost - $40,000/year
Funding - state

*7. The U.S. EPA should conduct a seasonal survey of Saginaw Bay plankton (phytoplankton and zooplankton) community composition once every five years to evaluate the present community structure and track historical trends, which indicate improvement or degradation of bay water quality.

Status - proposed in RAP
Schedule - every five years once implemented
Cost - $250,000/year
Funding - federal

8. Local health departments should conduct periodic bacterial sampling near the mouths of tributaries to the Saginaw River and Saginaw Bay and in the Saginaw River, particularly following runoff events, to document the extent of bacterial problems from municipal wastewater treatment plants, combined sewer overflows, and animal waste disposal areas.

Status - proposed in RAP
Schedule - as needed
Cost - $20,000/year
Funding - state

9. The U.S. FWS should analyze organic and metal contaminant levels in resident Saginaw Bay fish-eating birds and waterfowl on a periodic basis and determine contaminant impacts on these species and human health.

Status - proposed in RAP
Schedule - as needed
Cost - $40,000/year
Funding - state and federal

10. The NOAA should monitor bay currents, macrophyte growth and plankton populations through the use of satellite photos or other remote sensing imagery to document the present distribution pattern and track trends.

Status - proposed in RAP
Schedule - as needed
Cost - dependent on methods used
Funding - federal

*11. The U.S. EPA should conduct site-specific studies in the Saginaw River and Saginaw Bay to determine the rate and volume of contaminant uptake from sediments and water by plankton, benthic macroinvertebrates, fish and piscivorous birds.

Status - proposed in RAP
Schedule - as soon as possible

Cost - $100,000/year
Funding - federal

*12. The U.S. EPA should evaluate the acute and chronic toxicity and life history impacts of Saginaw River/Bay sediment contaminants on plankton, benthic macroinvertebrates, fish and piscivorous birds.

Status - proposed in RAP
Schedule - as soon as possible
Cost - $100,000/year
Funding - federal

These biota activities will help determine where problem areas exist, the severity and extent of the problems, and to assess progress towards achieving the RAP goals. As was the case with water, most of these activities are monitoring/evaluation in nature and have an average annual cost of $660,000.

E. RECOMMENDATIONS ON EXISTING PROGRAMS

1. Compliance with permit provisions needs to continue to be enforced by MDNR with equal accountability for all dischargers, large or small, municipal or industrial.

2. The MDNR should continue to set all basin NPDES permit discharge limits, where appropriate, on a watershed wasteload allocation basis, which also incorporates nonpoint source loads.

3. The MDNR should continue to base NPDES permit limits on the most restrictive criteria (including human health) for all toxic materials found on the Michigan Critical Materials Register.

4. The MDNR should continue to make all efforts possible to reissue the expired NPDES permits for minor facilities in the basin.

5. Parties responsible for seasonal sewage lagoon discharges should make sure they contact MDNR district staff prior to discharge, as required in their NPDES permit, to ascertain that flow rates of receiving waters are adequate to receive the discharge flow.

6. The MDNR should continue to require all municipal WWTPs receiving effluent discharges from federal categorical industrial facilities to continue participation in the Industrial Pretreatment Program.

7. The MDNR should continue to conduct both acute and chronic aquatic toxicity testing on wastewater discharges to the Saginaw River and Saginaw Bay to determine if unacceptable toxic effluents are present and if whole effluent toxicity (due to synergism) is a concern.

8. The MDNR should continue to maintain strict oversight of permittee compliance with established air discharge permit limits.

9. The MDNR should continue the yearly testing of municipal sewage sludges spread on agricultural lands, as well as the soil itself, for toxic metal and organic materials. The use of sludges on highly erodible land and land directly adjacent to watercourses should continue to be restricted.

10. The U.S. EPA needs to establish, as quickly as possible, sediment quality criteria with respect to contaminant release to water and impacts on biota.

11. The MDNR should continue to periodically review, and update as appropriate, Michigan's water quality standards with regard to

current environmental conditions and available practical technology.

12. Basin County Road Commissions and Mosquito Abatement Commissions should continue to follow manufacturers use instructions for applicable pesticides to lessen the potential impacts on water quality and wildlife. Biological controls, such as the mosquito larvicide BTI, should be used instead of chemicals whenever possible.

13. All agencies performing organic chemical analyses should continue to conduct congener specific analyses for PCBs, dioxins and furans whenever laboratory capabilities and budgets allow. PCB congeners should also be grouped and reported by chlorination number. Whenever practical, other techniques such as enzyme induction assays should be considered as a means to partially assess the integrated impact of toxic materials.

14. The MDNR should continue to issue air emission permits for criteria pollutants based on the existing air quality emissions from nearby sources and the potential impacts from the proposed equipment. A permit cannot be issued to any source that may cause injurious effects to human health or the environment, or unreasonable interference to life or property.

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SECTION IX - APPENDICES

Appendix I: Public Comments Received at the September 16, 1986 Public Meeting

This appendix is a list of comments expressed and questions raised at the September 16, 1986, initial public meeting for the Saginaw River/Bay Remedial Action Plan (RAP) project. The present status of each issue is described following the listed concern. A few days prior to this public meeting, the Saginaw River and its northern tributaries experienced their worst flooding in recorded history. As a result, there were many questions raised at this public meeting about the floods and flood hazards. Staff of the Michigan Department of Natural Resources (MDNR) gave a status report on the flooding situation and answered many questions. Questions which were of long-term interest to the Saginaw River/Bay RAP are included in this appendix.

1. We need proper management of our resources and the attendance today reflects great concern in the local area and a commitment for the future. We have made significant progress over the years but there is much more to do. The RAP is one of the steps, along with the Saginaw Bay symposium to be held in March 1987. Local, state and federal groups need to share research and ideas, improve resource management, develop an action plan in the next ten years, enhance economic development and improve water quality in the context of recreation.

   The RAP process includes many mechanisms that facilitate broad local, state and federal participation for developing and implementing actions to improve water quality in the Saginaw River/Bay Area of Concern (AOC). These mechanisms include participation by work group and review committees such as the Saginaw Basin Natural Resources Steering Committee and the Saginaw River/Bay RAP Technical Work Group.

2. Will the Tittabawassee and Saginaw rivers be monitored for the long-term impacts of this flooding on water quality and contaminated sediments?

   Yes, monthly water sampling is conducted by the MDNR on both the Tittabawassee and Saginaw rivers to monitor water quality trends. Sediment samples were collected by MDNR in both rivers and Saginaw Bay in 1988 to assess the current status of contaminated sediments.

3. Has a dioxin analysis been done since the flooding?

   Yes, one water sample was collected by MDNR for dioxin analysis from Dow Chemical Company's emergency outfall to the Tittabawassee River on September 12, 1987, during the flood.

4. Why was only one dioxin sample taken?

   Because the sample was believed to be representative of the discharge from Dow during the flood and additional samples were not needed. Dow had shut down all production facilities at the time the sample was collected so production waste concentrations were not expected to increase. The sample was collected as soon as access to the outfall could be obtained and it was not possible to collect a sample any earlier. Therefore, the information to be gained from additional samples did not warrant the additional costs.

5. We think the EPA should do extensive dioxin studies for the floods may have moved out the dioxins or changed their depositional zone. One sample is not enough and the EPA should take responsibility and do more sampling.

   Thirty walleye were collected from the Tittabawassee River in spring 1988 for dioxin analysis of fish tissue. The MDNR also anticipates collecting tissue samples for dioxin analysis from caged fish studies in the Tittabawassee River, Saginaw River and Saginaw Bay in summer 1988.

6. At the Greenpeace meeting today, the results of the organics testing surprised everyone because detectable levels were found. Was this surprising to the DNR?

   No, MDNR conducted water sampling for organics at various times during the flood because of the type of facilities that were being flooded and the potential for organic materials to reach the river. Laboratory analytical methods can presently detect very small quantities of certain organic compounds so it was not surprising that they were detected in floodwaters downstream of these facilities.

7. Are you taking samples on each of the rivers? Why not the Flint?

   The MDNR collected water samples on the Tittabawassee, Saginaw and Flint rivers during the flood.

8. Last year some data from the Department of Agriculture in Saginaw Township after the Flint River flood showed elevated levels of arsenic, chromium, copper, nickel, zinc and selenium. Will we get the same thing on farmlands and farm products such as beans because of the recent flooding?

   The potential exists that the same thing happened again because several municipal and industrial wastewater treatment plants were flooded and untreated wastewater was carried downstream from these facilities by the floodwaters.

9. Does the Department of Agriculture plan to do a follow-up like they did after the Flint flood?

   A similar study was not conducted. However, in 1987 the Michigan Department of Agriculture undertook a Michigan Food Safety survey of 230 food items from five Michigan cities and found that in all cases FDA human health safety standards were met or exceeded (safer).

10. Why do wastewater treatment plants continue to be in violation of their permits?

Several wastewater treatment plants remained out of compliance with their NPDES wastewater discharge permits for several days during and following the flood because of the severity of impact on their operational facilities.

11. In 1975, the Army Corps of Engineers said the majority of pollutants drops out in the first mile. Can we assume this to be true?

Because of the high velocity of river currents during the flood, and the resultant capacity to carry rather large soil particles downstream, it is likely that soils and contaminants were carried substantial distances downstream by the floodwaters.

12. We are very concerned about the long-term effects of contamination and if toxics are ending up in the food chain.

The MDNR is also concerned about the potential long-term effects of the flood on the uptake of toxic contaminants by aquatic organisms and the subsequent biomagnification of contaminants in the food chain. The ongoing MDNR fish contaminant monitoring program is one method the MDNR uses to monitor this situation. Sediment samples were also collected by MDNR throughout the Saginaw Bay watershed in 1988 to monitor contaminant concentrations in aquatic sediments to which resident biota are exposed.

13. The Niagara River and Lake Ontario have been deeply affected with many fish consumption health advisories. We want source reduction programs and have been working on a source reduction impact statement proposal. This would include doing a waste audit, looking at all technological processes there are, and then implementing the best available technology. We believe the Great Lakes are a good place to start this process. We urge Dow Chemical to do a waste audit of the plant and develop a comprehensive plan to reduce waste. All companies should do similar work. We need source reduction and a chemical audit around the bay.

Source reductions are being conducted by more and more dischargers throughout the Saginaw Bay watershed as raw material, waste disposal, and waste treatment costs rise.

14. The goal of zero discharge of toxic contaminants to our waterways was again emphasized by the Governor and at the World Conference on Large Lakes. Will part of the Remedial Action Plan require a scheduled reduction to reach the goal of virtual elimination?

Activities implemented as part of the RAP will strive to further reduce the discharge of toxic contaminants to the AOC, but there is no schedule in the RAP for achieving virtual elimination of toxic material discharges. Discharge permits are currently issued by the Michigan Water Resources Commission (WRC) to restrict the discharge of toxic materials to levels that protect wildlife and human health.

If practical technology exists to further reduce these levels, then the use of this technology is required. However, Michigan's water quality standards are reviewed every three years and more stringent standards can be sought at this time if they are needed. These revised levels are then incorporated into permits as they expire and are reissued.

15. We are very concerned with water quality in the bay. We are especially concerned about the mosquito spraying program which is being done for the Tittabawassee and Saginaw rivers and goes into the bay. They are using materials that are toxic to fish and they are not supposed to be spraying near fish or ponds. We are also very concerned about spreading this practice to other areas in the bay.

Mosquito control in Bay, Midland and Saginaw counties is accomplished by spraying larvacides on basin waters and adulticides in the terrestrial ecosystem. About a dozen different chemical compounds are used, each for use in specified environments at levels that pose no threat to other wildlife or human health. None of the compounds are restricted use pesticides. Biological controls are also used where possible to reduce chemical use and BTI, a bacteria, is a major component in the area spraying program. All materials are applied according to label use instructions.

16. We are very concerned with Dow Chemical and it seems that the attitude is that diluting pollution makes it okay.

Dow Chemical Company discharges treated wastewater within limits established in a NPDES permit issued by the WRC. The limits are set to protect wildlife and human health.

17. The goal of the federal Clean Water Act is to eliminate discharges, not to reach a certain level. If we followed this policy, we wouldn't have any concerns. This goal needs to be restated to the Natural Resources Commission and to Director Gordon Guyer. We have a strong system but the fish and birds are still being adversely impacted.

Though it is conceptually desirable to have no discharge of pollutants, the additional economic costs sometimes exceed the perceived benefits of discharging materials at levels further below already safe levels. It is suspected that sediments contaminated with materials from historical discharges are a greater cause of use impairment in the AOC than are current discharges.

18. The NPDES permit system is not doing a good job. We should be forcing industry and municipalities to meet zero discharges and they won't be met through this permit system.

The NPDES permit system is designed to restrict the discharge of materials to levels that protect wildlife and human health. Where practical technology exists to further reduce these levels, then the NPDES permit system requires the use of this technology.

Technological improvements and source reductions required by the NPDES program will continue to decrease the amount of materials discharged in the future to the greatest extent possible.

19. Why don't we implement the 1970 Michigan Environmental Protection Act which says you can't discharge if there is a feasible and prudent alternative?

The alternatives to discharge are reviewed during the permit application period.

20. We are very concerned about the growth rate of the fish in Saginaw Bay. Could this be due to the heavy metals?

Heavy metals have not been linked to reduced growth rates of Saginaw Bay fish. Present information indicates that the food base may be limiting the growth of yellow perch.

21. We are against Crow Island being used as a confined disposal facility.

Crow Island is no longer under consideration for use as a confined disposal facility.

22. We don't believe the bay is better than it used to be and we feel we need to be working to prevent what is already happening.

Pollutant concentrations in Saginaw Bay water samples are substantially less than in the past and further reduction efforts continue.

23. There are various serious bird deformity problems in the bay. The study of cormorant failures found one on Cherry Island in the bay. Birds are one of the finest monitors of the toxic situation. They cannot release required toxics to the water through respiration as fish can. They have to metabolize them.

Developmental defects have been noted in some fish-eating birds in Saginaw Bay and studies are being conducted to evaluate the situation. Part of the difficulty in assessing the situation is the migratory nature of these species and the fact that they spend over half the year outside the Great Lakes basin.

24. We are concerned about possible fish tumors and bird deformities. There are tern chicks with crossed bills and these health impacts that are affecting our fish and birds will lead to people being impacted.

Developmental defects noted in some fish-eating birds in Saginaw Bay have not been linked to toxic contaminants, though in any case, these species are not consumed by humans. However, public health fish consumption advisories do exist for several fish species in the AOC. One of the goals in the RAP is to reduce toxic material levels in the AOC so that fish consumption advisories can be removed.

Public drinking water supplies drawn from Saginaw Bay are safe for human consumption.

25. Have you found toxic induced tumors in Saginaw Bay?

Tumors have been found on fish in Saginaw Bay but their cause has not been linked to toxic materials.

26. What is the cause of the tumors in fish and are these fish edible?

A small percentage of any biological population is affected by tumors that have a diverse range of causes. It is not known if all fish affected by tumors are safe to eat, though if affected fish is eaten, it is recommended that the infested area be removed prior to cooking and consumption. Many fish in Saginaw Bay, particularly walleye, that appear to have external tumors actually have a viral infection, not tumors, and are safe to eat.

27. We need an upland disposal option for confined disposal with public comment in an open process.

The RAP recommends the development of a confined disposal facility, for containing contaminated sediments dredged from the lower Saginaw River, to replace the existing facility when it becomes filled. Upland sites will likely be considered in a site selection process that will include a public comment period. A site selection process is already under consideration for the upper Saginaw River.

28. We support the Symposium and on-going Saginaw Bay programs such as research done by the National Fisheries Center looking at historical lake trout issues and Michigan Sea Grant's funding of fish and wetlands studies in the Saginaw Bay.

The Workshop for the Future of Saginaw Bay (symposium) took place as scheduled on March 5, 1987. Many of these research programs were discussed at the workshop.

29. We urge that the RAP include a plan for intensively monitoring toxics in fish and the bay. The massive efforts begun this year need to be done each year.

The RAP recommends the continuation of the existing MDNR fish contaminant monitoring program in the AOC. Water and sediment samples collected from Saginaw Bay in 1988 were also analyzed for toxic materials.

30. We need to be concerned with the wildlife and fish in the bay. Saginaw River/Bay is unique for much of the land area is a wet prairie and home to 40% of Michigan's rare and endangered plants. This has never been addressed and needs to be. Use should be made of the DNR's Natural Features Inventory in the RAP process. The flyash brought in from city construction is one of the finest habitats for rare plants. We need to develop a regular mechanism to review issues like Crow Island on an on-going basis.

The RAP addresses fish and wildlife resources in the AOC by focusing on the two major environmental issues of water quality concern - eutrophication and toxic materials. The Natural Features Inventory computer system was used as an information base in developing the RAP. Public review mechanisms exist for comment on issues such as the once proposed Crow Island CDF. The RAP recommends participation by the Saginaw Basin Natural Resources Steering Committee in the development and review of RAP associated projects in order to provide basinwide input.

31. We need a uniform policy of enforcement for the whole river system. The City of Saginaw has gone through expensive repairs and building an interceptor sewer system while Saginaw Township is still dumping after all these years. We need to have combined sewer overflow facilities.

The MDNR has uniform policy of enforcement throughout the state. However, due to funding and staff limits, the most severe problems generally receive the greatest attention. The RAP recommends that CSO conditions be corrected.

32. The state needs to address household hazardous waste. Dow is now doing a household hazardous waste day. The agricultural community needs to know that not only do they contribute to nonpoint sources but they also have these wastes on their farm facilities. Rather than just be concerned about disposal, we need to stop using these toxic materials in the first place. Greenpeace has tips on what else to use. The Great Lakes Water Quality Board of the International Joint Commission has identified 42 Areas of Concern in the Great Lakes basin. These have been identified since 1973 and in many the water quality standards are still being broken and no action is being taken to improve the situation. In 1981, we decided to design a planning process preparing a plan for each area and these are now starting to be put into place. It is good to involve the public so that as the plan is being developed the cost and high levels of support will be there. The IJC will push recommendations for action on behalf of the Great Lakes. We would like to see long-term efforts taken in the Saginaw Bay/River system.

The MDNR is addressing the household hazardous waste situation through the efforts of the Waste Management Division. The RAP outlines several activities in the area of public information/education and the environmental remedial efforts presented are geared towards long-term solutions.

