SAGINAW RIVER/BAY

REMEDIAL ACTION PLAN

DRAFT 1995 BIENNIAL REPORT
VOLUME 2: APPENDICES

DECEMBER 1994

PREFACE

These appendices to the draft 1995 biennial report of the Saginaw River/Bay Remedial Action Plan (RAP) were jointly prepared by numerous governmental agencies (local, state and federal), local governments, public organizations, and business representatives, through the committee structure of the Saginaw Bay National Watershed Initiative. The purpose of the RAP is to track progress under the RAP program and to identify actions needed to take the next steps in the restoration, protection and enhancement of environmental conditions in Saginaw Bay and its watershed. These appendices provide supporting technical information to Volume 1.

Since completion of the original Saginaw River/Bay RAP document in September 1988, over 2/3 of the 101 actions identified have been at least partially implemented, and all 37 priority actions have been at least partially implemented. Volume 1 of this second iteration of the Saginaw River/Bay RAP document describes many of these actions; the current environmental status of, and goals for, Saginaw Bay and the watershed; the growth of the Saginaw RAP process; and the additional actions needed to move forward with the RAP effort. The draft biennial report focuses on land use, nutrients, conventional water quality parameters, soil erosion/sedimentation, and upland habitat. It is envisioned that the 1997 biennial report will focus on toxic substances, contaminated sediments, and aquatic habitat.

The Saginaw River/Bay RAP is a multimedia, ecosystem-based, locally-driven process and participation from any interested party is welcome at any time. Comments on the document and the Saginaw River/Bay RAP process, or questions on how to become involved, may be directed to:

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APPENDIX THREE: AREA DESCRIPTION

A. LOCATION AND SIZE

The Saginaw River/Bay Area of Concern is located in the east-central portion of Michigan's lower peninsula (Figure 1). Saginaw Bay is a large, and relatively shallow, southwestern extension of Lake Huron. One of the largest embayments of the Great Lakes, its 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 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 Saginaw Bay shoreline of 381 km (237 miles) constricts the bay to a width of 20.2 km (12.6 miles) between Point Lookout on the northwest side and Sand Point on the southeast, 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 of 1,480 km^2. However, the inner bay has a shoreline length of 176 miles compared to only 61 miles in the outer bay. 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 28.4 km^3 (6.8 cubic miles) is about 0.8% of Lake Huron's total volume (Great Lakes Basin Commission, 1975). Flushing time is dependent on wind driven circulation patterns but is approximately 93 days for the inner bay and 58 days for the whole bay.

The inner and outer bays are distinguished from each other by distinct differences in water quality, shoreline type and substrate. The shallower inner bay is surrounded by coastal marshes, has soft mud and sand substrates, and is predominantly influenced by tributary flow. The outer bay has sand and cobble beaches and substrates with water quality more similar to that of nearshore Lake Huron.

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). Approximately 1.4 million people live within the Saginaw Bay watershed. 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, and the largest in the state, covering 16,260 km^2 (6278 mi^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 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.

These Saginaw Bay tributaries have relatively low slopes and are event responsive. They drain watersheds with diverse soil types, though lacustrine glacial clays are most prevalent. Agricultural drains are major components of the drainage system in most of the watershed.

B. 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 continuous band of glacial moraine deposited at the margins and terminus of the ice. Moraines account for the most dramatic vertical 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. 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 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. 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.

C. HYDROLOGY AND SEDIMENTS

1. Precipitation

Precipitation within the basin averages about 30 inches annually (Figure 2), much of which falls as snow and is potentially available for release during spring meltoff. 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.

2. 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. Current speed and base flow in the Saginaw River have been found to increase significantly as southwest wind velocities rise. 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.

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).

3. 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 2 ft above chart datum level in March 1994. The 1994 lake level is still about one foot above Lake Huron's long-term average. Lake Huron lake levels typically fluctuate a foot or so over the course of a calendar year, with the low levels occurring in January and February, and the yearly highs coming in July and August.

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 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.

4. Flooding and Erosion

Virtually the entire shoreline of inner Saginaw Bay is flood prone (Figure 18) and the potential for environmental and property damage is a major concern. Prudent use and judicious development of the flood prone areas are major goals of state and local zoning and regulatory programs.

While virtually the entire inner bay is flood prone, much of the outer bay is highly erodible. Numerous stretches have been designated as high-risk erosion areas under Michigan's Shorelands Protection Act (Figure 19).

5. 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 (correlation between runoff per square mile and the drainage area known to exist below a given gage) of the four major tributaries at their confluence to form the Saginaw River. The tributary flows are used to calculate Saginaw River flows because discharge measurements at the mouth of the Saginaw River are generally considered unreliable due to the influence of seiche-induced flow reversals. Flow reversals in the Saginaw River are common during wind-driven seiches and storm surges in the bay. Flow reversals have been observed as far as 20 miles upstream. Reversals typically occur as wedges of cooler, denser bay water are driven upstream along the river bottom. However, the U.S. Geological Survey does have a mathematical model that accounts for these conditions to predict flow at the Saginaw River mouth when data are available for both the downstream and upstream gages on the Saginaw River.

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.

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.

River flows are also affected by the 346 dams in the Saginaw Bay watershed. These include lake level control structures and dams that do not meet Act 300 size criteria. Of these, only seven are registered for hydropower and 41 are owned by the MDNR. Many of the dams of maintained for recreational purposes. All of them, however, have potential impacts on the aquatic ecosystem including effects on the hydrologic regime, fish and wildlife passage, evapotranspiration rates, sedimentation rates, nutrient loading rates, and fragmentation and loss of habitat.

D. GROUNDWATER

The glaciers that left Michigan some 10,000 years ago deposited a complex series of unconsolidated materials including clay, silt, sand, gravel, boulders and mixtures -- which collectively are called drift. Water that occupies the pore spaces in this unconsolidated material, and in the underlying bedrock, is groundwater. Groundwater is an important source of water inflow, and a potential source of contamination, to surface waters in the Saginaw Bay watershed. Groundwater is also a source of drinking water for many basin residents.

The light-toned areas on Figure IV-1 depict regions of the state, including the Saginaw Bay basin, where one or more of the glacial Great Lakes covered the present upland surface and deposited clay-rich materials. These lake plains are low-relief surfaces generally underlain by fine-textured drift, which restricts groundwater movement. As a result, drift wells for drinking water are not routinely possible in these sections of the state and bedrock aquifers must be used instead. This area includes the tip of Michigan's "thumb", and a swath of variable width extending southwestward from Saginaw Bay to the state line in Branch and Hillsdale counties (Figure IV-2).

Figure IV-2 shows the accessibility of Michigan's bedrock aquifers in terms of the thickness of the glacial materials that bury them in most places. The good aquifers shown on this map routinely provide potable groundwater of adequate quantity and quality. The marginal aquifers are those that provide low-quality water and/or have highly variable characteristics. The marginal 1 class consists of saturated, sedimentary rock units. The marginal 2 class represents the igneous and metamorphic rock types in the western upper peninsula that have little or no primary porosity. In the marginal 2 hard rock areas, groundwater is found only in joint and fracture zones.

Generalized areal patterns of natural groundwater quality indicate that geology is a primary cause of differences across the state. Most of the natural groundwater in Michigan is hard to very hard. Some aquifers have high concentrations of iron, depending on the minerals in the formation. Water from bedrock deposits is more highly mineralized than that from glacial deposits. And among principal bedrock aquifers, the Saginaw Formation yields the most highly mineralized water.

In general, locations where sands and gravels dominate the glacial overburden tend to be vulnerable to contamination from surface sources. The most vulnerable areas encompass 31% of the state's land area and are composed of highly permeable soils over highly sensitive drift lithology. The least vulnerable portions, including much of the Saginaw Bay watershed (Figure IV-6), occupy about 25% of the state's land area and are made up of moderately and slowly permeable soils overlying the least sensitive drift lithologies. The moderately vulnerable areas comprise nearly 44% of the state. This moderate class includes areas of unknown or uncertain drift lithology, moderately or slowly permeable soils over highly sensitive drift lithology, or highly permeable soils over the least sensitive drift lithology.

E. WETLANDS

The most outstanding habitat feature of the Saginaw Bay area is the expansive coastal wetlands of the bay itself, which is the largest remaining freshwater coastal wetland system in the nation. Historic documents indicate that there were approximately 37,400 acres of emergent marsh along the perimeter of the bay prior to western settlement. There were also large expanses of submerged aquatic vegetation in the shallow water zone from the shoreline to a depth of approximately six feet.

This shallow water protected habitat, open to the entire Great Lakes system through Lake Huron, is critical to the sustainment of Great Lakes fish and waterfowl populations. By 1973, emergent coastal marsh vegetation had decreased to approximately 17,800 acres as the result of conversion to agricultural uses, fill for industrial or urban development, and erosion. Even today, many parcels of the remaining privately owned wetlands along Saginaw Bay are under increasing developmental pressure as demand for recreational access/use and shoreline living space intensifies with improving water quality conditions.

Many environmentally sensitive areas statewide are designated for special protection and emphasis under the Michigan Shorelands Protection Act. Because of the ecological importance of Saginaw Bay wetlands, most of the inner bay shoreline has been designated as "environmental areas" under this act (Figure 16).

Numerous wetland areas surrounding Saginaw Bay are in public ownership under the regulatory authority of the 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; Table 8).

Wetland 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 following three managed areas are especially significant.

The Shiawassee National Wildlife Refuge, operated by the U.S. Department of the Interior's Fish and Wildlife Service and managed for waterfowl, contains several thousand acres of wetland habitats at the mouth of the Shiawassee River. 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 adjacent Shiawassee State Game Area provides substantial additional habitat.

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.

All together, wetlands comprise approximately 15% of the land mass of the Saginaw Bay watershed. Additionally, much of the agricultural land in the watershed is converted wetlands.

F. ENDANGERED/THREATENED SPECIES

There are numerous plant and animal species in the Saginaw Bay watershed listed as probably extirpated, endangered, threatened, or of special concern (Table 74). In addition to these plant and animal species, Michigan lists natural communities which are globally scarce or unique (Table 74). On the national level, 15 plant species and 20 animal species (including fish) on the federal endangered or threatened species lists have been documented to occur in the Saginaw Bay watershed.

Saginaw Bay, like all the Great Lakes and their major embayments, is subject to water level fluctuations in the range of 1-4 feet over a several year period. As a result, most of the plant communities, plant species, and animal species occupying the coast either tolerate or require water level fluctuation for their ultimate survival. For example, high water conditions may destroy the populations of a plant species like Prairie Fringed Orchid, but it also prepares the seedbed for regeneration of the orchid and prevents the encroachment of shrubs into the orchid habitat. The Saginaw Bay area supports several plant communities with limited distribution.

Lakeplain Wet Prairie and Lakeplain Wet-Mesic Prairies are found only in the Great Lakes region and are among the most threatened natural communities in Michigan. The greatest concentration of wet prairie is along the Saginaw Bay coastline, where is was originally much more abundant, forming a narrow band between the emergent marshes located in the shallow bay and the swamp forests further inland. Many of the prairies were destroyed by the construction of an extensive drainage canal system in the shoreline counties; some of the prairies were farmed while others became drier, which resulted in shrub or forest encroachment. The remaining wet and wet-mesic prairies are the primary or sole habitat for several threatened and endangered species, including Prairie Fringed Orchid, Tall Green Milkweed, Sullivant's Milkweed, Prairie Indian-Plantain, and Silphium Borer Moth.

Inland Salt Marsh is another natural community once common along Saginaw Bay, Lake St. Clair, Lake Erie, and the bases of steep slopes along the Grand River. It is now considered an endangered natural community across its range by the Nature Conservancy. With the exception of a few salt marshes in Utah, all other salt marshes are located along the shorelines of one of the oceans. At present only two marshes in Michigan are known to support the characteristic vegetation of the salt marsh; these are located along the Maple River just west of the Saginaw basin. The most likely place for location of additional salt marshes is in the Saginaw Bay basin, probably in either Gladwin, Midland or Gratiot counties. State threatened species known from this community include Dwarf Spike-Rush and Olney's Bulrush.

Probably the most characteristic wetland natural community of the bay is Great Lakes Marsh, a term used to include the submergent marsh, emergent marsh, and wet meadow along the shorelines of the Great Lakes. Some of the marshes are quite extensive, covering approximately 8700 acres (based on 1978 color infrared photography and field surveys during 1988 and 1989). This acreage estimate is probably low, based on field surveys during the summer of 1990. These surveys revealed that many areas with no significant marsh during the high water years of 1985 and 1986 supported broad marshes in 1990. Extreme fluctuations of water level are characteristic of the marshes and were demonstrated by the original General Land Office surveys. The township boundaries were surveyed first, and when the survey crews returned approximately five years later to do the remaining section lines, they noted that the water level had dropped several feet since the original survey leaving extensive areas of mud flats unsurveyed. The marshes are important habitat for both game and non-game fauna, including waterfowl and fish, which breed and feed along the shorelines or in the shallow water of the marsh.

There are other important natural habitats further inland. Extensive marshes border portions of the major rivers, like the Pine, Tittabawassee and Saginaw. Extensive bogs and forested wetlands occur in the Au Sable State Forest, along the Tittabawassee River, in the Gratiot-Saginaw State Game Area, and in several other state game areas and national wildlife refuges. Although surveys of natural communities and threatened plants are very incomplete in these ares, several threatened and endangered plants and animals are known to inhabit these areas, which represent some of the largest remaining undeveloped forest/wetland complexes in the southern part of the state.

G. LAND USES

1. Introduction

Land use is very diverse in the Saginaw Bay basin spanning a spectrum from relatively undisturbed natural areas, to intensive agriculture lands, to heavily industrialized urban settings. The watershed is home to 1.4 million people who reside in four major urban areas -- Flint, Bay City, Saginaw and Midland -- 90 additional city or village municipalities, and rural locations.

Agricultural use predominates in the watershed **counties** (46% of land area; Table 1; Table 7-1) and includes extensive cash crop and livestock production (when only lands within the **watershed boundaries** are included, agriculture increases to 50%). Upland forests are next most abundant (19%) followed by wetlands (15%) -- which include the sum of the "wetlands" and "lowland forest" classifications.

Industrial activity is substantial, dominated by automobile manufacturing and related support operations, followed by fabricated and primary metals, nonelectric machinery, chemicals, electronic equipment, and food processing. Extractive land uses include aggregates (sand, gravel, stone), salt, brine, limestone, peat, gypsum, crude oil, and natural gas. Old waste disposal sites are common throughout the basin and consist of numerous closed landfills, dumps, and industrial facilities.

Recreational lands and designated wildlife areas occur over much of the northern and coastal portions of the basin. There is one national forest and one national wildlife refuge along with nine state wildlife areas, several tracts of state forests, four state parks, and many local parks.

2. Agriculture

Agriculture is the most extensive single category of land use in the Saginaw Bay drainage basin accounting for just over 50% of the land area. 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 (Figure II-15). 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 have the most acreage among basin counties (Table 7-1) and 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. 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 (Table 7-3).

Huron and Sanilac counties are the top two statewide for both beef cattle/calves and milk cow populations (Table 7-2). Poultry farms are also common in the basin, with Huron, Isabella and Tuscola counties ranking very high. Hogs, sheep and horses, on the other hand, are generally not as numerous within basin counties. Huron, Tuscola and Isabella counties have the most total livestock of all Saginaw Bay watershed counties (Table 6-8).

3. Residential

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 or villages containing 2,500 or more residents. 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.

All three of the basin's standard metropolitan statistical areas - Bay City, Flint and Saginaw - and 27 of the remaining 30 urban places identified above 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%) of the Saginaw River watershed.

4. Industrial/Municipal

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. 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 191 industrial dischargers to tributaries of Saginaw Bay, 11 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. The Saginaw River basin accounts for 82% of these dischargers, including all but two of the major sources. The west coastal basin and east coastal basin contain 25 and 9 industrial dischargers respectively.

There are 82 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. The Saginaw River basin receives municipal waste from 59 sources, including all but one of the major dischargers. The east coastal basin has 14 municipal dischargers and the west coastal basin has 9. 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.

5. Extractive

Extractive land uses in the Saginaw Bay basin primarily involve nonmetallic minerals, brine wells, aggregates, and oil or natural gas wells. 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. 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, limestone, peat or gypsum. Two of the three gypsum mines in Iosco County are among the largest in the nation.

6. 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. Many of the landfills or dumps in the basin have been identified as contaminant sources to surface waters, groundwaters or soils under the Michigan Act 307 program. 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 goes on and additional investigations are conducted.

7. Upland Wildlife Habitat and Recreation 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 areas bordering Saginaw Bay, provide refuge along the flyway routes of many waterfowl species, as well as habitat for other water dependent birds and animals.

The U.S. FWS has identified increasing public use of its existing lands for non-hunting uses, primarily for trail use (cross-country skiing, hiking and biking) and birding. The

Shiawassee National Wildlife Refuge is recognized by the Audubon Society as one of the top ten refuges in the country for overall birding. Hunting activity, for which the refuge is very popular, is directly related to the regulations placed on each game species as determined by population.

Human impacts on the refuge are directly related to the growth in population of Saginaw Township specifically, and the proximate and growing population of southeast Michigan in general. The FWS has leased Green Point Nature Center from the City of Saginaw, to operate for environmental education for both local schools and the general population. The center and its acreage lies on the south border of the City of Saginaw, and abuts the refuge on its north boundary. The FWS will be expanding interpretive type programming at this facility.

Future trends for FWS activity in the Saginaw Bay watershed rest primarily with expansion of the refuge, though the service is also interested in acquisition of the Charity Islands for habitat preservation. Approximately 7,000 acres of streamside habitat will be acquired along the Tittabawassee and Cass river corridors. While the primary purpose is to preserve open space and wildlife habitat, the growing interest in access for trail activities and birding will likely be addressed in some form of controlled access planning. Hunting activity will increase as well with the added opportunity of the expanded acreage.

The MDNR administered lands within the watershed reflect similar uses as described for the Shiawassee National Wildlife Refuge. Hunting activity is expected to remain generally stable, with a stable deer population, and a pheasant population that is likely to see some increase. Waterfowl hunting in state game areas is extremely popular along the bay, and is expected to remain so. Non-hunting uses of the game areas include birding and the "Watchable Wildlife Program", as well as increasing trail use activities.

Future trends include proposed land acquisition of approximately 6,100 acres to consolidate ownership within designated boundaries, to expand the Quanicassee State Game Area, and to link the Maple River State Game Area with the Gratiot/Saginaw State Game Area. The next Farm Bill (1995) will have a direct impact on wildlife management/habitat preservation activities for both the state and federal programs. An aspect of improved water quality is the resultant increase in perceived land values, and increasing pressure from the private sector to purchase land within the prescribed boundaries of the game areas, making it more difficult for state and federal programs to acquire.

Other 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.

Facilities for noncontact recreation activities, such as camping, bicycling, walking and hiking, picnicking, nature study, and bird watching, 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 Sleeper and Port Crescent (MDNR 1993). The 185 acre Tawas Point State Park in Iosco County received 278,391 visitor-days of use in 1993 (October 1992 through September 1993), divided between camping (83,931) and day-use (194,460). Bay City State Park, 224 acres in size, was the most heavily used receiving 408,183 visitor-days (70,676 camping and 337,507 day-use). Sleeper State Park, a 1,795 acre facility totaled 149,384 visitor days of use (75,424 camping and 73,960 day-use). Port Crescent State Park covers 569 acres and received 146,111 visitor-days of use (79,059 camping, 67,059 day-use). The total number of visitor-days recorded at the four State Park facilities was 982,069 in 1993, with 309,083 camping and 672,086 day-use.

Future trends in park use are seen to be reactive to improvements in water quality and related habitat/resource improvements. Day-use activity represents approximately two-thirds of the shoreline parks use, and with camping facilities remaining stable, day-use is expected to increase with improved water quality. Primary uses are similar to the day-use activities found in the wildlife areas, that being trail use and birding along with camping and picnicking. Future land acquisitions are expected to be limited and will represent only 100-200 acres.

In addition to state parks, there are 10 sites identified as county, township, or municipal parks and/or campgrounds, with frontage on Saginaw Bay. No use data are available for these sites, but their location suggests that water-related noncontact recreation activities 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. There are also numerous private beaches, campgrounds and other recreation facilities, particularly in Iosco, Arenac and Huron counties.

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 II-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.

Birdwatching is a significant recreational activity in the coastal areas of Saginaw Bay. With the arrival of waterfowl each spring, there is also a people migration to the bay area to witness the spring spectacular. On weekends, the roads in and around the Fish Point Wildlife Area near Unionville are crowded with visitors eager to view the waterfowl. There is also intensive viewing at Tobico Marsh north of Bay City and at Nayanquing Point.

Surveys conducted by the U.S. Fish and Wildlife Service for 1980 indicate that Michigan had over one million hunters and over 6.6 million people over six years of age who participate in viewing and enjoying wildlife. This represents approximately 70% of the state's population. Resource managers estimate that at least a quarter-million days are spent annually on viewing and other nonconsumptive uses of wildlife. Estimates are that these consumptive and nonconsumptive activities in 1987 resulted in an expenditure of almost $34 million in the Saginaw Bay area. This amount is approximately 3% of the $1.4 billion spent statewide.

H. WATER USES

1. Habitat

The important wetland and upland habitats suitable for wildlife were described previously. Additionally, the shallow productive waters of Saginaw Bay provide outstanding habitat for a wide variety of fish and other aquatic species. 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 stages.

In addition to the wetland habitats discussed earlier, there are numerous areas in Saginaw Bay with submerged rock reefs. From Tawas Point on the western shore of the outer bay to Port Austin in the east, there are scattered reefs of honeycombed rock at depths ranging from 6 to 120 feet.

Fish species spawn throughout most of Saginaw Bay (Figure 5). 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 Coryeon Reef, and in the vicinity of the Charity Islands, in shallow waters over a variety of substrates (Goodyear, et al., 1982). 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).

2. Recreational Use

a. Overview

Recreation in Michigan centers around the countless water-related opportunities offered by being nearly surrounded by the Great Lakes. Even winter sports opportunities are strongly influenced by the Great Lakes as "lake effect" snow provides excellent skiing and other land-based sports conditions. Opportunities for boating, swimming, fishing and hunting are unparalleled. Saginaw Bay, a protected embayment with major population centers nearby, attracts huge numbers of visitors annually seeking to participate in the diverse activities available in the region. These "quality of life" aspects not only create exemplary leisure opportunities, but also are a major factor in the region's industrial economy as they attract and retain a qualified labor force.

Nationally, with the Great Lakes as its focus, Michigan ranks first in the number of registered pleasure boats. Over 857,000 boats are registered (May 1994) with approximately half of them within 100 miles of Saginaw Bay. The bay, sheltered by land on three sides and with numerous access sites, marinas, harbors and islands, represents a nationally significant pleasure boating center. The Saginaw River system and Saginaw Bay are particularly important boating resources since this area of the state lacks inland lakes. In the counties inclusive within the watershed, there are only 38 inland lakes greater than or equal to 100 acres in size. In all counties included in the watershed, the total is only 222 lakes.

The Saginaw Bay area, particularly the five coastal counties, is a major tourism and water-related recreation center in Michigan. The bay is located near several major population centers and is convenient for both residents and visitors via the interstate highway system and Michigan trunk highways. Without a doubt, the intensity of use, and its economic value, depends heavily on the quality of the bay environment and its world-class walleye and yellow perch sport fisheries.

b. 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, northern pike, brown trout, lake trout, 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 value of this fishery is several million dollars per year and the fishery has the potential to expand substantially beyond its present status.

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. Substantial natural reproduction has been documented but the magnitude and significance to population recruitment is unknown. Walleye spawning runs attract thousands of anglers and ice fishing for walleye is also becoming extremely popular. The estimated sport harvest in 1993 was over 140,000 walleye. Saginaw Bay walleye grow faster than any other major walleye 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. Resource managers reported a sport harvest of 2.4 million perch from the bay in 1988 taken on a total of over 500,000 fishing trips.

The shallow waters of Saginaw Bay also provide excellent fishing for many other species, particularly in the inner bay. Panfish, largemouth bass, smallmouth bass, and northern pike concentrate in nearshore areas such as Wildfowl Bay and Wigwam Bay. Other species, such as carp, channel catfish, and bullheads are common and provide an additional sport fishery.

The Saginaw Bay region is one of Michigan's premier winter fishing areas. A 1984 creel census by the MDNR on the bay waters of Arenac, Bay, Huron and Tuscola counties revealed that from January through May, an estimated 1 million angler hours were expended on the bay. An estimated total of 2.3 million fish were caught, of which 97% were yellow perch. January was the month with the greatest angler-days and catch.

Terrific perch fishing action begins with the onset of "first ice" on Saginaw Bay. As the ice thickens, anglers move further from shore from sites such as Bay Port, Quanicassee, Fish Point, Sebewaing, Linwood, Standish, Pinconning and Au Gres. Throughout the winter, the perch usually range from 8-10 inches in length.

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.

The Saginaw and Tittabawassee rivers are the prime winter walleye fishing areas. February is the month with the highest catch. While the Saginaw River will usually freeze in the winter, the Tittabawassee often does not. A few boat anglers fish the Tittabawassee for walleye in the open water during winter.

It is expected that recreational fishing will continue to gain in popularity and economic importance throughout Saginaw Bay and its watershed in the foreseeable future.

c. Contact Recreation

Saginaw Bay is used extensively for many types of contact recreation including swimming, water skiing, and pleasure boating.

Public boating access is provided at 16 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). Future trends in boating will see continued increases in state boat registrations that will average approximately 4% per year. Furthermore, the success of the walleye sport fishery in Saginaw Bay has created an overwhelming demand for boat access facilities that will likely continue to increase the pressures for more access as the fishery expands. Yet because of environmental considerations (primarily wetlands) the opportunities for development of new boating facilities are limited on Saginaw Bay. The MDNR's current position is to develop large boat launching sites at a limited number of locations. The MDNR has placed a high priority on expansion on the Saginaw River (targeting close to the mouth), and other facilities served by existing maintained channels. Harbor expansions are planned in the future for Port Austin, Sebewaing and East Tawas.

In addition to the public access sites, 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 and limited access.

Recreational boating on the Saginaw River is supported by six public launch ramps (Figure II-22), 11 commercial marinas, and several private access sites in Saginaw and Bay counties. 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.

3. Commercial Use

a. Overview

An abundance of fresh water for both manufacturing and transportation, and the quality of life aspects of water-related recreation, make the Saginaw Bay area a nationally significant center of commerce and business. The bay is a major source of water for a variety of uses including municipal drinking water, irrigation, cooling for electric power generation, and industrial process supplies.

b. Water Supply

1) Industrial

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.

The 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 1% of the water withdrawn. The first of the two remaining units employs a wet-tower discharge cooling system, which consumes approximately 13% 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 5% 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).

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.

2) Drinking Water

There are five municipal water supplies that draw water from Saginaw Bay: the Saginaw-Midland Water Supply System -- drawing water from off Whitestone Point; the Bay City Water Supply System -- drawing water from a point on the bay just west of the mouth of the Saginaw River; and the water supplies of Caseville, Port Austin and East Tawas. The Saginaw-Midland system serves a total of about 330,000 people and withdraws an average of 55 MGD throughout the year. The Bay City system serves approximately 80,000 people, withdrawing an average of 12 MGD.

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 rely primarily on groundwater for a drinking water supply. However, the City of Alma maintains a water intake on the Pine River upstream of St. Louis, and the Genessee County Water Supply System maintains an emergency withdrawal system on the Flint River at Flint. Some others use supplies from outside the watershed, such as the city of Detroit Municipal Water Supply System.

3) Irrigation

Irrigation withdrawals from either Saginaw Bay or the watershed are sporadic and are governed largely by the amount and timing of seasonal precipitation. The amount of water withdrawn 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.

A new project testing the effectiveness of subirrigation of agricultural land though underground tile systems has recently been implemented in Huron County. Water is withdrawn from Saginaw Bay in the vicinity of Mud Creek for this project.

c. Navigation

Saginaw Bay and the Saginaw River are important to domestic and international waterborne commerce. Although not deep water ports, the ports of Bay City and Saginaw are vital links for midwest agricultural and mining industries to other Great Lakes regional and international ports. 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.

The U.S. Army Corps of Engineers maintains several navigation projects in Saginaw Bay. There are six federal navigation projects in Saginaw Bay, other than the Saginaw River channel, which receive periodic maintenance dredging; Tawas Bay, Au Gres, 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 13.5 miles beyond the mouth of the Saginaw River to the Sixth Street turning basin in Saginaw, about 18 miles upstream. 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.

The primary foreign export commodities from Saginaw River terminals are wheat, sand, gravel, rock, and animal feeds. Foreign imported commodities are primarily potassic chemical fertilizers, iron ore and concentrates, and residual fuel oil. Canada is the most active foreign trading partner.

Domestic freight traffic in the Saginaw River is primarily inbound. The most prevalent domestic commodities received at Saginaw River terminals are limestone, coal and lignite, non-metallic minerals, and building cement. Only two domestic commodities were shipped from terminals in the Saginaw River; distillate fuel oil and gasoline. Local commercial shipping traffic is negligible.

d. Hydroelectric Power

A series of reservoirs on the Tittabawassee River and its tributaries are used for power generation at Secord, Smallwood, Edenville and Sanford by the Wolverine Power Company. There are also registered dams for hydropower at Beaverton on the Tobacco River, St. Louis Municipal Dam on the Pine River, and Holloway Dam on the Flint River. The Cass River at Caro was dammed in the past for hydroelectric power, and though these dams are no longer operational, they are still in place.

These projects may impact the river resource and the watershed by affecting river flow, water quality, and fish passage. Specific impacts can include fluctuations in discharge, water temperature, and water levels; increased rates of evapotranspiration, sedimentation and nutrient loading; loss or fragmentation of fisheries and wildlife habitat; fish entrainment; impeding fish passage; and, altered recreational opportunities.

e. Waste Disposal

Saginaw Bay is also used for disposal of municipal and industrial wastes, with most of this waste stream originating in the Saginaw River watershed. Of the 273 active industrial and municipal dischargers in the Saginaw Bay drainage basin, only 57 (21%) are found outside of the Saginaw River watershed. The east coastal drainage basin has 23 dischargers, 9 industrial and 14 municipal. The west coastal drainage basin has 25 industrial and 9 municipal dischargers. Of these 57 discharges, only three are major dischargers.

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 157 industrial dischargers on the Saginaw River and its tributaries, including 9 major dischargers. These 157 facilities are concentrated in the industrial centers of Flint, Midland, Saginaw and Bay City. The basin also contains 59 municipal wastewater treatment facilities, 17 of which are considered major dischargers.

f. Commercial Fishing

Commercial fishing has been established as a prominent Saginaw Bay industry since the 1830s. Historically, the bay has provided a productive commercial fishery, but stocks have generally declined since the early part of the twentieth century (Figure II-19). Hile and Buettner (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 1885-1993 was slightly less than 1.5 million pounds in 1974 and 1975. Present commercial fish production remains below historic levels and, with the exception of significantly increasing whitefish catches, pursues a few generally low-value species with a substantially reduced effort.

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. The commercial season on lake trout was closed in Lake Huron in 1967. Although lake trout are no longer a commercial species in the bay, they commonly occur in the outer bay. The commercial walleye fishery was once the staple of the bay and the second largest walleye fishery of the Great Lakes, surpassed only by that of Lake Erie. Though the commercial walleye fishery once reached 2 million pounds, it collapsed in the late 1940s and was closed in 1970 to protect the remnant broodstock (Keller et al., 1987). Although walleye are once again abundant in the bay, they remain illegal for commercial harvest. Only 75,000 pounds of yellow perch were harvested in 1993, well below the historical average commercial catch of 465,000 pounds. By the early 1970s, 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, began to dominate other species taken commercially from Saginaw Bay (Table 18).

This trend to low value species began to reverse in the 1980s as lake whitefish catches started to increase. Hile and Buettner (1958) indicated that the peak year for commercial whitefish harvest in Saginaw Bay was 1932, with a total catch of 2.2 million pounds. The lowest annual catch on record for the period 1885-1993 was slightly less than 1,000 pounds during the years 1955 to 1958. By 1985 the whitefish harvest had increased to over 100,000 pounds, and in 1993 the whitefish harvest had risen to nearly 800,000 pounds (Table 18). Were it not for strict regulations on the harvest of whitefish in outer Saginaw Bay, the current whitefish harvest would approach the historical high harvest. This, coupled with a decrease in the harvest of carp due to fish tissue contaminant concerns, has reversed the trend to low value species.

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), contamination of the ecosystem with toxic chemicals (Hendrix and Yocum, 1984), and increasing regulation of the commercial fishery.

Despite the decline, commercial fishing remains an important element of the regional economy. In 1993, 25 licensed commercial fishing operations harvested approximately 1.6 million pounds of fish from Saginaw Bay. Included in this catch were whitefish (792,000 pounds), catfish (386,000 pounds), carp (84,000 pounds), and yellow perch (75,000 pounds). 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. Conflicts between sport and commercial fishers over fish stock allocations and fishing space, will probably be settled in favor of the recreational fishery. The MDNR is continuing to attempt to phase out the commercial harvest of yellow perch and to seasonally restrict commercial activity in high use recreational fishing areas. Sullivan et al. (1981) have suggested that further reductions in phosphorus loading to the bay could result in a decline in commercial harvest by reducing the productivity of the bay. However, others point out that other factors such as improved spawning habitat and a better forage base may contribute to an expanded fishery. Recent colonization of the bay by zebra mussels and white perch may also affect the size and composition of the fish community by potentially altering the food web.

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, fishing bans, and loss of commercial markets, testify to the potential for adverse effects from toxic contamination on the commercial fishery.

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) and was closed to commercial fishing in 1929.

Table II-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.

Table 8. State Game and Wildlife Areas on Saginaw Bay.

State Game or Wildlife Area and County	Date Project Started	Acreage Presently Owned by State
Wigwam Bay Arenac County	1966	2,975
Nayanquing Point Bay County	1943	1,401
Tobico Marsh Bay County	1955	1,848
Quanicassee Bay and Tuscola Counties	1950	218[1]
Fish Point Tuscola County	1950	3,200
Wildfowl Bay Huron County	1950	1,400[1]
Total Acreage		11,042

[1] Fluctuates with Saginaw Bay water levels.

Table 74. Threatened and endangered species and communities and global and state ranking by major basin in the Saginaw Bay Watershed

NAME	GLOBAL AND STATE RANK	Count
Western Coastal Basin		
Great Blue Heron Rookery	U/SU	5
Sistrurus catenatus catenatus	G3G4T3T4/S3S	3
Dendroica kirtlandii	G1/S1	2
Appalacachia arcana	G1G3/S2S3	1
Great Lakes Marsh	G2/S2	3
Interdunal Wetland	G2?/S2	1
Lakeplain Wet Prairie	G2?/S2	1
Oak Barrens	G2?/S2	1
Bog	G3/S3	1
Cirsium hillii	G3/S3	2
Cirsium pitcheri	G3/S3	2
Cypripedium arictinum	G3/S3	1
Dry Northern Forest	G3?/S3?	1
Merolonche dolli	G3/S2S3	1
Clemmys insculpta	G4/S3	1
Haliaeetus leucocephalus	G4/S3	8
Mesodon sayanus	G4G5/SU	1
Opuntia fragilis	G4G5/S1	1
Rallus elegans	G4Q/S1	1
Beckmannia Syzigachne	G5/S1	1
Dalibarda repens	G5/S1S2	1
Dentaria maxima	G5Q/S1	1
Epilobium palustre	G5/S3	1
Gavia immer	G5/S3	9
Nycticorax nycticorax	G5/S2S3	1
Pandion haliaetus	G5/S3	2
Percina copelandi	G5/S1S2	5
Platanthera ciliaris	G5/S2	1

NAME	GLOBAL AND STATE RANK	Count
<u>Eastern Coastal Basin</u>		
Eragrostis pilosa	G4NE/SH	1
Great Blue Heron Rookery	U/SU	1
Lanius ludovicianus migrans	G3G4T3T4/S3S	1
Sistrurus catenatus catenatus	G3G4T3T5/S3S	3
Lakeplain Wet-mesic Prairie	G1?/S1	6
Great Lakes Marsh	G2/S2	3
Lakeplain Oak Openings	G2/?/S1	4
Lakeplain Wet Prairie	G2?/S2	7
Platanthera leucophaea	G2/S1	17
Simpsoniconcha ambigua	G2/S1	1
Trimerotropis huroniana	G2G3/S2S3	1
Acipenser fulvescens	G3/S2	1
Astragalus neglectus	G3G4/S2	1
Charadrius melodus	G3/S1	1
Cirsium pitcheri	G3/S3	1
Dysnomia triquetra	G3/S1	1
Papaipema silphii	G3G4/S1S2	1
Emergent Marsh	GU/S4	1
Fontigens nickliniana	GU/SU	2
Acella haldemani	G4G5/S4	1
Cacalia plantaginea	G4G5/S2	6
Cypripedium candidum	G4/S2	3
Gentiana flavida	G4/S1	1
Haliaeetus leucocephalus	G4/S3	1
Mesodon sayanus	G4G5/SU	1
Panax quinquefolius	G4/SU	1
Rallus elegans	G4Q/S1	1
Scirpus clintonii	G4/S4	1
Elaphe vulpina gloydi	G5T3/S2	2
Asclepias hirtella	G5/S1	9
Asclepias sullivantii	G5/S1	1
Ictiobus niger	G5/S3	1

NAME	GLOBAL AND STATE RANK	Count
Nycticorax nycticorax	G5/S2S3	1
Percinaa copelandi	G5/S5S2	3
Percina shumardi	G5/S1	1
Pycnanthemum vertiuillatum	G5/S1S2	2
Silene virginica	G5/S1	1
Sterna forsteri	G5/S2	2
Sterna hirundo	G5/S2	3
Woodsia obtusa	G5/S1S2	1

NAME	GLOBAL AND STATE RANK	Count
Tittabawassee River		
Agalinis skinneriana	G3/S1	1
Aristida longespica	G5/S2	1
Carex haydenii	G5/SH	1
Carex seorsa	G4/S2	1
Champion tree	U/U	1
Clemmys insculpta	G4/S3	4
Dry-Mesic Northern Forest	G4/S4	1
Dysnomia triquetra	G3/S1	2
Eleocharis engelmannii	G5/S2S3	1
Gavia immer	G5/S3	3
Great Blue Heron Rookery	U/SU	2
Haliaeetus leucocephalus	G4/S3	1
Mesic Southern Forest	G3?/S3	1
Microtus pinetorum	G5/S3S4	1
Notropis anogenus	G3/S3	1
Rudbeckia sullivantii	G3Q/S3	1
Sistrurus catenatus catenatus	G3G4T3T4/S3S	1

NAME	GLOBAL AND STATE RANK	Count
Chippewa River		
Armoracia lacustris	G4?/S2	1
Astragalus neglectus	G3G4/S2	1
Beckmannia syzigachne	G5/S1	1
Bog	G3/S3	1
Calypso bulbosa	G5/S2	1
Carex scorsa	G4/S2	1
Champion Tree	U/U	1
Clemmys insculpta	G4/S3	7
Cypripedium arietinum	G3/S3	3
Diarrhena americana	G5/S1S2	1
Dysnomia triquetra	G3/S1	1
Gavia immer	G5/S3	5
Great Blue Heron Rookery	U/SU	3
Haliaeetus Leucocephalus	G4/S3	2
Isotria verticillata	G5/S2S3	2
Jeffersonia diphylla	G5/S3	1
Lithospermum latifolium	G3G5/S2	2
Microtus pinetorium	G5/S3S4	1
Notropis anogenus	G3/S3	1
Panax quinquefolius	G4/S2	2
Pandion haliaetus	G5/S3	2
Plantago cordata	G3/S1	1
Platanthera leucophaea	G2/S1	1
Prunus alleghaniensis var davisii	G3T2Q/S3	1
Rallus elegans	G4Q/S1	1
Rich Conifer Swamp	G4/S4	1
Rudebeckia sullivantii	G3Q/S3	1
Sisyrinchium strictum	G2G3/S2	1
Terrapene carolina carolina	G5T5/S3	1

NAME	GLOBAL AND STATE RANK	Count
<u>Shiawassee River</u>		
Angelica venenosa	G5/S3	1
Calephelis mutica	G4/S2S3	1
Carex richardsonii	G4/S3S4	1
Clemmys guttata	G5/S3	4
Cypripedium candidum	G4/S2	5
Elaphe vulpina gloydi	G5T3/S2	3
Great Blue Heron Rookery	U/SU	3
Haliaeetus leucocephalus	G4/S3	2
Hydrastis canadensis	G4/S2	2
Intermittent Wetland	G2/S2	1
Isotria verticillata	G5/S2S3	2
Jeffersonia diphylla	G5/S3	4
Microtus pinetorum	G5/S3S4	1
Muhlenbergia richardsonis	G5/S2	2
Myotis sodalis	G2/S1	1
Notropis texanus	G5/S1	2
Oarisma poweshiek	G2G3/S1S2	1
Plantago cordata	G3/S1	1
Poa paludigena	G3/S2	1
Potamogeton vaseyi	G4/SH	1
Prairie fen	G3/S3	3
Sistrurus catenatus catenatus	G3G4T3T4/S3S	6
Tradescantia virginiana	G5/S2	1
Trillium nivale	G4/S1S2	1

NAME	GLOBAL AND STATE RANK	Count
<u>Flint River</u>		
Astragalus neglectus	G3G4/S2	2
Bog	G3/S3	2
Calephelis mutica	G4/S2S3	1
Carex trichocarpa	G4/S2	1
Clemmys guttata	G5/S3	1
Cypripedium candidum	G4/S2	2
Dalea purpurea	G5/SX	1
Diarrhena americana	G5/S1S2	1
Dry-Mesic Southern Forest	G4/S3?	1
Elaphe vulpina gloydi	G5T3/S2	1
Gentiana flavida	G4/S1	1
Great Blue Heron Rookery	U/SU	3
Helianthus hirsutus	G5/S3	1
Isotria verticillata	G5/S2S3	1
Jeffersonia diphylla	G5/S3	2
Linum sulcatum	G5/S2S3	2
Oarisma poweshcik	G2G3/S1S2	2
Oecanthus laricis	G1G3/S2S3	1
Panax quinquefolius	G4/S2	1
Panicum microcarpon	G5T5/S2	1
Platanthera leucophaea	G2/S1	1
Polemonium reptans	G5/S2	1
Prairie fen	G3/S3	5
Rudbeckia sullivantii	G3Q/S3	1
Scirpus torreyi	G5?/S2	1
Southern Wet Meadow	G3?/S3?	1
Tyto alba	G5/S1	1

NAME	GLOBAL AND STATE RANK	Count
Cass River		
Astragalus neglectus	G3G4/S2	1
Carunculina glans	G1G2/S1	1
Chlidonias niger	G4/S3	1
Clemmys guttata	G5/S3	1
Clemmys insculpta	G4/S3	1
Elaphe vulpina gloydi	G5T3/S2	1
Gallinula chloropus	G5/S3	1
Great Blue Heron Rookery	U/SU	5
Panax quinquefolius	G4/S2	3
Percina copelandi	G5/S1S2	1
Percina shumardi	G5/S1	1
Southern Wet Meadow	G3?/S3?	1

Appendix 1 Global and State Ranks

Global Ranks

G1 =	critically imperiled globally because of extreme rarity (5 or fewer occurrences range-wide or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2 =	imperiled globally because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extinction throughout its range.
G3 =	either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g. a single western state, a physiographic region in the East) or because of other factors(s) making it vulnerable to extinction throughout its range; in terms of occurrences, in the range of 21 to 100.
G4 =	apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery.
G5 =	demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GH =	of historical occurrence throughout its range, i.e. formerly part of the established biota, with the expectation that it may be rediscovered (e.g. Bachman's Warbler).
GU =	possibly in peril range-wide, but status uncertain; need more information.
GX =	believed to be extinct throughout its range (e.g. Passenger Pigeon) with virtually no likelihood that it will be rediscovered.

STATE RANKS

S1 =	critically imperiled in the state because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extirpation in the state.
S2 =	imperiled in state because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor(s) making it very vulnerable to extirpation from the state.
S3 =	rare or uncommon in state (on the order of 21 to 100 occurrences).
S4 =	apparently secure in state, with many occurrences.
S5 =	demonstrably secure in state and essentially ineradicable under present conditions.
SA =	accidental in state, including species (usually birds or butterflies) recorded once or twice or only at very great intervals, hundreds or even thousands of miles outside their usual range.
SE =	an exotic established in the state; may be native elsewhere in North America (e.g. house finch or catalpa in eastern states).
SH =	of historical occurrence in state and suspected to be still extant.
SN =	regularly occurring, usually migratory and typically nonbreeding species
SR =	reported from state, but without persuasive documentation which would provide a basis for either accepting or rejecting the report.
SRF=	reported falsely (in error) from state but this error persisting in the literature.
SU =	possibly in peril in state, but status uncertain; need more information.
SX =	apparently extirpated from state.

Table 1. Land use, by category, for the entire state of Michigan (statewide), the 22 counties which comprise the Saginaw Bay watershed, the 42 Great Lakes coastal counties, and the five Saginaw Bay coastal counties, expressed as percentages of total land mass.

Land Use Category	Statewide	Saginaw Bay Watershed	Coastal Counties Statewide	Saginaw Bay Coastal Counties
Urban and Build-Up Land	6.26	8.17	5.39	4.3
Agricultural Land	29.33	45.65	22.21	57.2
Open Land	8.05	10.61	6.85	6.28
Upland Forest	37.19	19.09	43.23	15.31
Lowland Forest	11.59	10.3	13.77	12.28
Water Bodies	2.25	1.73	2.51	.88
Wetlands	5.2	4.44	5.80	3.72
Barren Land	.14	.01	.24	.03

Table 7-1

Total Acres of Land by Land Use Classification in Saginaw Bay Watershed Counties*

	Urban	Agriculture	Open	Forest	Wetlands	Other	Total Acres in County
Arenac	5,436	84,262	25,518	106,707	10,036	3,512	235,470
Bay	19,461	194,382	16,618	39,216	6,918	10,775	287,370
Clare	9,445	53,231	50,499	226,830	19,095	9,151	368,252
Genesee	93,223	168,858	68,819	57,665	7,177	19,850	415,592
Gladwin	7,745	67,698	43,629	175,233	28,863	7,064	330,233
Gratiot	6,470	277,602	19,061	49,253	9,309	4,086	365,782
Huron	9,443	439,071	14,608	53,517	16,355	4,414	537,408
Iosco	13,750	50,553	18,480	24,419	20,016	235,155	362,373
Isabella	9,926	217,346	36,219	86,152	13,025	7,076	369,744
Lapeer	19,190	242,506	56,318	75,396	19,847	10,874	424,132
Livingston	34,772	131,522	83,447	78,332	27,032	19,514	374,620
Mecosta	7,468	126,341	55,739	152,007	14,542	9,524	365,631
Midland	21,755	102,020	33,948	159,958	12,218	10,066	339,965
Montcalm	14,200	244,143	42,151	123,093	25,622	12,014	461,223
Oakland	195,206	86,410	122,906	84,387	34,838	56,972	580,719
Ogemaw	7,270	69,261	48,906	217,823	15,479	9,740	368,479
Osceola	7,575	106,045	62,694	163,897	18,929	7,618	366,757
Roscommon	10,554	4,447	15,018	260,784	38,645	41,709	371,158
Saginaw	56,622	334,714	19,140	91,411	5,375	14,902	522,165
Sanilac	14,127	481,318	35,182	52,336	26,270	7,803	617,035
Shiawassee	14,386	252,304	32,082	33,883	8,179	5,348	346,181
Tuscola	9,827	343,774	46,945	95,547	18,973	6,586	521,652
Total	587,850	4,077,807	947,927	2,407,850	396,743	513,753	8,931,941

*Core counties shaded, rounded to the nearest acre.
Source: Michigan Department of Natural Resources, Land and Water Management Division, Michigan Resource Information System: Land Use/Cover, 1978.

Table 7-2

1990 Rank of Michigan's Counties[1]
Livestock

County	Farms[2]	All Cattle	Milk Cows	All Hogs	HPLA[3]
Huron	6	1	2	9	4
Isabella		6	8		7
Saginaw	5				
Sanilac	2	2	1		
Tuscola					6

1. Rankings based on 1990 County estimates. Livestock rankings based on number of head. Crop rankings based on production. Corn rankings based on grain production.
2. Based on 1987 Census of Agriculture.
3. HPLA-Hens and Pullets of Laying Age.

Source: Michigan Agricultural Statistics; 1991, Michigan Department of Agriculture.

Table 7-3

1990 Rank of Michigan's Counties[1]
Crops

County	Corn	Soybeans	Wheat	Dry Beans	Oats	Potatoes	Barley
Arenac				8		9	
Bay				3		2	
Gratiot	9	5		4			
Huron	1		2	1	2		1
Isabella					10	6	
Mecosta						8	
Midland				9			
Montcalm				7		1	
Ogemaw							8
Saginaw	7*	2	4	5	9		
Sanilac	3	7	1	6	1		2
Shiawassee		4	5		4		
Tuscola	6	9	7	2	3	4	3

* Tied with another county.

Source: Michigan Agricultural Statistics; 1991, Michigan Department of Agriculture.

Table 6-8

Total Livestock in Saginaw Bay Watershed Counties: 1990*

	Cattle	Sheep/ Lambs	Hogs/ Pigs	Hens/ Pullets	Total
Huron	80,000	500	43,000	775,000	898,500
Tuscola	21,000	1,500	15,500	250,000	288,000
Isabella	33,000	2,000	18,500	225,000	278,500
Gratiot	31,500	1,100	21,000	52,000	105,600
Sanilac	70,000	1,100	14,500	5,000	90,600
Shiawassee	22,500	2,400	12,000	10,000	46,900
Lapeer	30,000	2,800	8,000	3,000	43,800
Montcalm	24,000	1,100	10,000	2,000	37,100
Genesee	15,000	1,100	14,500	2,000	32,600
Saginaw	14,500	2,900	8,500	6,000	31,900
Mecosta	18,000	1,900	7,500	1,500	28,900
Livingston	19,000	2,300	5,000	1,500	27,800
Osceola	19,000	1,100	3,000	1,500	24,600
Clare	10,500	1,600	8,000	N/A	20,100
Ogemaw	15,000	300	1,400	N/A	16,700
Arenac	8,000	150	5,000	2,500	15,650
Gladwin	9,500	1,300	2,700	1,500	15,000
Midland	7,500	400	5,300	1,000	14,200
Iosco	9,300	400	1,600	N/A	11,300
Oakland	5,000	1,500	1,500	1,500	9,500
Bay	5,500	250	1,500	1,500	8,750
Roscommon	500	50	100	N/A	650
Total	468,300	27,750	208,100	1,342,500	2,046,650

*Core counties shaded, ranked from highest to lowest.
**N/A = not applicable.
Source: Michigan Department of Agriculture, Michigan Agricultural Statistics, 1991.

TABLE 18
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REPORTED COMMERCIAL FISHERY HARVEST. REPORTED CATCH
(ROUND POUNDS) IN SAGINAW BAY (MH-4), BY SPECIES,
FOR THE YEARS 1972 TO 1979.

ST DISTRICT: MH-4

FISH SPECIES / YEAR	1972	1973	1974	1975	1976	1977	1978	1979	TOTAL
BOWFIN	114	10	744	2331	884	2076	390	565	7114
ALEWIFE	38	0	190	20	0	245	0	0	493
GIZZARD SHAD	0	0	35	439	5402	3213	17347	26864	53300
SMELT	20	20000	4000	0	16000	[illegible]	0	20000	60020
BULLHEAD	57425	39096	42872	39474	29968	20[illegible]	5352	3355	238114
CATFISH	253560	325427	272048	282815	378885	403752	433462	456640	2806589
BURBOT	0	0	0	0	0	0	0	225	225
WHITEBASS	363	193	1239	117	540	112	844	132	3540
SHEEPSHEAD	6386	103735	18993	15932	13413	8233	12809	13909	193410
GARFISH	0	0	0	0	0	0	0	124	124
WHITEFISH	26421	15029	16036	26994	28532	42383	40339	39323	235057
MENOMINEE	154	42	75	167	15	7987	20076	25117	53633
CHUB	0	0	0	0	0	0	0	585	585
SUCKER	90579	144724	110563	108608	124803	98407	131805	107684	917173
CARP	888296	765952	684062	629041	716004	787213	686723	654829	5812120
QUILLBACK	9102	9892	11776	16468	7492	8473	6802	13572	83577
BUFFALOFISH	0	227	8365	0	0	0	2620	0	11212
ROCK BASS	457	0	227	0	0	4	0	0	688
CRAPPIE	46437	56140	61941	85587	55575	26139	18850	7423	358092
YELLOW PERCH	326748	309018	229158	268929	322065	256937	164347	167613	2044815
---SUB TOTAL									
MH-4	1706100	1789485	1462324	1476922	1699578	1665746	1541766	1537960	12879881
-GRAND TOTAL									
	1706100	1789485	1462324	1476922	1699578	1665746	1541766	1537960	12879881

REPORTED COMMERCIAL FISHERY HARVEST. REPORTED CATCH
(ROUND POUNDS) IN SAGINAW BAY (MH-4), BY SPECIES,
FOR THE YEARS 1980 TO 1987.

ST DISTRICT: MH-4

FISH SPECIES	YEAR 1980	1981	1982	1983	1984	1985	1986	1987	TOTAL
BOWFIN	532	390	504	212	19	15	91	58	1821
ALEWIFE	0	150	1479	2956	2471	2630	2511	1336	13533
GIZZARD SHAD	0	0	0	84	3	0	0	0	87
SMELT	22000	20482	27023	0	14000	0	20000	33000	136505
MOONEYE	0	0	185	0	0	0	0	0	185
BULLHEAD	1768	2572	7632	7096	3331	5074	4154	1355	32982
CATFISH	492904	509352	669414	664075	515020	571062	586499	538208	4546534
BURBOT	159	208	328	184	486	935	88	432	2820
WHITE PERCH	0	0	0	19	269	178	314	983	1763
WHITEBASS	6	455	1725	8861	12389	17029	19763	15232	75460
SHEEPSHEAD	14042	15133	35137	20677	30026	43487	37840	39072	235414
GARFISH	373	282	309	80	38	50	0	0	1132
WHITEFISH	72609	65753	77167	89227	68245	104257	213588	321767	1012613
MENOMINEE	28725	31591	15895	31741	25318	18317	12883	11023	175493
CHUB	0	0	0	0	4238	0	0	0	4238
KOKANEE	0	0	0	15	0	0	0	0	15
SUCKER	129449	168532	141609	145641	136508	102210	126022	82219	1032190
CARP	562539	692396	726262	511149	551485	508808	850135	952930	5355704
QUILLBACK	59443	49058	80430	53546	73749	69733	55934	32378	474271
BUFFALOFISH	5451	261	1456	3353	4581	1062	323	1195	17682
ROCK BASS	322	0	682	19	567	1565	84	259	3498
CRAPPIE	7178	21591	11226	9172	5418	7416	11038	13831	86870
YELLOW PERCH	195075	185177	155244	136904	118806	79964	67792	99484	1038446
---SUB TOTAL---									
MH-4	1592575	1763383	1953707	1685011	1566967	1533792	2009059	2144762	14249256
-GRAND TOTAL---									
	1592575	1763383	1953707	1685011	1566967	1533792	2009059	2144762	14249256

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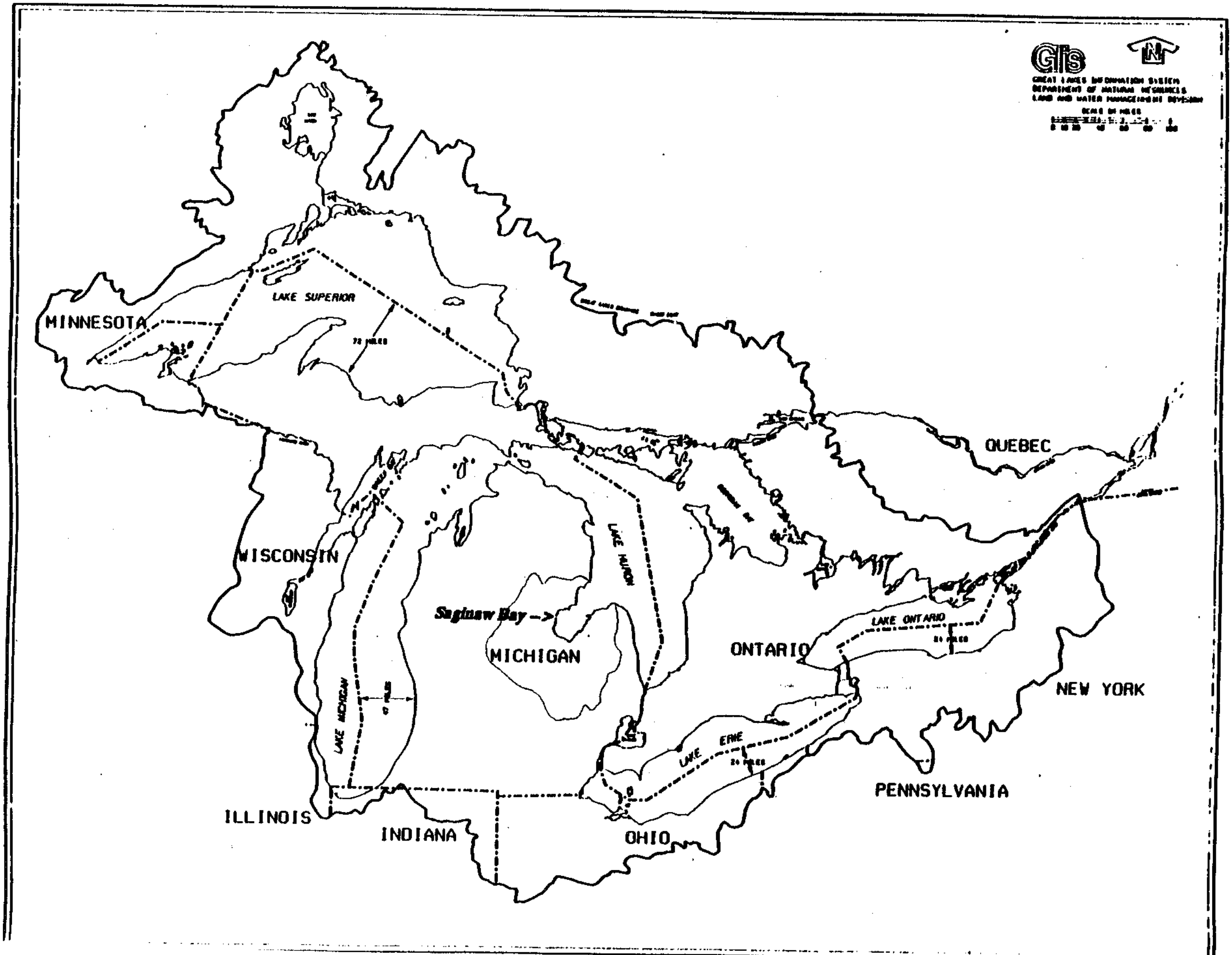
MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION INFO SYSTEM

REPORTED COMMERCIAL FISHERY HARVEST. REPORTED CATCH
(ROUND POUNDS) IN SAGINAW BAY (MH-4), BY SPECIES,
FOR THE YEARS 1988 TO 1993.

ST DISTRICT: MH-4

FISH SPECIES / YEAR	1988	1989	1990	1991	1992	1993	TOTAL
BOWFIN	939	6	4103	1600	0	0	6648
ALEWIFE	1115	1401	13981	1190	239	380	18306
GIZZARD SHAD	80	1978	0	3419	0	0	5477
SMELT	22950	12105	2898	15000	11499	10000	74452
BULLHEAD	2497	3325	5230	1964	888	344	14248
CATFISH	507523	659527	725528	662076	480553	386117	3421324
BURBOT	527	569	1104	1089	1208	3158	7655
WHITE PERCH	2678	17100	43748	15943	11291	3383	94143
WHITEBASS	6749	14562	31754	19104	36322	13447	121938
SHEEPSHEAD	23624	33743	48124	55711	41092	52350	254644
GARFISH	135	7	0	0	0	0	142
WHITEFISH	352990	436264	463523	553446	784341	792096	3382660
MENOMINEE	16926	14232	8186	4949	9373	6931	60597
CHUB	0	0	5	186	0	0	191
CHINOOK	0	5	0	0	0	0	5
RAINBOW	0	0	16	0	0	0	16
SUCKER	128571	132886	137765	164422	112711	83988	760343
CARP	667139	571708	479671	242751	123640	82501	2167410
QUILLBACK	30495	49490	48835	120232	110474	65232	424758
BUFFALOFISH	1324	10049	47400	0	0	0	58773
ROCK BASS	1043	735	1323	477	59	79	3716
CRAPPIE	10807	11459	5904	2875	3408	342	34795
YELLOW PERCH	88631	73576	91353	114911	102102	75010	545583
---SUB TOTAL---							
MH-4	1866743	2044727	2160451	1981345	1829200	1575358	11457824
-GRAND TOTAL-							
	1866743	2044727	2160451	1981345	1829200	1575358	11457824

Figure 1. Great Lakes drainage basin.



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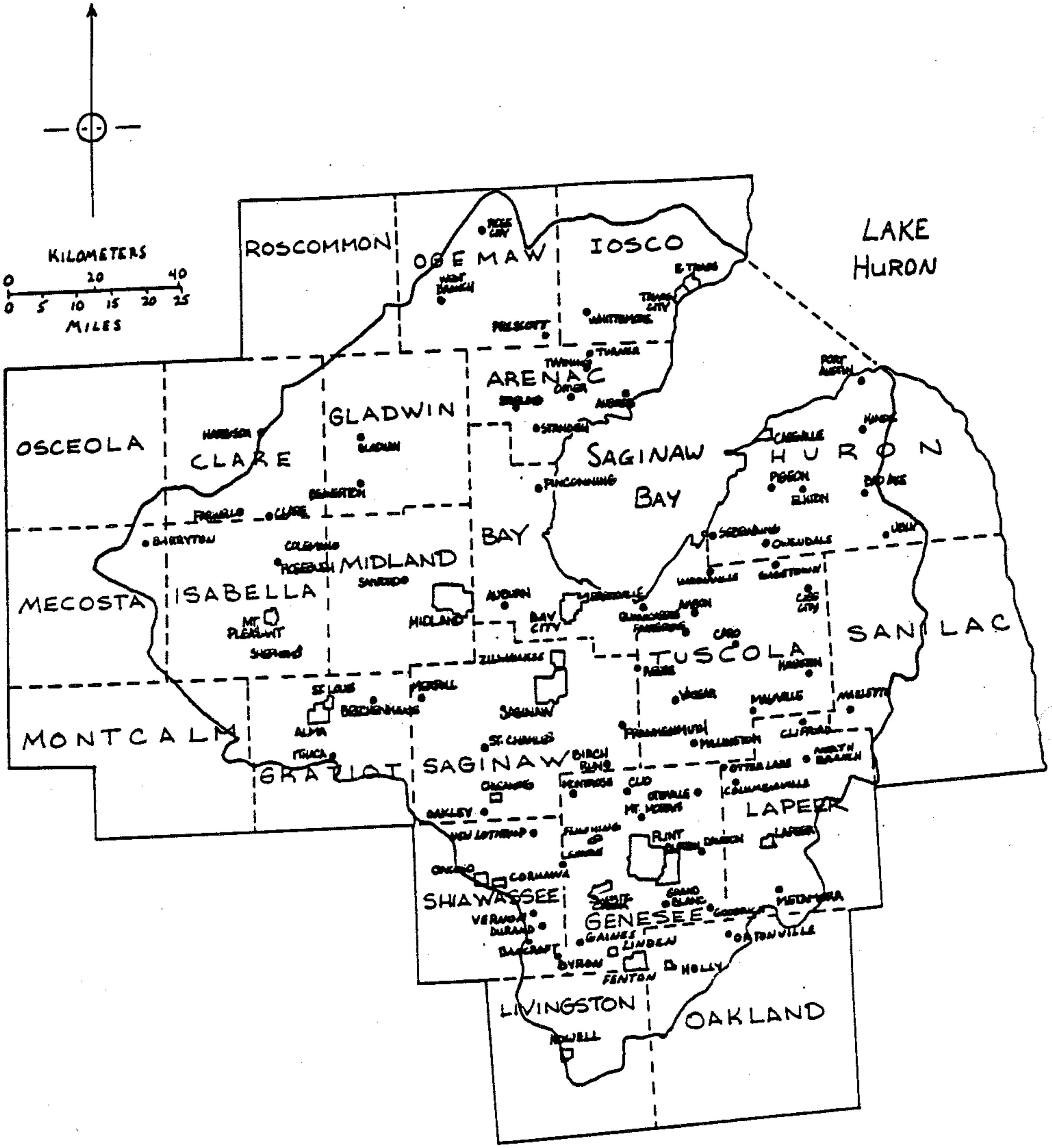


Figure II-2. Cities and villages located in the Saginaw Bay drainage basin.

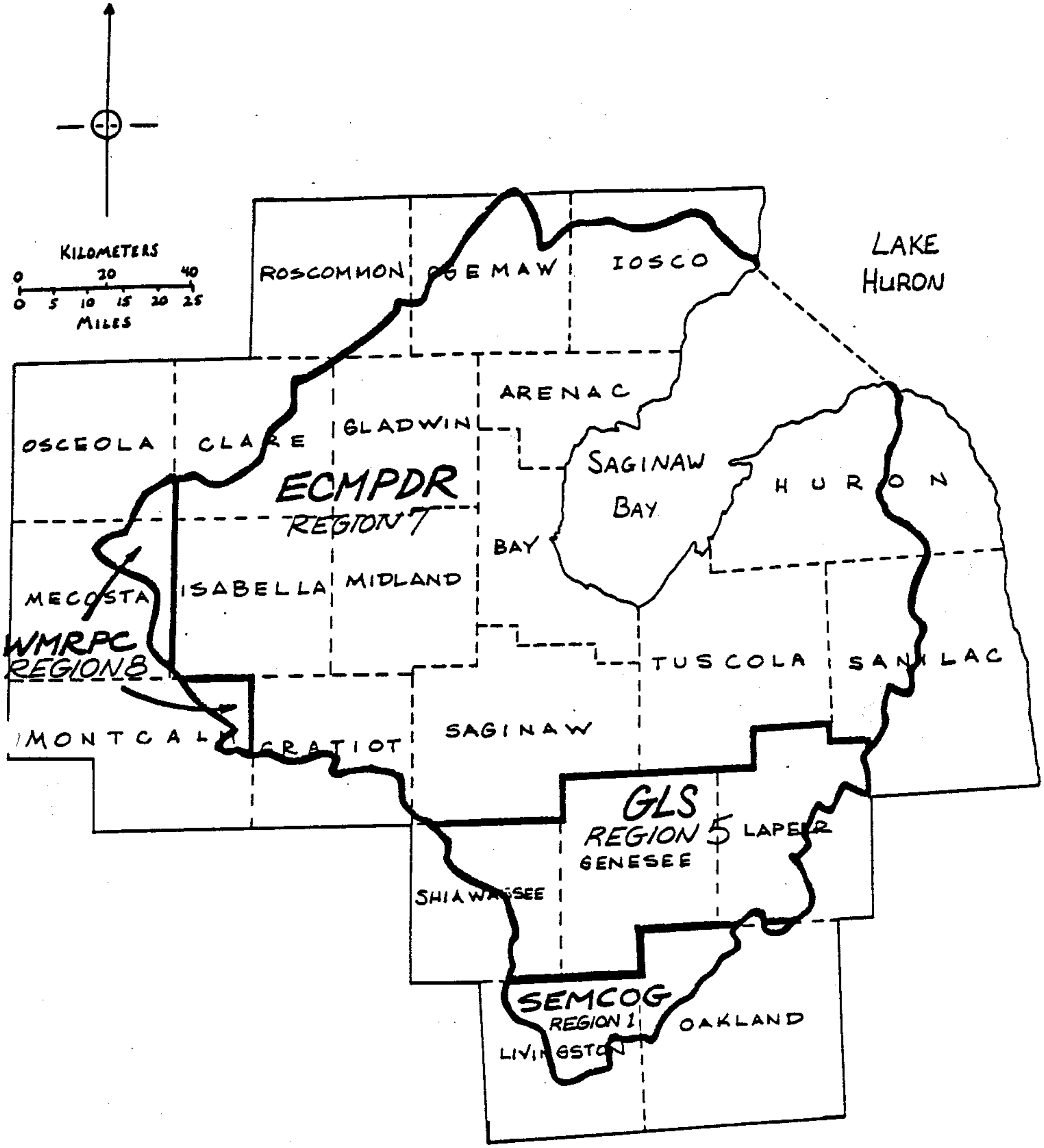


Figure II-3. Michigan regional planning agency service areas in the Saginaw Bay drainage basin.

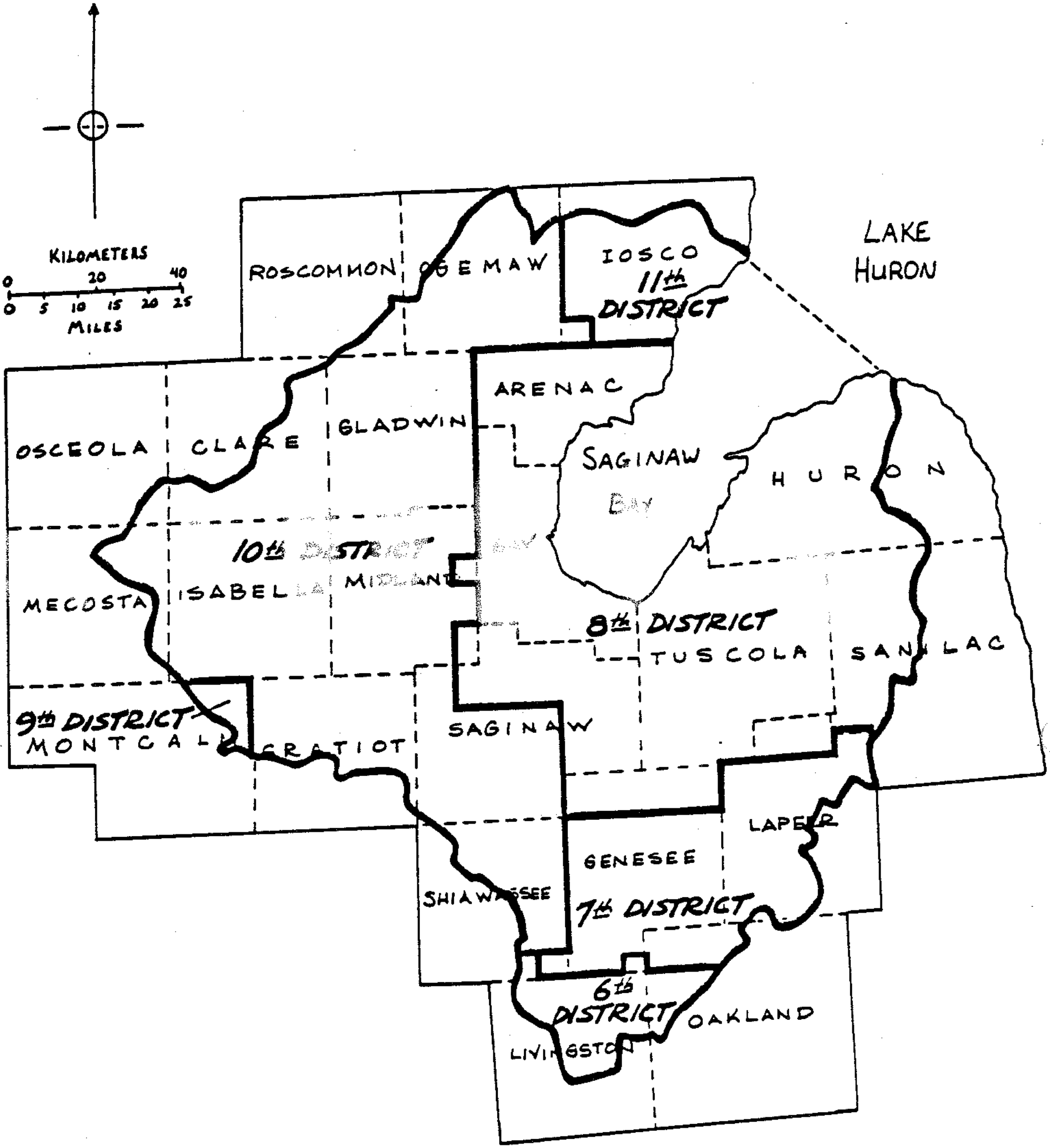


Figure II-4. United States congressional districts in the Saginaw Bay drainage basin.

Needs to be updated

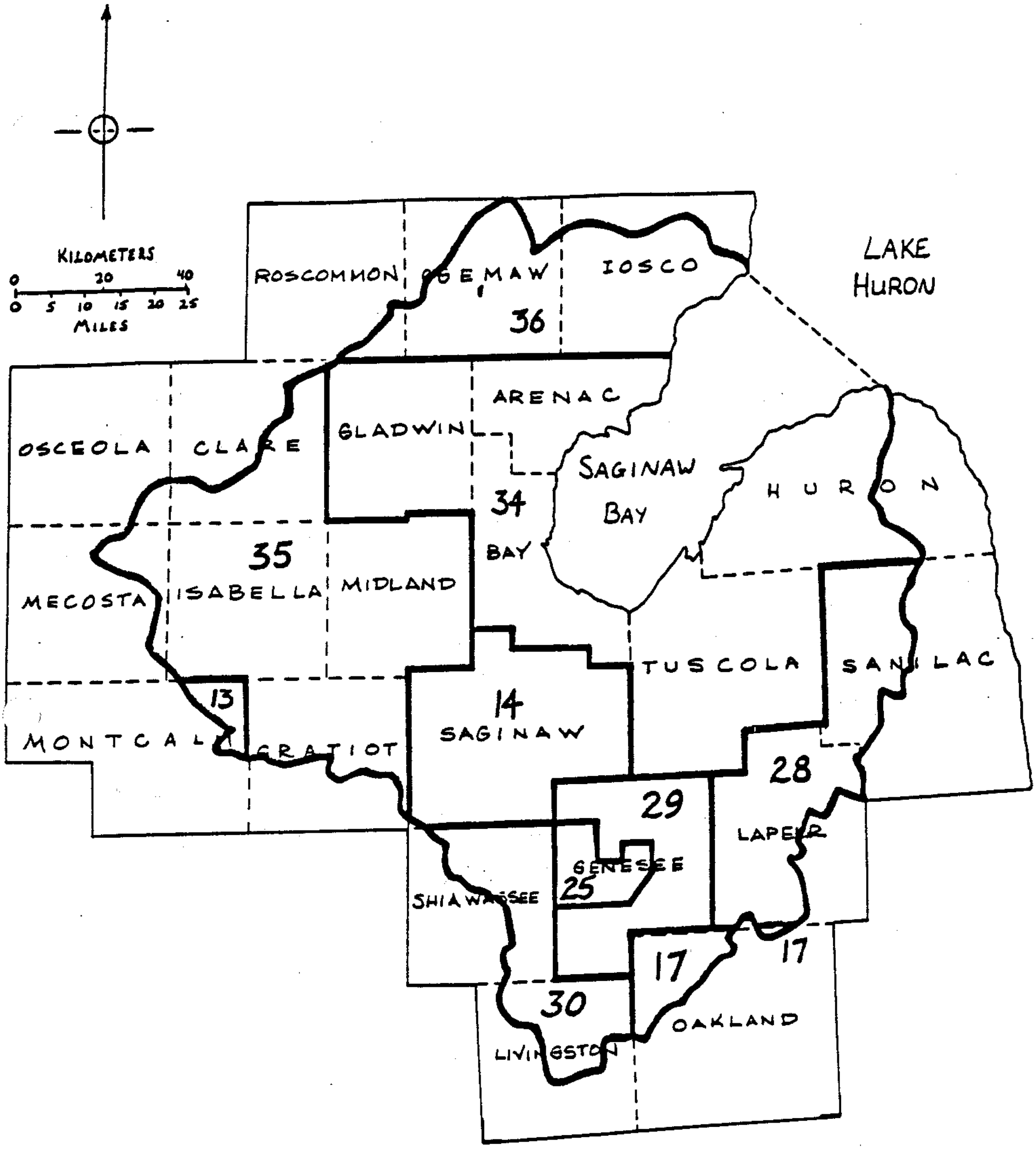


Figure II-5. State senate districts in the Saginaw Bay drainage basin.

Need to be updated

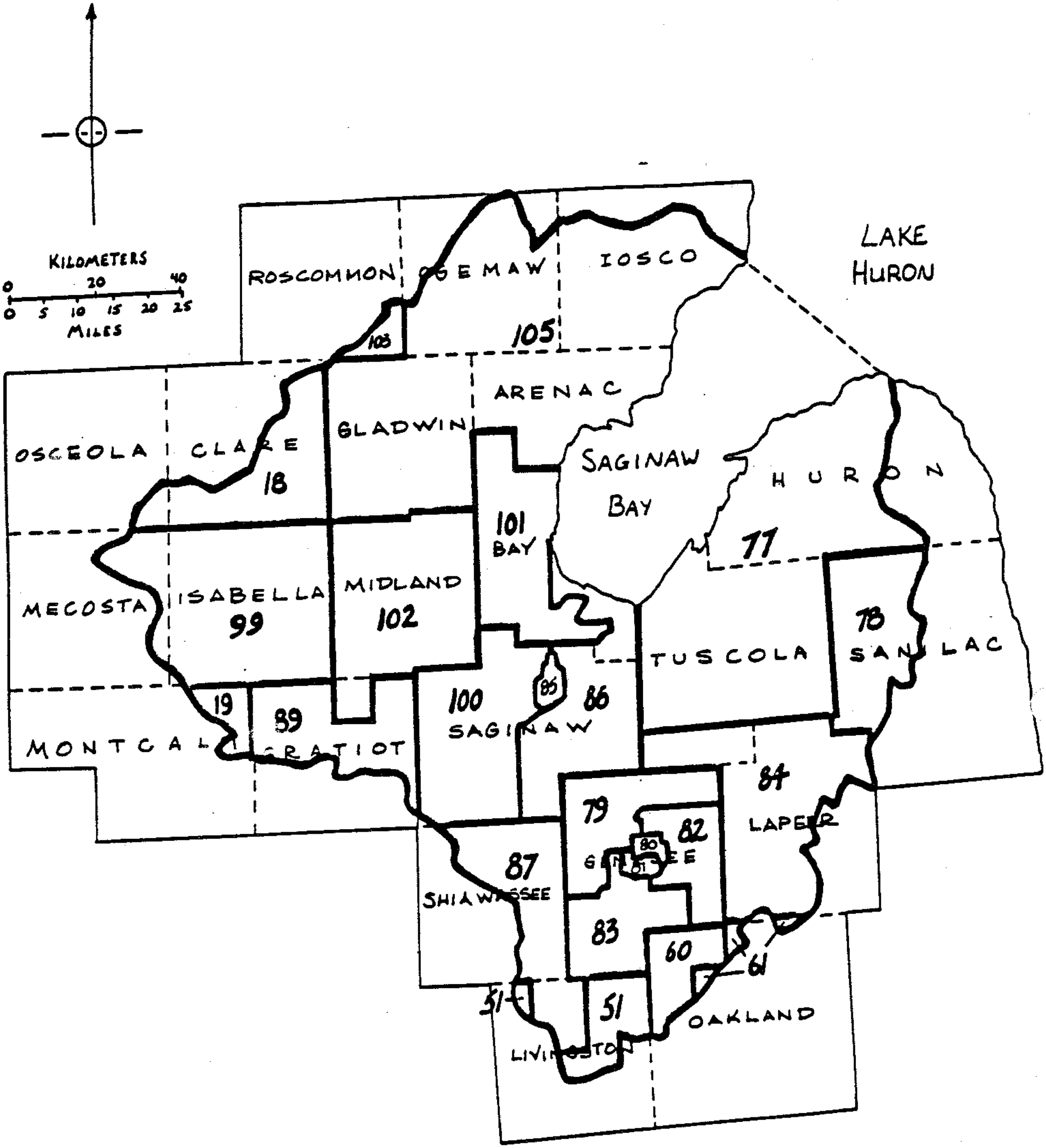


Figure II-6. State representative districts in the Saginaw Bay drainage basin.

Needs to be updated

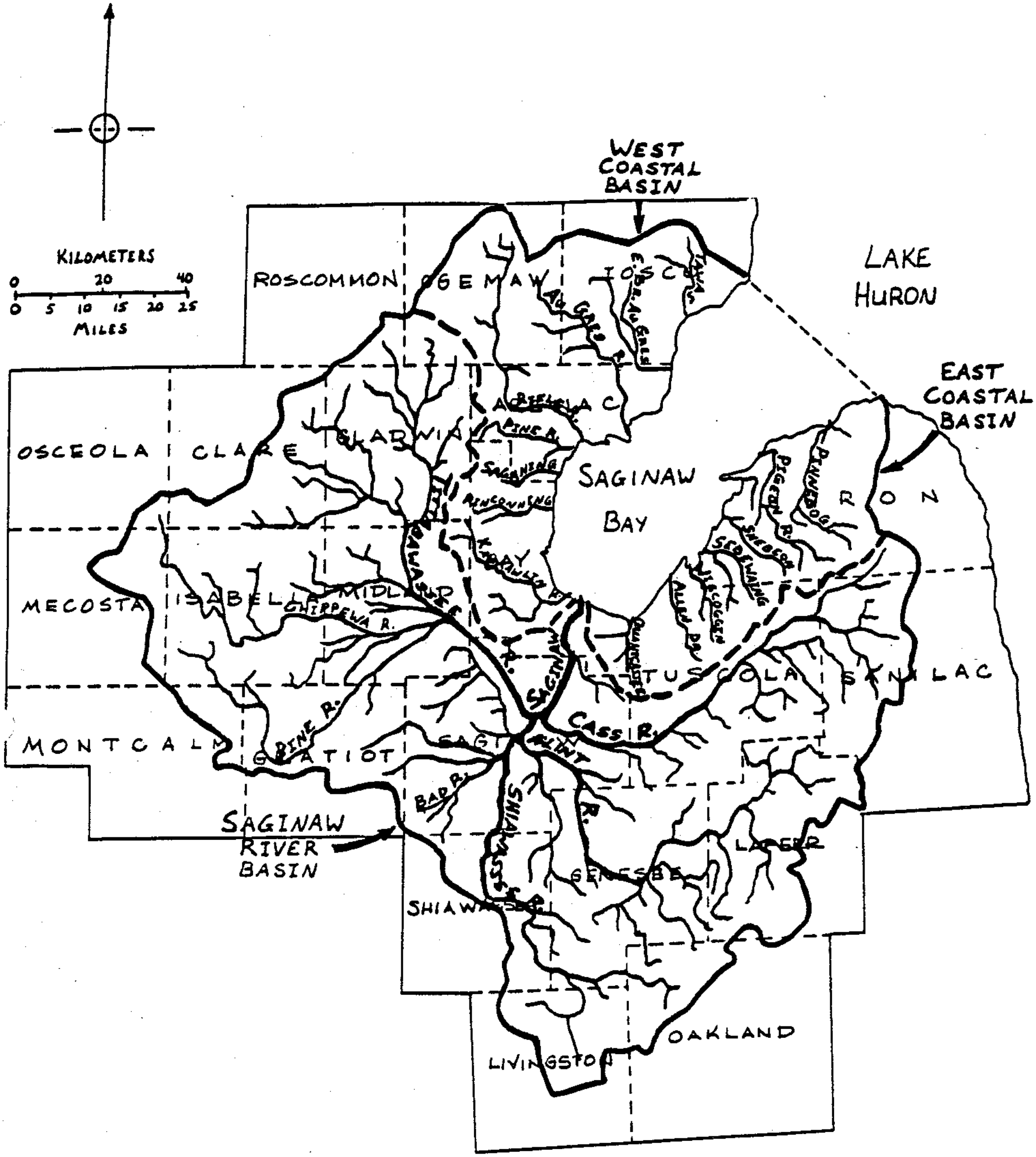


Figure II-7. Major tributaries to Saginaw Bay.