33. We would like to see clear labelling of products, such as malathion, with their effect on fish and wildlife.

Such products presently contain labels that describe how to apply the product to avoid impacting non-target fish and wildlife. These instructions are based on the known effects of the product, or chemicals therein, on fish and wildlife, which is too voluminous to include with a product label. The more toxic products are sold and use restricted to only certified applicators.

34. We would like to have the areas where runoff is likely to occur be identified.

The RAP outlines studies to further define these areas.

35. Some uses of products such as malathion are in violation of federal laws and we need to be able to enforce the restrictions that are included on the label.

Many such products can be used in certain conditions when applied in prescribed manners and are licensed under federal laws. Documented misuse subjects the responsible party to federal penalties.

36. The recent flooding points to the fact that in the Saginaw Bay/River area too many wetlands have been filled in so these natural sponges haven't been available during recent flooding events. It is critical that the remaining wetlands be especially protected in this area.

Remaining wetlands are protected by a variety of state environmental laws.

37. We are opposed to any relaxation of fish consumption advisories in the Saginaw Bay/River system.

Public health fish consumption advisories are modified by the Michigan Department of Public Health when new data warrants a change in the advisory.

38. We fully support the proposed water quality standards and urge area legislators, including Representative Tom Alley, to support these standards. It is an election year and we need to ask our representatives and senators how they stand on these issues.

The revised Michigan water quality standards were supported and took effect on November 29, 1986.

39. We are very concerned about air emissions and believe that there are some hazardous waste incinerators.

The MDNR issues permits for air emissions which limit the discharge of pollutants in order to protect public health. The RAP outlines several activities to determine the impact of pollutants from atmospheric sources on the AOC.

40. It has been stated that wastewater is not a significant problem, but many industrial plants do not remove toxics. This must result in chemical accumulations in Saginaw Bay. What are the residence times of the materials in the bay?

If an industrial facility is discharging materials for which there are no limits or monitoring requirements in the permit, then it was determined during the permit issuance process that that material was being discharged at levels that would not impact wildlife or human health and therefore no restrictions were needed. The residence time of these materials in Saginaw Bay varies with their characteristics of volatility, adsorption and desorption to sediment particles, rate of biota uptake, and other factors. However, the general residence time of water in the bay is approximately 60 days.

41. We aren't against dredging but we are against redeposition with overflow dredging. The Army Corps of Engineers stopped the overflow dredging a few years ago but then reestablished the practice in 1984 and 1985 without telling anybody. The Corps maintains that it is too costly to not overflow. We are against this and would like to see this practice stopped.

Studies were conducted in 1987 and 1988 to determine the potential impact of overflow dredging on water quality and biota. The WRC is presently considering the issue and are awaiting the study results. The RAP recommends that overflow dredging not be used anywhere in the AOC where there are contaminated sediments and that it be suspended in all areas of the AOC unless it is demonstrated that there are no adverse impacts in the AOC from the practice.

42. Dow is putting a lot of compounds into the river, things that we can't even detect. In addition, old sources of contamination are being resuspended. We need to ask the federal government to spend money in the bay to get the toxics problem solved. Michigan only gets $0.62 on each dollar it sends to the federal government. We need federal money to stop the practice of overflow dredging.

The RAP outlines a variety of evaluation and remedial actions that require substantial federal funding if they are to be implemented.

43. The East Central Michigan Planning and Development Region (ECMPDR), the regional planning agency, has been awarded a contract to develop the first draft of the Remedial Action Plan along with the National Wildlife Federation (NWF) and the University of Michigan School of Natural Resources. They will complete the draft plan by August 1987. The planning agency also has an on-going environmental advisory committee to review environmental directives in the bay area. ECMPDR represents 14 counties in the bay region.

The ECMPDR and NWF completed the RAP first draft as scheduled and it was distributed for public review and comment in September 1987.

44. We urge all interested people to attend the Great Lakes United public hearing next Thursday to express their concerns about, and interest in, the Great Lakes Water Quality Agreement.

The Great Lakes United public hearing was held as scheduled. Many of the same concerns expressed at this RAP public meeting were reiterated at the hearing.

45. The Great Lakes Water Quality Agreement alludes to possible regulation of nonpoint sources. How might this affect the Saginaw Bay?

The potential effects on Saginaw Bay water quality would depend on what specific activities are implemented or regulated. Since the most recent information available indicates that nonpoint sources are responsible for a major portion of the phosphorus entering Saginaw Bay, there is the potential for substantial water quality improvements as a result of this action.

46. We need more clean water incentives and to change tillage operations. We need more technical assistance so that we can work to change and modernize family farming traditions. With 55% of the phosphorus and 88% of the sedimentation coming from agricultural lands, we need to implement more clean water incentives.

The RAP recommends that funding be expanded for clean water incentives in the AOC to reduce pollutant inputs from nonpoint sources.

47. How are agricultural wastes disposed of?

A 1983 ECMPDR survey of agricultural producers in the four counties surrounding Saginaw Bay indicated that 65 percent dispose of empty chemical containers in public landfills, 23 percent burn them, 4 percent bury them, 6 percent return them to distributors, and 3 percent are disposed of in other ways. Most producers use leftover chemicals the following year though 4 percent reported disposing of them in a public landfill.

48. As to the question of resources needed to clean up the Saginaw Bay/River, there is evidence that when people are asked if money should be spent for environmental protection on a particular issue, 90% of the people would support this.

This supposition will be tested on general environmental issues in November 1988 if the state environmental bond proposal is put on the election ballot. In any case, it is important that these people let their legislators know this, which can be done by participating in the RAP process as outlined in this RAP.

49. Because of recent flooding, this is a unique time to study in-place pollutants and their resuspension. Based on flow velocity information, the floods were at least a 1,000, perhaps 10,000 times event. We need to study this as scientists. Rossman coauthored a study showing that flooding scoured and moved PCB's into the bay. These do settle but, because the bay is only 15 feet deep, they resuspend and move out of the bay.

Flow rates in the Tittabawassee River during the September 1986 flood were determined to be 100 to 150 times drought flow. Sediments were sampled throughout the AOC by MDNR in 1988 to assess the present status of contaminant concentrations in in-place sediments.

50. In terms of farming practices, most farmers didn't know about no-till practices. Farmers have been expecting talk of their

excessive uses of chemicals for some time and we don't think the farmers will resist very strongly. The strict water quality standards that the Water Resources Commission passed in June are up for review September 24 by the legislature. We urge people to write or call to express their support of final passage of these standards by the Joint Rules Committee.

Education and demonstration projects are routinely conducted on conservation tillage and conservative chemical practices for AOC agricultural producers. The revised Michigan Water Quality Standards were approved as previously discussed.

51. We are very concerned that for the Flint River it will be pushing to get the flow rates increased in order to get actual discharge limits increased. We need more public input into this process.

    An agreement has been reached on this issue among the City of Flint, Genesee County, MDNR and local public that resulted in an increase in the river low flow rate used for calculating permit discharge limits.

52. We do not support the overflow method of dredging and Section 404 should prevent the Corps and the DNR from using Crow Island as a disposal site. We need upland disposal.

    All three of these items were discussed previously.

53. Information from the International Joint Commission's workshop on the types of information needed to develop the RAP should be used as a reference of source materials for Saginaw Bay/River RAP. How was the Saginaw Bay/River selected as an Area of Concern?

    The workshop information was referred to in the RAP development process. The Saginaw River/Bay area was identified as an Area of Concern to the IJC by the MDNR because of nutrient and toxic material problems.

54. We believe that air deposition is a major source of pollution in the Saginaw Bay area. We believe that a significant source of air toxics is from wastewater treatment plants, both industrial and municipal. The EPA Philadelphia study found this to be true. There are no standards for air toxics. EPA has published a few source specific standards but they do not address the problem as a whole.

    Several actions are proposed in the RAP to evaluate the extent of atmospheric pollutant inputs to the AOC and the sources of these contaminants to the atmosphere.

55. The Michigan Environmental Protection Act did not define what is acceptable to public health. We need to debate this issue.

    Public discussions on this issue were held during the RAP development process and it is anticipated that these discussions will continue throughout the RAP project.

56. We need better enforcement of regulations and we need harsher penalties.

The RAP recommends the expansion of MDNR compliance verification activities and authorization for MDNR to levy administrative fines.

57. At the meeting, Greenpeace submitted the following written statement entitled "How to Ensure a Successful Saginaw Bay Remedial Action Plan".

Greenpeace, along with many other environmental groups and individuals, has been advocating source reduction as the solution to toxic waste problems. Source reduction is process management techniques which reduce and eliminate the production of toxic wastes at their source. It is not treatment or disposal of such wastes after they have been produced. More specifically, source reduction is:

-- Substitution of particular hazardous raw materials with less toxic or non-toxic materials.
-- Process modifications to eliminate waste production.
-- Substitution of particular toxic products with non-hazardous ones.
-- Recycling of wastes.
-- Reusing of wastes.

On August 25th, Greenpeace, along with several other local environmental groups, met with the New York State Commissioner of the Department of Environmental Conservation to discuss pollution problems. The result of this meeting was a source reduction impact statement (SRIS) agreement. Briefly, this agreement would require all industries applying for a permit to discharge toxic chemicals into the environment to do the following:

* Perform and document a comprehensive, plant-wide waste audit; and
* Investigate and document all available source reduction technologies that industry could employ to reduce and/or eliminate their production of toxic wastes.

No permit would be issued if source reduction technologies were available but not employed. Specific, reasonable schedules would be developed for implementing all source reduction measures.

This SRIS will undoubtedly eliminate much of the production of toxic waste. Such a program should be initiated throughout the nation - certainly here in Saginaw Bay. No clean-up program should begin without such a program in order to prevent further contamination.

This SRIS requirement is not something new to Michigan. Section 5(2) of the Michigan Environmental Protection Act basically requires such a program. Unfortunately, this requirement has not been enforced. Section 5(2) sets forth:

In any such administrative, licensing or other proceedings, and in judicial review thereof, any alleged pollution, impairment or destruction...shall be determined, and no conduct shall be authorized or approved which does, or is likely to have such effect so long as there is a feasible and prudent alternative consistent with the reasonable requirements of the public health, safety and welfare.

As stated in item 13, source reduction efforts are generally being undertaken by more and more facilities each year. Feasible and prudent alternatives to discharge are reviewed during the discharge permit issuance process.

Appendix 2: Saginaw River/Bay RAP Resolution

MICHIGAN WATER RESOURCES COMMISSION

RESOLUTION DECLARING SAGINAW BAY AS AN EXTREMELY VALUABLE RESOURCE AND SUPPORTING THE SAGINAW RIVER/SAGINAW BAY REMEDIAL ACTION PLAN PROCESS

WHEREAS, Saginaw Bay is a large embayment of Lake Huron in east central Michigan covering 1,143 square miles with 149 miles of coastal shoreline and has an extensive watershed drainage area of 8,709 square miles containing 17 major tributary streams including the Saginaw River, which is the largest river basin in Michigan; and

WHEREAS, 1.5 million people live in the Saginaw Bay watershed which includes portions of 22 counties, 94 municipalities and 14 percent of Michigan's total land area; and

WHEREAS, Saginaw Bay is used as a source of drinking water and recreational activity to many Michigan residents; and

WHEREAS, Saginaw Bay is an important resource to wildlife, particularly as a spawning area for over 90 species of fish and as a shelter and food base for waterfowl on a major migratory flyway; and

WHEREAS, Michigan's water quality standards declare that Michigan's waters of the Great Lakes are of special significance and are designated as outstanding state resource waters; and

WHEREAS, Saginaw Bay and the Saginaw River are defined as a Great Lakes Area of Concern by the International Joint Commission because certain designated uses of these waters are impaired; and

WHEREAS, Saginaw Bay, being part of Lake Huron, is a boundary water between the United States and Canada and degraded water quality conditions affect both countries; and

WHEREAS, environmental programs have produced substantial improvements in Saginaw Bay water quality over the past two decades, but some degraded conditions remain with respect to eutrophication and toxic materials; and

WHEREAS, staff are preparing, with input from public and technical review groups, the Saginaw River/Saginaw Bay Remedial Action Plan to address the eutrophication and toxic material problems; and

WHEREAS, the implementation of remedial measures as proposed in the Remedial Action Plan will require acceptance and support by Saginaw basin residents and local units of government as well as the dedication of financial and other resources by state and local governments;

NOW THEREFORE BE IT RESOLVED, that the Water Resources Commission declares the Saginaw River and Bay an extremely valuable resource which can provide substantial economic, recreational and aesthetic benefits to the people of the State of Michigan;

BE IT FURTHER RESOLVED, that the Water Resources Commission endorses the goals of the Saginaw River/Bay Remedial Action Plan to describe and implement actions that when completed will (1) reduce toxic material levels in fish tissue to the point where public health fish consumption advisories are no longer needed for any fish species in the Area of Concern, and (2) reduce eutrophication in Saginaw Bay to a level where Saginaw Bay will support a balanced mesotrophic biological community;

BE IT FURTHER RESOLVED, that the Water Resources Commission supports the Saginaw River/Bay Remedial Action Plan process and encourages continued participation from the public, in the design and implementation of remedial measures, through the Saginaw Basin Natural Resources Steering Committee and general public meetings.

BE IT FURTHER RESOLVED, that the Michigan Water Resources Commission commits to do all within its power to return the Saginaw River/Saginaw Bay to a condition that supports its designated uses.

This Resolution adopted this 18th day of September, 1987, upon motion by Commissioner Murray, Commissioner Raad, and unanimously carried.

9-18-87
DATED

Appendix 3. Recent and Projected Populations for Townships, Villages and Cities within the Saginaw Bay Drainage Basin.

Location	Population 1980	Population 2000
Arenac Co.		
Townships		
Adams	457	562
Arenac	892	1,198
Au Gres	907	1,301
Clayton	967	1,237
Deep River	1,874	2,479
Lincoln	1,090	1,497
Mason	852	1,074
Moffatt	657	906
Sims	695	1,011
Standish	2,011	2,802
Turner	791	933
Whitney	1,078	1,526
Villages		
Sterling	457	608
Turner	187	215
Twining	196	234
Cities		
Au Gres	768	1,085
Omer	403	495
Standish	1,264	1,675
Bay Co.		
Townships		
Bangor	17,494	18,293
Beaver	3,027	3,129
Frankenlust	2,525	2,595
Fraser	3,934	4,135
Garfield	1,810	1,846
Gibson	1,068	951
Hampton	10,418	10,894
Kawkawlin	5,077	5,309
Merritt	1,676	1,521
Monitor	10,143	10,606
Mt. Forest	1,444	1,462

Bay Co. cont.

Pinconning	2,984	3,093
Portsmouth	4,291	4,385
Williams	4,414	4,465
Cities		
Auburn	1,921	1,919
Bay City	41,593	34,843
Essexville	4,378	4,146
Pinconning	1,430	1,411

Clare Co.

Townships		
Arthur	567	755
Franklin	635	987
Freeman	437	582
Frost	852	1,252
Garfield	1,416	2,283
Grant	2,227	3,252
Hamilton	1,595	2,343
Hatton	638	937
Hayes	3,609	5,819
Lincoln	974	1,431
Sheridan	1,033	1,408
Surrey	3,101	4,845
Villages		
Farwell	804	1,144
Cities		
Clare	3,300	4,738
Harrison	1,700	2,538

Genesee Co.

Townships		
Argentine	4,180	4,534
Atlas	4,891	5,401
Clayton	7,269	8,074
Davison	13,708	15,301
Fenton	11,744	12,774
Flint	35,405	34,369
Flushing	9,246	10,273
Forest	4,255	4,718
Gaines	5,209	5,839

Genesee Co. cont.

Genesee	25,065	24,312
Grand Blanc	24,413	26,644
Montrose	6,164	6,719
Mt. Morris	27,928	27,121
Mundy	10,786	11,750
Richfield	6,895	7,658
Thetford	8,499	9,548
Vienna	12,914	14,082
Cities		
Burton	29,976	28,965
Clio	2,669	2,844
Davison	6,087	6,761
Fenton	8,098	8,729
Flint	159,611	145,598
Flushing	8,624	9,378
Grand Blanc	6,848	8,159
Montrose	1,706	1,855
Mt. Morris	3,246	3,465
Swartz Creek	5,013	5,826
Villages		
Gaines	440	433
Goodrich	795	790
Lennon	114	115
Linden	2,174	2,191
Otisville	682	670
Otter Lake	14	14

Gladwin Co.

Townships		
Beaverton	1,612	2,727
Bentley	771	1,164
Billings	2,076	3,412
Bourret	315	517
Buckeye	970	1,522
Butman	834	1,192
Clement	781	1,371
Gladwin	743	907
Grim	115	151
Grout	1,542	2,424
Hay	1,056	1,834
Sage	2,049	3,325
Secord	850	1,353
Sherman	773	1,212
Tobacco	1,966	3,152

Gladwin Co. cont.		
Cities		
Beaverton	1,025	1,392
Gladwin	2,479	3,444
Gratiot Co.		
Townships		
Arcadia	1,784	1,797
Bethany	1,526	1,432
Elba	1,537	1,400
Emerson	1,092	958
Hamilton	530	435
Lafayette	776	627
Newark	1,097	1,009
New Haven	1,021	913
North Star	1,171	993
Pine River	1,939	1,866
Seville	2,091	2,150
Sumner	1,897	1,982
Wheller	3,219	3,276
Villages		
Breckenridge	1,495	1,584
Cities		
Alma	9,652	9,548
Ithaca	2,950	2,668
St. Louis	4,107	4,115
Huron Co.		
Townships		
Bingham	1,679	1,768
Brookfield	998	896
Caseville	2,067	2,381
Chandler	555	460
Colfax	1,907	2,284
Dwight	1,145	[illegible]
Fairhaven	1,292	1,325
Grant	819	806
Hume	753	70[illegible]
Lake	822	920
Lincoln	1,042	1,053
McKinley	555	540
Meade	789	766
Oliver	1,756	1,743
Paris	732	613
Pte Aux Barques	6	6

Huron Co. cont.