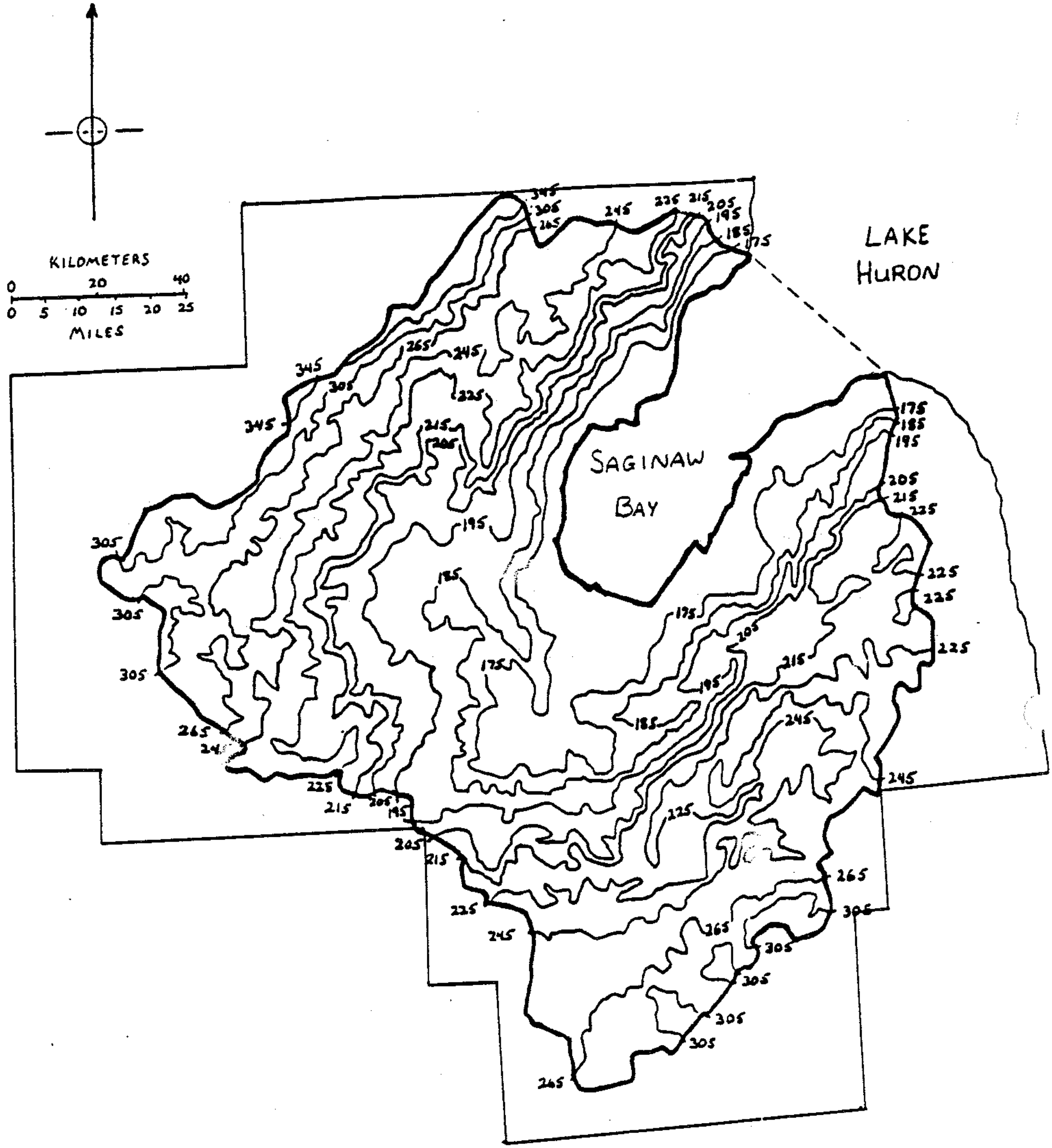


Figure II-12. Generalized contour (m) map of the Saginaw Bay basin.

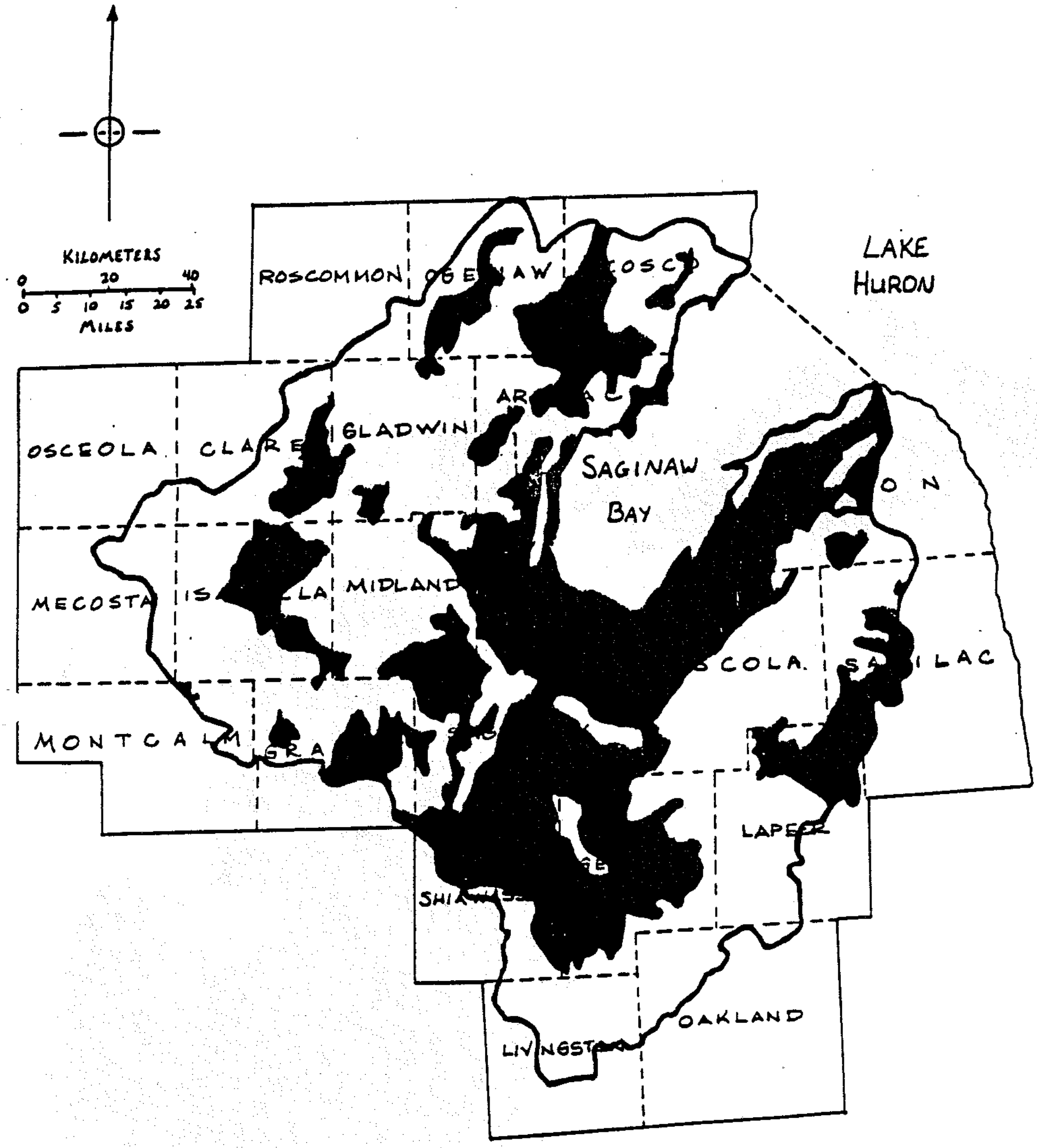
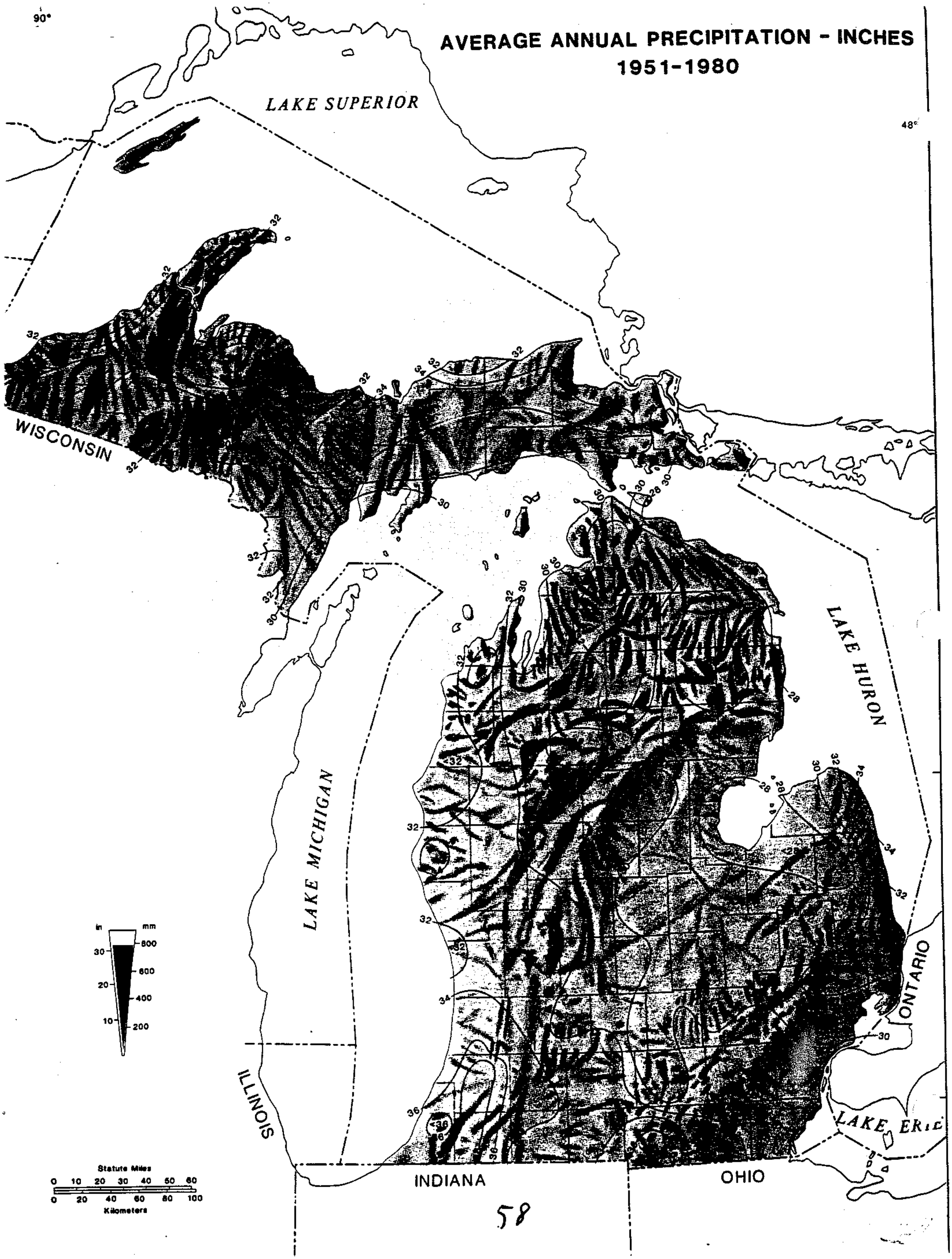


Figure II-14. Soil associations containing more than 13 percent clay in their surface layer (ECMPDR, 1987).

AVERAGE ANNUAL PRECIPITATION - INCHES
1951-1980



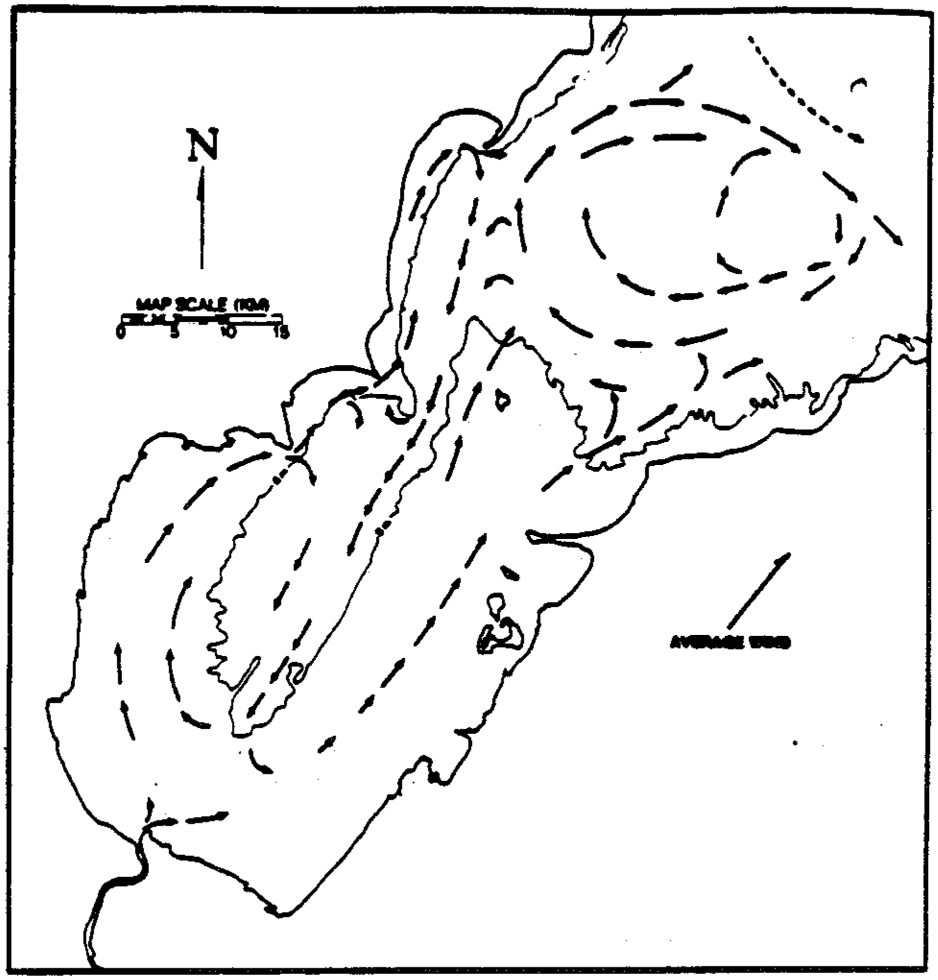


Figure II-9. Circulation pattern in Saginaw Bay for a southwest wind.

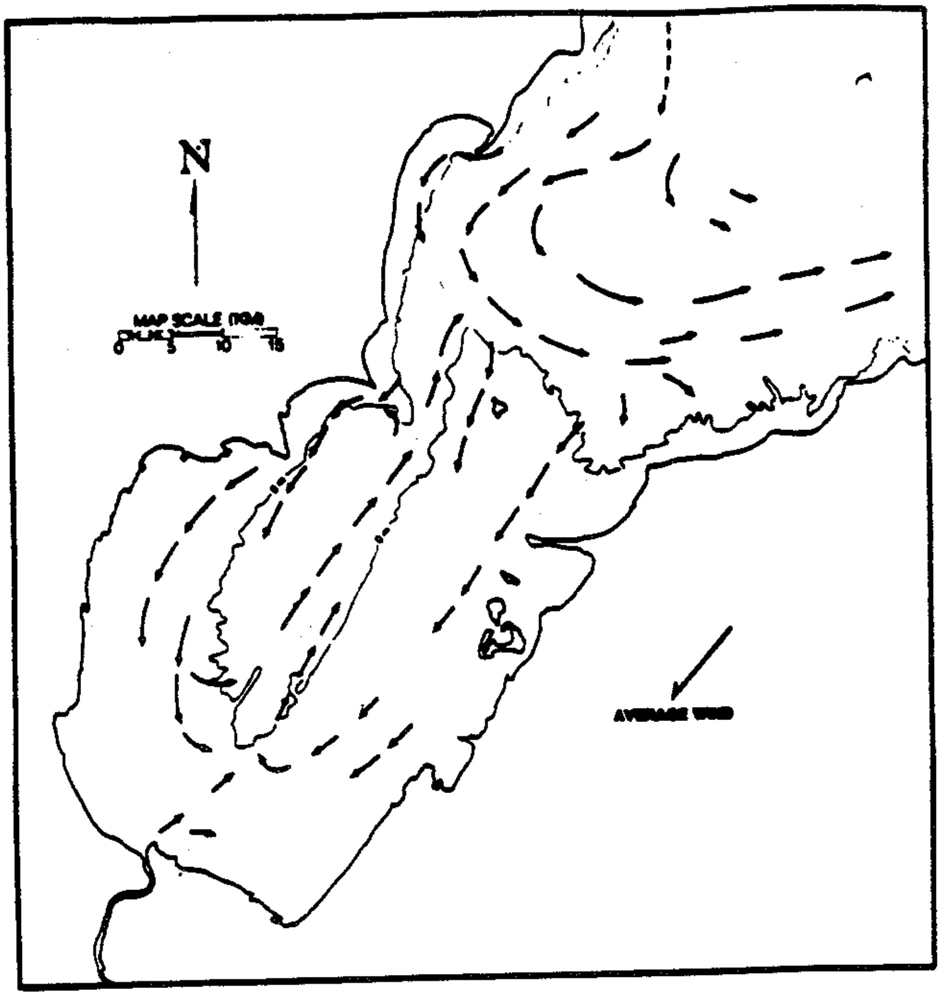


Figure II-10. Circulation pattern in Saginaw Bay for a northeast wind.

Figure 18. Floodprone areas of inner Saginaw Bay that are below the 100-year flood elevation.

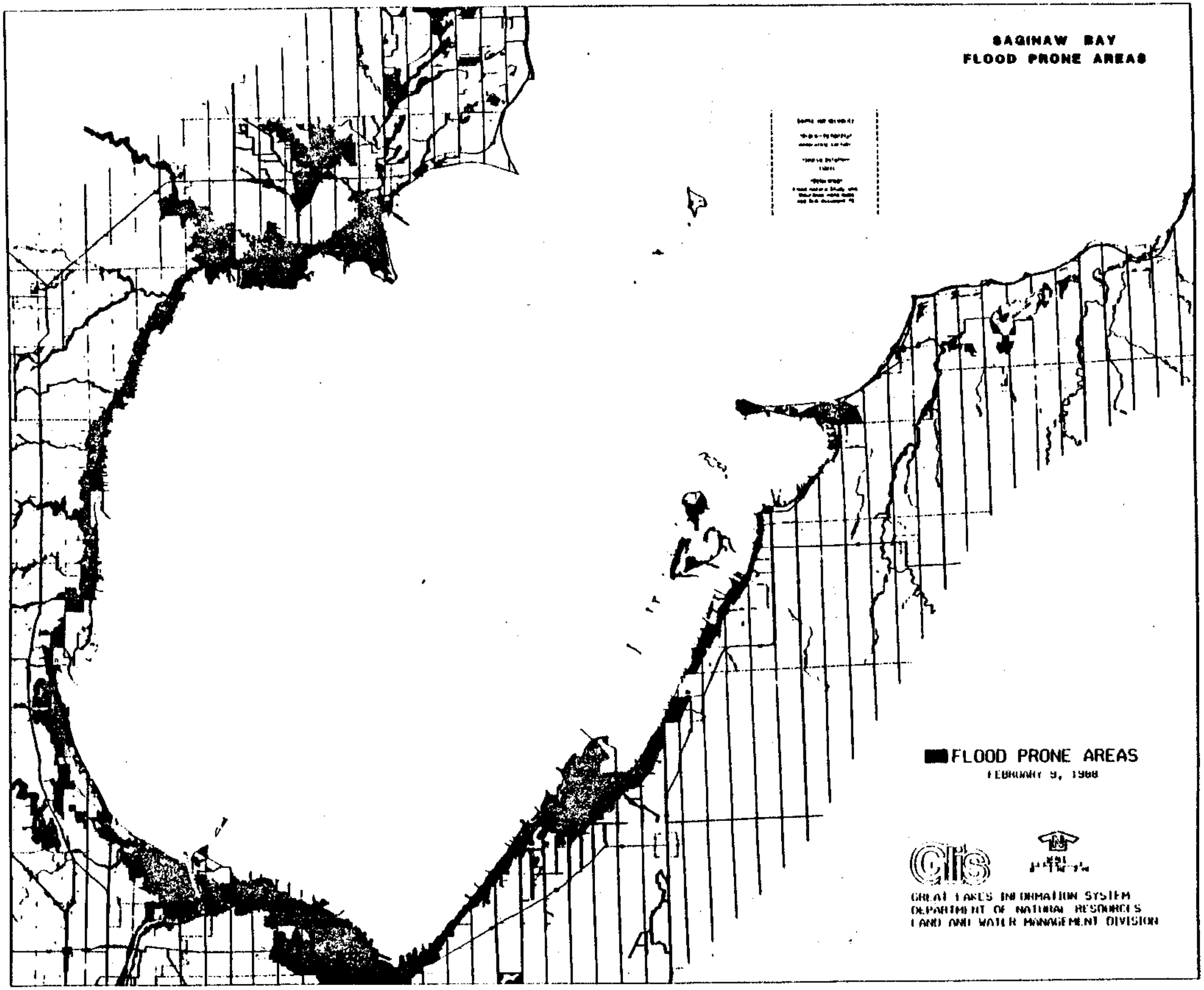
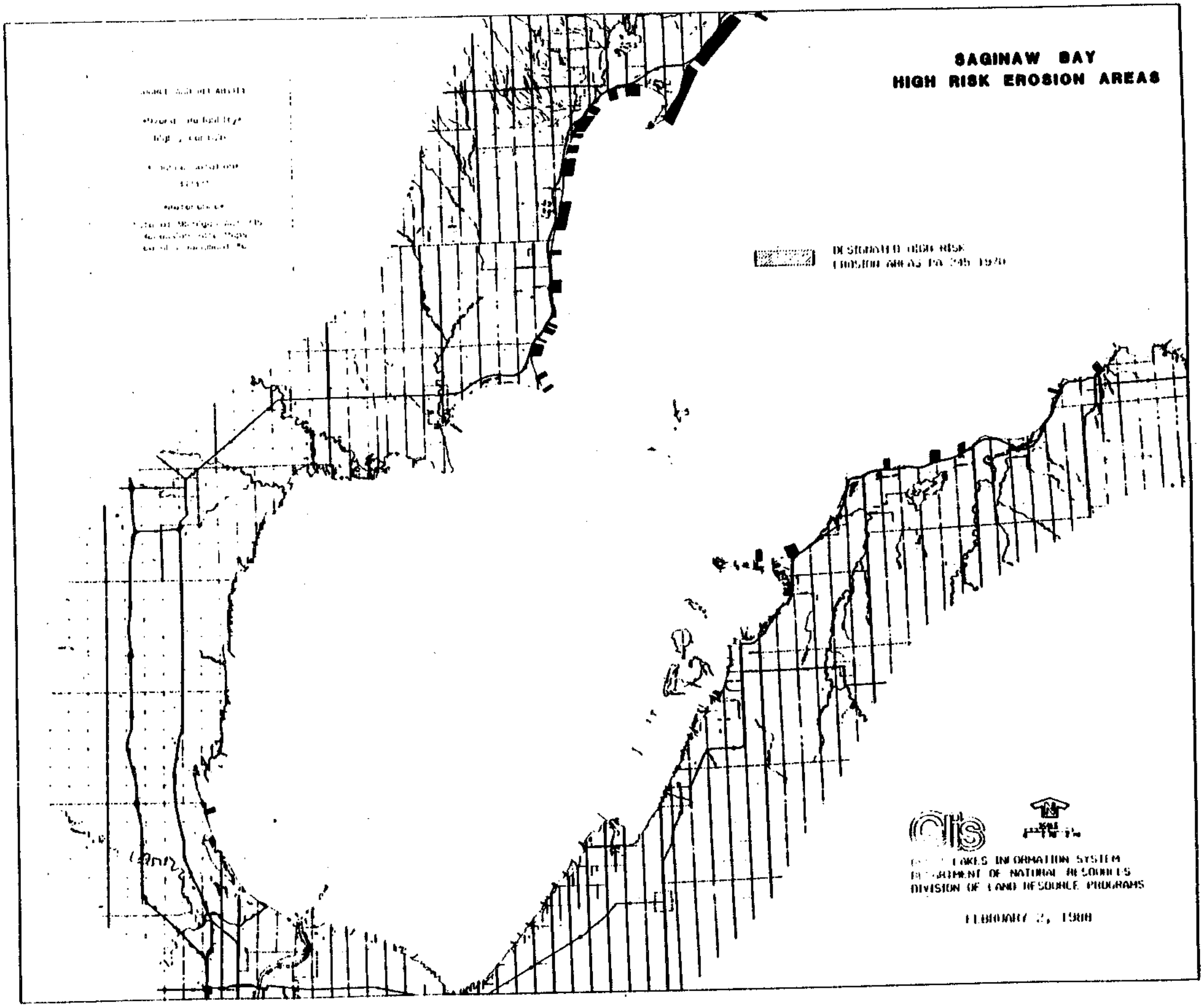
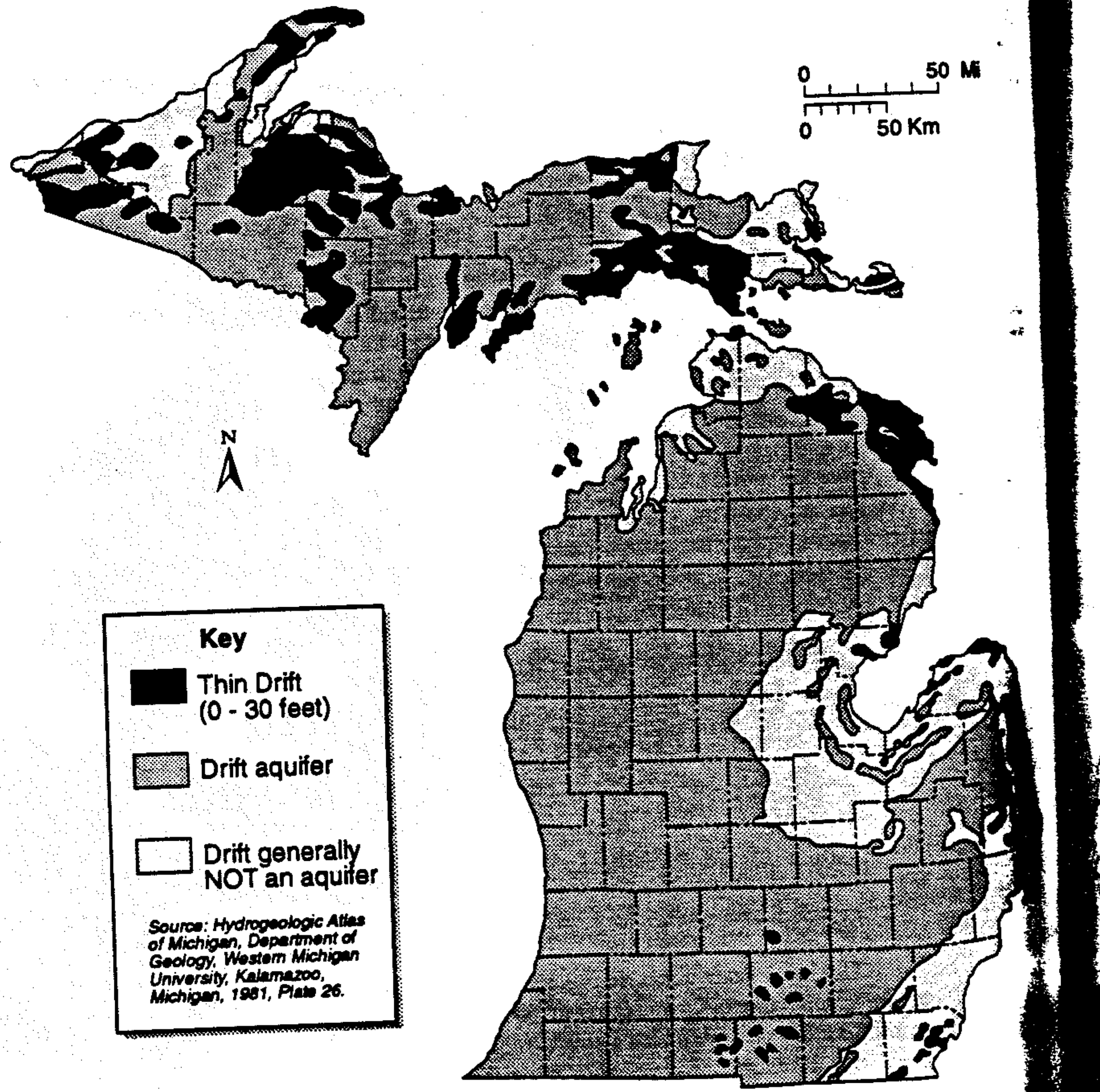


Figure 19. High risk erosion areas of the Saginaw Bay shoreline.





CONSERVATION GEM

Center for Remote Sensing, Michigan State University, East Lansing, Michigan 48824

Figure IV-1. Drift aquifers in Michigan.

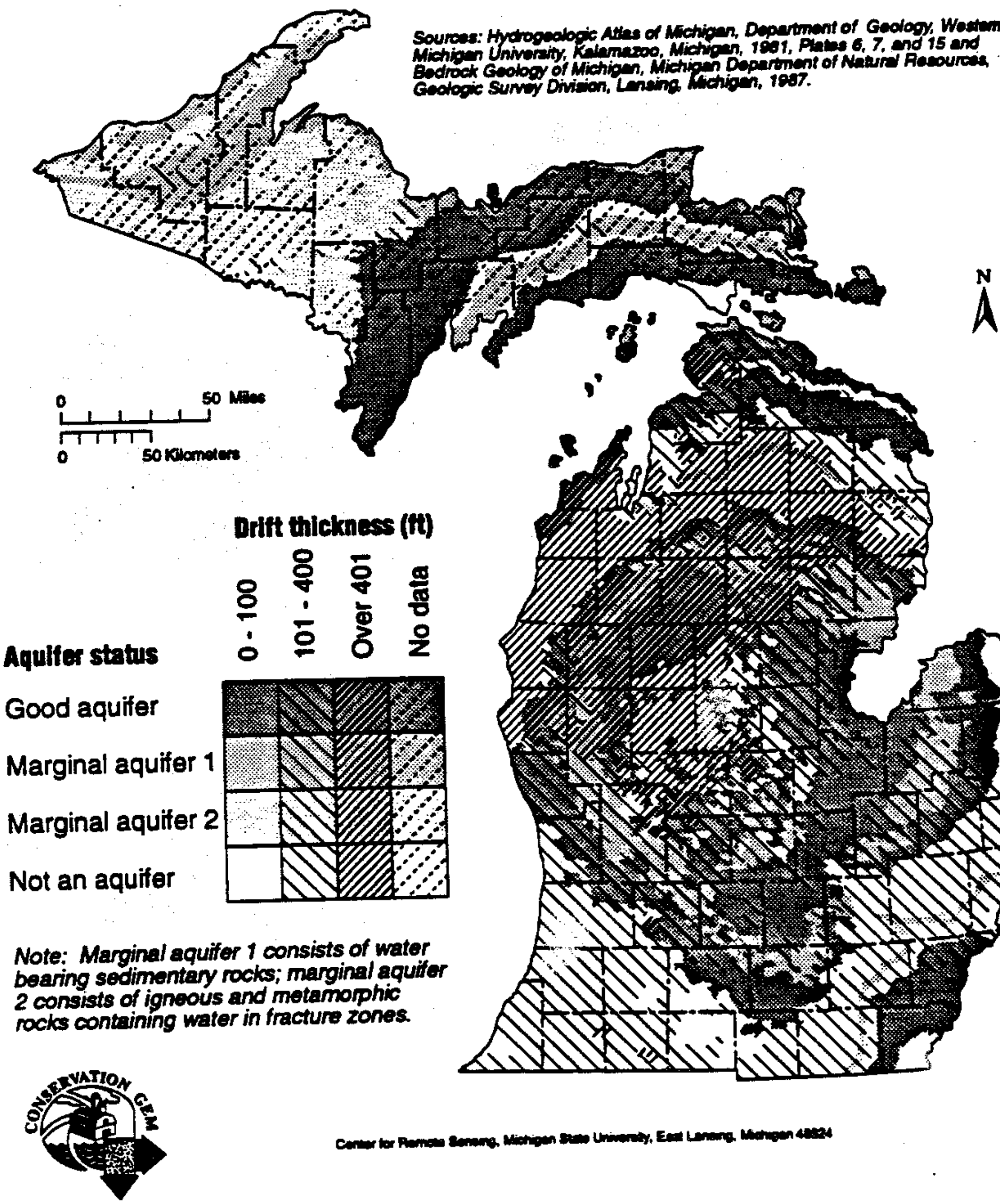


Figure IV-2. Accessibility of bedrock aquifers in Michigan.

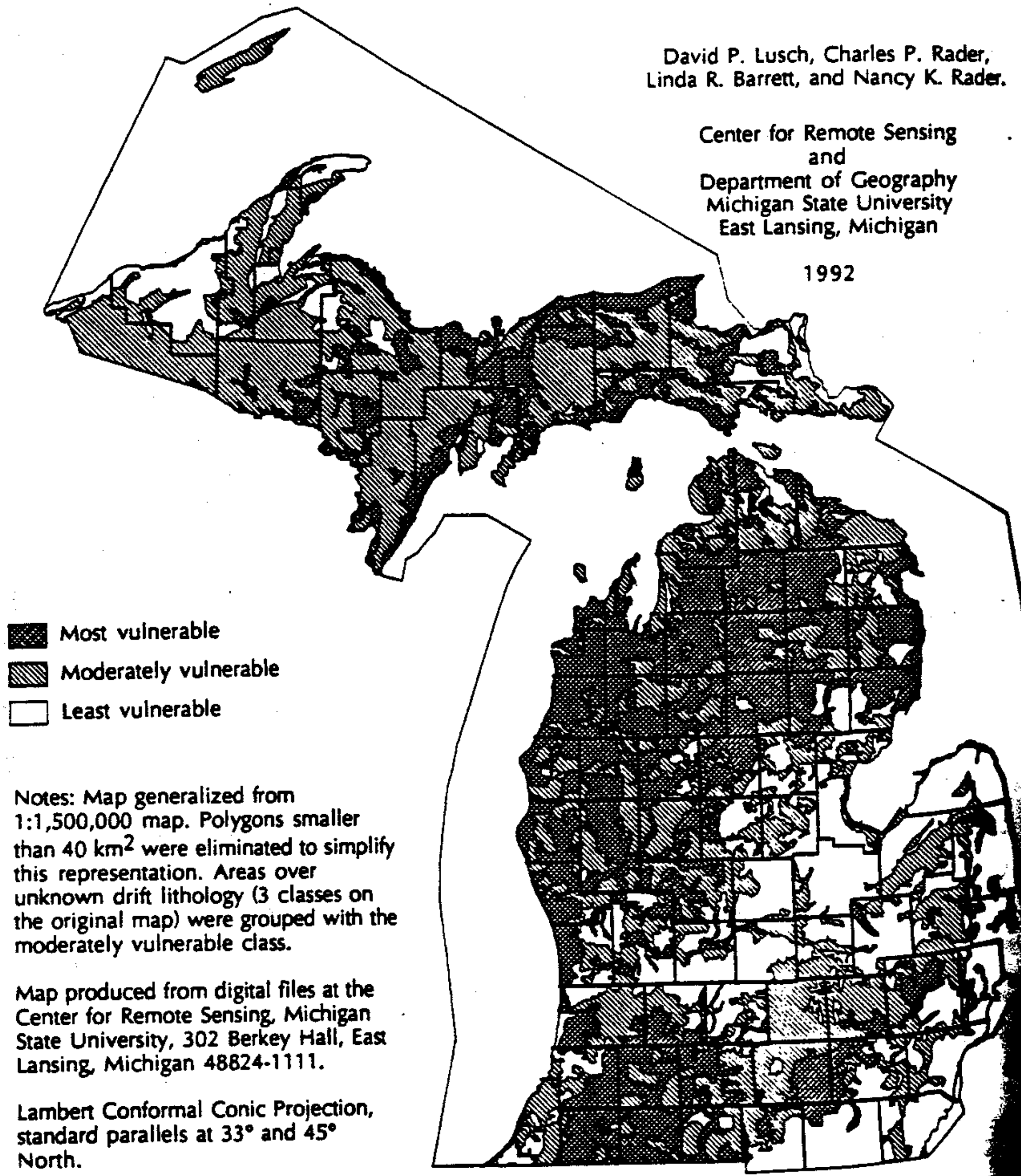
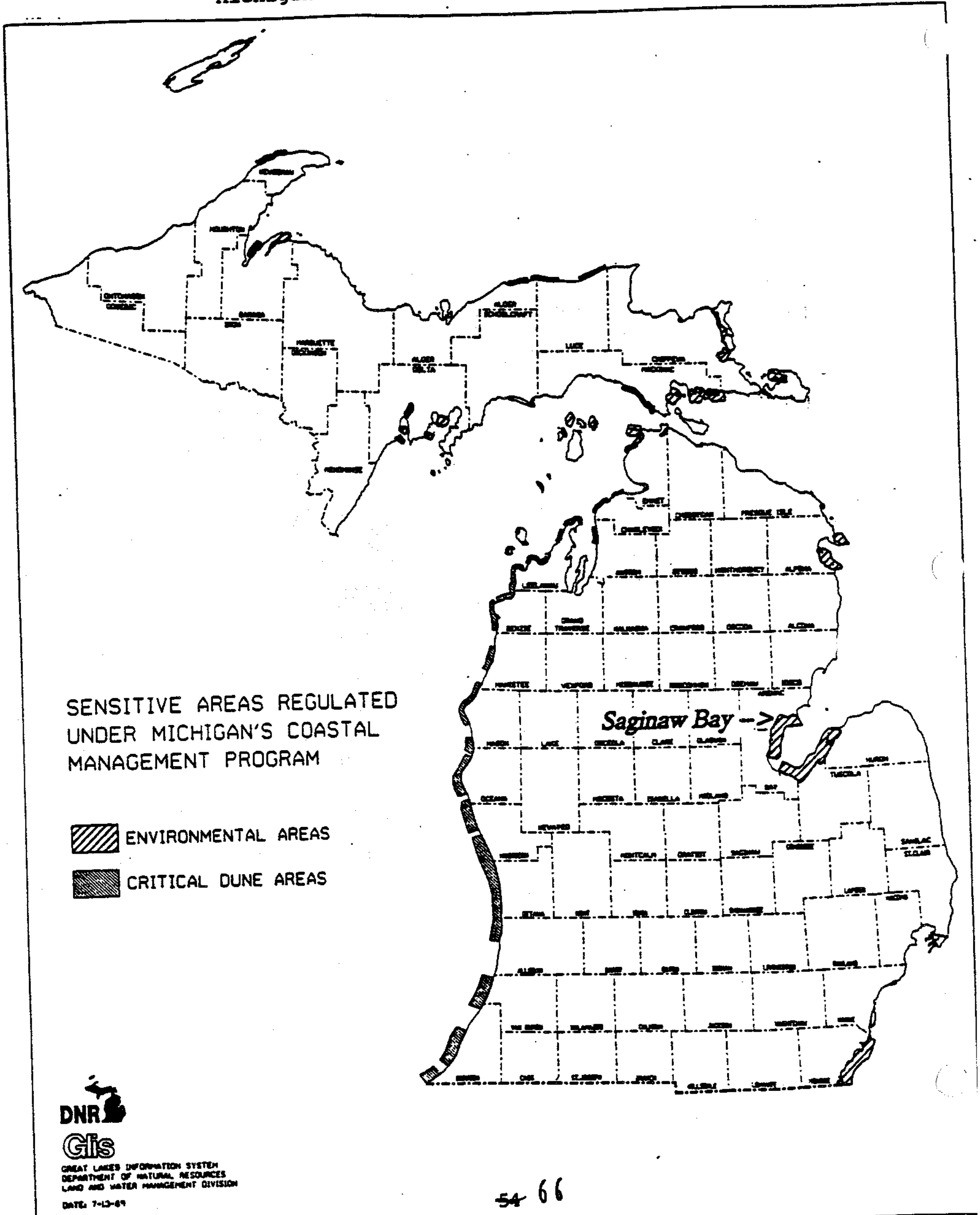


Figure IV-6. Aquifer vulnerability to surface contamination in Michigan.

Figure 16. Sensitive environmental areas regulated under Michigan's Coastal Management Program.



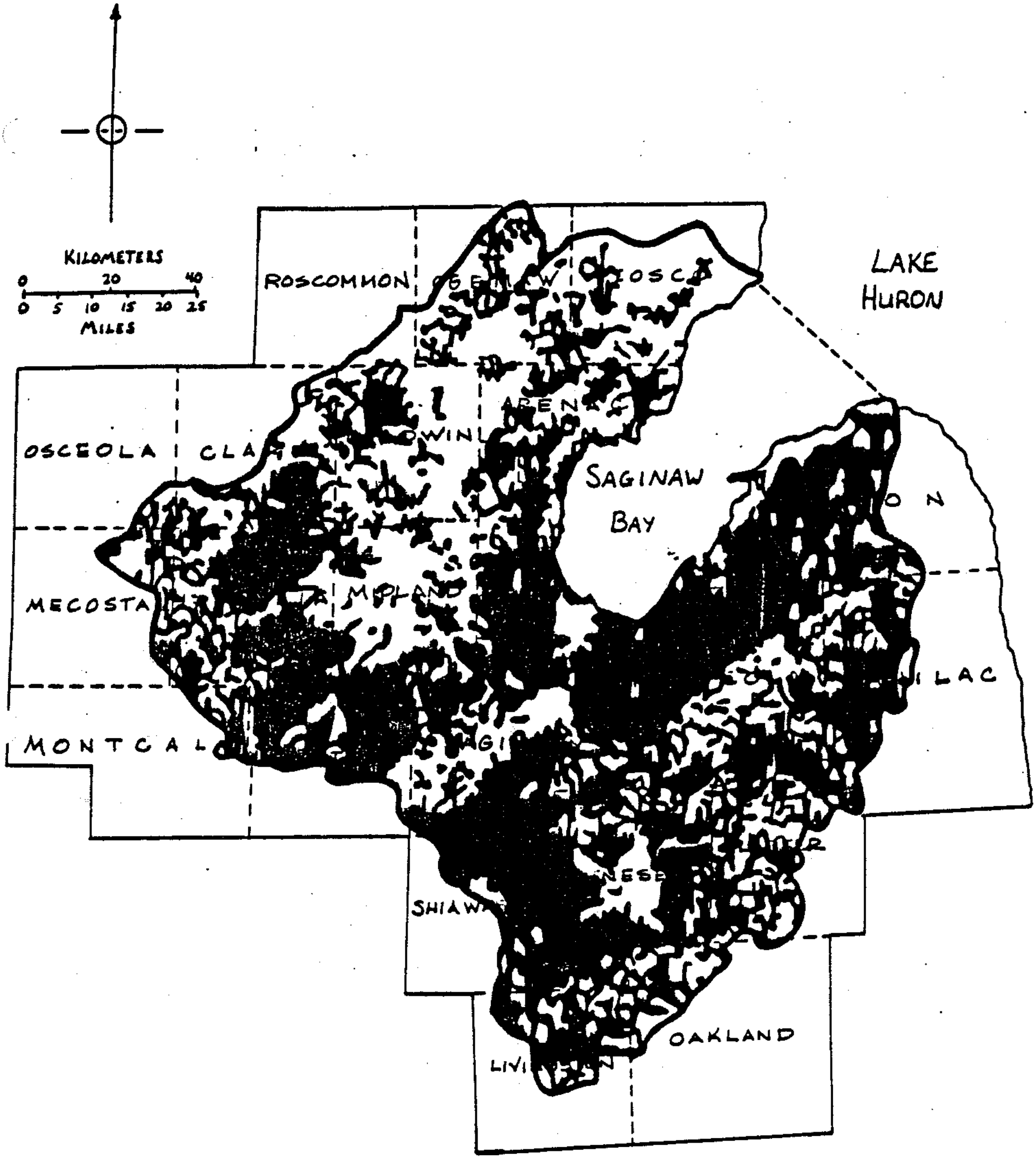


Figure II-15. Agricultural land in the Saginaw Bay drainage basin (ECMPDR, 1987).

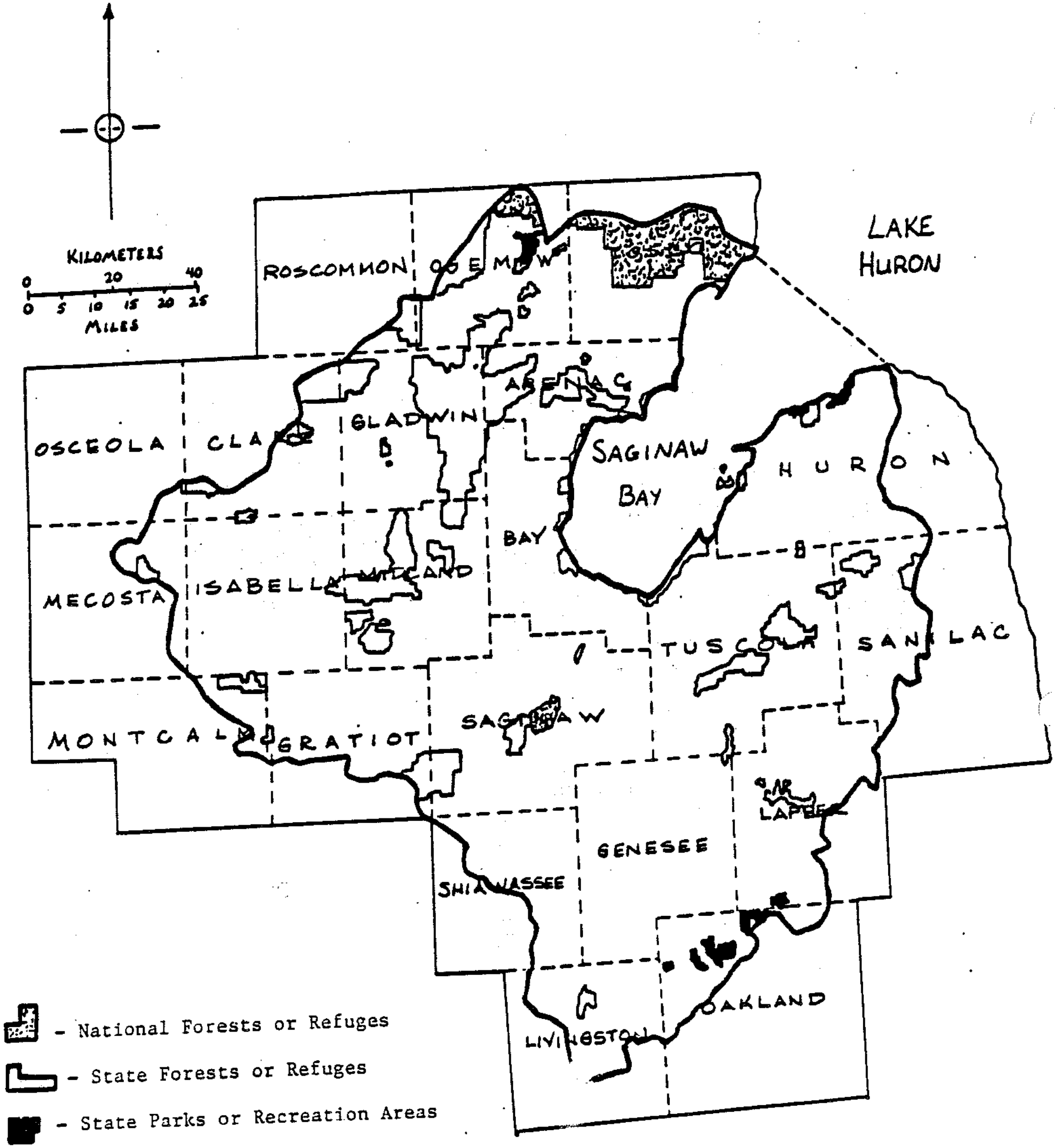


Figure II-18. Public land in the Saginaw Bay drainage basin.

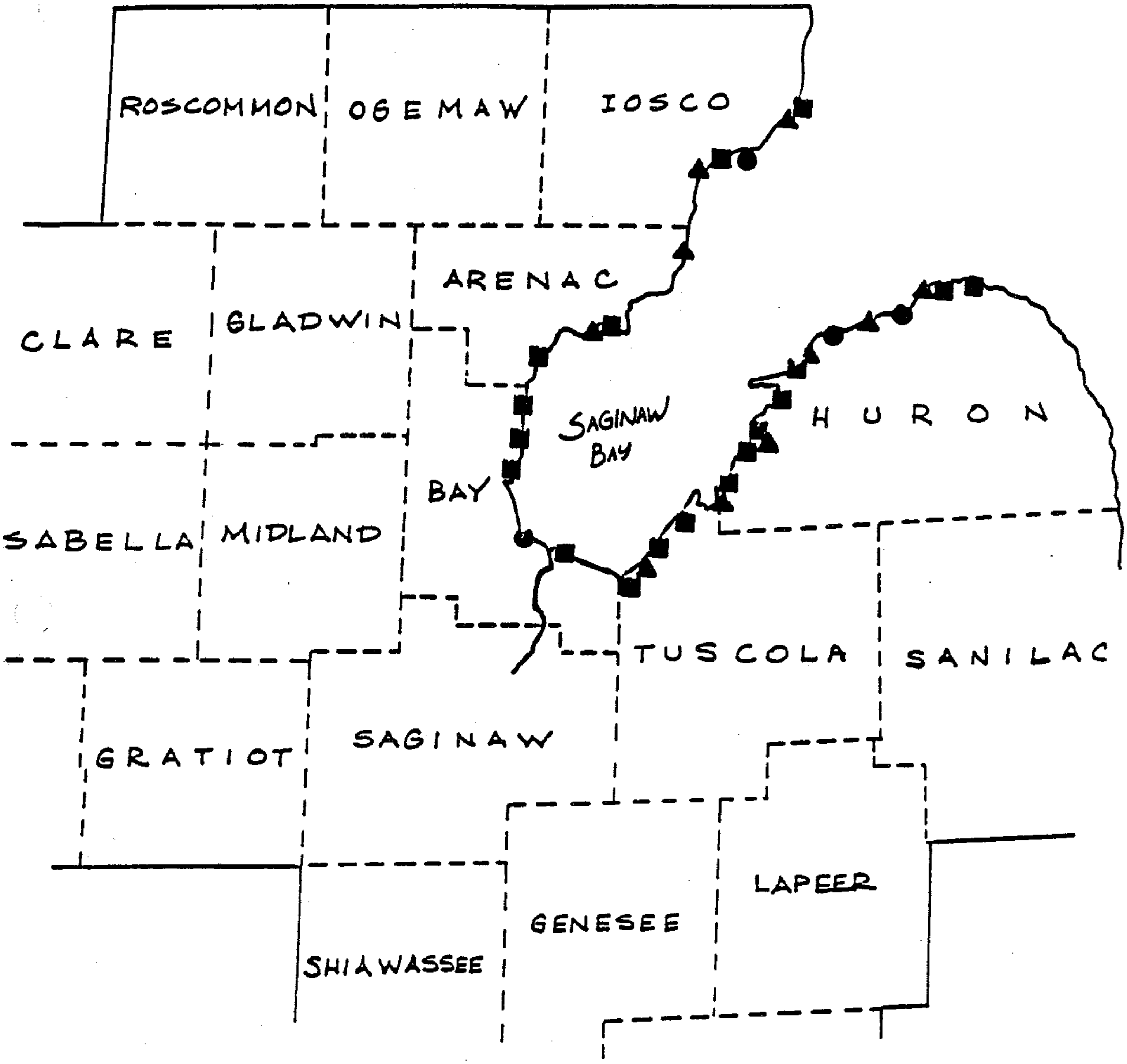


Figure II-21. Saginaw Bay shoreline recreation sites.

KEY

● STATE PARKS
■ PUBLIC ACCESS SITES
▲ CAMPGROUNDS/PICNIC AREAS

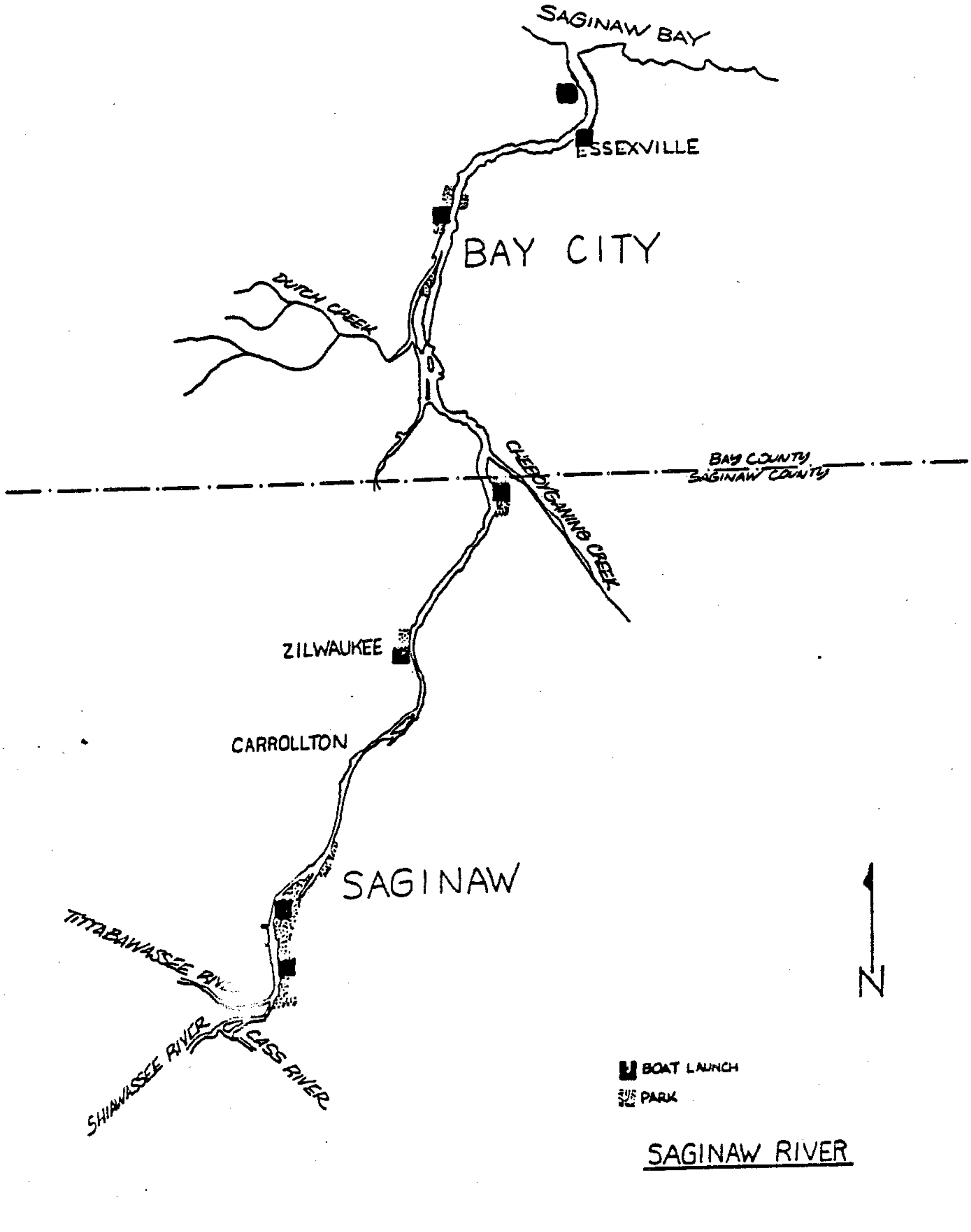
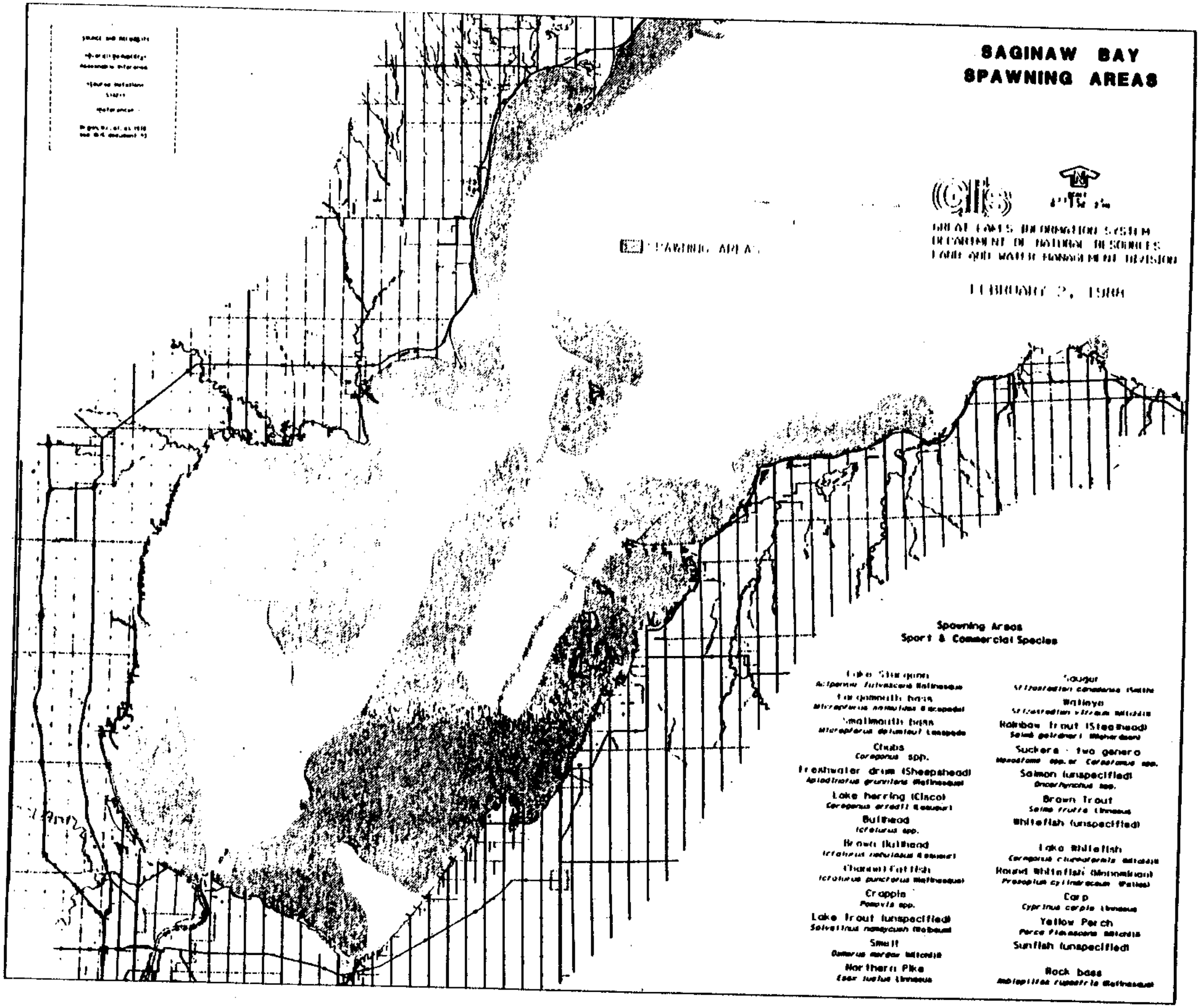


Figure II-22. Saginaw River recreation sites.

Figure 5. Saginaw Bay spawning areas for sport and commercial fish species.



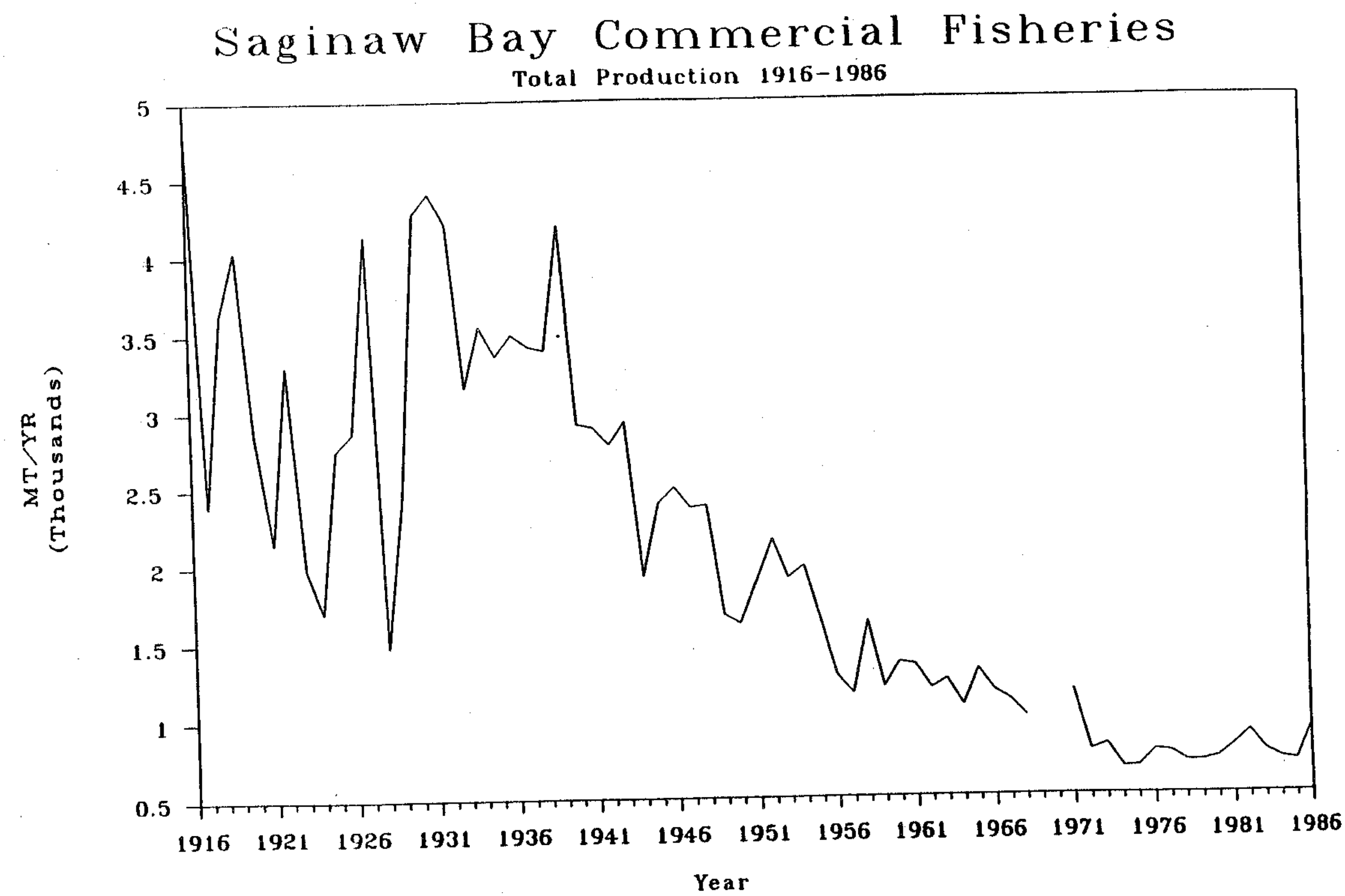


Figure II-19. Total commercial fisheries catch in Saginaw Bay, 1916-1986 (MDNR unpublished).

APPENDIX FOUR

AQUATIC ECOSYSTEM CONDITIONS: CONVENTIONAL PARAMETERS AND NUTRIENTS

A. WATER QUALITY

1. Data Introduction

a. Overview

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 are primarily from monthly samples collected by the MDNR. However, some data were collected on an event response sampling basis. The time period over which samples were collected varied with each station dependent upon data needs and the budget for monitoring activities.

b. 1991-1993 Tributary Sampling Project

An intensive water sampling effort was undertaken from spring 1991 through spring 1993 on the tributaries to Saginaw Bay and the Saginaw River. The study was a joint effort of the MDNR, ECMPDR, the University of Michigan, and Saginaw Valley State University. It was the most comprehensive tributary monitoring effort ever implemented on a scale large enough to simultaneously include all the major tributaries to Saginaw Bay. Monitoring was conducted on an event-response basis in addition to periodic scheduled sampling.

Caution should be used in interpreting the results however, because some years and rivers had many more data points than others. Additionally, because of the large size of the watershed, each sampling run often took two or more days to complete, resulting in samples being taken at different times following a storm event. There could also be large variations in the amount of rainfall among portions of the watershed for a single storm event.

In the following figures, "Scheduled" stations refers to stations that were sampled periodically and during events. "Event" stations were those that were sampled only during events, and consequently have fewer data points. The best year of data, in terms of the number of samples collected, was 1992. Fewer samples were collected in 1991, and more effort was expended in the fall of that year, resulting in a seasonal bias in annual summaries. The fewest samples were collected in 1993, and this effort was more concentrated in the spring, again resulting in a seasonal bias.

2. Temperature

a. Tributaries

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.

b. 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).

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

3. Oxygen

a. Dissolved Oxygen

1) Saginaw River

Dissolved oxygen concentrations in the Saginaw River were measured monthly at the Midland Street Bridge, approximately five miles upstream of Saginaw Bay, by MDNR from 1973 to early 1992. Dissolved oxygen concentrations at this site dropped below Michigan's water quality standard of 5.0 mg/l only twice since 1980 (Figure III-4), once in 1985 (September) and once in 1987 (August), which is an improvement over levels observed in the 1970s.

However, these results were not reflected in more intensive, continuous dissolved oxygen monitoring conducted at Liberty Street bridge during summer 1988 (Buda, 1989). Of the 79 days monitored from June 16th through September 24th, the dissolved oxygen level was less than 5.0 mg/l on 60 days, or 76% of the time (Table III-4). This discrepancy highlighted the limited usefulness of dissolved oxygen measurements made at a single point in time, due in part to diurnal oxygen fluctuations, and contributed to the 1992 elimination of dissolved oxygen measurements taken as part of the MDNR monthly water monitoring program.

There was very little rainfall during the spring of 1988 and the Saginaw River flow approached the 95% exceedance flow in mid-July. From mid-July through mid-September, periodic rainfall kept stream flow above the 95% exceedance flow but still lower than average. Point source discharges of BOD were also lower than permitted levels, with the Saginaw WWTP discharging an average of 6 mg/l of BOD5 during June-August, which was well below the facility's average permit limit of 30 mg/l. If point sources had been discharging the maximum allowable BOD, stream dissolved oxygen would have been even lower than observed.

Significant dissolved oxygen sags were expected from storm related BOD loads due to urban stormwater runoff and CSOs. Indeed, the period of lowest dissolved oxygen followed a heavy rainfall event by about seven days. This was consistent with the expected travel time from Saginaw to the monitoring location.

Algal oxygen consumption by respiration was also thought to be high in the Saginaw River based on the high average chlorophyll a concentration. The low diurnal variation indicated that oxygen production rates were probably not high enough to compensate for the oxygen consumption by the algae. It was thought the low algal oxygen production was due to the very turbid Saginaw River water. On the other hand, algal abundance (indicated by chlorophyll a concentrations) was high, contributing to depressed oxygen levels, perhaps because of algal inputs from the tributaries.

2) Saginaw River Tributaries

Monthly dissolved oxygen concentrations were also measured periodically in the four major tributaries to the Saginaw River from 1971 to 1992. Samples were taken from the Cass River at M-13, the Flint River at M-13, the Shiawassee River at Fergus Road, and the Tittabawassee River at Center Road. Dissolved oxygen concentrations below 5.0 mg/l have not been observed in the Tittabawassee or Shiawassee rivers since 1971, and not in the Flint or Cass rivers since the late 1970s.

3) Saginaw Bay Tributaries

Dissolved oxygen levels have also been monitored sporadically in Saginaw Bay coastal tributaries since the early 1970s. From 1980 to 1992, dissolved oxygen concentrations below 5.0 mg/l were recorded only at 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).

4) 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).

b. Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) was determined in water samples collected monthly by the MDNR from the Midland Street site on the Saginaw River from 1973 to 1992, which was the year the MDNR stopped BOD analyses in the sampling program. As was the case with dissolved oxygen, BOD conditions have improved since the late 1970s. BOD concentrations for much of the 1980s stayed below 6.0 mg/l, whereas in the 1970s levels above 6.0 mg/l were common and there were numerous times BOD measurements exceeded 8.0 mg/l (Figure 95). From 1983 on, BOD concentrations in the Saginaw River have averaged about 3-4 mg/l.

Samples were also periodically collected for BOD analysis from the four major Saginaw River tributaries. Historically, BOD levels were highest in the Flint River where they almost always exceeded 6.0 mg/l (Figure 96). Except for occasional elevated levels, BOD values in the Flint River now cluster around 3.0 mg/l, which is still somewhat higher than values in the other three tributaries that have averages of just above 2.0 mg/l (Figures 96 and 97).

4. 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, agricultural 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.

In the early 1930s, about one million gallons a day of brine was being discharged to the Pine River in the Alma-St. Louis vicinity. As a result, chloride concentrations in the Saginaw River during 1934 and 1935 averaged over 500 mg/l, making the water undrinkable. About that same time, growth of Dow Chemical Company in Midland was creating additional brine problems. During high flow conditions in the Tittabawassee River, brine would be discharged from the company's storage lagoons at a rate of 120-170 million gallons a day. This not only contributed to the chloride problems in the Saginaw River, but resulted in chloride concentrations of over 1000 mg/l at the bottom of Saginaw Bay all the way out to the Charity Islands -- 33 miles from the mouth of the Saginaw River.

By 1963, annual average chloride concentrations in the Saginaw River had decreased by more than 50% to 230 mg/l. Chloride concentrations continued to decline in the following years, dropping below 100 mg/l by 1973, and falling to 50 mg/l in 1993 (Figure III-36). Chloride concentrations in Saginaw River tributaries are currently highest in the Tittabawassee and Flint rivers, which average 60-70 mg/l (Figure 99).

Annual average chloride concentrations measured during 1991-1993 in coastal basin tributaries were highest in the southern and eastern tributaries, generally falling in the 30-60 mg/l range (Figures 100 and 101). West coastal basin tributaries from the Rifle River north averaged only 10-20 mg/l.

5. Solids

a. Saginaw Bay Turbidity

Clarity in inner Saginaw Bay is affected by wave-resuspension of sediments in shallow water (Smith et al., 1977; Bierman et al., 1983) and by suspended solids loads from tributaries following storm events.

From 1974 to 1980, water clarity was consistently poor in the inner 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 (Figure 102). Water clarity appeared to be about the same 11 years later when it was next measured in spring 1991. But by fall 1991, clarity had increased dramatically, to almost 2.5 m, and remained higher in both 1992 and 1993. It is thought that this dramatic increase was due to the rapid colonization of Saginaw Bay by zebra mussels, which filter large volumes of water as they feed, beginning in 1991.

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).

b. Suspended Solids

There were only three coastal tributaries with measured total suspended solids concentrations of 700 mg/l or higher during the 1991-1993 sampling project. All three tributaries were in the east coastal basin -- Northwest Drain (1825 mg/l), Pigeon River (1048 mg/l) and Columbia Drain (799 mg/l) -- and all three measurements were made in the spring (Figures 103 and 104). Four other east coastal basin tributaries had maximum concentrations that exceeded 500 mg/l, including State Drain, Pinnebog River, Shebeon Creek, and Allen Drain. Among west coastal basin tributaries, three had maximum concentrations that exceeded 500 mg/l, including Pinconning River, South Branch Kawkawlin River, and Kawkawlin River (Figures 105 and 106).

At the mouth of the Saginaw River, total suspended solids concentrations never exceeded 400 mg/l and topped 200 mg/l only three times during the 1991-1993 period (Figure 107). Among Saginaw River tributaries, the highest maximum concentrations were reported from the Cass and Shiawassee rivers (Figure 108). The increase in suspended solids concentrations above base flow conditions following storm events was much less for the large Saginaw River tributaries and the Saginaw River itself, than for the smaller coastal basin tributaries.

Annual average suspended solids concentrations exceeded 50 mg/l in 1992 and 1993 for all the east coastal basin tributaries from the Quanicassee River north to Columbia Drain (Figure 109). Though west coastal basin tributaries generally had annual average concentrations below 50 mg/l, three northern rivers -- Whitney Drain, Au Gres, and Rifle -- all had annual averages that exceeded 130 mg/l in 1993, though these were the result of limited sampling that occurred in the spring (Figure 110).

Annual average suspended solids concentrations at the mouth of the Saginaw River ranged from 37 mg/l in 1992 to 63 mg/l in 1993 (Figure 111). There was not a large difference among average suspended solids values for the major tributaries to the Saginaw River, though the Shiawassee and Flint rivers had higher values than the Tittabawassee and Cass rivers on two of the three years (Figure 111).

6. Flow

The highest suspended solids concentrations in the east coastal basin tributaries during 1991-1993 occurred on the dates that the greatest river flows were recorded (Figures 112 and 113). The Pigeon, Pinnebog and Quanicassee rivers all had maximum flows recorded over 1500 CFS. Among west coastal basin tributaries, the greatest peak flows were in the Au Gres and Rifle rivers, both of which had flows over 2000 CFS on at least two dates (Figures 114 and 115).

During this same time period, the peak flow measured on the Saginaw River at the time samples were collected was over 42,000 CFS (Figure 116). Of the major tributaries to the Saginaw River, the Tittabawassee River had the highest maximum flow with a flow rate of over 12,000 CFS (Figure 117). The Cass River had the next highest maximum flow at 6,000 CFS. Both the Shiawassee and Flint rivers never exceeded 3,000 CFS.

7. Taste and Odor

a. Definition

Taste and odor in municipal water supplies drawn from Saginaw Bay have historically been one of the principal water quality issues for Saginaw Bay (Dolan et al., 1986). Although these problems have diminished in recent years, tastes and odors still occur and remain a concern to public water suppliers using the bay (Timm, 1994). Odor is generally caused by blue-green algae, actinomycete bacteria, 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

The Saginaw-Midland water intake at Whitestone Point accounts for over 80% of the water withdrawn from Saginaw Bay by public water supplies. This intake extends two miles from shore and terminates in 50 feet of water (Figure III-10). A second parallel intake is currently being constructed at this site. This intake will extend just over one mile from shore and terminate in 30 feet of water.

Historically, water drawn from this site has had taste and odor problems. The USPHS standard threshold odor value of three was exceeded for a total of 56 days in 1974, and for shorter periods in 1975, 1976, 1978 and 1979. Since that time, taste and odor problems have been negligible. Staff at the city of Saginaw have reported raw water quality to be much improved over the last 10 to 20 years, with algae counts decreasing 10-fold from the 1970s to the 1980s (Love, pers. comm., 1994).

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. 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 (Figure III-10). Historically, raw water samples have had routine taste and odor problems. However, raw water quality has noticeably improved over the last five to 10 years, and taste and odor problems have diminished. Despite this, taste and odor problems still occur at this site, some of which have been severe. A particularly severe taste and odor problem occurred in the summer of 1993, which was apparently caused by actinomycete bacteria (DeKam, pers. comm., 1993). Ozone treatment is employed on a continuous basis to minimize tastes and odors in the finished water.

d. Caseville Water Intake

The city of Caseville's intake was constructed in 1988, and extends 1810 feet into Saginaw Bay from the Caseville County Park (Figure III-10). Unlike other intakes that terminate in a crib raised above the floor of the bay, the Caseville intake terminates in a series of perforated collection pipes buried below the floor of the bay. As a result, the water is pre-filtered prior to entering the intake. No significant taste and odor problems have been noted at this site since being placed in service in 1989 (Champagne, pers. comm., 1994).

8. Nutrients

a. Phosphorus

1) 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 & Sayler, 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 (Figure III-6). Total phosphorus concentrations reached their overall highest level of 47.3 ug/l during the spring of 1978. Concentrations in the inner bay declined from 1978 levels to 26.8 ug/l and 24.8 ug/l in the spring and fall of 1980, respectively. When the bay was next surveyed in 1991, total phosphorus concentrations measured were about the same as those observed in 1980. However, a dramatic decline to around 17 ug/l was noted in 1992, with levels remaining at about that level in 1993 as well.

Both the 1992 and 1993 mean total phosphorus concentrations for the inner bay fell, for the first time, within the mesotrophic range when using either Carlson (1977) or U.S. EPA (1981) trophic status criteria (Table III-9).

2) Coastal Tributaries

Among Saginaw Bay coastal tributaries, the highest annual mean total phosphorus concentrations during 1991-1993 were measured at Mud Creek, which had values above 0.27 mg/l in all three years (Figures 120 and 121). The next highest annual mean concentrations for east coastal basin tributaries were measured in the Pigeon River, Quanicassee River, Shebeon Creek and Pinnebog River. Excluding 1993, which contained few data points for most of the coastal basin tributaries, the greatest total phosphorus concentrations among west coastal basin tributaries were found in the Pinconning, South Branch Kawkawlin, and Kawkawlin rivers. These same tributaries had the highest maximum total phosphorus concentrations measured among coastal basin tributaries during 1991-1993 (Figures 122, 123, 124 and 125).

For the most part, annual mean orthophosphorus concentrations were substantially higher in the east coastal basin tributaries during 1991-1993 than in the west coastal basin tributaries (Figures 126 and 127). Again, the greatest concentrations were found in Mud Creek (over 0.25 mg/l), followed by Shebeon Creek, Pigeon River and Quanicassee River.

3) Saginaw River and Tributaries

During 1991-1993, annual mean total phosphorus concentrations at the mouth of the Saginaw River ranged from 0.101 mg/l to 0.149 mg/l (Figure 128). There was little difference between concentrations observed at the mouth to those measured upstream of the city of Saginaw at the head of the Saginaw River. Total phosphorus concentrations were higher in the Flint River in all three years than any of the other three Saginaw River tributaries, ranging from 0.139 mg/l to 0.158 mg/l (Figure 128). The Flint River also had the highest annual average orthophosphorus concentrations of 0.02-0.05 mg/l (Figure 129).

Though total phosphorus concentrations measured in spring 1991 at the mouth of the Saginaw River were higher than those measured in 1992 and 1993 (Figure 130), these observations are most likely the result of sampling during higher flow conditions in spring 1991 (Figure 116) and not representative of a downward trend in concentrations in 1992 and 1993. However, there has been a definite decline from 1973 levels of total phosphorus that were near 0.3 mg/l, to about 0.1 mg/l in 1993 (Figure III-21). Orthophosphorus values declined to an even greater extent from about 0.15 mg/l in 1973 to 0.03 mg/l in 1993 (Figure III-22).

Among Saginaw River tributaries, the Flint River generally had the highest total phosphorus concentrations during 1991-1993, followed by the Shiawassee River (Figure 133). This has historically been the case for both total phosphorus and orthophosphorus, where annual average concentrations were highest in the Flint River, followed by the Shiawassee River (Figure III-23 and III-24). Annual average total phosphorus levels in the Flint River declined from over 1.14 mg/l in 1977 to less than 0.15 mg/l in 1993. Orthophosphorus concentrations also dropped in the Flint River from 1.1 mg/l in 1977 to 0.025 mg/l in 1993. However, annual average concentrations in the Flint River remain higher than the other three Saginaw River tributaries. This decrease in Flint River phosphorus concentrations was reflected in the Saginaw River, which also showed corresponding substantial declines as just discussed.

b. Nitrogen

1) 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).

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).

2) Coastal Tributaries

Annual mean nitrogen concentrations during 1991-1993 were substantially higher in the east coastal basin tributaries than the west coastal basin tributaries. As an example, dissolved NO2+NO3 concentrations were typically 6 mg/l or higher among the eastern tributaries, whereas among the western tributaries, only the Pinconning and South Branch Kawkawlin rivers had levels that high (Figures 138 and 139). Figures plotted for total nitrogen and total NO2+NO3 looked very similar to these dissolved NO2+NO3 graphs.

Annual mean dissolved ammonia concentrations were much more similar between the east and west coastal basin tributaries, with the striking exception of Mud Creek, which had values of over 1.2 mg/l compared to less than 0.5 mg/l for any other coastal tributary (Figures 140 and 141).

3) Saginaw River and Tributaries

Annual mean dissolved nitrite-nitrate concentrations at the mouth of the Saginaw River during 1991-1993 ranged from 1.47 mg/l to 1.87 mg/l (Figure 142), which was substantially less than the levels observed in the coastal basin tributaries. In contrast to phosphorus levels in

Saginaw River tributaries where the Flint River had the highest values, dissolved nitrite-nitrate concentrations were highest in the Cass River for two of the three years.

Also in contrast to the notable decline in phosphorus levels observed in the Saginaw River, no discernable trend could be detected for total NO2+NO3 concentrations over the last 20 years (Figure 143). Among the tributaries to the Saginaw River, however, apparent increases in total nitrite-nitrate were observed in the Cass and Shiawassee rivers (Figure 144). The highest annual means were measured in the Cass and Flint rivers, where total NO2+NO3 reached 3 mg/l or higher. Mean levels in the Shiawassee and Tittabawassee rivers never surpassed 1.5 mg/l.

Another observation to note was that dissolved ammonia concentrations increased substantially between the head and mouth of the Saginaw River in both 1991 and 1992 (Figure 145). This did not occur with any of the other nutrient parameters discussed previously.

c. 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).

Annual average unfiltered reactive silicate concentrations in the Saginaw River typically average between 2.0 mg/l and 2.5 mg/l and have not shown any trend during the last 20 years.

B. SEDIMENT QUALITY

1. Saginaw Bay 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 (Robbins, 1986). 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.

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 Cesium 137 (137Cs) 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. When the values for the depth to which 90% of the macrozoobenthos occurred were regressed against the values for the depth to which 90% of the ^{137}Cs occurred, defined as the mixed layer by Robbins (1982), there was a nearly linear relationship. This 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 range 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).

2. 1988 Nutrient Concentrations

a. Areas Surveyed

The MDNR conducted an extensive sediment survey of the Saginaw Bay watershed in 1988. Over 300 sediment samples were collected. Most were surficial grab samples of the top 2-3 cm. Four major areas of the watershed were assessed including Saginaw Bay (Figure 150), the mouths of Saginaw Bay tributaries (Figure 151), the Saginaw River (Figures 152, 153 and 154), and Saginaw River tributaries (Figure 155). Tributary samples were collected in depositional zones. Saginaw River samples were collected in depositional zones outside the federally maintained navigation channel.

b. Total Phosphorus

Total phosphorus concentrations in most of Saginaw Bay sediments were below 300 mg/kg (Figure 156) and would be considered to be non-polluted if compared to the 1977 U.S. EPA Interim Guidelines for the Disposal of Great Lakes Harbor Sediments (Table III-19). However, elevated concentrations were found near Quanicassee and the Maisou Island/Wildfowl Bay area, where one sample exceeded the heavily polluted criteria.

The highest total phosphorus concentration in Saginaw Bay tributary sediments was over 750 mg/kg in Mud Creek. Concentrations were generally greater in the east coastal basin tributaries (Figure 156). Levels above 420 mg/kg were observed in the Pinnebog River, Sebewaing River, Wiscoggin Drain, Quanicassee River, and Kawkawlin River.

Only four of the 30 sediment samples (13%) collected from the Saginaw River exhibited total phosphorus concentrations below the 650 mg/kg heavily polluted criteria (Figures 157, 158 and 159). Though the maximum concentration of 2,000 mg/kg was found at station 68, immediately downstream on the city of Saginaw WWTP, high concentrations were found throughout the length of the Saginaw River.

U.S. Army Corps of Engineers (ACOE) surveys of the Saginaw River navigation channel in 1983 and 1988 also found the highest total phosphorus concentration at the station immediately downstream of the Saginaw WWTP, 1,500 mg/kg and 1,900, respectively (ACOE 1983, 1988). However, these surveys also detected increased levels of total phosphorus in stations downstream of the Bay City WWTP relative to stations between Bay City and Saginaw. And in the 1992 ACOE survey, total phosphorus concentrations were higher downstream of the Bay City WWTP than they were below the Saginaw WWTP (ACOE, 1992).

Of all the sediment samples collected throughout the watershed in the MDNR 1988 survey, the highest overall total phosphorus concentration of over 2,700 mg/kg was found in the Flint River (Figure 160). Concentrations above the 650 mg/kg level were also found in the Cass, Shiawassee and Tittabawassee rivers.

c. Orthophosphate

Orthophosphate sediment concentrations were generally highest at the same locations where total phosphorus concentrations were greatest. The lowest values were found in Saginaw Bay, where most concentrations were below 30 mg/kg and none were over 70 mg/kg. Among Saginaw Bay tributaries, the highest concentration was again at Mud Creek (>95 mg/kg) followed by Wiscoggin Drain (78 mg/kg). The largest concentration noted in the watershed was in the Saginaw River at station 68 (1,800 mg/kg) below the city of Saginaw WWTP. All other samples in the Saginaw River were under 1,000 mg/kg, though all except one were over 200 mg/kg. Of the tributaries to the Saginaw River, the Flint River had substantially higher concentrations than the others, reaching 1,200 mg/kg (Figure 161).

d. Total Kjeldahl Nitrogen

Over one-half the total kjeldahl nitrogen concentrations measured in the sediments of inner Saginaw Bay exceeded the heavily polluted criteria (Table III-19) of 2,000 mg/kg (Figure 162), with the maximum value reaching 4,000 mg/kg. Concentrations were also elevated in the Maisou Island area, where one sample measured over 4,700 mg/kg.

There was less difference among the eastern and western coastal basin tributaries for total kjeldahl nitrogen than there had been for total phosphorus (Figure 162). The highest value was observed in the Pinnebog River (1,500 mg/kg) followed by the Kawkawlin River (1,400 mg/kg). All other rivers had concentrations below 1,100 mg/kg.

As was the case for total phosphorus, total kjeldahl nitrogen concentrations showed no upstream/downstream trends in the Saginaw River (Figures 157, 158 and 159). Two-thirds of the samples measured 1,000 mg/kg or greater, with the highest values observed at stations 78 (Weiss Street Drain -- 3,300 mg/kg) and 39B (Middle Grounds Island -- 3,200 mg/kg).

Again for Saginaw River tributaries, the Flint River had the highest concentrations of total kjeldahl nitrogen, reaching a high of 4,700 mg/kg (Figure 163).

e. Ammonia Nitrogen

The maximum ammonia nitrogen sediment concentration detected in the watershed was 340 mg/kg at Saginaw Bay station 225 near Maisou Island. Ammonia concentrations above 200 mg/kg are classified as heavily polluted in the EPA 1977 dredge disposal guidelines (Table III-19). All other Saginaw Bay stations had concentrations less than 45 mg/kg except for three other nearshore stations: 140 mg/kg at station 215 near Wigwam Bay, 100 mg/kg at station 217 at Nayanquing Point, and 80 mg/kg at station 228 near Quanicassee. Ammonia concentrations between 75 mg/kg and 200 mg/kg are considered to be moderately polluted for dredge disposal purposes. All four of these samples were collected at the edges of coastal marshes.

The highest ammonia nitrogen concentrations found in the coastal tributaries was 44 mg/kg in the Kawkawlin River, followed by 37 mg/kg in the Sebewaing River, and 30 mg/kg at Mud Creek. All other tributaries had concentrations below 30 mg/kg, and all other west coast tributaries had values below 10 mg/kg.

Ammonia nitrogen concentrations in the Saginaw River were substantially greater at stations sampled in the city of Saginaw than downstream, with the highest value of 140 mg/kg observed at station 88 (Figure 164). The stations downstream of the city of Saginaw had concentrations of 25 mg/kg or less, with many around 10 mg/kg.

Once again, among the Saginaw River tributaries, the Flint River had the highest concentration of ammonia nitrogen, reaching 160 mg/kg (Figure 165). Both the Tittabawassee and Shiawassee rivers had concentrations that exceeded 100 mg/kg. Cass River samples were both below 30 mg/kg.

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

U.S. EPA Interim Guidelines for the Disposal of Great Lakes Harbor Sediments, 1977.

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

Parameter	Non-Polluted	Moderately Polluted	Heavily Polluted
	Classification		
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 HWF)

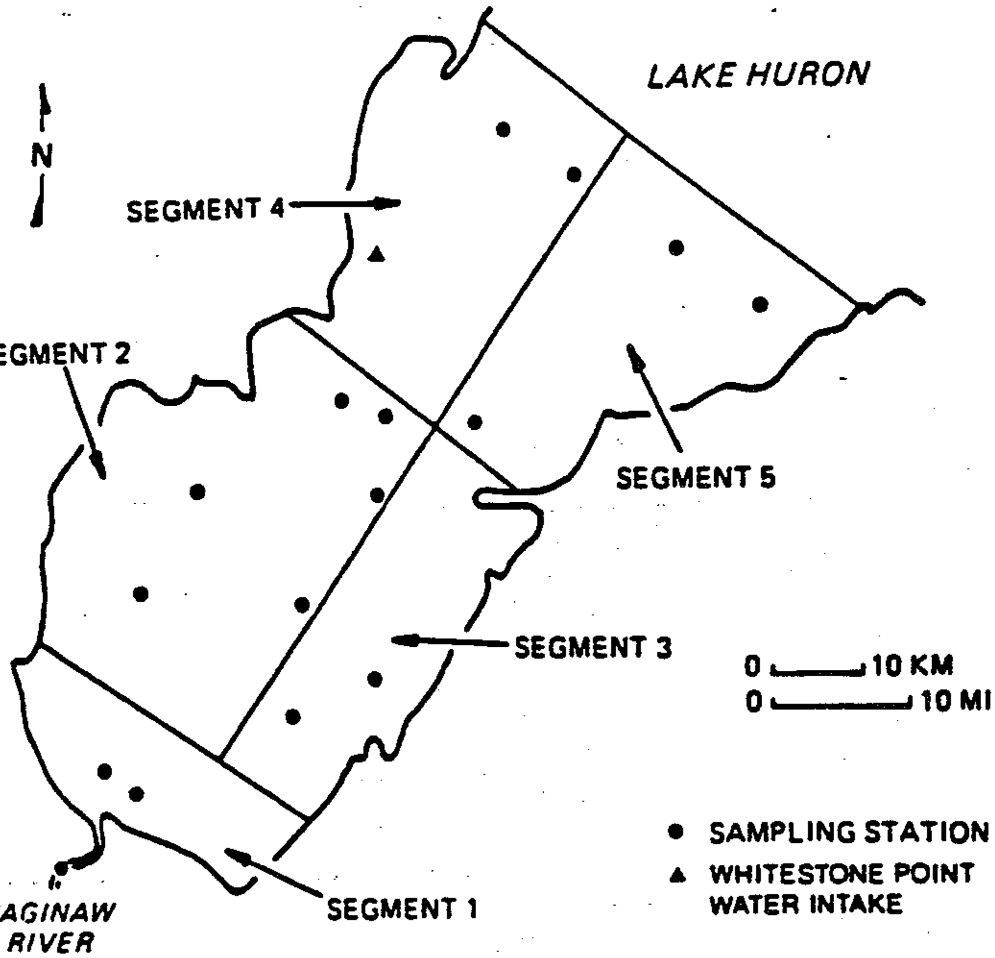


Figure III-12. Segments and sampling stations in Saginaw Bay (Dolan, et al., 1986).

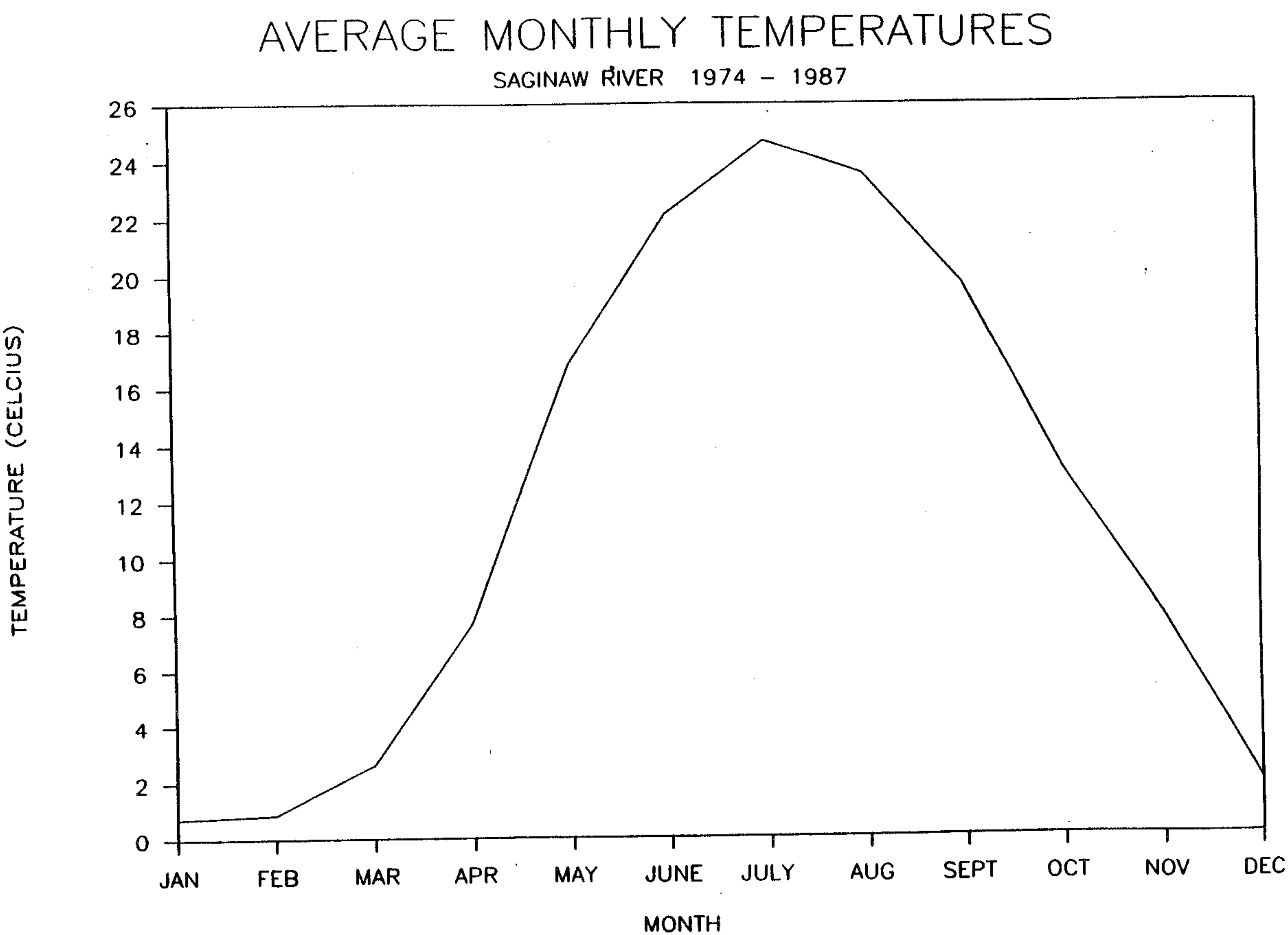


Figure III-2. **Average monthly water temperatures in the Saginaw River, 1974-1987.**

Saginaw River (Midland St)
Dissolved Oxygen Concentration

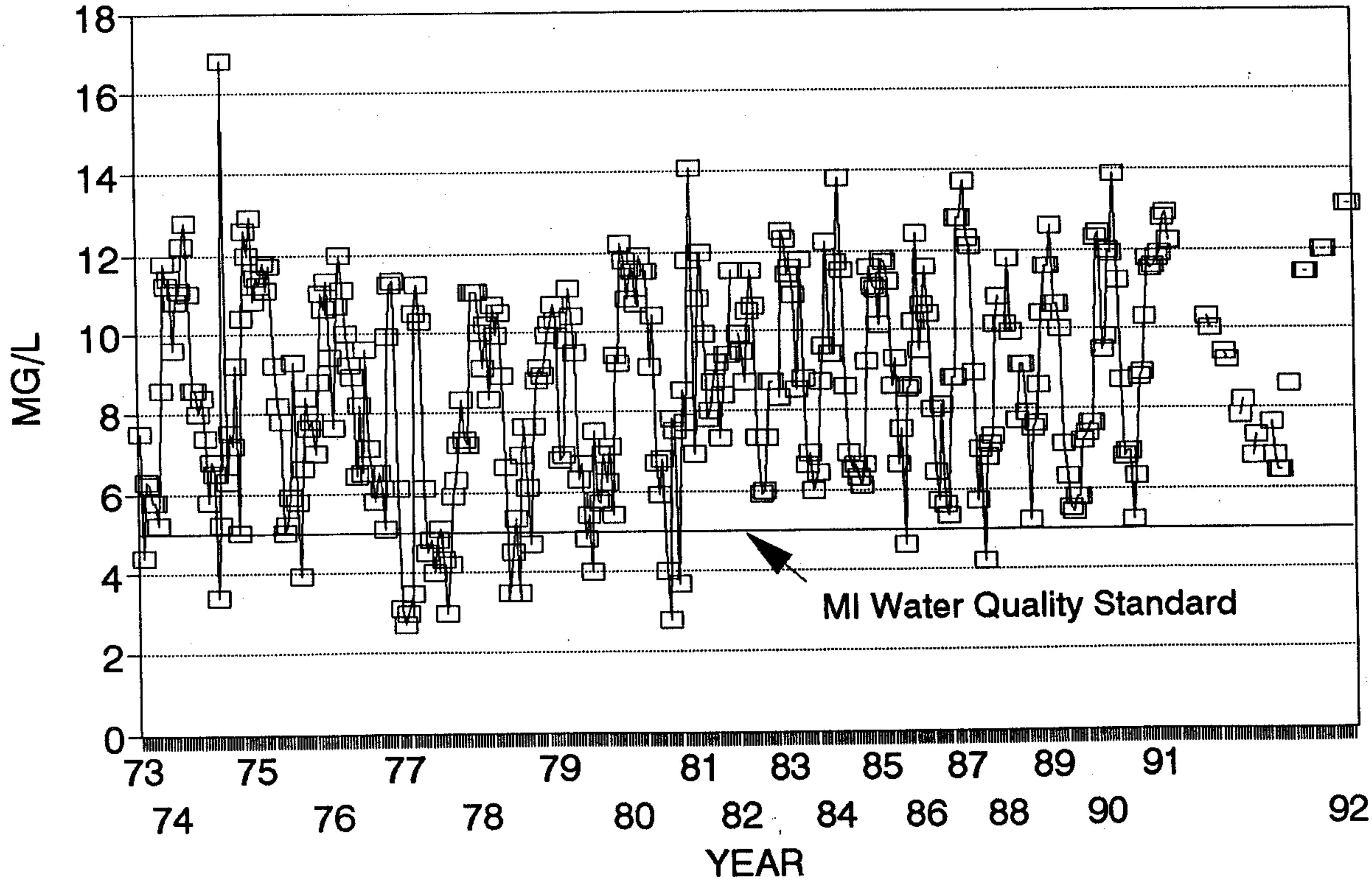
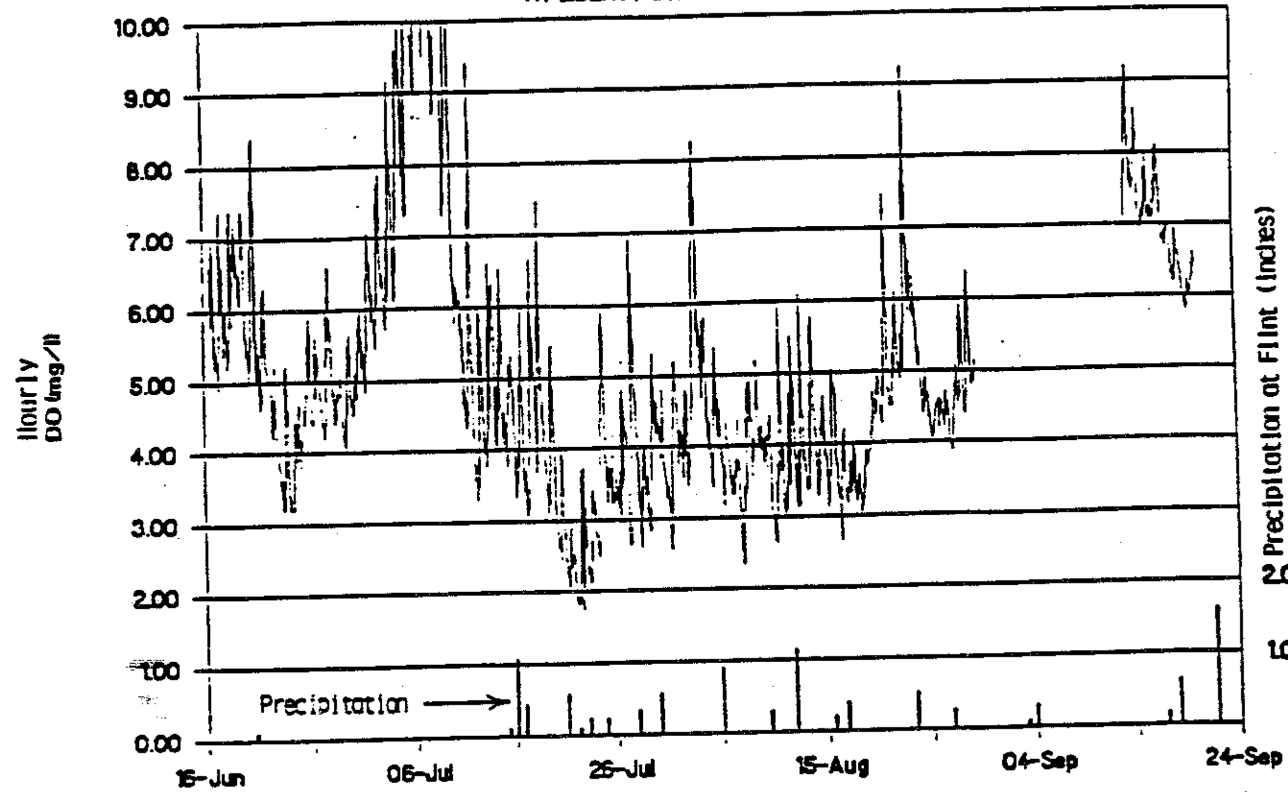
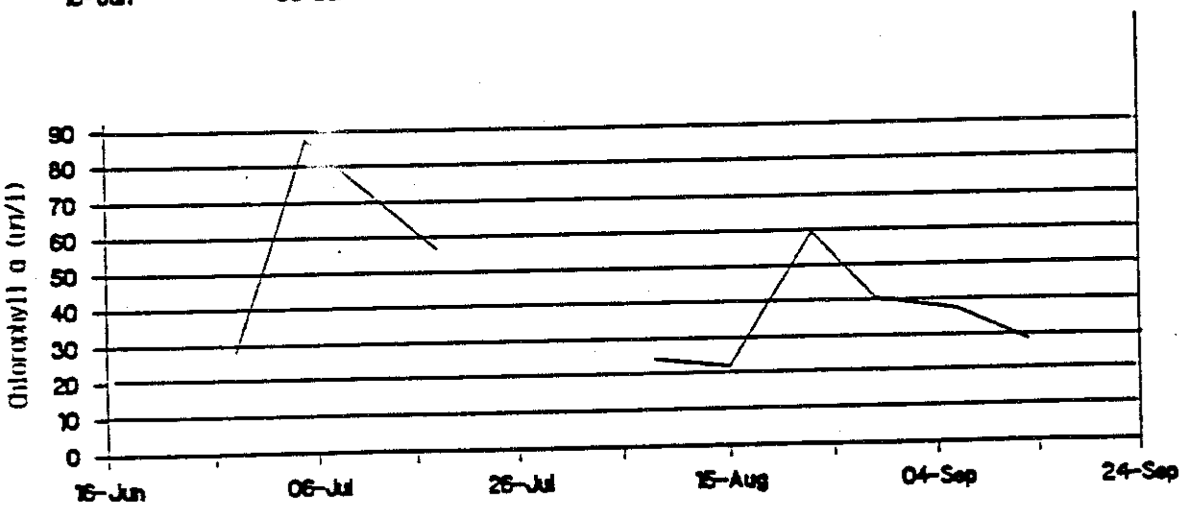


Figure III-4

SAGINAW RIVER DISSOLVED OXYGEN

AT LIBERTY STREET BRIDGE





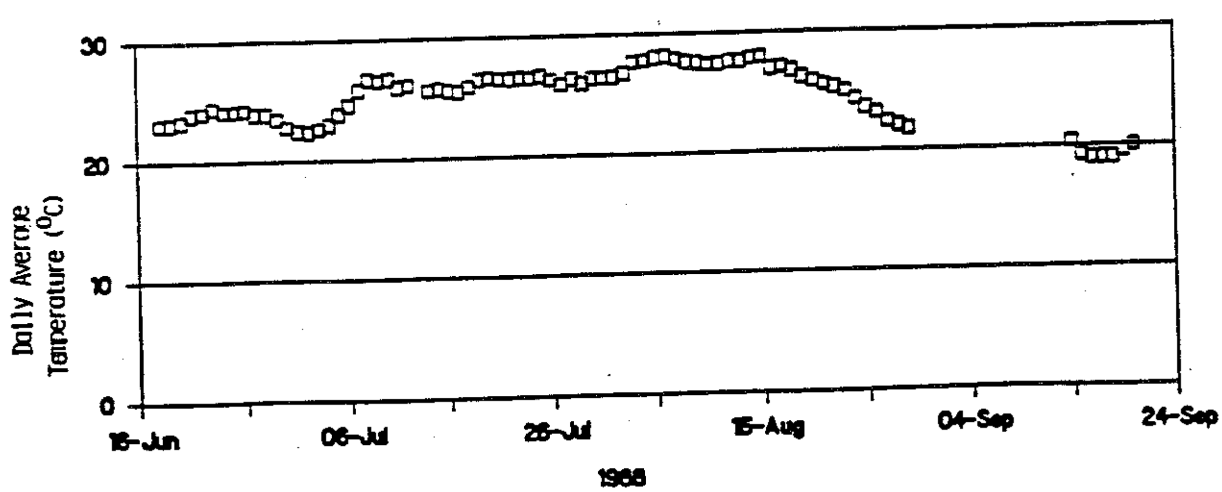
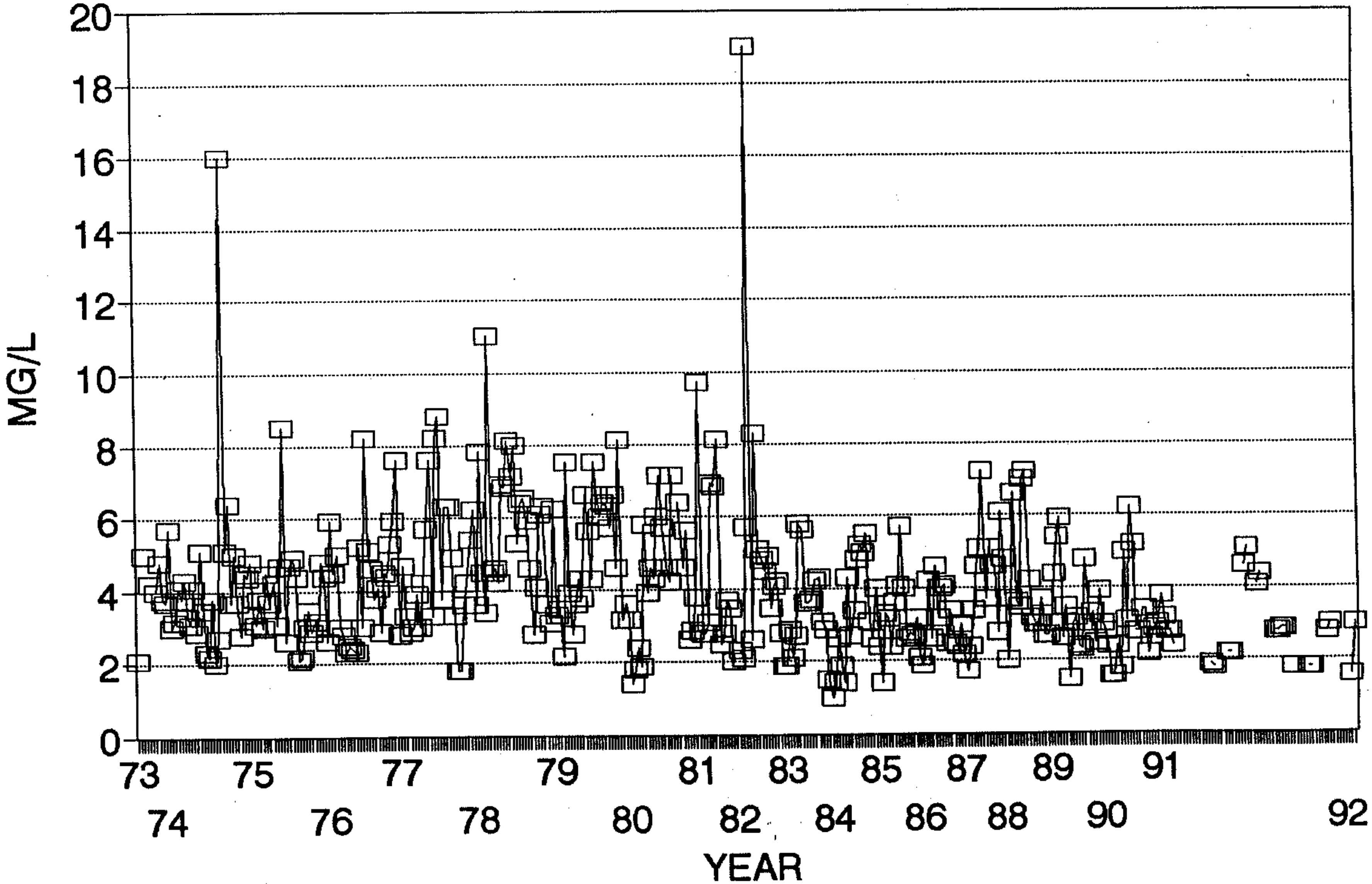


Table III-4

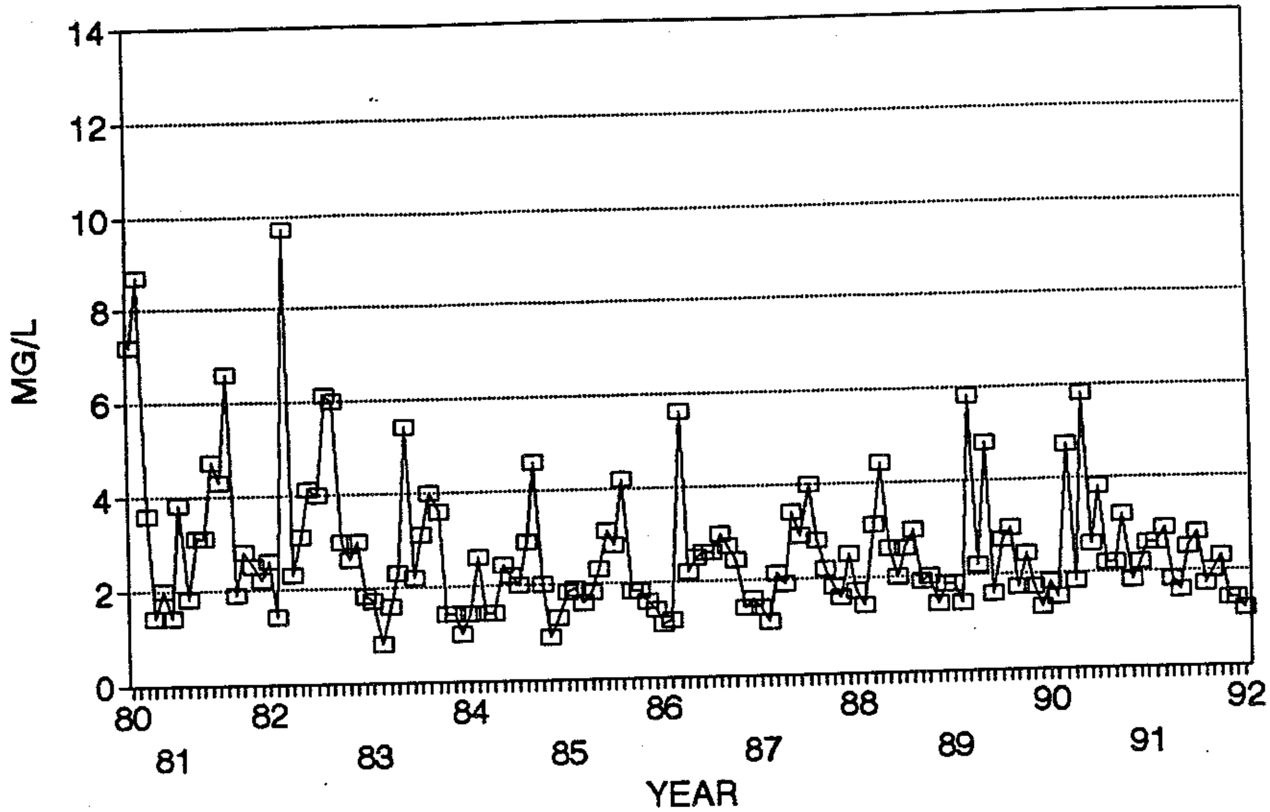
Saginaw River (Midland St)

Biochemical Oxygen Demand



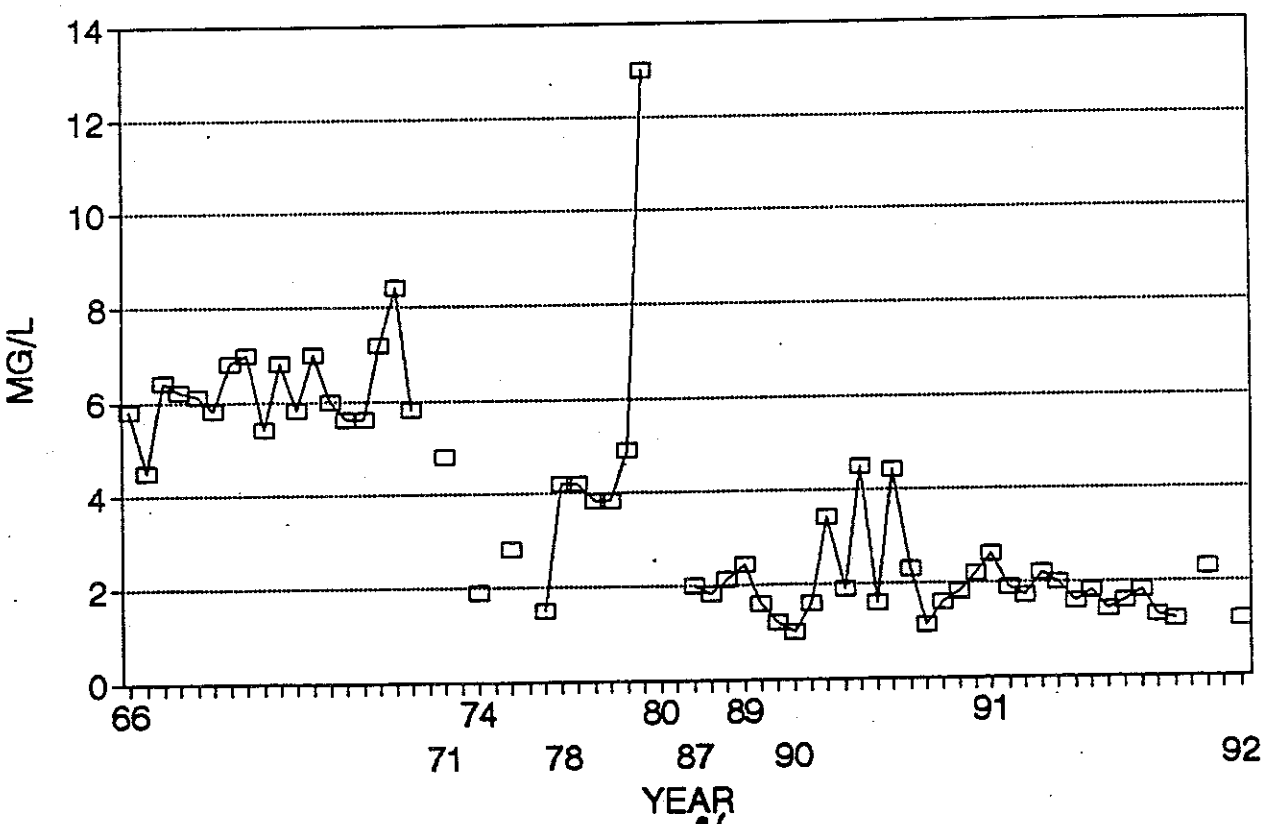
Tittabawassee R. (Gordonville Rd)

Biochemical Oxygen Demand



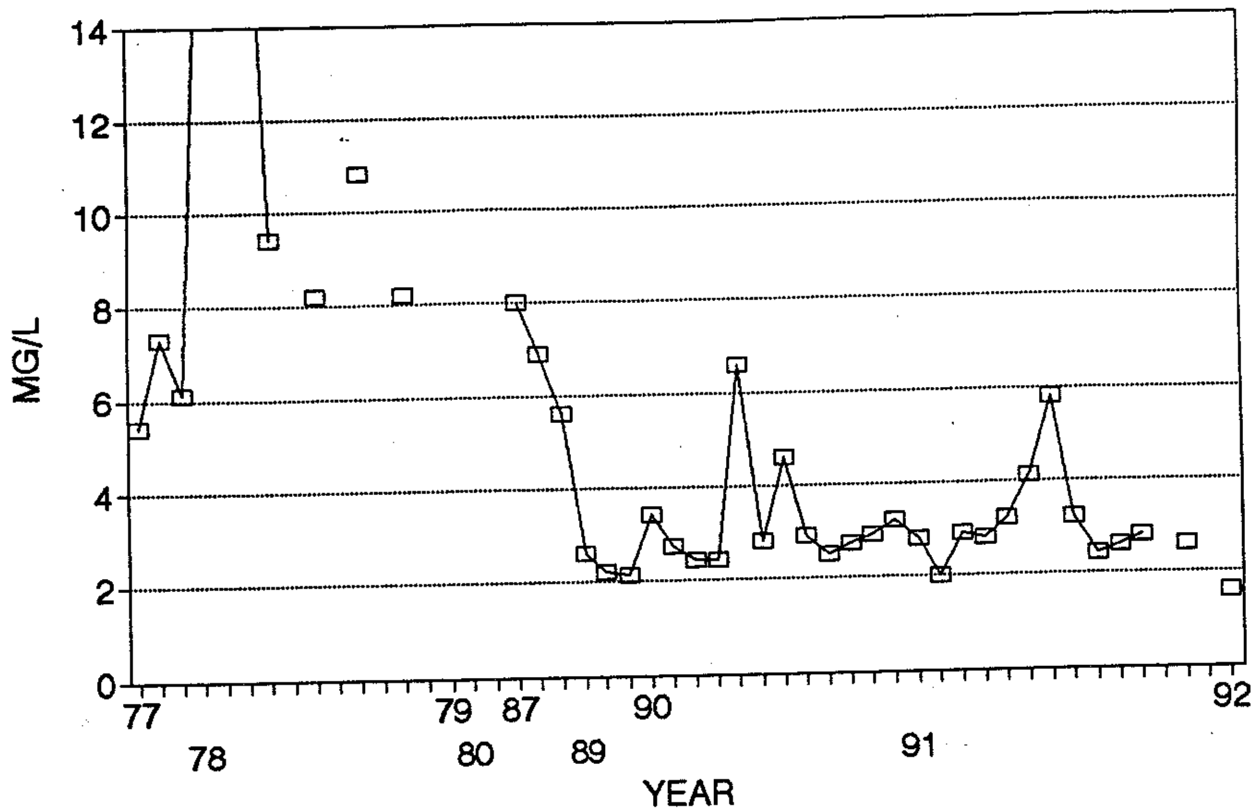
Shiawassee River (Fergus Rd)

Biochemical Oxygen Demand



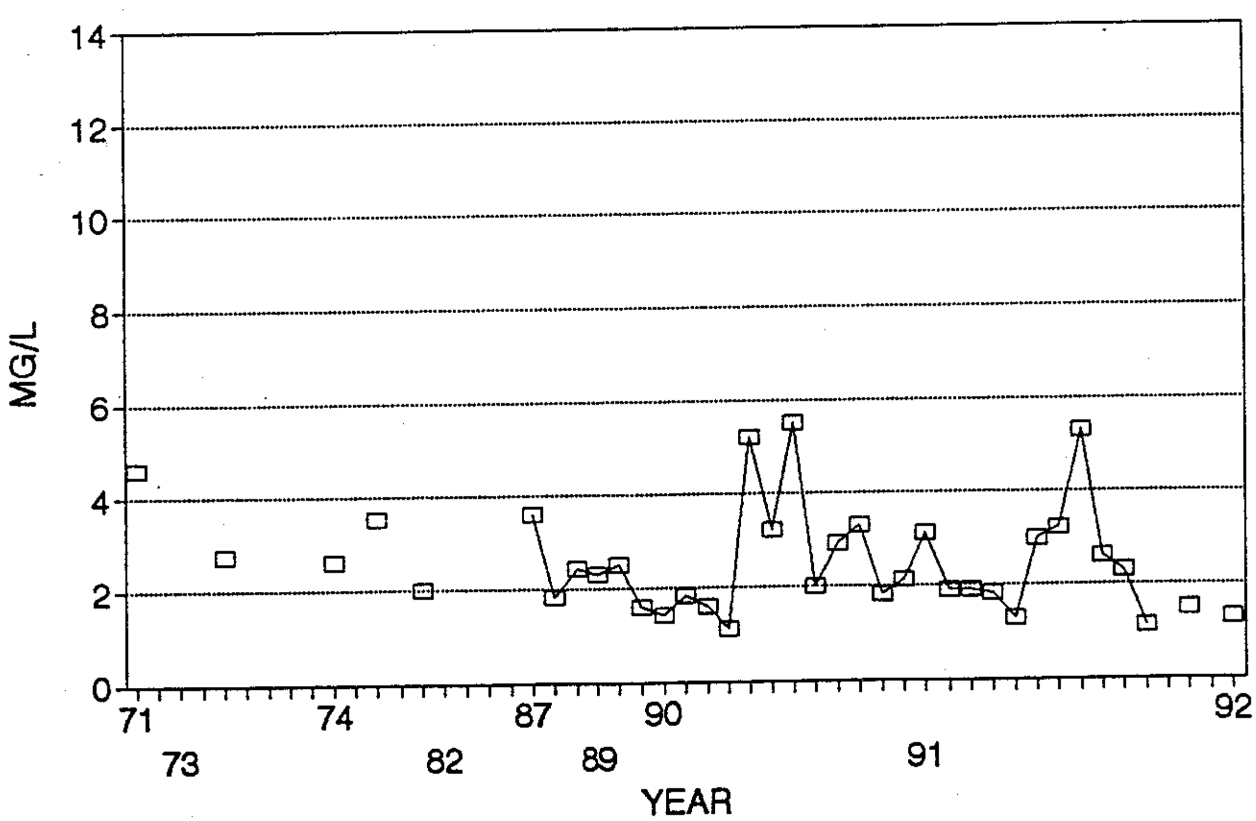
Flint River (M-13)

Biochemical Oxygen Demand



Cass River (M-13)

Biochemical Oxygen Demand



Saginaw River Mouth

Annual Mean Chloride Concentration

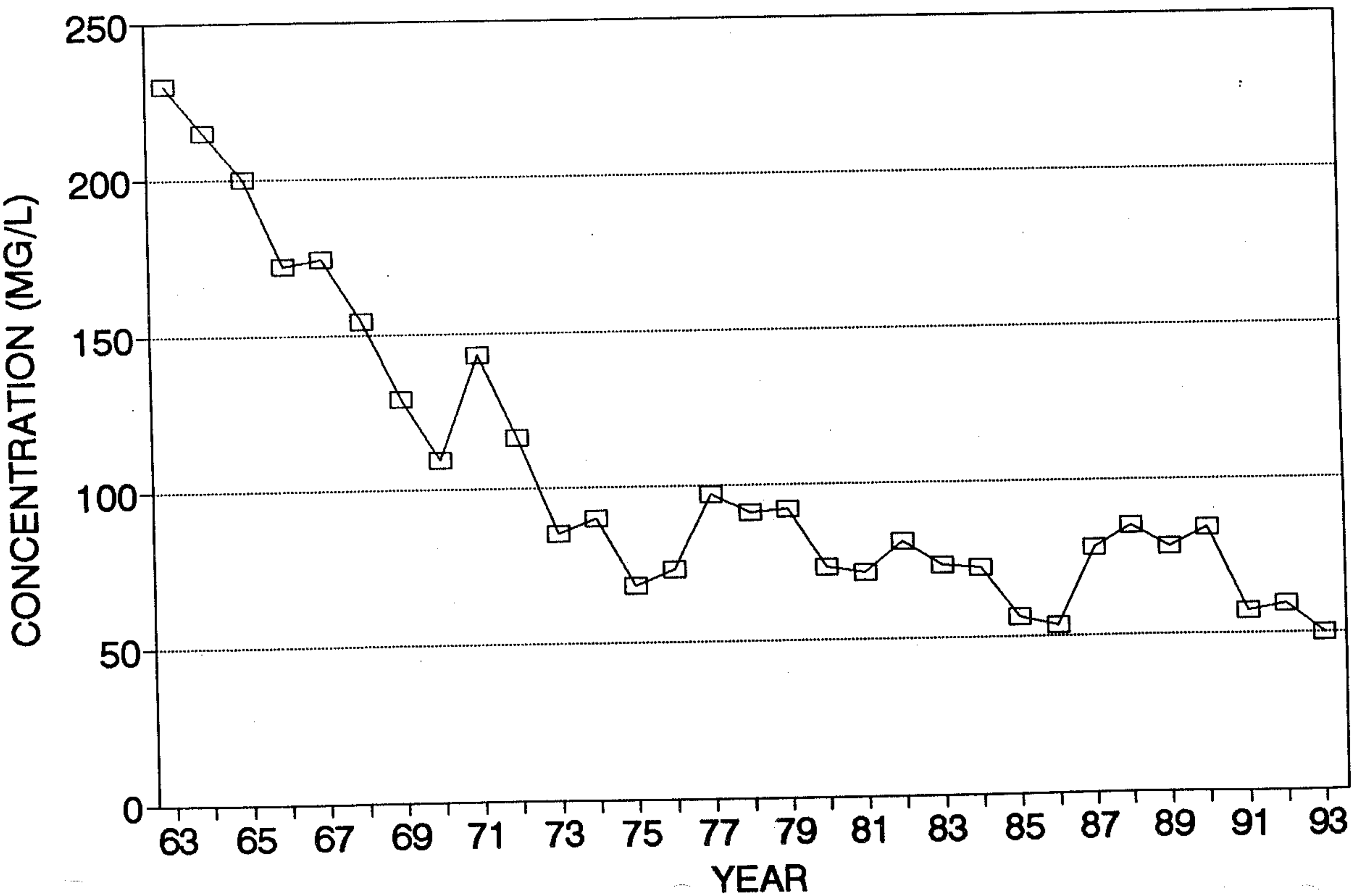
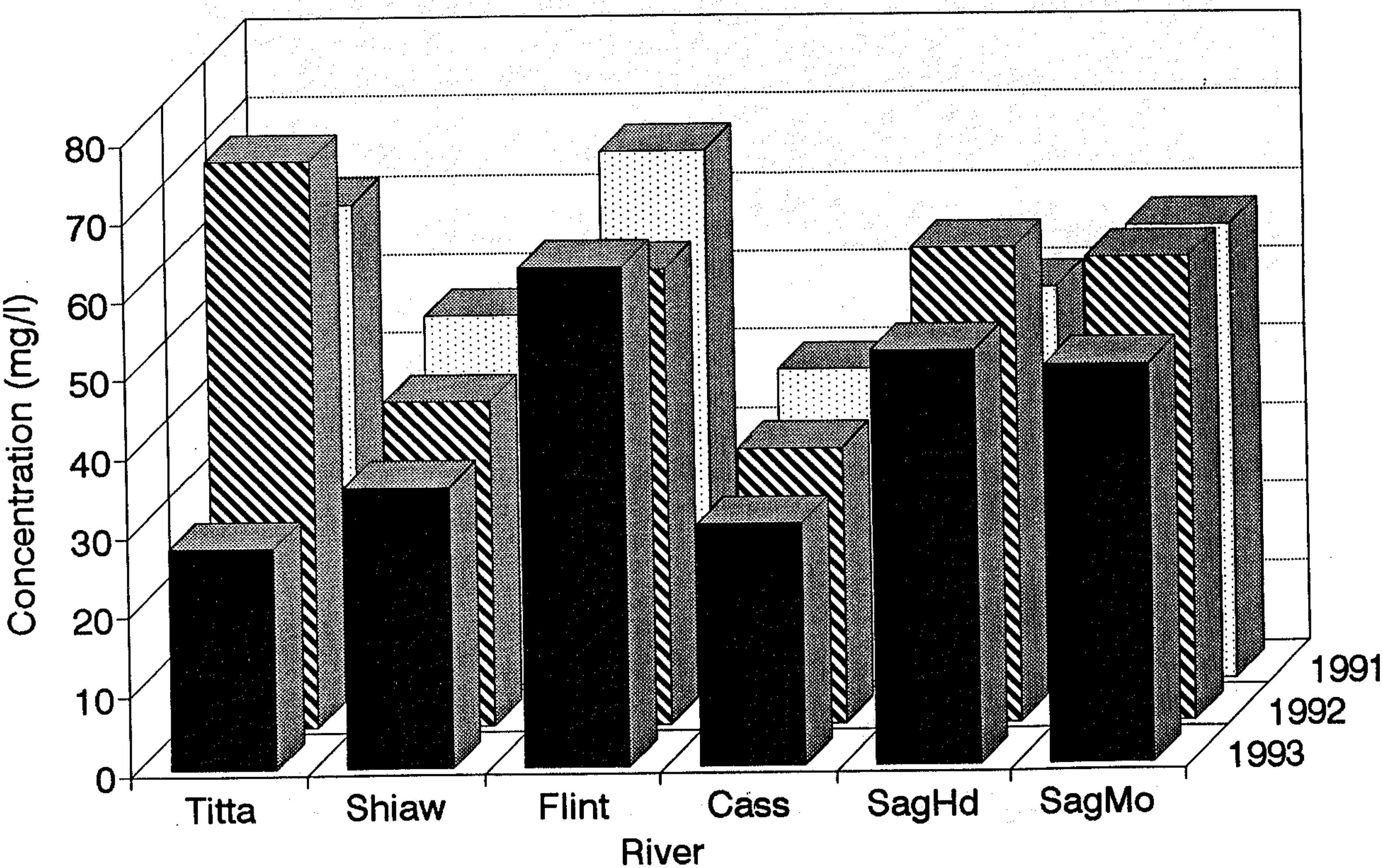


Figure III-36
98

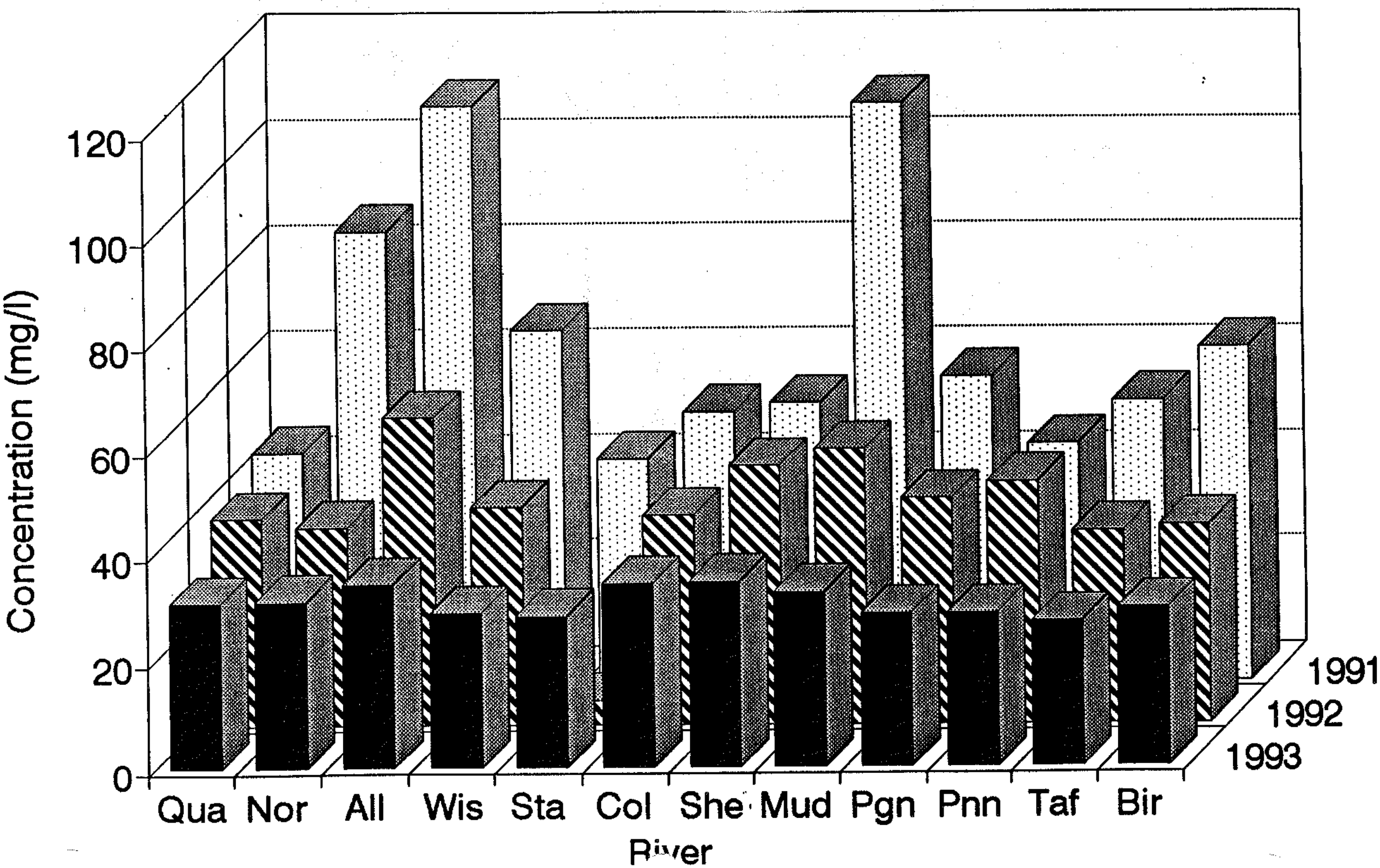
Saginaw River and its Tributaries

Total Chloride Concentration



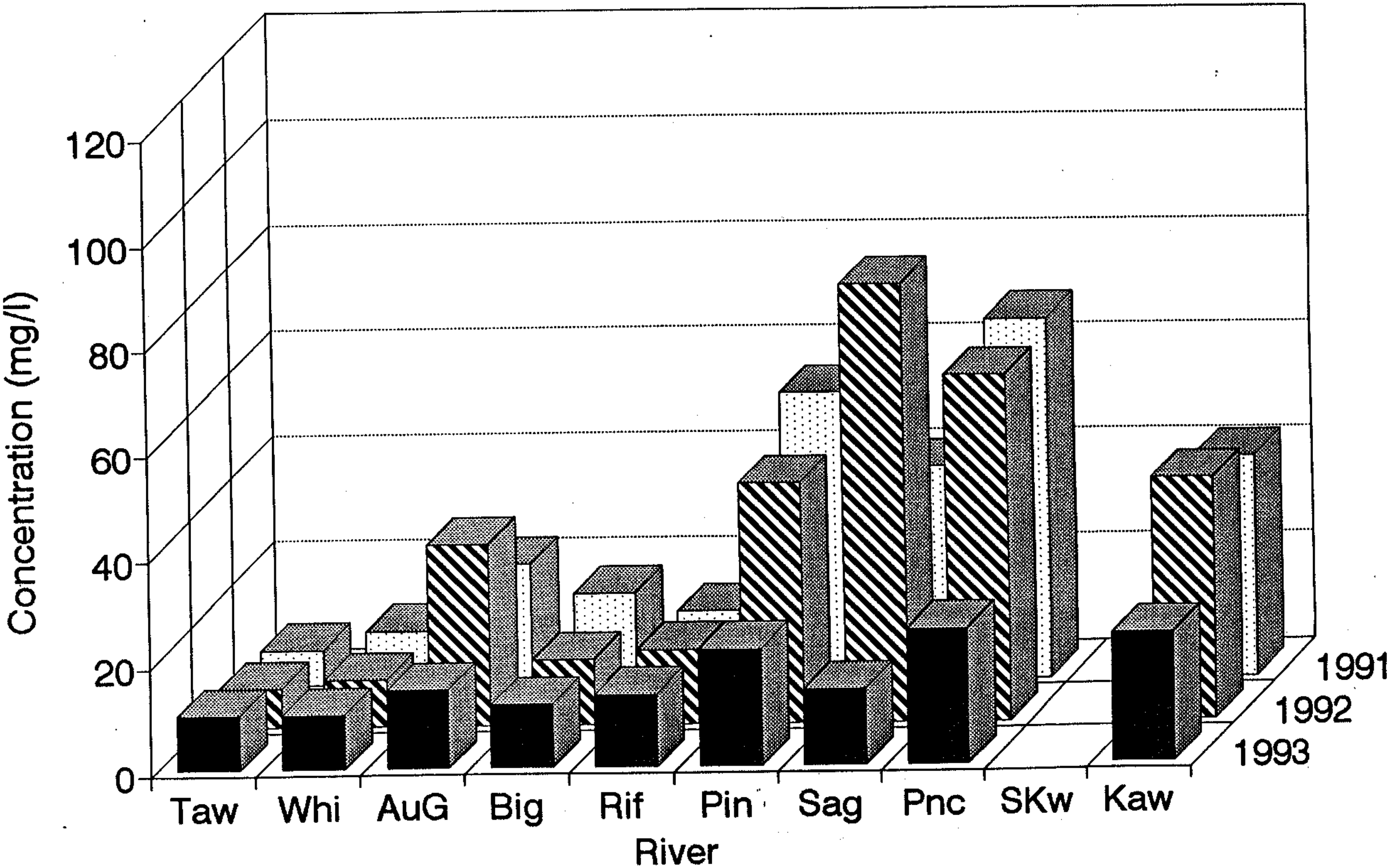
East Coastal Basin Tributaries

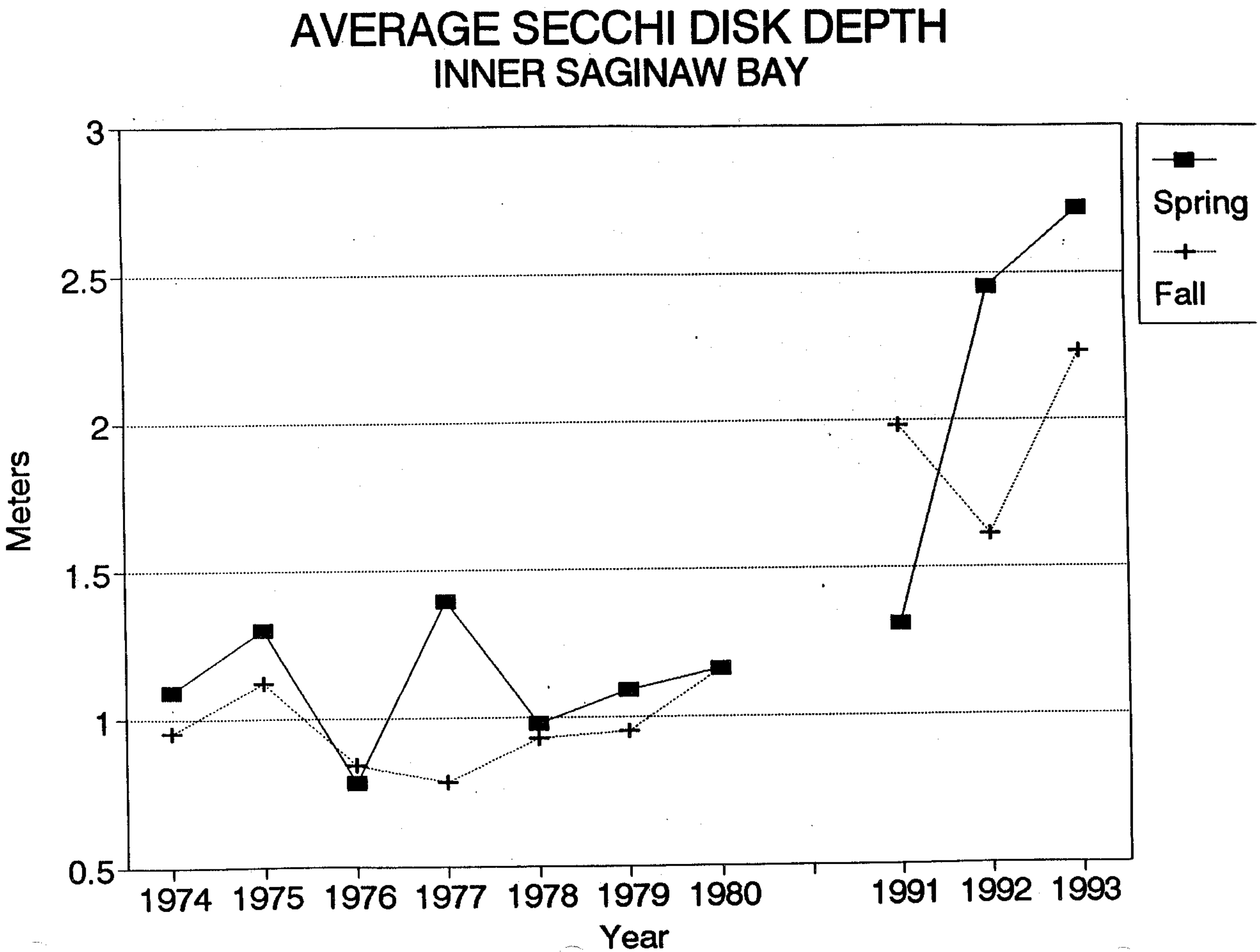
Total Chloride Concentration



West Coastal Basin Tributaries

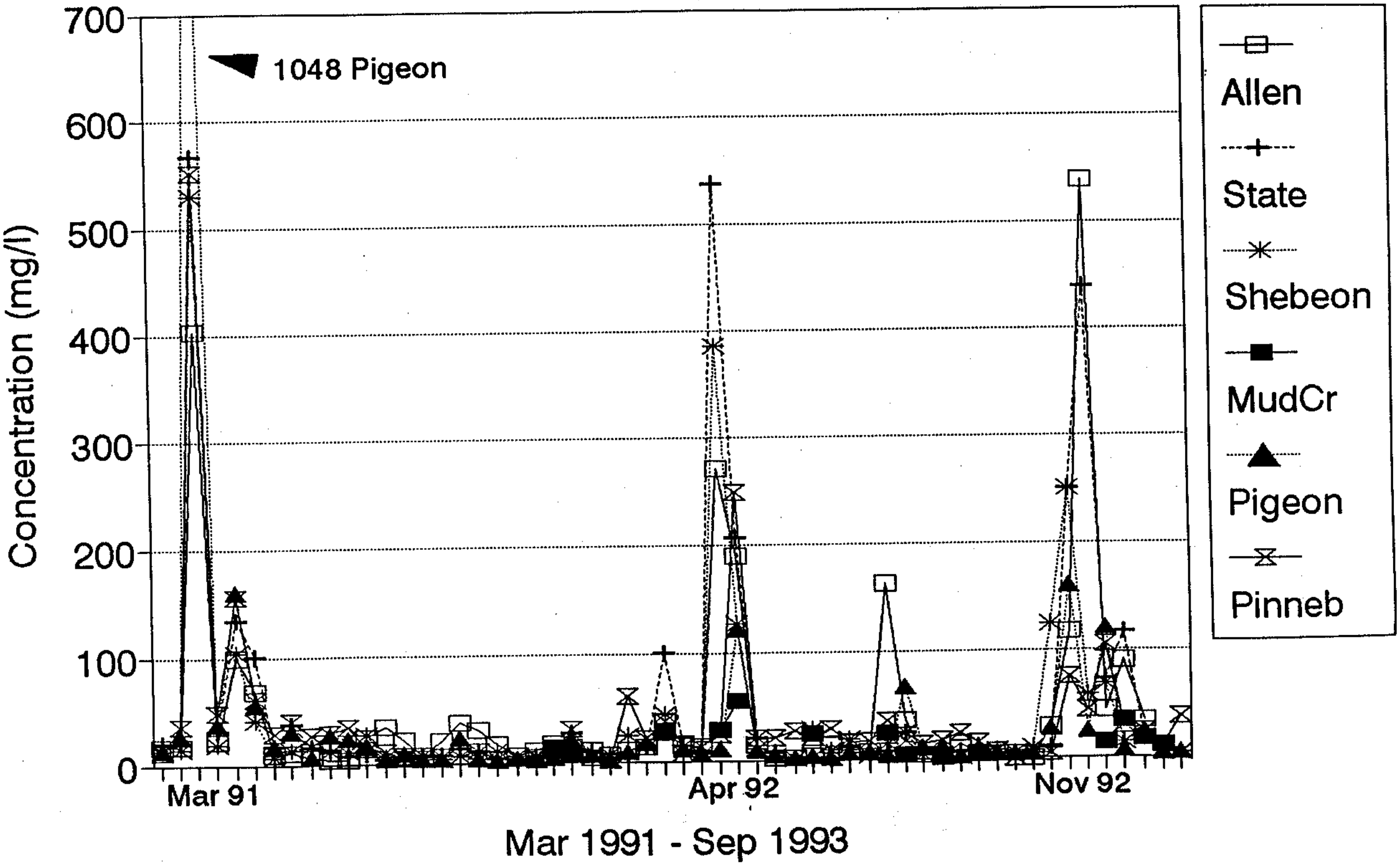
Total Chloride Concentration




AVERAGE SECCHI DISK DEPTH
INNER SAGINAW BAY
Meters
3
2.5
2
1.5
1
0.5
1974
1975
1976
1977
1978
1979
1980
1991
1992
1993
Year
Spring
Fall