Port Austin	1,570	1,734
Sebewaing	3,259	3,417
Sheridan	812	763
Verona	1,122	1,284
Winsor	2,140	2,164
Villages		
Caseville	851	924
Elkton	953	1,010
Kinde	600	635
Owendale	308	311
Pigeon	1,247	1,372
Port Austin	839	883
Sebewaing	2,046	2,201
Ubly	862	966
Cities		
Bad Axe	3,184	3,427

Iosco Co.

Townships		
Alabaster	371	406
Au Sable	2,198	2,699
Baldwin	1,393	1,697
Burleigh	761	789
Grant	1,043	1,281
Oscoda	11,386	13,155
Plainfield	3,160	3,862
Reno	566	581
Sherman	465	481
Tawas	1,463	1,678
Wilber	554	635
Cities		
East Tawas	2,584	2,964
Tawas City	1,967	2,222
Whittemore	438	451

Isabella Co.

Townships		
Broomfield	1,246	1,625
Chippewa	3,784	5,160
Coe	3,141	4,362
Coldwater	714	882
Deerfield	2,160	2,930
Denver	1,059	1,321

Isabella Co. cont.

Fremont	1,215	1,579
Gilmore	966	1,202
Isabella	1,916	2,375
Lincoln	1,698	2,262
Nottawa	2,042	2,706
Rolland	1,105	1,326
Sherman	1,405	1,709
Union	5,306	7,633
Vernon	1,389	1,654
Wise	1,218	1,540
Villages		
Shepherd	1,534	2,158
Rosebush	336	N.A.
City		
C.M.U.[a]	16,912	13,500
Bal. of City	6,834	8,833
Mt. Pleasant	23,746	22,333

Lapeer Co.

Townships		
Arcadia	2,347	3,109
Attica	3,642	4,987
Burlington	1,562	1,774
Burnside	1,772	2,192
Deerfield	4,672	6,346
Dryden	2,977	4,056
Elba	4,604	5,007
Goodland	1,534	1,799
Hadley	3,331	4,843
Lapeer	4,261	5,948
Marathon	4,336	5,335
Mayfield	7,098	9,787
Metamora	3,220	4,459
North Branch	2,721	3,518
Oregon	5,652	7,862
Rich	1,249	1,422
City		
Lapeer	6,198	6,363
Villages		
Clifford	406	543
Columbiaville	953	982
Metamora	552	564
North Branch	896	1,143
Otter Lake	442	499

Livingston Co.		
Townships		
Cohoctah	2,436	4,365[b]
Conway	1,722	2,488[b]
Deerfield	2,611	3,645[b]
Genoa	9,261	17,388[b]
Hartland	6,034	14,558[b]
Howell	3,999	8,288[b]
Marion	4,754	9,723[b]
Oceola	4,175	8,935[b]
Tyrone	6,077	12,231[b]
City		
Howell	6,976	9,269[b]
Mecosta Co.		
Townships		
Chippewa	1,009	1,400
Fork	1,348	1,900
Martiny	1,210	1,800
Millbrook	947	1,280
Sheridan	1,007	1,200
Wheatland	1,424	1,870
Village		
Barryton	422	N.A.
Midland Co.		
Townships		
Edenville	2,029	2,180
Geneva	1,257	1,205
Greendale	1,244	1,315
Homer	4,477	5,195
Hope	1,249	1,320
Ingersoll	3,011	3,375
Jasper	1,129	1,152
Jerome	4,171	4,840
Larkin	3,303	3,832
Lee	3,325	3,858
Lincoln	1,643	1,906
Midland	2,389	2,346
Mills	1,461	1,695
Mount Haley	1,586	1,840
Porter	1,113	1,089
Warren	1,846	2,131

<u>Midland Co. cont.</u>		
Villages		
Sanford	864	N.A.
Cities		
Coleman	1,429	1,602
Midland	37,250	42,418
<u>Montcalm Co.</u>		
Townships		
Crystal	2,224	2,700
Ferris	1,133	1,400
Home	2,614	2,850
Richland	2,421	3,300
<u>Oakland Co.</u>		
Townships		
Addison	4,184	8,636[b]
Brandon	8,336	16,720[b]
Groveland	4,114	6,595[b]
Highland	16,958	29,918[b]
Holly	3,612	5,027[b]
Oxford	7,823	15,236[b]
Rose	4,465	9,290[b]
Springfield	8,295	16,097[b]
Village		
Ortonville	1,190	2,316[b]
City		
Holly	4,874	6,263[b]
<u>Ogemaw Co.</u>		
Townships		
Churchill	1,058	1,507
Cumming	675	921
Edwards	1,036	1,470
Goodar	374	476
Hill	1,301	1,745
Horton	729	1,034
Klacking	386	504
Logan	567	718
Mills	2,624	4,042
Ogemaw	814	1,189

Ogemaw Co. cont.

Richland	803	966
Rose	1,085	1,630
West Branch	2,075	3,054
Village		
Prescott	322	367
Cities		
Rose City	661	938
West Branch	1,785	2,092

Osceola Co.

Townships		
Evart	1,029	1,300
Orient	635	900
Sylvan	657	700

Roscommon Co.

Townships		
Backus	213	302
Kester	245	331
Richfield	2,926	4,786

Saginaw Co.

Townships		
Albee	2,642	2,814
Birch Run	5,488	5,638
Blumfield	2,047	2,137
Brady	2,498	2,536
Brant	1,849	1,800
Bridgeport	13,978	14,781
Buena Vista	12,768	12,587
Carrollton	7,482	7,262
Chapin	1,054	1,020
Chesaning	5,317	5,354
Frankenmuth	2,389	2,497
Fremont	2,087	2,066
James	2,168	2,293
Jonesfield	1,920	1,854
Kochville	2,828	3,012
Lakefield	960	949
Maple Grove	2,994	3,189

Saginaw Co. cont.

Marion	913	878
Richland	4,402	4,689
Saginaw	38,668	41,190
St. Charles	3,689	3,580
Spaulding	3,164	3,109
Swan Creek	2,530	2,745
Taymouth	4,581	4,770
Thomas	11,184	11,875
Tittabawassee	4,908	5,228
Zilwaukee	89	N.A.
Villages		
Birch Run	1,196	1,266
Chesaning	2,656	2,531
Merrill	851	786
Oakley	412	407
St. Charles	2,276	2,364
Cities		
Frankenmuth	3,753	3,994
Saginaw	77,508	67,969
Zilwaukee	2,201	N.A.

Sanilac Co.

Townships		
Argyle	912	905
Austin	802	807
Custer	1,122	1,202
Elmer	829	826
Evergreen	1,042	1,046
Flynn	963	1,058
Greenleaf	746	772
Lamotte	1,065	1,145
Marlette	2,029	2,476
Minden	710	700
Moore	1,318	1,393
Wheatland	582	583
City		
Marlette	1,761	2,034

Shiawassee Co.

Townships		
Antrim	1,752	2,421
Burns	3,273	4,098
Caledonia	4,785	5,404
Fairfield	904	984
Hazelton	2,411	2,762
New Haven	1,425	1,522
Owosso	4,530	5,188
Rush	1,500	1,585
Shiawassee	2,709	3,161
Venice	3,063	3,416
Vernon	5,003	5,678
Cities		
Corunna	3,206	3,668
Durand	4,241	4,099
Owosso	16,455	17,531
Villages		
Bancroft	618	614
Byron	689	656
Lennon	486	482
New Lothrop	646	716
Vernon	1,008	977

Tuscola Co.

Townships		
Akron	1,811	1,855
Almer	2,720	3,179
Arbela	3,192	3,856
Columbia	1,428	1,390
Dayton	1,728	2,027
Denmark	3,615	4,313
Elkland	3,449	4,044
Ellington	1,214	1,351
Elmwood	1,337	1,427
Fairgrove	1,946	2,125
Fremont	2,871	3,349
Gilford	915	857
Indianfields	7,037	8,059
Juniata	1,619	2,018
Kingston	1,539	1,667
Koylton	1,339	1,581
Millington	4,429	5,434
Novesta	1,482	1,632
Tuscola	2,255	2,719

Tuscola Co. cont.

Vassar	3,709	4,631
Watertown	2,122	2,575
Wells	1,501	1,695
Wisner	916	1,043
Villages		
Akron	538	617
Caro	4,317	5,079
Cass City	2,258	2,716
Fairgrove	693	823
Gagetown	482	481
Kingston	417	457
Mayville	958	1,082
Millington	1,237	1,442
Reese	1,645	2,057
Unionville	578	625
City		
Vassar	2,727	3,075
Saginaw Bay Drainage Drainage Basin Total	1,458,339	1,648,036

Sources: - Bureau of the Census. 1983
- ECMPDR Region 7
- GLS Region 5
- SEMCOG Region 1
- WMRPC Region 8

[a]Central Michigan University figures supplied by Mt. Pleasant Department of Community Affairs.

[b]Projected to the year 2005 by SEMCOG.

Appendix 6. Distribution of Establishments by Major Industrial Group and Employment Range for Counties in the Saginaw Bay Drainage Basin.

Major group descriptions are: 20-food and kindred products; 22-textile mill products; 23-apparel and other textile products; 24-lumber and wood products; 25-furniture and fixtures; 26-paper and allied products; 27-printing and publishing; 28-chemicals and allied products; 29-petroleum and coal products; 30-rubber and misc. plastics products; 31-leather and leather products; 32-stone, clay, and glass products; 33-primary metal industries; 34-fabricated metal products; 35-machinery, except electrical; 36-electric and electronic equipment; 37-transportation equipment; 38-instruments and related products; 39-miscellaneous manufacturing industries (Bureau of the Census, 1985).

	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Administra-
Arenac																				
1 to 19 employees	3			6									1	5	3				1	
20 to 99 employees							2							1	5		1	1		
Bay																				
1 to 19 employees	4	1		6	5	2	12	2	2	6		10	3	13	21	4	3		2	2
20 to 99 employees	1					1	2	1		0		2	2	5	6	1	0		1	1
100 to 249 employees	5					1	2			1			1	1	0	2	2			0
250 employees or more			1												1	1	1			1
Clare*																				
1 to 19 employees	7			5			1					4		3	3				1	
20 to 99 employees	2			1						2			1	2	2				1	
Genesee																				
1 to 19 employees	8	1	1	7	4	4	42	7		11	1	12	3	24	46	6	5	8	9	1
20 to 99 employees	7	1				1	9	0		8		4	1	10	12	1	3	1	2	7
100 to 249 employees	2					1	4	0						0	1	1	9			
250 employees or more							1	1						2			6			
Gladwin																				
1 to 19 employees				3			1	2		0				4	8		2			
20 to 99 employees										2					1		1			
100 to 249 employees															1					

Appendix 6. Continued.

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Auxil-iaries
Gratiot*																				
1 to 19 employees	2			5		4	6	10	8	4	0	2	6	1	3	1	0		1	2
20 to 99 employees				1			7	1	8	7	0		1	2	3		3			1
100 to 249 employees									1	1	0			0			0			1
250 employees or more											1			1			1			
Huron*																				
1 to 19 employees	5		1	2			2	2		2		4	1	5	8		2			
20 to 99 employees	7						1	1		2		2	2	1	4		1			
100 to 249 employees	1												1	0						
250 employees or more														1						
Ionia*																				
1 to 19 employees	1		1	10			5					3		1	5		1		2	
20 to 99 employees							1					0		2	3		1		2	
100 to 249 employees												1		2						
Isabella																				
1 to 19 employees	2		1	6	1	2	2					3		0	7			3	1	
20 to 99 employees	1						1							0	2					
100 to 249 employees														1	2					
Lapeer*																				
1 to 19 employees	1		1	2			6			1		3	2	10	15	1	7	4	3	10
20 to 99 employees	0			3			1			2			2	4	4		3	1		1
100 to 249 employees	1									1				1						
250 employees or more										1										
Livingston*																				
1 to 19 employees	2	1		2		1	13	5	3	2		3	2	15	25	9	1	6	2	0
20 to 99 employees	5			1		1	1		0	6		1	4	4	10	2	6	1		3
100 to 249 employees							1		1					0	2		1			
250 employees or more														1						

Appendix A. Continued.

	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Auxil-iaries
Mecosta*																				
1 to 19 employees	1			6	1		1	2			1	2		0	3		0			
20 to 99 employees					1		1				8			7	6		1			
100 to 249 employees											1			7						
250 employees or more											1									
Midland																				
1 to 19 employees	1			3	1		6	6		2		3	1	6	5	1		1	3	8
20 to 99 employees				1	1			6		1		2		1	1				1	3
100 to 249 employees							2	6		1										1
250 employees or more								1												1
Montcalm*																				
1 to 19 employees	1		1	9	1	0	4	2	2	4	3	7		6	8	0	5		1	0
20 to 99 employees	1					2	1		1	4				0	2	0	0			7
100 to 249 employees	0						1							1		1	0			
250 employees or more	1													1		2	1			
Oakland*																				
1 to 19 employees	29	5	16	51	26	1	210	65	12	84	2	60	61	212	617	63	36	28	62	57
20 to 99 employees	4	1	6	2	2	1	15	26	2	15		10	27	114	225	36	16	18	20	58
100 to 249 employees	1			1	1	1	3	1		8		1	3	17	23	13	4	4	2	17
250 employees or more							1	2					3	3	9	3	8	1	1	13
Ogemaw*																				
1 to 19 employees				15	0		1			1		4	2	3	4	2			1	
20 to 99 employees					1								1	2	4					
100 to 249 employees														2						
Osceola*																				
1 to 19 employees	0			7			3			2	0	1		4	3	0	8		3	
20 to 99 employees	0									0	0			3	1	2	1			
100 to 249 employees	2									0	1			0	1					
250 employees or more										1			1							

Appendix 4. Continued.

	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	Ancillaries
Roscommon*																				
1 to 19 employees				6			4					6		7				1	1	
20 to 99 employees							1							2						
Saginaw																				
1 to 19 employees	7	2	1	17	4	6	26	5		3		13	5	16	36	1	2	5	1	7
20 to 99 employees	4		1	1	0	1	3	2		3		1	3	7	22	3	1	1		3
100 to 249 employees	5				6		3			1			3		2	6	0	2		
250 employees or more	1						1						7		3	1	3			
Sanilac*																				
1 to 19 employees	5		4	7	1		5	1		3		6	0	10	9	0	2	1		
20 to 99 employees	0			1						5		7	1	6	2	2	2			
100 to 249 employees	1									1				3			1			
250 employees or more	1									1										
Shiawassee*																				
1 to 19 employees	3		1	3	1	6	7			5	1	6	0	6	15	0	0		1	0
20 to 99 employees					2	1	1			3		2	1	3	5	0	1			2
100 to 249 employees						1						1			1	3	2			0
250 employees or more																2	1			2
Tuscola																				
1 to 19 employees	1			4			6	3		0		5	0	3	9		1	2	1	2
20 to 99 employees	2						2			7			1	2	2		3		1	
100 to 249 employees	7												9		0					
250 employees or more													7		1					

*Only a portion of county is within the Saginaw Bay drainage basin.

APPENDIX 5

NPDES PERMITTED FACILITIES IN THE SAGINAW BASIN

MAJOR AND MINOR

08/24/88

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
AKRON-FAIRGROVE WWSL DAN CRAGG 4903 DARBEE RD FAIRGROVE , MI 48733	MI0028378	08/31/89	210302
ALCO STANDARD-DELFIELD CO 980 SOUTH ISABELLA RD. MT. PLEASANT , MI 48858	MI0044971	10/01/91	[illegible]
ALMA PRODUCTS CO 2000 MICHIGAN AVENUE ALMA , MI 48801	MI0044334	05/30/90	[illegible]
ALMA WWTP PO BOX 271 ALMA , MI 48801	MI0020265	10/01/88	210402
AMOCO OIL CO-BAY CITY 411 TIERNAN ROAD BAY CITY , MI 48707	MI0046060	08/01/92	[illegible]
ASTECH INC 5512 SCOTCH RD. VASSAR , MI 48768	MI002641[illegible]	10/31/92	[illegible]
AU GRES WWSL 124 W. HURON RD. AU GRES , MI 48703	MI00222[illegible]	[illegible]	[illegible]
AVONDALE MHP WWTP ATT: ARNIE YANK 1034 MIDLAND FREELAND , MI 48627	MI0029479	[illegible]	[illegible]
BAD AXE WWTP 515 CHICKORY ST. BAD AXE , MI 48413	MI0020954	[illegible]	[illegible]

FACILITY NAME / ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
BAY CITY COUNTRY CLUB 7255 S. 3 MILE ROAD ATT:HORACE DAVID BAY CITY , MI 48706	MI0028371	06/31/[illegible]	210407
BAY CITY METRO WTP 301 WASHINGTON AVE. BAY CITY , MI 48706	MI0005291	07/31/[illegible]	210401
BAY CITY WWTP 2905 N. WATER STREEET BAY CITY , MI 48706	MI0022284	05/31/89	2104[illegible]
BEAVERTON WWSL BLADES ROAD BEAVERTON , MI 48612	MI0022306	10/01/92	210403
BEECHER METRO NO 3 WTP 1057 LOUIS AVENUE FLINT , MI 48505	MI0044547	01/31/91	2104[illegible]
BERNTHAL SAND & GRAVEL INC 2021 GATES STREET REESE , MI 48757	MI002[illegible]	10/31/92	210403
BEST WESTERN-HOWELL 1500 PINCKNEY ROAD HOWELL , MI 48843	MI004[illegible]915	11/30/89	[illegible]
BIRCH RUN WWSL 12060 HEATH STREET BIRCH RUN , MI 48415	MI0022390	09/31/88	2104[illegible]
BOB S MARINA WWSL 3710 EAST MICHIGAN AUGRES , MI 48703	MI0043154	[illegible]/88	[illegible]