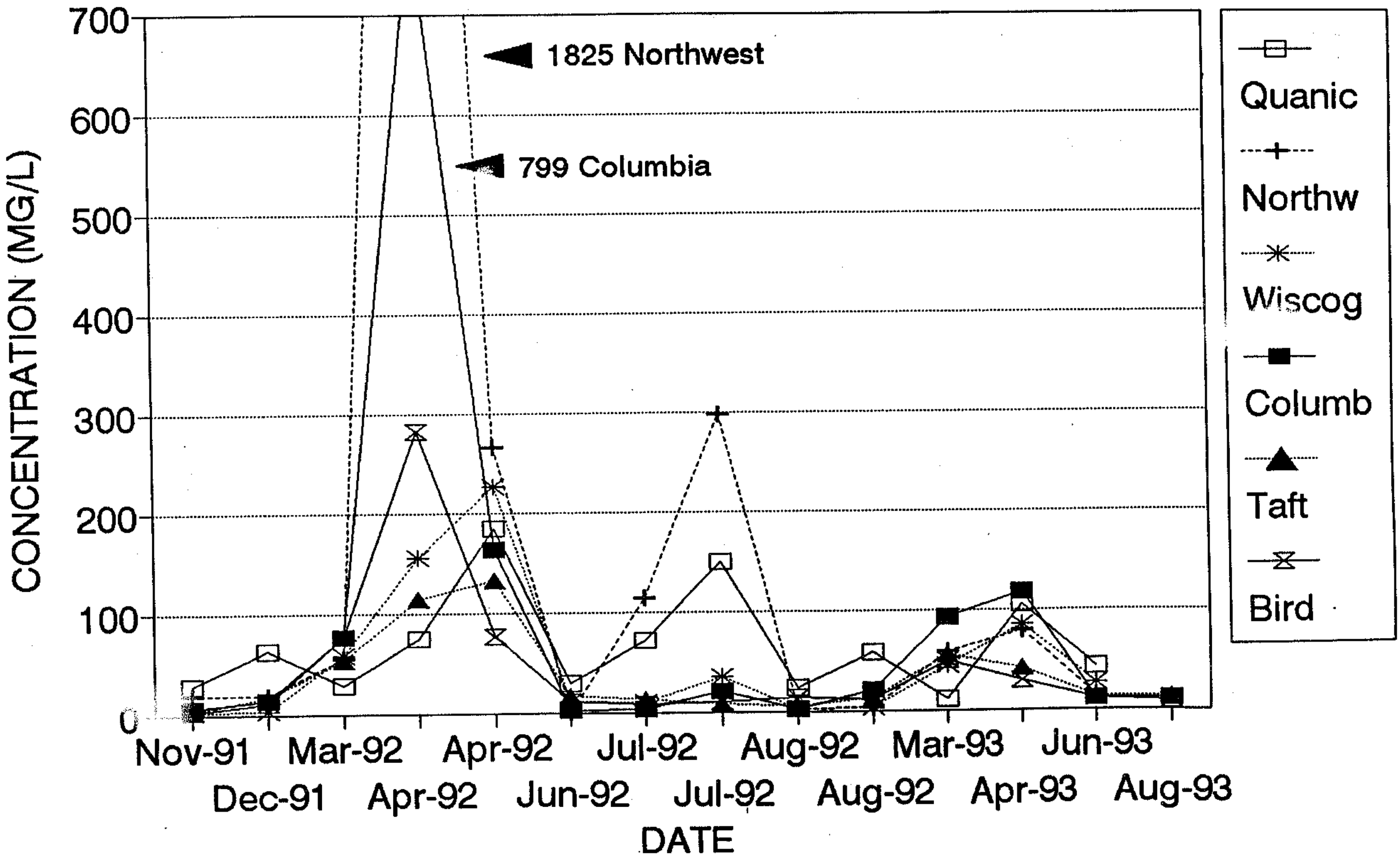
East Coastal Scheduled Stations

Total Suspended Solids



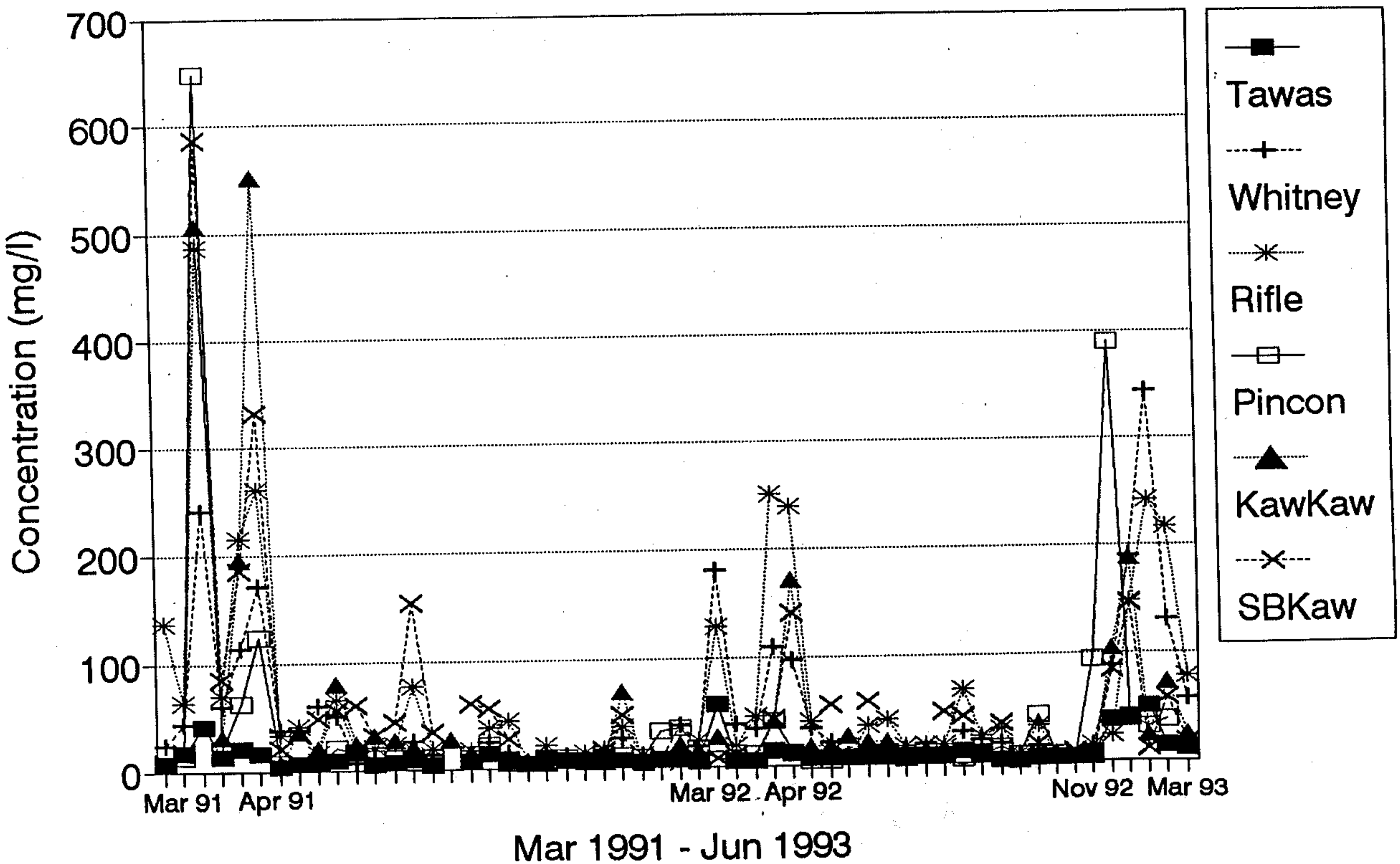
East Coastal Event Stations

Total Suspended Solids

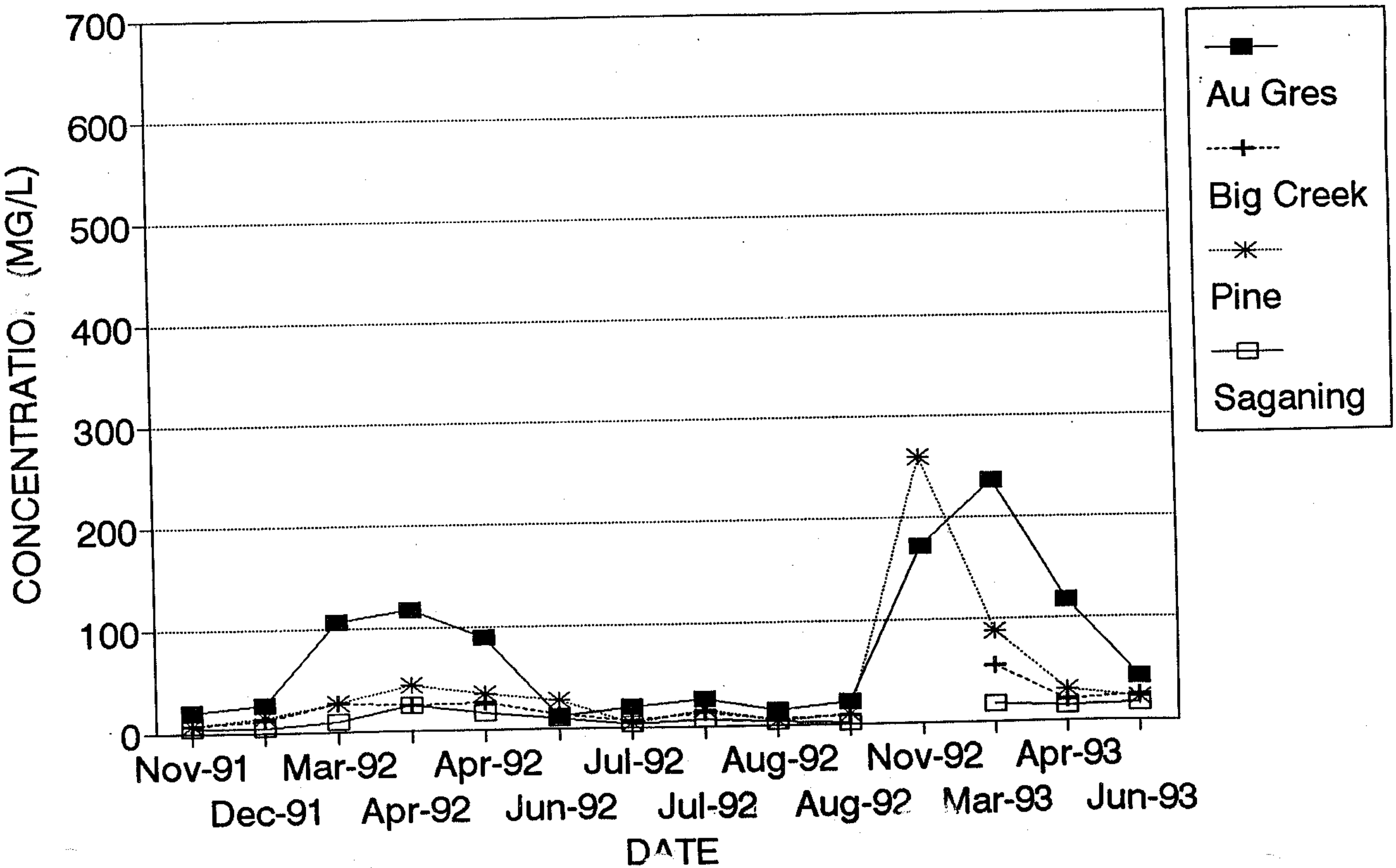


West Coastal Scheduled Stations

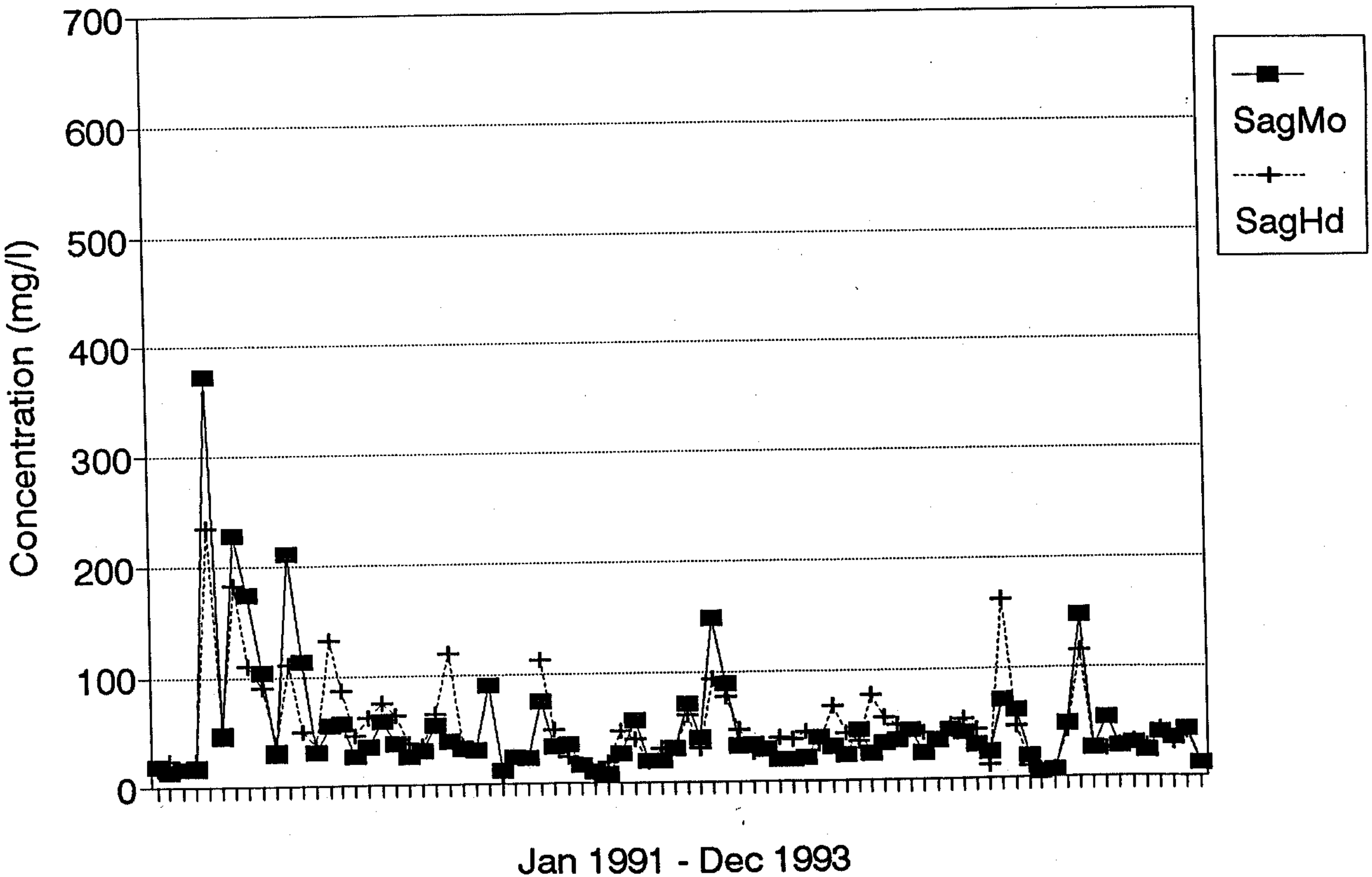
Total Suspended Solids



West Coastal Event Stations
Total Suspended Solids

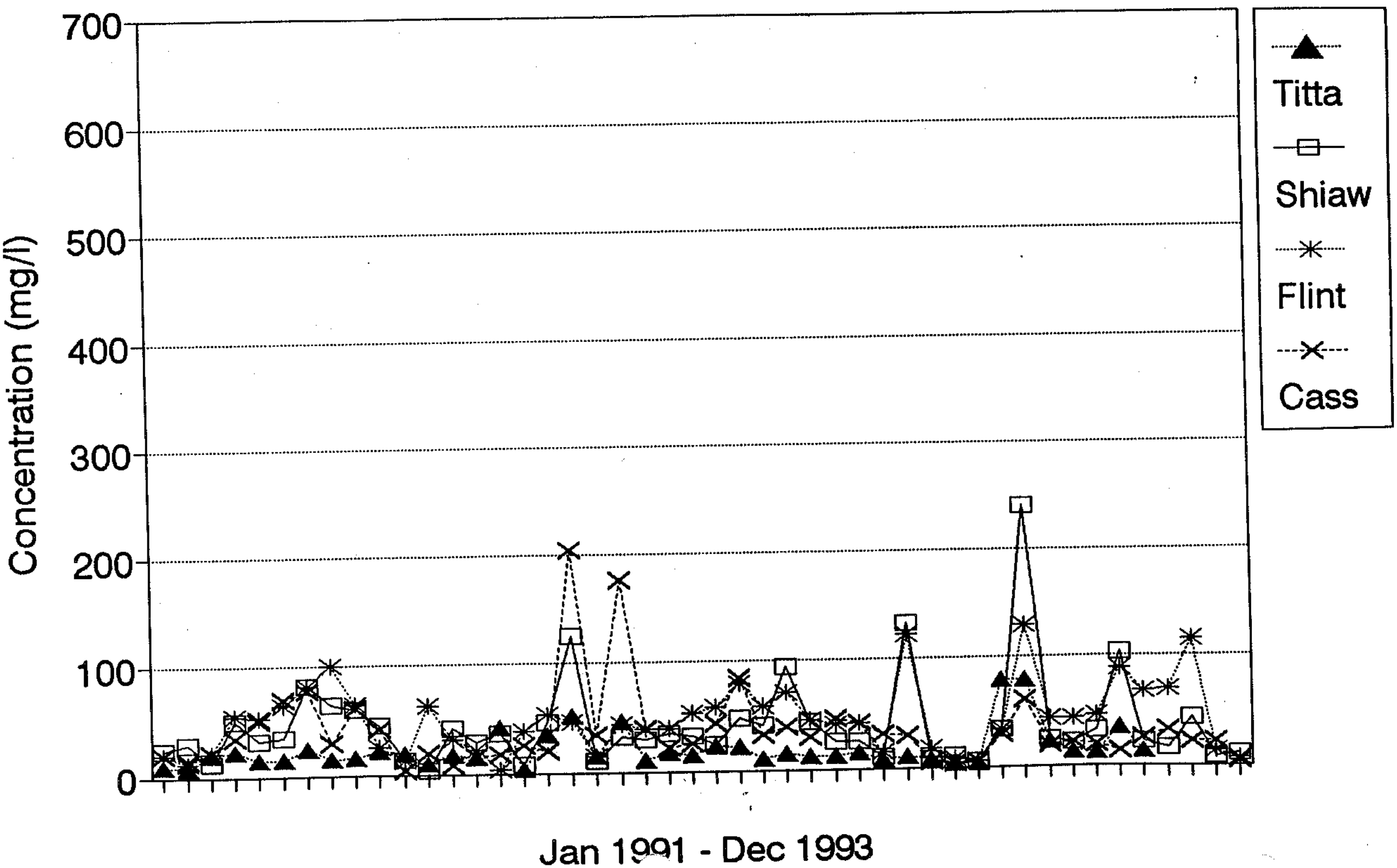


Saginaw River
Total Suspended Solids



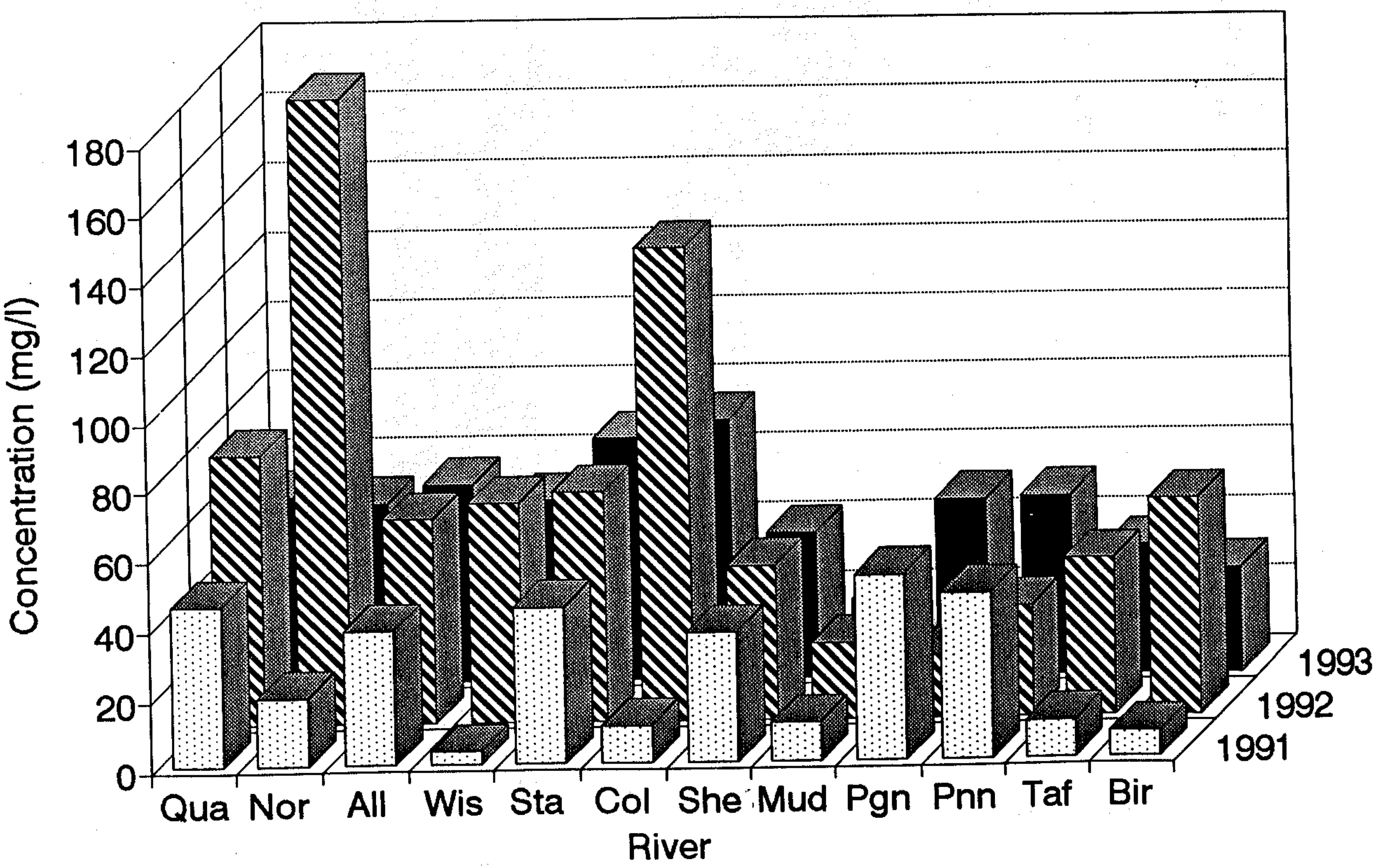
Saginaw River Tributaries

Total Suspended Solids

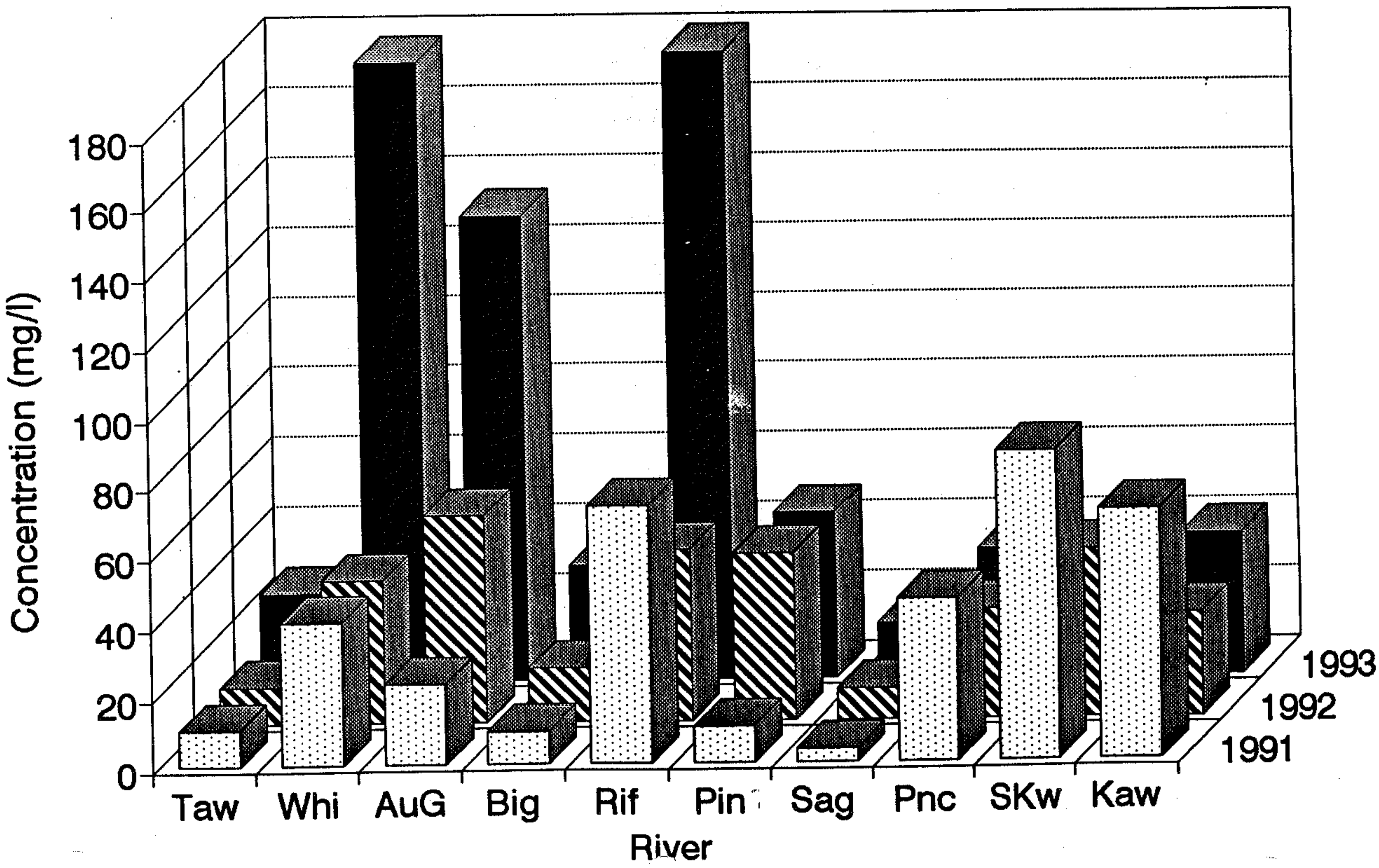


East Coastal Basin Tributaries

Suspended Solids Concentrations

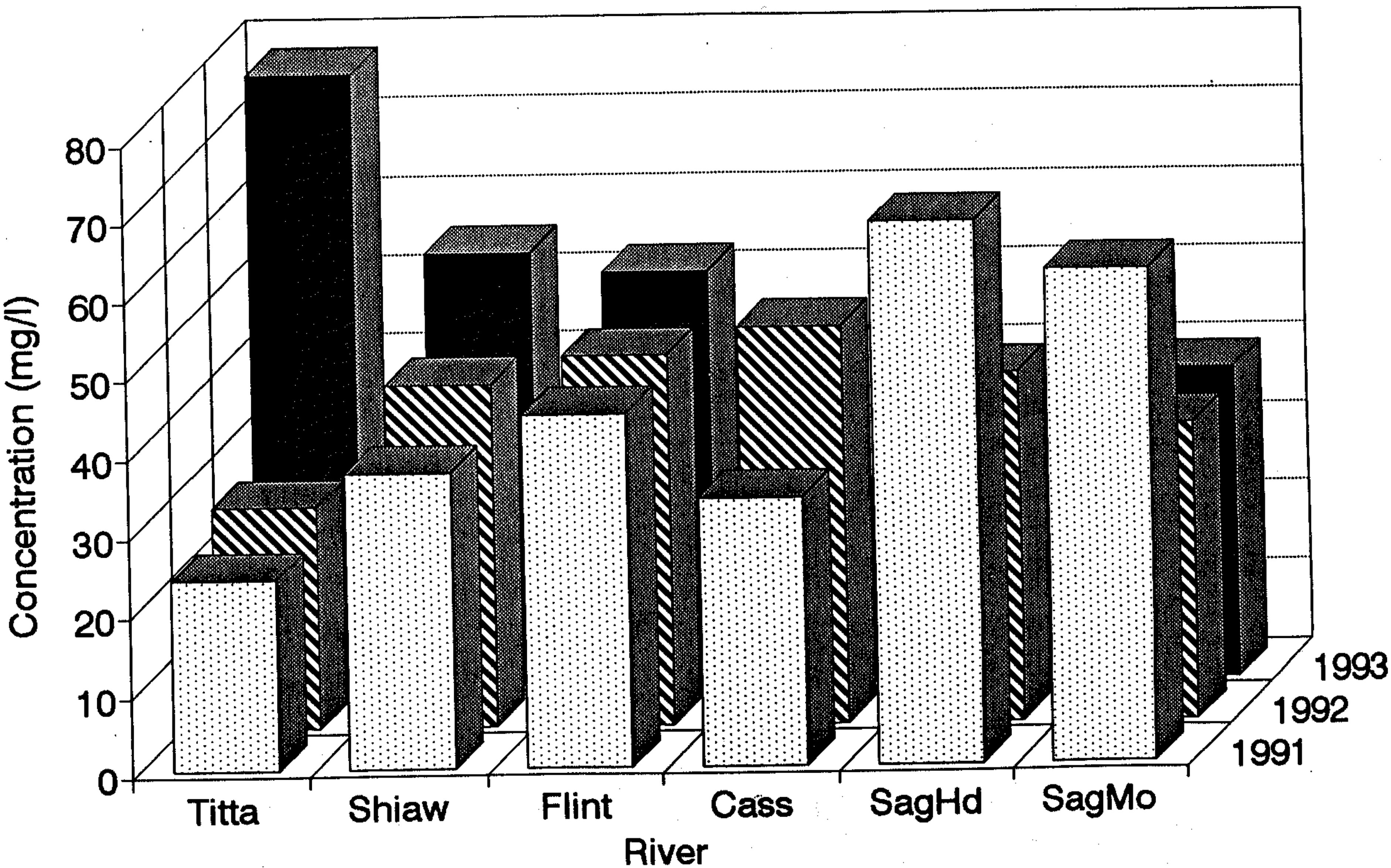


West Coastal Basin Tributaries
Suspended Solids Concentrations



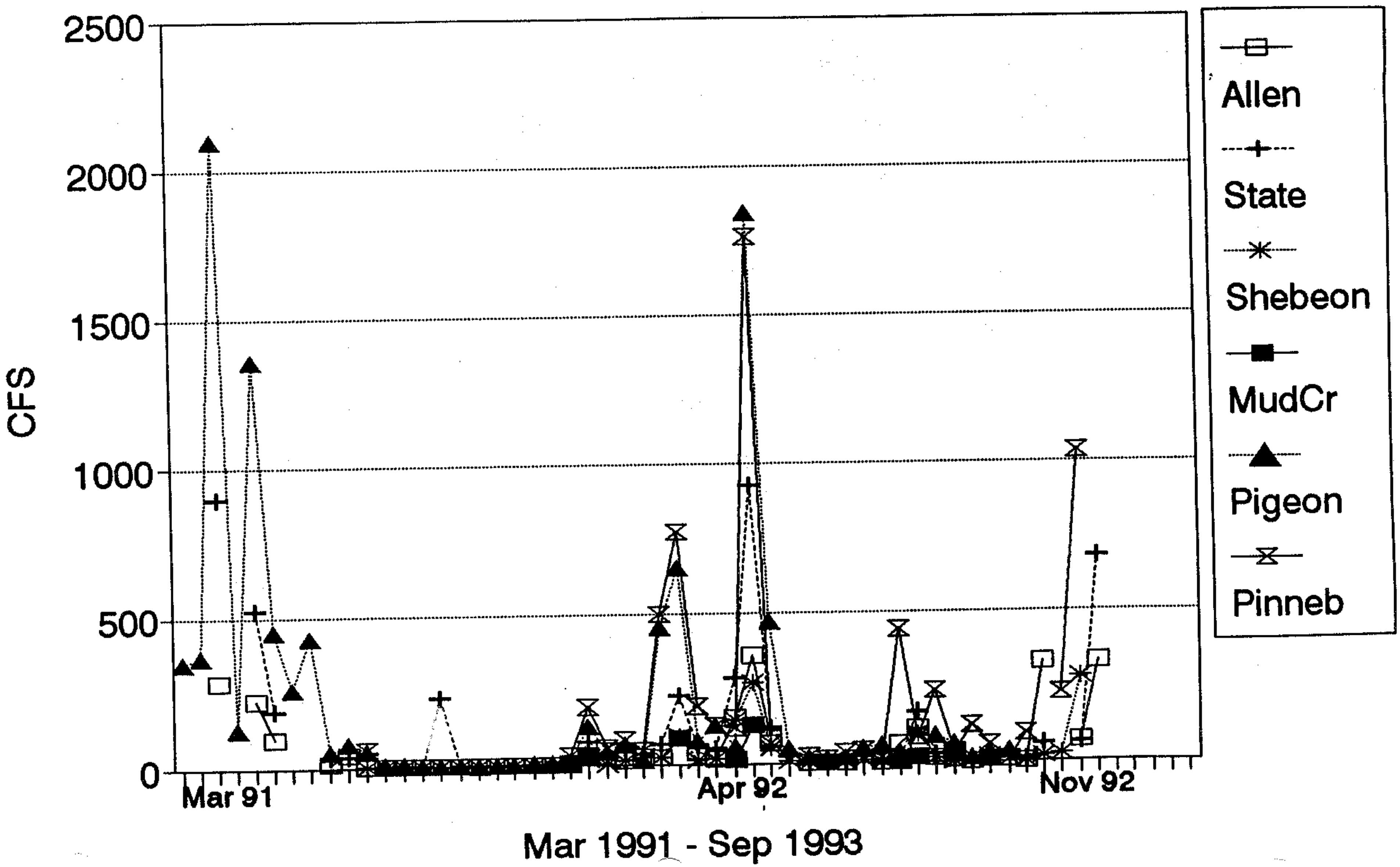
Saginaw River and its Tributaries

Suspended Solids Concentrations



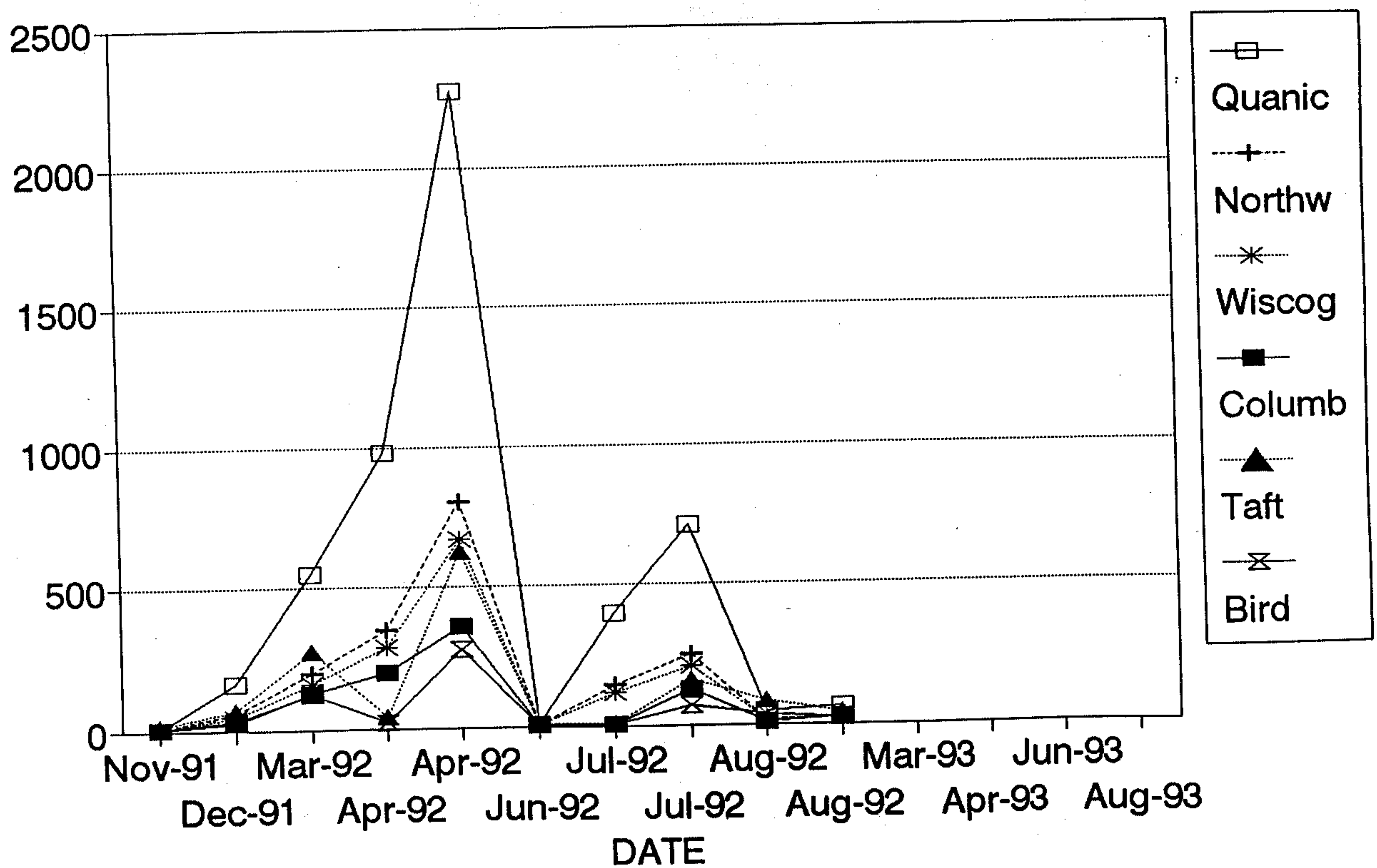
East Coastal Scheduled Stations

Flow



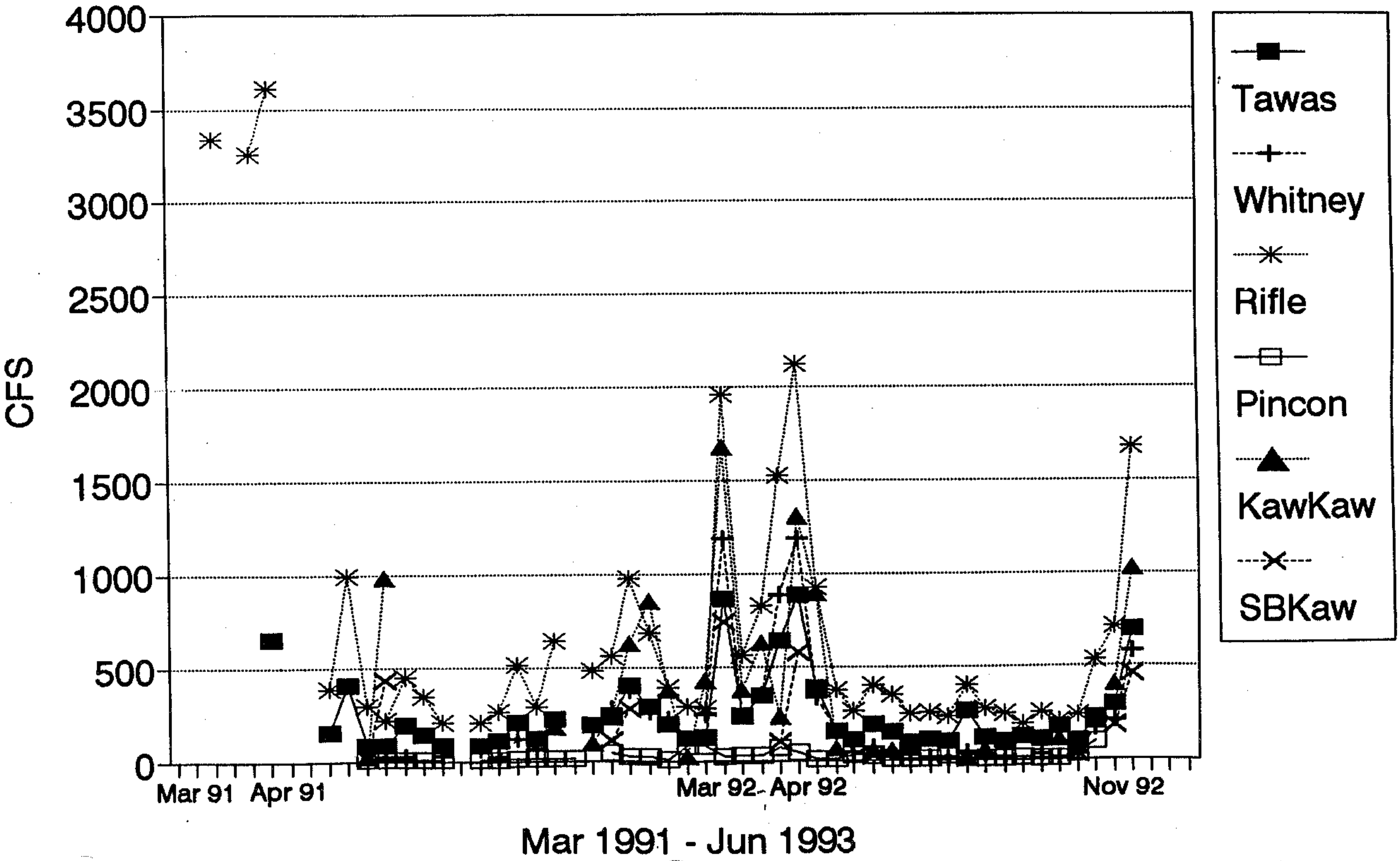
East Coastal Event Stations

Flow

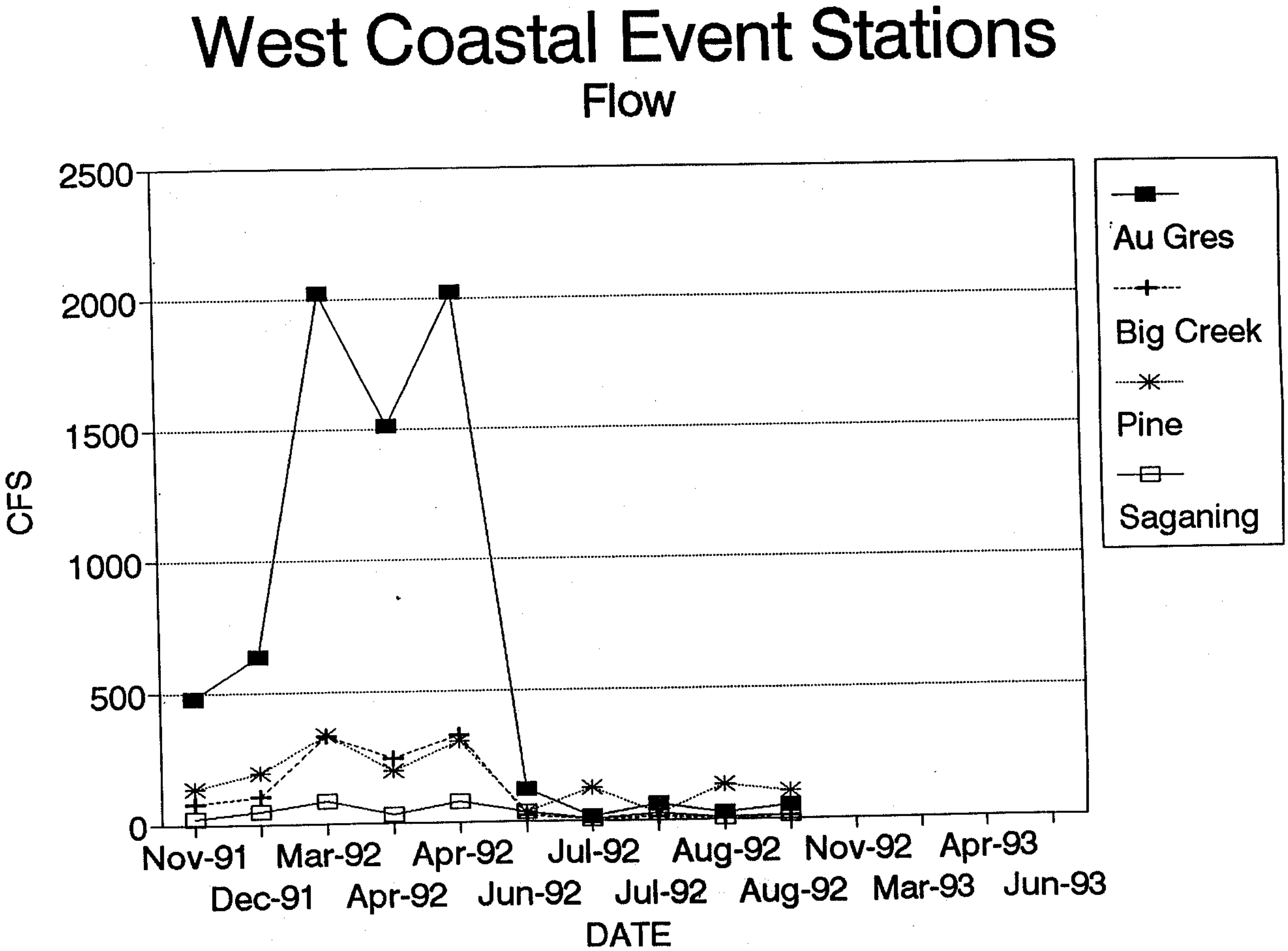


West Coastal Scheduled Stations

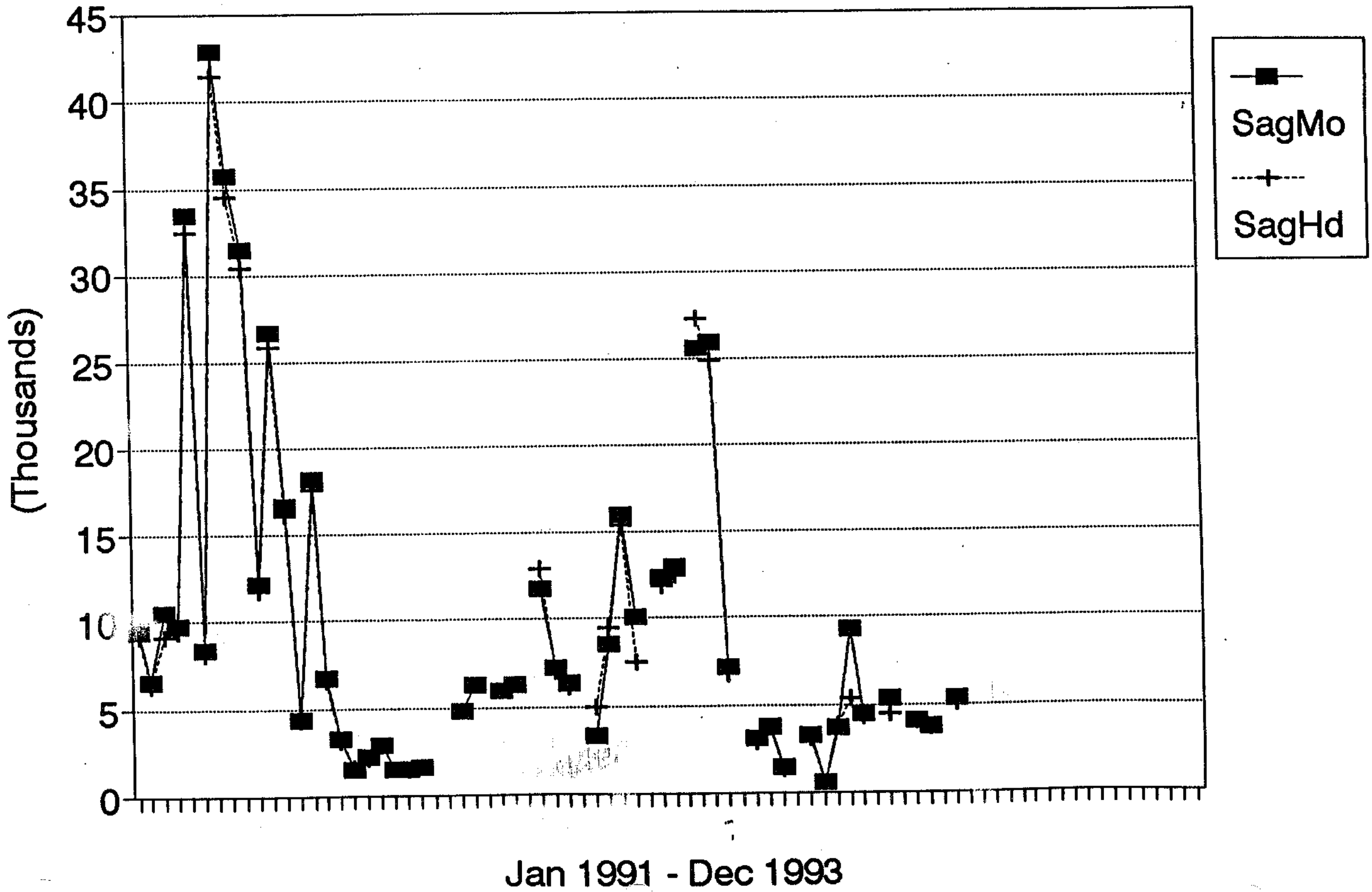
Flow



114


West Coastal Event Stations
Flow
CFS
2500
2000
1500
1000
500
0
Nov-91
Dec-91
Mar-92
Apr-92
Apr-92
Jun-92
Jul-92
Jul-92
Aug-92
Aug-92
Nov-92
Mar-93
Apr-93
Jun-93
DATE
Au Gres
Big Creek
Pine
Saganing

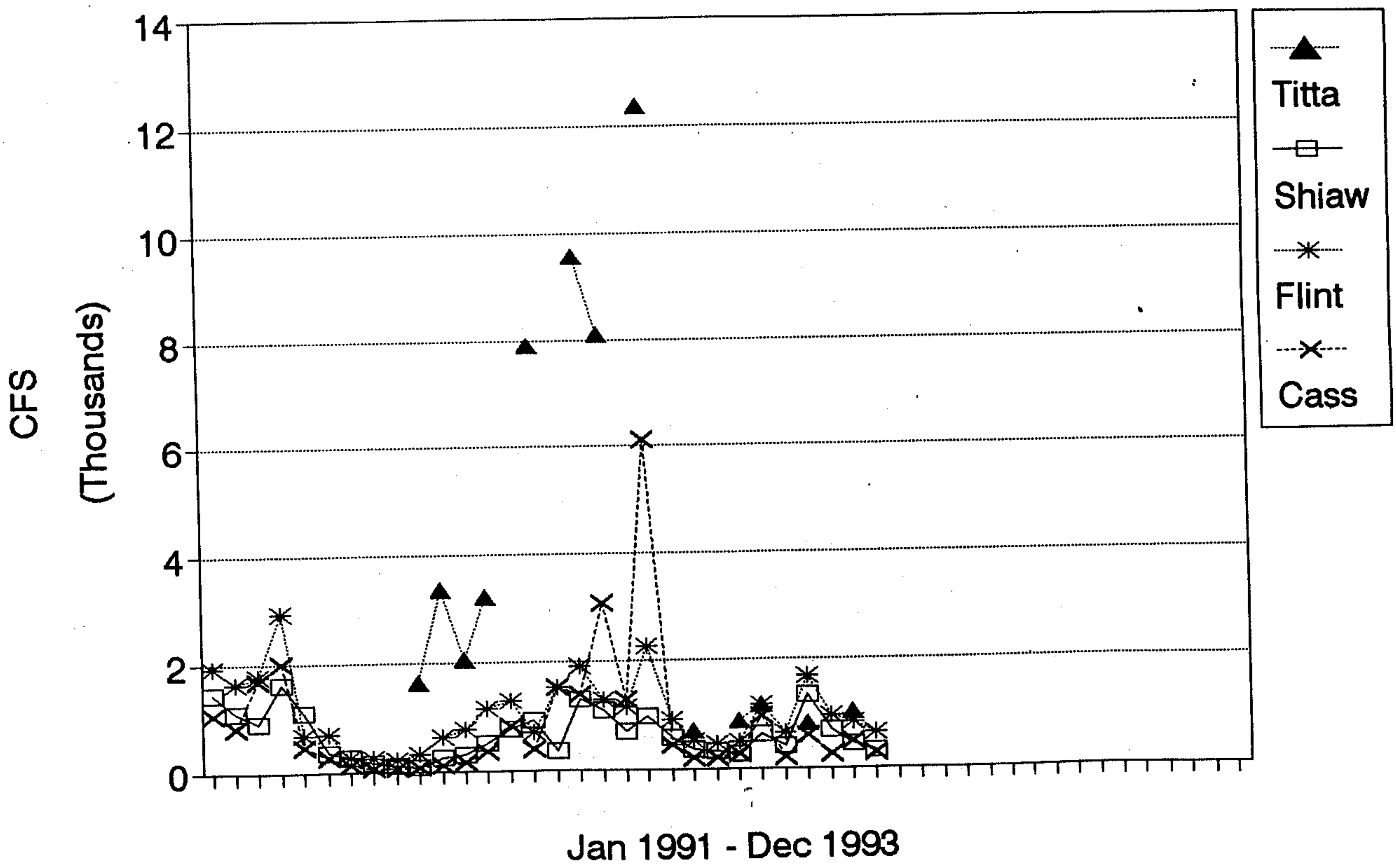
Saginaw River
Flow



9/6

Saginaw River Tributaries

Flow



117

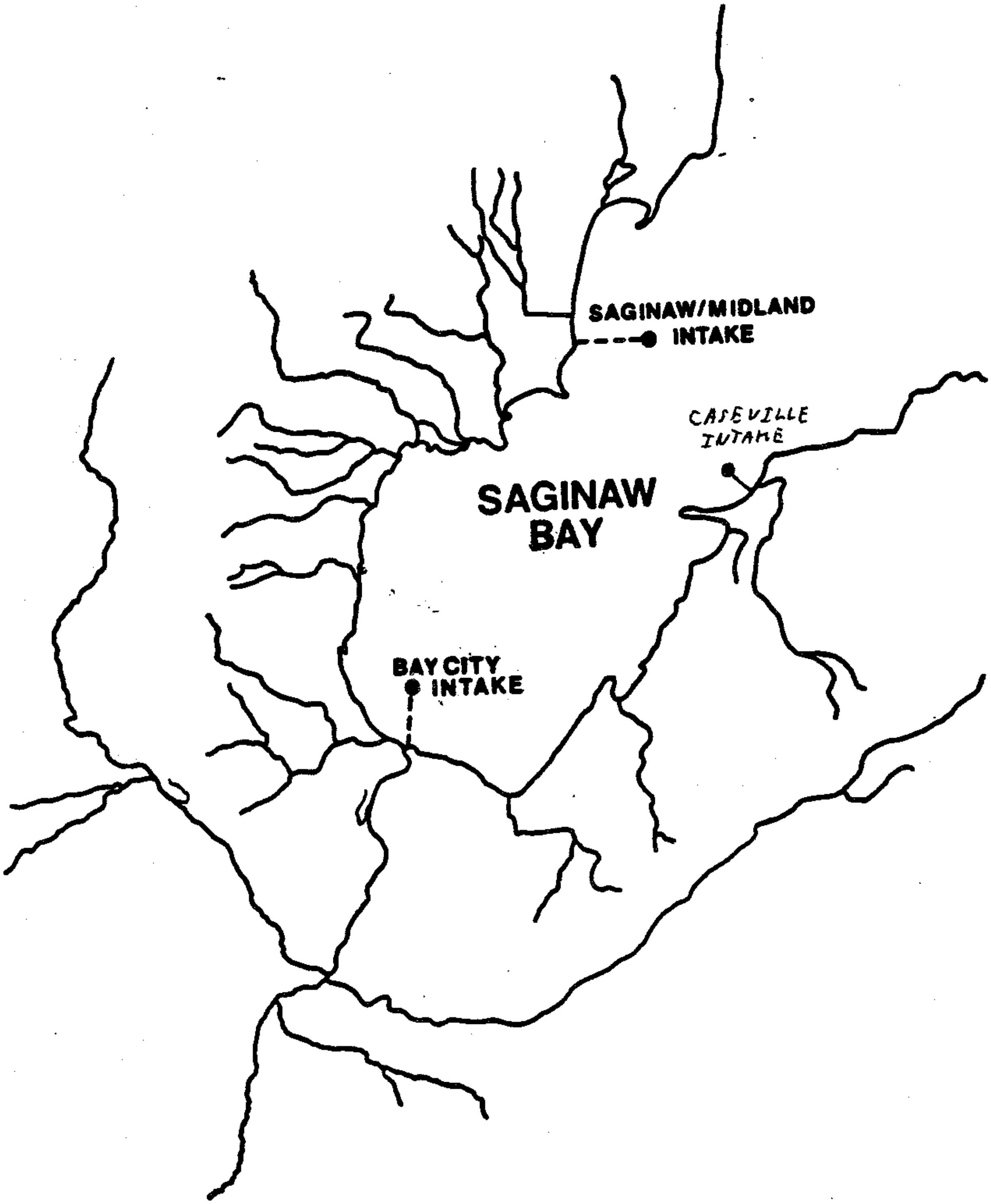


Figure III-10. Public drinking water supply intakes, Saginaw Bay, Lake Huron (USEPA, 1985).

AVERAGE TOTAL PHOSPHORUS CONCENTRATIONS
INNER SAGINAW BAY

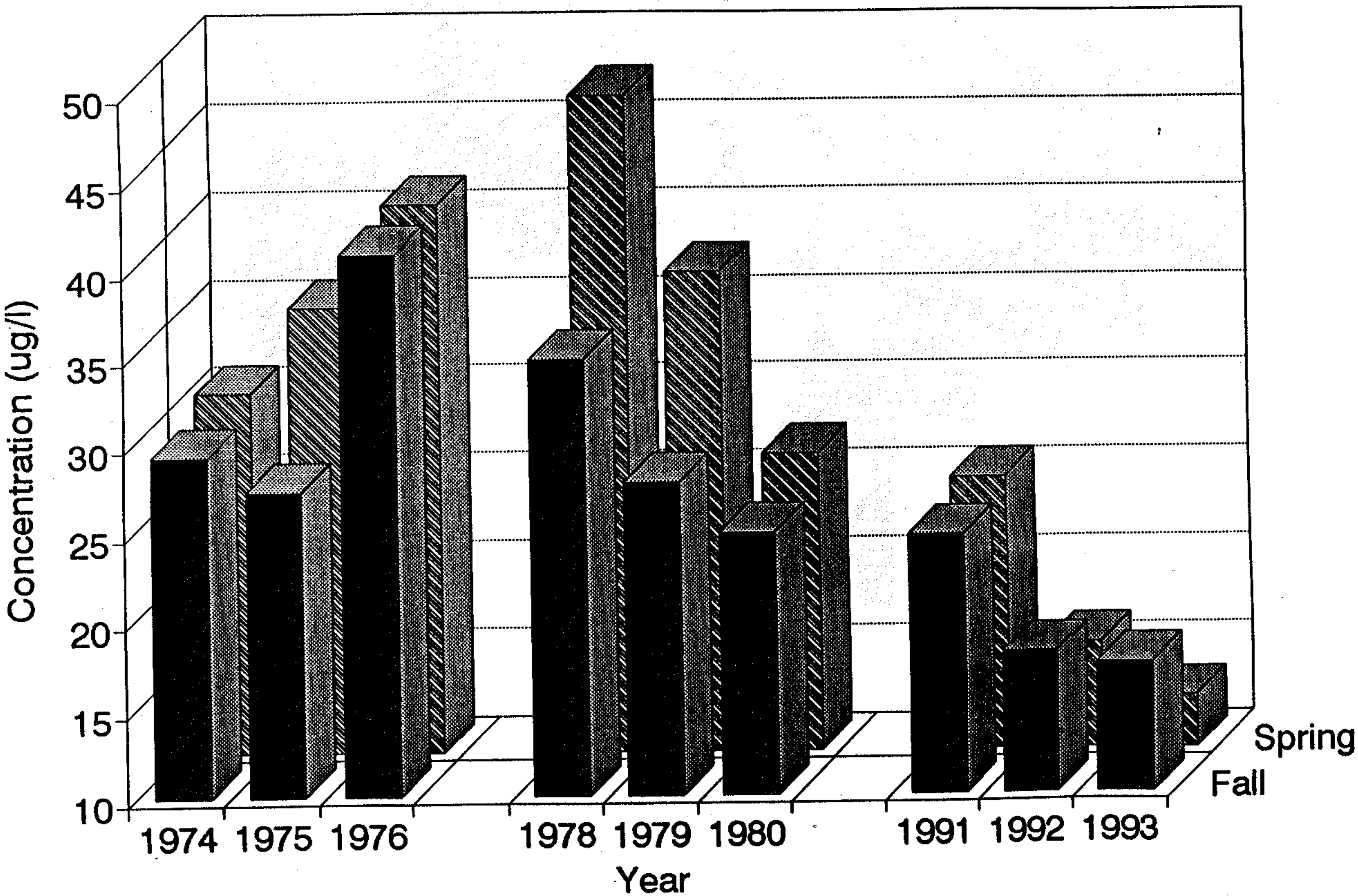
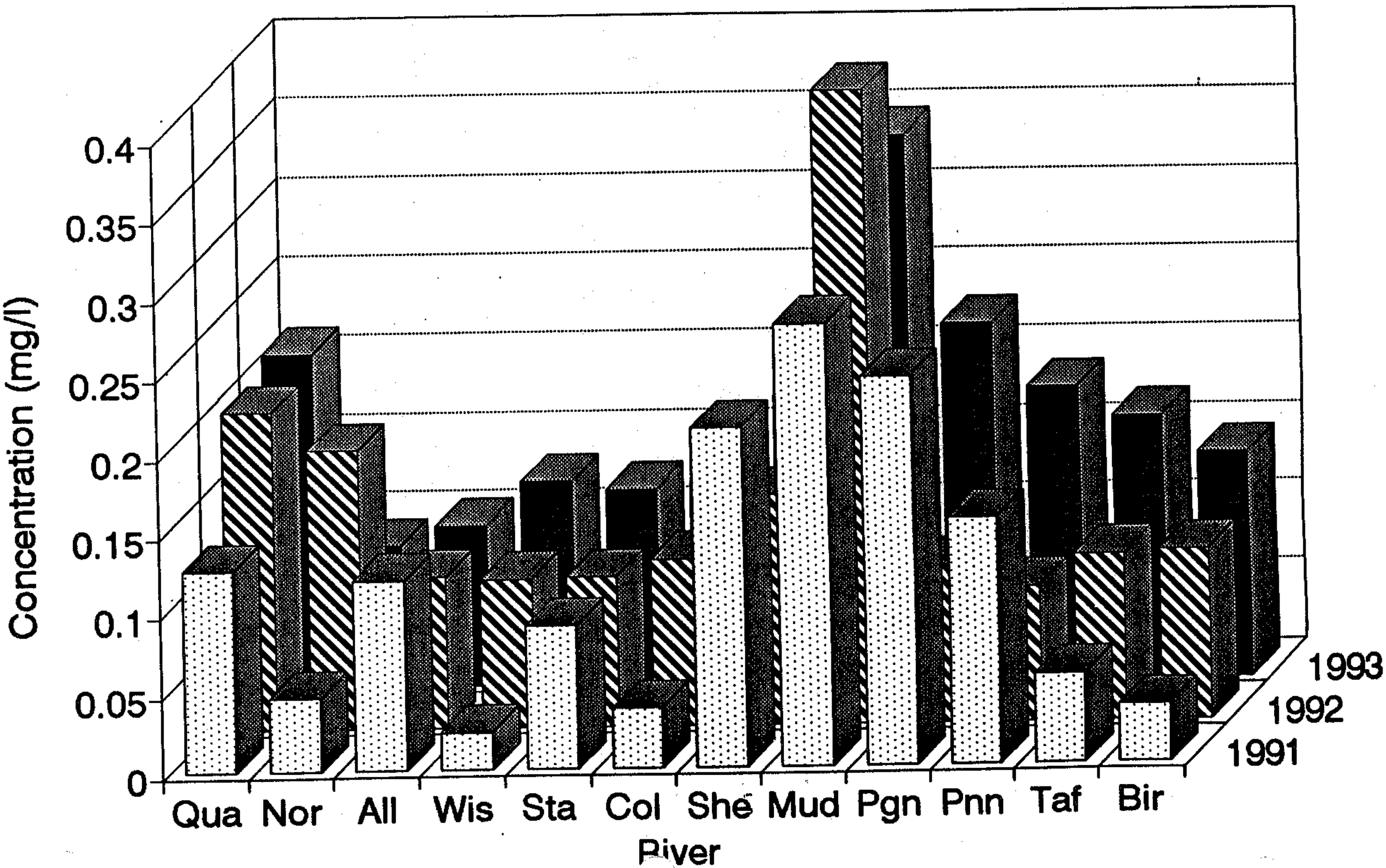


Figure III-6

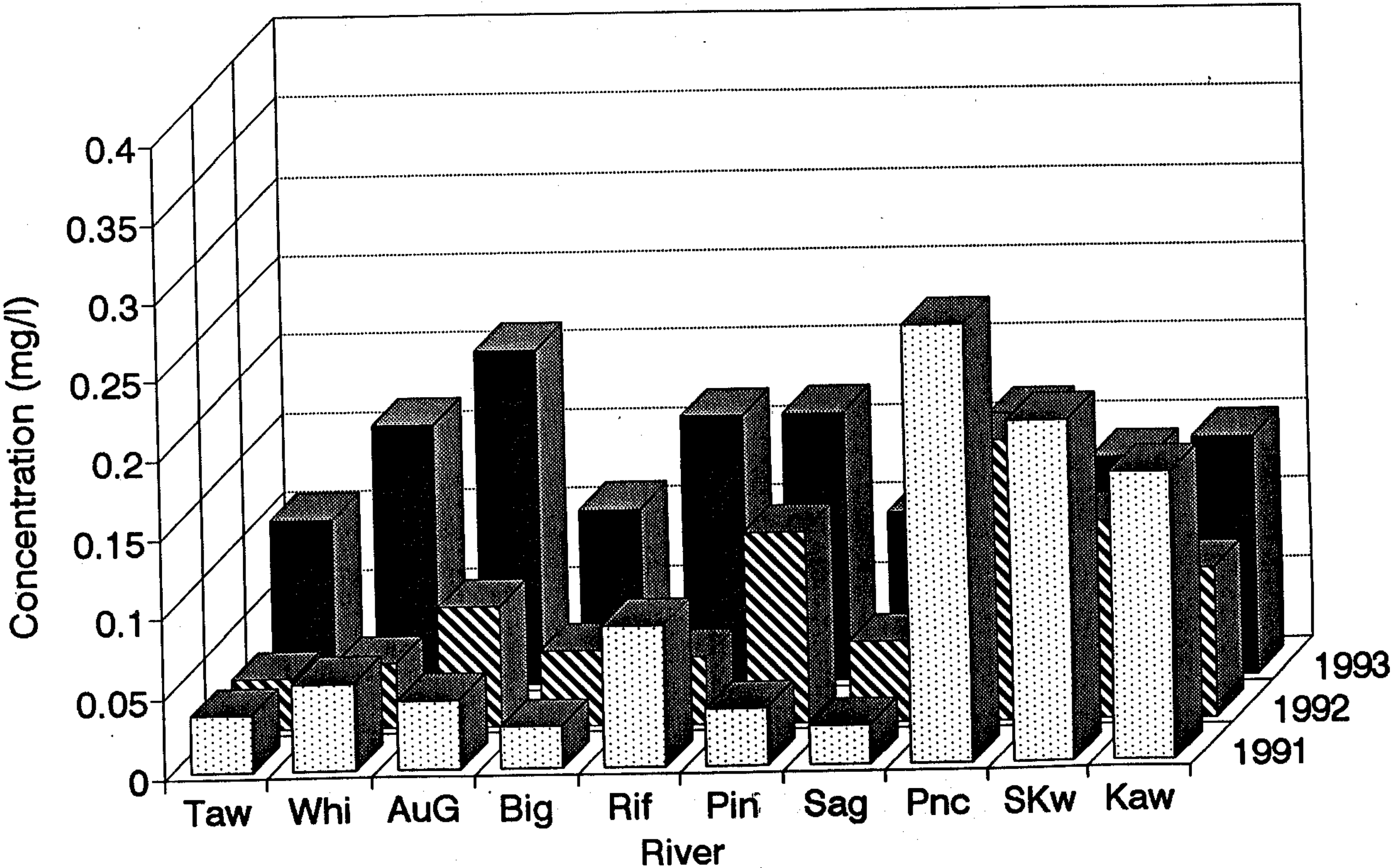
East Coastal Basin Tributaries

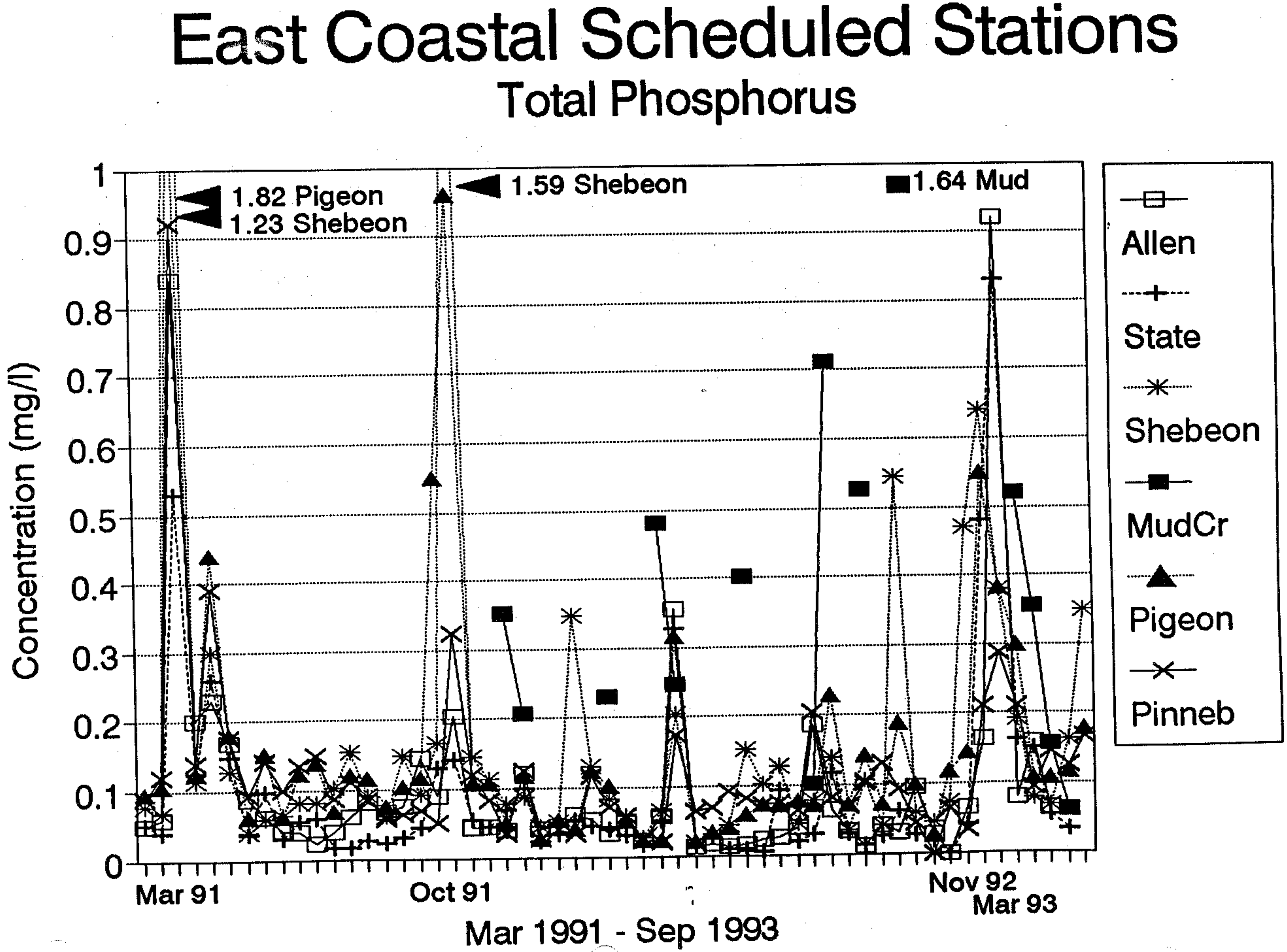
Total Phosphorus Concentrations

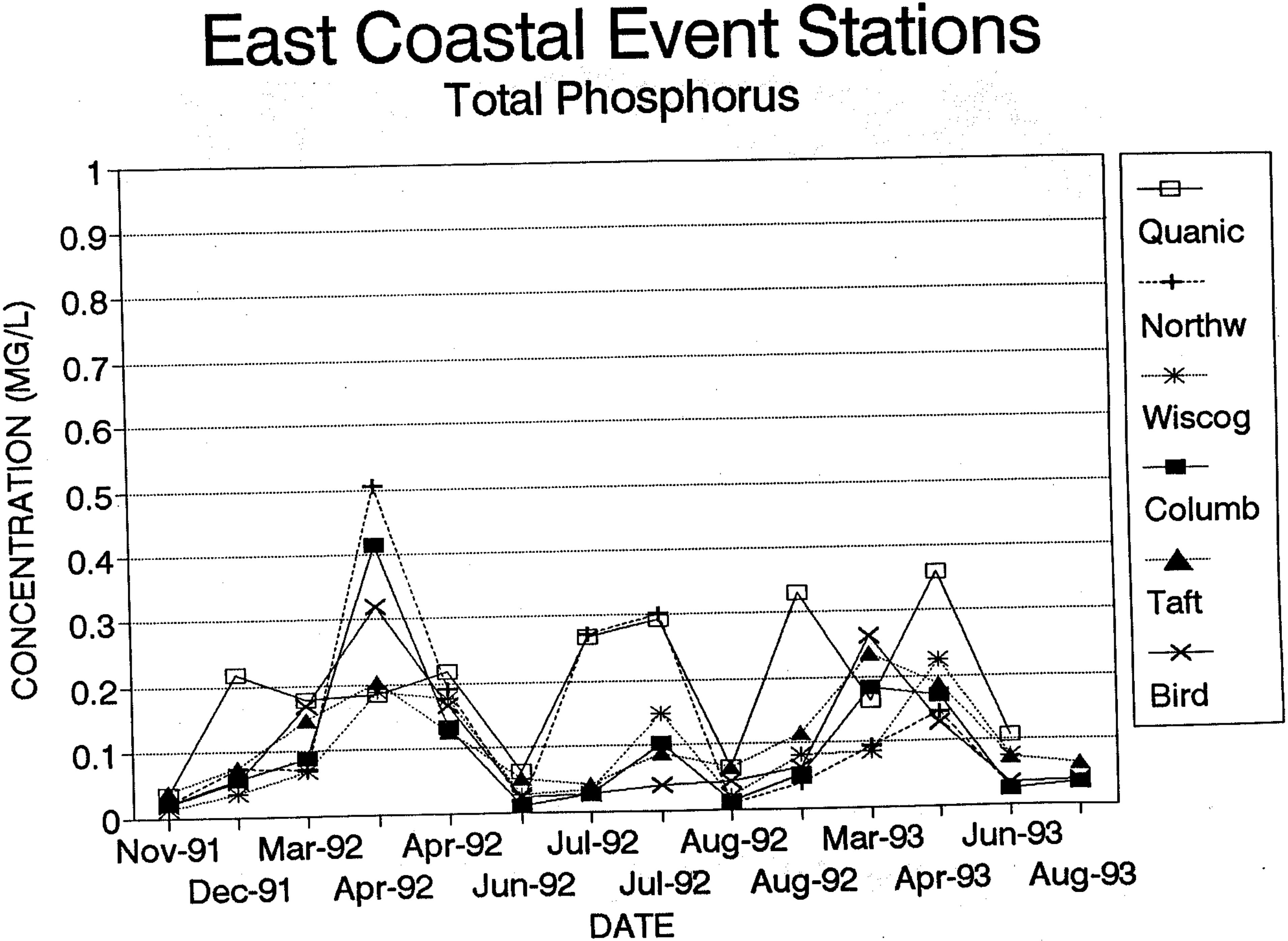


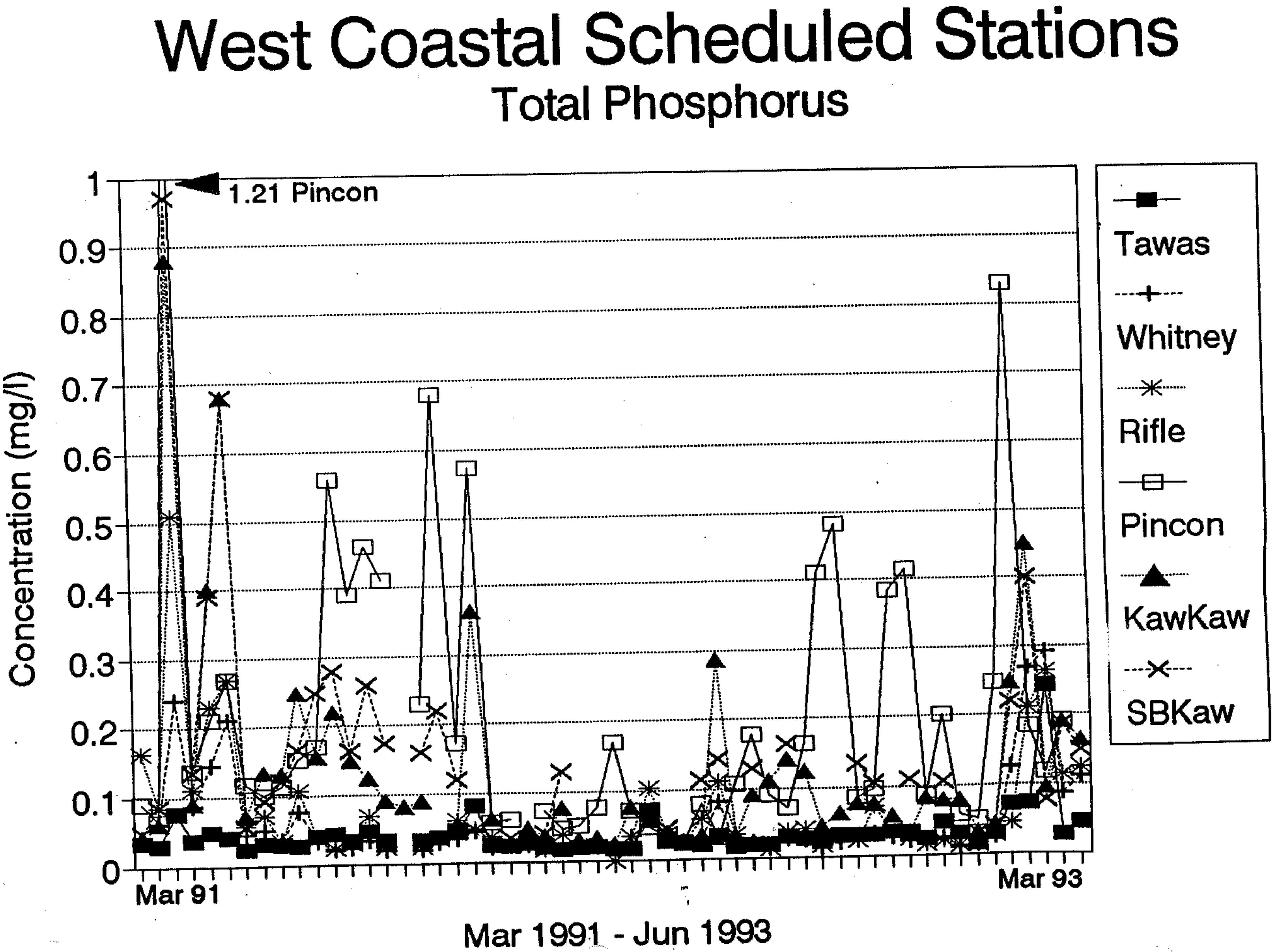
West Coastal Basin Tributaries

Total Phosphorus Concentrations

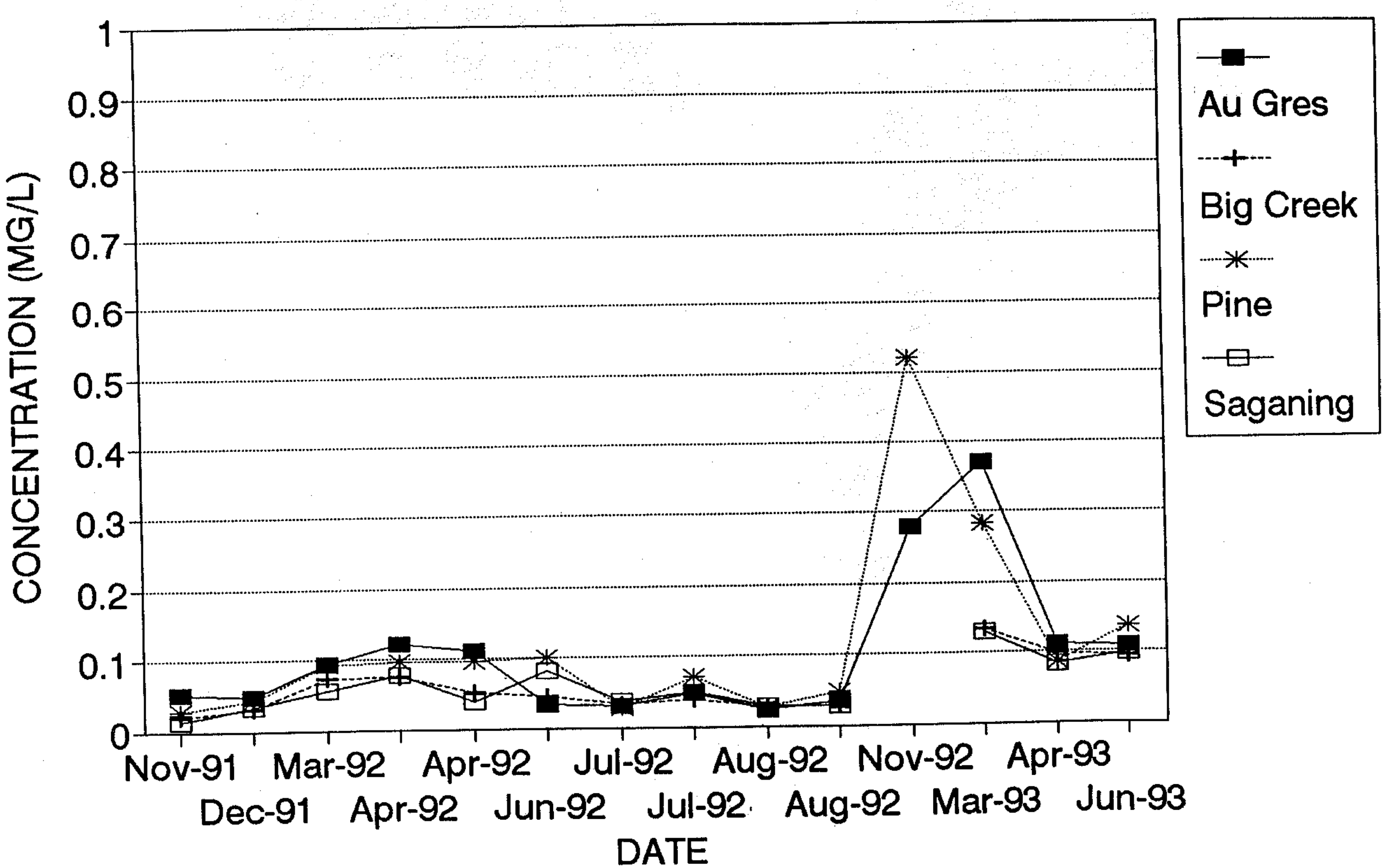



East Coastal Scheduled Stations
Total Phosphorus
Concentration (mg/l)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1.82 Pigeon
1.23 Shebeon
1.59 Shebeon
1.64 Mud
Mar 91
Oct 91
Nov 92
Mar 93
Mar 1991 - Sep 1993
Allen
State
Shebeon
MudCr
Pigeon
Pinneb

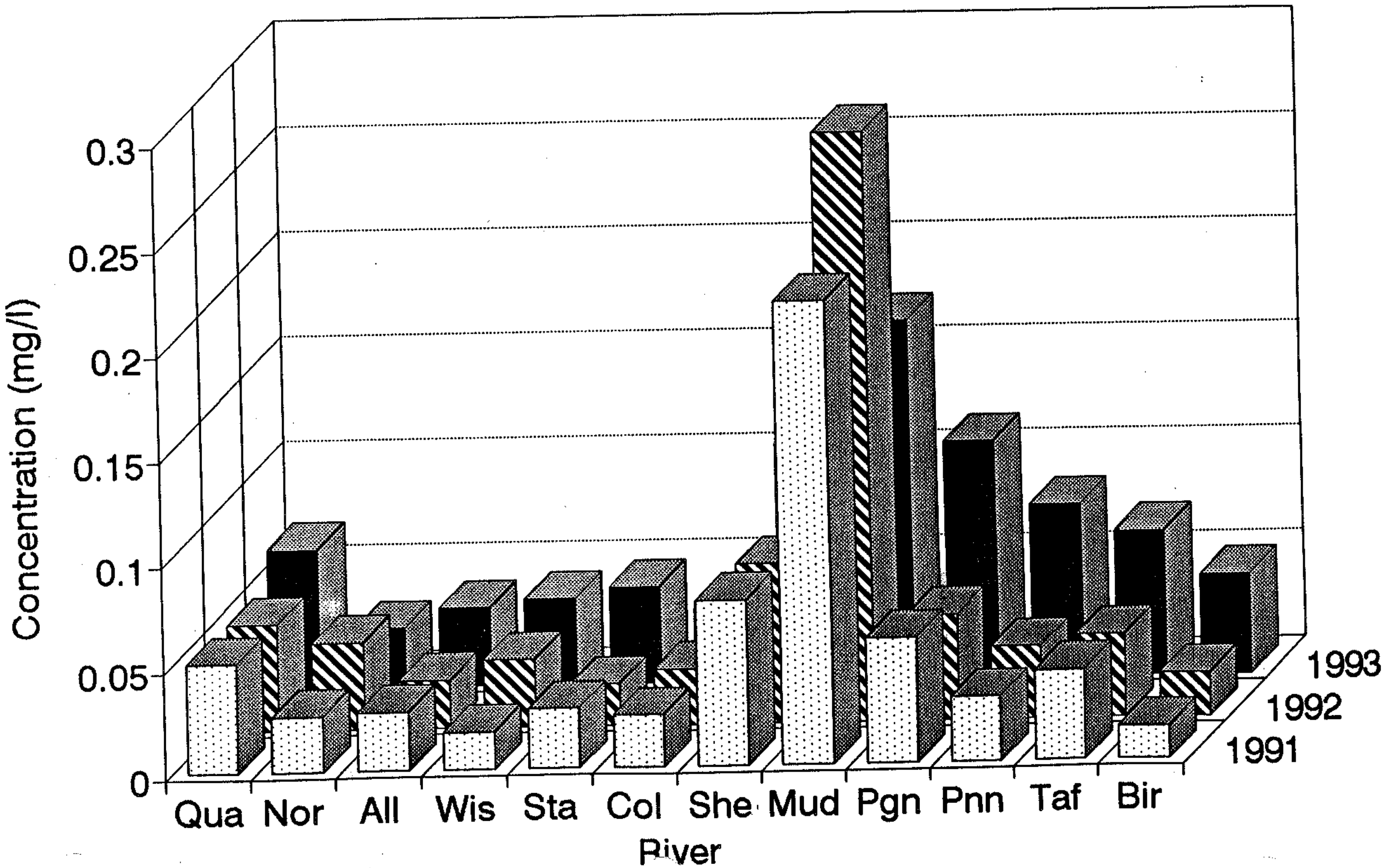

East Coastal Event Stations
Total Phosphorus
CONCENTRATION (MG/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Nov-91
Dec-91
Mar-92
Apr-92
Apr-92
Jun-92
Jul-92
Jul-92
Aug-92
Aug-92
Mar-93
Apr-93
Jun-93
Aug-93
DATE
Quanic
Northw
Wiscog
Columb
Taft
Bird


West Coastal Scheduled Stations
Total Phosphorus
1.21 Pincon
Concentration (mg/l)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Mar 91
Mar 93
Mar 1991 - Jun 1993
Tawas
Whitney
Rifle
Pincon
KawKaw
SBKaw

West Coastal Event Stations
Total Phosphorus

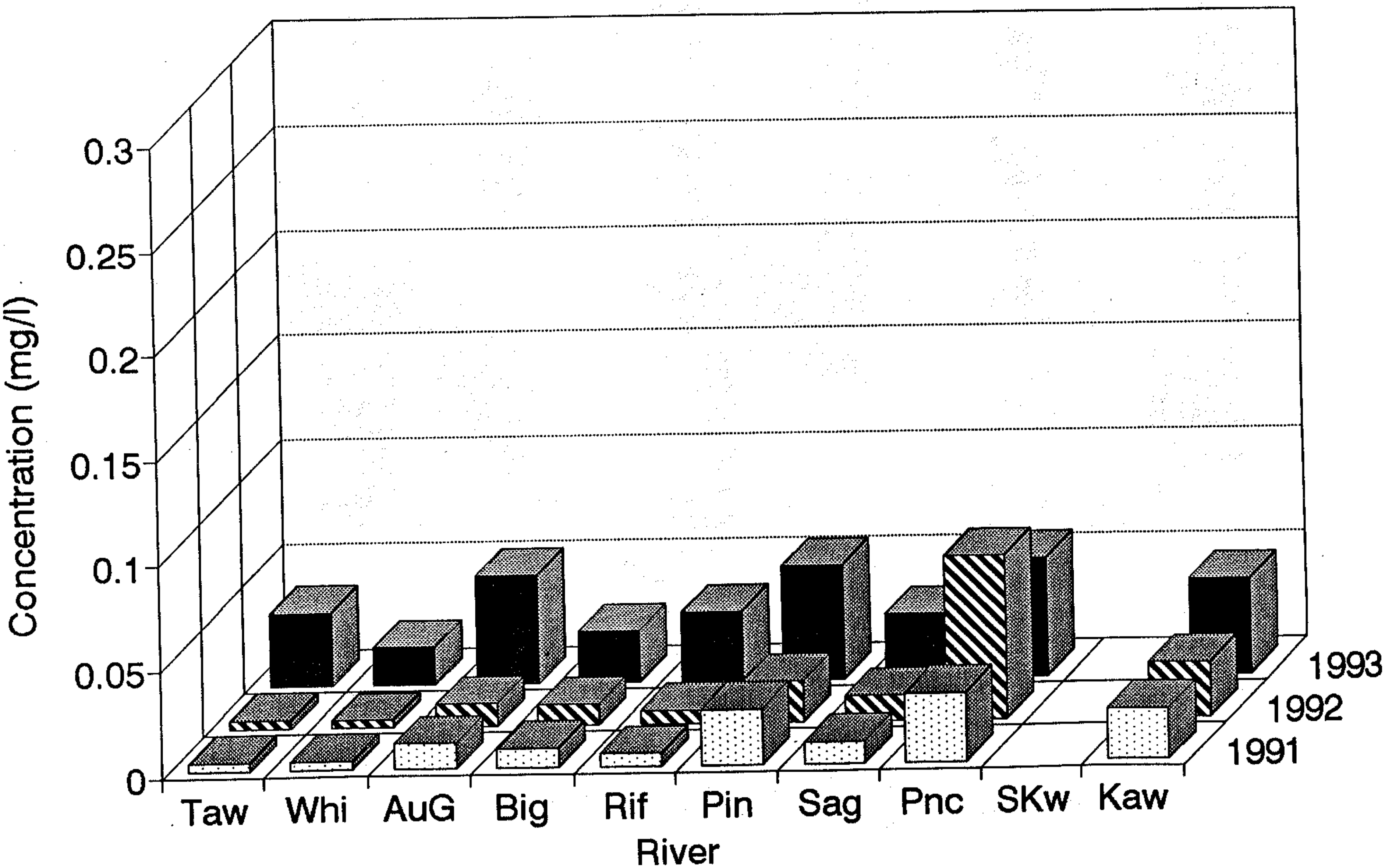


East Coastal Basin Tributaries
Dissolved Ortho Phosphorous Conc.



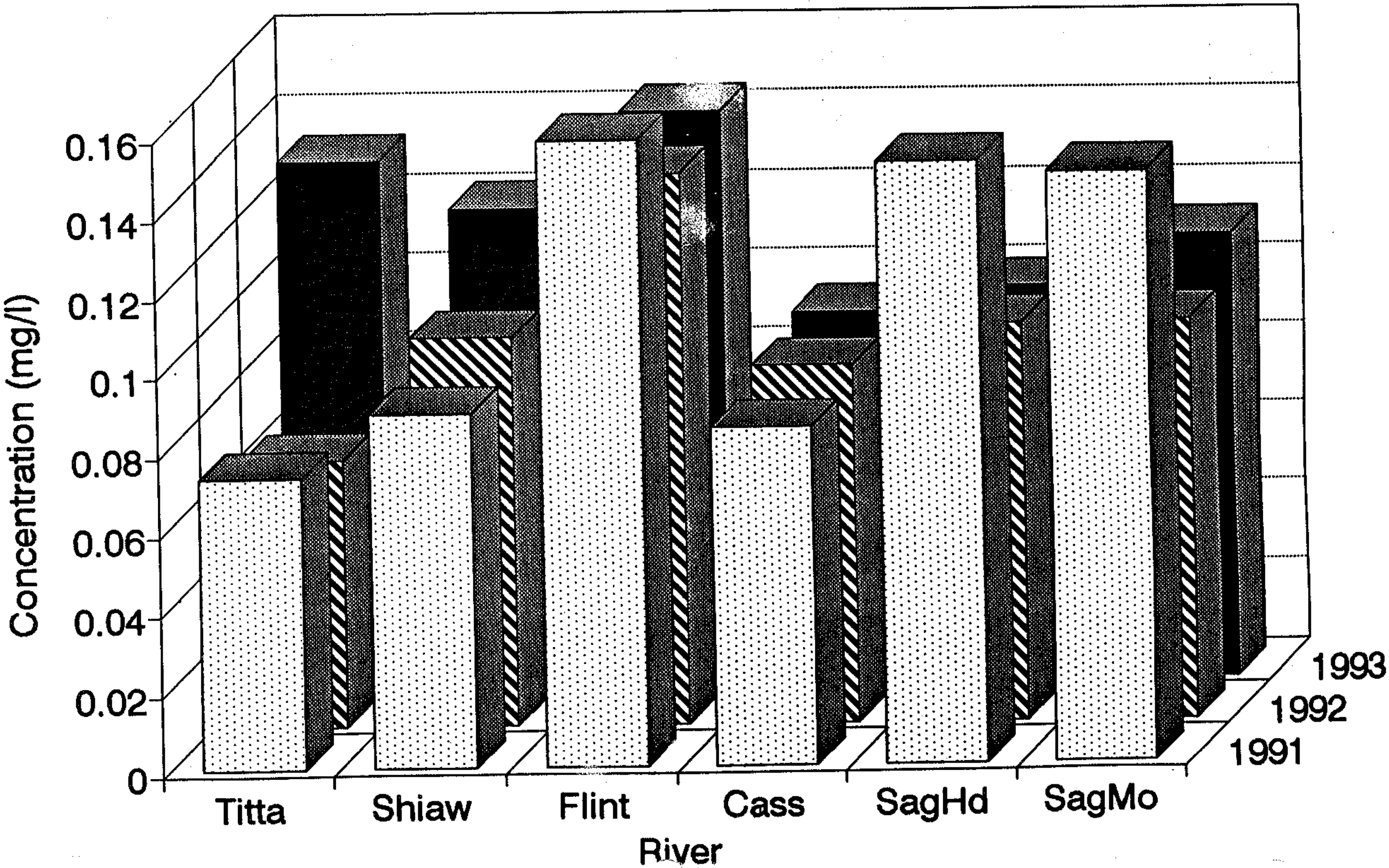
West Coastal Basin Tributaries

Dissolved Ortho Phosphorous Conc.

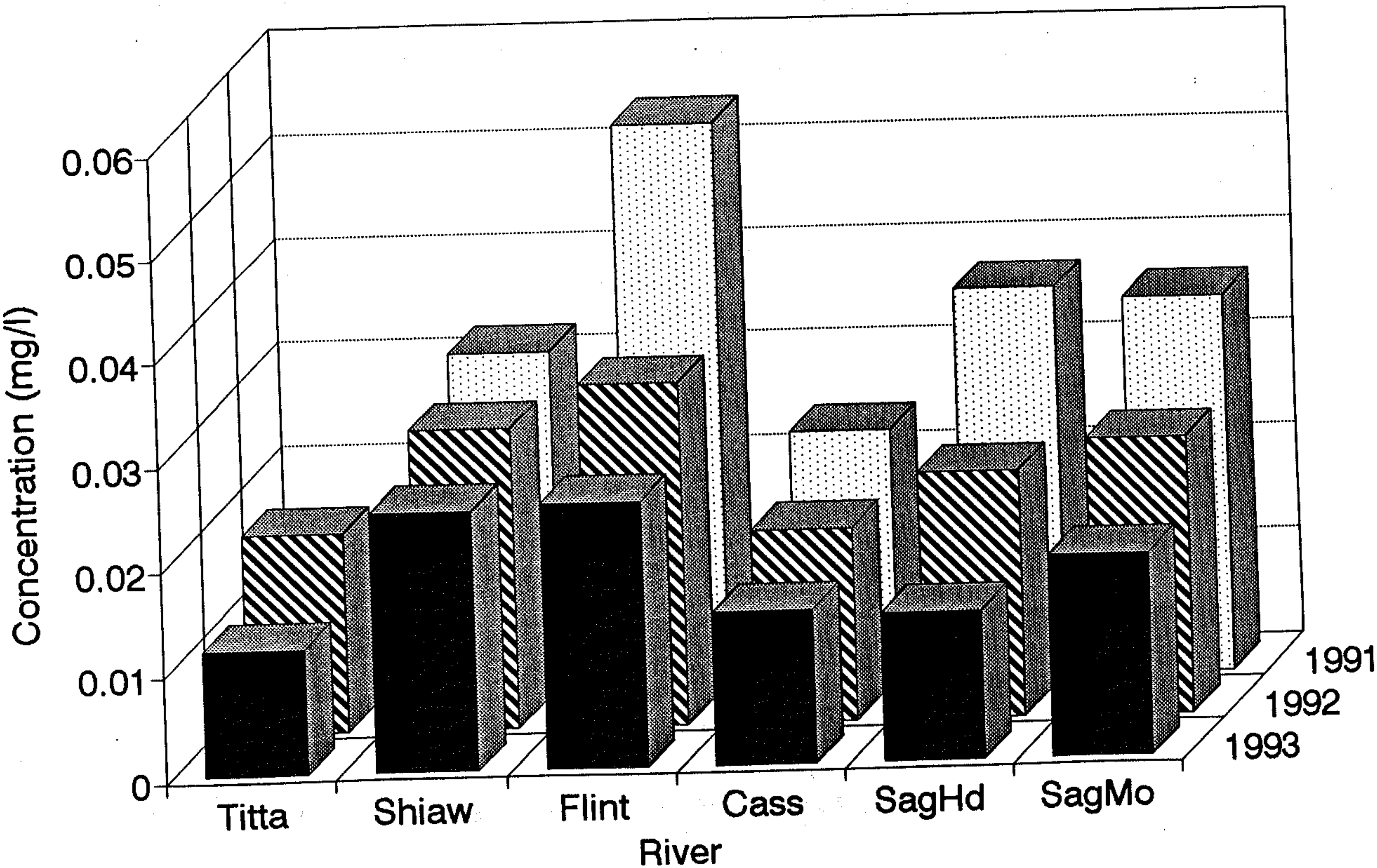


Saginaw River and its Tributaries

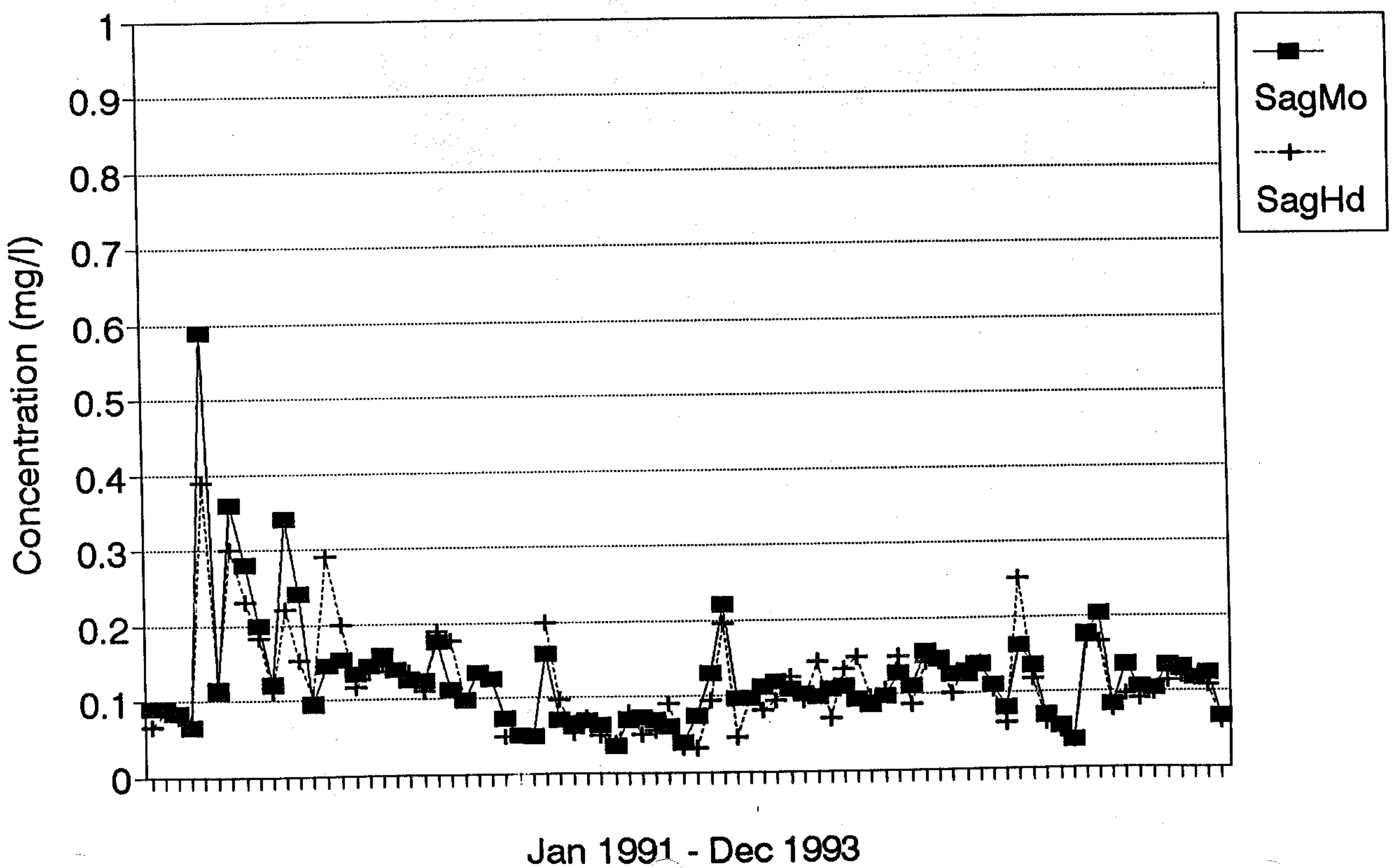
Total Phosphorus Concentrations



Saginaw River and its Tributaries
Total Ortho Phosphorous Concentrations



Saginaw River
Total Phosphorus



Saginaw River (Midland St)
Total Phosphorus Concentration

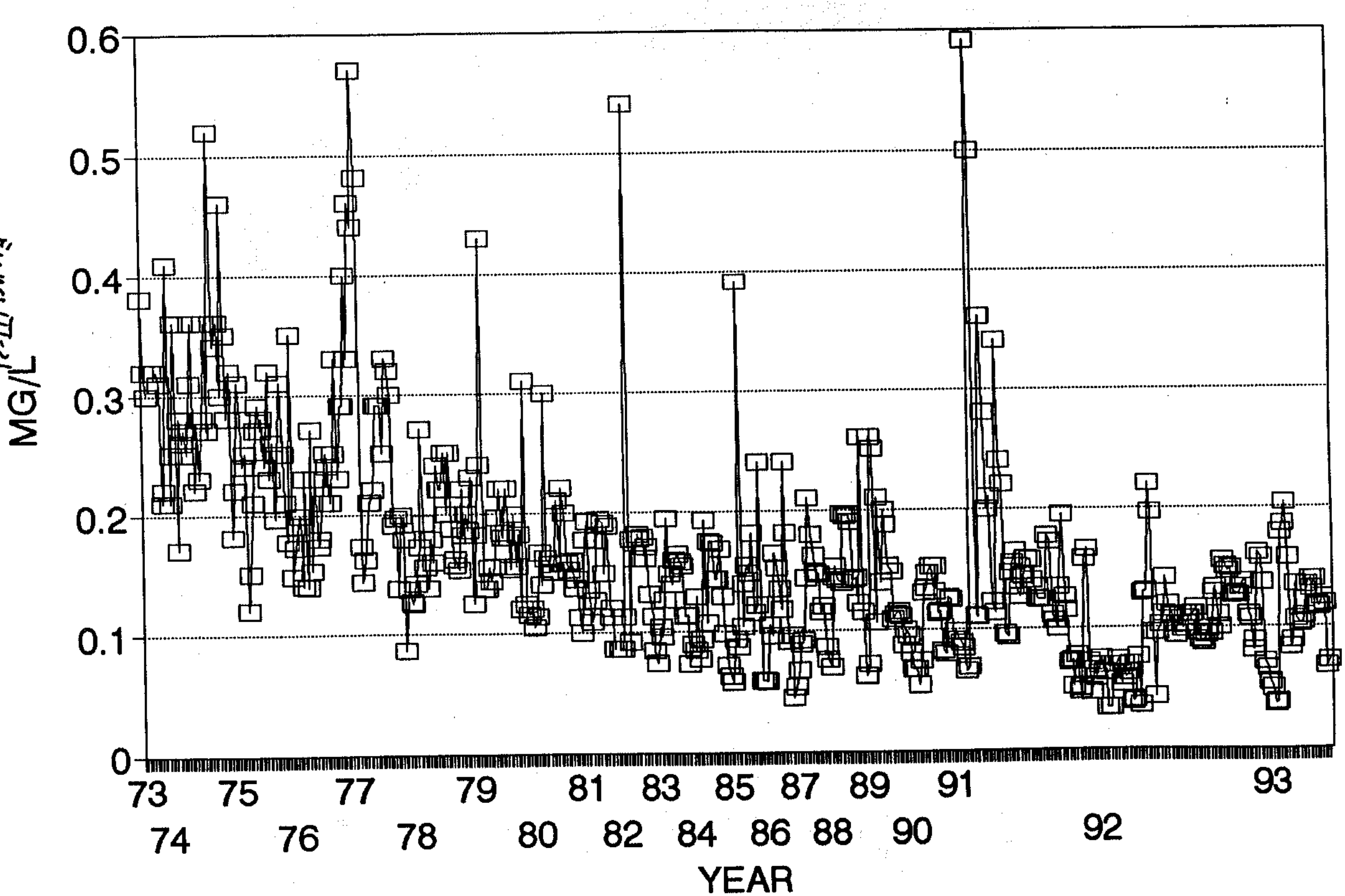


Figure III-21

Saginaw River (Midland St)

Ortho-Phosphorus Concentration

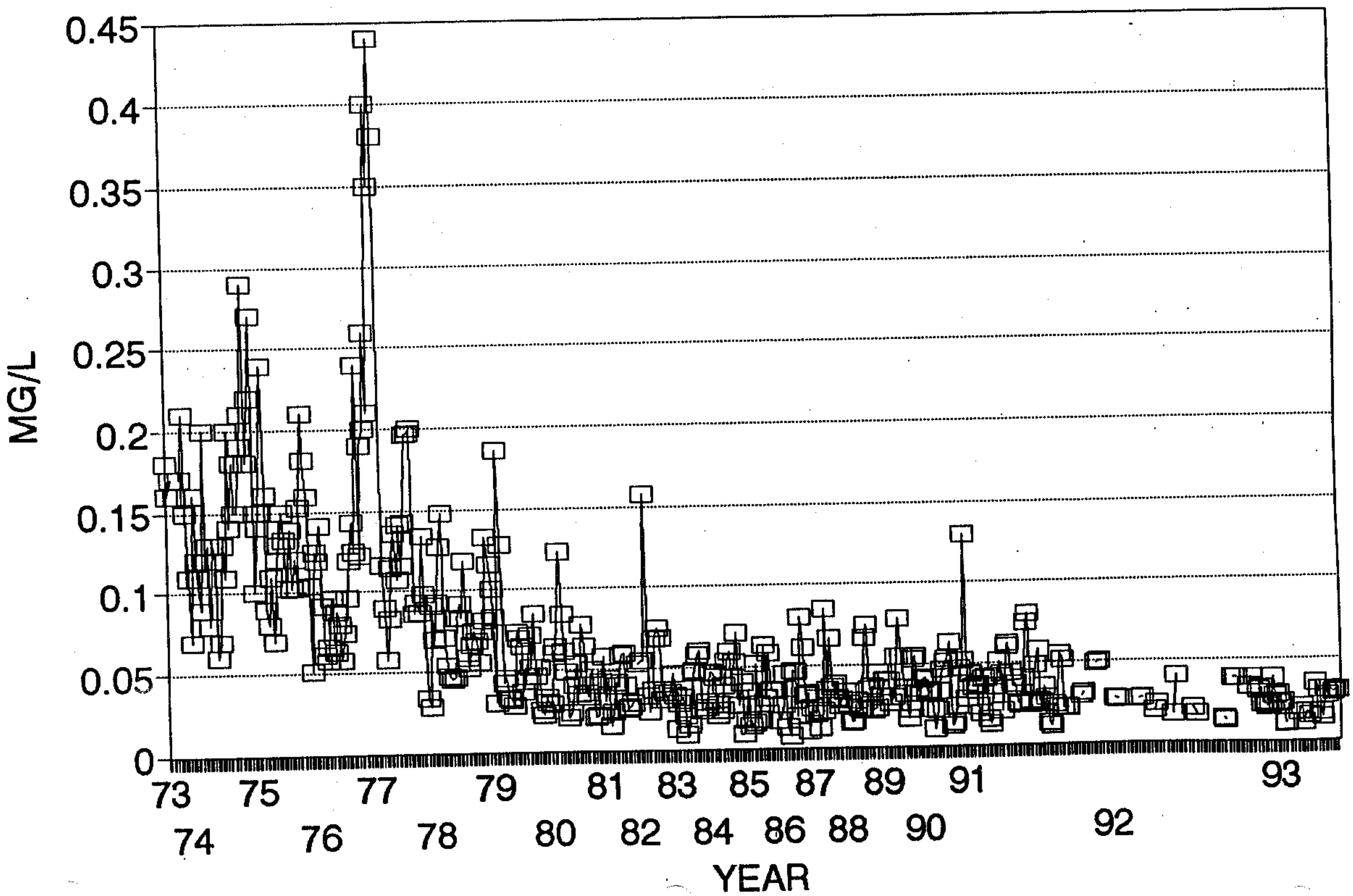
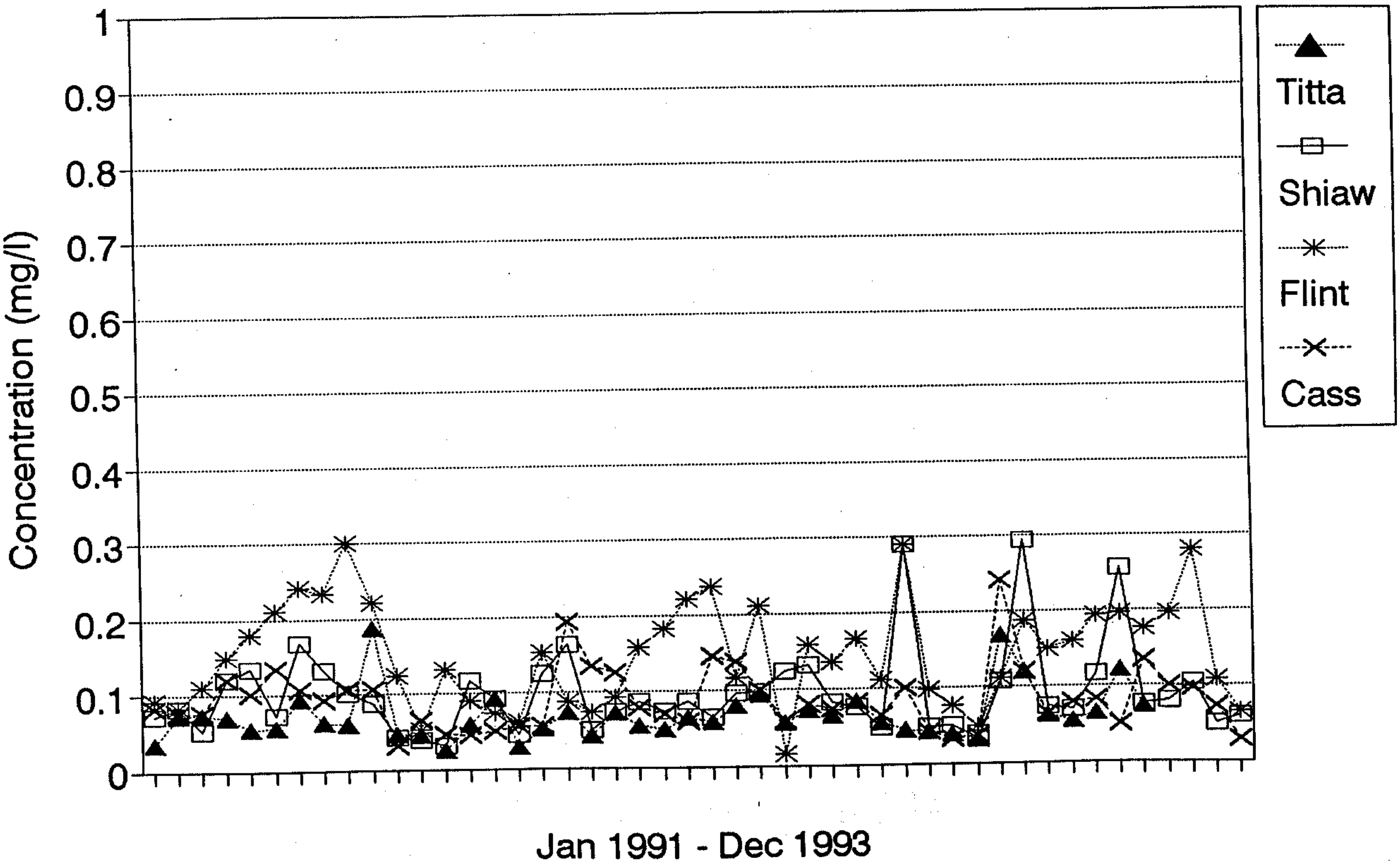


Figure III - 22

Saginaw River Tributaries

Total Phosphorus



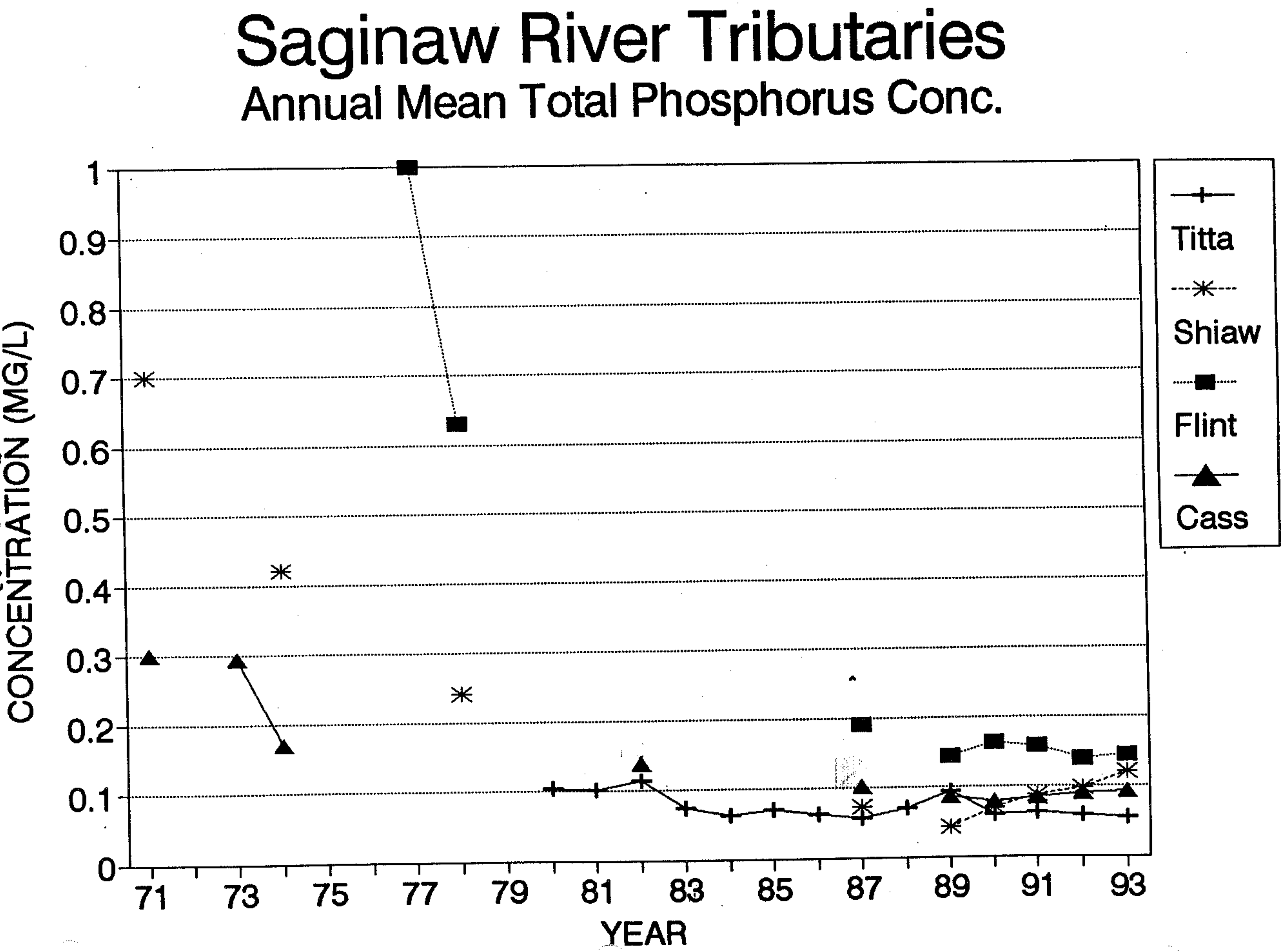


Figure III-23

134

Saginaw River Tributaries
Annual Mean Ortho-Phosphorus Conc.

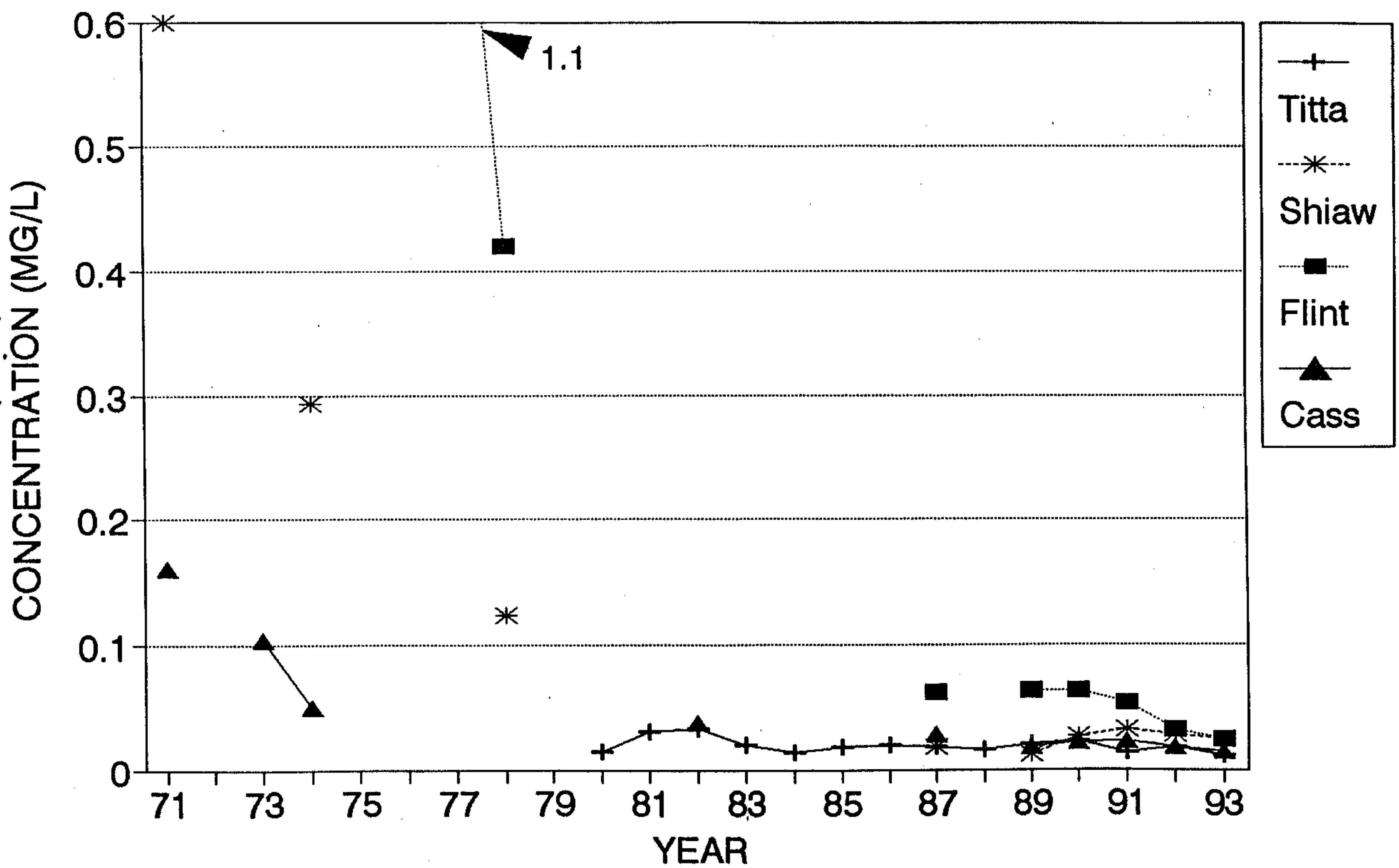


Figure III-24

135

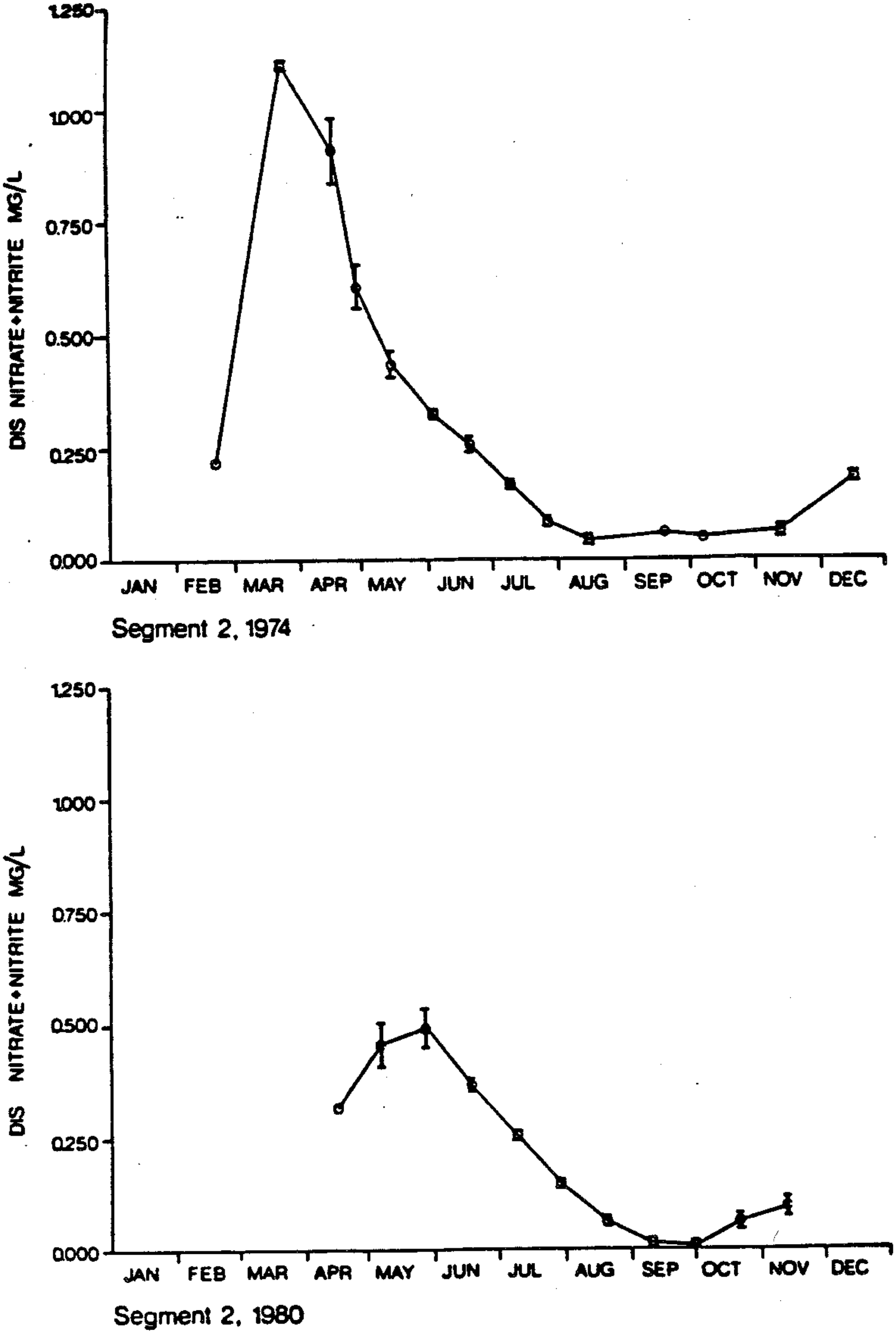


Figure III-29. Nitrate-nitrite concentrations (mg/l) in Saginaw Bay, 1974 and 1980 (Dolan, et al., 1986).

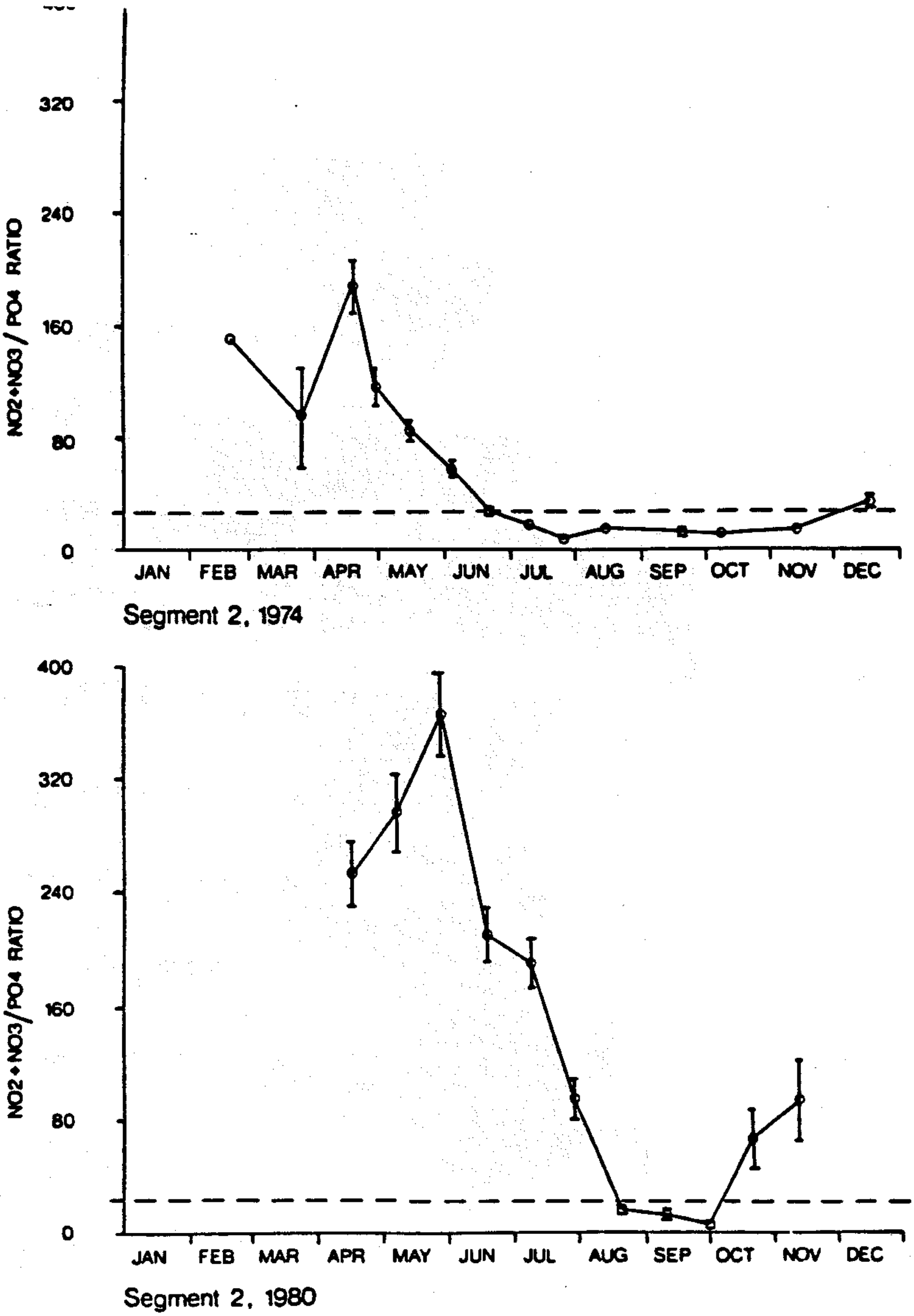
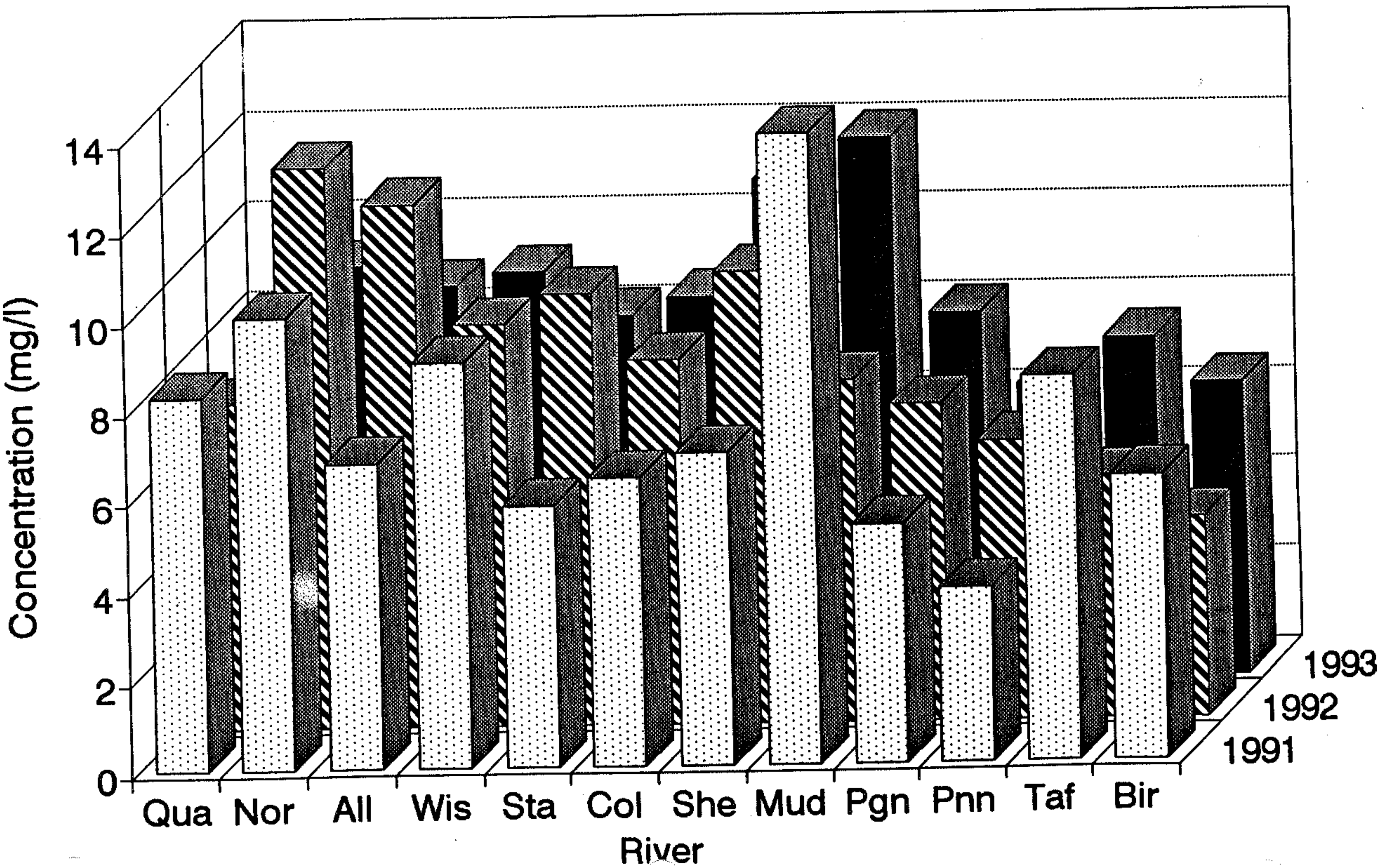


Figure III-30. Nitrogen/phosphorus ratios in Saginaw Bay, 1974 and 1980 (Dolan, et al., 1986).

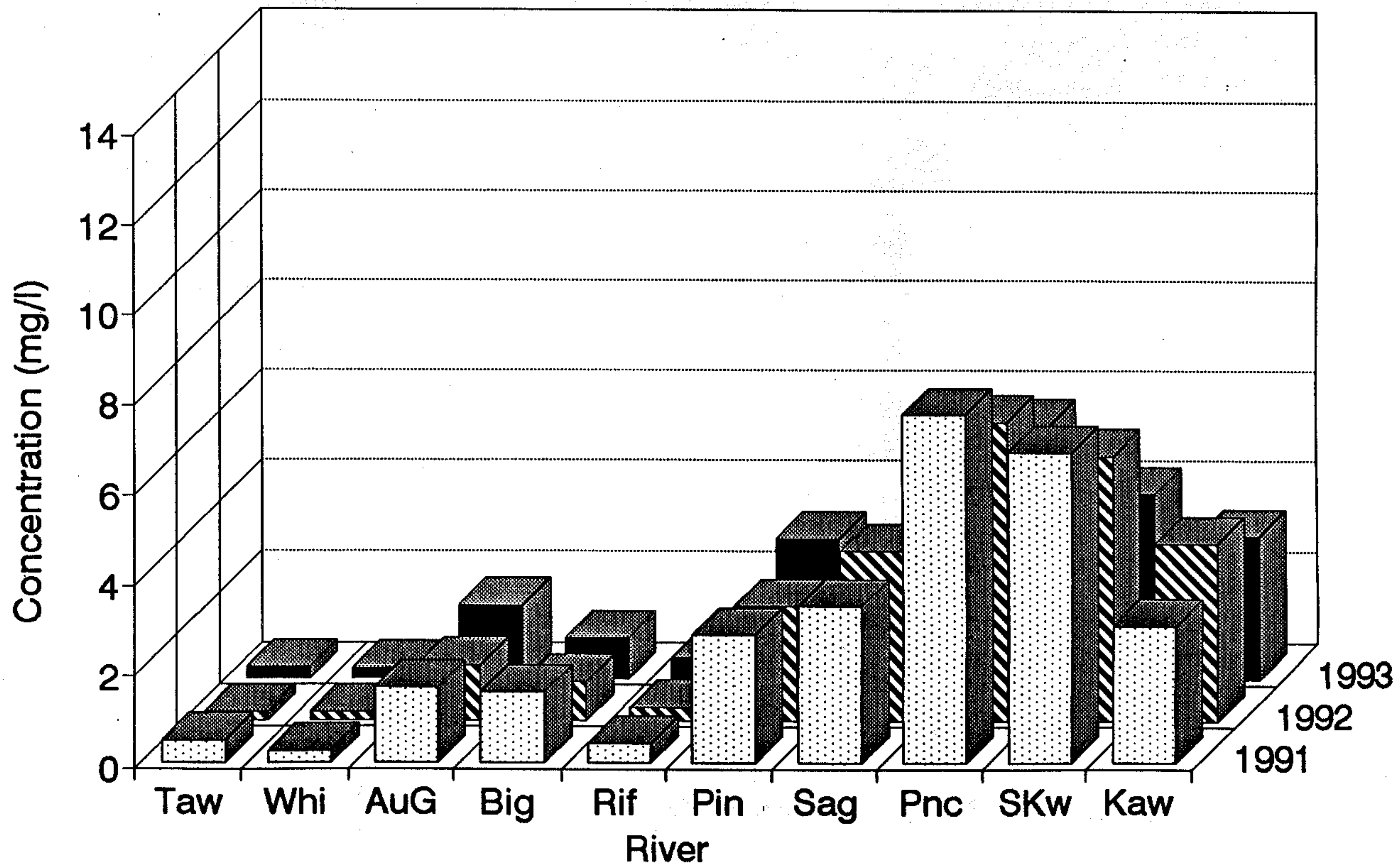
East Coastal Basin Tributaries

Dissolved NO2+NO3 Concentrations

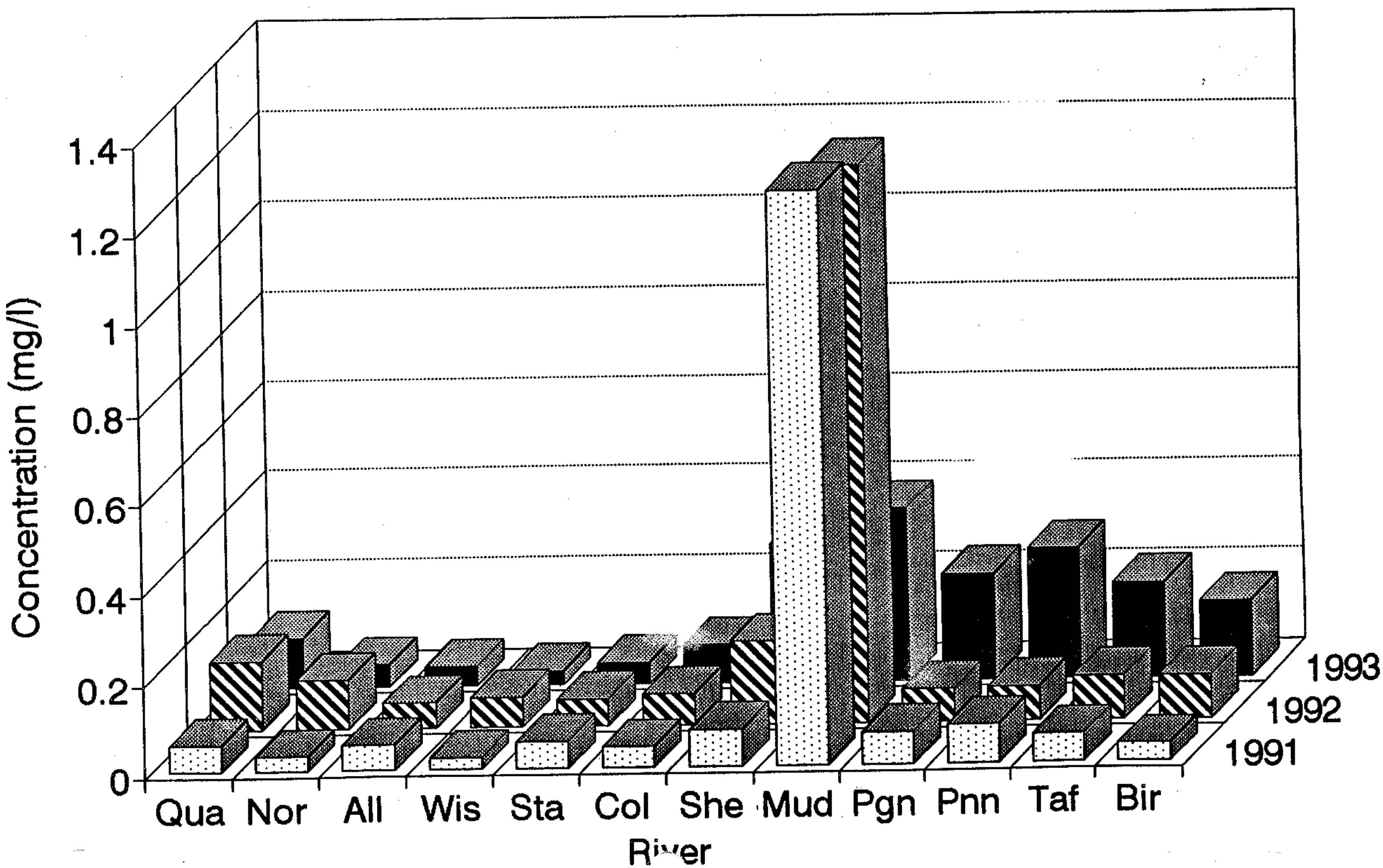


West Coastal Basin Tributaries

Dissolved NO2+NO3 Concentrations

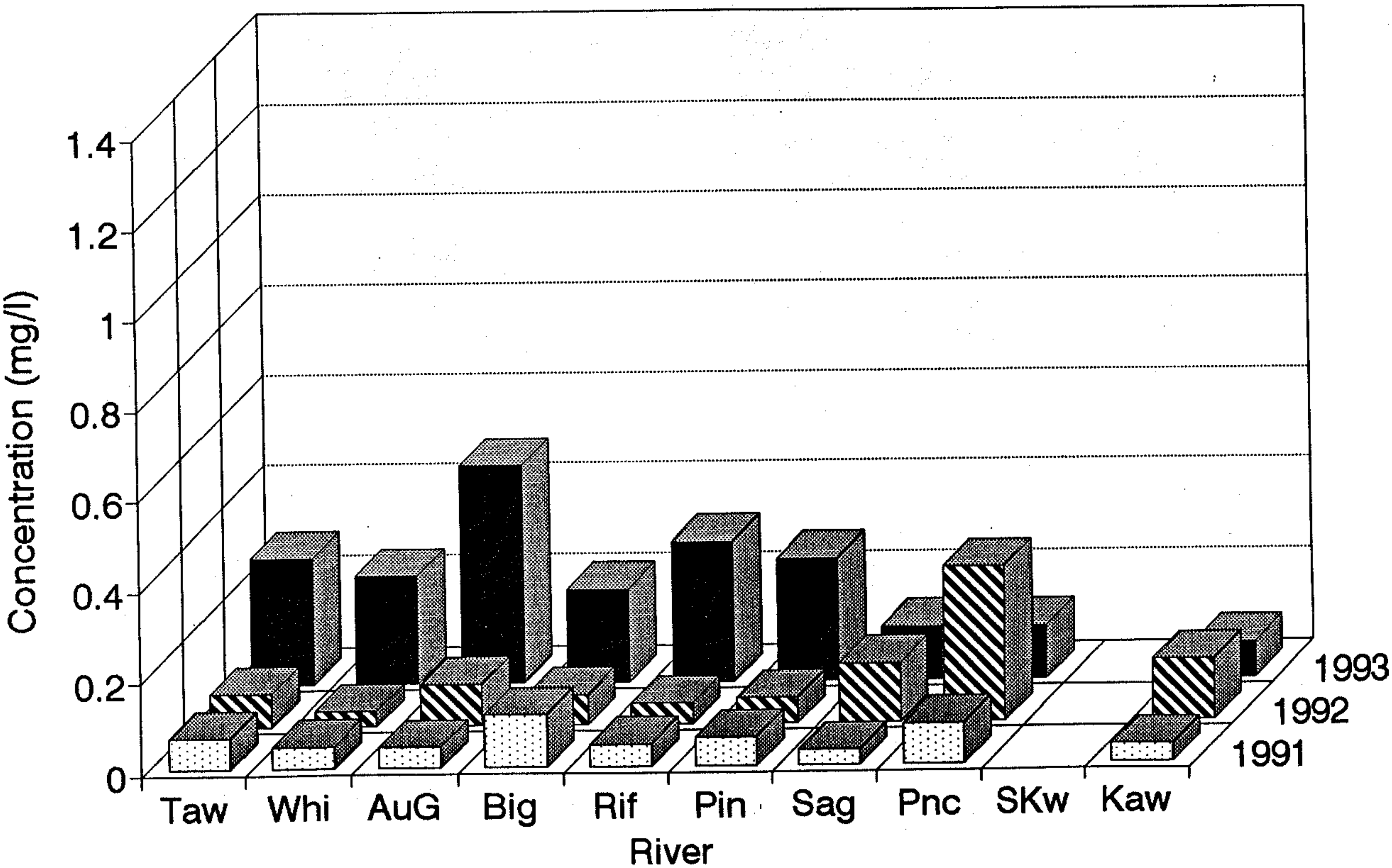


East Coastal Basin Tributaries
Dissolved Ammonia Concentration



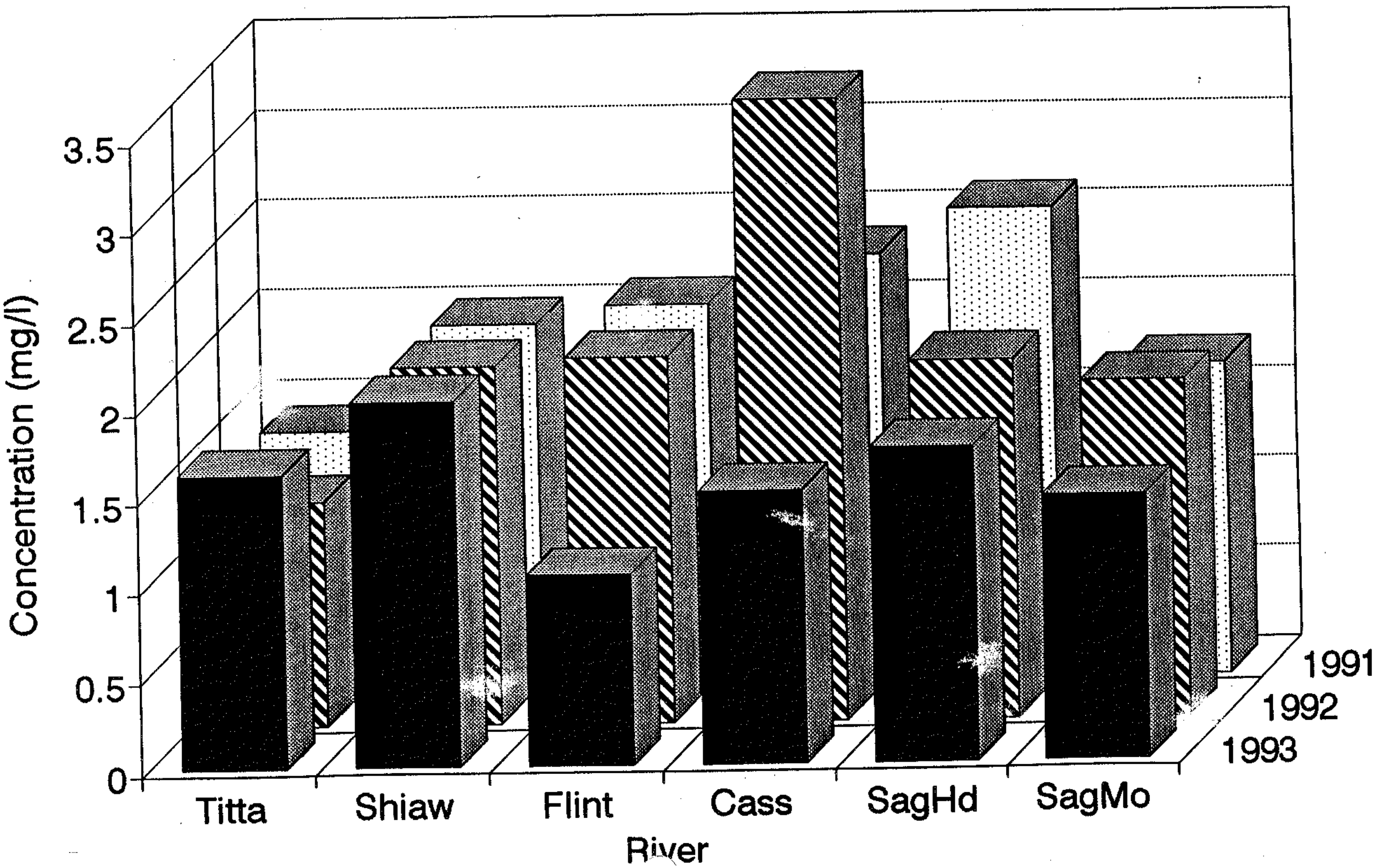
West Coastal Basin Tributaries

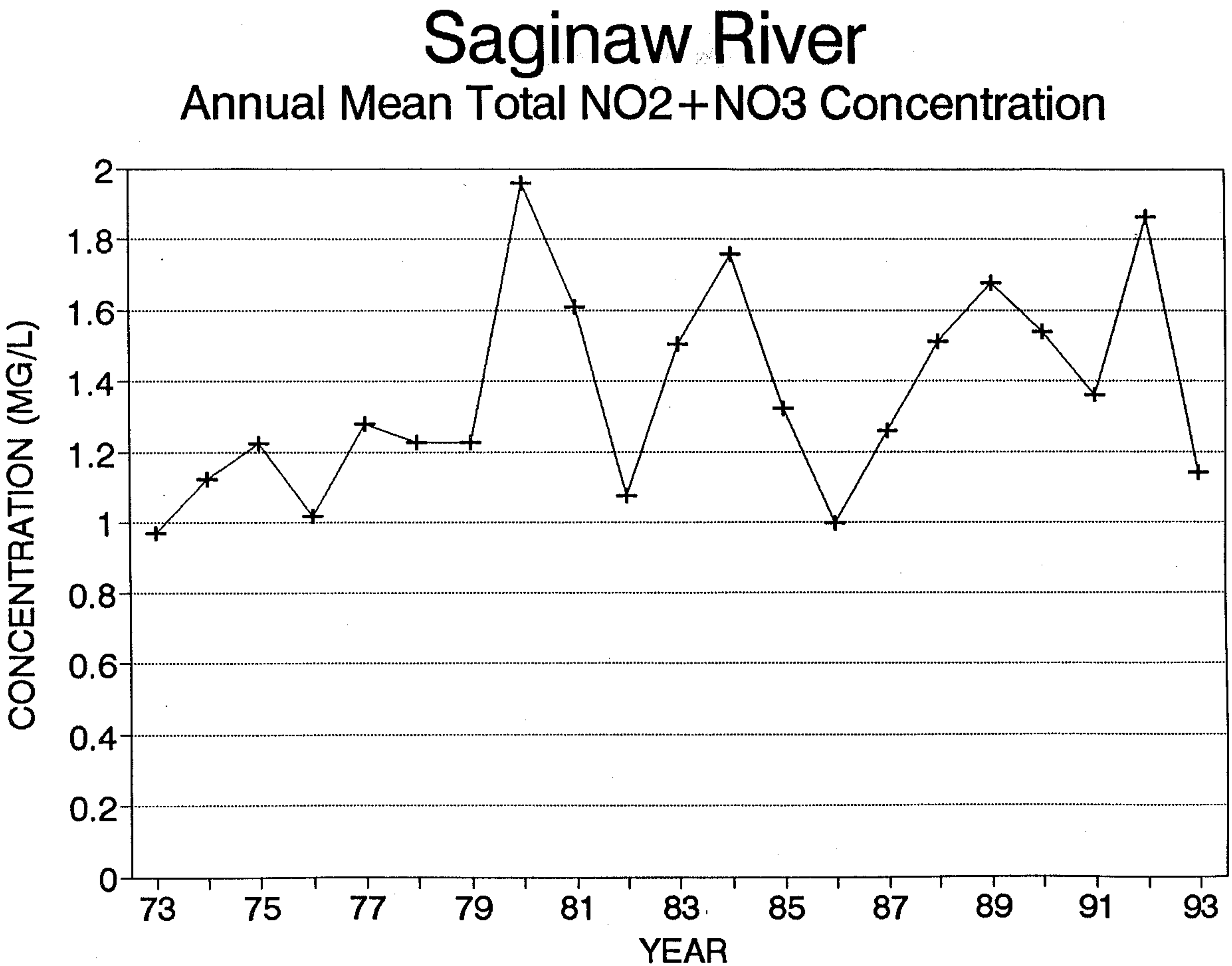
Dissolved Ammonia Concentration



Saginaw River and its Tributaries

Dissolved NO2 + NO3 Concentration

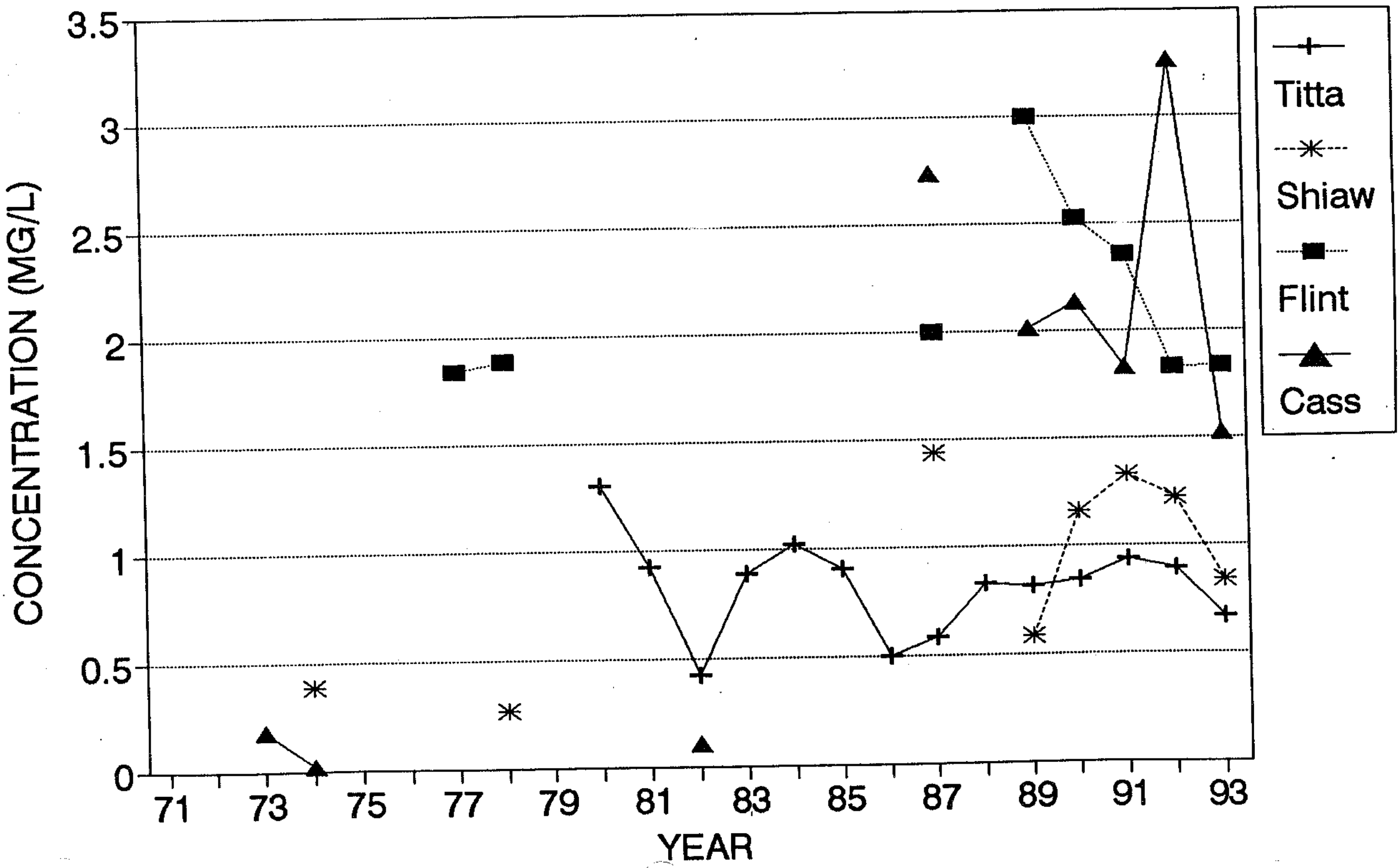



Saginaw River
Annual Mean Total NO2+NO3 Concentration
CONCENTRATION (MG/L)
YEAR
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
73
75
77
79
81
83
85
87
89
91
93

143

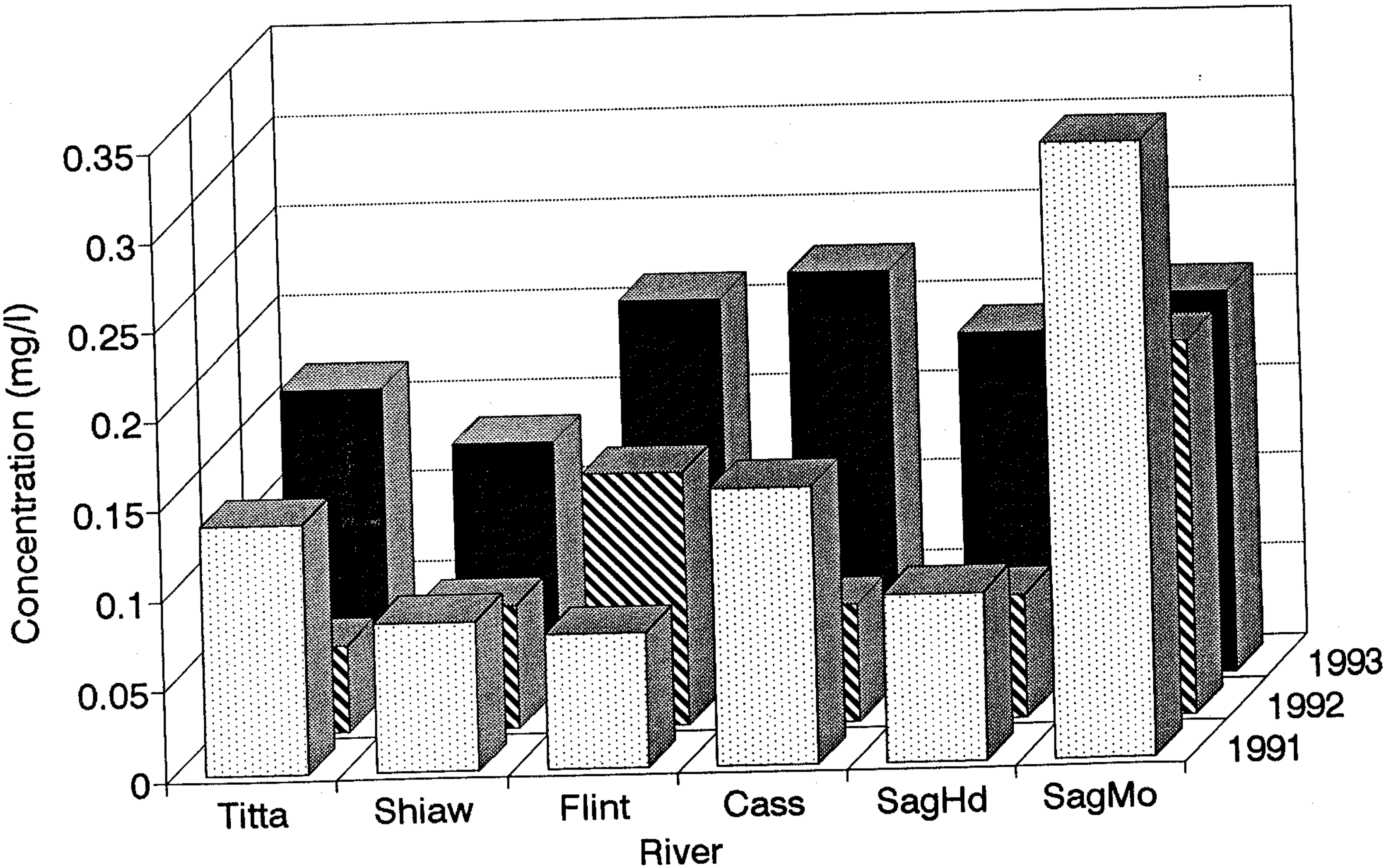
Saginaw River Tributaries

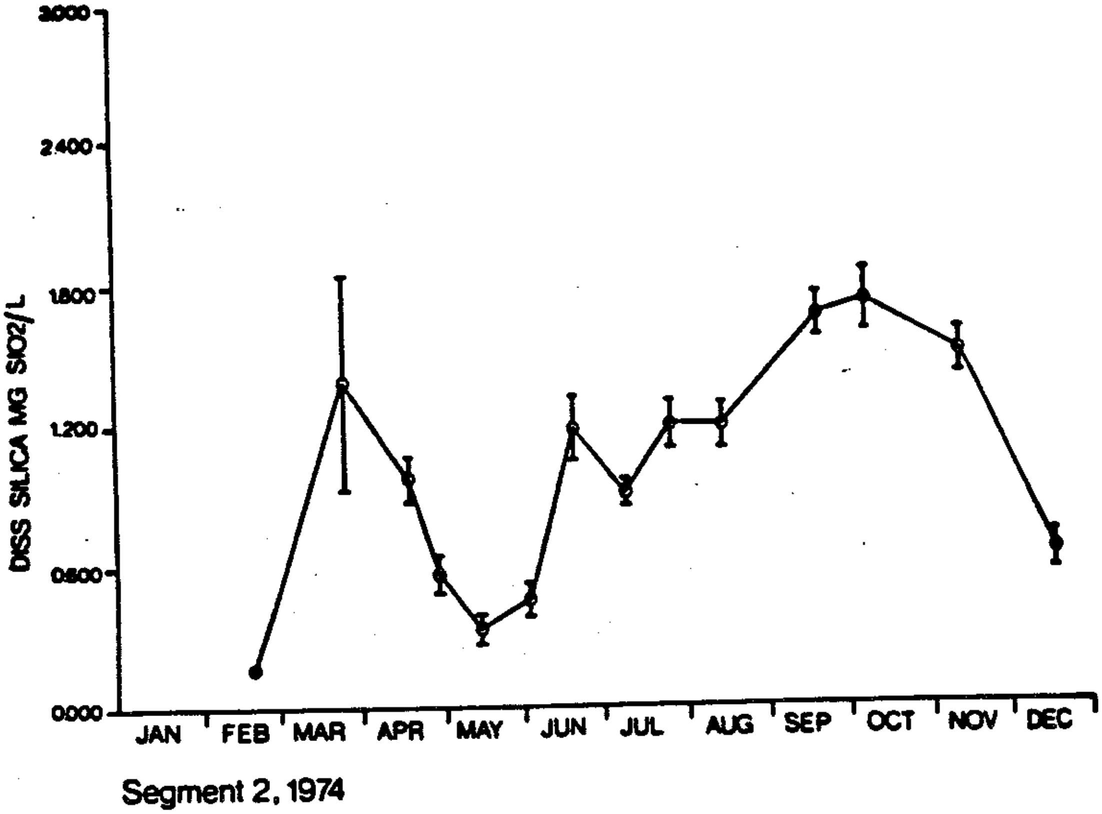
Annual Mean Total NO2+NO3 Concentration



Saginaw River and its Tributaries

Dissolved Ammonia Concentration





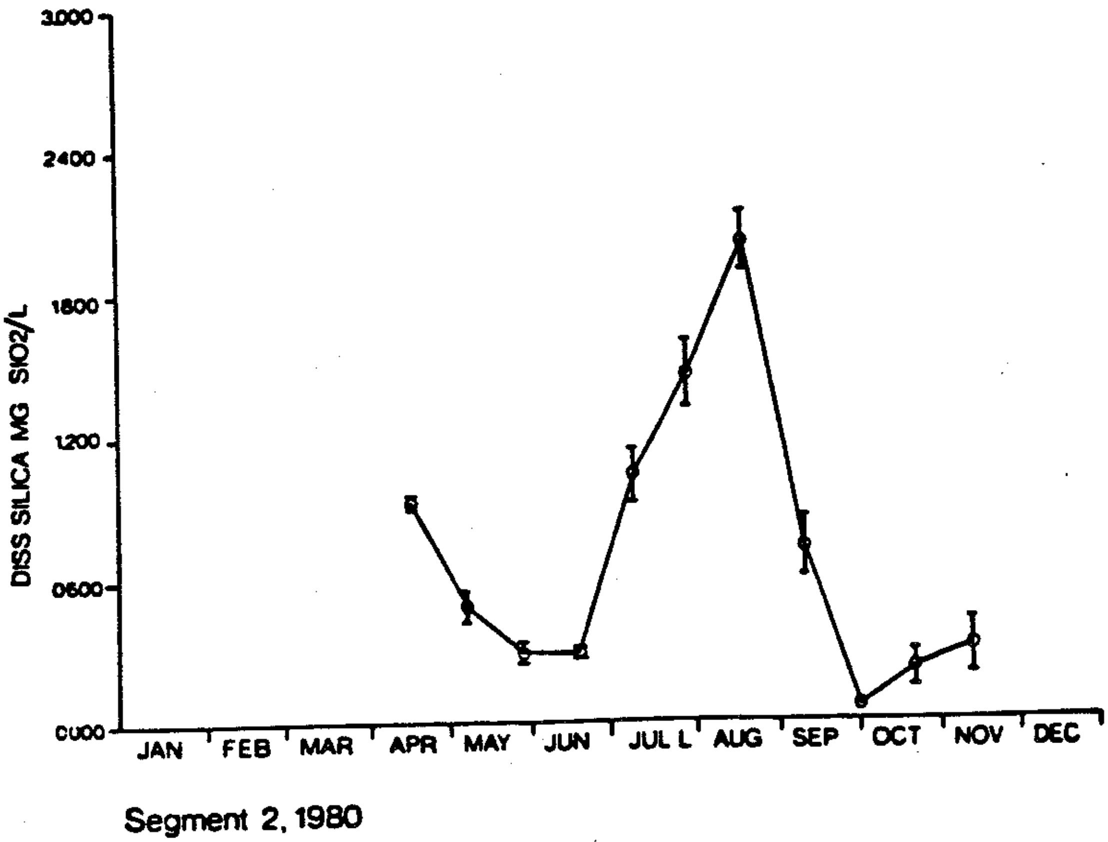


Figure III-35. Dissolved silica concentrations (mg/l) in Saginaw Bay, 1974 and 1980 (Dolan, et al., 1986).

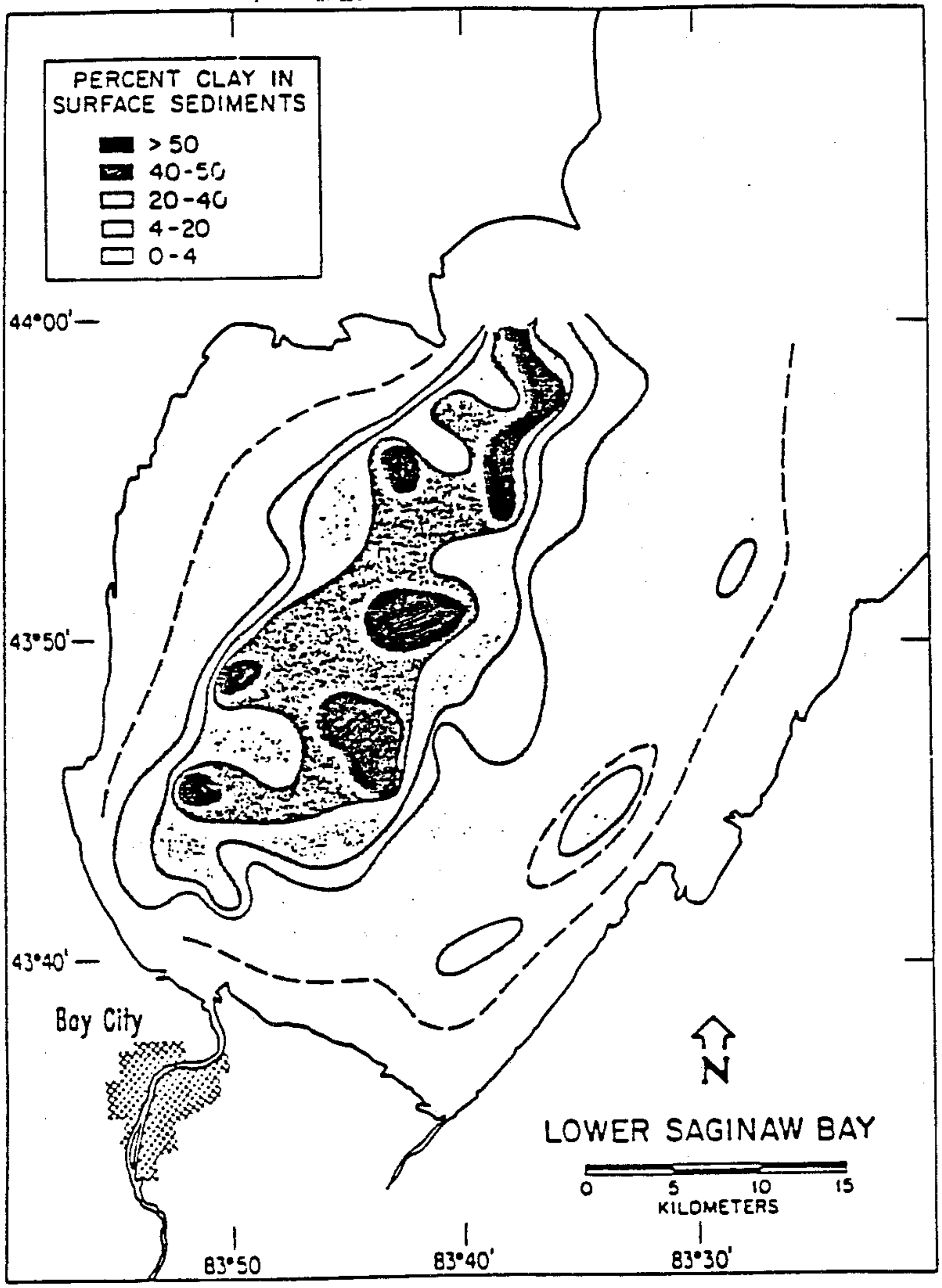


Figure III-72. Percent clay in surface sediments (1-2 cm) of inner Saginaw Bay, 1978 (Robbins, 1986).

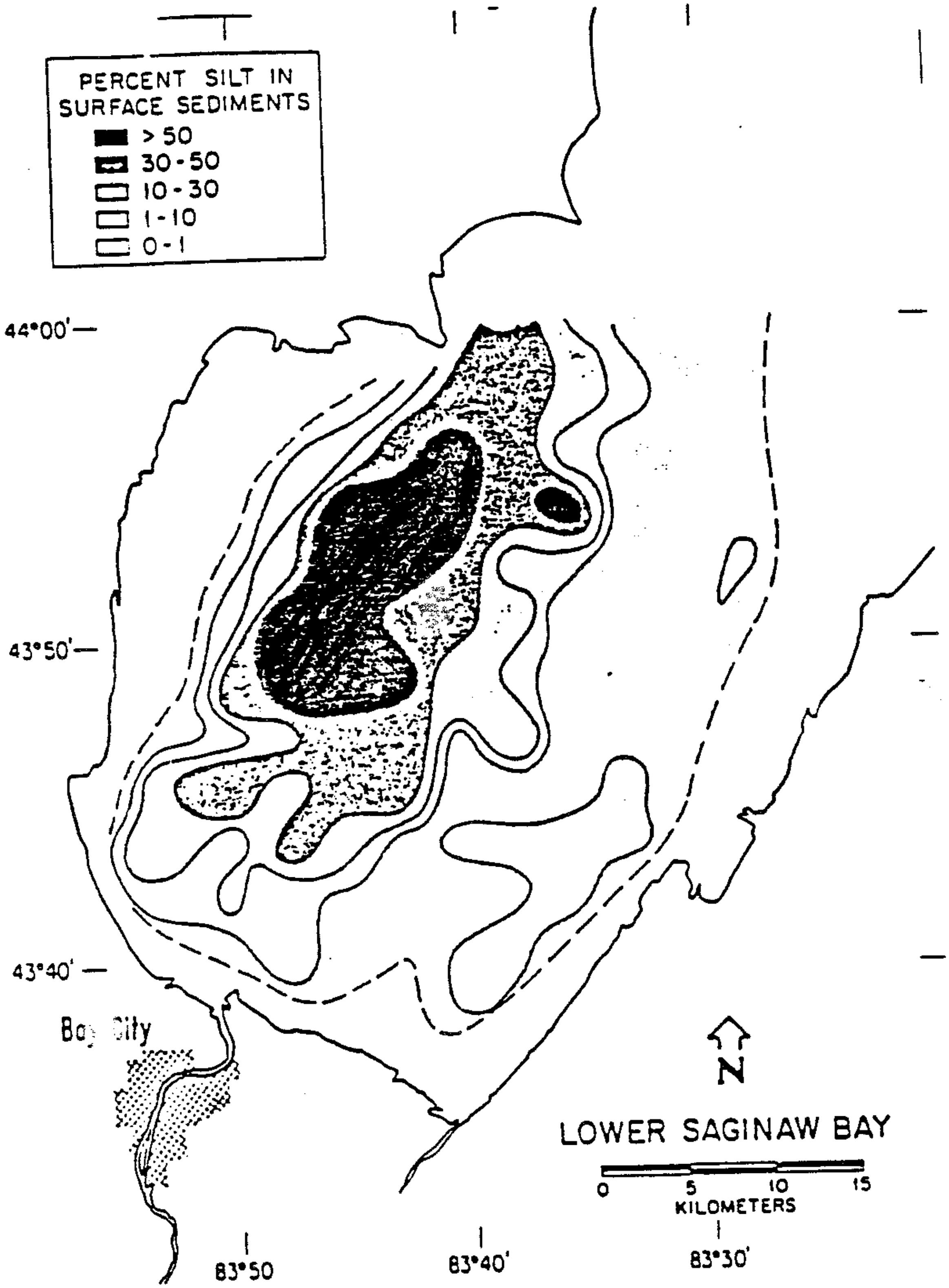


Figure III-73. Percent silt in surface sediments (1-2 cm) of inner Saginaw Bay, 1978 (Robbins, 1986).

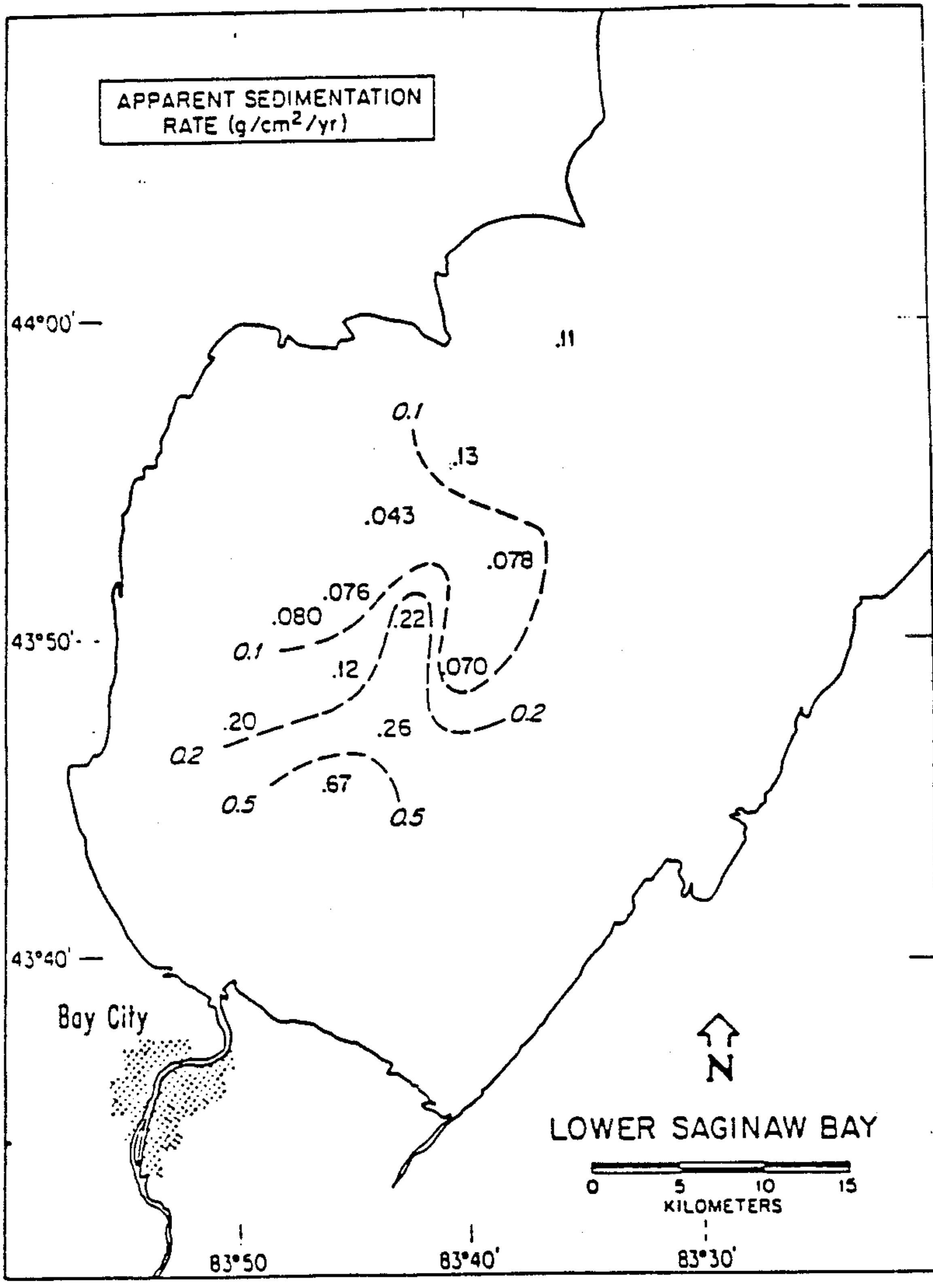
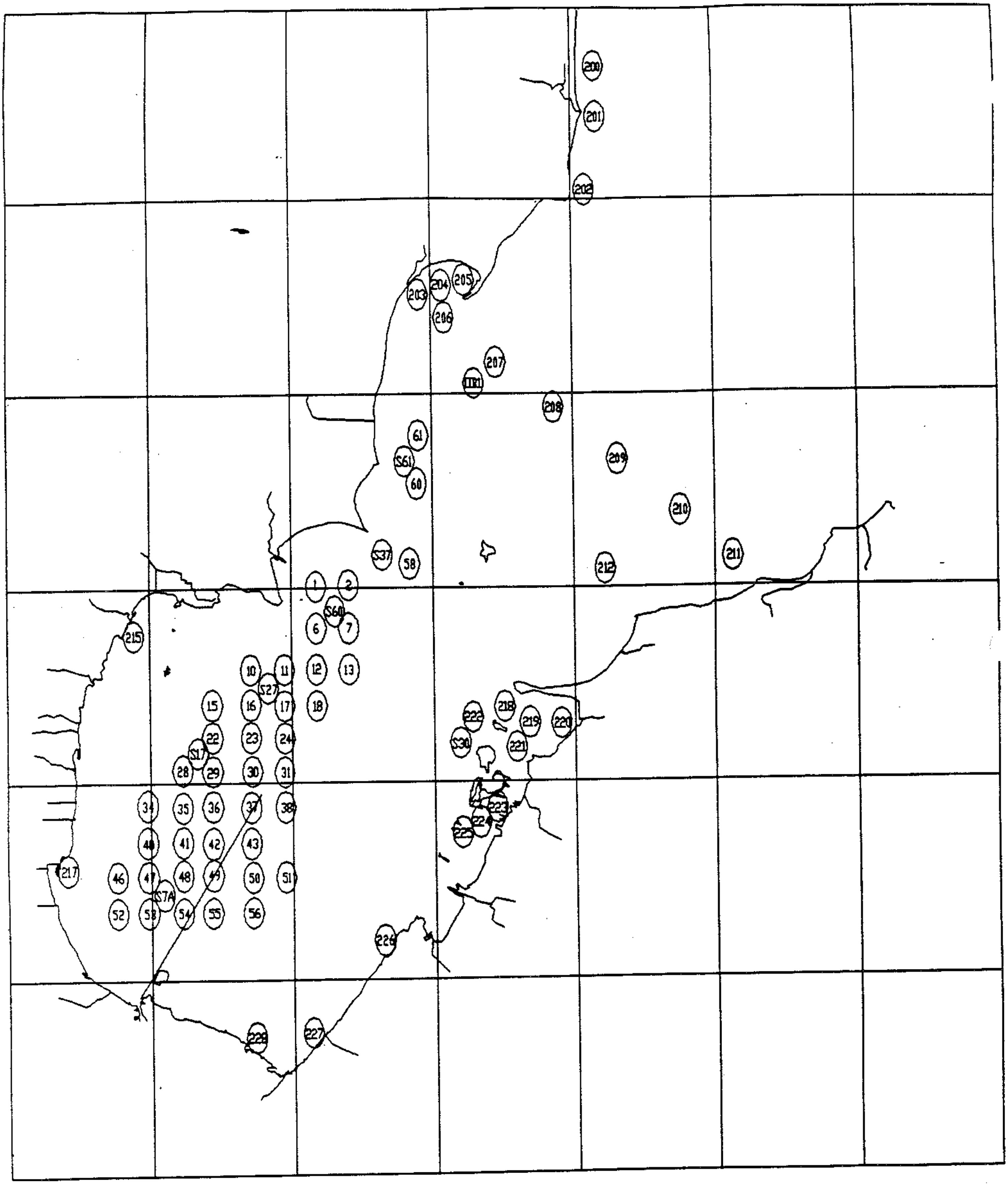
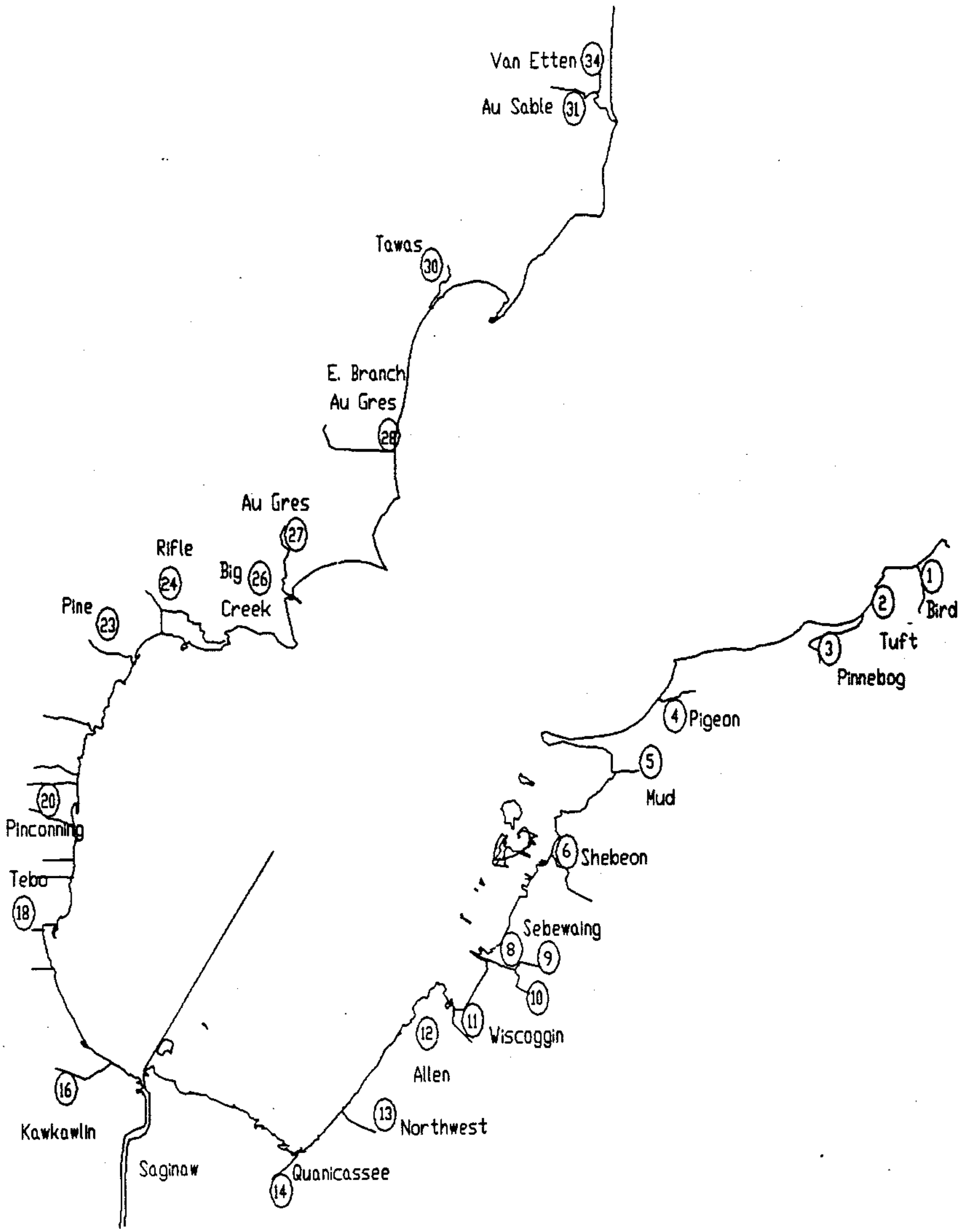
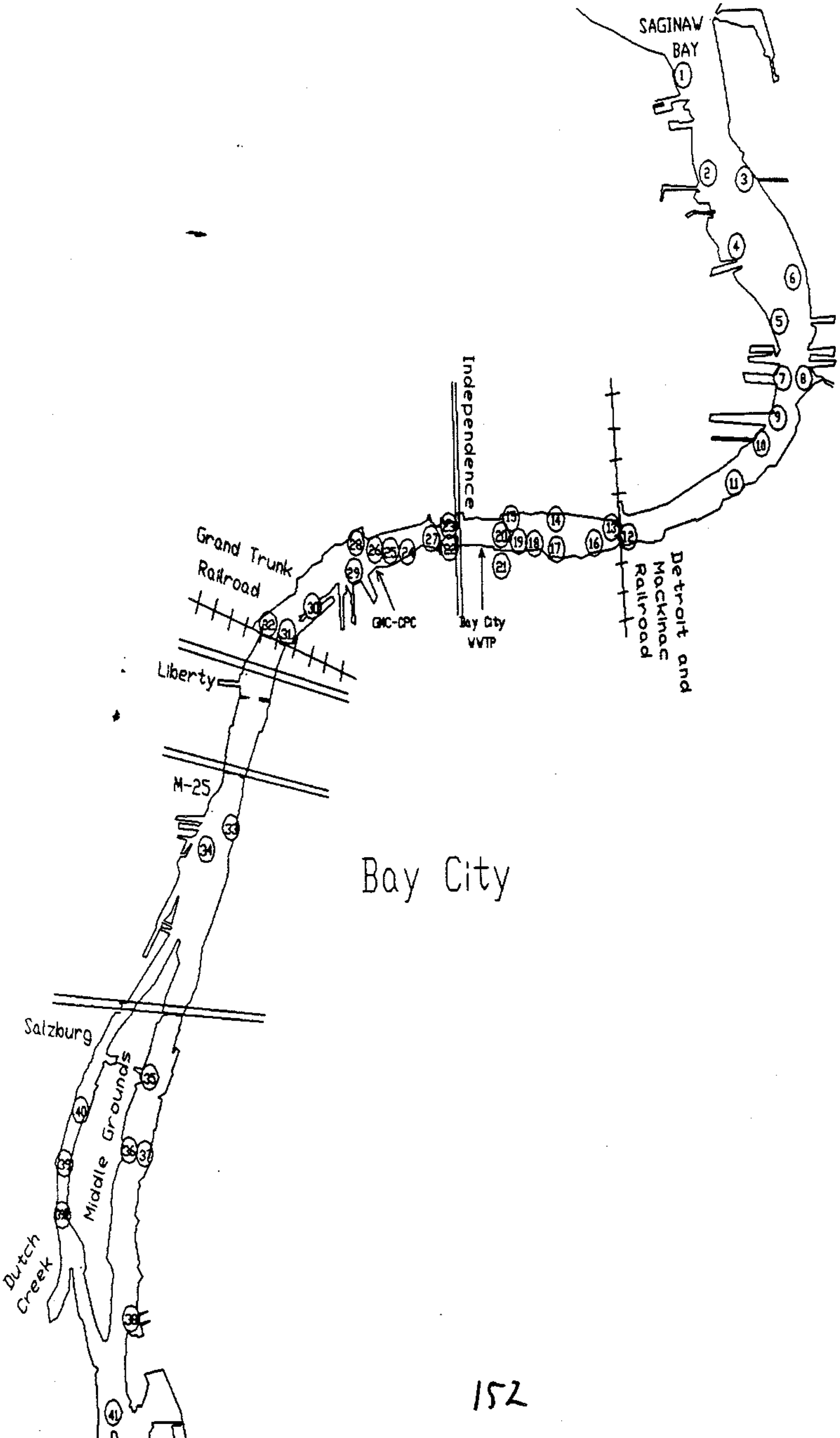
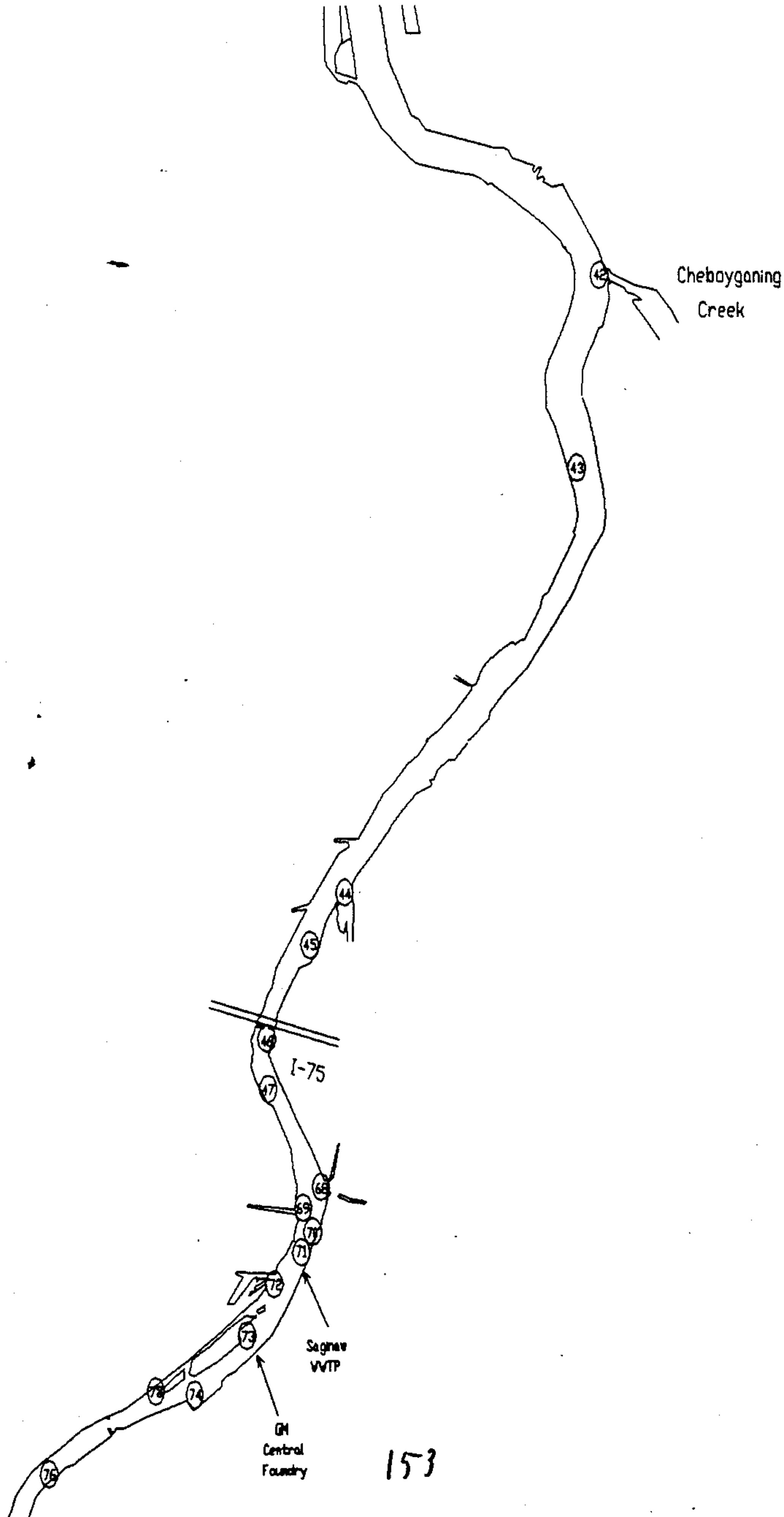


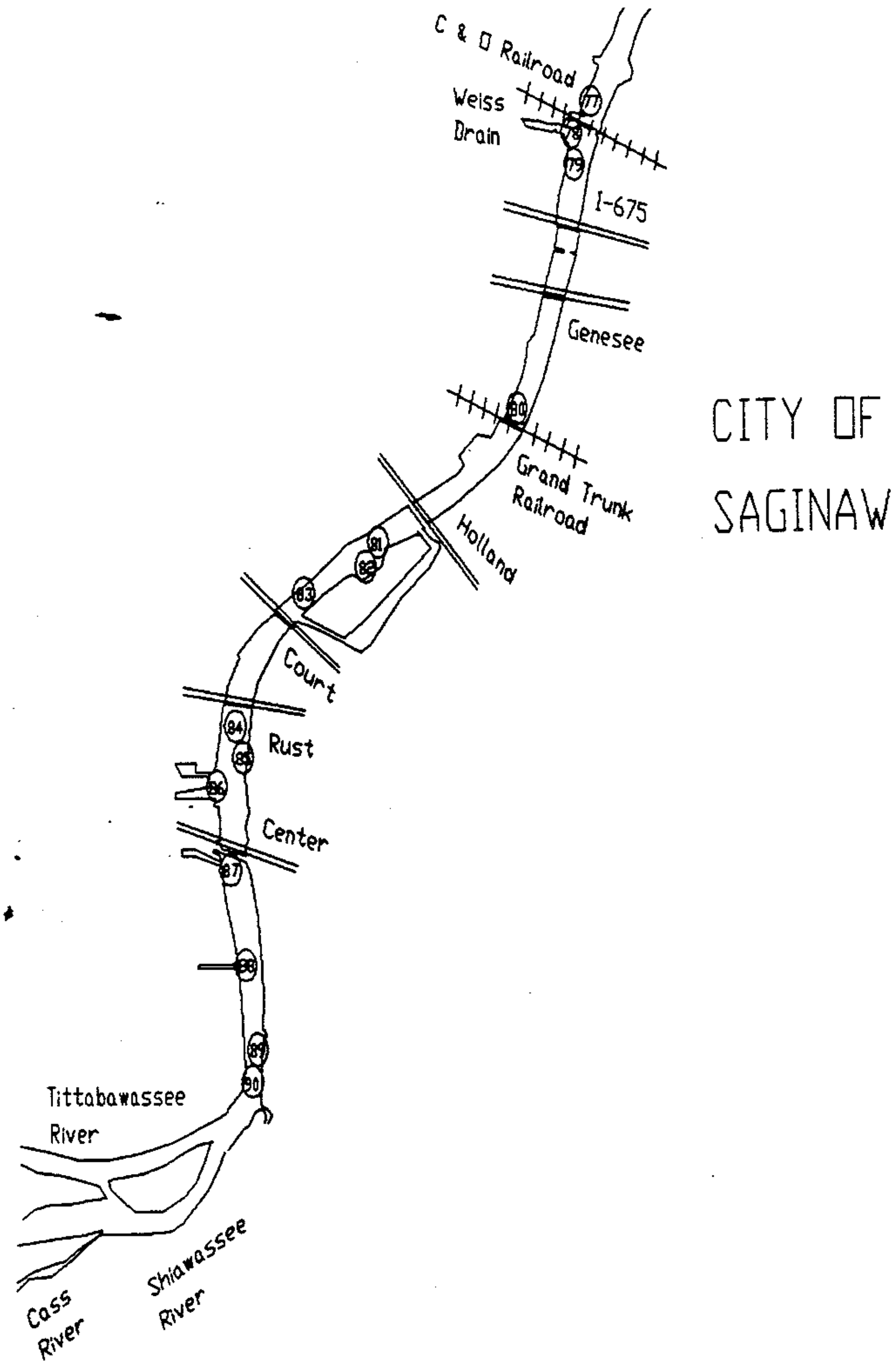
Figure III-76. Apparent sedimentation rates in inner Saginaw Bay (Robbins, 1986).