NPDES PERMITTED FACILITIES IN THE SAGINAW BASIN
MAJOR AND MINOR
08/04/88

FACILITY NAME / ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
BOPP-BUSCH MFG CO 545 E HURON AL GRES , MI 48703	MI0026662	10/01/92	[illegible]
BRECKENRIDGE WWSL ATTN: DON EICHORN 124 SAGINAW STREET BRECKENRIDGE , MI 48615	MI0022438	[illegible]	[illegible]
BRIDGEPORT TWP WWTP MR. JAMES E MINARD, CLERK 6202 DIXIE HIGHWAY BRIDGEPORT , MI 48722	MI0022446	[illegible]	[illegible]
BRIGHTON METAL PRODUCTS INC 6977 MAIN STREET CASEVILLE , MI 48725	MI0045331	01/01/92	[illegible]
BROWN MACHINE P O BOX 434 BEAVERTON , MI 48612	MI0004308	08/31/89	[illegible]
BUENA VISTA TWP WWTP 2961 HACK ROAD SAGINAW , MI 48601	MI0022497	[illegible]	[illegible]
BUTMAN TWP WWSL 5305 N HOLLADAY RD GLADWIN , MI 48624	[illegible]	[illegible]	[illegible]
BYRON WWSL C/O VILLAGE HALL 12056 FAIRBANKS ROAD BYRON , MI 48418	[illegible]	[illegible]	[illegible]
CANDLELITE INN CANDLELITE INN 6817 DIXIE HWY. BRIDGEPORT , MI 48722	[illegible]	[illegible]	[illegible]

NPDES PERMITTED FACILITIES IN THE SAGINAW BASIN
MAJOR AND MINOR
02/04 82

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
CARL SCHULTZ INC 715 SOUTH MAIN STREET LAPEER , MI 48446	MI0046329	12/31 82	[illegible]
CARMET CO 345 E. SOPHER RD. ATT: MICHAEL BULL BAD AXE , MI 48413	MI0005991	[illegible]	[illegible]
CARO WWTP 724 COLUMBIA AVE. CARO , MI 48723	MI0022551	[illegible]	[illegible]
CARROLLTON TWP STM WTR OFLW TP CARROLLTON TOWNSHIP 1645 MAPLERIDGE SAGINAW , MI 48604	MI00440[illegible]	[illegible]	[illegible]
CARROLLTON TWP-STORM WATE 1645 MAPLERIDGE SAGINAW , MI 48604	MI0022578	[illegible]	[illegible]
CASS CITY WWTP 6737 CHURCH ST. CASS CITY , MI 48726	MI0022594	[illegible]	[illegible]
CENTRAL MICHIGAN RAILWAY CO BAY CITY YARD 2688 N. EUCLID ST BAY CITY , MI 48706	MI000[illegible]45	[illegible]	[illegible]
CHEM-TREND INC ATT: ANN FARMES 3205 E GRAND RIVER HOWELL , MI 48843	MI004[illegible]718	[illegible]	[illegible]
CHEM-TREND INC-MCPHERSON 1445 MCPHERSON PARK DRIVE HOWELL , MI 48843	MI0045[illegible]	[illegible]	[illegible]

NPDES PERMITTED FACILITIES IN THE SAGINAW BASIN
MAJOR AND MINOR
09/04/88

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
CHESANING WWTP 1101 N MAIN STREET CHESANING , MI 48616	MI0070087	04 30.8[illegible]	2104[illegible]
CLARE WFP 206 WEST FIFTH STREET CLARE , MI 48617	MI0037311	08 31 [illegible]	2104[illegible]
CLARE WWTP 202 W FIFTH ST CLARE , MI 48617	MI0020176	[illegible]	[illegible]
CLIFFORD WWTP 4548 MADISON STREET CLIFFORD , MI 48727	MI0029441	09.30.87	210400
COLEMAN WWSL 201 E. RAILWAY ST.,PO BOX156 COLEMAN , MI 48618	MI0020206	12/31/78	[illegible]
COLFAX TWP WWSL-HURON CO R#1, N. MCMILLAN RD. BAD AXE , MI 48413	MI0027513	09 30/88	[illegible]
COUNTRY MANOR MHP ATT: MIRLANE LINTZ 5649 VERON ROAD DURAND , MI 48429	MI0038967	12 31 8[illegible]	2104[illegible]
COUNTRY PLACE PARK MHP ATT:ROBERT DIDUR 4151 E JORDAN ROAD MT. PLEASANT , MI 48858	MI0041947	07 31 8[illegible]	[illegible]
CPCO-KARN & WEADOCK PLANT ATTN: KEN BIESKE 135 W. TRAIL RD JACKSON , MI 49201	MI0001679	09.31.[illegible]	[illegible]

NPDES PERMITTED FACILITIES IN THE SAGINAW BASIN
MAJOR AND MINOR
05/04.88

FACILITY NAME / ADDRESS		NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
CPCO-MIDLAND NUC PLT ATT: KEN BIESZKE 135 W. TRAIL JACKSON	, MI 49201	MI0042668	05 30 87	[illegible]
CPCO-THETFORD GENERATING ATTN: K. BIESZKE 135 W. TRAIL JACKSON	, MI 49201	MI0047161	02 28 86	[illegible]
CREW PRODUCTS CO 205 MACKINAW STREET AU GRES	, MI 48703	MI0002445	[illegible]	[illegible]
CULLIGAN-WEST BRANCH 2254 WEST M-55 WEST BRANCH	, MI 48661	MI0037559	[illegible]	[illegible]
DOW CHEM USA-BAY CITY ATT: WILLIAM CARMODY 4868 EAST WILDER RD. BAY CITY	, MI 48706	MI0000655	[illegible]	211407
DOW CHEM USA-MIDLAND MICHIGAN DIVISION BUILDING 1261 MIDLAND	, MI 48667	MI0000868	06 30 88	[illegible]
DOW CORNING CORP-CORP CENTER 2200 WEST SALZBURG RD AUBURN	, MI 48611	MI0000329	[illegible]	[illegible]
DOW CORNING CORP-MED PRODUCTS MEDICAL PRODUCTS PLANT 1635 NORTH GLEANER ROAD HEMLOCK	, MI 48626	MI0042911	[illegible]	[illegible]
DURAND WWTP 201 E. MAIN ST. DURAND	, MI 48429	MI0022063	[illegible]	[illegible]

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FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
ELKTON COOP ELEVATOR	MI0046698	06 01 [illegible]	[illegible]
ELKTON WWSL 57 N MAIN STREET ELKTON , MI 48731	MI0022988	12 31 [illegible]	[illegible]
ELKTON-PIGEON-BAY PORT SCHOOLS 6136 PIGEON ROAD PIGEON , MI 48755	MI0039209	[illegible]	[illegible]
ESSEXVILLE WWTP 1008 BURNS ST. ESSEXVILLE , MI 48732	MI0022918	10 01 [illegible]	[illegible]
FENTON HTS APTS WWSL 10519 DENTON HILL ROAD FENTON , MI 48430	MI0037173	[illegible]	[illegible]
FLINT WTP 1101 S. SAGINAW ST. FLINT , MI 48502	MI0043617	08 31 88	[illegible]
FLINT WWTP G-4652 BEECHER ROAD FLINT , MI 48532	MI0022926	[illegible] 88	[illegible]
FLUSHING MHP 7416 GILLETTE ROAD FLUSHING , MI 48433	MI0029149	[illegible] 85	[illegible]
FLUSHING WWTP 4400 N. SEYMOUR RD. FLUSHING , MI 48433	MI0020281	[illegible]	[illegible]

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FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
FOAMSEAL INC 253 DEMILLE STREET LAPEER , MI 48446	MI0045811	15/31/92	11 4 3
FRANKENMUTH WWTP 190 PLANT STREET FRANKENMUTH , MI 48734	MI0022942	[illegible] 92	[illegible]
GAGETOWN WWSL ATTN: DON BARRIGAR 4793 STATE ST. GAGETOWN , MI 48735	MI0028711	14/3[illegible] 89	11 [illegible]
GENESEE CO-RAGNONE WWTP 9290 FARRAND ROAD MONTROSE , MI 48457	MI0022977	[illegible] 88	[illegible]
GENESSEE CO #3 WWTP 14412 HOGAN ROAD LINDEN , MI 48451	MI0022993	[illegible]	[illegible]
GLADWIN WWTP 1000 W. CEDAR AVE P.O. BOX 615 GLADWIN , MI 48624	MI0023[illegible]	08 [illegible]	[illegible]
GM-BOC-FLINT BUICK MOTOR DIVISION 902 EAST HAMILTON AVE FLINT , MI 48505	MI[illegible]	[illegible]	[illegible]
GM-CENTRAL FOUNDRY DIV 2100 VETERANS MEMORIAL PARKWAY SAGINAW , MI 48601	MI[illegible]	[illegible]	[illegible]
GM-CPC-BAY CITY CHEVROLET-PONTIAC-CANADA GP 100 FITZGERALD ST. BAY CITY , MI 48706	MI[illegible]	[illegible]	[illegible]

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[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
GM-CPC-FLINT ENGINE PLT FLINT ENGINE PLANT/MEDACURE LAB G-3248 VAN SLYKE RD. FLINT , MI 48551	MI0044471	[illegible]	[illegible]
GM-CPC-FLINT MFG DIV CHEVROLET-FLINT MFG DIVISION 300 N. CHEVROLET AVE. FLINT , MI 48555	MI000[illegible]	[illegible]	[illegible]
GM-FISHER BODY DIV-FLINT FISHERBODY DIV. FLINT PLT #1 4300 S. SAGINAW ST. FLINT , MI 48557	MI0001147	[illegible]	[illegible]
GM-FISHER BODY DIV-GR BLANC FISHER BODY-GRAND BLANC PLT 10800 S. SAGINAW ST. GRAND BLANC , MI 48439	MI0001082	11 30 [illegible]	[illegible]
GM-FISHER GUIDE DIV-FLINT FISHER GUIDE DIVISION G-1245 EAST COLDWATER RD FLINT , MI 48505	MI0025174	[illegible]	[illegible]
GM-SERVICE PARTS OPRTNS-FLINT ATTN: B. WEILLER 6060 WEST BRISTOL RD. FLINT , MI 4855[illegible]	MI0001[illegible]	10 [illegible] 8[illegible]	[illegible]
GM-TRUCK & BUS-FLINT ASSEMBLY ATT:MEDACURE LAB-DAN MCCOMB G-3248 VANSLYKE ROAD FLINT , MI 48550	MI000110[illegible]	[illegible]	[illegible]
GM-TRUCK & BUS-FLINT METAL FAB FLINT METAL FABRICATING G-2238 W. BRISTOL RD. FLINT , MI 48553	MI[illegible]44440	[illegible]	[illegible]
GOODRICH AREA SCHOOLS WWTP 8029 S. GALE RD. GOODRICH , MI 48438	MI[illegible]	[illegible]	[illegible]

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FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
GOODRICH WWSL 10237 HEGEL ROAD GOODRICH , MI 48438	MI0036501	04/30/91	[illegible]
GRAND TRUNK WRR-DURAND 409 WEST JAMESON STREET BATTLE CREEK , MI [illegible]	MI0039756	[illegible]	[illegible]
GRAND TRUNK WRR-FLINT NORTH YARD-FLINT G-3180 AIRPORT DRIVE FLINT , MI 48507	MI0041971	[illegible]	[illegible]
GREDE FOUNDRIES-VASSAR FOUNDRY DIVISION 700 E. HURON ST VASSAR , MI 48768	MI0001112	10/01/92	[illegible]
HARTLAND CONSOLIDATED SCHOOLS 3600 HARTLAND HARTLAND , MI [illegible]	MI0037389	09/30/90	[illegible]
HEMLOCK SEMI-CONDUCTOR CORP ATT: WAYNE WINSLOW 12334 GEDDES ROAD HEMLOCK , MI 48626	[illegible]	[illegible]	[illegible]
HEPPNER VILLA INC 770 E. PINCONNING RD. PINCONNING , MI 48650	MI0071466	[illegible]	[illegible]
HI-STAT MFG CO INC 2111 WEST THOMPSON ROAD P.O. BOX 268 FENTON , MI 48430	MI0046566	[illegible]	[illegible]
HITACHI MAGNETICS CORP 7800 N. NEFF ROAD EDMORE , MI 48829	[illegible]	[illegible]	[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
HOLLY WWTP 402 AIRPORT DRIVE HOLLY , MI 48442	MI0020184	[illegible]	[illegible]
HOMER TWP-HANDICARE WWSL 750 PINE RIVER ROAD MIDLAND , MI 48640	MI0043328	02/29/84	[illegible]
HOWELL TWP WWSL MARY BERING 95 BRENDA DRIVE HOWELL , MI 48843	MI004M103	[illegible]	[illegible]
HOWELL WWTP 1191 PICKNEY RD. HOWELL , MI 48843	MI0021113	[illegible]	[illegible]
HURON CO DPW-KINDE WWSL KINDE WWSL 400 HURON KINDE , MI 48445	MI0024520	12/31/78	[illegible]
HURON CO MEDICAL CARE WWSL 1116 SOUTH VAN DYKE ROAD ATT:NEIL HERFORD BAD AXE , MI 48413	MI0037494	[illegible]	[illegible]
HURON MEMORIAL HOSP ATT:DAVE EILERS 1100 S VANDYKE BAD AXE , MI 48413	MI0037508	[illegible]	[illegible]
IOSCO CRC QUARRY WATER 3939 WEST M55 TAWAS CITY , MI 48763	MI0042576	[illegible]	[illegible]
ISABELLA RESERVATION MAIN WWSL	MI0046591	[illegible]	[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRIRATION	BASIN CODE
ITHACA WWSL 1340 EAST ITHACA , MI 48847	MI0021687	12/31/85	210402
JOHNSON CONTROLS INC 951 AIKEN ROAD ATT:JAMES STALEY OWOSSO , MI 48867	MI0003484	[illegible]	[illegible]
JOSEPH H LEBOWSKI CENTER FELLOWSHIP P O BOX 186 OWOSSO , MI 48867	MI0045250	[illegible]	[illegible]
KRIS KAY MHP 1909 SOUTH GRAHAM RD SAGINAW , MI 48603	MI0029131	10/01/91	210407
LAKE ISABELLA WWSL 200 NORTH MAIN, ROOM 213 MT. PLEASANT , MI 48858	MI0029459	07/31/88	21.407
LAKEHEAD PIPELINE CO INC 119 NORTH 25TH ST. EAST P.O. BOX 789 SUPERIOR , WI 54880	MI0046221	10/01/88	[illegible]
LAKEVIEW ESTATES MHP ATT: CATHY HANCHETT P.O. BOX 795 VERNON , MI 48476	MI00356[illegible]	[illegible]	21.407
LAPEER CO PARKS & REC COMM 255 CLAY STREET LAPEER , MI 48446	MI0045632	07/01/92	[illegible]
LAPEER WWTP 1064 INDUSTRIAL DR LAPEER , MI 48446	[illegible]	[illegible]	[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
LAUR SILICON RUBBER CO 4930 S. M-18 P.O. BOX 309 BEAVERTON , MI 48612	MI0041931	[illegible]	[illegible]
LEPRINO FOODS CO-REMUS 311 NORTH SHERIDAN REMUS , MI 49340	MI0044113	[illegible]	[illegible]
LINCOLN APTS LINCOLN TWP WWSL ATT: GEORGE FULK 7545 S. MISSION ROAD MT PLEASANT , MI 48858	MI0026581	[illegible]	[illegible]
LINWOOD METRO DIST WFP P.O. BOX 57 LINWOOD , MI 48634	MI0005444	10-15-87	[illegible]
LIVINGSTON SOFT WATER SERVICE P O BOX 45 HOWELL , MI 48844	MI0028037	[illegible]	[illegible]
LK ONTARIO CMT-AETNA CMT CORP DIV OF LK ONTARIO CEMENT LTD P.O. BOX 80 ESSEXVILLE , MI 48732	MI0004138	[illegible]	[illegible]
LOBDELL-EMERY MFG CO 401 REPUBLIC STREET ALMA , MI 48801	MI0005550	11-30-84	[illegible]
MARATHON PETRO CO-MT MORRIS G-6065 NORTH DORT HWY MT MORRIS , MI 48458	MI0045411	[illegible]	[illegible]
MARLETTE WWTP 6436 MORRIS STREET MARLETTE , MI 48453	MI0021024	[illegible]	[illegible]

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FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
MAYVILLE WWSL 5942 FOX STREET MAYVILLE , MI 48744	MI0023558	07/31/87	21.40[illegible]
MDNR-LAPEER REG COR FAC WWSL J. SULLIVAN-LAPEER REG COR FAC P.O. BOX 30026 LANSING , MI 48909	MI0044304	[illegible]	21.4[illegible]
MDNR-PORT CRESCENT SP WWSL 1775 PORT AUSTIN ROAD P.O. BOX 30028 PORT AUSTIN , MI 48467	MI0043842	11/30/89	[illegible]
MDOT US-27 RA CLARE P.O. BOX 30050 LANSING , MI 48909	MI0037168	06/30/80	21.4[illegible]
MDOT-LINWOOD RA ATT:GARY ROUSE P.O. BOX 4949 SAGINAW , MI 48601	MI0037150	06/30/[illegible]	21.502
MERRILL WWSL 148 W. MAHONEY, VILLAGE HALL MERRILL , MI 48637	MI0024678	06/30/[illegible]	21.40[illegible]
MICH GYPSUM CO 2940 BAY RD. SHERMAN TWP. SAGINAW , MI 48603	MI0002453	[illegible]	[illegible]
MICH SUGAR CO-CARO 725 S. ALMER STREET CARO , MI 48723	MI0002267	[illegible]	[illegible]
MICH SUGAR CO-SEBEWAING 501 PINE ST. SEBEWAING , MI 48759	MI000[illegible]	[illegible]/28/[illegible]	[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
MICHAEL A RYBAK CO 1006 MULHOLLAND RD. BAY CITY , MI 48706	MI0059691	09/30/84	[illegible]
MICHIGAN SUGAR-CARROLLTON 241 SUGAR STREET CARROLLTON , MI 48724	MI0002274	[illegible]	[illegible]
MIDLAND WWTP C/O CITY HALL PO BOX 1647 MIDLAND , MI 48640	MI0023583	09/30/89	[illegible]
MILLINGTON WWSL 8059 MILLINGTON MILLINGTON , MI 48746	MI0023671	12/31/78	[illegible]
MMPA-SEBEWAING PLANT 420 UNION STREET SEBEWAING , MI 48759	MI0002569	01/31/88	[illegible]
MOBIL OIL CORP-FLINT TERMINAL ATT:JOE WYATT G5340 NORTH DORT FLINT , MI 48505	MI0036421	[illegible]	[illegible]
MONITOR SUGAR CO P.O BOX 316 2600 S. EUCLID AVE. BAY CITY , MI 48706	MI0001091	10/01/9[illegible]	[illegible]
MSP INDUSTRIES CORP 45 WEST OAKWOOD ROAD OXFORD , MI 48051	MI0042358	[illegible]	[illegible]
MT PLEASANT WWTP 1755 N. FRANKLIN ST. MT PLEASANT , MI 48858	MI0022659	[illegible] 88	[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRIFATION	BASIN CODE
NAT GYPSUM-TAWAS QUARRY P. O. BOX 14 NATIONAL CITY , MI 48748	MI0003531	05/31/79	[illegible]
NAT GYPSUM-WALLBOARD GOLD BOND BUILDING PRODUCTS P.O. BOX 14 NATIONAL CITY , MI 48748	MI002802?	11/31/8c	[illegible]
NEW LOTHROP WWSL 11488 HENDERSON ROAD NEW LOTHROP , MI 48460	MI0023498	03/31/82	[illegible]
NORTH BRANCH WWSL 4018 HURON NORTH BRANCH , MI 48461	MI0021709	12/31/78	[illegible]
OAKRIDGE MHP 11315 EAST ROAD BURT , MI 48417	MI0029505	11/30/79	210407
OCEOLA TWP-THOMPSON LAKE WWSL OCEOLA TWP P.O. BOX 406 HOWELL , MI 48843	MI0043249	09/30/88	[illegible]
OTISVILLE WWTP 130 EAST MAIN ST. OTISVILLE , MI 48463	MI0028720	[illegible]	[illegible]
OWENDALE WWSL ATTN: ROGER KLING 308 HURON OWENDALE , MI 48754	MI0024491	[illegible]	[illegible]
OWOSSO MID-SHIAWASSEE CO WWTP 1410 CHIPPEWA TRAIL OWOSSO , MI 48867	MI0023752	[illegible]	[illegible]

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FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
PACKAGING RESOURCES INC 5700 SHAFFER ROAD POST OFFICE BOX K COLEMAN , MI 48618	MI0045900	[illegible]/30 [illegible]	[illegible]4[illegible]
PAUL RITTER & BRUCE GEE 301 GATEWOOD DRIVE LANSING , MI 48917	MI0077766	[illegible]	[illegible]
PEACH TREE MANOR 7575 DIXIE HIGHWAY ATT:BRAD A. BLISS BRIDGEPORT , MI 48722	MI0028827	[illegible]	[illegible]
PEBBLE CREEK MHP AWSL 1145 BRADFORD ROAD REESE , MI 48757	MI0043257	12/31/88	[illegible]
PEET PACKING CO-CHESANING 1100 NORTH LINE ROAD CHESANING , MI 48616	MI0000311	[illegible] 30 [illegible]	[illegible]
PIGEON WWTP 29 S. MAIN STREET PIGEON , MI 48755	MI0021737	[illegible]	[illegible]
PINCONNING WFP 3060 EAST PINCONNING ROAD PINCONNING , MI 48650	MI0004740	[illegible]	[illegible]
PINCONNING WWTP 415 E. SECOND ST. PINCONNING , MI 48650	[illegible]	[illegible]	[illegible]
PLAINFIELD TWP AWSL P O BOX [illegible] HALE , MI [illegible]	[illegible]	[illegible]	[illegible]

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FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
PMC INC-VCF FILMS DIV 1100 SUTTON AVENUE HOWELL , MI 48843	MI0002194	10/31/91	[illegible]
PORT AUSTIN WWTP SEWER &WATER AUTHORITY PO BOX 307 PORT AUSTIN , [illegible]	[illegible]	[illegible]	[illegible]
PRESCOTT PRODUCTS INC P O BOX 70 PRESCOTT , MI 48756	[illegible]	[illegible]	[illegible]
PRESTOLITE ELECTRIC INC MORTON STREET BAY CITY , MI 48706	MI0002232	[illegible]	[illegible]
PROGRESSIVE MACHINERY CORP 2280 W. GRAND RIVER HOWELL , MI 48843	MI0043672	[illegible]	[illegible]
PVS CHEM-BAY CHEM CO 100 PICARD HWY BAY CITY , MI 48707	[illegible]	[illegible]	[illegible]
REESE WWSL DIXON WEST OF VANBUREN REESE , MI 48757	[illegible]	[illegible]	[illegible]
REGULAR BAPTIST CHILDRENS AGEN 11793 RIVERSIDE DR. ST. LOUIS , MI 48880	[illegible]	[illegible]	[illegible]
RICHLAND TWP WWSL ATTN: LOWELL DOYLE 1140 N. HEMLOCK RD HEMLOCK , MI [illegible]	[illegible]	[illegible]	[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
RIDGEWAY MHP 11215 BEACH DRIVE SEBEWAING , MI 48759	MI0035629	06 30 [illegible]	[illegible]
RIVERVIEW ESTATES MHP WWTP 755 S. RIVER RD. BAY CITY , MI 48706	MI0021828	[illegible]	[illegible]
ROBIN GLEN MHP 5720 E. WASHINGTON AVE. SAGINAW , 48601	MI0027583	[illegible]	[illegible]
ROBINSON INDUSTRIES INC 3051 CURTICE ROAD COLEMAN , MI 48619	MI0005762	[illegible]	[illegible]
ROSE CITY WWSL ATT: KURT KILLACKEY P.O. BOX 779 ROSE CITY , MI 48654	MI0020613	11/30/[illegible]	[illegible]
ROSEBUSH WWSL VILLAGE HALL U.S. 27 ROSEBUSH , MI 48878	MI0023957	12 31 [illegible]	[illegible]
SAGINAW CHIPPEWA INDIANS 7070 E BROADWAY MOUNT PLEASANT , MI 48858	[illegible]	[illegible]	[illegible]
SAGINAW TWP WWTP 5790 WEST MICHIGAN AVE SAGINAW , MI [illegible]	[illegible]	[illegible]	[illegible]
SAGINAW WWTP 2406 VETERANS MEMORIAL PARKWAY SAGINAW , MI 48601	[illegible]	[illegible]	[illegible]

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SEBEWAING INDUSTRIES INC 249 N. CENTER ST.,P.O.BOX 646 SEBEWAING , MI 48759	MI0002178	10/31/86	[illegible]
SEBEWAING WWSL 108 WEST MAIN STREET SEBEWAING , MI 48759	MI0024082	06/30/88	[illegible]
SHEILDS MHP WWSL 1610 SOUTH GRAHAM ROAD SAGINAW , MI 48603	MI0046230	[illegible]	[illegible]
SHEPHERD WWSL 401 E. DRIVE SHEPHERD , MI 48883	MI0021431	03/31/92	[illegible]
SNOVER STAMPING CO 3279 W. SNOVER ROAD SNOVER , MI 48472	MI0042157	12/31/9[illegible]	[illegible]
ST CHARLES WWSL VILLAGE HALL 110 W. SPRUCE ST. CHARLES , MI 48655	MI0074007	[illegible]	[illegible]
ST LOUIS WWTP 108 W. SAGINAW ST. ST. LOUIS , MI 48880	MI0021555	[illegible]	[illegible]
STABLEX CORP SUITE [illegible] 2 RADNOR CORP. CENTER RADNOR , PA 19087	MI004200[illegible]	[illegible]	[illegible]
STACKPOLE ULTRACARBON	[illegible]	[illegible]	[illegible]

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STANDISH WWTP 399 E. BEAVER STREET P.O. BOX 726 STANDISH , MI 48658	MI0024139	07 31 88	[illegible]
STAUNTON INDUSTRIES INC P.O. BOX 488 2784 METAMORE RD. OXFORD , MI 48051	MI0042111	[illegible]	[illegible]
STERLING WWSL 1201 STATE STREET STERLING , MI 48659	MI0042340	[illegible]	[illegible]
STOCKHOLM FOREST VIL MHP WWSL 800 MIER RD. SANFORD , MI 48657	MI0043746	[illegible]	[illegible]
STODDARD MHP WWSL 16940 S. OAKLEY ROAD CHESANING , MI 48616	MI0029092	12 31 87	[illegible]
TAWAS CITY WWTP 520 INDUSTRIAL AVE P O BOX 568 TAWAS CITY , MI 48763	MI0024010	[illegible]	[illegible]
TAWAS UTILITY AUTHORITY WWTP 120 WEST WESTOVER EAST TAWAS , MI 48730	MI0021091	[illegible]	[illegible]
TITTABAWASSEE TWP WWSL 355 CHURCH STREET TITTABAWASSEE TWP. , MI 48623	MI0027793	[illegible]	[illegible]
TOTAL PETROLEUM INC E SUPERIOR STREET ALMA , MI 48802	MI0001066	[illegible]	[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
TRI-CITY AIRPORT WWSL P.O. BOX P FREELAND , MI 48623	MI0024236	12/31/78	21403
TUSCARORA PLASTICS INC 624 BRADY STREET CHESANING , MI 48616	MI0042765	03/31/87	[illegible]
TUSCOLA CO DPW-KINGSTON WWSL VILLAGE HALL 3655 ROSS ST. KINGSTON , MI 48741	MI0024864	12/31/78	[illegible]
UBLY RSD 4481 N QUEEN STREET UBLY , MI 48475	MI0028991	[illegible]	[illegible]
UNIONVILLE WWSL ATT: DON BARRIGAR P.O. BOX 132 UNIONVILLE , MI 48767	MI0028703	03/31/87	[illegible]
UNOCAL-BAY CITY 5011 WILDER RD. BAY CITY , MI 48706	[illegible]	[illegible]	[illegible]
US GYPSUM CO ATT: ERIC BERKHIMER ROUTE #2 TAWAS CITY , MI 48763	[illegible]	[illegible]	[illegible]
USAF-PORT AUSTIN WWTP 8185 N. VANDYKE AUSTIN , MI 48467	[illegible]	[illegible]	[illegible]
VASSAR WWTP 344 S. WATER STREET VASSAR , MI 48768	[illegible]	[illegible]	[illegible]

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN CODE
VENICE TWP-HOLIDAY SHORES WWSL ATT: WILLIAM ATKINSON 10915 GOODALL ROAD DURAND , MI 48429	MI0041640	[illegible]	[illegible]
VERNON WWSL 120 E. MAIN ST. VERNON , MI 48476	MI0024079	[illegible]	[illegible]
VIKING ENERGY-MCBAIN PLT 4008 WEST WACKERLY MIDLAND , MI 48640	MI0044512	12/31/91	[illegible]
VLASIC FOODS-BRIDGEPORT 415 S BLACKS CORNERS ROAD IMLAY , MI 48444	MI0001651	[illegible]	[illegible]
VORPLEX CORP 6556 OAK RD. VASSAR , MI 48768	MI0027774	10/31/92	110410
WAX BRO CORP CARBURETOR GROUP 61242 GARFIELD STREET CASS CITY , MI 48726	MI0045741	[illegible]	[illegible]
WEST BAY CO REGIONAL WWTP 3933 PATTERSON ROAD BAY CITY , MI 48706	MI0047439	[illegible]	[illegible]
WEST BRANCH CONCRETE P O BOX 336 3272 COOK ROAD WEST BRANCH , MI 48661	MI0044675	[illegible]	[illegible]
WEST BRANCH WWTP 119 N FOURTH STREET WEST BRANCH , MI 48661	MI0020095	[illegible]	[illegible]

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MAJOR AND MINOR
08/04/88

FACILITY NAME ADDRESS	NPDES NUMBER	PERMIT EXPIRATION	BASIN UNIT
WHEATLAND TWP WWSL 201 SOUTH SHERIDAN REMUS , MI 49340	MI0024350	11/30/92	[illegible]
WHEELOCK MEMORIAL HOSP WWTP ATT:CLARENCE BALL 7280 S STATE ROAD GOODRICH , MI 48438	MI0037591	05/31/9[illegible]	[illegible]
WHITE BIRCH MHP 749 LOUNSBURY ROCHESTER , MI 48063	MI0029106	01/31/[illegible]	[illegible]
WHITE BIRCH VILLAGE MHP WWSL ATT:THOMAS PRIEM 2419 BIRCH DRIVE KAWKAWLIN , MI 48631	MI0044377	08/30/90	[illegible]
WILLOWCREST TRAILER PARK 11697 EAST LANSING RD. DURAND , MI 48429	MI0038059	06/30/91	[illegible]
WOLVERINE CHRIST SERVICE CAMP 3926 FLINT RIVER ROAD COLUMBIAVILLE , MI 48421	MI0042790	08/31/87	[illegible]
ZILWAUKEE-CARROLLTON TWP WWTP 3355 N. WESTERVELT ZILWAUKEE , MI 48604	MI0023981	[illegible]	[illegible]

Appendix A. Act 307 Sites Affecting Surface Water in the Saginaw Bay Watershed (MDNR, 1988).

SAS Score	County Date Scored	Common Site Name/ Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
GROUP 1							
855	Saginaw 02/05/87	Saginaw River/Bay Saginaw to East Tawas Saginaw	Multiple Sources	Unknown	PCB, TCDD, TCDF	Surface Water, Sediment, Fauna	IR (F), EP
823	Gratiot 07/16/87	Alma Iron Metal Scrap Corp 29-[illegible] Bethany	Scrap Metal Yard	Aboveground Tank Barrel, Surface Discharge	Chromium, Nickel, Lead, PCB, PBB	Surface Water Sediment, Soil, Wetland	RA
770	Livingston 01/01/86	Shiawassee River 47-[illegible]-041-2[illegible] Howell	Forging Stamping	Surface Discharge	PCB	Surface Water, Sediment	E (S,I)
723	Bay 06/23/87	GM CPC Plant 09-165-05[illegible] Bay City, City of	Auto Mfg	Pile Lagoon	PCB	Soil Groundwater Surface Water	IR (F) E (P)
718	Midland 10/04/86	Tittabawassee River 56-165-02[illegible] Midland	Chem Product Mfg	Unknown	Dichlorobenzene, TCDs, PCT, Chlordane, Halogenated Biphen	Surface Water, Sediment, Fauna	EP
661	Midland 01/22/87	Porter Field 56-1[illegible] Porter	Oil Drilling	Geologic Form	Brine, Crude	Surface Water, Groundwater, Wetland, Flora	EP
600	Genesee 05/26/86	Buckeye Pipeline Co. 25-[illegible]-066-23[illegible] Vienna	Pipeline	Pipeline	Naphthalene, Xylene, Toluene, Benzene, Trimethylbenzene	Surface Water Groundwater	EP

Appendix 6. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
306	Montcalm 01/14/87	Hitachi Magnetics Corp 59-10N-06W-27AC Home	Metal Processing	Lagoon	Mercury	Sediment, Groundwater, Surface Water, Residential Well	IR (P) RA
307	Saginaw 07/26/86	Hall Barrel Co 73-12N-04E-27AA Kochville	Barrel Reclaiming	Lagoon	Light Industrial, Heavy Mfg, Even Prod Mfg	Surface Water, Soil	E (P) FR (P)
309	Osceola 11/05/86	Dickson LF 79-18N-07E-03DA	Landfill	Landfill	Ammonia, Organics, Zinc	Surface Water, Groundwater	RA
310	Arenac 02/27/86	Skidway Disposal 65-20N-04E-26DD Clayton	Landfill	Landfill	Domestic Comm, Light Industrial	Surface Water, Soil	RA
GROUP 2							
9	Bay 06/16/87	Union Oil Bay City 09-14N-05E-11C Bangor	Oil Storage	Pipeline	Benzene, Toluene, Xylene, Acetone Ethylbenzene	Surface Water, Groundwater, Soil	RP
8	Bay 02/24/86	C & O Railroad Bay City 09-14N-05E-10DC Bangor	Railroad	Barrel	Light Industrial	Surface Water	IR (P) EP
8	Bay 06/15/87	Prestolite 09-14N-05E-12CB Bay City, City of	Motor Vehicle Part Mfg.	Surface Discharge	Organics, Heavy Metals	Surface Water Groundwater, Soil	IR (P) E (P)

Appendix 6. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
9	Lapeer 09/30/86	Jack's Radiator Service 44-07N-20E-06 Lapeer	Auto Repair	Surface	Lead, Ethylene Glycol	Surface Water, Soil, Wetland, Fauna	IR (P) E (P)
8	Lapeer 09/29/87	CPS Harvey Lapeer 44-07N-10E-08BD Lapeer, City of	Gas Station	Underground Tank	Gasoline	Surface Water Soil	E (P) ER (P)
8	Livingston 11/01/84	Brighton Foundry 47-02N-06E-[illegible] Brighton	Metal Casting	Surface Discharge	Zinc, Lead, Chromium	Surface Water, Soil	NA
8	Livingston 08/14/87	Thompson Lake Sediments 47-03N-04E-25DCA Howell, Oceola	Unknown	Unknown	PCB	Sediment, Surface Water, Fauna	NA
8	Oakland 08/19/85	Oakland Co Rd Comm Dixie 63-04N-08E-[illegible] Springfield	Salt Storage	Pile	Sodium, Chloride	Surface Water, Groundwater, Residential Well	IR (P) EP
8	Sanilac 08/06/87	Mid Towns Sanitary LF 76-11N-16E-21B Argyle	Landfill	Landfill	Arsenic, Phenol, Cadmium	Surface Water, Groundwater	E (P) IR (P)
8	Shiawassee 01/28/85	Gd Trunk Western Railroad 78-06N-04E-26[illegible] Vernon	Railroad	Surface Discharge	Benzene, Xylene	Surface Water, Sediment, Soil	EP
8	Shiawassee 10/01/84	RJ Marshall 78-06N-04E-[illegible] Vernon	Chem Prod Mfg	Waste Pile	Boric Acid, Sulfuric Acid	Surface Water, Air, Soil	IR (P) EP