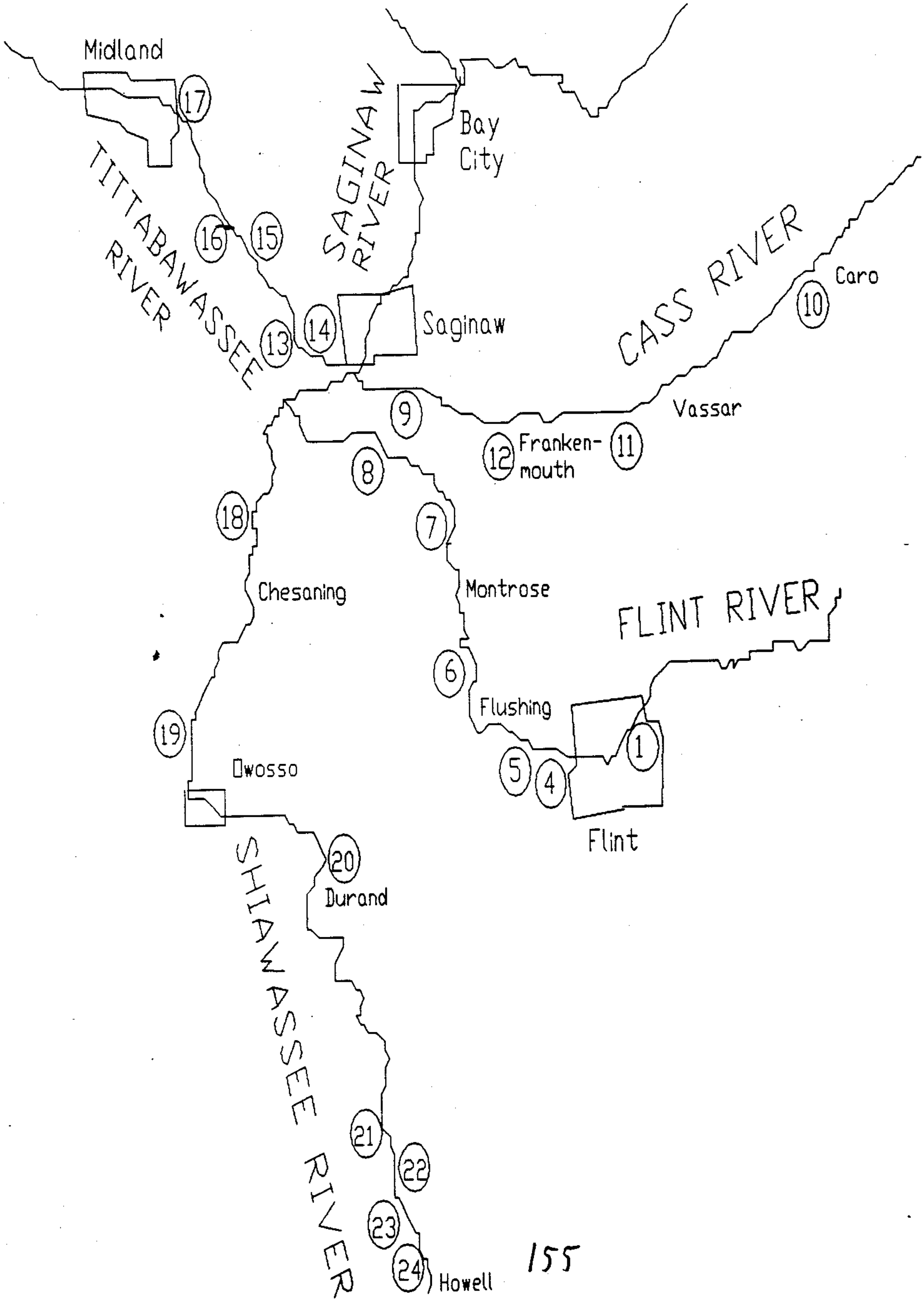

200
201
202
203
204
205
206
207
208
209
210
211
212
61
S61
60
S37
58
1
2
S60
6
7
215
10
11
12
13
S27
15
16
17
18
22
23
24
S17
28
29
30
31
34
35
36
37
38
40
41
42
43
217
46
47
48
49
50
51
S7A
52
53
54
55
56
222
218
219
220
S30
221
223
224
225
226
228
227

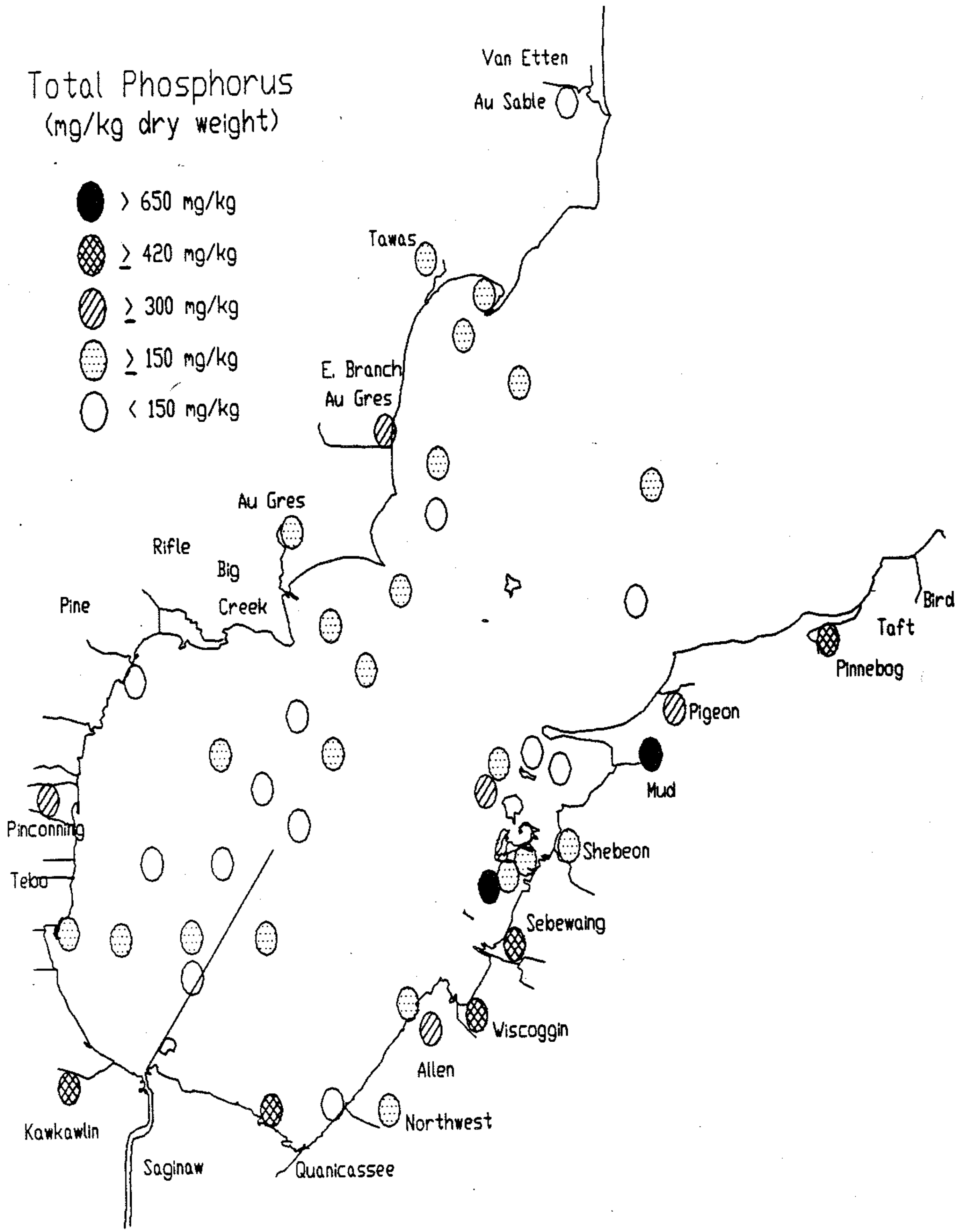

Van Etten 34
Au Sable 31
Tawas 30
E. Branch
Au Gres 28
Au Gres 27
Rifle 24
Big 26
Creek
Pine 23
1 Bird
2 Tuft
3 Pinnebog
4 Pigeon
5 Mud
6 Shebeon
20
Pinconning
Tebo
18
Sebewaing
8
9
10
11 Wiscoggin
12
Allen
13 Northwest
16
Kawkawlin
Saginaw
Quanicassee
14


SAGINAW BAY
Independence
Detroit and Mackinac Railroad
Grand Trunk Railroad
GMC-CPC
Bay City WWTP
Liberty
M-25
Bay City
Salzburg
Middle Grounds
Dutch Creek

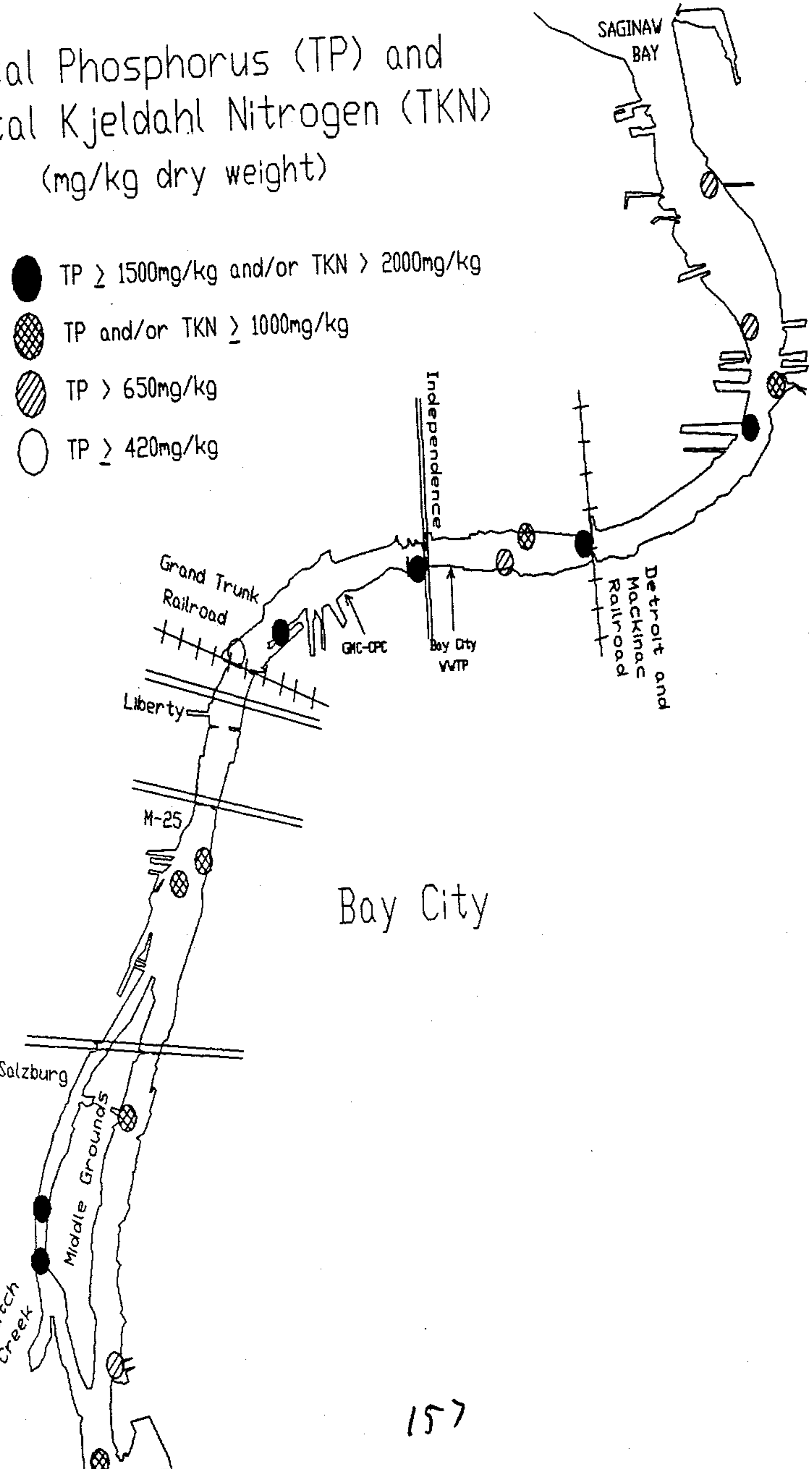

Cheboyganing
Creek
42
43
44
45
46
I-75
47
68
69
70
71
72
73
74
76
Saginaw
WWTP
GM
Central
Foundry

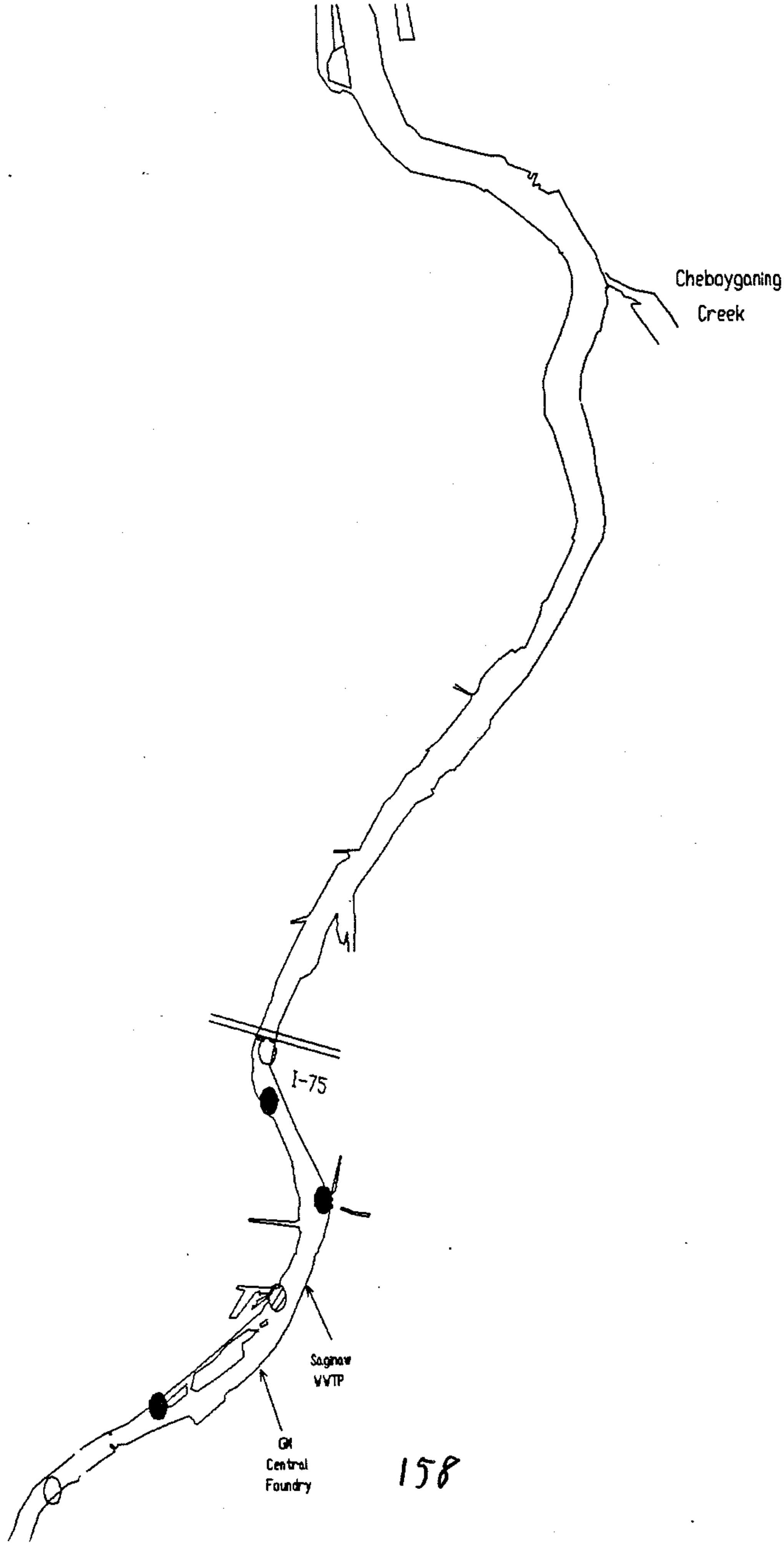

C & O Railroad
Weiss
Drain
I-675
Genesee
Grand Trunk
Railroad
Holland
Court
Rust
Center
Tittabawassee
River
Shiawassee
River
Cass
River
CITY OF
SAGINAW

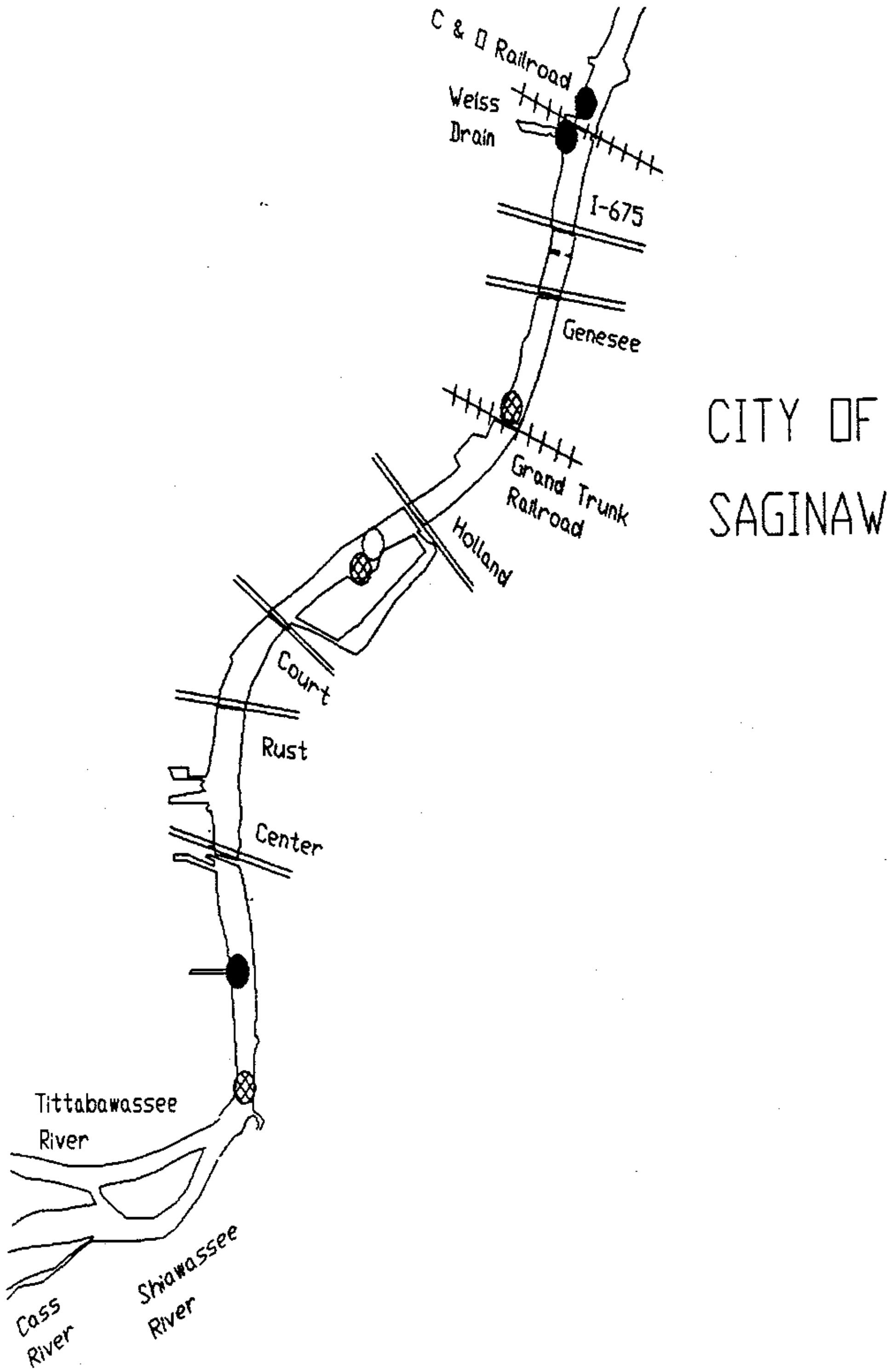

Midland
17
TITTABAWASSEE RIVER
16
15
SAGINAW RIVER
Bay City
14
13
Saginaw
CASS RIVER
Caro
10
9
Vassar
12
Franken-mouth
11
8
18
7
Chesaning
Montrose
FLINT RIVER
6
Flushing
19
1
5
4
Owosso
Flint
20
Durand
SHIAWASSEE RIVER
21
22
23
24
Howell

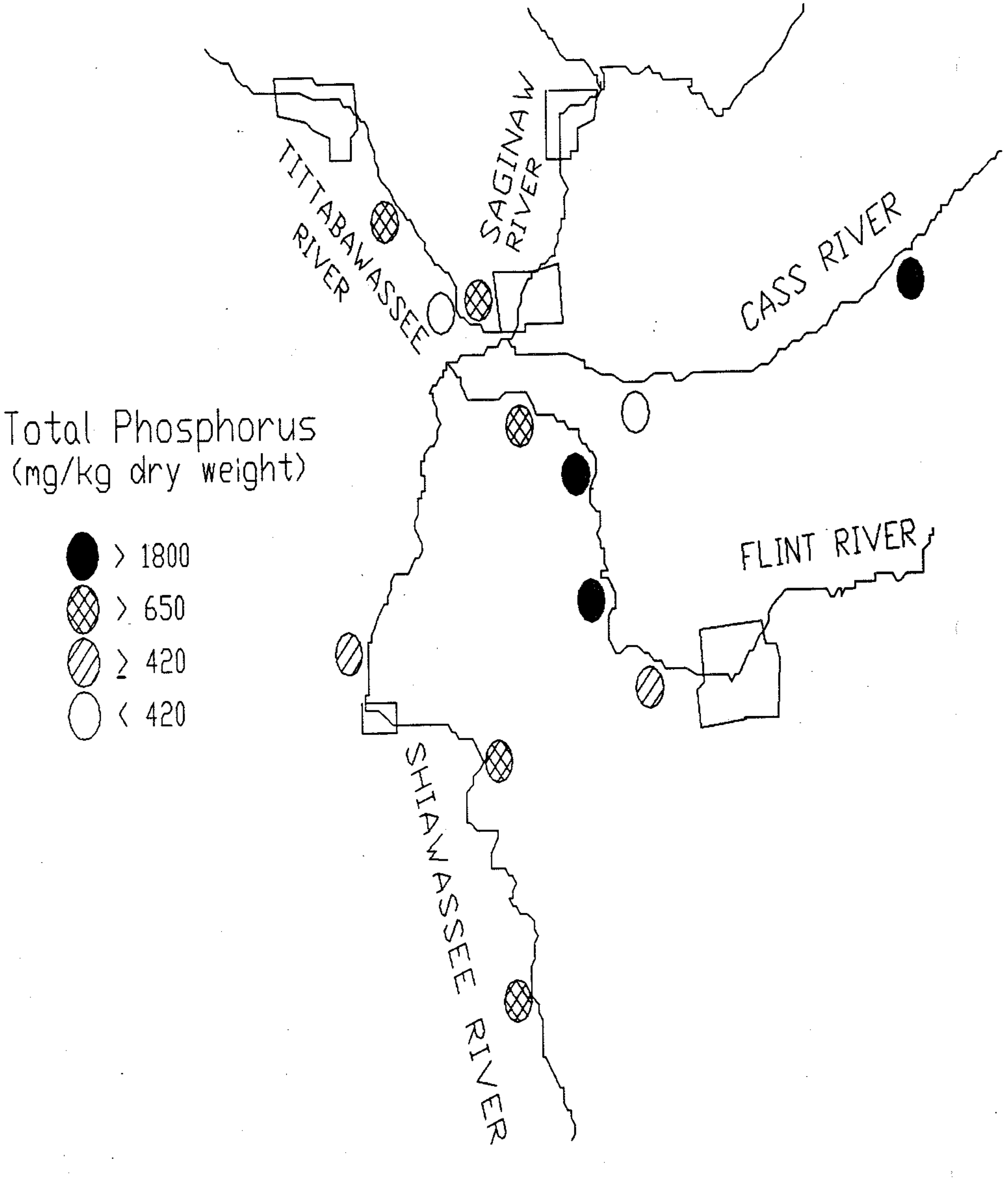

Total Phosphorus
(mg/kg dry weight)
> 650 mg/kg
≥ 420 mg/kg
≥ 300 mg/kg
≥ 150 mg/kg
< 150 mg/kg
Van Etten
Au Sable
Tawas
E. Branch
Au Gres
Au Gres
Rifle
Big
Creek
Pine
Pinconning
Tebo
Kawkawlin
Saginaw
Quanicassee
Northwest
Allen
Wiscoggin
Sebewaing
Shebeon
Mud
Pigeon
Pinnebog
Taft
Bird

Total Phosphorus (TP) and Total Kjeldahl Nitrogen (TKN) (mg/kg dry weight)



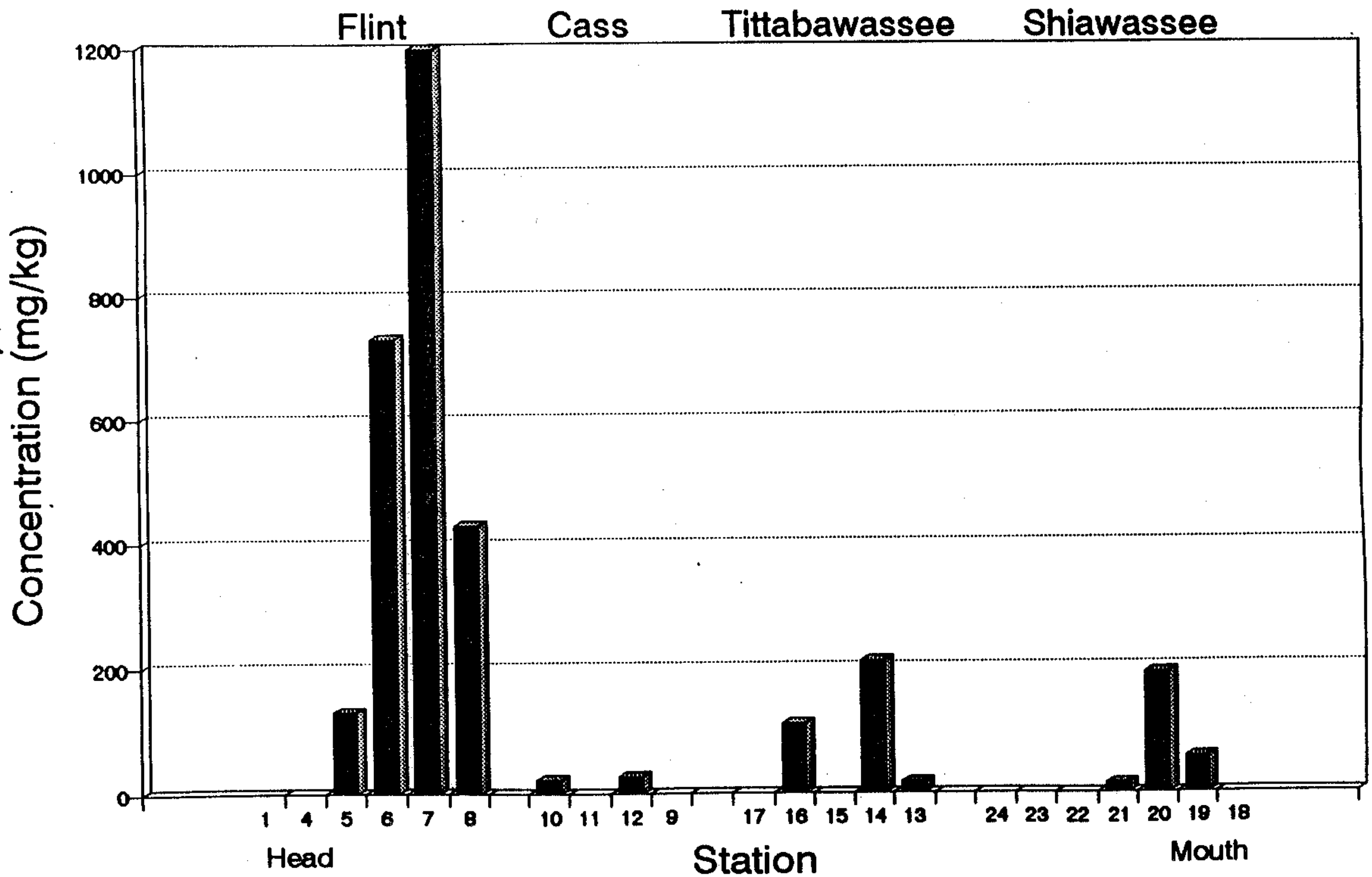

Cheboyganing
Creek
I-75
Saginaw
WWTP
GM
Central
Foundry

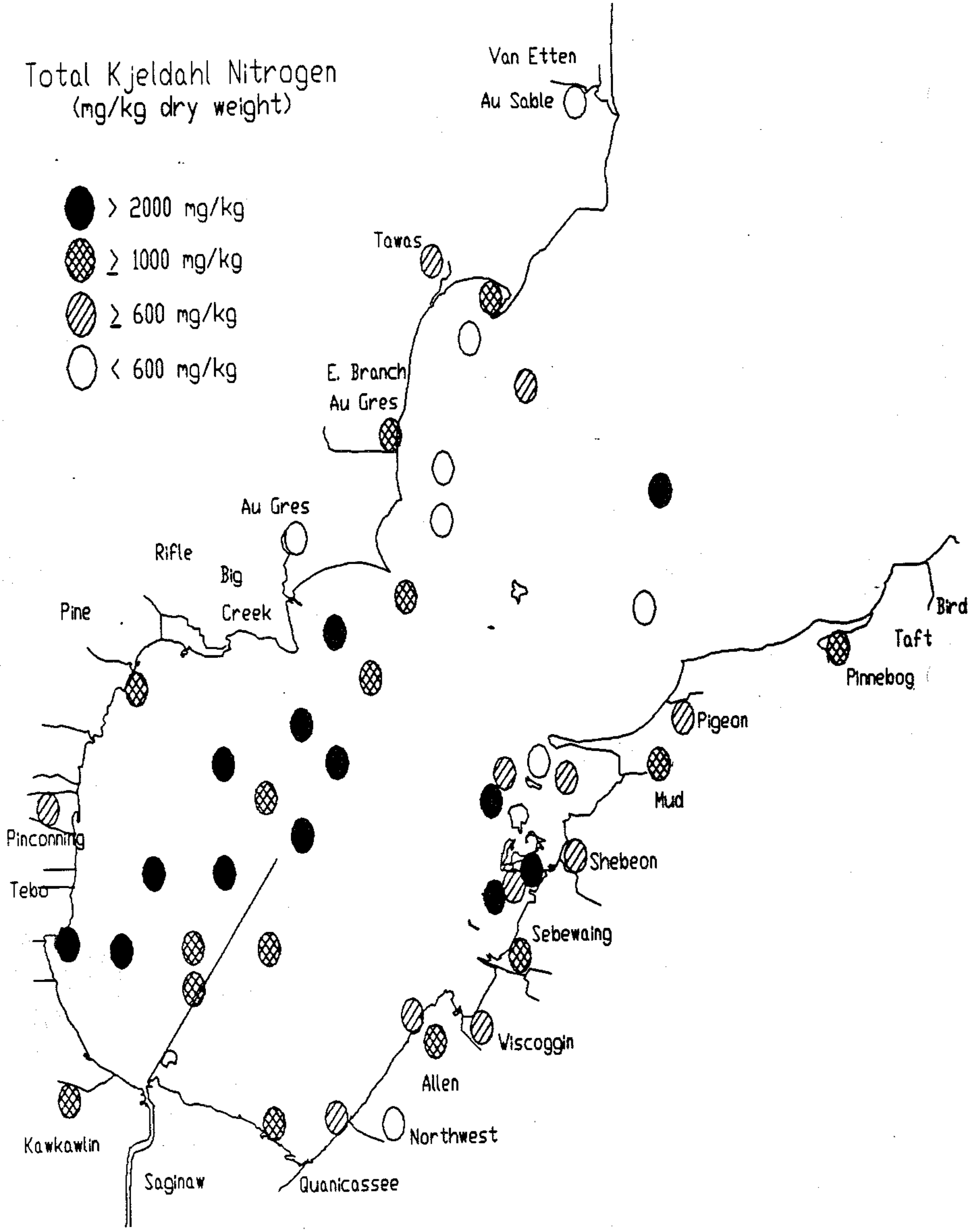

C & O Railroad
Weiss Drain
I-675
Genesee
Grand Trunk Railroad
Holland
Court
Rust
Center
Tittabawassee River
Cass River
Shiawassee River
CITY OF SAGINAW


TITTABAWASSEE RIVER
SAGINAW RIVER
CASS RIVER
FLINT RIVER
SHIAWASSEE RIVER
Total Phosphorus
(mg/kg dry weight)
> 1800
> 650
≥ 420
< 420

SAGINAW RIVER TRIBUTARIES

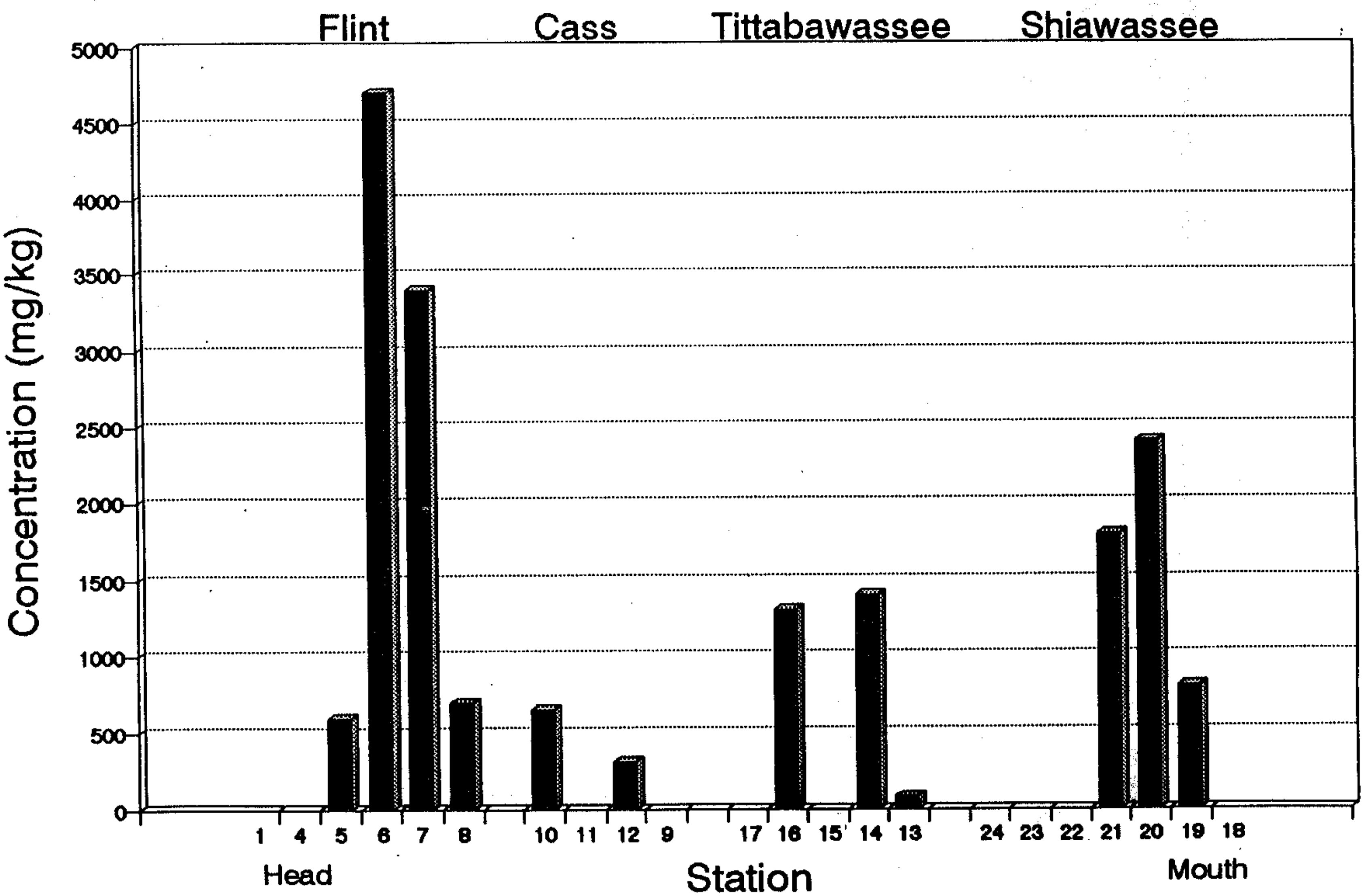
Ortho Phosphate in Sediment



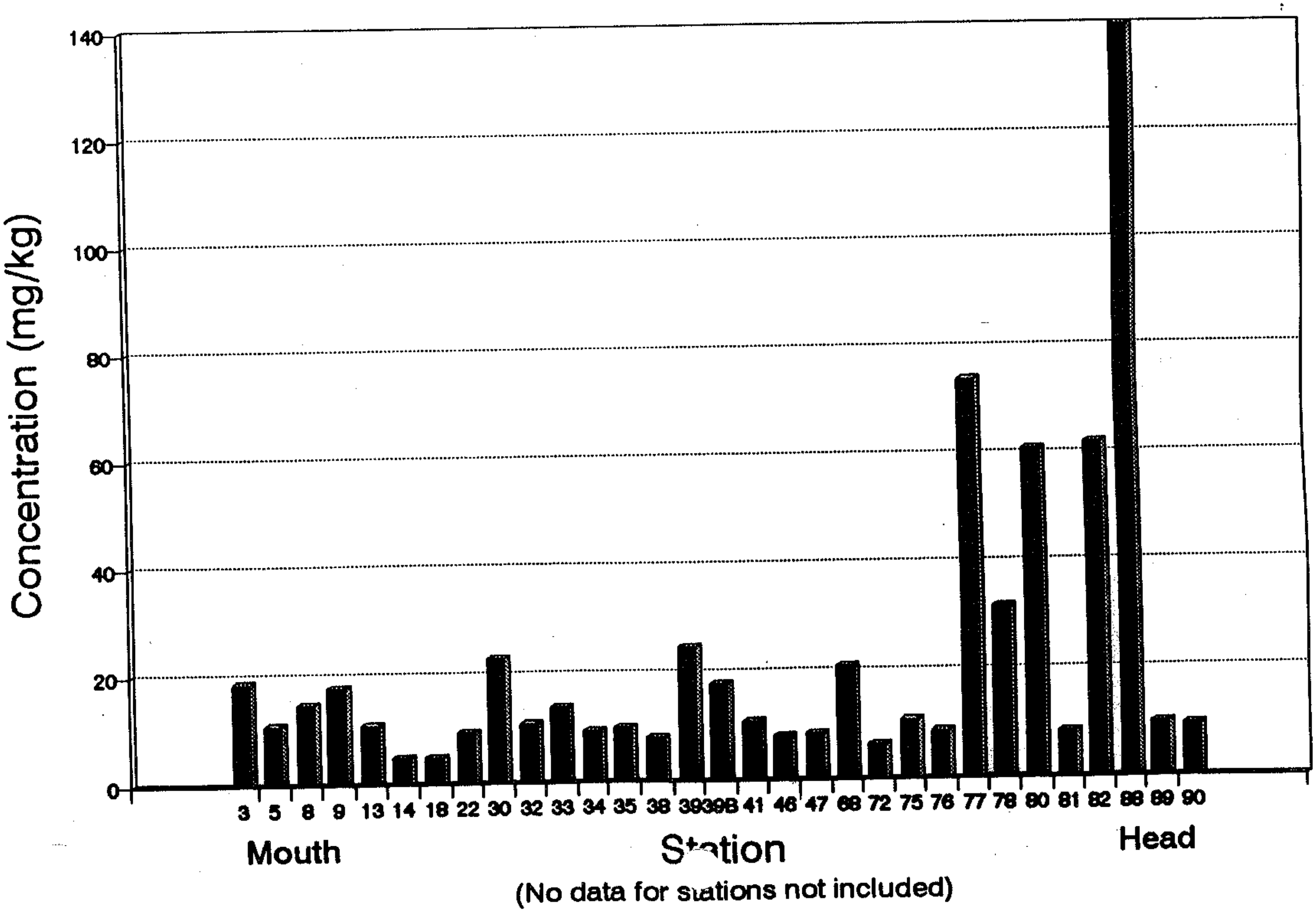

Total Kjeldahl Nitrogen
(mg/kg dry weight)
> 2000 mg/kg
≥ 1000 mg/kg
≥ 600 mg/kg
< 600 mg/kg
Van Etten
Au Sable
Tawas
E. Branch
Au Gres
Au Gres
Rifle
Big
Creek
Pine
Pinconning
Tebo
Kawkawlin
Saginaw
Quanicassee
Northwest
Allen
Viscoggin
Sebewaing
Shebeon
Mud
Pigeon
Pinnebog
Taft
Bird

SAGINAW RIVER TRIBUTARIES

Total Kjeldahl Nitrogen in Sediment

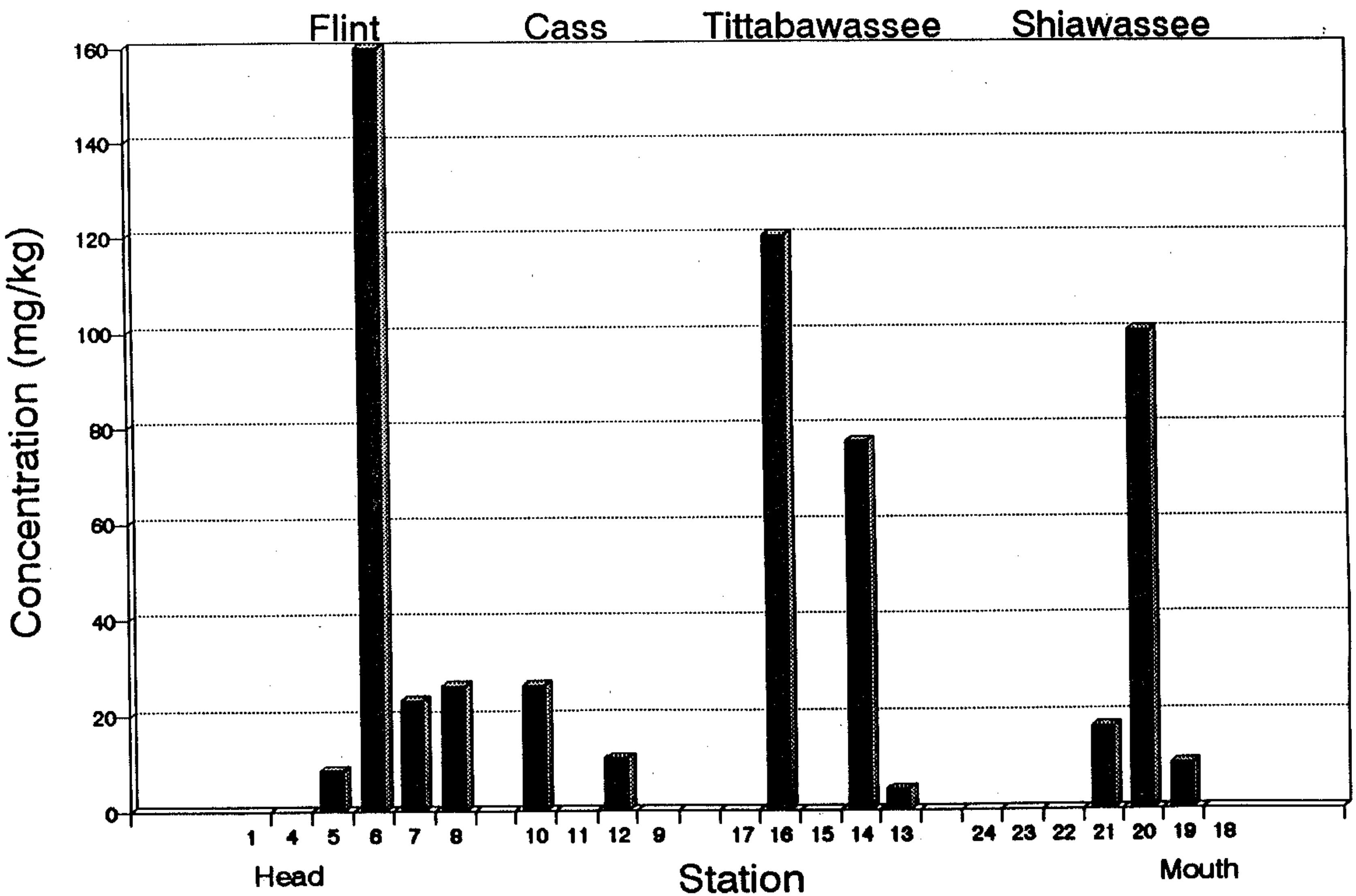


SAGINAW RIVER
Ammonia Nitrogen in Sediment



SAGINAW RIVER TRIBUTARIES

Ammonia Nitrogen in Sediment



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APPENDIX FIVE: AQUATIC BIOTA

A. PHYTOPLANKTON

1. Saginaw Bay Communities

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 (Table III-5). 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 that 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 these 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).

2. Chlorophyll a

a. Saginaw Bay

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) could not 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 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. Furthermore, spring 1984 measurements showed that concentrations of chlorophyll a dramatically increased from the mouth of the bay southward toward the Saginaw River (Figure III-88), resulting in a bay-wide area weighted mean of 10.1 ug/l (Neilson et al., 1986).

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 (Figure 35). When the bay was next sampled a decade later, spring chlorophyll a levels did not appear to differ substantially from those of 1980 (Nalepa, pers. com.). However, by fall 1991, preliminary data from the NOAA zebra mussel project indicated that chlorophyll a concentrations had dropped dramatically, and that they stayed substantially lower in 1992 and 1993 (Figure 35).

b. Saginaw Bay 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).

c. Tributaries

The most recent data available on chlorophyll a levels in Saginaw Bay tributaries is from 1991. Among the coastal basin tributaries sampled, the Pinconning River had the highest concentration at 20.5 ug/l, followed by the Kawkawlin River with 16.4 ug/l (Figure 36). The east coastal basin tributaries with the highest concentrations were the Pinnebog and Pigeon rivers with values of 14.4 ug/l and 10.1 ug/l, respectively.

Once again, the Flint River had the highest concentration relative to the other three major tributaries to the Saginaw River. The Flint River chlorophyll a mean of 22.7 ug/l was substantially greater than the next highest average of 13.7 ug/l in the Cass River (Figure 37). The Tittabawassee and Shiawassee rivers had similar concentrations of around 8 ug/l. Chlorophyll a concentrations in the Saginaw River were only slightly lower than in the Flint River, averaging 21.2 ug/l at the head of the river and 18.6 ug/l at the mouth.

B. SAGINAW BAY ZOOPLANKTON

1. 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).

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 load reductions to 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).

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 (A nuraeopsis 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).

2. 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.

3. 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 rotifers 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).

C. BENTHIC MACROINVERTEBRATES

1. Saginaw Bay

a. Navigation Channel

Benthic macroinvertebrate samples were collected from 11 stations in the Saginaw Bay navigation channel in July 1983 by ERG for the U.S. Army Corps of Eng[illegible]eers. 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 (P isidium sp.).

Colle[illegible]ons in the channel yielded only taxa classified as pollution tolerant, primarily chironomids and tubificids. 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.

b. Saginaw Bay Proper

The offshore macrozoobenthic community in Saginaw Bay has been studied periodically sin[illegible] the mid-195[illegible] (Surber, 1957; Brinkhurst, 1967; Schneider et al. 1969; Schelske and Roth, 19[illegible] 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 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, inc[illegible]ding 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 b[illegible] due to the exceptionally high salinity of the Saginaw River; water analyses at that time occa[illegible]ly 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/m² in early spring but declining to less than 50/m² 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/m² in 1955, to 9/m² in 1956, to 1/m² in 1965 (Schneider et al., 1969), to 0/m² 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/m² 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/m² at station 31 to 35,675/m² 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/m² in 1956 (Brinkhurst, 1967), and 3,500/m² 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).

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 valuable 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 suggest decreasing water and sediment quality in inner Saginaw Bay during this time period.

c. Changes in Trophic Status

Both oligochaetes and chironomids have been used as indicators of water and sediment quality in the Great Lakes (Nalepa 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).

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.

2. Tributaries

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.

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 (A sellus sp.), and a single pelecypod specimen (S phaeridum sp.).

All taxa collected from the Saginaw River were classified as pollution tolerant. Tubificids, including Limnodrilus hoffmeisteri, L. cervix, and L. maumeensis, were present at all stations. Mature tubificids contributed 100% of the total at the station just upstream of the city of Saginaw WWTP, 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. Watershed Comparisons

Between June 1991 and September 1992, 65 subwatersheds within the Saginaw Bay basin were examined to identify relationships to stream habitat, water quality, and macroinvertebrate communities (Richards et. al., 1993). Forty-six of these sites underwent comparative analysis (Figure 1).

Considerable variation was observed among the major basins with respect to the 15 macroinvertebrate community metrics during summer (Table 11). Metric values for the Flint, Shiawassee, and Chippewa river watersheds were similar. But sites within the Kawkawlin River basin and east coastal basin differed considerably from the Flint, Shiawassee and Chippewa river watersheds.

The Kawkawlin watershed was notable for the high proportion of shredders and filterers, and low proportion of detritivores. The east coastal basin also had a high proportion of shredders. Both the east coastal and Kawkawlin basins had higher proportions of depositional taxa and lower proportions of strictly erosional taxa and than the other major basins. Taxa in the east coastal and Kawkawlin watersheds also exhibited lower oxygen tolerance than other major basins. In addition, their Hilsenhoff Biotic Index scores (which are sensitive to oxygen availability) were higher than other basins, and they had the lowest EPT richness. However, total richness at Kawkawlin was relatively high. Richness was highest in the Chippewa/Pine watershed and lowest in the east coastal basin.

In general, macroinvertebrate metrics for fall exhibited patterns among the major basins similar to those observed during summer (Table 12). The Kawkawlin and east coastal watersheds had high HBI scores, low EPT scores, low proportions of erosional taxa, and high proportions of depositional taxa. The proportion of predators was exceptionally high in the Kawkawlin basin due to the abundance and trophic classification of one chironomid genus.

Macroinvertebrates were most strongly related to channel morphology, substrate characteristics, and nutrient concentrations. At the largest scale, geomorphic differences among watersheds and the extremes of land use (extensive row crop agriculture) had the strongest influence on macroinvertebrate communities, through their influence on stream habitat. At smaller scales, land use patterns (type, heterogeneity) exhibited more influence through their association with water chemistry and habitat alterations.

Macroinvertebrate data from various MDNR biological surveys have been summarized to produce "generic" stream compositions for several of the major watersheds in the Saginaw Bay basin. Again, numerous differences are apparent between the coastal streams and the Saginaw River tributaries (Table 29).

D. FISH

1. Saginaw Bay Communities

The shallow productive waters of Saginaw Bay provide outstanding habitat for a wide variety of fish and other aquatic species. Over 90 fish species have been recorded in Saginaw Bay, the most common of which are listed in Table 7. 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, have 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). However, the population collapsed with commercial overfishing and predation by sea lamprey the probable causes. 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 Bay, Point Au Gres, Charity Islands, Sand Point, and Port Austin, but, for unknown reasons, with little success. However, lake trout eggs and fry have been collected on Tawas Reef, and several apparently wild, older lake trout have been observed.

Alteration of spawning habitats, pollution of the Saginaw River, and over fishing have been implicated as the causes of the historical decline of walleye stocks in Saginaw Bay. Walleye were once the premier commercial species in the region, and Saginaw Bay supported the second largest walleye fishery in the Great Lakes, exceeded only by that of Lake Erie, providing harvests as large as two million pounds (Schneider, 1977). But the walleye fishery collapsed in the late 1940s and did not recover after the commercial fishery was closed. 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 Coryeon Reef, and in the vicinity of the Charity Islands, in shallow waters over a variety of substrates (Goodyear, et al., 1982). Organic enrichment, increased turbidity, and siltation in Saginaw Bay; and the impoundment and pollution of many tributary streams, are among the factors believed to have contributed to the decline.

Rehabilitation of the Saginaw Bay walleye population began in the 1970s with the stocking of fingerlings. This stocking program has been tremendously successful and walleye harvest by sport anglers increased from near zero in 1980 to over 140,000 fish in 1993. However, the walleye yield is currently about 500,000 pounds, or only 25% of the historical level. The extent to which the walleye fishery is supported by natural reproduction is presently unknown and is the focus of current research. Recovery of reproducing walleye stocks in the bay would be indicative of progress in the restoration of water quality and habitat conditions.

So that the number of wild recruits to the walleye fishery could be measured, no walleye were stocked in 1993. Walleye fry have been very abundant in the Saginaw River in recent years and were again in 1993. Wild young-of-the-year were also collected in 1993 in the Tittabawassee River (71 individuals), Saginaw River (40), and Saginaw Bay (16). In addition, several young walleye were collected in the Flint River. Substantial reproduction of walleye has been reestablished in the Tittabawassee/Saginaw River system and in some of the smaller Saginaw Bay tributaries. Though a significant portion of the bay's walleye are wild, some of these fish may have traveled to Saginaw Bay from other areas such as Lake St. Clair and Lake Erie. Ongoing research efforts will attempt to quantify the relative contributions of stocking and natural reproduction to the Saginaw Bay walleye population.

Despite the habitat alteration problems experienced in recent years, Saginaw Bay remains a productive habitat for a variety of species. Yellow perch remain abundant and have made up from 1/3 to 1/2 the fish biomass of the bay, although their numbers have dropped since 1989. 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.

Geographically, recent MDNR trawling data indicate that walleye are most abundant on the west side of the bay. White perch and white bass densities are highest at Fish Point. Yellow perch are abundant throughout the bay except for the open waters in the middle of the bay.

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). Saginaw Bay fish densities are about 10 times that found in Lake Erie (Haas, pers. comm.). However, a potential emerging problem exists now that zebra mussels have become established in Saginaw Bay.

Zebra mussels may produce substantial changes in the fish community due to a large diversion of energy from the pelagic food chain to the benthic component. Indeed, the adult fish community may already be demonstrating significant responses. In 1992 and 1993 fall trawl surveys, the MDNR found zebra mussels in the stomachs of white suckers, freshwater drum, redhorse spp., yellow perch, and common carp. Zebra mussels were also found to be a major component of the lake whitefish diet, and in fact, appear to be a staple for whitefish and white sucker. This may be part of the reason that the commercial harvest of lake whitefish from Saginaw Bay has increased dramatically in recent years, rising from 460,000 pounds in 1990 to over 790,000 pounds in 1993, and has become the bay's leading commercial species. Whitefish are apparently reproducing in Saginaw Bay because whitefish fry and fingerlings have been frequently collected in MDNR surveys.

Although mechanisms are not well understood, a number of explanations for the reduction of populations of several desired species in the Saginaw Bay fishery have been offered. Toxic materials, conventional pollutants, and siltation influence the viability of fish populations directly by altering physiology and behavior, and indirectly by modifying habitat and prey abundance. Competition from exotic species (such as smelt, alewife, and white perch) for available food resources is another factor. Carp rooting of macrophyte beds disturbs spawning/nursery areas and increases turbidity, causing potential negative impacts on other species present. Historical overfishing of commercial fish stocks appears to have impacted several species. The damming of tributary streams and shoreline development have altered flow regimes and habitats. And of course, predation by sea lamprey on several species, particularly lake trout, is a well known problem.

Nutrient related changes in water quality are yet another factor that 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 fish production by prohibiting egg development. This mechanism may be limiting reproduction of lake trout and walleye in Saginaw Bay. Sedimentation may make the substrate of spawning beds unsuitable for spawning, or smother eggs.

2. Saginaw River Communities

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).

3. Watershed Comparisons

Fish communities were recently surveyed during July and September, 1993, at 22 selected locations in the Saginaw Bay watershed: five in the east coastal basin, five in the Cass River watershed, five in the Flint River drainage, and seven in the Chippewa River basin (Arthur and Roush, 1993). The most common fish collected (>5% of catch) were common shiners, bluntnose minnows, creek chubs, white suckers, and Johnny darters. Other species that made up at least 1% of the catch were gizzard shad, hornyhead chub, golden shiner, fathead minnow, blacknose dace, rock bass, green sunfish, pumpkinseed sunfish, and blackside darter.

Darters, suckers and shiners occurred more frequently in the Saginaw River watershed. Sunfish and minnows were more common in the east coastal basin samples. Species richness was equivalent between the two major basins, but average abundance was greater in the Saginaw River basin.

Overall, more pollution tolerant than intolerant fish species were collected. A greater percentage of tolerant species occurred at the downstream stations. The Chippewa River drainage had a greater occurrence of intolerant species than the other watersheds. Darters were the most abundant group followed by suckers, minnows and sunfish. Darters were especially numerous at the Cass and Flint basin stations. White suckers were common in all four drainages.

E. WATERFOWL

Though certainly not aquatic biota by definition, waterfowl are dependent on aquatic resources and are therefore discussed in this appendix.

It has been estimated that more than three million waterfowl migrate through the Great Lakes area annually. Large numbers of both dabbling and diving ducks, Canada geese, lesser snow geese, tundra swans, coots, mergansers, and shore birds pass through the region each spring and fall.

Saginaw Bay lies in a historic migration corridor for both dabbling and diving ducks, as well as Canada geese and tundra swans. There are two diving duck migration corridors that converge on Saginaw Bay from prairie Canada (Figure 6). These routes then split, one goes to the Atlantic coast and the other goes south to the Gulf of Mexico. The dabbling duck corridor comes from Ontario, western Quebec, and northern Michigan, moving southerly from Michigan to Ohio, Tennessee, Kentucky, and to the southeast Atlantic states (Figure 7). Canada geese move southerly from the James Bay region with most birds continuing south to winter in the Tennessee Valley or in northern Alabama (Figure 8). A few birds migrate through the Saginaw Bay region and winter in southern Illinois from the Mississippi Valley Population breeding area along the Hudson Bay coast. In addition, Saginaw Bay provides breeding, nesting and rearing habitat for a significant number or local waterfowl.

There has been a marked change in the species composition of waterfowl using Saginaw Bay. In the 1960s and early 1970s, there was a shift away from diving duck use, associated with the loss of submerged aquatic plants and associated macroinvertebrates, that may have been caused by deteriorating water quality in the bay.

The coastal marshes of Saginaw Bay provide nesting habitat for ducks, geese, coots, grebes, gallinules, rails, and a host of songbird species. Mallards, blue-winged teal, wood ducks, and black ducks are the primary nesting dabbling duck species. It is estimated that 0.82 duckling are produced per acre, per year in Saginaw Bay coastal marshes, resulting in approximately 14,600 ducklings per year (Table 9). The primary nesting species are mallard, blue-winged teal, and black ducks. In addition, local giant Canada geese nesting in the bay area have increased significantly in the past few years and produce at least 1,200 young per year. There are many species of marsh, wading, and shore birds that nest in bay marsh habitats or use these areas during the spring and fall migration. Shore birds, tundra swans, grebes, loons, rails, common snipe and other birds are found throughout the region.

In late August, a segment of the waterfowl produced in Michigan start staging in the bay area. The first migrants usually arrive in mid-September (both ducks and geese). Aerial survey data show that an average of 34,000 birds are present by late September increasing to an average of 97,000 by the early November migration peak. As the fall progresses, repeated storm systems and ice conditions cause the birds to migrate further east or south. Most waterfowl have left the region by the time permanent ice cover and snow conditions set in.

Few waterfowl overwinter in the area. In open water areas, such as at the mouth of the Saginaw River or in the cooling water discharge of power plants, mergansers, goldeneyes, oldsquaws, mallards, and black ducks can be found.

Survey data show that over the past 40 years, spring waterfowl use has averaged 62,400 ducks, geese, and swans, with birds concentrating at or near the Nayanquing Point Wildlife Area, Tobico Marsh State Game Area, the Fish Point Wildlife Area, and the Sebewaing/Wildfowl Bay area.

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	19.2	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	

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	19.5	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

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

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

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

Order Family Species	Year 1956	 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 elinquis	X	
Nais simplex		X
Ophidonais serpentina	X	X
Paranais litoralis	X	
Piguetiella mighiganensis		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
Psectrotanypus sp.		X

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

Taxon	Family	Species
Nematoda		
Oligochaeta	Tubificidae	Aulodrilus piqueti
		Ilyodrilus templentoni
		Limnodrilus cervix
		Limnodrilus hoffmeisteri
		Limnodrilus maumeensis
		Limnodrilus udekemianus
		Ouistadrilus multisetosus
		Spirosperma ferox
	Naidiae	Arcteonais lomondi
		Dero digitata
Diptera	Chironomidae	Chironomus sp.
		Cricotopus sp.
		Cryptochironomus sp.
		Glyptotendipes sp.
		Procladius sp.
	Chaoboridae	Chaoborus sp.
	Ceratopogonidae	
Cladocera	Leptodoridae	Leptodor kindti
Coleoptera	Elmidae	Dubiraphia sp.
Isopoda	Asellidae	Asellus sp.
Pelecypoda	Sphaeriidae	Sphaeridum sp.

Table 11. Mean and standard deviation of macroinvertebrate metrics calculated for summer collection periods for six major basins of the Saginaw River drainage.

	East Basin	Cass	Flint	Shiawassee	Chippewa/ Pine	Kawkawlin
n	8	7	8	5	15	3
Chironomidae	59.1 35.3	57.9 20.3	45.9 27.9	32.2 28.5	45.5 29.6	67.1 18.6
Omnivores	19.4 13.7	19.1 7.1	18.1 13.9	14.4 3.8	21.5 9.8	22.0 16.7
Detritivores	57.1 34.1	69.7 9.7	75.3 16.0	79.9 6.4	70.4 9.8	29.0 26.1
Shredders	30.3 33.9	18.7 5.1	10.6 6.0	7.7 6.8	14.4 15.6	51.0 26.9
Gatherers	59.8 32.9	18.7 5.1	64.3 12.8	65.0 14.1	65.8 17.2	39.8 30.1
Filterers	27.4 38.1	23.4 18.5	22.4 14.1	18.9 12.8	17.6 15.1	39.9 35.7
Grazers	32.2 34.4	13.6 16.2	26.2 21.0	40.1 22.7	25.5 21.1	25.4 22.9
Predators	1.5 2.2	1.2 1.2	1.5 2.0	1.0 1.0	1.4 0.8	1.9 0.8
2 Dominants	64.5 25.5	54.3 6.1	50.3 15.2	54.2 9.5	51.9 11.6	60.0 21.7
Total Abundance	2077 4951	650 739	574 622	325 91	497 230	433 297
HBI	7.1 1.4	5.6 ?	5.6 0.8	6.0 0.5	5.1 1.1	8.1 0.8
Erosional Taxa	25.9 12.4	36.1 5.5	35.5 9.5	38.9 14.7	36.1 11.0	14.9 5.3
Depositional Taxa	35.5 13.2	23.7 9.6	27.5 11.5	27.0 6.6	25.4 10.7	52.4 6.5
Species Richness	17.2 4.5	18.3 9.6	22.1 8.2	20.6 4.7	26.6 3.0	23.3 4.9
EPT Taxa Richness	5.0 2.7	5.7 2.8	7.3 3.0	8.0 2.3	10.0 3.7	3.3 0.5

Table 12. Mean and standard deviation of macroinvertebrate metrics calculated for fall collection periods for six major basins of the Saginaw River drainage.

	East Basin	Cass	Flint	Shiawassee	Chippewa/ Pine	Kawkawli n
n	8	7	8	5	15	3
Chironomidae	57.2 33.8	56.0 21.7	32.1 15.7	52.4 18.6	38.8 25.0	67.3 22.2
Omnivores	18.5 13.2	14.3 9.4	14.4 8.0	18.3 7.8	13.1 9.4	2.8 1.9
Detritivores	57.6 31.7	69.2 12.7	80.2 8.7	77.3 10.1	78.6 9.7	13.6 5.4
Shredders	26.7 31.6	21.2 11.6	9.1 5.6	12.8 9.1	15.2 13.8	2.6 2.0
Gatherers	58.1 33.4	65.6 20.8	60.7 12.7	64.3 13.0	74.3 14.4	8.1 4.8
Filterers	22.6 37.8	28.3 23.5	30.5 18.6	9.4 12.0	17.2 14.7	3.7 2.1
Grazers	25.4 29.6	9.1 6.6	31.9 18.8	21.4 14.5	26.1 18.0	19.0 24.0
Predators	1.9 2.2	0.9 1.0	0.7 0.4	3.0 2.5	1.6 1.6	66.0 24.8
2 Dominants	61.1 19.7	48.2 8.8	57.6 10.4	47.2 8.9	48.8 11.2	76.6 10.3
Total Abundance	3965 10596	527 460	580 265	602 327	711 388	2002 2167
HBI	7.1 1.4	5.0 1.4	5.1 1.6	5.7 0.8	4.3 1.4	7.8 0.0
Erosional Taxa	16.1 9.4	34.7 3.9	37.4 4.3	29.5 11.1	33.9 7.8	11.7 1.9
Depositional Taxa	48.4 4.4	25.5 6.4	26.0 8.9	33.4 6.0	27.5 8.4	54.7 6.3
Species Richness	18.0 4.9	19.9 6.4	20.3 6.0	26.4 8.5	25.6 7.8	22.7 1.5
EPT Taxa Richness	3.3 2.6	6.1 2.0	6.8 3.0	8.2 3.9	9.4 3.9	2.7 1.2

Table 29

Qualitative macroinvertebrate survey summary for Saginaw Bay Basin Streams (% of occurrence)

TAXA	Rifle River	Tittabawassee R.	Chippewa R.	Pine R.
PORIFERA (sponges)	1		1	4
PLATYHELMINTHES (flatworms)				
Turbellaria	2	1		5
BRYOZOA (moss worms)	1	1	2	
ANNELIDA (segmented worms)				
Hirudinea (leeches)				
Oligochaeta (worms)	2	3	1	2
ARTHROPODA				
Crustacea				
Amphipoda (scuds)	4	5	8	7
Decapoda (crayfish)	3	5	10	2
Isopoda (sowbugs)			2	
Arachnoidea				
Hydracarina	1	1		
Insecta				
Ephemeroptera (mayflies)				
Baetiscidae	1	4		
Baetidae	5	15	8	3
Caenidae			2	4
Ephemerellidae			5	
Heptageniidae	25	15	8	6
Oligoneuriidae	20			
Potamanthidae			1	
Siphlonuridae		2		
Tricorythidae			2	
Odonata				
Anisoptera (dragonflies)				
Aeshnidae	1	4	2	1
Corduliidae	1			
Gomphidae	2	2	1	
Libellulidae				
Zygoptera (damselflies)				
Calopterygidae	4	5	2	
Coenagrionidae			3	2
Plecoptera (stoneflies)				
Perlidae	7	2	8	
Perlodidae			6	
Pteronarcyidae	5		1	
Hemiptera (true bugs)				
Belostomatidae	2	2		
Corixidae	2	1	3	7
Gerridae	1	3	2	4
Mesoveliidae	1			2
Megaloptera				
Corydalidae (Dobson flies)	3	1	1	
Sialidae (alder flies)				1
Trichoptera (caddisflies)				
Brachycentridae	3	2	3	
Helicopsychidae	5		5	
Hydropsychidae	20	15	10	10
Hydroptilidae				
Leptoceridae	1			
Limnephilidae	1	5	6	5
Philopotamidae		3	2	
Polycentropodidae			1	
Coleoptera (beetles)				
Dytiscidae (total)				
Gyrinidae (adults)	1	3	2	
Haliplidae (adults)	1			
Hydrophilidae (total)	1	2		1
Psephenidae (adults)		2	2	
Elmidae	2	6	6	3
Diptera (flies)				
Athericidae	2	5		
Ceratopogonidae			1	2
Chironomidae	6	7	6	6
Culicidae				
Simulidae	2	5	3	3
Tabanidae	1	1	3	
Tipulidae	1	1		
MOLLUSCA				
Gastropoda (snails)				
Campeloma				
Ferrissia (limpet)			3	
Goniobasis				
Stagnicola	1			
Physa	1	10	6	3
Pelecypoda (clams)				
Sphaerium	5	2	4	3

Qualitative macroinvertebrate survey summary for Saginaw Bay Basin Streams (Cont'd).

	Shiawassee R.	Flint R.	Cass R.	Coastal Streams
PORIFERA (sponges)	2		2	1
PLATYHELMINTHES (flatworms)				
Turbellaria	1	10	2	3
BRYOZOA (moss worms)			2	
ANNELIDA (segmented worms)				
Hirudinea (leeches)	1			3
Oligochaeta (worms)	1	4	1	3
ARTHROPODA				
Crustacea				
Amphipoda (scuds)	3	5	5	20
Decapoda (crayfish)	2	1	8	10
Isopoda (sowbugs)	2	1		7
Arachnoidea				
Hydracarina		1	2	
Insecta				
Ephemeroptera (mayflies)				
Baetiscidae				
Baetidae	15	1	3	4
Caenidae		1	8	
Ephemerellidae				
Heptageniidae	13		15	20
Oligoneuriidae			4	
Potamanthidae				
Siphlonuridae				
Tricorythidae	12	1		
Odonata				
Anisoptera (dragonflies)				
Aeshnidae		1		3
Corduliidae				
Gomphidae				
Libellulidae		1		
Zygoptera (damselflies)				
Calopterygidae			2	2
Coenagrionidae	10	4	2	3
Plecoptera (stoneflies)				
Perlidae			3	
Perlodidae				
Pteronarcyidae				
Hemiptera (true bugs)				
Belostomatidae				1
Corixidae	1	1	4	3
Gerridae	1	2	3	2
Mesoveliidae			1	1
Megaloptera				
Corydalidae (Dobson flies)			1	
Sialidae (alder flies)	1	1	1	1
Trichoptera (caddisflies)				
Brachycentridae				
Helicopsychidae	2			
Hydropsychidae	11	12	10	5
Hydroptilidae		3		
Leptoceridae		1	3	
Limnephilidae	3		6	3
Philopotamidae	1			
Polycentropodidae		4	4	
Coleoptera (beetles)				
Dytiscidae (total)		1		2
Gyrinidae (adults)		1	2	2
Haliplidae (adults)	1		1	3
Hydrophilidae (total)		1	2	1
Psephenidae (adults)	2		2	
Elmidae	2	3	5	2
Diptera (flies)				
Athericidae				
Ceratopogonidae		1		
Chironomidae	6	10	4	6
Culicidae				1
Simulidae	5	3	3	
Tabanidae				
Tipulidae		1		
MOLLUSCA				
Gastropoda (snails)				
Campeloma				1
Ferrissia (limpet)	4	2	2	
Goniobasis			2	
Stagnicola				
Physa	6	1	2	6
Pelecypoda (clams)				
Sphaerium			4	3

Table 7. Fish species found in Saginaw Bay, listed in decreasing order of relative abundance.

1. Yellow perch	35. Splake
2. Alewife	36. Longnose sucker
3. Spottail shiner	37. Logperch
4. Smelt	38. Goldfish
5. Trout perch	39. Rock bass
6. Black crappie	40. Rainbow trout
7. Channel catfish	41. Lake sturgeon
8. White sucker	42. Bluegill
9. Emerald shiner	43. Largemouth bass
10. Gizzard shad	44. Ninespine stickleback
11. Walleye	45. Slimy sculpin
12. Pumpkinseed	46. Bluntnose minnow
13. Common carp	47. Sea Lamprey
14. Freshwater drum	48. Silvery lamprey
15. Brown bullhead	49. Yellow bullhead
16. Stonecat	50. Tadpole Madtom
17. White bass	51. Mudminnow
18. White perch	52. Banded killifish
19. Johnny darter	53. American eel
20. Quillback	54. Burbot
21. Lake trout	55. Longjaw cisco
22. Longnose gar	56. Lake herring
23. Golden shiner	57. Bloater
24. White crappie	58. Hogsucker
25. Northern pike	59. Stoneroller
26. Round whitefish	60. Longnose dace
27. Lake whitefish	61. Common shiner
28. Smallmouth bass	62. Sand shiner
29. Redhorse spp.	63. Spotfin shiner
30. Coho salmon	64. Fathead minnow
31. Bowfin	65. Sauger
32. Black bullhead	66. Iowa darter
33. Brown trout	67. Blackside darter
34. Chinook salmon	68. Mottled sculpin

Table 9. Estimates of Nesting Pairs and Potential Duckling Production in Surveyed Areas of Saginaw Bay.

Area and County	Potential No. Young/Wetland Acre	No. Nesting Pairs/Square Mile Habitat	Wetland Acres/Nesting Pair
Nayanquing Point Bay County	1.60	200	3.2
Tobico Marsh Bay County	0.80	100	6.4
Quanicassee Area Bay County	0.89	113	5.7
Saginaw Bay Shoreline Tuscola County	0.65	75	8.5
Quanicassee Area Tuscola County	0.14	13	49.2
AVERAGE	0.82	100	14.6

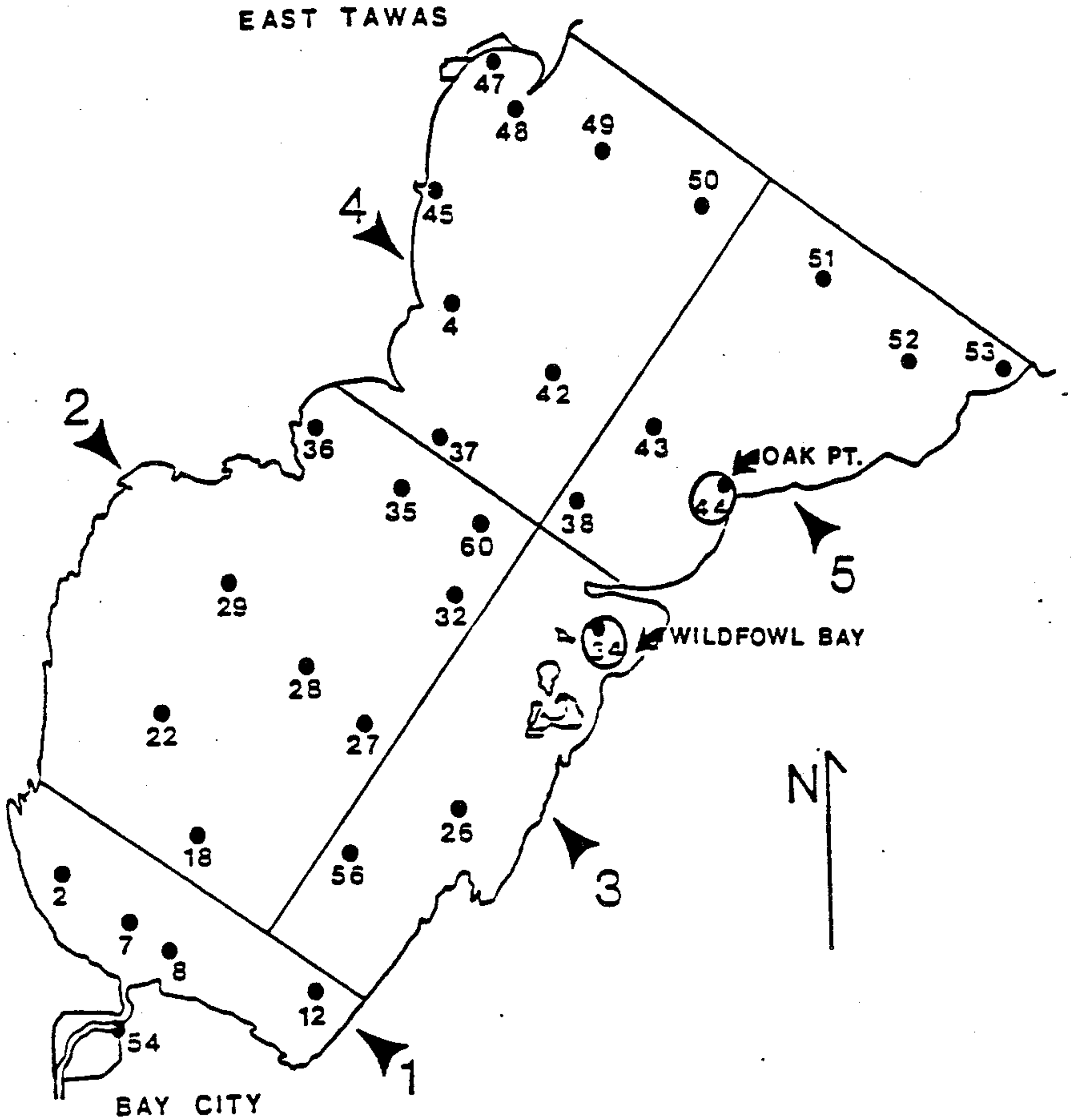


Figure III-85. Plankton station locations in Saginaw Bay, 1980 (Stoermer and Theriot, 1983).