Appendix 6. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
7	Arenac 10/19/84	Amoco Oil Co 06-[illegible] Lincoln	Oil Storage	Pipeline	Benzene, Xylene Toluene	Surface Water, Groundwater	EP
7	Bay 08/13/85	Bangor Twp Dump 09-[illegible] Bangor	Landfill	Landfill	Domestic Comm., Light Industrial, Unknown	Surface Water, Wetland	EP
7	Bay 08/11/87	Monitor Sugar 09-[illegible] Monitor	Food Processing	Lagoon Site	Light Industrial Lime, BOD	Air, Surface Water, Groundwater	IR (P) E (P)
7	Genesee 10/15/85	McKinley & M57 Dump Site NE 25-[illegible] Montrose	Dump	Dump	Chromium, Lead, Phenol	Surface Water	RA
7	Gladwin 10/07/85	Gladwin City of 13 Closed 26-19N-02W-[illegible] Grout	Landfill	Landfill	Domestic Comm., Light Industrial, Arsenic	Surface Water, Groundwater, Soil	IR (P) EP RA
7	Huron 09/18/87	Englehart Oil Sebewaing 32-15N-09E-[illegible] Sebewaing, City of	Gas Station	Underground Tank	Gasoline	Surface Water, Groundwater, Soil	E (P)
7	Isabella 10/12/84	Total Petroleum Inc Roosevelt 37-14N-04W-[illegible] Union	Petro Refining	Lagoon	Chem Prod Mfg	Surface Water, Groundwater	IR (P) RA
7	Lapeer 09/29/87	Star Oil Co. Lapeer 44-07N-10E-05 Lapeer, City of	Gas Station	Underground Tank	Gasoline	Surface Water	EP

Appendix C. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
7	Midland 09/25/84	Bridge Area 56-1[illegible]-02[illegible]-20[illegible] Midland	Landfill	Landfill	Domestic Comm	Surface Water, Soil	RA
[illegible]	Oakland 05/09/86	Holly Area School Bus Garage 63-[illegible]56-07[illegible] Holly	Municipal Facility	Underground Tank	Petroleum Product	Surface Water, Groundwater, Soil	IR (P) EP RA
7	Shiawassee 09/27/83	Johnson Controls Globe Union 78-[illegible]-20[illegible] Caledonia	Battery Mfg	Lagoon	Heavy Mfg.	Surface Water, Sediment	RA
7	Shiawassee 9/26/84	Ann Arbor Railroad Yard 78-0[illegible]-01[illegible]-19[illegible]C Caledonia	Railroad	Underground Tank	Benzene, Xylene, Other Constituents of Fuel Oil	Surface Water Soil	EP
6	Midland 08/22/86	P & H Laundercenter 56-1[illegible]-02[illegible] [illegible]AC Jerome	Laundry Dry Cleaner	Lagoon, Underground Tank	PCE, Dichloroethane, Bromodichloromethane	Surface Water	S (P)
6	Midland 08/25/86	Warren Township Dump 56-1[illegible]-02[illegible]-2[illegible]A Warren	Landfill	Landfill	Domestic Comm	Surface Water	FS (S)
6	Ogemaw 09/27/84	Cayuga Refining Co 65-[illegible]-02[illegible]-10[illegible]C West Branch	Petro Refining	Lagoons	Phenols, Lead, PCB	Surface Water, Soil	IR (P) FT RA
5	Bay 08/23/85	Bay City Middlegrounds 09-1[illegible]-0[illegible]-1[illegible]A Bay City	Landfill	Landfill	Domestic Comm, Light Industrial	Surface Water, Groundwater	IR (F,S) S (S)

Appendix 6. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
5	Bay 05/15/87	Coal Mine Disch. to Culver Cr. 09-[illegible] Monitor	Coal Mining	Geologic Form	Brine, Iron	Sediment, Surface Water, Fauna, Flora	EP
5	Saginaw 09/18/87	[illegible] Pickles [illegible] Frankenmuth, City of	Food Processing	Lagoon, Surface Discharge	Brine	Surface Water, Soil, Wetland	LP
6	Clare 10/02/84	Clare LF Clsd City of 18-[illegible] Grant	Landfill	Landfill	Domestic Comm	Surface Water, Groundwater	RA
6	Huron 09/18/87	United Manufacturing [illegible] Bad Axe, City of	Motor Vehicle Parts	Surface Discharge	Phosphorus, Softening Agent	Surface Water, Wetland, Fauna, Flora	EP
2	Bay 09/22/86	Bayview Food Products Co. I [illegible] Kawkawlin	Food Processing	Lagoon, Container	Brine, Raw Sewage, BOD	Groundwater, Surface Water, Sediment, Soil	E (P)
1	Iosco 05/22/86	Sherman Twp Dump [illegible] Sherman	Landfill	Landfill	Domestic Comm	Groundwater, Surface Water	LP
3	Midland 08/31/83	Oil Field Area Anderson Rd [illegible] Lee	Oil Drilling	Lagoon	Chlorides	Surface Water, Groundwater	RA
7	Arenac 10/10/84	Au Gres Twp Dump Closed 06-[illegible] Au Gres	Landfill	Landfill	Domestic Comm	Surface Water, Soil	EP

Appendix 6. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
2	Bay 08/01/85	Bayview Food Products No 3 09-16S-[illegible] Kawkawlin	Food Processing	Lagoon Container	Brine, Raw Sewage, Oil	Groundwater, Surface Water, Sediment, Soil	IR (P) EP
2	Gladwin 07/22/86	Tobacco Twp Refuse Closed 26-17S-01W-13[illegible] Tobacco	Dump	Dump	Domestic Comm	Surface Water	IR (P) EP

*The common site name is for identification only and is not necessarily a party responsible for contamination.

**IR=Interim Response; E=Evaluation; FR=Final Response; RA=Regulatory Action; EP=Evaluation Pending; P=Privately Funded Actions; F=Federally Funded Actions.

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Appendix 7. Act 307 Sites Affecting Groundwater in the Saginaw Bay Watershed (MDNR, 1988).

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
GROUP I							
913	Genesee 08/21/85	Forest Waste Products 25-09N-08E-09[illegible] Forest	Landfill	Lagoon, Landfill	Dieldrin, Lead, Cyanide, PCB, Oil	Groundwater	IR (S,F) E (S,F)
921	Lapeer 10/04/84	Metamora Sanitary LF 44-06N-10E-19[illegible] Metamora	Landfill	Barrel, Landfill	Dichlorobenzene, Hexachlorobenzene, Methyl Chloroform	Groundwater	IR (S,F) E (S,F)
905	Saginaw 09/11/87	GM Saginaw Malleable Iron Plant 73-12N-04E-35 Saginaw	Iron, Steel Foundry	Barrel, Landfill	Nickel, Manganese, Zinc, Chromium, PCB, Benzene, Toluene	Groundwater, Soil	IR (P) E (P)
812	Oakland 10/4/84	Milford Rd Highland Arena 63-03N-07E-02[illegible] Highland	Unknown	Unknown	Ethyl Benzene, Trichloroethane, Perchloroethylene	Groundwater, Soil	E (P)
797	Livingston 01/29/86	Rasmussens Dump 47-01N-06E-[illegible] Green Oak	Landfill	Landfill, Barrel	Volatile Organics, Dioxins, PCB, Lead Arsenic, Copper	Groundwater, Soil	IR (S,F) E (S,F)
777	Oakland 08/19/85	[illegible] Fuel Storage 63-05N-07E-[illegible] Holly	Oil Storage	Aboveground/ Underground Tanks	Benzene, Toluene, Xylene, Ethyl-benzene	Groundwater, Soil	E (P)
758	Ogemaw 10/05/87	[illegible] Lk. Rd. Mills Twp. 65-[illegible] Mills	Unknown	Unknown	TCE, DCE, PCE, DCA, Trichloroethane, Chlorobenzene	Groundwater, Soil, Residential Wells	IR (S) E (P) RA

Appendix 2. Continued.

HRS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
741	Genesee 08/26/86	Berlin and Farro 25-07N-05E-29DA Gaines	Haz Waste Facility	Lagoon Landfill	Toluene, Ethylbenzene, Creosotes	Groundwater, Soil	IR (P,S,F) E (P,S,F) RE (P,S,F)
701	Livingston 10/05/87	Spiegelberg II 47-01N-06E-31CD Green Oak	Dump	Dump Barrels	Liquid Paints, Zinc, Arsenic Thallium	Groundwater, Soil	IR (S) E (S,F)
707	Clare 01/07/87	Clare Municipal Wells, City of 18-17N-04W-03 Grant	Auto Component Mfg	Lagoon, Surface Discharge	Dichloroethane, Trichloroethane	Groundwater, Municipal Well	E (F)
704	Genesee 09/29/87	Action Auto #2 25-07N-07E-25BC Burton	Gas Station	Underground Tank	Xylene, Benzene, Naphthalene, Toluene, Hexane, Cyclohexane	Groundwater	RA
683	Midland 01/20/87	Sanford [illegible] 56-14N-02W-25AB Greendale	Landfill	Landfill	Pentachlorophenol, Dichlorophenol, Benzene, Toluene	Groundwater	IR (P) E (P) RE (P)
657	Livingston 09/13/87	Livingston Co. Rd. Comm. Howell Garage 47-03N-04E-36DA Howell	Road Commission	Underground Tank	Gasoline	Groundwater, Soil	E (P)
650	Livingston 08/25/86	Lucy Rd Tri City Center Area 47-03N-[illegible]-36[illegible] Howell	Unknown	Unknown	Tetrahydrofuran	Groundwater, Residential Well	IR (S) EP

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Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
639	Bay 10/01/87	Amoco Oil Terminal-Bay City 09-[illegible] Bay City, City of	Oil Storage	Pipeline	Oil, Jet Fuel	Groundwater, Soil	IR (P) E (P)
628	Bay 10/04/84	Dow Chem Benzene Pipeline [illegible] Auburn	Chem Product Mfg	Pipeline	Benzene	Groundwater, Soil	IR (P) E (P) FR (P)
590	Genesee 09/29/87	A.C. Spark Plug 25-07N-07E-[illegible] Burton	Engine Component Mfg	Underground Tank	Xylene, Benzene, Naphthalene, Toluene, Hexane, Cyclohexane	Groundwater	E (P) RA
585	Saginaw 09/18/87	GM, Malleable Iron Foundry - Saginaw [illegible] Saginaw, City of	Iron, Steel Foundry	Landfill, Pile	Cyanide, Phenol	Groundwater, Air	IP
560	Midland 10/04/87	Rec Center & Isabella Rd. 56-[illegible] Lee	Unknown	Unknown	Benzene, Toluene, Xylene, Ethyl-benzene	Groundwater, Soil Residential Well	EP
552	Iosco 08/28/85	Ken Wells Pecker [illegible] Grant	Unknown	Unknown	Benzene, Ethyl-benzene, Dichloro-ethylbenzene, Dichloropropane	Groundwater	IR (S) RA
550	Livingston 07/23/87	Drake Gasoline 47-[illegible] Howell	Gas Station	Underground Tank	Fuel Oil	Groundwater, Soil	EP
547	Genesee 10/02/87	Mission Road Fill 25-[illegible] Flint	Auto Mfg	Landfill	Phenol, Sulfide, Oil, Iron, Zinc, Dichloroethane	Groundwater	RA

Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name/ Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
540	Livingston 07/23/87	Local Gas Pinckney 47-015-[illegible] Putnam	Gas Station	Underground Tank	Benzene, Toluene, Chlorobenzene Ethylbenzene	Groundwater, Residential Well	LR (P) RA
533	Livingston 07/23/87	[illegible] Rd Old US 23 Area 47-109-[illegible]-2820 Hartland	Gas Station	Underground Tank	Gasoline	Groundwater, Soil, Residential Well	EP
522	Iosco 07/27/87	Oscoda Twp Municipal Well 35-[illegible]-0400 Oscoda	Unknown	Unknown	Tetrachloroethylene	Groundwater	LR (P) RA
511	Iosco 10/01/87	[illegible] Industries 35-[illegible]-0400 Au Sable	Forging, Stamping	Surface Discharge	Trichloroethylene	Groundwater Residential Well	LR (P,S) E (F)
506	Genesee 10/11/84	Sunshine Food Store 25-[illegible]-2265 Richfield	Gas Station	Unknown	Benzene, Xylene, Toluene	Groundwater	RA
496	Midland 10/07/87	[illegible] Oil Company 56-[illegible] Coleman, City of	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	EP
490	Livingston 09/13/87	[illegible] Station Hartland 47-[illegible] Hartland	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	RA
490	Isabella 07/23/86	Blanchard Area W Center 37-[illegible]-1096 Rolland	Unknown	Unknown	Methylene Chloride, Ethylene Dibromide 1,2-Dichloroethane	Groundwater, Residential Wells	JR (S) RA

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Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
160	Midland 02/14/86	Res Well Nine Mile Rd [illegible] Jerome	Unknown	Unknown	Toluene, Ethylbenzene Xylene	Groundwater	IR (S) EP
370	Tuscola 10/04/84	Walbro Corp [illegible] Elkland	Engine Component Mfg	Lagoon	Toluene, Xylene, Mineral Spirits, Styrene, TCE	Groundwater, Soil	IR (P) E (P)
164	Livingston 02/23/87	Green Oak Fire Station [illegible] Brighton	Gasoline Storage	Underground Tank	Xylene, Toluene, Benzene, Ethyl-benzene	Groundwater, Residential Well	EP
322	Bay 09/24/86	[illegible] Inc [illegible] Pinconning	Forging, Stamping	Pile	Magnesium, Oxide, Phenol, Lead, Boron	Groundwater, Residential Well, Fauna, Flora	E (P)
124	Saginaw 08/25/87	[illegible] Products [illegible] Swan Creek	Forging, Stamping	Surface Discharge	Trichloroethylene, Zinc Chloroethane Hydraulic Oils	Groundwater, Soil, Flora	E (P)
308	Isabella 10/30/84	Res Well Schulz [illegible] Union	Unknown	Unknown	Xylene, Toluene, Isopentane, Ethylbenzene	Groundwater, Residential Well	EP
306	Saginaw 09/24/86	Thomas Twp LF [illegible] Thomas	Landfill	Landfill	Specific Cond., Ammonia, Lead, Total Organic Carbon	Groundwater	IR (P)
252	Livingston 10/01/87	G and G Paint Developers [illegible] Genoa	Paint Products	Pile, Surface Discharge, Container	Benzene, Toluene Xylene, Ethyl-benzene	Groundwater, Soil, Residential Well	IR (P)

Appendix [illegible]. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
165	Midland 09/20/86	Sheperd Rd 56-17N-02W-19DC Jasper	Landfill	Unknown	Ethylbenzene, Xylene	Groundwater, Residential Well	RP NA
138	Oakland 10/11/86	[illegible] Manufacturing 63-03N-07E-[illegible] Highland	Valves Pipe Mfg	Lagoon	Heavy Mtg	Groundwater, Soil	IR (P)
GROUP 2							
11	Ogemaw 08/20/87	Horseshoe Lk Rd W. Branch 65-21N-01E-11CA Foster	Unknown	Unknown	Ethylbenzene, Benzene, Toluene, Xylene	Groundwater, Soil	EP
10	Isabella 08/20/87	[illegible] Groundwater Contam. 37-15N-05W-10DD Fremont	Unknown	Unknown	Dichloroethane, Benzene	Groundwater, Residential Well	IR (S) EP
10	Midland 09/18/87	[illegible] Repairs 56-14N-02E-18CD Midland, City of	Auto Repair	Surface Discharge	Toluene, Methylene Chloride	Groundwater, Soil	RP
8	Bay 09/18/87	Consumers Power Weadock Plant 09-14N-05E-03CD Hampton	Gas/Electric Utility	Underground Tank	Fuel Oil	Groundwater, Soil	E (P)
8	Bay 09/11/87	Farmers Petroleum Coop. 09-15N-04E-[illegible] Fraser	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	IR (F) E (P) FR (F)

Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
8	Clare 07/25/86	Clare Sanitary LF City of 18-18N-04W-34AA [illegible]	Landfill	Landfill	Chloroform, Cis 1,2-Dichloro Trichloroethylene	Groundwater, Residential Well	RA
5	Genesee 08/13/87	GM Fisher Guide Flint 25-07N-06E-[illegible] Flint	Gasoline Storage	Underground Tank	Benzene, Toluene, Ethylbenzene, Xylene	Groundwater, Soil	RA
8	Genesee 08/13/87	[illegible] Corp. [illegible] Site 25-08N-07E-31A Flint	Chem. Prod. Mfg.	Unknown	Benzene, Dichloro- ethylene, Chlorobenzene	Groundwater, Soil	RA
8	Genesee 08/13/87	[illegible] Corp. Warehouse Site 25-07N-07E-[illegible] Flint	Oil Storage	Unknown	Benzene, Toluene, Dichloroethane Naphthalene	Groundwater, Soil	RA
9	Genesee 08/02/85	[illegible] Waste Collection 25-06N-08E-[illegible] Atlas	Landfill	Landfill	[illegible], Chromium, Iron	Groundwater	RA
8	Gladwin 12/08/84	Elliot Gas & Oil Co 26-18N-01W-[illegible] Buckeye	Oil Storage	Aboveground Tank	Chem Prod Mfg	Groundwater	IR (P) RA
8	Gladwin 09/19/86	Gladwin Gulf Oil Plant State Street 26-19N-01W-[illegible] Buckeye	Gasoline Storage	Underground Tank	Benzene, Toluene, Ethylbenzene, Xylenes	Groundwater, Soil	IR (P) RA
8	Gladwin 08/14/87	Gladwin City Public Works Garage 26-18N-01W-[illegible] Buckeye	Municipal Facility	Surface Spill	Gasoline	Soil, Groundwater	IR (P) RA

Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
8	Clinton 02/24/87	[illegible] Industries [illegible] 19-[illegible] [illegible]	Misc. Machinery Mfg.	Surface Discharge	Benzene, Toluene, Xylene, Ethyl-benzene	Groundwater, Soil	IR (P)
8	Gratiot 10/09/85	Alma Products 29-[illegible] Pine River	Engine Components Mfg	Lagoon	Trichloroethylene, Cyanide, Dichloro-ethylene	Groundwater	EP
8	Gratiot 02/20/84	Total Petroleum Alma 29-119-[illegible] Arcada	Petro Refining	Lagoon	Phenols, Chlorides	Groundwater	RA
8	Livingston 06/13/85	[illegible] Inc 47-[illegible]-0500 Genoa	Oil, Grease [illegible]	Surface Discharge	Dichloroethane, Trichloroethene	Groundwater, Soil	E (P)
8	Livingston 05/07/84	K & M Manufacturing 47-[illegible] Hamburg	Rubber, Plastic Production	Surface Discharge	Dichloroethane, Trichloroethane, Methylene Chloride	Groundwater	E (P)
8	Midland 08/15/85	Gordonville Road 56-[illegible] Lee	Scrap Metal Yard	Pile, Barrel	PCBs, Oil	Soil, Groundwater	RA
8	Midland 08/15/87	Res. Well Bradford Road 56-[illegible] Porter	Brine Use, Disposal	Surface Discharge	Brine	Groundwater, Residential Well, Soil	E (P)
8	Oakland 10/02/87	Pontiac Steel 63-[illegible] Springfield	Metal Processing	Dry Well	Heavy Metals	Groundwater	IR (P) RA

Appendix J. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
8	Saginaw 09/18/87	[illegible] Gas [illegible] & [illegible] 73-125-051-[illegible] Saginaw, City of	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	EP
8	Saginaw 09/18/87	Grand Trunk [illegible] Genesee St. 73-125-[illegible] Saginaw, City of	Rail Transport	Surface Discharge	Fuel Oil	Groundwater, Soil	IR (P) E (P)
8	Saginaw 08/06/87	[illegible] Car Wash 73-125-[illegible] Saginaw, City of	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	IR (P) EP
8	Saginaw 08/22/86	[illegible] 73-125-[illegible] Saginaw, City of	Metal Coating	Surface Discharge	Benzene, Toluene, Oil	Groundwater Soil	IR (P)
8	Shiawassee 08/14/85	[illegible] Gasoline [illegible] 78-[illegible] Vernon	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	IR (P) EP
7	Bay 09/04/84	Peters [illegible] 09-[illegible] Kawkawlin	Metal Hardware Mfg	Surface Discharge	Heavy Mfg	Groundwater, Flora	RA
7	Clare 09/16/85	Clare Co. [illegible] Bulk Storage Site 18-[illegible] Grant	Gasoline Storage	Aboveground Tank	Benzene, Xylene, Ethylbenzene, Toluene	Groundwater, Soil	E (S,P) RA
7	Genesee 09/21/84	[illegible] Gas Station 25-[illegible] Vienna	Gas Station	Underground Tank	Naphthalene, Xylene, Toluene, Ethylbenzene	Groundwater	EP

Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Origin of Release	Pollutant	Resource Affected	Status**
7	Genesee 09/26/84	[illegible] Fisher Guide Coldwater Rd 25-[illegible] Genesee	Plating, Polishing	Waste, Pile Lagoon	Lead, Chromium, Nickel, Chlorides, Sulfate	Groundwater, Soil	RA
7	Genesee 07/10/86	Kinn [illegible] 25-[illegible] Grant	Landfill	Landfill	Chlorides, Lead	Groundwater	RA
7	Genesee 08/21/85	Union 76 Station Flint 25-[illegible] Genesee	Gas Station	Underground Tank	Benzene, Toluene, Xylene	Groundwater, Soil	
7	Gratiot 09/26/84	Alma, City of 29-[illegible] Arcada	Petro Refining	Lagoon	Phenol	Groundwater, Soil	RP
7	Gratiot 09/25/84	Gratiot Farmers Supply 29-[illegible] Pine River	Gas Station	Underground Tank	Naphthalene, Xylene, Toluene, Benzene, Ethyl-benzene	Groundwater	RP
7	Isabella 10/02/84	Stanley Oil Co 37-[illegible] Coe	Gas Station	Underground Tank	Benzene, Toluene, Xylene	Groundwater	ID (P) RA
7	Isabella 10/02/84	Wickes Agriculture 37-[illegible] Rolland	Grain Elevator	Aboveground Tank	Ammonium Nitrate, Urea	Groundwater, Residential Well, Ogemaw	RA
7	Livingston 10/02/84	MI Dept. of Transportation 47-[illegible] Brighton	Salt Storage	Waste, Pile	Salt	Groundwater, Residential Well	E (P)

Appendix [illegible] Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
7	Livingston 09/12/85	Wellman Property Disposal 47-[illegible]-0AL-25[illegible] Marion	Municipal Facility	Pit	2,4-D, 2,4,5-T	Groundwater, Soil	IR (P) RP
7	Livingston 01/07/86	Winters Hotel Clean 47-015-051-265P Hamburg	Laundry Dry Cleaner	Lagoon	Perchloroethylene	Groundwater	RA
7	Midland 08/05/85	Dow Chem Brine Pipeline Spills [illegible]-56-75 Midland	Brine Prod, Disposal	Pipeline	Brine	Groundwater, Soil, Flora	F (P) IR (P)
7	Midland 09/18/87	Dow Chemical 56-[illegible]-020-2600 Midland, City of	Plastic Rubber Mfg.	Aboveground Tank	Toluene	Groundwater, Soil	IR (P)
7	Midland 07/30/87	Forward Car Wash 56-[illegible]-021-0[illegible] Midland, City of	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	RP
7	Saginaw 09/27/87	Amoco Gas Stn Center & State 73-[illegible]-0AE-20[illegible] Saginaw, City of	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	RP
7	Saginaw 09/29/87	[illegible] Road 73-[illegible] [illegible]	Farming	Surface Discharge	Atrazine	Groundwater, Residential Well	RP
6	Arenac 10/08/86	[illegible] Sterling River 06-[illegible] Rifle River	Ag Chem Products	Unknown	Nitrates	Groundwater, Residential Wells	RA

Appendix 2. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
6	Bay 09/19/87	Dave Fletcher Gas Station 09-[illegible] Frankenlust	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	RP
6	Bay 09/19/87	Fostard Corp. Essexville 09-[illegible] Essexville, City of	Gas Station	Underground Tank	Gasoline	Groundwater, Soil	IR (P)
6	Bay 09/23/86	Aerospace America Inc 09-[illegible] Bangor	Misc Metal Prod	Barrel	Xylene, Toluene, Naphthol, Acetone, Chromic Acid	Groundwater	RA
6	Clare 09/25/87	Harrison Lf, City of 18-[illegible] Hayes	Dump	Dump	Domestic Trash	Groundwater	RA
6	Clare 09/24/86	[illegible] Lake Garage 18-[illegible] Lincoln	Unknown	Unknown	Gasoline	Groundwater	IR (S) RP
6	Clare 09/24/87	Lincoln/Saginaw [illegible] RR Derail 18-[illegible] Surrey	Rail Transport	Surface Discharge	Fuel Oil	Groundwater	IR (P) RA
6	Gladwin 10/08/86	Buckeye Oil Field 26-[illegible] Buckeye	Oil Drilling	Geologic Zone	Brine	Groundwater, Residential Well	IR (P)
6	Gladwin 05/20/87	[illegible] Res Leaking Pipeline 26-[illegible] Sherman	Private Residence	Aboveground Tank	Fuel Oil	Groundwater	IR (P) RA

Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
6	Huron 09/19/87	Brighton Metals Caseville 32-18N-10E-35AC Caseville, City of	Metal Coating	Surface Discharge	Chromium, Chlor Solvents	Groundwater, Soil	S (P) FS (P)
6	Iosco 09/19/85	Straits Aggregate 35-22N-09E-10 Baldwin	Wood Preserving		Arsenic, Selenium, Chromium	Groundwater, Soil	IR (P) EP RA
6	Isabella 10/15/85	Michigan Ohio Pipeline Co 37-15N-04W-30 Union	Pipeline	Pipeline	Chem Prod Mfg	Groundwater	IR (P) RA
6	Lapeer 09/18/87	U.S. Post Office, Lapeer 44-07N-10E-05 Lapeer, City of	U.S. Postal Svc.	Underground Tank	Gasoline	Groundwater, Soil	I (P)
6	Livingston 09/15/86	Livingston Co LF 47-03N-04E-15AB Howell	Landfill	Landfill	Domestic Comm, Heavy Mfg	Groundwater	RA
6	Mecosta 08/10/87	Forcey, Inc. 54-15N-07W-16 Wheatland	Gas Station	Underground Tank	Benzene, Toluene Xylene, Ethyl-benzene	Groundwater, Soil	IR (A) RA
6	Midland 11/08/84	Central Michigan Petroleum 56-14N-02E-16 Midland	Gas Station Underground Tank		Benzene, Toluene, Xylene, Isopentane	Groundwater	EP
6	Montcalm 09/24/86	Zee Wells Venting 59-12N-09W-27CA Richland	Salt Storage	Waste Pile	Salt, Brine	Residential Well, Groundwater	IR (P) RA

Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
5	Ogemaw 09/27/86	[illegible] Main St Lupton [illegible] Rose	Unknown	Unknown	Ethylene, Dibromide	Groundwater, Soil	EP RA
6	Roscommon 08/27/86	Artesia Beach Fuel Oil Spill [illegible] Richfield	Private Residence	Aboveground Tank	Benzene, Styrene, Xylene, Toluene, Ethylbenzene	Groundwater, Flora, Soil	IR (P) E (P)
5	Saginaw 09/20/86	[illegible] Engineering [illegible] Buena Vista	Carbon Graphite Production	Pile, Surface Discharge	Trichloroethene, 1,1,1-Trichloroethane, 1,1,1-Dichloroethane	Groundwater, Soil	IR (P) E (P)
6	Shiawassee 09/13/85	[illegible] 78-07N-03E-[illegible] Caledonia	Valves Pipe Mfg	Surface Discharge	Chromium	Groundwater, Soil	IR (P) FS (P)
5	Clare 09/06/84	American Dry Cleaners 18-1[illegible] Grant	Laundry Dry Cleaners	Xylene, Carbon, Tetrachloroethene	Soil	Groundwater, Soil	EP
5	Clare 03/30/87	Res Well (Farrell) 18-17N-04W-[illegible] Grant	Unknown	Unknown	Nitrates	Groundwater	EP
5	Gratiot 09/25/84	Fowler Farm & City Supply 29-12N-[illegible] Arcada	Gas Station	Underground Tank	Naphthalene, Xylene Toluene, Benzene, Ethylbenzene	Groundwater	EP
5	Isabella 10/07/84	Mt. Pleasant City of 37-14N-04W-15 Union	Unknown	Unknown	Hydrogen Sulfide	Groundwater	EP

Appendix ?. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
5	Isabella 09/22/87	Mt. Pleasant Tar Pit 37-14S-04W-10?? Union	Coal Gasification	Surface Discharge	Chem Prod Mfg. Cyanide, Benzene Phenol, Xylene, PNAs	Groundwater Soil	RA
4	Isabella 10/07/86	Res Well [illegible] 37-16S-01W-[illegible] Wise	Unknown	Unknown	Benzene, Toluene Xylene	Groundwater	EP
3	Isabella 08/21/86	Res Well N [illegible] Twp 37-13S-05W-[illegible] [illegible]	Private Residence	Underground Tank	Gasoline	Groundwater	RA
7	Montcalm 08/11/85	Res Well [illegible] 59-12N-06W-[illegible] Home	Petro Refining	Unknown	Benzene, Ethyl Benzene, Xylene	Groundwater, Residential Well	RA
3	Saginaw 08/24/86	Tri City [illegible] 73-12N-05E-07 Buena Vista	Landfill	Landfill	Zinc	Groundwater, Soil	1P
9	Saginaw 02/18/87	SCA Saginaw Twp LF 73-12N-04E-[illegible] Saginaw	Landfill	Landfill	[illegible]	Groundwater	IR (S) E (S)
5	Shiawassee 08/16/85	Aiken Rd Homes 78-07N-01E-19[illegible] Caledonia	Unknown	Unknown	Iron, Zinc	Groundwater, Residential Well	2A
4	Clare 05/13/86	GW Contamination Meredith 18-20N-03W-[illegible] Franklin	Unknown	Unknown	Tetrachloro-ethylene, Toluene	Groundwater	IR (S) EP

Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
4	Clare 10/19/84	Valcast Inc [illegible] Grant	Metal Container Mfg	Surface Discharge	Salt	Groundwater	RA
4	Isabella 10/05/84	[illegible] Pipeline Co [illegible] Coldwater	Pipeline	Pipeline	Hydrocarbons	Groundwater	RA
4	Lapeer 10/19/84	Lapeer Co Rd Comm Mayfield [illegible] North Branch	Road Commission	Salt Pile	Salt	Groundwater	EP
4	Livingston 10/09/84	US 23-I96 Interchange Area [illegible] Brighton	Salt Storage	Surface Discharge	Salt	Groundwater	EP
4	Mecosta [illegible]/84	Farm and Gas Well [illegible] Morton	Farming	Container	[illegible] Herbicide	Groundwater	RA
4	Mecosta 10/03/84	Mecosta Co Rd Comm Remus [illegible] Wheatland	Unknown	Salt Pile	Salt	Groundwater	RA
3	Clare [illegible]/84	Clare Co Rd Comm [illegible] [illegible] [illegible]	Road Commission	[illegible] Storage	Salt	Groundwater	RA
3	Clare 10/02/84	[illegible] [illegible] Hayes	Landfill	Landfill	[illegible]	Groundwater	RA

Appendix 7. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
3	Clare 10/11/84	Harrison Lagoon System City of 18-19N-04W-29[illegible] Hayes	Landfill	Lagoon	Ammonia Nitrate	Groundwater	RA
3	Isabella 10/12/84	Fursman Race Track 37-14N-06W-31A Union	Unknown	Surface Discharge	Brine	Groundwater	RA
3	Mecosta 10/25/84	Mecosta Co SW 54-[illegible] Colfax	Landfill	Landfill	Domestic Comm	Groundwater	RA
3	Tuscola 10/09/84	Sutton & DeShaw Stewart 79-[illegible] Arbela	Oil Drilling	Geologic Form	Chlorides	Groundwater	EP
2	Gladwin 10/08/84	Texas Gulf Hope No 1 26-17N-02W-36BB Beaverton	Pipeline	Pipeline	Brine	Groundwater, Flora	EP
2	Ogemaw 01/24/85	Res Well [illegible] 65-22N-02E-[illegible] West Branch	Unknown	Unknown	Chloride	Groundwater	IR (P) EP
1	Gladwin 10/08/84	Buckeye Twp Dump Closed 26-18N-[illegible] Buckeye	Dump	Sump	Domestic Comm	Groundwater	IR (F) RA

*The common site name is for identification only and is not necessarily a party responsible for contamination.

**IR = Interim Response; E = Evaluation; FR = Final Response; RA = Regulatory Action; EP = Evaluation Pending; P = Privately Funded Actions; F = Federally Funded Actions

Appendix 8. Act 307 Sites Affecting Resources other than Surface Water or Groundwater in the Saginaw Bay Watershed (MDNR, 1988).

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
GROUP 1							
[illegible]	Gratiot 09/2?/86	Pine R Sediments, St. Louis 29 12N 02W Bethany	Chem Product Mfg	Unknown	Chem Prod Mfg	Sediment	EP
7?6	Livingston 10/0?/87	[illegible] Corp 47-03N-04E-28?? Howell	Soap, Cleaners Mfg	Aboveground Tank, Barrel Surface Discharge	Heavy Mfg	Soil Air	RA
7?6	Saginaw 03/12/87	Saginaw Paint Saginaw Coatings 73 [illegible] Saginaw, City of	Paint Products	Container Barrel	Xylene, MEK, Naptha, Diethyla-amine, Glycol Ether	Soil	IR (S,P) EP
6?1	Genesee 08/2?/87	Container Specialties 25-[illegible] Flint	Laundry, Dry Cleaner	Underground Tank	Perchloroethylene, Trichloroethylene	Soil	IR (P) RA
519	Oakland 10/09/85	Old [illegible] LF 63-[illegible] Rose	Landfill	Landfill	Heavy Metals, PCBs, Organics	Sediment, Soil	RA
4?2	Livingston 11/01/87	[illegible] Ideal Steel 47-01N-05E-25?? Hamburg	Unknown	Barrel	Heavy Mfg	Soil	IR (P) RA
4??	Bay 09/23/87	[illegible] Salvage Yard 09-14N-05E-[illegible] Bangor	Scrap Metal Yard	Pile	PCB, Oil	Soil	E (P)

Appendix B. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Locality	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
305	Livingston 10/01/87	[illegible] Electric 47-[illegible] Howell	Electronic Components	Container, Barrel	PCBs	Soil	IR (P)
303	Tuscola 08/12/87	Vassar Electroplating Metallizing 79-[illegible]-27AB Vassar	Plating, Polishing	Pile, Container, Barrel	Heavy Metals	Soil	E (P)
300	Livingston 05/26/86	Internat. Paper Disposal 47-035-[illegible] Genoa	Paper Products	Surface	Phenols, PCB, Chromium, Copper		RA
300	Shiawassee 10/01/87	Kline Industrial Plating 78-[illegible]-14BB Owosso	Plating, Polishing	Surface Discharge	Chromium, Cyanide	Soil	IR (P) RA
266	Lapeer 01/09/85	[illegible] Rd Dump 44-[illegible] Metamora	Landfill	Waste Pile	PCBs	Soil	IR (P) E (P) ER (P)
225	Midland 11/28/84	Dow Chemical Midland Plant 56-14N-02E Midland	Chem Prod. Mfg	Unknown	Dioxin	Soil	E (P)(S) ER (P)
163	Arenac 09/25/86	Sims Whitney Twp Disposal 06-20N-07E-25CC Whitney	Landfill	Landfill	Domestic Comm	Fauna	ER RA

Appendix 6. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
GROUP 2							
8	Clare 09/28/84	Hoover Univ. Forest Prop. 18-17N-05W-15AC Surrey	Unknown	Container, Landfill	Heavy Mfg	Soil,	PP
8	Genesee 08/07/85	Auto Price Collision Inc 25-07N-07E-29AA Burton	Auto Repair	Surface Discharge	Chem Prod Mfg	Soil	RA
8	Genesee 08/30/87	[illegible] Oil Co. 25-07N-07E-05PC Flint	Oil Storage	Aboveground Tank	Fuel Oil	Soil	RA
8	Isabella 10/07/84	Total Pet. Inc Mt Pleasant 37-14N-04W-14CB Union	Gas Station	Unknown	Benzene, Toluene, Xylene		IR (P) RA
8	Midland 09/18/87	Res [illegible] Curtis Rd. 56-16N-01W-02BC Edenville	Private Residence	Underground Tank	Gasoline	Soil	EP
8	Oakland 12/19/85	Spazer Property 63-04N-08E-25P Rose	Scrap Metal Yard	Pile	Phenol, PCB, Lead, Chromium, Cadmium, Nickel, Zinc	Air, Soil	EP
8	Oakland 08/26/85	Delta Tube & Fabrication Corp 63-03N-08E-27DB Pellis	Metal Processing	Barrel	Heavy Mfg	Soil	IR (P) EP RA
8	Oakland 09/26/86	Kelly Containers Inc 63-03N-07E Holly	Barrel Reclaiming	Surface Discharge	Oil, Grease	Soil	EP RA

Appendix B. Continued.