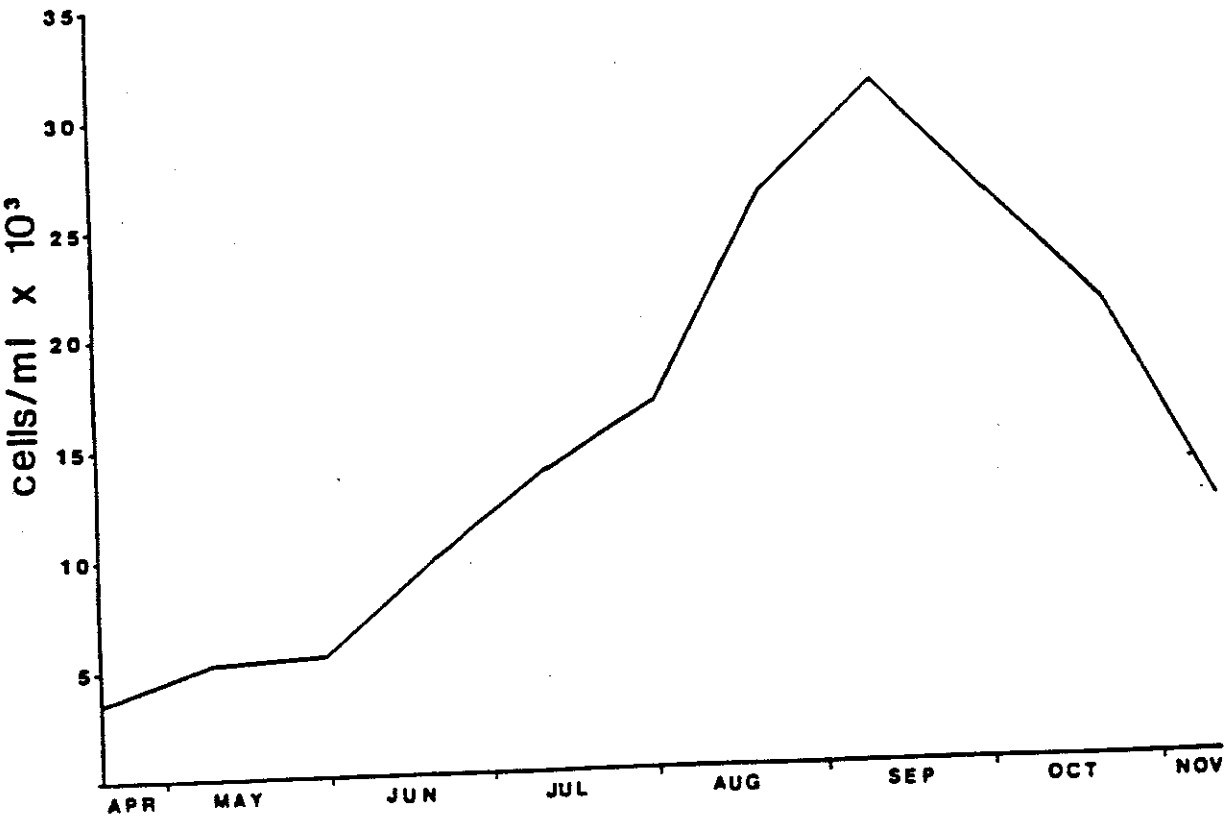


Figure III-86. Seasonal variation of mean total phytoplankton cell abundance in Saginaw Bay, April–November, 1980 (Stoermer and Theriot, 1983).

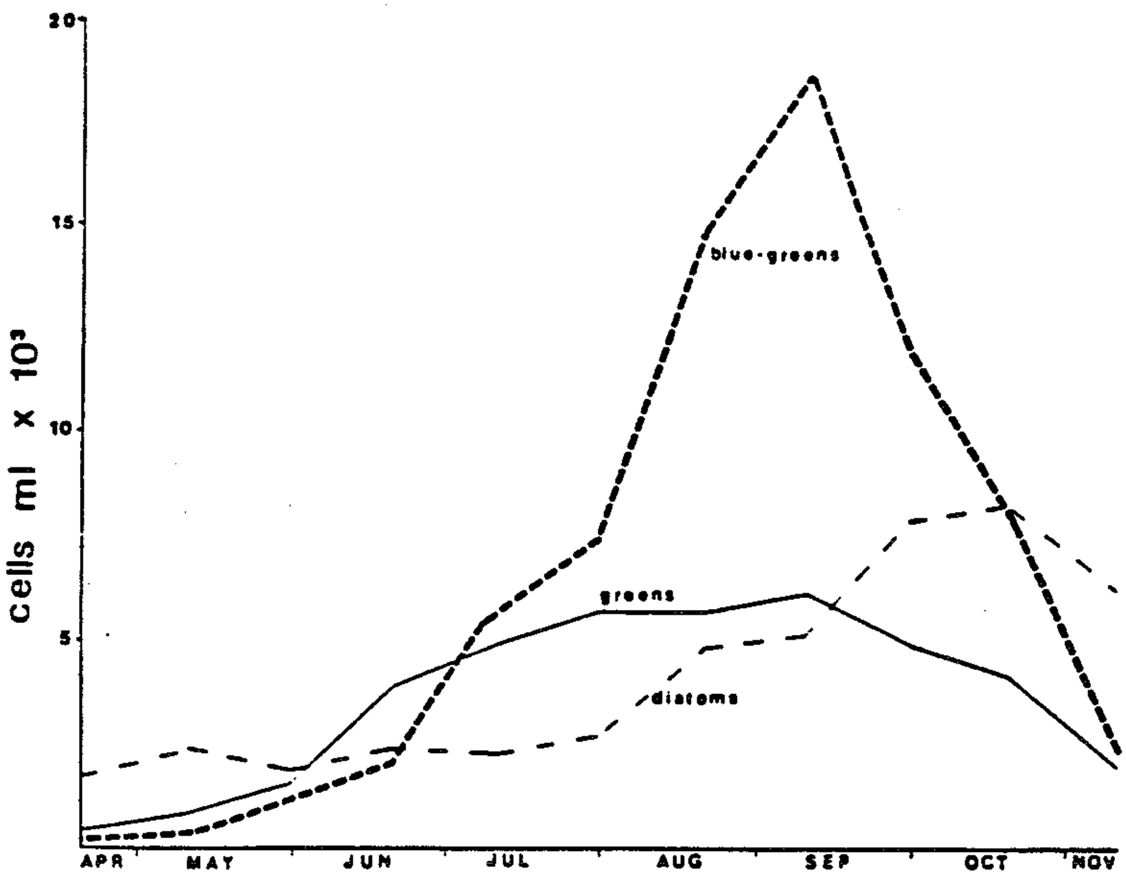


Figure III-87. Seasonal variation of abundance of the three dominant algal divisions in Saginaw Bay, April-November, 1980 (Stoermer and Theriot, 1983).

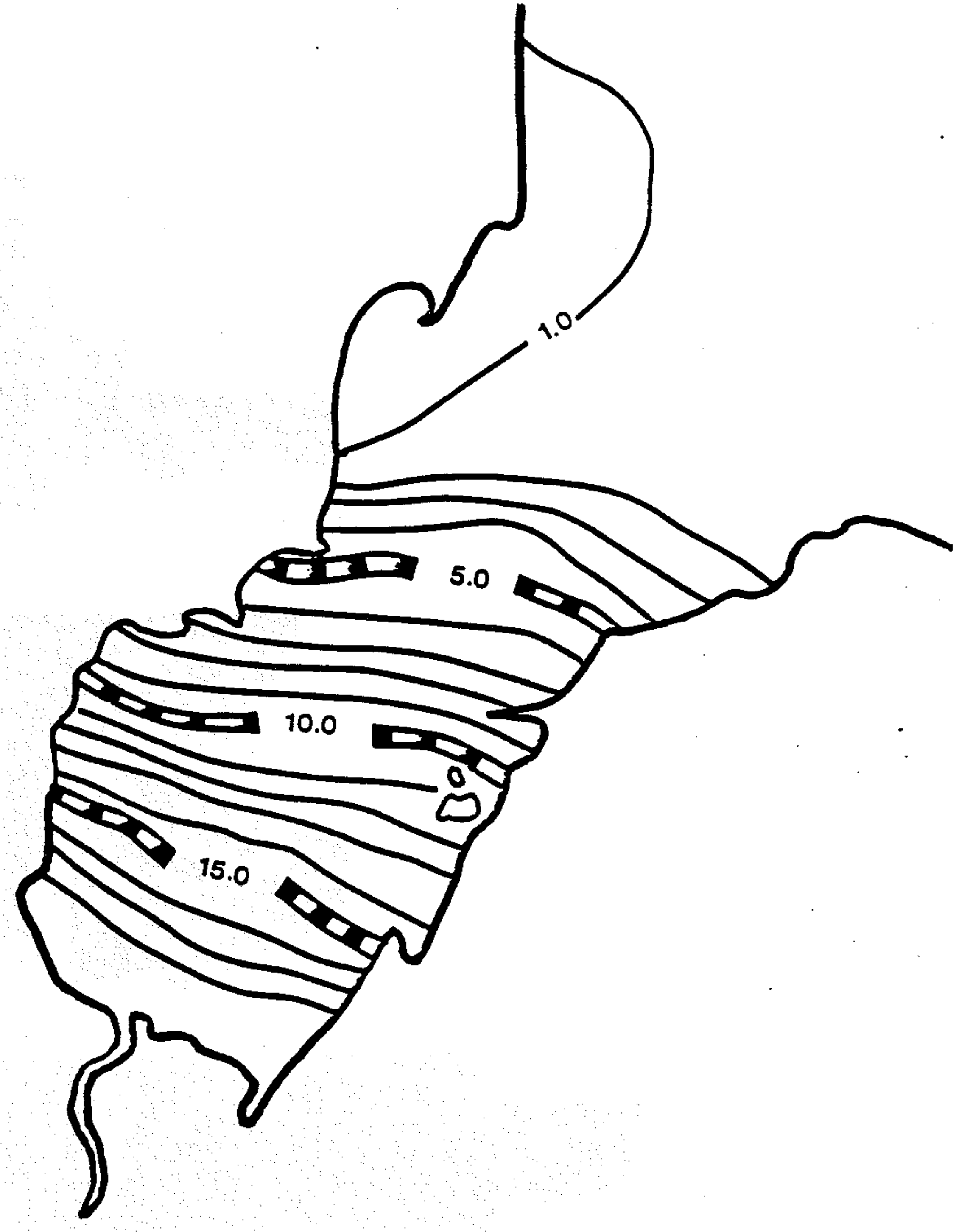


Figure III-24. Integrated (0-20 m) chlorophyll a levels (ug/l) in Saginaw Bay, May, 1984 (Neilson et al., 1986).

AVERAGE CHLOROPHYLL a CONCENTRATIONS
INNER SAGINAW BAY

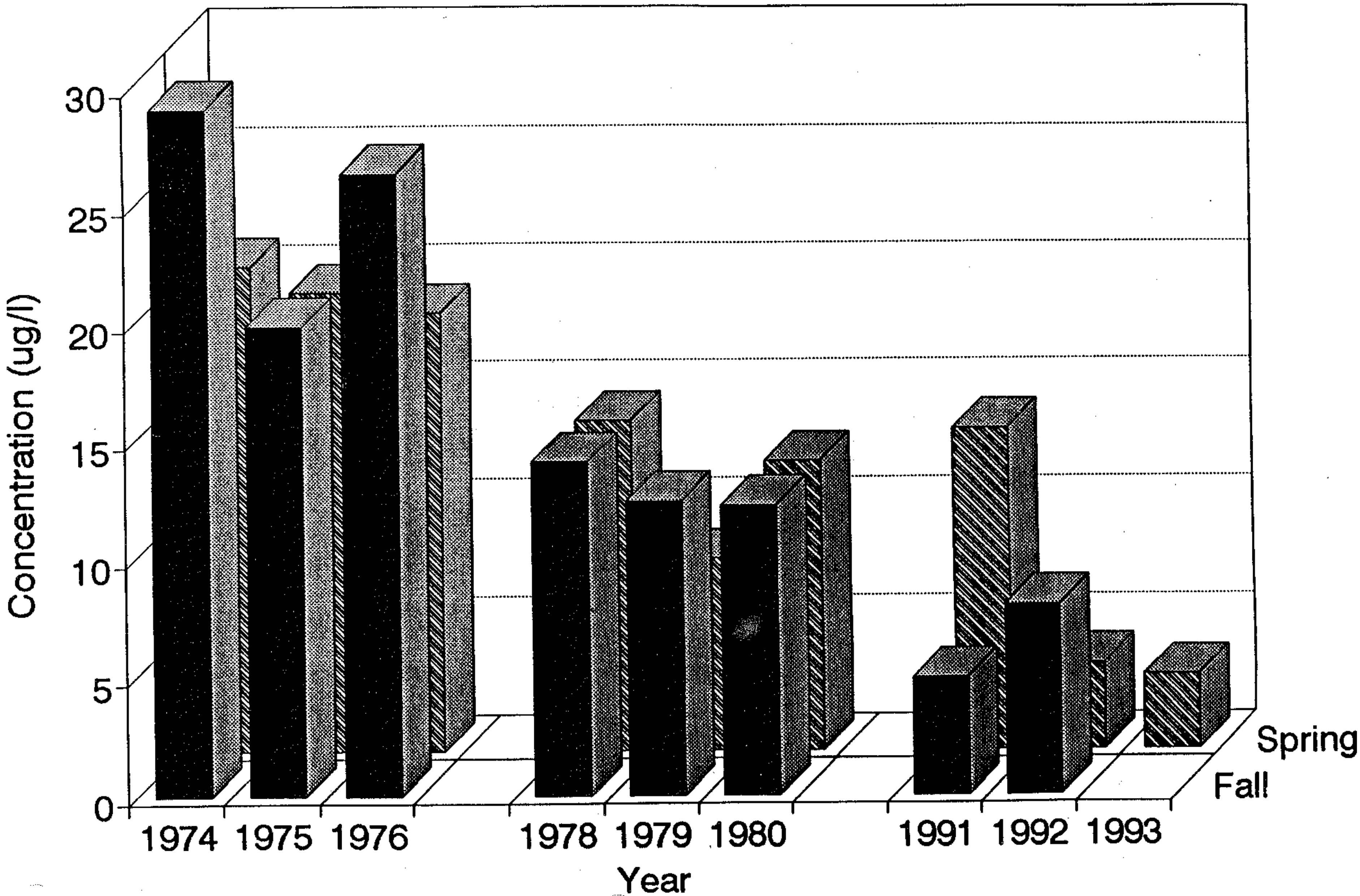


Figure 85

COASTAL BASIN TRIBUTARIES

1991 Chlorophyll a Annual Means

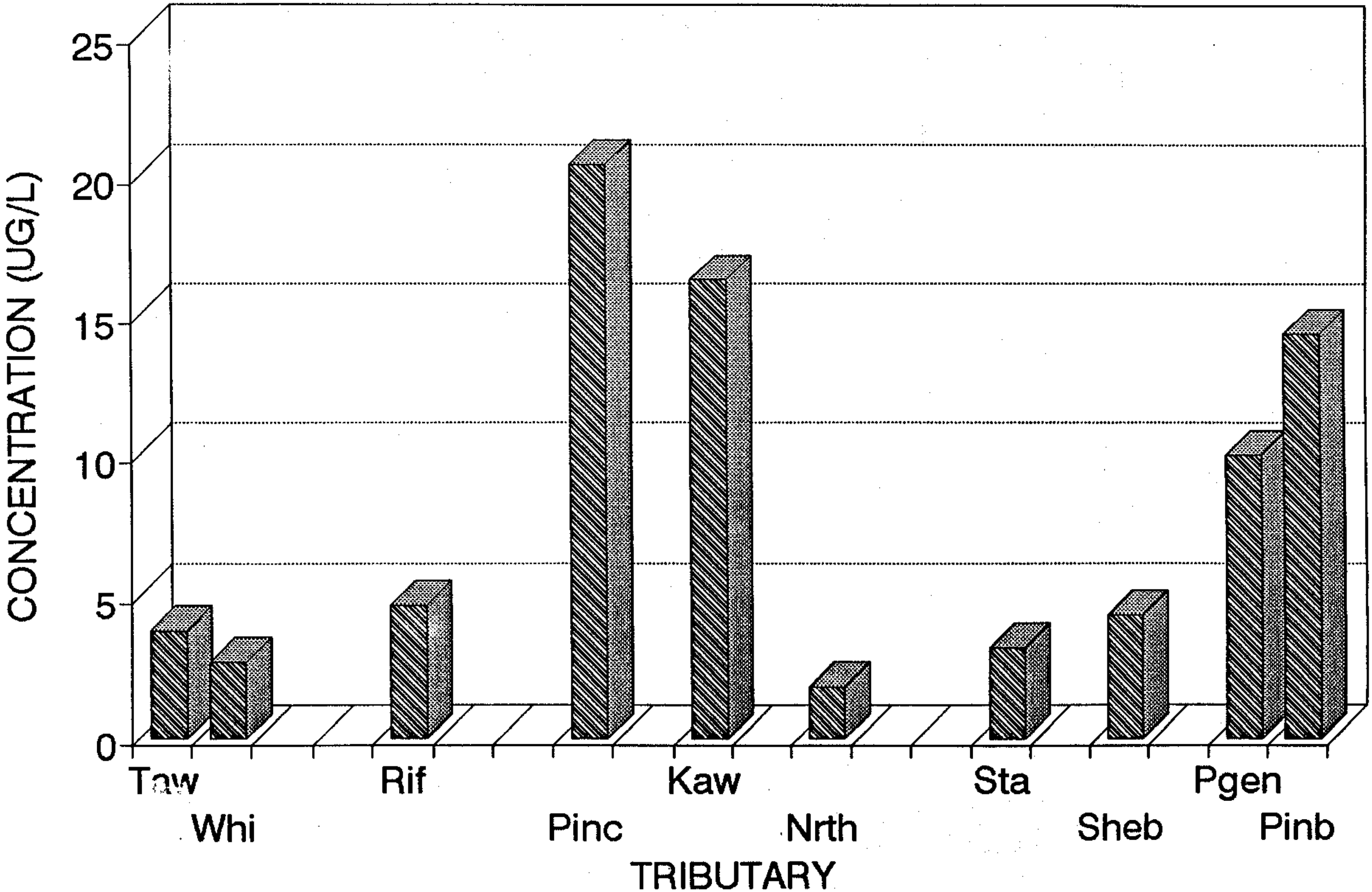


Figure 36

SAGINAW RIVER AND TRIBUTARIES

1991 Chlorophyll a Annual Means

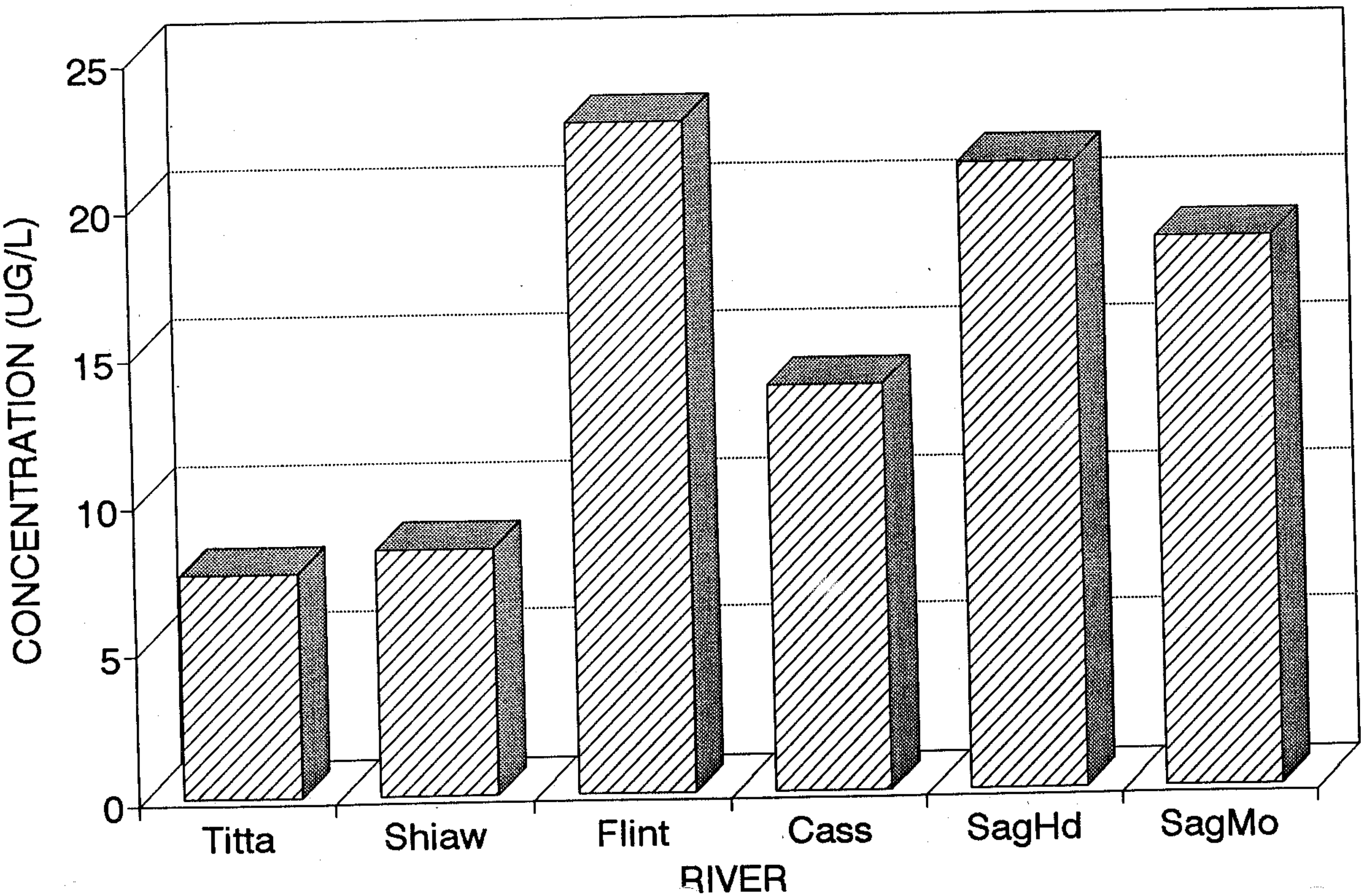


Figure 37

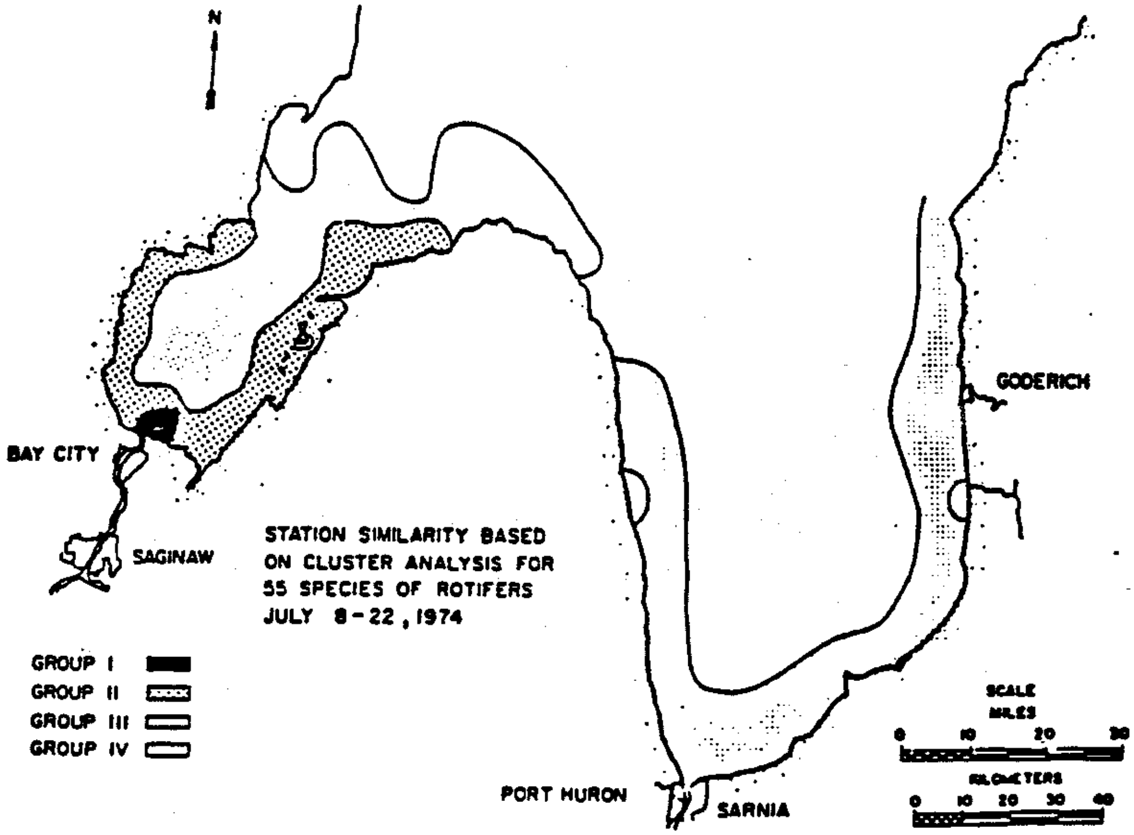


Figure III-89. Grouping of 78 stations determined by cluster analysis of rotifer data for Saginaw Bay and southern Lake Huron during July 1974 (Stemberger and Gannon, 1977).

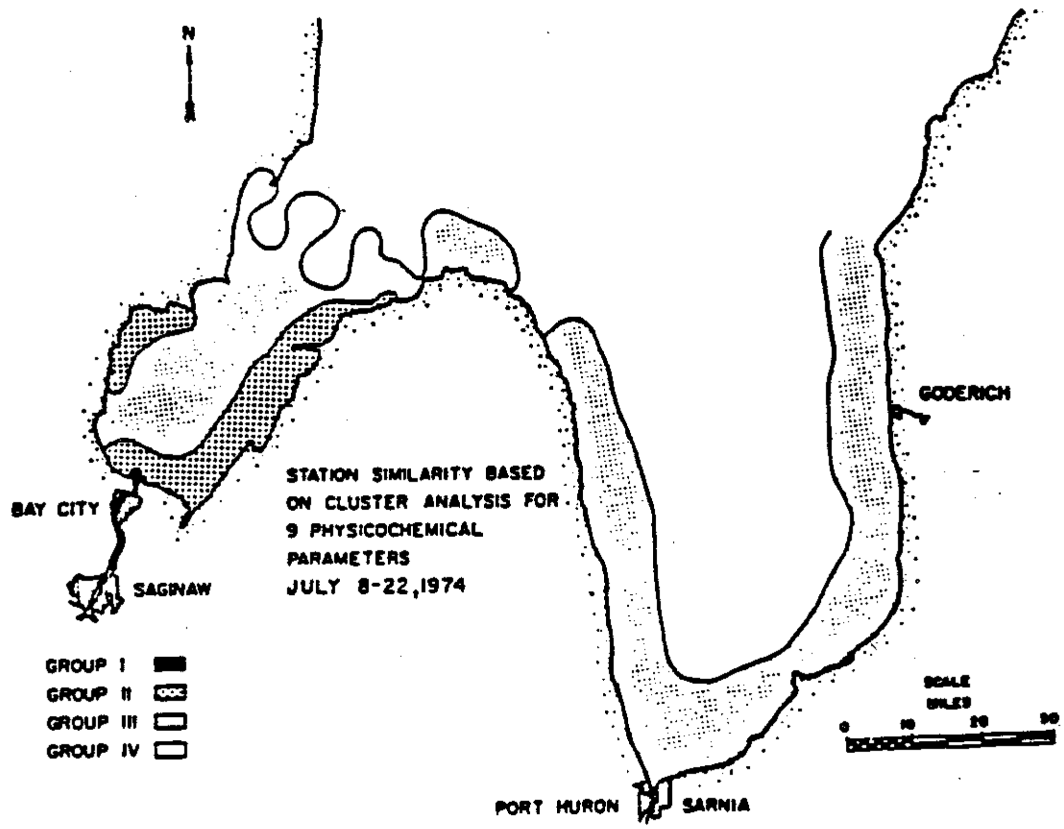


Figure III-90. Grouping of 99 stations determined by cluster analysis of physiochemical data for Saginaw Bay and southern Lake Huron during July, 1974 (Stemberger and Gannon, 1977).

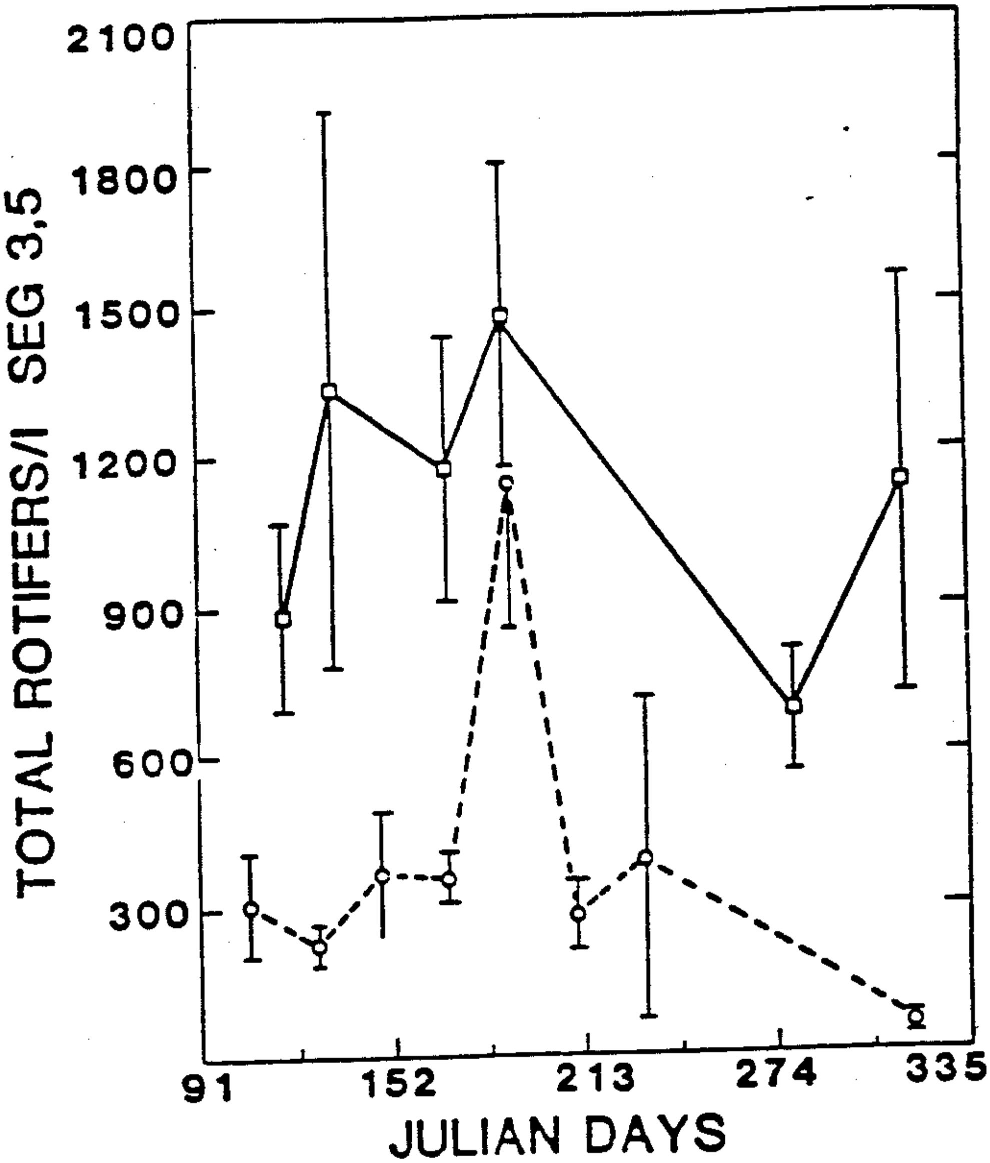


Figure III-91. Numbers of rotifers (#/l) found in segments 3 and 5 in 1974 (□) contrasted to 1980 (○) (McNaught et al., 1983).

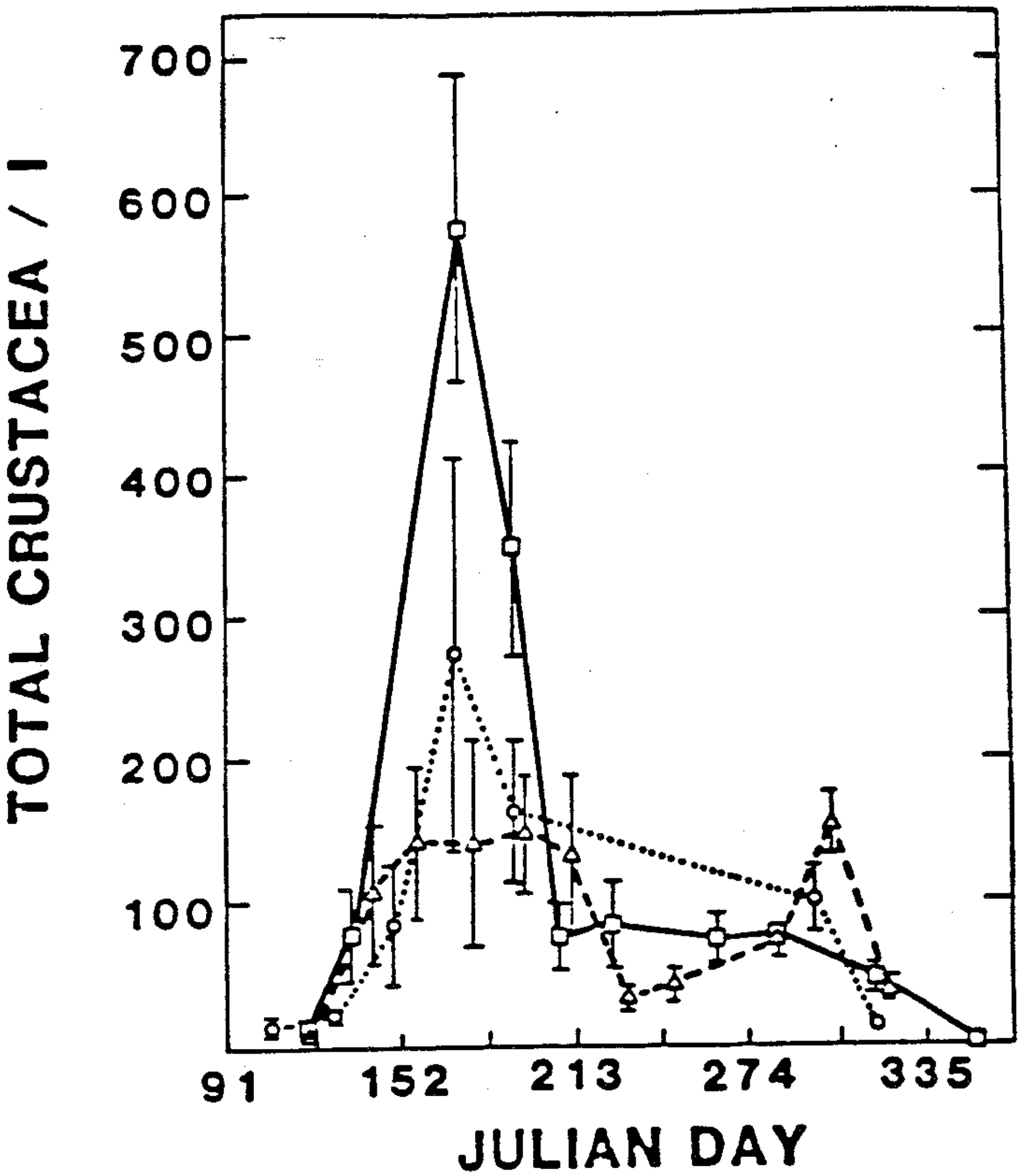


Figure III-92. Numbers of crustacean zooplankton (#/l) found in segments 3 and 5 during 1974, 1975, and 1980 (McNaught et al., 1983).

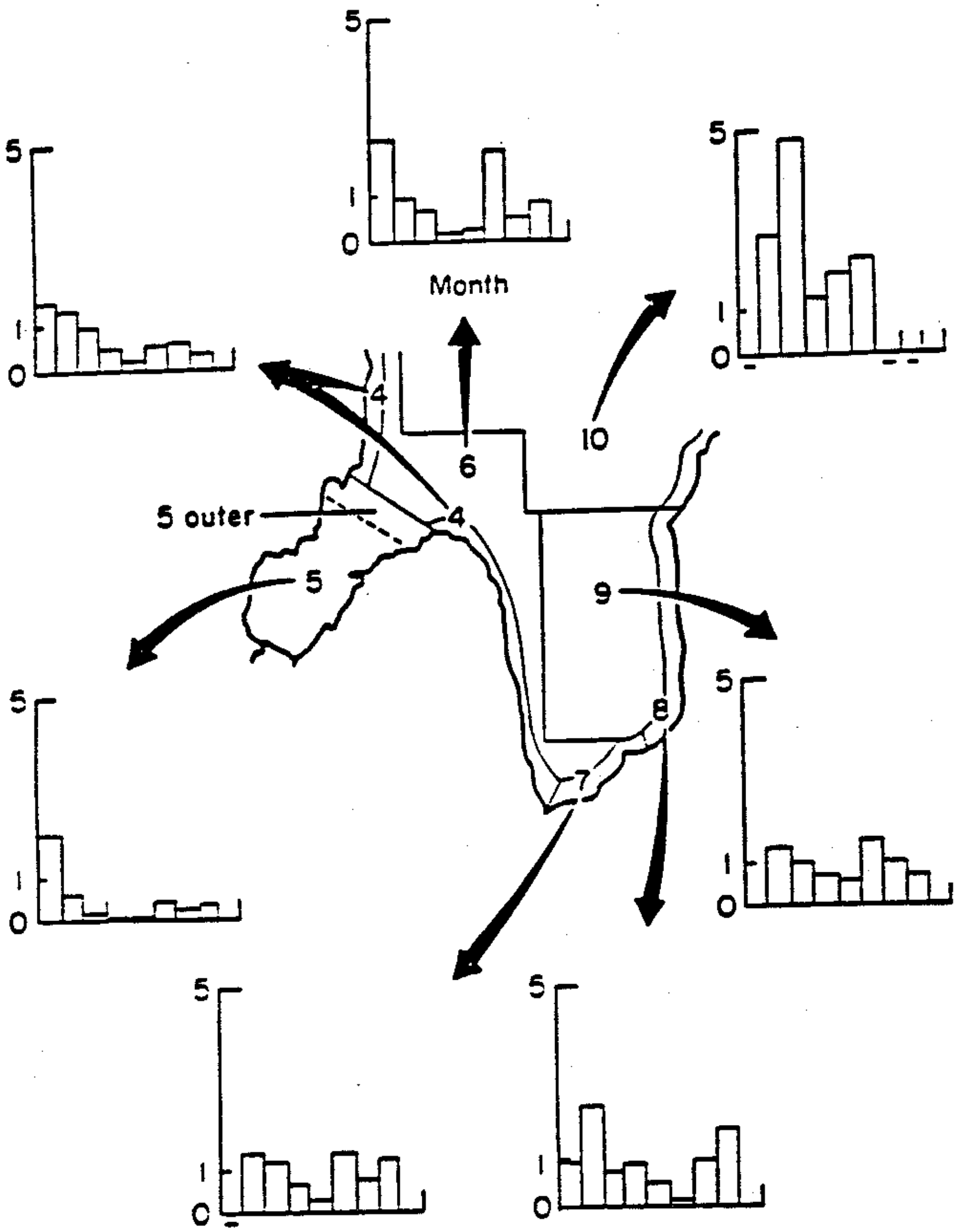


Figure III-93. The ratio of calanoids to cyclopoids (adults and copepods) plus cladocerans for April through October 1974 in southern Lake Huron (McNaught et al., 1980).

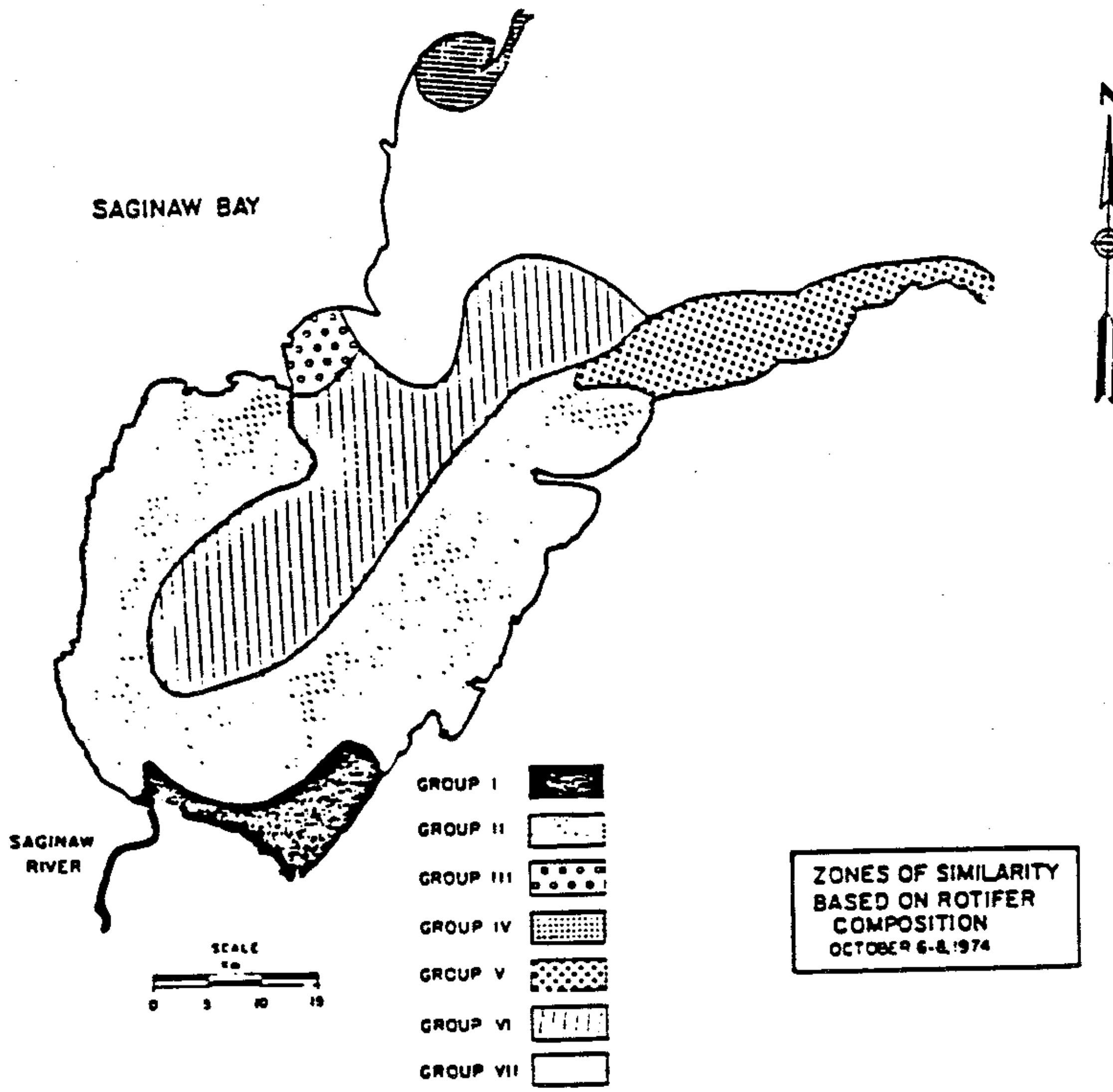


Figure III-94. Grouping of 38 stations determined by cluster analysis of rotifer data for Saginaw Bay during October, 1974 (Gannon, 1981).

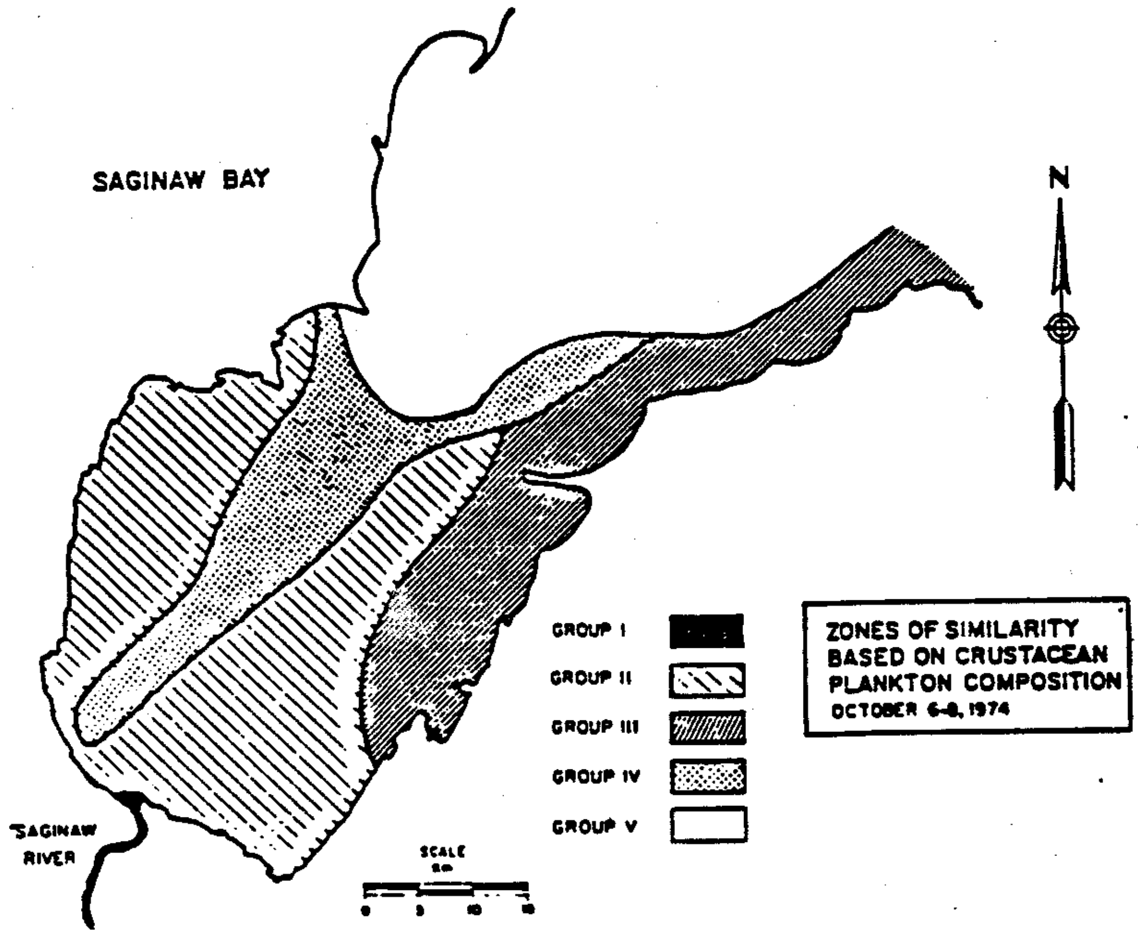


Figure III-95. Grouping of 38 stations determined by cluster analysis of crustacean plankton data for Saginaw Bay during October, 1974 (Gannon, 1981).

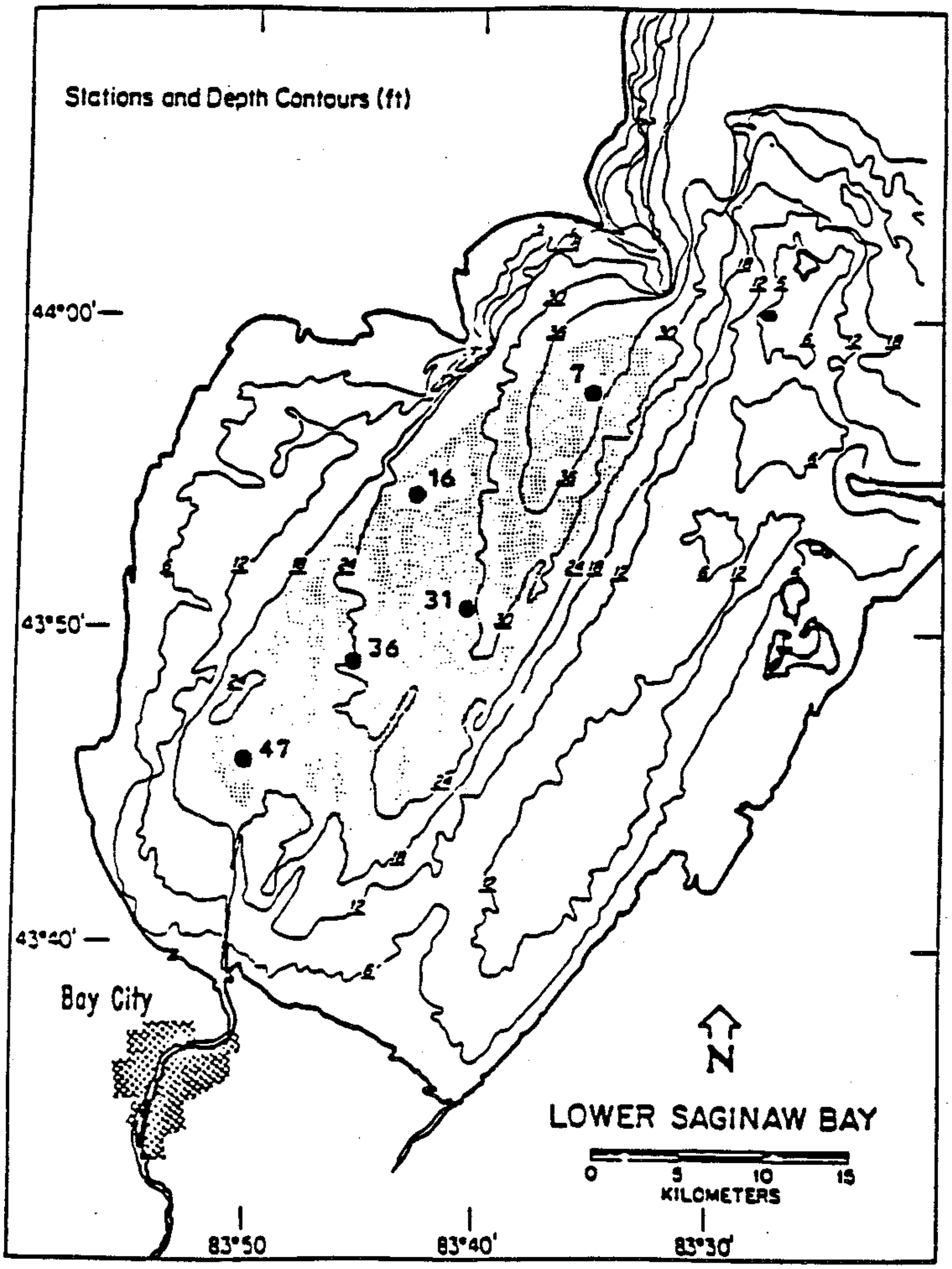


Figure III-96. Saginaw Bay sampling stations; shaded area depicts region of fine-grained sediments after Wood (1964) (White et al., unpublished).

Saginaw Basin Station Locations

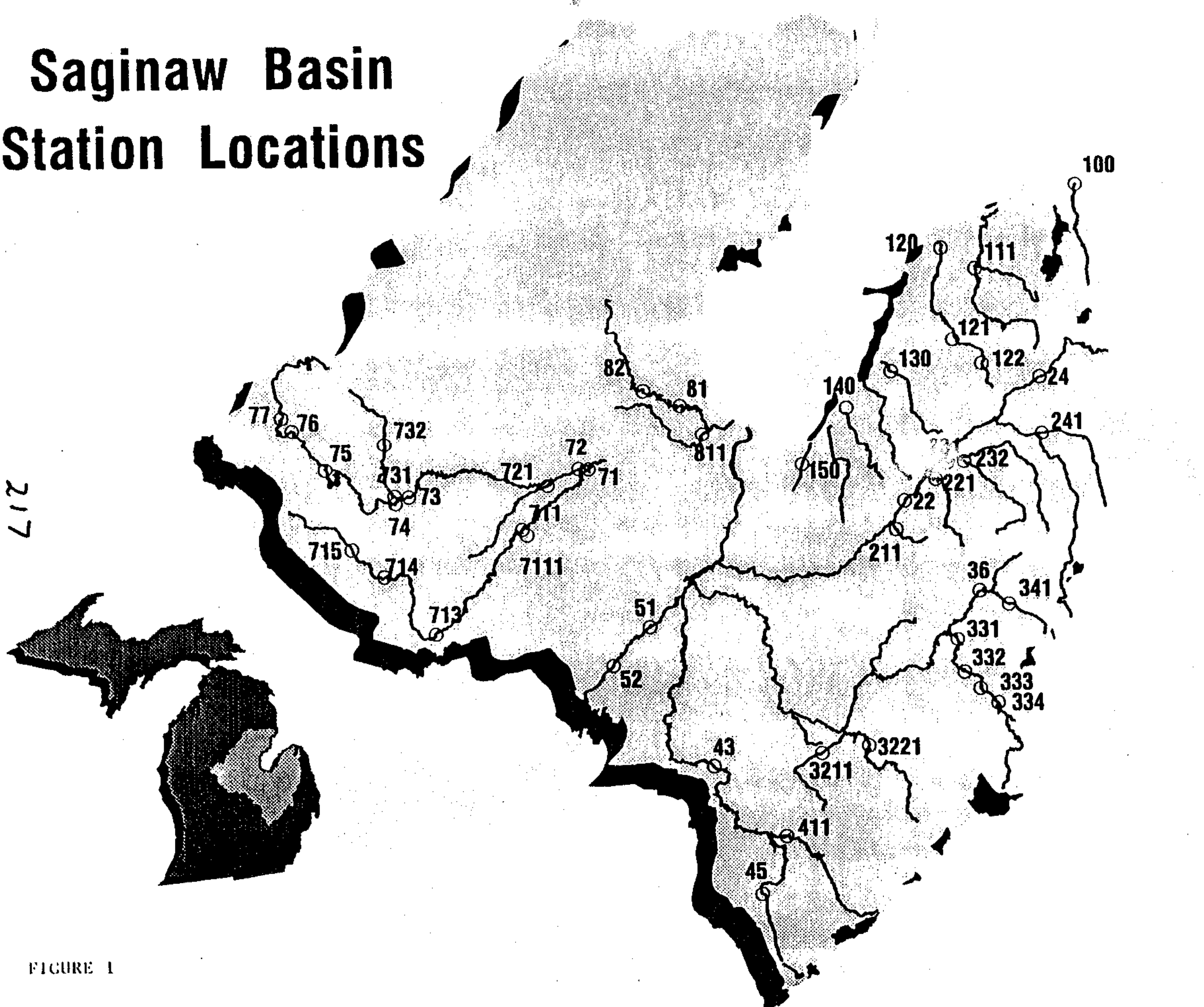


FIGURE 1

Figure 6. Fall migration corridors across Michigan for diving ducks.

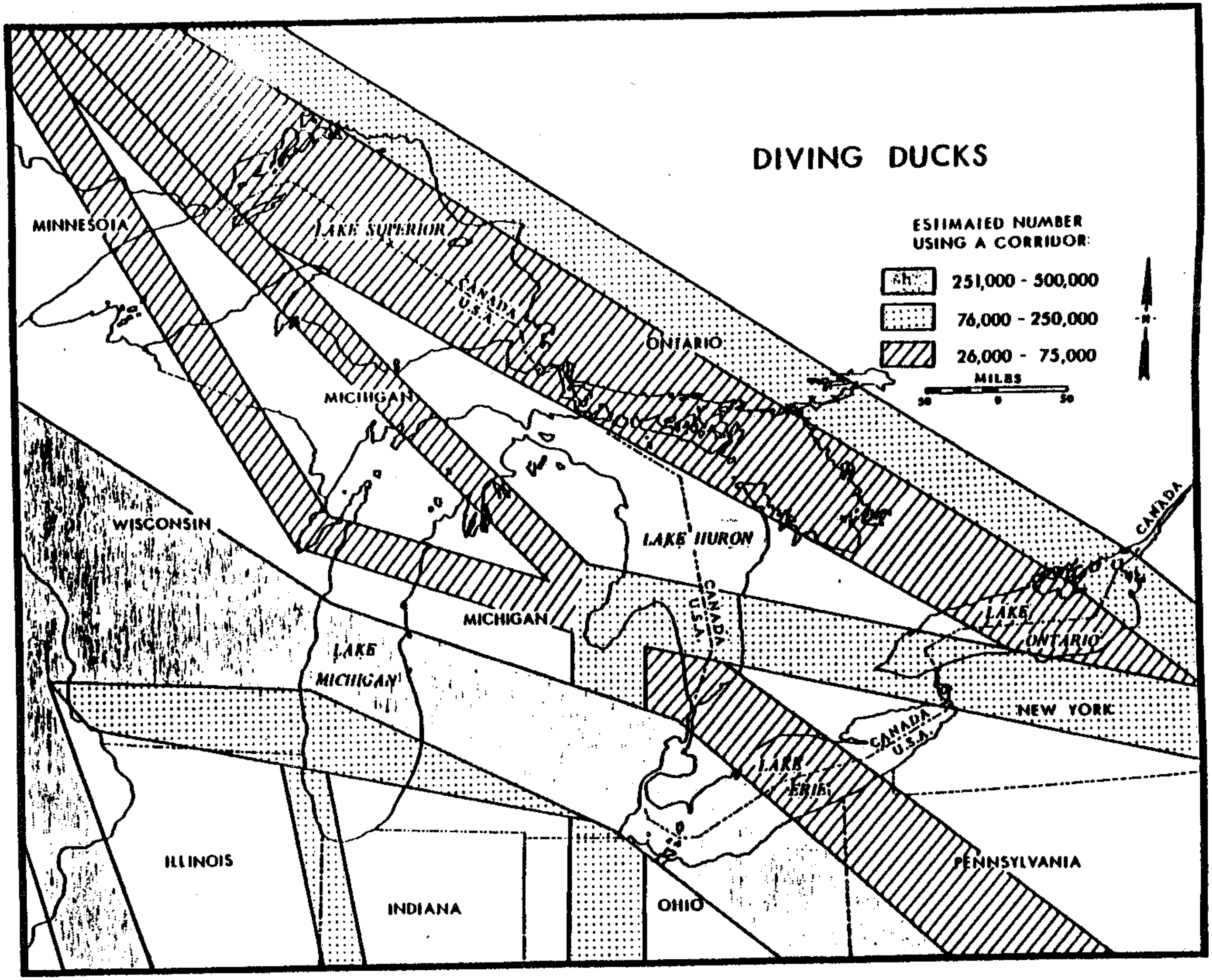


Figure 7. Fall migration corridors acros~ Michigan for dabbling ducks.

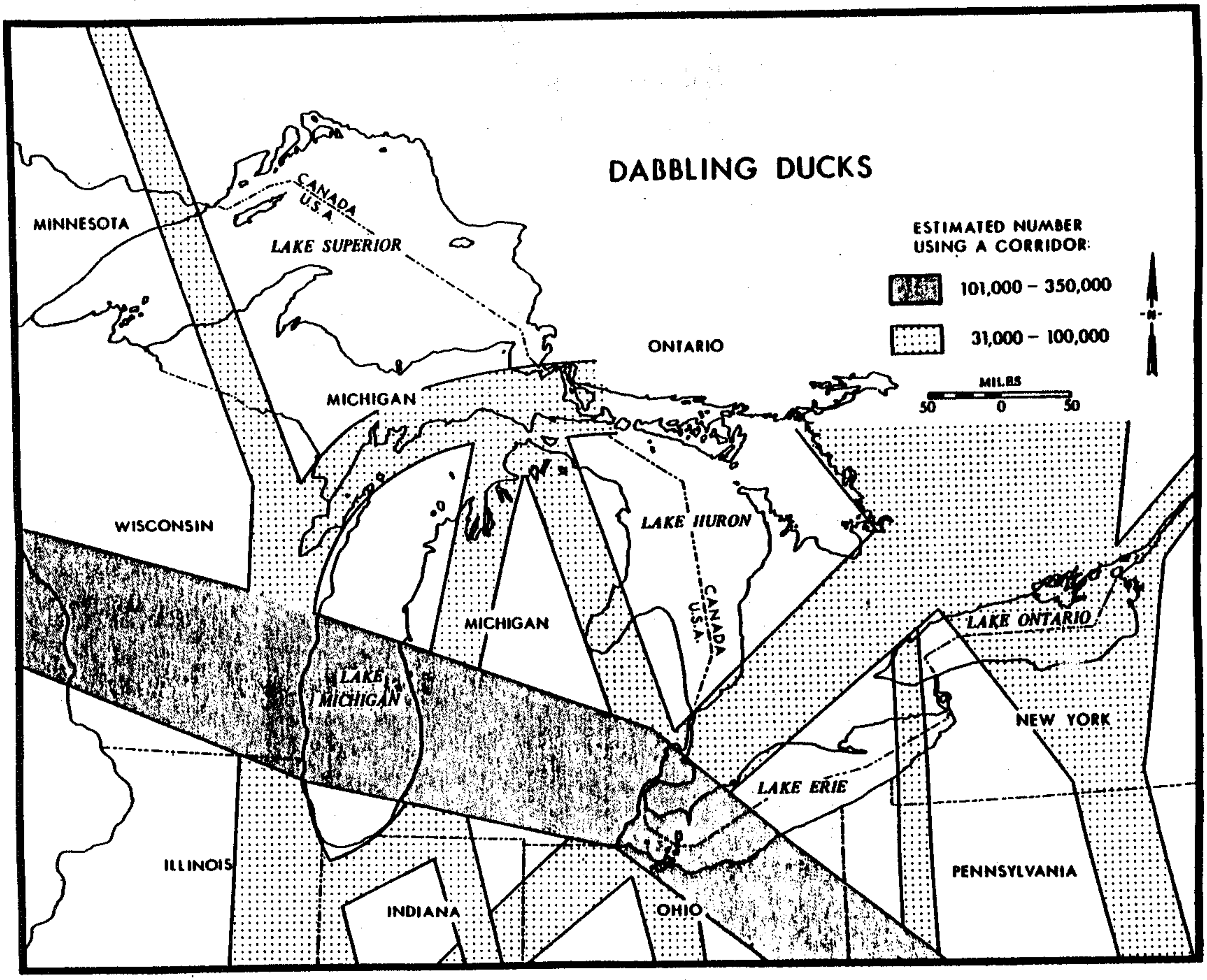
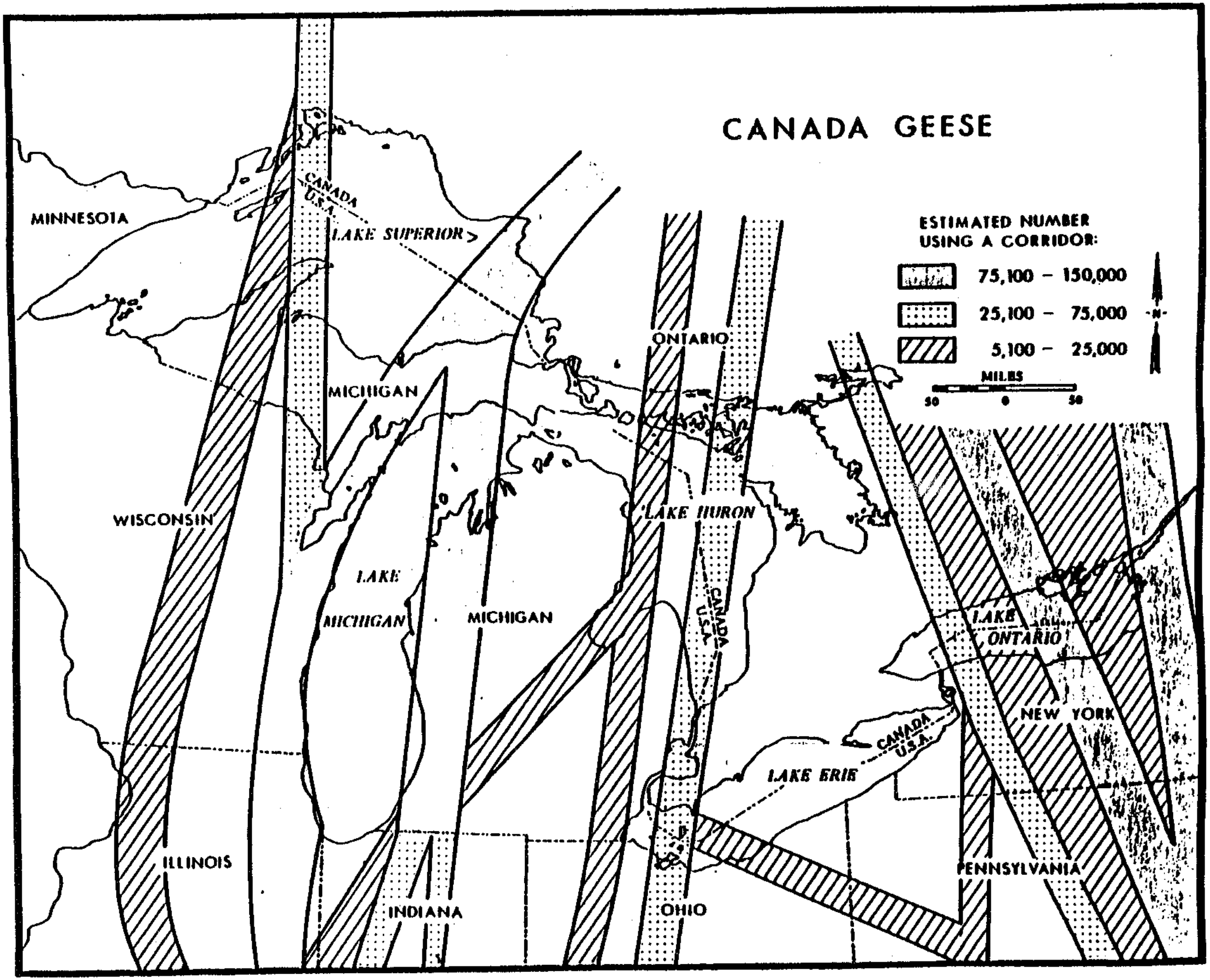


Figure 8. Fall migration corridors across Michigan for Canada geese.



APPENDIX SIX: NUTRIENT SOURCES AND LOADS

A. POINT SOURCES

1. Discharge Permits

Permits regulating direct industrial and municipal discharges to Michigan surface waters are issued under the National Pollutant Discharge Elimination System administered by the Michigan Department of Natural Resources (MDNR). Submittal of monthly Discharge Monitoring Reports (DMRs) is required for most surface water discharge permit holders. Summarized DMR information is available on the U.S. EPA Permit Compliance System (PCS). The PCS database can provide an inventory of the parameters being monitored by dischargers and is suitable for loading calculations. The MDNR also inputs DMR reporting information to the EPA STORET computer system.

2. Types and Distribution of Permitted Dischargers

Discharges of wastewater that require permits originate from a wide variety of practices in the Saginaw Bay watershed including such diverse activities as mining, manufacturing, stormwater runoff, and sewage waste treatment.

Currently, there are 273 NPDES permitted municipal and industrial dischargers to surface waters in the Saginaw Bay watershed. These are divided into 29 major and 244 minor dischargers (Table 1). 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 health impacts, and whether the effluent limits are water quality or technology based.

There are 11 major industrial and 180 minor industrial dischargers in the Saginaw Bay watershed. Among municipal dischargers, there are 18 majors and 64 minors. Standard Industrial Classification (SIC) codes (Table 9) are included for each facility in Tables 2-8. These codes identify the type of activities conducted at each facility.

The Saginaw Bay watershed can be divided into seven major basins: East Coastal, West Coastal, Cass River, Flint River, Shiawassee River, Tittabawassee River and the Saginaw River. The distribution of dischargers by major basin can be found in Table 1. The following discussion summarizes the distribution within each basin.

- **East Coastal Basin** - 23 industrial and municipal dischargers (Table 2). These are divided into 9 industrial and 14 municipal dischargers. There is one major discharger in this basin.

- **West Coastal Basin** - 34 industrial and municipal dischargers (Table 3). These are divided into 25 industrial and 9 municipal dischargers. There are two major dischargers in this basin.

- **Cass River Basin** - 22 industrial and municipal dischargers (Table 4). These are divided into 12 industrial and 10 municipal dischargers. There are three major dischargers in this basin.

- **Flint River Basin** - 66 industrial and municipal dischargers (Table 5). These are divided into 55 industrial and 11 municipal dischargers. There are four major dischargers in this basin.

- **Shiawassee River Basin** - 47 industrial and municipal dischargers (Table 6). These are divided into 34 industrial and 13 municipal dischargers. There are four major dischargers in this basin.

- **Tittabawassee River Basin** - 57 industrial and municipal dischargers (Table 7). These are divided into 38 industrial and 19 municipal dischargers. There are 8 major dischargers in this basin.

- **Saginaw River Basin** - 24 industrial and municipal dischargers (Table 8). These are divided into 18 industrial and 6 municipal dischargers. There are 7 major dischargers to the Saginaw River.

In addition to industrial and municipal dischargers, there are 84 other permitted dischargers in the Saginaw Bay Watershed that are not classified as industrial or municipal.

B. NONPOINT SOURCES

NOTE: For a more in-depth discussion of soil erosion, sediment delivery to area watercourses, and sedimentation control, than the summaries provided below, refer to Chapter V of this report, which was prepared by the Soil Erosion and Sedimentation Control Technical Advisory Committee.

1. Agriculture

a. Sedimentation

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, water infiltration rates, vegetative cover, management techniques, and climate. Agricultural crop lands generally have higher erosion rates than permanently vegetated 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. 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. However, these numbers are for soil erosion on the land surface and it appears that most of the movement of this eroded soil to Saginaw Bay is via water transport of soils deposited in watercourses or eroded during runoff events.

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).

Subsurface drainage tiles are used extensively in many areas of the Saginaw Bay drainage basin with heavy soils, which can reduce surface erosion. Generally, water discharged from a subsurface drainage tile carries less suspended sediments than surface water runoff (Baker and Johnson, 1977). In side-by-side field plots studied in Tuscola County during 1981-1983, suspended solids concentrations were greater in the overland flow than in the tile drainage flow, with means of 443 mg/1 versus 69 mg/1 on a conventionally tilled field, and 176 mg/1 versus 63 mg/1 on a field with conservation tillage (Gold and Loudon, 1986).

b. Nutrients

Wind and water erosion of agricultural land is also the major source of nutrients in the Saginaw River and Saginaw Bay (LTI, 1983). One of the primary reasons is the use of phosphorus and nitrogen fertilizers to increase overall soil fertility and productivity. Fertilizer use has become an integral part of agriculture over the past several decades and the amounts used continue to increase. 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 101 kg/ha (90 lbs P/acre) or more since 1980 (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 excess nutrients can be transported to Saginaw Bay and contribute to eutrophication problems.

Priority river basins for fertilizer use were designated in the coastal and Cass River watersheds of the Saginaw Bay drainage basin by Yocum et al (1987). Priority basins were defined as those that were 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. Bay, Huron, Saginaw and Tuscola counties are also considered priority management counties for phosphorus reduction efforts under Michigan's phosphorus reduction strategy and receive greater consideration for 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. However, the extensive use of drainage tiles in the Saginaw Bay watershed makes phosphorus transport more complex. Though subsurface drainage tiles increase water percolation through the soil, and thereby generally reduce soil transport, they can contain higher concentrations of soluble phosphorus than surface water runoff. Conservation tillage has been found to reduce edge-of-field losses of total phosphorus by reducing sediment erosion, but has not proved as effective for reducing losses of soluble phosphorus.

Animal wastes are another significant source of phosphorus to Saginaw Bay. 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 animal waste priority river basins identified by Yocum et al (1987).

All river basins in the Saginaw Bay watershed were evaluated for designation as "nutrient critical areas" by Yocum et al (1987). An area must have met 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. As a result, the entire Saginaw Bay drainage basin was identified as a nutrient critical area.

2. Urban Stormwater Runoff

Stormwater runoff from urban areas is also a source of both nutrients and sediments. Most of the soil erosion occurs in construction areas where the land has been disturbed. Nutrient sources are lawns and golf courses where fertilizers have been applied. Illegal sewage connections to storm drains also serve as a source of nutrients. There has been little quantification of urban sources in the Saginaw Bay watershed, but based on studies in other areas, it is thought that the loads are significant.

3. Atmosphere

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) and 1983 (20.6 kg/km) and at Port Austin in 1984 (13.0 kg/km; 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), at Tawas Point in 1983 (351 kg/km); and at Port Austin again in 1984 (488 kg/km; 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), at Tawas Point in 1983 (406 kg/km), and at Port Austin in 1984 (577 kg/km; Table IV-21). The average annual atmospheric loading of TKN decreased from 1336 tons in 1982 to 987 tons in 19823, 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.

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), in 1983 (215 kg/km) and in 1984 (284 kg/km; Table IV-21). Average annual atmospheric loading of chloride into Saginaw Bay varied from a high of 866 tons per year in 1982 to 555 tons per year in 1983.

4. Streambank Erosion

Recent studies in southern Michigan have shown that erosion of stream banks can be a major source of sedimentation. Though no data exist for the Saginaw Bay area, this could be a significant source of sediments because of the flashy flow characteristics of the extensive system of linear drains throughout the area that are periodically disturbed by dredging maintenance activities. The U.S. Soil Conservation Service examined the potential for streambank erosion in the Saginaw Bay watershed and that information is discussed in Chapter V and summarized in Table 2.

5. Transportation

Again, though little data are available on the Saginaw Bay area, erosion of gravel road beds and stream road crossings have been shown to contribute substantial amounts of sediments to watercourses.

C. LOADS

1. Suspended Solids

Estimates of total sediment loads to Saginaw Bay 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 estimated to be 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) though the percentage of agricultural suspended solids loads was slightly greater for the southeast segment (Figure IV-2). Sediment loads by tributary in the Saginaw Bay drainage basin are currently being calculated, as part of watershed prioritization efforts.

2. Total Phosphorus

a. Loads

Total phosphorus loads to Saginaw Bay averaged 1700 metric tons/year from 1973 through 1975, with nonpoint sources accounting for nearly 60% of the load (Canale et al., 1976; Bierman and Dolan, 1980).

In 1980, total phosphorus loads to the inner Saginaw Bay had dropped to 898 metric tons of (LTI, 1983). Once again, agricultural nonpoint sources contributed an estimated 59% of the load. 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 metric tons, of which 432 metric tons came from agricultural sources. As was the case with suspended solids, 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 total phosphorus load to Saginaw Bay to have dropped to about 665 metric tons for 1982. The 665 mt represented what was considered to be an average load over the preceding couple of years, though the task force noted that actual calculated loads had been higher in more recent years (MDNR, 1985).

The task force also calculated the 1982 contribution of phosphorus by major tributaries. The Saginaw River, which accounts for approximately 75% to 85% of the total tributary flow to the bay, was determined to have contributed only about half the total nonpoint phosphorus load to the bay, or 162 metric tons/year (Great Lakes Phosphorus Task Force, 1986). The remainder of the nonpoint phosphorus load to Saginaw Bay was contributed by the Rifle-AuGres rivers area (73 metric tons), Kawkawlin River area (27 metric tons), and the thumb area complex (86 metric tons).

The Great Lakes Phosphorus Task Force 1982 estimate of the Saginaw River percentage contribution to the total nonpoint phosphorus load was much smaller than previous data had indicated. When this estimate was investigated recently in a historical analysis by MDNR, it was found that the 665 metric ton average annual load estimate used for 1982 was also substantially less than the 1844 metric tons calculated by MDNR for 1982 (Table 5), and the over 1700 metric tons recently estimated to have been contributed by the Saginaw River alone in 1982 in a retrospective analysis conducted by Limno-Tech (Figure 283).

The large discrepancy between the task force estimate and the newer calculations is the result of the task force averaging several years of prior data to obtain an "typical" load for use in the 1982 estimates. In fact, the task force had noted that between the time the estimate was developed and the report printed, that loads from more recent years had been substantially higher than 665 metric tons. The difference has a major impact on the interpretation of phosphorus load reduction results obtained under the Saginaw Bay phosphorus reduction strategy discussed in the following section.

Limno-Tech investigated total phosphorus loads from the Saginaw River to Saginaw Bay from 1974 through 1990 (Figure 283). During that time period, annual loads fluctuated dramatically, and appeared to be related to annual average discharge (Figure 284). Figure 283 shows that the 1982 load was the highest calculated for the period investigated, but that loads in 1985 and 1986 were of similar magnitude.

Limno-Tech also examined trends in annual total phosphorus loads from the Saginaw River during the 10-year period from 1981 through 1990. Total phosphorus loads had a statistically significant downward trend ($p<0.01$) and were significantly dependent on flow. Mean total phosphorus loads for the periods 1981-1985 and 1986-1990 were 1032 and 648 mt/yr, respectively, suggesting a 384 mt/yr decrease in Saginaw River loads. Mean orthophosphate loads also had a downward trend, but it was only significant at the $p<0.1$ level.

Trend analyses of total phosphorus loads to Saginaw Bay were also conducted by Dolan (1993) for the 1981-1990 time period. Estimates for 1981-1985 and 1986-1990 were 1312 and 950 mt/yr, respectively, for a decrease of 362 mt/yr between the two periods.

The MDNR conducted some rough estimates of 1991 and 1992 total phosphorus loads from the intensive tributary monitoring done in conjunction with the NOAA Saginaw Bay zebra mussel study. The calculated loads were 2158 metric tons in 1991 and 946 metric tons in 1992 (Table 5), indicating that substantial year-to-year fluctuations are continuing. Limno-Tech will be doing more thorough phosphorus load calculations (under contract to the U.S. EPA) as part of the modeling work for the zebra mussel project.

b. Sources

1) Point Sources

Phosphorus loads to surface water in the Saginaw Bay watershed from major municipal wastewater treatment plants have decreased significantly since 1974, falling from 800 mt/yr to 108 mt/yr in 1992 (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 18 major municipal WWTPs in the Saginaw Bay watershed discharged an average of 142 million gallons per day of treated effluent in 1992, which was very close to the 146 MGD discharged in 1982 (Table 4).

Substantial reductions in phosphorus loads have occurred at some minor municipal treatment plants as well. Improvements in treatment capabilities at the Pinconning WWTP reduced the average total phosphorus concentration in this discharge from 5.07 mg/l in 1983 to 0.39 mg/l in 1986.

The total phosphorus load from industrial point sources also decreased substantially dropping from 56 mt/yr in 1982 to 20 mt/yr in 1992. The major improvement was made at the Dow Chemical Company plant in Midland. In 1981, discharge from Dow was the largest point source of phosphorus to the Saginaw Bay drainage basin, contributing an estimated 44 mt (EPA, 1986). But due to a decrease in discharge flows and to the construction of a sand filtration treatment system, Dow reduced their average annual total phosphorus concentration from 1.7 mg/l in 1982 to 0.84 mg/l in 1986 (EPA, 1986), reducing the total phosphorus load to approximately 13 mt in 1986.

On the other hand, total phosphorus loads from municipal sewage lagoons nearly tripled, increasing from less than 8 mt/yr in 1982 to over 22 mt/yr in 1992.

Nevertheless, the 1991/1992 total point source load estimate for total phosphorus to Saginaw Bay of 189 mt/yr was a reduction of 128 mt/yr from the 317 mt/yr calculated for 1982, which also approximated the loads for 1983 and 1984.

2) Nonpoint Sources

Relative to point sources, the nonpoint source contribution to Saginaw Bay annual total phosphorus loads was quite large, ranging from 80% to 91% and averaging 85% (Table 5). This percentage contribution was substantially greater than the 52% contribution estimated by the Great Lakes Phosphorus Task Force for 1982.

During 1981-1990, the atmospheric deposition of total phosphorus was estimated by Dolan (1993) to range from 9-27 mt/yr. This represented less than 2% of the total phosphorus load.

c. Watershed Loads

The MDNR has made rough calculations of 1992 total phosphorus loads from individual watersheds draining directly into Saginaw Bay. These data should be considered preliminary, however, since Limno-Tech will be performing more detailed calculations on these data as part of the modeling component of the Saginaw Bay zebra mussel project.

On a per acre basis, total phosphorus loads in 1992 were greatest in Mud Creek, followed by Quanicassee River and Northwest Drain (Table 6). The lowest per acre phosphorus loads were from watersheds in the west coastal basin.

D. PHOSPHORUS REDUCTION STRATEGY

1. Background

Control of phosphorus inputs was the principal means adopted under the 1972 Great Lakes Water Quality Agreement between the United States and Canada for attempting to reverse or prevent the symptoms of cultural eutrophication in the Great Lakes. 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. It was determined that target loads for Lake Superior, Lake Michigan and most of Lake Huron could be accomplished through point source controls. However, achieving target loads for Saginaw Bay and Lake Erie would require nonpoint source load abatements in addition to continued point source control. Consequently, the 1983 amendments to Annex 3 required the development of a phosphorus reduction strategy to meet the established goals for Lake Erie and Saginaw Bay by 1990.

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 was the lead state agency in the 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.

Attainment of the target load of 440 mt/yr (calculated from an estimated annual average load of 665 mt/yr for the 1982 base year) for Saginaw Bay would result in maintaining a bay phosphorus concentration of 15 micrograms of phosphorus per liter of water (ug/l) and reduce other indicators of eutrophication, including excessive algal growths, taste and odor problems and filter clogging at water filtration plants, and increased turbidity.

The strategy focused upon point and nonpoint phosphorus reductions achieved since 1982 and reductions attainable through implementation of point and nonpoint source control programs through 1990. As a result of significant point source phosphorus reductions prior to 1982, and costs of further point source reductions, the strategy emphasis was on developing effective nonpoint programs.

The strategy sought nonpoint source phosphorus reductions primarily through the implementation of agricultural programs for crop residue management, fertilizer management, and the control of animal wastes. In addition to existing programs, the strategy proposed accelerated efforts in additional technical assistance to agricultural producers, additional cost-sharing funds for cropland residue management, and an information and education program for fertilizer management. Bay, Huron, Saginaw and Tuscola counties were designated as priority counties for accelerated fertilizer and residue management programs.

2. Fertilizer Management

Agricultural soils are generally able to immobilize a certain amount of phosphorus through a process called adsorption. Adsorption involves a 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 1962, the average available phosphorus level in the Saginaw basin was 23 lbs/acre, but this increased to over 90 lbs/acre during the 1980s and was 86 lbs/acre in 1990 (Table IV-14). 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 were applying roughly twice the amount of phosphorus fertilizer that was necessary. The largest number of acres receiving fertilizer applications in the Saginaw Bay watershed in 1987 were in Huron, Sanilac, Tuscola and Saginaw counties (Figure 6-2).

The strategy recommended that 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. The primary means for implementing fertilizer management under the strategy was through the Michigan Energy Conservation Program.

3. Residue/Resource Management

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.

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% of the cropland in the Saginaw Bay drainage area is fall plowed, which contributes to surface erosion of exposed soils.

In 1982, residue management was conducted on 206,800 acres, or approximately 9% of the total cropland in the Saginaw Bay watershed (MDNR 1987). By 1986 this had increased to 405,389 acres (18%), with an estimated reduction in phosphorus load to Saginaw Bay of 42.2 metric tons/year (MDNR 1987). The SCS Conservation Tillage Report estimated that 19% of the cropland in the Saginaw Bay watershed was conservation tilled in 1990 (MDNR, 1991). It appears that there was a similar level of residue management in 1993, when it was estimated that

467,398 acres (21%) were in conservation tillage in the watershed (when 1993 county acreage totals for conservation tillage implementation were adjusted for the percentage of each county in the Saginaw Bay watershed) (Table 3). Additional reductions of 34 metric tons/year have been achieved since 1982 through the planning and installation of permanent and annual resource management systems.

By 1990, the compliance provisions of the 1985 Food Securities Act were to ensure that highly erodible cropland would be managed to reduce soil losses to tolerable levels.