SAS Score	County Date Scored	Facility/Site Name Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
8	Saginaw 09/28/87	[illegible] 73-[illegible] Bridgeport	Gas Station	Underground Tank	Gasoline	Soil	EP
8	Saginaw 09/18/87	[illegible] 73-[illegible] Saginaw, City of	Private Residence	Aboveground Tank	Heating Oil	Soil	EP
8	Saginaw 09/18/87	Saginaw Steering Gear Division/GM 73-[illegible] Saginaw, City of	Auto Mfg.	Pile Surface Discharge	[illegible]	Soil	EP
8	Saginaw 08/21/86	Severance Tool Industries Inc 73-118-[illegible] Bridgeport	Tool and Die	Underground Tank	Cyanide, Barium, Chromium, Lead [illegible]	Soil	E (P) RA
8	Saginaw 02/05/87	[illegible] 73-[illegible] Thomas	Auto Repair	Underground Tank	Mineral Spirits	Soil	E (P) FR (P)
8	Shiawassee 09/11/87	[illegible] Corp. 78-[illegible] Owosso	Plating, Polishing	Container Surface Discharge	Chromium Nickel		RA
7	Bay 11/05/84	[illegible] Oldsmobile 09-[illegible] Bay City	Car Dealer	Unknown	Light Industrial		RA
7	Bay 09/28/87	[illegible] City Scrap Yard 09-[illegible] Bay City, City of	Scrap Metal Yard	Pile Barrel	[illegible]/Cans Light Industrial	Soil	EP

Appendix B. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
7	Clare 05/24/84	Renosol Plant 18-17N-05W-26AA Surrey	Rubber Plastic Products	Surface Discharge	Diethylhexylphthalate	Soil	EP
7	Genesee 11/02/84	AJS Hook 25-07N-07E-09BA Burton	Unknown	Surface Discharge	PCB	Soil	RA
7	Genesee 07/10/85	Richfield Rd Dump [illegible] 25-08N-05E-02A Richfield	Landfill	Landfill	Domestic Con., Heavy Mfg		RA
7	Genesee 11/05/84	[illegible] Oil Site [illegible] 25-07N-07E-22[illegible] Burton	Oil, Solvent Recycle	Surface Discharge	Chem Prod Mfg	Soil	EP
7	Gratiot 09/10/87	Gratiot Metal Property 29-12N-03W-01BA Newark	Scrap Metal Yard	Surface Discharge	Heavy Mfg.		EP
7	Huron 09/18/87	Niederfeld Dump 32-15N-11E-21DD Oliver	Dump	Lagoon, Landfill Surface Discharge	Paint Cutting Oils Refuse, Cars	Soil	EP
7	Lapeer 01/22/87	Albar Industries 44-07N-10E-05[illegible] Lapeer	Rubber Plastic Products	Barrel	Xylene, Toluene, MEK	Soil	E (P)
7	Livingston 09/26/86	Bullock Farm 47-01N-06E-15[illegible] Hartland	Sanitary Services	Surface Discharge	Dichlorobenzene	Soil	RA

Appendix B. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
7	Midland 08/11/87	American Service Station 56-155-021-1949 Midland, City of	Gas Station	Underground Tank	Gasoline	Soil	E (P)
7	Saginaw 08/27/86	Agri[illegible] 73-125-051-[illegible] Buena Vista	Fertilizer Mfg	Surface Discharge Aboveground Tank Container	PCB, Phosphoric Acid	Soil	E (P) FS (P)
7	Saginaw 04/24/86	[illegible] for Saginaw 73-125-051-2920 Buena Vista	AG Lime Products	Pit	Cadmium, Nickel, Chromium, Lead, Copper, Zinc, pH	Soil	EP
7	Saginaw 04/23/86	[illegible] 73-098-010-1454 Oakley	Grain Elevator	Aboveground Tank	Gasoline, Fuel, Oil	Soil	IR (P) E (P)
7	Saginaw 09/23/86	Johnson Carbide 73-125-051-2901 Buena Vista	Metal Hardware	Aboveground/ Underground Tanks, Barrel	Solvents, 1,1,1-Trichloroethane, Cutting Oils	Soil, Flora	FR (P)
7	Saginaw 09/18/87	Lara Iron Salvage Yard 73-125-051-1588 Buena Vista	Auto Junkyard	Surface Discharge	Light Industrial	Soil	EP
7	Saginaw 09/18/87	Sargent Docks & Terminal Co. 73-125-051-3278 Kochville	Coal Gasification	Surface Discharge	Polynuclear Aromatics	Soil	EP
7	Saginaw 09/18/87	Stroebel & S. River Rd. Dump 73-128-045-1790 Saginaw	Dump	Dump	Domestic Comm Heavy Mfg	Soil	EP

Appendix 6. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
7	Saginaw 09/18/87	Zilwaukee City [illegible] [illegible] Zilwaukee, City of	Municipal Facility	Underground Tank	Gasoline, Other	Soil	EP
6	Clare 10/01/84	Surrey Twp LF [illegible] Surrey	Landfill	Landfill	Chem. Prod Mfg		RA
6	Genesee 10/01/87	[illegible] [illegible] Flint	Dump	Dump, Buried	Domestic Comm, Heavy Mfg.	Soil	RA
5	Genesee 09/13/87	Genesee Co. Jail Project [illegible] Flint	Municipal Facility	Unknown	Gasoline, Oil	Soil	IR (P) RA
6	Huron 10/19/84	Dowie Wash Kleen [illegible] Colfax	Laundry Dry Cleaner	Lagoon	PCE	Soil	EP
6	Huron 09/18/87	Port Austin State Bank [illegible] Port Austin	Dump	Pile, Barrel Surface Discharge	Light Industrial	Soil	EP
6	Huron 09/18/87	Sebewaing Industries [illegible] Sebewaing, City of	Dump	Pile, Barrel Surface Discharge	Light Industrial	Soil	EP
6	Lapeer 09/18/87	Lapeer Foundry & Mach., Inc. [illegible] Lapeer, City of	Iron Steel Foundry	Pile, Barrel	Heavy Mfg.	Soil	EP

Appendix B. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
5	Livingston 09/18/86	Old Howell [illegible] Rd Park [illegible] Genoa	Landfill	Landfill	Domestic Comm. Light Industrial		RA
5	Saginaw 09/19/87	[illegible] Auto [illegible] Spaulding	Auto Repair	Pile	Oil, Gasoline, Antifreeze	Soil	EP
5	Saginaw 09/18/87	[illegible] Shiawassee & Bay [illegible] Kochville	Gas Station	Underground Tank	Gasoline	Soil	E (P)
6	Saginaw 09/28/87	[illegible] Saginaw [illegible] Saginaw, City of	Gas Station	Aboveground Tank	Gasoline	Soil	EP
6	Saginaw 09/18/87	[illegible] Salvage Yard [illegible] Saginaw, City of	Scrap Metal Yard	Surface Discharge	PCB, Oil	Soil	EP
6	Saginaw 09/18/87	[illegible] Street [illegible] Saginaw, City of	Unknown	Unknown	Oil	Soil	EP
6	Shiawassee 08/23/85	[illegible] Owosso	Forging, Stamping	Unknown	Zinc, Cadmium, Copper, Lead	Soil	EP
5	Shiawassee 09/13/85	Old Country [illegible] Caledonia	Laundry Dry Cleaner	Lagoon	Copper, Chromium, Cadmium, Nickel, Lead, Zinc		IR (P) RA

Appendix 5. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
6	Tuscola 09/18/87	Avtech Industries 79-T15-08[illegible] Vassar	Iron Steel Foundry	Pile	Foundry Sands	Soil	E (P)
6	Tuscola 10/09/86	Fulton Grede Vassar 79-T12N-09E-[illegible] Vassar	Iron, Steel Foundry	Lagoons, Piles	Light Industrial		E (P)
6	Tuscola 09/26/87	Fairgrove Gas Stn 79-T13N-[illegible] Fairgrove	Gas Station	Surface Discharge	Gasoline	Soil	EP
5	Isabella 10/03/86	Rana Corp 37-T14N-04W-[illegible] Union	Misc Machinery Mfg	Underground Tank	PCE, TCE, Methylene Chloride		RA
5	Isabella 09/26/86	Shepherd School Gas Spill 37-T13N-[illegible] Coe	Gasoline Storage	Underground Tank	Gasoline	Soil	RA
5	[illegible] 09/28/86	[illegible] Twp Dump 67-T2N-06E-[illegible] [illegible]	Landfill	Landfill	Domestic Chem		EP
5	Midland 09/18/87	Midland Iron Works 56-T14N-[illegible] Lee	Iron Steel Foundry	Pile	Heavy Mfg.	Soil	EP
5	Ogemaw 09/27/86	Consolidated Store Area 65-T22N-[illegible] Churchill	Gas Station	Underground Tank	Benzene, Toluene, Xylene	Soil	EP

Appendix 8. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
5	Saginaw 10/13/84	Agrico Chemical Co. 73-[illegible] [illegible]	Fertilizer Mfg	[illegible]	Chem Prod Mfg		IR (P)
5	Saginaw 10/09/84	C & O Railroad 73-[illegible] Frankenmuth	Rail Transport	Underground Tank	Diesel Fuel, Salt		EP
5	Saginaw 09/06/87	Saginaw Products Corp. 73-[illegible] Saginaw, City of	Metal Hardware Mfg	Surface Discharge	PCB		EP
5	Saginaw 09/10/87	Chemtex [illegible] 73-[illegible] Carrollton	Chem Products Mfg	Surface Discharge	Caustic Soda, Detergents, Phosphoric Acid	Soil	EP
5	Shiawassee 09/11/85	Midwest Abrasives 78-[illegible] Rush	Abrasives	Surface Discharge	Phenol		IR (P) EP
5	Tuscola 10/09/84	Rudac Products Inc 79-[illegible] Vassar	Paint Products	Surface Discharge	Light Industrial	Soil	[illegible] (P)
5	Genesee 05/07/85	[illegible] Plating Plant 25-[illegible] Vienna	Plating, Polishing	Barrel, Pits, Surface Discharge	Cyanide, Chromium	Soil	IR (P) EP
4	Huron 09/18/87	Port Austin [illegible] 32-[illegible] Port Austin, City of	Laundromat	Surface Discharge	Domestic Coms	Soil	EP

Appendix H. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
5	Iosco 10/09/84	Rack Glove & Manufacturing 35-21N-06E-01D Wilber	Rack Glove Mfg	Waste Pile	Vinyl Chloride, Polyvinyl Chloride, Diethyl Phthalate	Soil	IR (P) E (P) RA
4	Isabella 10/05/84	Isabella Co Sanitary LF 37-14N-05W-19CA Union	Landfill	Landfill	Domestic Comm, Light Industrial		RA
4	Isabella 10/19/84	Wise Twp LF 37-15N-03W-18CB Wise	Landfill	Landfill	Domestic Comm		RA
4	Lapeer 09/26/86	Otter Lake Marathon Field 56-09N-09E-28AC Marathon	Oil Drilling	Geologic Form	Hydrogen, Sulfide	Air	EP
4	Saginaw 09/22/86	Merrill Dump 73-12N-01E-27DA Jonesfield	Landfill	Landfill	Domestic Comm		EP
3	Isabella 10/25/84	Gilmore Twp Sanitary LF 37-14N-03W-28AA Gilmore	Landfill	Landfill	Domestic Comm		RA
2	Arenac 09/12/86	Mason Turner Twp Dump 06-20N-05E-15AA Mason	Landfill	Landfill	Domestic Comm	Soil	EP
2	Arenac 12/05/84	Standish Moseley Dump Closed 06-18N-05E-07CD Standish	Landfill	Landfill	Domestic Comm	Wetland, Soil	EP

Appendix B. Continued.

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
2	Clare 11/02/84	Arthur Twp Dump 18-18N-03W-13AD Arthur	Landfill	Landfill	Domestic Comm		RA
2	Shiawassee 10/24/85	C & C Disposal 78-05N-03E-19BA Burns	Landfill	Landfill	Iron	Soil	EP
1	Gladwin 11/05/84	B & B Disposal Closed 26-18N-01W-06AA Buckeye	Dump	Dump	Domestic Comm		IR (P) EP
1	Gladwin 07/01/85	Gladwin Co Rd Comm 26-18N 01W-06AA Buckeye	Unknown	Waste Pile	Salt		RA
1	Gladwin 10/08/84	Sage Twp Dump Closed 26-19N-02W-12CC Sage	Dump	Dump	Domestic Comm		EP

*The common site name is for identification only and is not necessarily a party responsible for contamination.

**IR=Interim Response; E=Evaluation; FR=Final Response; RA=Regulatory Actions; EP=Evaluation Pending; P=Privately Funded Actions; F=Federally Funded Actions

Appendix 9. Act 307 Priority List of Sites in the Saginaw Bay Watershed (MDNR, 1988).

SAS Score	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
0753	Lapeer 01/28/87	Oregon Twp Dump 44-095-097-[illegible] Oregon	Landfill	Barrel Landfill	Toluene Xylene TCE Zinc Benzene PCB Carbon disulfide	Surface Water Groundwater Soil Wetland	E (S) IR (S)
0751	Oakland 02/09/87	Springfield Twp Dump Site 63-[illegible] Springfield	Dump	Barrel	TCE Benzene Toluene Xylene	Groundwater Soil	IR (S,F) E (S,F)
0725	Bay 01/13/86	[illegible] 09-[illegible] [illegible]	Landfill	Lagoon Barrel Landfill	TCE Xylene Dichloroethane Diethyl Phthalate	Groundwater Wetland	E (S)
0725	Oakland 02/09/87	Rose Twp Dump Site 63-[illegible] Rose	Dump	Pit Barrel	Lead Cadmium Phenol PCB Dichloroethylene	Surface Water Groundwater Soil	IR (S,F) E (S,F)
0696	Oakland 02/10/87	Rose Twp Cemetery Site 63-[illegible] Rose	Dump	Barrel	Phenol PCB Arsenic Lead Nickel Chromium		IR (S,F) E (S,F)

*The common site name is for identification only and is not necessarily a party responsible for contamination.

**IR=Interim Response (alternate water, surface removal, site security, and other partial remedies; E=Evaluation (studies); FR=Final Response (final cleanups); RA Regulatory Action (specific actions to initiate site work, e.g., negotiations, preliminary investigations); EP=Evaluation Pending (sites currently with insufficient priority for publicly funded response); P=Privately Funded Actions; S=State-funded actions; F=Federally Funded Actions

Appendix 10. Environmental Protection Agency Superfund Sites in the Saginaw Bay Watershed.

Act 307 List Group	County Date Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
1,1	Clare	Clare Municipal Wells City of 18-[illegible] Grant	Auto Component Mfg	Lagoon Surface Discharge	Dichloroethane Trichloroethene	Groundwater Sediment Municipal well Surface Water	1R (F) E (P,S,F)
1,1	Genesee	Forest Waste Products 25-[illegible] Forest	Landfill	Lagoon Landfill	Dieldrin Lead Cyanide PCB Oil	Groundwater	1S (S,F) E (S,F)
1,1	Genesee	Berlin and Farro 25-[illegible] Gaines	Haz waste facility	Lagoon Landfill	Toluene Ethylbenzene Bromoform	Groundwater Soil	1R (P,S,F) E (P,S,F) FR (P,S,F)
Unlisted	Gratiot	Gratiot Co. Landfill	Landfill	Landfill	Leachate, PBB		
Unlisted	Gratiot	Velsicol	Plant site	Discharge	PBB	Surface Water Sediments	
1,1	Iosco	Hedblum Industries [illegible] Au Sable	Forging stamping	Surface discharge	Trichloroethylene	Groundwater	1R (P,S) E (S)
1,1	Lapeer	Metamora Landfill [illegible] Metamora	Landfill	Barrel Landfill	Dichlorobenzene Hexachlorobenzene Methyl Chloroform	Groundwater	1R (S,F) E (S,F)
1,1	Livingston	Rasmussens Dump 47-[illegible] Green Oak	Dump	Dump Barrel	Volatile Organics Dioxins PCB Lead Arsenic Copper	Groundwater Soil	1R (S,F) E (S,F)

Appendix IV. Continued.

Act 307 Risk Group	County Rate Scored	Common Site Name* Location Code Township	Source of Contamination	Point of Release	Pollutant	Resource Affected	Status**
2,1	Livingston	Shiawassee River [illegible] Howell	Leaking [illegible]	Surface discharge	PCB TCE	Surface Water Sediment	E (S,F)
2,1	Livingston	Spiegelberg LF [illegible] Green Oak	Dump	Dump Barrel	Liquid Paints Zinc Arsenic Thallium	Groundwater Soil	IR (S) E (S,F)
2,	Oakland	Springfield Twp Dump Site [illegible] Springfield	Dump	Barrel	PCB Benzene Toluene Xylene	Groundwater Soil	IR (S,F) E (S,F)
2,	Oakland	Rose Twp Dump Site [illegible] Rose	Dump	Pit Barrel	Lead Cadmium Phenol PCB Dichloroethylene	Surface Water Groundwater Soil	IR (S,F) E (S,F)
2,	Oakland	Rose Twp Cemetery Site [illegible] Rose	Dump	Barrel	Phenol PCB Arsenic Lead Nickel Chromium		IR (S,F) E (S,F)

*The common site name is for identification only and is not necessarily a party responsible for contamination.

**IR=Interim Response (alternate water, surface removal, site security, and other partial remedies); E=Evaluation (studies); FR=Final Response (final cleanup); RA=Regulatory Action (agency actions to initiate site work, e.g., negotiations, preliminary investigation); EP=Evaluation Pending (sites currently with insufficient priority for publicly-funded response); P=Privately Funded Actions; S=State-funded Actions; F=Federally Funded Actions