4. Animal Waste Management

A large amount of the phosphorus load to surface waters in the Saginaw Bay basin comes from animal wastes. Cattle, sheep and pigs total over 500,000 animals within the Saginaw Bay watershed (Table 6-8). 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 basin annually.

Between 1983 and 1987, forty animal waste control facilities were constructed with federal Agricultural Conservation Program cost-share dollars within Saginaw Bay basin counties (Table V-9). This has resulted in improved management of almost 70,000 tons of material, which has been estimated to have helped reduce phosphorus loads to Saginaw Bay by as much as 9.15 metric tons/year. Between 1988 and 1990, an additional 7,926 acres of livestock management was implemented in the Saginaw Bay watershed (MDNR, 1991). All together, 78 animal waste treatment facilities had been constructed by May, 1991, reducing phosphorus loads by 10.9 metric tons (MDNR, 1991).

5. Progress to Date

Michigan has made substantial progress in implementing the phosphorus reduction strategy through both point and nonpoint source phosphorus load reductions. The total phosphorus reduction through May 1991 was estimated to be 300.9 metric tons, or 134% of the total needed to meet the goal for Saginaw Bay (Table III-27). Planning and installation of soil resources management systems resulted in an estimated phosphorus reduction of 60 metric tons. Residual management generated reductions of another 120 metric tons. Total reductions in point source phosphorus loads, since the 1982 base year, were 68 metric tons, substantially exceeding point source goals for Saginaw Bay.

Although Michigan has exceeded the phosphorus reduction goals for Saginaw Bay, it is unknown what changes in water quality have occurred in the bay as a result of the estimated load reductions. Furthermore, as discussed previously, it appears that the 1982 base load used in the strategy may have been an underestimate of actual loading conditions.

In order to determine if the phosphorus reduction goal has really been met, or if new phosphorus reduction goals should be established to meet the desired uses identified for Saginaw Bay, an updated nutrient budget needs to be defined. Work began in 1991 on a multi-agency, multi-year project to assess nutrient loads to, and concentrations in, Saginaw Bay. However, rapid colonization of Saginaw Bay by the zebra mussel -- an invasive, exotic, European species accidently introduced into the Great Lakes in 1986 -- may complicate interpretation of the new data. The recent data are currently being modeled to answer some of these questions, and the results are expected in early 1995.

6. Future Phosphorus Reduction

In light of the absence of definitive information on the nutrient conditions in, and loads to, Saginaw Bay, and the continued impairment of nutrient related beneficial uses, Michigan is currently continuing to further reduce phosphorus inputs.

Point sources will continue to be regulated with NPDES permits, with all municipal discharges limited to 1 mg/l. This approach continues that advocated in the phosphorus reduction strategy due to significant previous investments in point source discharges and the high cost of additional treatment. This position was reaffirmed with a recent analysis of the impact of reducing the discharge limits of the largest Saginaw Bay watershed WWTPs to 0.5 mg/l. Based on 1991 data, this change would result in a total phosphorus load reduction to Saginaw Bay of only 2.4%, while achieving a point source load reduction of 18%. Because significant additional costs would be incurred by affected WWTPs to achieve a relatively small reduction in phosphorus loads, to date this has not been determined to be cost beneficial.

However, substantial point source phosphorus reductions are expected in the next several years due to CSO improvements. Combined sewer overflows discharge approximately 2.4 billion gallons/year to the Saginaw Bay basin (MDNR, 1988). Current NPDES permits for municipalities with CSOs set time schedules for eliminating or providing adequate treatment of all CSOs.

Most of the future phosphorus load reductions will need to focus on nonpoint sources. Activities identified under the nonpoint source portion of the strategy will continue to be implemented. The selection of particular actions should be improved by the ongoing small watershed prioritization process, which will facilitate the identification of critical areas for nutrient reduction and focus implementation actions where the most benefit can be obtained. In addition, it appears that increased emphasis will be placed on reducing erosion and sediment delivery, and thereby phosphorus loads, in riparian stream corridors.

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

Drainage Basin	Facility Description			Total
	Type	Major	Minor	
Cass R.	Industrial	1	11	12
	Municipal	2	8	10
East Coastal	Industrial	1	8	9
	Municipal	0	14	14
Flint R.	Industrial	0	55	55
	Municipal	4	7	11
Saginaw R.	Industrial	3	15	18
	Municipal	4	2	6
Shiawassee R.	Industrial	1	33	34
	Municipal	3	10	13
Tittabawassee R.	Industrial	4	34	38
	Municipal	4	15	19
West Coastal	Industrial	1	24	25
	Municipal	1	8	9
Saginaw Bay	Industrial	11	180	191
	Municipal	18	64	82
Total # of Facilities		29	244	273

Table 2: Point Source Dischargers in the Saginaw Bay Eastern Coastal Basin (1994)

NPDES Facility Name	NPDES Permit No.	Receiving Waters	County	SIC Code
Industrial Facilities (9)				
Bayside Mobile Home Park	MI0035629	Jahr Dr.	Huron	6515
Elkton Coop Elevator	MI0046698	Clunis Dr.	Huron	723
Elkton-Pigeon-Bay Port Schools	MI0039209	Gorke Dr. - Pigeon R.	Huron	8211
Huron Co Medical Care WWSL	MI0037494	Pinnebog R-McDowell Dr-Siver Cr	Huron	8099
Huron Memorial Hosp	MI0037508	Pinnebog R-McDowell Dr-Siver Cr	Huron	8062
MDNR-Port Crescent SP WWSL	MI0043842	Ahearn Dr.	Huron	4952
Mich. Sugar Co.-Sebewaing #	MI0002003	Saginaw Bay	Huron	2063
Pebble Cr. MHP WWSL	MI0043257	Squaw Cr.	Tuscola	4959
Sebewaing Industries Inc.	MI0002178	Sebewaing R.	Huron	3465
Municipal Facilities (14)				
Akron - Fairgrove WWSL	MI0028398	Soper to Allen Dr.	Tuscola	4952
Bad Axe WWTP	MI0020958	Bad Axe Dr. to Pinnebog R.	Huron	4952
Caseville WWSL	MI0047520	Pigeon R.	Huron	4952
Colfax Twp WWSL	MI0037613	Pinnebog-Bad Axe Dr.	Huron	4952
Elkton WWSL	MI0022888	Pinnebog R.	Huron	4952
Fairhaven Twp WWSL	MI0049212	Wallace Dr.	Huron	4952
Gagetown WWSL	MI0028711	Bearess Dr.	Tuscola	4952
Huron Co DPW-Kinde WWSL	MI0024520	Schram Dr.	Huron	4952
Owendale WWSL	MI0024481	Dufty Dr.	Huron	4952
Pigeon WWTP	MI0021237	Pigeon R.	Huron	4952
Port Austin WWTP	MI0028517	Baranski Dr. & Grant Cr.	Huron	4952
Reese WWSL	MI0023884	Ryan Dr.	Tuscola	4952
Sebewaing WWSL	MI0024082	Saginaw Bay - Werschky Dr.	Huron	4952
Unionville WWSL	MI0028703	Wiscoggin Dr.	Tuscola	4952

Total Number of Facilities in Basin = **23**
Total Number of Major Dischargers in Basin = **1**

NOTES:

- Designates Major Discharger
* - Designates Facility with Pretreatment Program

Table 3: Point Source Dischargers in Saginaw Bay Western Coastal Basin (1994)

NPDES Facility Name	NPDES Permit No.	Receiving Waters	County	SIC Code
Industrial Facilities (25)				
Bessinger Pickle Co. Inc	MI0048755	Au Gres R.	Arenac	2035
Bopp-Busch MFG Co.	MI0026662	AuGres R.	Arenac	3465
Central Michigan Railway Co.	MI0027545	Kawkawlin R.	Bay	4011
CPCO-Karn & Weadock Plant #	MI0001678	Saginaw Bay	Bay	4911
Crew Products Co.	MI0002445	Au Gres R.	Arenac	3471
Culligan-West Branch	MI0037559	Flowage Lake-Wood Cr.	Ogemaw	7389
Dow Corning Corp-Corp Center	MI0000329	Hoppler Cr.	Midland	6512
EDS Refinery Stn-Bay City	MI0050318	Kawkawlin R.	Bay	9999
Farmers Petroleum Co-op	MI0047651	Railroad Dr.	Bay	9999
Gold Star Coatings Inc.	MI0048747	Rifle Cr.	Ogemaw	3479
Heppner Villa Inc.	MI0021466	Pinconning Dr. - Pinconning R.	Bay	7933
Iosco CRC Quarry Water	MI0042536	Hammel Cr.-Silver Dr.	Arenac	4941
Linwood Metro Dist WFP	MI0005444	Saginaw Bay	Bay	4941
Linwood MHP WWSL	MI0049433	Greg[illegible]y Dr.	Bay	4959
MDOT-Linwood RA	MI0037150	Gregory Dr.	Bay	4952
Mich. Gypsum Co.	MI0002453	Iosco/Arenac Intercounty Dr.	Iosco	1499
Nat. Gypsum-Tawas Quarry	MI0003531	Sand Cr.	Iosco	1499
Nat. Gypsum-Wallboard	MI0028029	Elm Cr.	Iosco	3275
Northport Marina WWSL	MI0043184	Saginaw Bay	Arenac	5551
Perch International	MI0047023	Lk Huron - Standish Dr.	Arenac	912
[illegible]bak CG	MI0039691	Kawkawlin R. - Hembling Dr.	Bay	7032
[illegible]andish Oil Co. -Standish	MI0050792	MB Pine R.	Arenac	9999
US Gypsum Co.	MI0002437	Lk. Huron	Iosco	1499
US Gypsum Co. - GWCU	MI0049590	Lk. Huron	Iosco	9999
White Birch Village MHP WWSL	MI0044377	Hembling Dr.	Bay	6515
Municipal Facilities (9)				
Au Gres WWTP *	MI0022233	AuGres R.	Arenac	4952
Pinconning WWTP *	MI0020711	Pinconning R.	Bay	4952
Plainfield Twp WWSL	MI0023817	Smith Cr.	Iosco	4952
Rose City WWSL	MI0020613	Houghton Cr.	Ogemaw	4952
Standish WWTP	MI0024139	MB Pine R.	Arenac	4952
Sterling WWSL	MI0042340	Pine R. - Sterling Cr.	Arenac	4952
Tawas Utility Authority # *	MI0021091	Tawas R.	Iosco	4952
Twining WWSL	MI0044717	Cedar Cr. Dr.	Arenac	4952
West Branch WWTP	MI0020095	Rifle R.	Ogemaw	4952

Total Number of Facilities in Basin = 34
Total Number of Major Dischargers in Basin = 2

NOTES:

- Designates Major Discharger
- Designates Facility with Pretreatment Program

Table 4: Point Source Dischargers in the Cass River Watershed (1994)

NPDES Facility Name	NPDES Permit No.	Receiving Waters	County	SIC Code
Industrial Facilities (12)				
Anrod Screen Cylinder Co.	MI0046736	Center B Dr.	Tuscola	3499
Astech Inc.	MI0026417	Unnamed Dr.	Tuscola	3322
Candlelite Inn	MI0027162	Unnamed County Dr.	Saginaw	7933
Grede Foundries - Vassar	MI0001112	Cass R.	Tuscola	3321
Marathon Petro Co-Bridgeport	MI0046825	Cass R.	Saginaw	7538
Mich. Sugar Co.-Caro #	MI0002267	Cass R.	Tuscola	2063
Peachtree Manor MHP *	MI0028827	Cass R.	Saginaw	6515
Snover Stamping Co.	MI0042153	Turtle Cr.	Sanilac	5961
Vlasic Foods-Bridgeport	MI0001651	Cass R.	Saginaw	2035
Voplex Corp.	MI0027774	Goodings Cr.	Tuscola	3471
Walbro Corp.	MI0045241	Cass R.	Tuscola	9999
Wood Valley MHP WWSL	MI0050075	Goodings Cr.	Tuscola	4959
Municipal Facilities (10)				
Bridgeport Twp WWTP # *	MI0022446	Cass R.	Saginaw	4952
Caro WWTP	MI0022551	Cass R.	Tuscola	4952
Cass City WWTP *	MI0022594	Cass R.	Tuscola	4952
Frankenmuth WWTP #	MI0022942	Cass R.	Saginaw	4952
Marlette WWTP	MI0021024	Duff Cr.	Sanilac	4952
Mayville WWSL *	MI0023558	Squaw Cr. Dr.	Tuscola	4952
Millington WWSL	MI0023621	Millington Cr.	Tuscola	4952
Tuscola Co. DPW- Kingston WWSL	MI0024864	Alder Cr.	Tuscola	4952
Ubly RSD	MI0028991	Cass R.	Huron	4952
Vassar WWTP	MI0024252	Cass R.	Tuscola	4952

Total Number of Facilities in Basin = 22
Total Number of Major Dischargers in Basin = 3

NOTES:

- Designates Major Discharger
* - Designates Facility with Pretreatment Program

Table 5: Point Source Dischargers in the Flint River Watershed (1994)

NPDES Facility Name	NPDES Permit No.	Receiving Waters	County	SIC Code
Industrial Facilities (55)				
Amoco Oil Co - Flushing	MI0048984	Flint R.	Genesee	9999
Amoco-Flint-Miller Rd.	MI0051420	Swartz Cr.	Genesee	9999
Austin-Burton-Davison Rd. Gas Stn.	MI0051756	Gilkey Cr.	Genesee	9999
Austin-Burton-S.Saginaw	MIG990015	Flint R.	Genesee	9999
Austin-Clio-Vienna Rd. Gas Stn.	MI0051381	Pine Run	Genesee	9999
Austin-Flint Twp-Miller Rd.	MI0051659	Swartz Cr.	Genesee	9999
Austin-Flint-East Atherton	MI0051900	Thread Cr.	Genesee	9999
Austin-Flint-Fenton Rd. Gas Stn.	MI0051748	Carmen Cr.	Genesee	9999
Austin-Flint-N. Dort Hwy. Gas Stn.	MI0051390	Flint R.	Genesee	9999
Austin-Flint-S. Saginaw Gas Stn.	MI0051730	Thread Cr.	Genesee	9999
Austin-Flint-West Atherton Gas Stn.	MI0052248	Swartz Cr.	Genesee	9999
Austin-Gd Blanc-Gd Blanc Rd.	MI0051403	Swartz Cr.	Genesee	9999
BP Oil Co. - Clio	MIG990147	Flint R.	Genesee	9999
Brazeway Inc.	MI0047422	SB Flint R.	Oakland	9999
Carl Schultz Inc.	MI0046329	Farmers Cr.	Lapeer	4925
Carl Schultz Inc.-Davison	MI0049727	Powers Cullen Dr.	Genesee	9999
Carl Schultz-Burton-Richfield	MI0051641	Kearsley Reservoir	Genesee	9999
Clio-Webster and Garner	MI0050342	Pine Run	Genesee	9999
Davison DPW	MI0048593	Black Cr.	Genesee	9999
Deerfield Pines MHP WWSL	MI0053180	Crystal Cr.	Lapeer	4959
[illegible]S Refinery Stn-Flint	MI0050296	WB Swartz Cr.	Genesee	9999
[illegible]ro-Flint-N. Dort Hwy.	MI0051691	Gilkey Cr.	Genesee	9999
Flint WTP	MI0043613	Flint R.	Genesee	4941
Flushing DPW *	[illegible]G990075	Flint R.	Genesee	9999
Flushing MHP *	MI0029149	Flint R.	Genesee	6515
Foamseal Inc	MI0045811	Hunters Cr.	Lapeer	9999
Foamseal Inc.- Oxford	MI0047384	SB Flint R.	Oakland	2821
GM-AC Rochester-Flint West *	MI0001074	Flint R.	Genesee	2396
GM-BOC-Flint	MI0001597	Flint R.	Genesee	3711
GM-Cadillac Motor Car Div.	MI0001082	Thread & Swartz Cr.	Genesee	3711
GM-CPC-Flint Engine Plant	MI0044431	Carman Cr.	Genesee	3711
GM-Fisher Guide Div. - Flint	MI0025194	Brent Run via Hughes Dr.	Genesee	3711
GM-Service Parts Oprtns-Flint	MI0001627	Swartz Cr.	Genesee	3714
GM-Truck & Bus-Flint Assembly	MI0001104	Swartz Cr.	Genesee	3714
GM-Truck & Bus-Flint Metal Fab	MI0044440	Call Dr.	Genesee	3465
Grand Trunk WRR-Flint	MI0041971	Call Dr. - Swartz Cr.	Genesee	4011
Great Lakes Gas Trans LP II	MI0053503	Butternut Cr. & Belle R.	Lapeer	4925
Knickerbocker Inc.	MI0048429	Brent Run	Genesee	7542
Koegel Meats Inc - Flint	MI0050067	Swartz Cr.-Franklin Dr.	Genesee	2013
Lapeer Co Parks & Rec. Comm.	MI0045632	Pero Lake	Lapeer	7996
Marathon Petro Co-Mt. Morris	MI0045411	Flint R.	Genesee	5171
McNally Chevrolet - Flushing	MIG990135	Flint R.	Genesee	9999
MDNR-ERD-Oregon Twp	MI0052191	SB Flint R.	Lapeer	9999
[illegible]ijer Inc.-Burton	MI0050431	Thread Cr.	Genesee	9999
Meijer-Flint-W. Pierson Rd.	MI0051331	Hartshorn Dr.	Genesee	9999
Mobil Oil Corp - Flint	MI0047295	Hartshorn Dr.	Genesee	9999
Mobil Oil Corp - Flint Terminal	MI0036421	Flint R.	Genesee	5171

Table 5: Point Source Dischargers in the Flint River Watershed (1994)

NPDES Facility Name	NPDES Permit No.	Receiving Waters	County	SIC Code
Industrial Facilities (55)				
MSP Industries Corp.	MI0042358	SB Flint R.	Oakland	3462
Oakridge MHP	MI0029505	Pattee Cr. & Peart Dr.	Saginaw	6515
PepsiCola - Flint Warehouse	MIG990129	Swartz Cr.	Genesee	9999
Phil - Flint Oil Co.	MI0049174	Brent Run Dr.	Genesee	4925
Phil Flint-Flint Twp-Miller Rd.	MI0050920	Swartz Cr.	Genesee	9999
Possums Party Store	MI0051799	Northwood Cr.	Saginaw	9999
Robert Eastman Enterprises	MI0051136	Drudge Dr.	Genesee	9999
Wolverine Christ Service Camp	MI0042790	SB Flint R.	Lapeer	7032
Municipal Facilities (11)				
Birch Run WWSL	MI0022390	Briggs Dr.	Saginaw	4952
Clifford WWSL *	MI0029441	Indian Cr.	Lapeer	4952
Elba Twp-Lake Nepessing WWSL	MI0047538	Farmers Cr.	Lapeer	4952
Flint WWTP #	MI0022926	Flint R.	Genesee	4952
Flushing WWTP #	MI0020281	Flint R.	Genesee	4952
Genesee Co-Otisville WWTP	MI0028720	Coe Dr. & McCormick Lake	Genesee	4952
Genesee Co-Ragnone WWTP #	MI0022977	Flint R.	Genesee	4952
Lapeer WWTP #	MI0020460	SB Flint R.	Lapeer	4952
Metamora WWSL	MI0049841	Kintz Cr.	Lapeer	4952
New Lothrop WWSL *	MI0023698	Misteguay Cr.	Shiawassee	4952
North Branch WWSL	MI0021709	NB Flint R.	Lapeer	4952

Total Number of Facilities in Basin = 66
Total Number of Major Dischargers in Basin = 4

NOTES:

- Designates Major Discharger
* - Designates Facility with Pretreatment Program

Table 6: Point Source Dischargers in the Shiawassee River Watershed (1994)

NPDES Facility Name	NPDES Permit No.	Receiving Waters	County	SIC Code
Industrial Facilities (34)				
Adelphian Academy	MI0049042	Shiawassee R.	Oakland	9999
Amoco Oil Co - Fenton	MI0050849	Egytian Dr.	Genesee	9999
Amoco Oil Co - Howell	MI0049018	Marion & Genoa Dr.	Livingston	9999
Best Western-Howell	MI0043915	Marion-Genoa Dr.	Livingston	7011
Blackbeards-Fenton	MIG990233	Fenton Lk.	Genesee	9999
Buckeye-Owosso Valve Site	MIG990148	Shiawassee R.	Shiawassee	9999
Carl Schultz Inc.-Owosso	MI0050351	Shiawassee R.	Shiawassee	9999
Chem-Trend Inc.-Howell	MI0041718	Marion-Genoa Dr.	Livingston	9229
Chem-Trend Inc.-McPherson	MI0045322	Shiawassee R.	Livingston	2891
Country Manor MHP	MI0028967	Hovey Dr.	Shiawassee	6515
Dama Farms Golf Course	MI0052426	Unnamed Pond	Livingston	9999
Dow Corning Corp-Med Products	MI0042811	McClellan Run - Swan Cr.	Saginaw	2833
Fenton Hts Apts WWSL *	MI0037192	Denton Cr.	Genesee	6513
Grand Trunk WRR-Durand	MI0039756	Holly Dr.	Shiawassee	4011
Hartland Public Schools	MIG990101	N. Ore Cr.	Livingston	9999
Hemlock Semi-Conductor Corp	MI0027375	McClellan Run - Swan Cr.	Saginaw	3295
Homestead Estates MHP WWTP *	MI0050181	Shiawassee R.	Oakland	4959
Johnson Controls Inc. #	MI0003484	Shiawassee R.	Shiawassee	3691
Joseph H. Lebowski Center	MI0045250	Shiawassee R.	Shiawassee	8661
Kris Kay MHP	MI0029131	Williams Cr.	Saginaw	4959
Lakeview Estates MHP WWSL	MI0035670	Holly Dr.	Shiawassee	4959
Livingston Soft Water Service	MI0028037	Marion-Genoa Dr.	Livingston	7389
Nazarene Church WWSL *	MI0051055	SB Shiawassee R.	Livingston	8661
Peet Packing Co-Chesaning	MI0000311	Shiawassee R.	Saginaw	2011
Progressive Machinery Corp	MI0043672	SB Shiawassee R.	Livingston	3559
Stoddard MHP WWSL	MI0029092	Lev Dr. - Deer Cr.	Saginaw	6515
Total Oil Co. - Owosso	MIG990219	Shiawassee R.	Shiawassee	9999
Tuscarora Plastics Inc.	MI0042765	Shiawassee R.	Saginaw	3081
US Brick Inc	MI0047333	Escott Dr.	Shiawassee	3251
Venice Twp-Holiday Shores WWSL	MI0043648	Chalker Dr.	Shiawassee	7032
Wakeland Oil Co. - Howell	MIG990041	Unnamed Wetland	Livingston	9999
Wakeland-Owosso-E. Main	MI0051781	Coleman Dr.	Shiawassee	9999
White Birch MHP	MI0029106	Birch Run-Hicks Dr.	Saginaw	6515
Willowcrest Trailer Park	MI0038059	Webb Dr. - Branch No. 1	Shiawassee	6515
Municipal Facilities (13)				
Byron WWSL	MI0022501	Shiawassee R.	Shiawassee	4952
Chesaning WWTP	MI0020087	Shiawassee R.	Saginaw	4952
Durand WWTP	MI0022063	Holly Dr.	Shiawassee	4952
Genesee Co NO. 3 WWTP # *	MI0022993	Shiawassee R.	Genesee	4952
Holly WWTP	MI0020184	Shiawassee R.	Oakland	4952
Howell Twp WWSL *	MI0044903	Shiawassee R.	Livingston	4952
Howell WWTP #	MI0021113	SB Shiawassee R.	Livingston	4952
Ithaca WWSL	MI0021687	Bad R.-Brady Cr.	Gratiot	4952
Merrill WWSL	MI0024678	Swan Cr.-Handy Cr.	Saginaw	4952
Owosso/Mid-Shiawassee Co WWTP #	MI0023752	Shiawassee R.	Shiawassee	4952
Richland Twp WWSL	MI0029572	McClellan Run Dr.	Saginaw	4952
St. Charles WWSL	MI0024007	Bad R.-Beaver Cr.	Saginaw	4952
Vernon WWSL	MI0044512	Holly Dr.	Midland	4952

Total Number of Facilities in Basin = 47
Total Number of Major Dischargers in Basin = 4

NOTES:

\# - Designates Major Discharger
* - Designates Facility with Pretreatment Program

Table 7: Point Source Dischargers in the Tittabawassee River Watershed (1994)

NPDES Facility Name	NPDES Permit No.	Receiving Waters	County	SIC Code
Industrial Facilities (38)				
Alma Products Co.	MI0044334	Pine R.	Gratiot	3714
Amoco Oil Co - Saginaw	MI0050156	Tittabawassee R.	Saginaw	9999
Amoco Oil Co - Shepherd	MI0047953	Salt Cr.	Isabella	9999
Amoco-Mt. Pleasant-S. Mission	MI0051721	Chippewa R.	Isabella	9999
Blodgett Oil Co.-Mt. Pleasant	MI0048992	Chippewa R.	Isabella	9999
Brown Machine	MI0004308	Ross Lake	Gladwin	3531
Clare WFP	MI0020176	Tobacco R.	Clare	4941
CMU-Central Energy Facility	MI0049999	Chippewa R.	Isabella	4911
Country Fresh-Frostbite Brands	MI0047813	Little Tobacco Dr.	Clare	2024
Country Place Park MHP	MI0041947	Jordan Cr.	Isabella	6515
Delfield Co.	MI0044971	Chippewa R.	Isabella	3499
Dow Chem USA-Midland #	MI0000868	Tittabawassee R.	Midland	2821
EDS Refinery Stn-Mt. Pleasant	MI0050300	Chippewa R.	Isabella	9999
Freeland MHP *	MI0028479	Ames Dr.	Saginaw	6515
General Electric - GWCU	MI0047198	Wolf Cr.	Montcalm	9999
Harris Gas-Barryton-N. 30th St.	MI0052507	SB Chippewa R.	Mecosta	9999
Hitachi Magnetics Corp #	MI0027812	Wolf Cr.	Montcalm	3313
Hubscher & Sons Inc *	MI0046931	Chippewa R.	Isabella	1442
Imperial Oil Co.- Gladwin *	MIG990049	Cedar R.	Isabella	9999
Jenkins Oil Co. - Farwell	MIG990198	S.B. Tobacco R.	Clare	9999
Laur Silicone Rubber Comp Inc *	MI0041831	Tobacco R.-Bear Cr. Dr.	Gladwin	2822
Leprino Foods Co.-Remus	MI0044113	Pine Lake - Pony Creek	Mecosta	2022
Lincoln Apartments WWSL	MI0026581	Salt R. - Saunders Dr.	Isabella	6513
Lobdell-Emery MFG Co	MI0005550	Pine R. & Horsebrook Cr.	Gratiot	3465
MDOT-Clare Bulk Plt.	MI0048348	Tobacco R.	Clare	9999
Midland Cogeneration Venture #	MI0042668	Bullock Cr.	Midland	4911
Old Oak Trails Est. MHP WWSL	MI0053392	Draves Dr.	Midland	4959
Packaging Resources Inc. *	MI0045900	Dozer Dr.	Midland	3081
PepsiCola - Mt. Pleasant	MIG990153	Chippewa R.	Isabella	9999
Prescott Products Inc.	MI0027031	Mud Cr.	Ogemaw	3451
Regular Baptist Childrens Agen	MI0043044	Pine R.	Gratiot	8361
Richard Purcell-GWCU	MI0052256	NB Chippewa R.	Mecosta	9999
Robinson Industries Inc	MI0005762	Mud Cr.	Midland	3081
Total Petroleum Inc. #	MI0001066	Pine R. - County Dr. No. 52	Gratiot	2911
Total Petroleum Inc. - Saginaw	MI0050661	Kochville Dr.	Saginaw	9999
Tri County Electric Coop	MI0048003	Pine R. - Decker Cr.	Isabella	9999
Viking Energy-McBain Plt.	MI0044512	North Branch Cr.	Midland	4911
West Branch Concrete *	MI0044695	Cook Cr.	Ogemaw	1442

Table 7: **Point Source Dischargers in the Tittabawassee River Watershed (1994)**

Municipal Facilities (19)				
Alma WWTP #	MI0020265	Pine R.	Gratiot	4952
Barryton WWSL	MI0048470	Chippewa R.	Mecosta	4952
Beaverton WWSL	MI0022306	Tobacco R.	Gladwin	4952
Breckenridge WWSL	MI0022438	No. 170 Co. Dr.-Bush Cr.-Pine R.	Gratiot	4952
Butman Twp WWSL	MI0027898	Sugar R.	Gladwin	4952
Clare WWTP	MI0020176	SB Tobacco R.	Clare	4952
Coleman WWSL	MI0020206	Arnold Dr.-Bluff Cr.-Salt R.	Midland	4952
Gladwin WWTP	MI0023001	Cedar R.	Gladwin	4952
Lake Isabella WWSL	MI0029459	Chippewa R.	Isabella	4952
Midland WWTP	MI0023582	Lingle Dr.	Midland	4952
Mt. Pleasant WWTP #	MI0023655	Chippewa R.	Isabella	4952
Rosebush WWSL	MI0023957	Spring Cr.	Isabella	4952
Sag-Chip Indian Isabella Res WWSL	MI0046591	Chippewa R. - Granger Dr.	Isabella	4952
Saginaw Chippewa Indians	MI0038300	Miser Dr.-Onion Cr. Dr.	Isabella	4952
Saginaw Twp WWTP #	MI0023973	Tittabawassee R.	Saginaw	4952
Shepherd WWSL	MI0021431	Little Salt R.	Isabella	4952
St. Louis WWTP	MI0021555	Pine R.	Gratiot	4952
Tittabawassee Twp. WWSL	MI0027383	Ralph Dr.	Saginaw	4952
Wheatland Twp WWTP *	MI0024350	Pony Cr.	Mecosta	4952

Total Number of Facilities in Basin = 57
Total Number of Major Dischargers in Basin = 8

NOTES:

- Designates Major Discharger
* - Designates Facility with Pretreatment Program

Table 8: Point Source Dischargers to the Saginaw River (1994)

NPDES Facility Name	NPDES Permit No.	Receiving Waters	County	SIC Code
Industrial Facilities (18)				
Amoco Oil Co - Bay City	MI0046060	Saginaw R.	Bay	5171
Amoco Oil Co - Bay City II	MI0049549	Dutch Cr.	Bay	5541
Detroit & Mackinac RR Co.	MI0045462	Saginaw R.	Bay	4011
DMJ Corp. 1 Stop Food Store	MI0051101	Saginaw R.	Saginaw	9999
Dow Chem USA-Bay City	MI0000655	Saginaw R.	Bay	3081
GM-Central Foundry Div.	MI0001139	Saginaw R.	Saginaw	3321
GM-Engine Div.-Bay City #	MI0001121	Saginaw R.	Bay	3714
Imperial Oil Co. - Saginaw	MIG990124	Saginaw R.	Saginaw	9999
Meijer No. 43 - Saginaw	MI0051349	Kochville Dr.	Saginaw	9999
Mich. Sugar Co.-Carrollton #	MI0002224	Saginaw R.	Saginaw	2063
Monitor Sugar #	MI0001091	Columbia Dr.	Bay	2063
Paul Ritter & Bruce Gee	MI0027766	Saginaw R.	Bay	6512
Riverview Est MHP WWTP	MI0025828	Bullock Chamber Dr.	Bay	6515
Robin Glen MHP	MI0037583	English Quaterline Dr.	Saginaw	6515
Rock Products Co	MI0046469	Saginaw R.	Bay	3273
Rock Products Co - Saginaw	MI0048445	Saginaw R.	Saginaw	3273
Thomas Design & Engineering Co.	MI0048488	Lake Linton	Saginaw	6512
Uno-Ven-Bay City	MI0026026	Saginaw R.	Bay	5171
Municipal Facilities (6)				
Bay City WWTP # *	MI0022284	Saginaw R.	Bay	4952
Buena Vista Twp WWTP #	MI0022497	Saginaw R.	Saginaw	4952
Carrollton Twp Wt Weather WWTP	MI0044016	Saginaw R.	Saginaw	4952
Essexville WWTP	MI0022918	Saginaw R.	Bay	4952
Saginaw WWTP # *	MI0025577	Saginaw R.	Saginaw	4952
West Bay Co Regional WWTP #	MI0042439	Saginaw R.	Bay	4952

Total Number of Facilities in Basin = **24**
Total Number of Major Dischargers in Basin = **7**

NOTES:

- Designates Major Discharger
* - Designates Facility with Pretreatment Program

140 SIC CODES (1987)

SIC2	DESCRIPTION
0101	COCOA
0111	WHEAT
0112	RICE
0115	CORN
0116	SOYBEANS
0119	CASH GRAINS, NEC
0131	COTTON
0132	TOBACCO
0133	SUGARCANE AND SUGAR BEETS
0134	IRISH POTATOES
0139	CROPS, EXCEPT CASH GRAINS, NEC
0161	VEGETABLES AND MELONS
0171	BERRY CROPS
0172	GRAPES
0173	TREE NUTS
0174	CITRUS FRUITS
0175	DECIDUOUS TREE FRUITS
0179	FRUITS AND TREE NUTS, NEC
0181	ORNAMENTAL NURSERY PRODUCTS
0182	FOOD CROPS GROWN UNDER COVER
0191	GENERAL FARMS, PRIMARILY CROP
02[illegible]	BEEF CATTLE FEEDLOTS
02[illegible]	BEEF CATTLE, EXCEPT FEEDLOTS
0213	HOGS
0214	SHEEP AND GOATS
0219	GENERAL LIVESTOCK, NEC
0241	DAIRY FARMS
0251	BROIL, FRY AND ROAST CHICKENS
0252	CHICKEN EGGS
0253	TURKEY AND TURKEY EGGS
0254	POULTRY HATCHERIES
0259	POULTRY AND EGGS, NEC
0271	FUR-BEARING ANIMALS & RABBITS
0272	HORSES AND OTHER EQUINES
0273	ANIMAL AQUACULTURE
0279	ANIMAL SPECIALTIES, NEC
0291	FARMS, PRIMARILY LIVESTOCK
0711	SOIL PREPARATION SERVICES
0721	CROP PLANTING & PROTECTION
0722	HARVESTING, PRIMARILY MACHINE
0723	CROP PREP SERVICES FOR MARKET
0724	COTTON GINNING
0741	VET SERVICES FOR LIVESTOCK
0742	VET SERV FOR ANIMAL SPECIALTY
0751	LIVESTOCK SERVICES, EXCEPT VET
0752	ANIMAL SPECIAL SERV EXCEPT VET
0761	FARM LABOR CONTRACT & CREW
0762	FARM MANAGEMENT SERVICES
0781	LANDSCAPE COUNSELING AND PLAN
0782	LAWN AND GARDEN SERVICES
0783	ORNAMENTAL SHRUB AND TREE SERV
0811	TIMBER TRACTS

140 SIC CODES (1987)

SIC2	DESCRIPTION
0831	FOREST PRODUCTS
0851	FORESTRY SERVICES
0912	FINFISH
0913	SHELLFISH
0919	MISCELLANEOUS MARINE PRODUCTS
0921	FISH HATCHERIES AND PRESERVES
0971	HUNT & TRAP & GAME PROPOGATION
1011	IRON ORES
1021	COPPER ORES
1031	LEAD AND ZINC ORES
1041	GOLD ORES
1044	SILVER ORES
1061	FERROALLOY ORES, EXCL VANADIUM
1081	METAL MINING SERVICES
1094	URANIUM-RADIUM-VANADIUM ORES
1099	METAL ORES, NEC
1221	BITUMINOUS COAL & LIG, SURFACE
1222	BITUMINOUS COAL & LIG, UNDERGR
1231	ANTHRACITE MINING
1241	COAL MINING SERVICE
1311	CRUDE PETROLEUM & NATURAL GAS
1321	NATURAL GAS LIQUIDS
1381	DRILLING OIL AND GAS WELLS
1382	OIL AND GAS FIELD EXPLORATION
1389	OIL AND & FIELD SERVICES, NEC
1411	DIMENSION STONE
1422	CRUSHED AND BROKEN LIMESTONE
1423	CRUSHED AND BROKEN GRANITE
1429	CRUSHED AND BROKEN STONE, NEC
1442	CONSTRUCTION SAND AND GRAVEL
1446	INDUSTRIAL SAND
1455	KAOLIN AND BALL CLAY
1459	CLAY, CERAMIC & REFRAC MAT NEC
1474	POTASH, SODA & BORATE MINERALS
1475	PHOSPHATE ROCK
1479	CHEM & FERT MINERA MINING, NEC
1481	NONMETAL MINERAL (EXCEPT FUELS
1499	MISC NONMETAL MINERALS, NEC
1521	CONTRACTORS-SINGLE FAMILY HOUS
1522	GEN CONTRACT-RES, NOT SINFA
1531	OPERATIVE BUILDERS
1541	GEN CONTRACT-INDUST. BLDGS.
1542	GEN CONTRACT, NON-RES BLDGS.
1611	HWY & ST CONST., EXC. ELEV HWY
1622	BRIDGE, TUNNEL & ELEV HWY CONS
1623	H2O, SEW, PIPE & COM. & POWR
1629	HEAVY CONSTRUCTION, NEC
1711	PLUMB, HEAT & AIR CONDITIONING
1721	PAINTING AND PAPER HANGING
1731	ELECTRICAL WORK
1741	MASONRY, STONE SET, STONE WORK
1742	PLSTR, DRYWALL, ACOUS, & INSUL

140 SIC CODES (1987)

SIC2	DESCRIPTION
1743	TERRAZZO,TILE,MARBLE, MOSAIC
1751	CARPENTRY WORK
1752	FLOOR LAY & OTHER FLOOR WORK
1761	ROOF, SIDE & SHEET METAL WORK
1771	CONCRETE WORK
1781	WATER WELL DRILLING
1791	STRUCTURAL STEEL ERECTION
1793	GLASS AND GLAZING WORK
1794	EXCAVATION WORK
1795	WRECKING AND DEMOLTION WORK
1796	INST OR ERECTION OF BLDG EQUIP
1799	SPECIAL TRADE CONTRACTORS, NEC
2011	MEAT PACKING PLANTS
2013	SAUSAGES & PREPARED MEAT PROD
2015	POULTRY SLAUGHTERING & PROCESS
2021	CREAMERY BUTTER
2022	CHEESE, NATURAL AND PROCESSED
2023	CONDENSED AND EVAPORATED MILK
2024	ICE CREAM AND FROZEN DESSERTS
2026	FLUID MILK
2032	CANNED SPECIALTIES
2033	CANNED FRUITS, VEG, PRES, JAM
2034	DEHYDRATED FRUITS, VEG, SOUPS
2035	PICKLED FRTS & VEG. SAUCES
2037	FROZEN FRTS, FRT JUICES & VEG
2038	FROZEN SPECIALTIES, NEC
2041	FLOUR & OTHER GRAIN MILL PROD
2043	CEREAL BREAKFAST FOODS
2044	RICE MILLING
2045	BLENDED AND PREPARED FLOUR
2046	WET CORN MILLING
2047	DOG AND CAT FOOD
2048	PREP FEEDS & INGRED FOR ANIMA
2051	BREAD & OTHER BAKERY PRODUCTS
2052	COOKIES AND CRACKERS
2053	FROZEN BAKERY PRODUCTS
2061	CANE SUGAR, EXCEPT REFINE ONLY
2062	CANE SUGAR REFINING
2063	BEET SUGAR
2064	CANDY & OTHER CONFECTION PROD
2066	CHOCOLATE AND COCOA PRODUCTS
2067	CHEWING GUM
2068	SALTED & ROASTED NUTS & SEEDS
2074	COTTONSEED OIL MILLS
2075	SOYBEAN OIL MILLS
2076	VEG. OIL MILLS, EXCEPT CORN
2077	ANIMAL AND MARINE FATS & OILS
2079	SHORT, TABLE OILS, MARGERINE
2082	MALT BEVERAGES
2083	MALT
2084	WINES, BRANDY & BRANDY SPIRIT
2085	DIST, RECTIFIED & BLENDED LIQ

SIC2	DESCRIPTION
2086	BOT & CAN SOFT DRNK & CARB WA
2087	FLAV EXTR & FLAV SYRUPS, NEC
2091	CANNED & CURED FISH & SEAFOOD
2092	FRE OR FROZ PCK FISH, SEAFOOD
2095	ROASTED COFFEE
2096	POTATO CHIPS & SIMILAR SNACKS
2097	MANUFACTURED ICE
2098	MACARONI, SPAGH, VERMI, NOODL
2099	FOOD PREPARATIONS, NEC
2111	CIGARETTES
2121	CIGARS
2131	TOBACCO (CHEW & SMOK) & SNUFF
2141	TOBACCO STEMMING AND REDRYING
2211	BROAD WOVEN FABRIC MILLS, COTT
2221	BROAD WOVEN FABRIC MILLS, SYNT
2231	BROAD WOVEN FABRIC MILLS, WOOL
2241	NARROW FAB & OTHER SMALLWARES
2251	WOMEN'S FULL/KNEE LENGTH HOSRY
2252	HOSIERY, NEC
2253	KNIT OUTERWEAR MILLS
2254	KNIT UNDERWEAR MILLS
2257	CIRCULAR KNIT FABRIC MILLS
2258	WARP KNIT FABRIC MILLS
2259	KNITTING MILLS, NEC
2261	FINISH OF BRD WOV FAB OF COTTN
2262	FINISH OF BRD WOV FAB/MAN-MADE
2269	FINISHERS OF TEXTILES, NEC
2273	CARPETS AND RUGS, NEC
2281	YARN SPIN MILLS:COTTON, MM FIB
2282	YARN TEXT, THROW, TWIST & WIND
2284	THREAD MILLS
2295	COATED FABRICS, NOT RUBBERIZED
2296	TIRE CORD AND FABRIC
2297	NONWOVEN FABRICS
2298	CORDAGE AND TWINE
2299	TEXTILE GOODS, NEC
2311	MEN'S & BOY'S SUITS, COATS
2321	MEN'S, & BOY'S SHIRTS
2322	MEN'S & BOYS UNDERWEAR & NIGHT
2323	MEN'S, YOUTH'S & BOYS NECKWEAR
2325	MEN & BOY SEP TROUSERS & SLACK
2326	MEN'S & BOY'S WORK CLOTHING
2329	MEN'S, YOUTH'S & BOY'S CLOTHNG
2331	WOMEN, MIS, JR' BLSES, WAISTS
2335	WOMEN'S, MISSES' & JRS' DRESS
2337	WOMEN, MIS', JRS' SUITS, SHIRT
2339	WOMEN'S, MISS' & JR' OUTERWEAR
2341	WOMENS,MIS',CHLD'S,INF UNDERWE
2342	BRASSIERS,GIRDLES & ALLIED GAR
2353	HATS, CAPS AND MILLINERY
2361	GIRLS, CHILDS & INFS OUTERWEAR
2369	GIRLS, CHILDS & INFS OUTERWEAR

140 SIC CODES (1987)

SIC2	DESCRIPTION
2371	FUR GOODS
2381	DRESS & WK GLOVE EXC KNIT/LEAT
2384	ROBES & DRESSING GOWNS
2385	RAINCOATS & RAINGEAR
2386	LEATHER & SHEEP-LINED CLOTHING
2387	APPAREL BELTS
2389	APPAREL & ACCESSORIES, NEC
2391	CURTAINS & DRAPERIES
2392	HOUSEFURNISHINGS, EXC CURTAINS
2393	TEXTILE BAGS
2394	CANVAS & RELATED PRODUCTS
2395	PLEATING, DECOR/NOVELTY STITCH
2396	AUTOMOTIVE TRIMMINGS, APPAREL
2397	SCHIFFLI MACHINE EMBROIDERIES
2399	FABRCATED TEXTILE PRODUCTS NEC
2411	LOGGING CAMPS/LOGGING CONTRACT
2421	SAWMILLS & PLANING MILLS, GEN
2426	HARDWOOD DIMEN & FLOORING MILL
2429	SPECIAL PRODUCT SAWMILLS NEC
2431	MILLWORK
2434	WOOD KITCHEN CABINETS
2435	HARDWOOD VENEER AND PLYWOOD
2436	SOFTWOOD VENEER AND PLYWOOD
2439	STRUCTURAL WOOD MEMBERS, NEC
2441	NAILED/LOCK CORNER WOOD BOXES
2448	WOOD PALLETS AND SKIDS
2449	WOOD CONTAINERS NEC
2451	MOBILE HOMES
2452	PREFAB WOOD BLDGS & COMPONENTS
2491	WOOD PRESERVING
2493	RECONSTITUTED WOOD PRODUCTS
2499	WOOD PRODUCTS, NEC
2511	WOOD HOUSEHOLD FURN, EXC UPHOL
2512	WOOD HOUSEHOLD FURN, UPHOLSTER
2514	METAL HOUSEHOLD FURNITURE
2515	MATTRESSES AND BEDSPRINGS
2517	WOOD TV, RADIO, PHONO CABINET
2519	HOUSEHOLD FURNITURE, NEC
2521	WOOD OFFICE FURNITURE
2522	METAL OFFICE FURNITURE
2531	PUBLIC BUILDING/RELATED FURNIT
2541	WOOD PARTI,SHELF,LOCK,ETC
2542	METAL PARTI,SHELF,LOCKERS
2591	DRAPE HARDWARE/WINDOW BLINDS
2599	FURNITURE AND FIXTURES, NEC
2611	PULP MILLS
2621	PAPER MILLS
2631	PAPERBOARD MILLS
2652	SET-UP PAPERBOARD BOXES
2653	CORRUGATED/SOLID FIBER BOXES
2655	FIBER CANS, TUBES,DRUMS & PROD
2656	SANITARY FOOD CONTAINERS

140 SIC CODES (1987)

SIC2	DESCRIPTION
2657	FOLDING PAPERBOARD BOXES
2671	COATED & LAMINATED PACKAGING
2672	COATED & LAMINATED, NEC
2673	BAGS, PLASTIC, LAMINA & COATED
2674	BAGS,UNCOATD PAPER & MULTIWALL
2675	DIE-CUT PAPER,PAPERBRD/CARDBRD
2676	SANITARY PAPER PRODUCTS
2677	ENVELOPES
2678	STATIONERY,TABLETS & REL PROD
2679	CONV PAPER & PAPERBRD PRODUCTS
2711	NEWSPAPERS: PUBLISHING & PRINT
2721	PERIODICALS: PUBLISHING & PRIN
2731	BOOKS: PUBLISHING & PRINTING
2732	BOOK PRINTING
2741	MISCELLANEOUS PUBLISHING
2752	COMMERCIAL PRINT, LITHOGRAPHIC
2754	COMMERCIAL PRINTING, GRAVURE
2759	COMMERCIAL PRINTING, NEC
2761	MANIFOLD BUSINESS FORMS
2771	GREETING CARD PUBLISHING
2782	BLANKBOOKS,LOOSELEAF BINDERS
2789	BOOKBINDING & RELATED WORK
2791	TYPESETTING
2796	PLATEMAKING SERVICES
2812	ALKALIES AND CHLORINE
2813	INDUSTRIAL GASES
2816	INORGANIC PIGMENTS
2819	INDUSTRIAL INORGANIC CHEMICALS
2821	PLSTC MAT./SYN RESINS/NV ELAST
2822	SYN RUBBER (VULCAN ELASTOMERS)
2823	CELLULOSIC MAN-MADE FIBERS
2824	SYN ORG FIBERS,EXCEPT CELLULOS
2833	MEDICINAL CHEM/BOTANICAL PRODU
2834	PHARMACEUTICAL PREPARATIONS
2835	DIAGNOSTIC SUBSTANCES
2836	BIOLOGCAL PROD, EXCEPT DIAGNOS
2841	SOAP/DETERG EXC SPECIAL CLEANR
2842	SPECIALTY CLEANING, POLISHING
2843	SURF ACTIVE AGENT, FIN AGENTS
2844	PERFUMES,COSMETICS,TOILET PREP
2851	PAINTS/VARNISH/LACQUERS/ENAMEL
2861	GUM AND WOOD CHEMICALS
2865	CYCLIC CRUDES INTERM., DYES
2869	INDUST. ORGANIC CHEMICALS NEC
2873	NITROGEN FERTILIZERS
2874	PHOSPHATIC FERTILIZERS
2875	FERTILIZERS, MIXING ONLY
2879	PESTICIDES & AGRICULTURAL CHEM
2891	ADHESIVES AND SEALANTS
2892	EXPLOSIVES
2893	PRINTING INK
2895	CARBON BLACK

140 SIC CODES (1987)

SIC2	DESCRIPTION
2899	CHEMICALS & CHEM PREP, NEC
2911	PETROLEUM REFINING
2951	PAVING MIXTURES AND BLOCKS
2952	ASPHALT FELT AND COATINGS
2992	LUBRICATING OILS AND GREASES
2999	PROD OF PETROLEUM & COAL, NEC
3011	TIRES AND INNER TUBES
3021	RUBBER AND PLASTICS FOOTWEAR
3052	RUBBER & PLASTICS HOSE & BELT
3053	GASKETS, PACKING & SEALING DEV
3061	MECHANICAL RUBBER GOODS
3069	FABRICATED RUBBER PRODUCTS,NEC
3081	UNSUPPORTED PLSTICS FILM/SHEET
3082	UNSUPPORTED PLASTICS PROF SHAP
3083	LAMINATED PLASTICS PLATE/SHEET
3084	PLASTIC PIPE
3085	PLASTIC BOTTLES
3086	PLASTICS FOAM PRODUCTS
3087	CUSTOM COMPOUNDED PURCH. RESIN
3088	PLASTICS PLUMBING FIXTURES
3089	PLASTICS PRODUCTS, NEC
3111	LEATHER TANNING AND FINISHING
3131	BOOT & SHOE CUT STOCK & FINDNG
3142	HOUSE SLIPPERS
3143	MEN'S FOOTWEAR,EXCEPT ATHLETIC
3144	WOMEN'S FOOTWEAR,EXCEPT ATHLET
3149	FOOTWEAR, EXCEPT RUBBER NEC
3151	LEATHER GLOVES AND MITTENS
3161	LUGGAGE
3171	WOMEN'S HANDBAGS AND PURSES
3172	PERSONAL LEATHER GOODS,EXC HAN
3199	LEATHER GOODS NEC
3211	FLAT GLASS
3221	GLASS CONTAINERS
3229	PRESSED & BLOWN GLASS & GWARE
3231	GLASS PROD MADE OF PURCH. GLAS
3241	CEMENT, HYDRAULIC
3251	BRICK AND STRUCTURAL CLAY TILE
3253	CERAMIC WALL AND FLOOR TILE
3255	CLAY REFRACTORIES
3259	STRUCTURAL CLAY PRODUCTS NEC
3261	VITREOUS CHINA PLUMBING FIXTUR
3262	VIT CHINA TABLE & KTCHN ARTICL
3263	FINE EARTHENWARE
3264	PORCELAIN ELECTRICAL SUPPLIES
3269	POTTERY PRODUCTS, NEC
3271	CONCRETE BLOCK & BRICK
3272	CONCRETE PROD EXC BLCK & BRICK
3273	READY-MIXED CONCRETE
3274	LIME
3275	GYPSUM PRODUCTS
3281	CUT STONE & STONE PRODUCTS

140 SIC CODES (1987)

SIC2	DESCRIPTION
3291	ABRASIVE PRODUCTS
3292	ASBESTOS PRODUCTS
3295	MINE & EARTHS, GROUND OR TREAT
3296	MINERAL WOOL
3297	NONCLAY REFRACTORIES
3299	NONMETALLIC MINERAL PROD, NEC
3312	BLAST FURN/STEEL WORKS/ROLLING
3313	ELECTROMETALLURGICAL PRODUCTS
3315	STEEL WIRE DRAW & STEEL NAILS
3316	COLD ROLLED STEEL SHEET/STRIP
3317	STEEL PIPE AND TUBES
3321	GRAY IRON FOUNDRIES
3322	MALLEABLE IRON FOUNDRIES
3324	STEEL INVESTMENT FOUNDRIES
3325	STEEL FOUNDRIES, NEC
3331	PRIMRY SMELTING & COPPER REFIN
3334	PRIMARY PRODUCTION OF ALUMINUM
3339	PRMRY SMELT/NONFERROUS METALS
3341	2NDARY SMELT/NONFERROUS METALS
3351	ROLL/DRAW/EXTRUDING OF COPPER
3353	ALUMINUM SHEET, PLATE AND FOIL
3354	ALUMINUM EXTRUDED PRODUCTS
3355	ALUMINUM ROLLING & DRAWING NEC
3356	ROLL, DRAW & EXTRUD NONFERROUS
3357	DRAW/INSULAT OF NONFERROUS WIR
3363	ALUMINUM DIE CASTING
3364	NONFERROUS DIE CAST, EXC. ALUM
3365	ALUMINUM FOUNDRIES
3366	COPPER FOUNDRIES
3369	NONFERROUS FOUNDRIES, EXC ALUM
3398	METAL HEAT TREATING
3399	PRIMARY METAL PRODUCTS, NEC
3411	METAL CANS
3412	METAL BARRELS, DRUMS AND PAILS
3421	CUTLERY
3423	HAND AND EDGE TOOLS, NEC
3425	HAND SAWS AND SAW BLADES
3429	HARDWARE, NEC
3431	METAL SANITARY WARE
3432	PLUMB FIXTURE FITTINGS & TRIM
3433	HEATING EQUIP, EXCEPT ELECTRIC
3441	FABRICATED STRUCTURAL METAL
3442	METAL DOORS, SASH, AND TRIM
3443	FAB PLATE WORK (BOILER SHOPS)
3444	SHEET METAL WORK
3446	ARCHITECTURAL METAL WORK
3448	PREFABRICATED METAL BUILDINGS
3449	MISC. STRUCTUAL METAL WORK
3451	SCREW MACHINE PRODUCTS
3452	BOLTS, NUTS, RIVETS & WASHERS
3462	IRON AND STEEL FORGINGS
3463	NONFERROUS FORGINGS

140 SIC CODES (1987)

SIC2	DESCRIPTION
3465	AUTOMOTIVE STAMPINGS
3466	CROWNS AND CLOSURES
3469	METAL STAMPINGS, NEC
3471	PLATING AND POLISHING
3479	METAL COATING & ALLIED SERVIC
3482	SMALL ARMS AMMUNITION
3483	AMMUNIT., EXC. FOR SMALL ARMS
3484	SMALL ARMS
3489	ORDNANCE AND ACCESSORIES, NEC
3491	INDUSTRIAL VALVES
3492	FLUID POWER VALVES & HOSE FITT
3493	STEEL SPRINGS, EXCEPT WIRE
3494	VALVES AND PIPE FITTINGS, NEC
3495	WIRE SPRINGS
3496	MISC. FABRICATED WIRE PRODUCTS
3497	METAL FOIL AND LEAF
3498	FABRICATED PIPE AND FITTINGS
3499	FABRICATED METAL PRODUCTS NEC
3511	TURBINES & TURBINE GENERATOR
3519	INTERNAL COMBUSTION ENGINES,
3523	FARM MACHINERY AND EQUIPMENT
3524	LAWN AND GARDEN EQUIPMENT
3531	CONSTRUCTION MACHINERY
3532	MINING MACHINERY
3533	OIL FIELD MACHINERY
3534	ELEVATORS AND MOVING STAIRWAYS
3535	CONVEYORS & CONVEYING EQUIPMEN
3536	CRANES/HOISTS/MONORAIL SYSTEMS
3537	INDUSTRIAL TRUCKS AND TRACTORS
3541	MACHINE TOOLS, METAL CUTTING
3542	MACHINE TOOLS, METAL FORMING
3543	INDUSTRIAL PATTERNS
3544	SPECIAL DIES/TOOLS/JIGS & FIXT
3545	MACHINE TOOL ACCESSORIES
3546	POWER DRIVEN HAND TOOLS
3547	ROLLING MILL MACHINERY
3548	WELDING APPARATUS
3549	METALWORKING MACHINERY, NEC
3552	TEXTILE MACHINERY
3553	WOODWORKING MACHINERY
3554	PAPER INDUSTRIES MACHINERY
3555	PRINTING TRADES MACHINERY
3556	FOOD PRODUCTS MACHINERY
3559	SPECIAL INDUSTRY MACHINERY,NEC
3561	PUMPS AND PUMPING EQUIPMENT
3562	BALL AND ROLLER BEARINGS
3563	AIR AND GAS COMPRESSORS
3564	BLOWER AND FANS
3565	PACKAGING MACHINERY
3566	SPEED CHANGERS, DRIVES & GEARS
3567	INDUSTRIAL FURNACES AND OVENS
3568	POWER TRANSMISSION EQUIPMENT

SIC2	DESCRIPTION
3569	GENERAL INDUSTRIAL MACHINERY
3571	ELECTRONIC COMPUTERS
3572	COMPUTER STORAGE DEVICES
3575	COMPUTER TERMINALS
3577	COMPUTER PERIPHERAL EQUIP,NEC
3578	CALC & ACCOUNTING EQUIPMENT
3579	OFFICE MACHINES
3581	AUTOMATIC MERCHANDISING MACHIN
3582	COMMERCIAL LAUNDRY EQUIPMENT
3585	REFRIGERATION & HEATING EQUIP
3586	MEASURING & DISPENSING PUMPS
3589	SERVICE INDUSTRY MACHINERY
3592	CARBURETORS,PISTONS,RINGS,VALV
3593	FLUID POWER CYLINDERS & ACTUAT
3594	FLUID POWER PUMPS AND MOTORS
3596	SCALES AND BALANCES, EXC. LAB
3599	INDUSTRIAL MACHINERY, NEC
3612	TRANSFORMERS
3613	SWITCHGEAR & SWITCHBOARD APPAR
3621	MOTORS AND GENERATORS
3624	CARBON AND GRAPHITE PRODUCTS
3625	RELAYS AND INDUSTRIAL CONTROLS
3629	ELECTRICAL INDUSTRIAL APPARATS
3631	HOUSEHOLD COOKING EQUIPMENT
3632	HOUSEHOLD REFRIG. & FREEZERS
3633	HOUSEHOLD LAUNDRY EQUIPMENT
3634	ELECTRIC HOUSEWARES AND FANS
3635	HOUSEHOLD VACUUM CLEANERS
3639	HOUSEHOLD APPLIANCES, NEC
3641	ELECTRIC LAMPS
3643	CURRENT-CARRYING WIRING DEVICE
3644	NONCURRENT-CARRYING WIRING DEV
3645	RESIDENTIAL LIGHTING FIXTURES
3646	COMMERCIAL LIGHTING FIXTURES
3647	VEHICULAR LIGHTING EQUIPMENT
3648	LIGHTING EQUIPMENT, NEC
3651	RADIO AND TV RECEIVING SETS
3652	PHONOGRAPH RECORDS
3661	TELEPHONE/TELEGRAPH APPARATUS
3663	RADIO & TV COMMUNICATION EQUIP
3669	COMMUNICATIONS EQUIPMENT, NEC.
3671	ELECTRON TUBES
3672	PRINTED CIRCUT BOARD
3674	SEMICONDUCTORS & RELATED DEVIC
3675	ELECTRONIC CAPACITORS
3676	RESISTORS FOR ELEC APPLICATION
3677	ELEC COILS, TRANSF. & INDUCTOR
3678	CONNECTORS FOR ELEC APPLICATIO
3679	ELECTRONIC COMPONENTS, NEC
3691	STORAGE BATTERIES
3692	PRIMARY BATTERIES, DRY & WET
3694	ELEC EQUIP FOR INT COMBUS ENGI

	140 SIC CODES (1987)
SIC2	DESCRIPTION
3695	MAG & OPTICAL RECORDING MEDIA
3699	ELEC MACHINERY,EQUIP & SUPPLIE
3711	MOTOR VEHICLES & CAR BODIES
3713	TRUCK & BUS BODIES
3714	MOTOR VEHICLE PARTS & ACCESSOR
3715	TRUCK TRAILERS
3716	MOTOR HOMES
3721	AIRCRAFT
3724	AIRCRAFT ENGINES & ENGINE PART
3728	AIRCRAFT PARTS AND EQUIP, NEC
3731	SHIP BUILDING AND REPAIRING
3732	BOAT BUILDING AND REPAIRING
3743	RAILROAD EQUIPMENT
3751	MOTORCYCLES, BICYCLES AND PART
3761	GUIDED MISSILES & SPACE VEHICL
3764	SPACE PROPULSION UNITS & PARTS
3769	SPACE VEHICLE EQUIPMENT, NEC
3792	TRAVEL TRAILERS AND CAMPERS
3795	TANKS AND TANK COMPONENTS
3799	TRANSPORTATION EQUIPMENT, NEC
3812	SEARCH & NAVIGATION EQUIPMENT
3821	LAB APPARATUS & FURNITURE
3822	ENVIRONMENTAL CONTROLS
3823	PROCESS CONTROL INSTRUMENTS
3824	FLUID METERS & COUNTING DEVICE
3825	INSTRUMENTS TO MEASURE ELECTRI
3826	ANALYTICAL INSTRUMENTS
3827	OPTICAL INSTRUMENTS AND LENSES
3829	MEASURING & CONTROLLING DEVICE
3841	SURGICAL & MEDICAL INSTRUMENTS
3842	SURGICAL APPLIANCES & SUPPLIES
3843	DENTAL EQUIPMENT AND SUPPLIES
3844	X-RAY APPARATUS AND TUBES
3845	ELECTROMEDICAL EQUIPMENT
3851	OPHTHALMIC GOODS
3861	PHOTOGRAPHIC EQUIP & SUPPLIES
3873	WATCHES, CLOCKS & WATCHCASES
3911	JEWELRY, PRECIOUS METAL
3914	SILVERWARE AND PLATED WARE
3915	JEWELERS' MATERIALS & LAPIDARY
3931	MUSICAL INSTRUMENTS
3942	DOLLS
3944	GAMES, TOYS & CHILDREN'S VEHIC
3949	SPORTING & ATHLETIC GOODS, NEC
3951	PENS & MECHANICAL PENCILS
3952	LEAD PENCILS AND ART GOODS
3953	MARKING DEVICES
3955	CARBON PAPER AND INKED RIBBONS
3961	COSTUME JEWELRY
3965	FASTENERS, BUTTONS, NEEDLES
3991	BROOMS AND BRUSHES
3993	SIGNS AND ADVERTISING DISPLAYS

140 SIC CODES (1987)

SIC2	DESCRIPTION
3995	BURIAL CASKETS
3996	HARD SURFACE FLOOR COVERINGS
3999	MANUFACTURING INDUSTRIES, NEC
4011	RAILROADS, LINE HAUL OPERATING
4013	RAILROAD SWTCHING & TERM ESTAB
4111	LOCAL AND SUBURBAN TRANSIT
4119	LOCAL PASSENGER TRANSPORTATION
4121	TAXICABS
4131	INTERCITY & RURAL BUS TRANSPOR
4141	LOCAL BUS CHARTER SERVICE
4142	BUS CHARTER SERVICE, EXC LOCAL
4151	SCHOOL BUSES
4173	BUS TERMINAL & SERVICE FACILIT
4212	LOCAL TRUCKING WITHOUT STORAGE
4213	TRUCKING, EXCEPT LOCAL
4214	LOCAL TRUCKING WITH STORAGE
4215	COURIER SERVICES, EXCEPT AIR
4221	FARM PROD WAREHOUSING & STORAG
4222	REFRIGERTAED WAREHOUSING & STO
4225	GENERAL WAREHOUSING & STORAGE
4226	SPECIAL WAREHOUSING & STORAGE
4231	TRUCKING TERMINAL FACILITIES
4311	UNITED STATES POSTAL SERVICE
4412	DEEP SEA FOREIGN TRANSP OF FRE
4424	DEEP SEA DOMES TRANSP OF FREIG
4432	FREIGHT TRANSP ON THE GR LAKES
4449	WATER TRANSP OF FREIGHT, NEC
4481	DEEP SEA PAS TRANSP, EXC FERRY
4482	FERRIES
4489	WATER PASSENGER TRANSPORTATION
4491	MARINE CARGO HANDLING
4492	TOWING AND TUGBOAT SERVICE
4493	MARINAS
4499	WATER TRANSPORTATION SERIVCES
4512	AIR TRANSPORTATION, SCHEDULED
4513	AIR COURIER SERVICES
4522	AIR TRANSP, NONSCHEDULED
4581	AIRPORTS, FLYING FIELDS & SER
4612	CRUDE PETROLEUM PIPELINES
4613	REFINED PETROLEUM PIPELINE
4619	PIPELINES, NEC
4724	TRAVEL AGENCIES
4725	TOUR OPERATORS
4729	PASSENGER TRANSP ARRANGEMENT
4731	FREIGHT TRANSP ARRANGEMENT
4741	RENTAL OF RAILROAD CARS
4783	PACKING AND CRATING
4785	INSPECTION & FIXED FACILITIE
4789	TRANSPORTATION SERVICES, NEC
4812	RADIOTELEPHONE COMMUNICATIONS
4813	TELEPHONE COM, EXCEPT RADIO
4822	TELEGRAPH & OTHER COMMUNICATI

140 SIC CODES (1987)

SIC2	DESCRIPTION
4832	RADIO BROADCASTING, NEC
4833	TELEVISION BROADCASTING
4841	CABLE & OTHER PAY TV SERVICES
4899	COMMUNICATION SERVICES, NEC
4911	ELECTRICAL SERVICES
4922	NATURAL GAS TRANSMISSION
4923	NAT GAS TRANSMISSION & DISTRIB
4924	NATURAL GAS DISTRIBUTION
4925	MIXED,MANUFAC,OR LIQ GAS PROD
4931	ELEC & OTHER SERVICES COMBINED
4932	GAS & OTHER SERVICES COMBINED
4939	COMBINATION UTILITIES, NEC
4941	WATER SUPPLY
4952	SEWERAGE SYSTEMS
4953	REFUSE SYSTEMS
4959	SANITARY SERVICES, NEC
4961	STEAM & AIR-CONDITIONING SUP
4971	IRRIGATION SYSTEMS
5012	AUTOMOBILES AND OTHER VEHICLES
5013	MOTOR VEHICLE PARTS & NEW SUP
5014	TIRES AND TUBES
5015	MOTOR VEHICLE PARTS, USED
5021	FURNITURE
5023	HOMEFURNISHINGS
5031	LUMBER,PLYWOOD,MILLWORK,& PANL
5032	BRICK, STONE & RELAT MATERIALS
5033	ROOFING, SIDING AND INSULATION
5039	CONSTRUCTION MATERIALS, NEC
5043	PHOTOGRAPHIC EQUIP & SUPPLIES
5044	OFFICE EQUIPMENT
5045	COMPUTERS, PERIPHERALS, & SOFT
5046	COMMERCIAL EQUIPMENT, NEC
5047	MEDICAL AND OFFICE EQUIPMENT
5048	OPHTHALMIC GOODS
5049	PROFESSIONAL EQUIPMENT, NEC
5051	METAL SERVICE CENTERS & OFFICE
5052	COAL & OTHER MINERALS & ORES
5063	ELECTRICAL APPARATUS AND EQUIP
5064	ELEC APPLIANCES/TV & RADIO SET
5065	ELECTRONIC PARTS AND EQUIPMENT
5072	HARDWARE
5074	PLUMB & HEAT EQUIP & SUPPLIES
5075	AIR HEAT & AIR-COND. EQUIP/SUP
5078	REFRIGERATION EQUIP & SUPPLIES
5082	CONST & MINING MACHINE & EQUIP
5083	FARM & GARDEN MACHINE & EQUIP
5084	INDUSTRIAL MACHINERY AND EQUIP
5085	INDUSTRIAL SUPPLIES
5087	SERVICE ESTABLISH EQUIP & SUPP
5088	TRANS EQUIP & SUPP, EXC MOTOR
5091	SPORTING & RECREATIONAL GOODS
5092	TOYS & HOBBY GOODS & SUPPLIES

140 SIC CODES (1987)

SIC2	DESCRIPTION
5093	SCRAP & WASTE MATERIALS
5094	JEWELRY, WATCHES, PRECIOUS STO
5099	DURABLE GOODS, NEC
5111	PRINTING AND WRITING PAPER
5112	STATIONERY AND OFFICE SUPPLIES
5113	INDUST & PERSONAL PAPER SERVIC
5122	DRUGS, DRUG PRPPRIE & SUNDRIES
5131	PIECE GOODS AND NOTIONS
5136	MALE'S CLOTHING & FURNISHINGS
5137	WOMEN'S, CHILD & INF CLOTHING
5139	FOOTWEAR
5141	GROCERIES, GENERAL LINE
5142	PACKAGED FROZEN FOODS
5143	DAIRY PROD, EXC DRIED & CANNED
5144	POULTRY AND POULTRY PRODUCTS
5145	CONFECTIONERY
5146	FISH AND SEAFOODS
5147	MEATS AND MEAT PRODUCTS
5148	FRESH FRUITS AND VEGETABLES
5149	GROCERIES & RELATED PRODUCTS
5153	GRAIN AND FIELD BEANS
5154	LIVESTOCK
5159	FARM-PRODUCT RAW MATERIALS
5162	PLASTIC MATER & BASIC SHAPES
5169	CHEMICALS AND ALLIED PRODUCTS
5171	PETROLEUM BULK STATIONS & TERM
5172	PETROL & PET PROD WHOLESALERS
5181	BEER AND ALE
5182	WINE & DIST ALCOHOLIC BEVERAGE
5191	FARM SUPPLIES
5192	BOOKS, PERIODICALS & NEWSPAPER
5193	FLOWERS AND FLORISTS' SUPPLIES
5194	TOBACCO AND TOBACCO PRODUCTS
5198	PAINTS, VARNISHES AND SUPPLIES
5199	NONDURABLE GOODS, NEC
5211	LUMBER & BUILD MATERIAL DEALER
5231	PAINT, GLASS & WALLPAPER STORE
5251	HARDWARE STORES
5261	RET NURSERIES,LAWN/GARDN STORE
5271	MOBILE HOME DEALERS
5311	DEPARTMENT STORES
5331	VARIETY STORES
5399	MISCELLANEOUS GENERAL STORES
5411	GROCERY STORES
5421	MEAT AND FISH MARKETS
5431	FRUIT AND VEGETABLE MARKETS
5441	CANDY, NUT & CONFECTION STORES
5451	DAIRY PRODUCTS STORES
5461	RETAIL BAKERIES
5499	MISCELLANEOUS FOOD STORES
5511	MOTOR VEH. DEALERS (NEW/USED)
5521	MOTOR VEH. DEALERS (USED ONLY)

140 SIC CODES (1987)

SIC2	DESCRIPTION
5531	AUTO AND HOME SUPPLY STORES
5541	GASOLINE SERVICE STATIONS
5551	BOAT DEALERS
5561	RECREATIONAL VEHICLE DEALERS
5571	MOTORCYCLE DEALERS
5599	AUTOMOTIVE DEALERS, NEC
5611	MALE'S CLOTHING & ACCESS STORE
5621	WOMEN'S CLOTHING STORES
5632	WOMEN'S ACCESS & SPEC STORES
5641	CHILDREN'S & INF WEAR STORES
5651	FAMILY CLOTHING STORES
5661	SHOE STORES
5699	MISC APPAREL & ACCESS STORES
5712	FURNITURE STORES
5713	FLOOR COVERING STORES
5714	DRAPE, CURTAIN & UPHOL STORES
5719	MISC HOMEFURNISHINGS STORES
5722	HOUSEHOLD APPLIANCE STORES
5731	RADIO, TV & ELECTRONICS STORES
5734	COMPUTER AND SOFTWARE STORES
5735	RECORD & PRERECORDED TAPE STOR
5736	MUSICAL INSTRUMENT STORES
5812	EATING PLACES
5813	DRINKING PLACES (ALCOHOLIC BEV
5912	DRUG STORES & PROPRIETARY STOR
5921	LIQUOR STORES
5932	USED MERCHANDISE STORES
5941	SPORTING GOODS/BICYCLE STORES
5942	BOOK STORES
5943	STATIONERY STORES
5944	JEWELERY STORES
5945	HOBBY, TOY AND GAME SHOPS
5946	CAMERA & PHOTO SUPPLY STORES
5947	GIFT, NOVELTY & SOUVENIR SHOPS
5948	LUGGAGE & LEATHER GOODS STORES
5949	SEW/NEEDLEWK/PIECE GOODS STORE
5961	CATALOG AND MAIL-ORDER HOUSES
5962	AUTO MERCHANDIS MACHINE OPERAT
5963	DIRECT SELLING ESTABLISHMENTS
5983	FUEL OIL DEALERS
5984	LIQ PETROL GAS (BOT GAS) DEALR
5989	FUEL DEALERS, NEC
5992	FLORISTS
5993	TOBACCO STORES AND STANDS
5994	NEWS DEALERS AND NEWSSTANDS
5995	OPTICAL GOODS STORES
5999	MISCELLANEOUS RETAIL STORES
6011	FEDERAL RESERVE BANKS
6019	CENTRAL RESERVE REPOSITORY
6021	NATIONAL COMMERCIAL BANKS
6022	STATE COMMERCIAL BANKS
6029	COMMERCIAL BANKS, NEC

SIC2	DESCRIPTION
6035	FEDERAL SAVINGS INSTITUTIONS
6036	SAVINGS INSTITUTIONS, EXC FED
6061	FEDERAL CREDIT UNIONS
6062	STATE CREDIT UNIONS
6081	FOREIGN BANK & BRANCHES & AGEN
6082	FOREIGN TRADE & INTERNAT BANKS
6091	NONDEPOSIT TRUST FACILTIES
6099	FUNCT RELATED TO DEP BANKING
6111	FEDERAL & FED-SPONSORED CREDIT
6141	PERSONAL CREDIT INSTITUTIONS
6153	SHORT-TERM BUS. CREDIT INSTITU
6159	MISC BUSINESS CREDIT INSTITUTI
6162	MORTG BANKERS & LOAN CORRESPON
6163	LOAN BROKERS
6211	SEC BROKERS/DEALERS/FLOTAT. CO
6221	COMMODITY CONTR BROKERS & DEAL
6231	SECURITY & COMMODITY EXCHANGES
6282	INVESTMENT ADVICE
6289	SECURITY & COMMODITY SERVICES
6311	LIFE INSURANCE
6321	ACCIDENT AND HEALTH INSURANCE
6324	HOSPITAL & MEDICAL SERV PLANS
6331	FIRE, MARINE & CASUALTY INSUR
6351	SURETY INSURANCE
6361	TITLE INSURANCE
6371	PENSION, HEALTH & WELFARE FUND
6399	INSURANCE CARRIERS, NEC
6411	INSUR AGENTS, BROKERS, & SERVI
6512	OPER OF NONRESIDENTIAL BLDGS
6513	OPERATORS OF APART BUILDINGS
6514	OPER OF DWELL OTHER THAN APART
6515	OPER OF RES MOBILE HOME SITES
6517	LESSORS OF RAILROAD PROPERTIES
6519	LESSORS OF REAL PROPERTY, NEC
6531	REAL ESTATE AGENTS & MANAGERS
6541	TITLE ABSTRACT OFFICES
6552	LAND SUBDIVIDERS & DEV, EX CEM
6553	CEMETERY SUBDIVIDERS & DEVELOP
6712	BANK HOLDING COMPANIES
6719	HOLDING COMPANIES, NEC
6722	MGMT INVEST. OFFICES, OPEN END
6726	INVESTMENT OFFICES, NEC
6732	EDUCAT.,RELIG & CHARITY TRUSTS
6733	TRUSTS,EXC EDUCAT,RELIG & CHAR
6792	OIL ROYALTY TRADERS
6794	PATENT OWNERS AND LESSORS
6798	REAL ESTATE INVESTMENT TRUSTS
6799	INVESTORS, NEC
7011	HOTELS AND MOTELS
7021	ROOMING AND BOARDING HOUSES
7032	SPORTING & RECREATIONAL CAMPS
7033	REC VEHICLE PARKS & CAMPSITES

140 SIC CODES (1987)

SIC2	DESCRIPTION
7041	ORG. HOTEL & LODG HSE, ON MEMB
7211	POWER LAUNDRIES, RES & COMMERC
7212	GARM PRESSING/LAUNDRIES/DRYCLE
7213	LINEN SUPPLY
7215	COIN-OPERATED LAUNDRIES/DRYCLE
7216	DRYCLEAN PLANTS, EXC RUG CLEAN
7217	CARPET & UPHOLSTERY CLEANING
7218	INDUSTRIAL LAUNDERERS
7219	LAUNDRY & GARMENT SERVICES,NEC
7221	PHOTOGRAPHIC STUDIOS, POTRAIT
7231	BEAUTY SHOPS
7241	BARBER SHOPS
7251	SHOE REP SHOPS & SHOESHINE PAR
7261	FUNERAL SERVICES & CREMATORIES
7291	TAX AND PREPARATION SERVICES
7299	MISCELLANEOUS PERSONAL SERVICE
7311	ADVERTISING AGENCIES
7312	OUTDOOR ADVERTISING AGENCIES
7313	RADIO, TV & PUBLISHERS AD REPS
7319	ADVERTISING, NEC
7322	ADJUSTMENT & COLLECT SERVICES
7323	CREDIT REPORTING SERVICES
7331	DIRECT MAIL ADVERTIS SERVICES
7334	PHOTOCOPYING/DUPLICATING SERV
7335	COMMERCIAL PHOTOGRAPHY
7336	COMM ART & GRAPHIC DESIGN
7338	SECRETARIAL & COURT REPORTING
7342	DISINFECTING & EXTERMINAT SERV
7349	BUILDING MAINTNENANCE SERVICE
7352	MEDICAL EQUIPMENT RENTAL
7353	HEAVY CONSTRUCTON EQUIP RENTAL
7359	EQUIPMENT RENTAL AND LEASING,
7361	EMPLOYMENT AGENCIES
7363	HELP SUPPLY SERVICES
7371	CUSTOM COMPUTER PROG SERVICES
7372	PREPACKAGED SOFTWARE
7373	COMPUTER INTEGRATED SYS DESIGN
7374	DATA PROCESSING & PREPARATION
7375	INFORMATION RETRIEVAL SERVICES
7376	COMPUTER FACILITIES MANAGEMENT
7377	COMPUTER RENTAL AND LEASING
7378	COMPUTER MAINTENANCE & REPAIR
7379	COMPUTER RELATED SERVICES, NEC
7381	DETECTIVE & ARMORED CAR SERVIC
7382	SECURITY SYSTEMS SERVICES
7383	NEWS SYNDICATES
7384	PHOTOFINISHING LABORATORIES
7389	BUSINESS SERVICES, NEC
7513	TRUCK RENT & LEASE, NO DRIVERS
7514	PASSENGER CAR RENTAL
7515	PASSENGER CAR LEASING
7519	UTILITY TRAILER & RV RENTAL

SIC2	DESCRIPTION
7521	AUTOMOBILE PARKING
7532	TOP & BODY REPAIR & PAINT SHOP
7533	AUTO EXHAUST SYSTEM REP SHOPS
7534	TIRE RETREADING & REPAIR SHOPS
7536	AUTO GLASS REPLACEMENT SHOPS
7537	AUTO TRANSMISSION REPAIR SHOPS
7538	GENERAL AUTO REPAIR SHOPS
7539	AUTOMOTIVE REPAIR SHOPS, NEC
7542	CAR WASHES
7549	AUTO SERV, EXC REP & CARWASHES
7622	RADIO & TELEVISION REPAIR SHOP
7623	REFRIG & AC SERV & REP SHOPS
7629	ELEC & ELECTRONIC REPAIR SHOPS
7631	WATCH, CLOCK & JEWELRY REPAIR
7641	REUPHOLSTERY & FURNITURE REP
7692	WELDING REPAIR
7694	ARMATURE REWINDING SHOPS
7699	REPAIR SHOPS & RELATED SERVICE
7812	MOTION PICTURE & VIDEO PROD
7819	SERV. ALLIED TO MOTION PICTURE
7822	MOTION PICTURE & TAPE DISTRIB
7829	SERV ALLIED TO MOTION PIC DIST
7832	MOTION PIC THEA., EX DRIVE-IN
7833	DRIVE-IN MOTION PIC THEATRES
7841	VIDEO TAPE RENTAL
7911	DANCE STUDIOS, SCHOOLS & HALLS
7922	THEA. PROD (EXC MOTION PICTURE
7929	BANDS, ORCH, ACTORS & ENTERTAI
7933	BOWLING CENTERS
7941	PROF SPORTS CLUBS & PROMOTERS
7948	RACING, INCLUDING TRACK OPERA
7991	PHYSICAL FITNESS FACILITIES
7992	PUBLIC GOLF COURSES
7993	COIN OPERATED AMUSEMENT DEVI
7996	AMUSEMENT PARKS
7997	MEMBERSHIP SPORTS & REC CLUBS
7999	AMUSEMENT AND RECREATION, NEC
8011	OFFICES & CLINICS OF MED DOCT
8021	OUTPATIENT CARE FACILITIES
8031	OFFICES/CLINCS OF DOC OF OSTEO
8041	OFFICES & CLINICS OF CHIROPRAC
8042	OFFICES & CLINICS OF OPTOMETRI
8043	OFFICES & CLINICS OF PODIATRIS
8049	OFFICES OF HEALTH PRACTITIONER
8051	SKILLED NURSING CARE FACILITIE
8052	INTERMEDIATE CARE FACILITIES
8059	NURSING AND PERSONAL CARE, NEC
8062	GEN. MEDICAL/SURGICAL HOSPITAL
8063	PSYCHIATRIC HOSPITALS
8069	SPECIALTY HOSPITALS
8071	MEDICAL LABORATORIES
8072	DENTAL LABORATORIES

140 SIC CODES (1987)

SIC2	DESCRIPTION
8082	HOME HEALTH CARE SERVICES
8092	KIDNEY DIALYSIS CENTERS
8093	SPECIALITY OUTPATIENT CLINICS
8099	HEALTH & ALLIED SERVICES, NEC
8111	LEGAL SERVICES
8211	ELEMENTARY & SECONDARY SCHOOLS
8221	COLLEGES, UNIV & PROF SCHOOLS
8222	JUNIOR COLLEGES & TECH INSTITU
8231	LIBRARIES
8243	DATA PROCESSING SCHOOLS
8244	BUSINESS & SECRETARIAL SCHOOLS
8249	VOCATIONAL SCHOOLS, NEC
8299	SCHOOLS & EDUCATIONAL SERVICES
8322	INDIVIDUAL AND FAMILY SERVICES
8331	JOB TRAINING & VOC REHAB SERVI
8351	CHILD DAY CARE SERVICES
8361	RESIDENTIAL CARE
8399	SOCIAL SERVICES, NEC
8412	MUSEUMS AND ART GALLERIES
8422	BOTANICAL & ZOOLOGICAL GARDENS
8611	BUSINESS ASSOCIATIONS
8621	PROFESSIONAL MEMBERSHIP ORGAN
8631	LABOR UNIONS & LABOR ORGANIZA
8641	CIVIC, SOCIAL & FRATERNAL ASS.
8651	POLITICAL ORGANIZATIONS
8661	RELIGIOUS ORGANIZATIONS
8699	MEMBERSHIP ORGANIZATIONS, NEC
8711	ENGINEERING SERVICES
8712	ARCHITECTURAL SERVICES
8713	SURVEYING SERVICES
8721	ACC., AUDITING & BOOKKEEPING
8731	COMMERCIAL PHYSICAL RESEARCH
8732	COMMERCIAL NONPHYSICAL RESEAR
8733	NONCOMMERCIAL RESEARCH ORGANI
8734	COMMERCIAL TESTING LABORATORY
8741	MANAGEMENT SERVICES
8742	MANAGEMENT CONSULTING SERVICE
8743	PUBLIC RELATIONS SERVICES
8744	FACILITIES SUPPORT SERVICES
8748	BUSINESS CONSULTING, NEC
8811	PRIVATE HOUSEHOLDS
8999	SERVICES, NEC
9111	EXECUTIVE OFFICES
9121	LEGISLATIVE BODIES
9131	EXEC & LEGIS OFFICES COMBINED
9199	GENERAL GOVERNMENT, NEC
9211	COURTS
9221	POLICE PROTECTION
9222	LEGAL COUNSEL & PROSECUTION
9223	CORRECTIONAL INSTITUTIONS
9224	FIRE PROTECTION
9229	PUBLIC ORDER AND SAFETY, NEC

140 SIC CODES (1987)

SIC2	DESCRIPTION
9311	PUBLIC FINANCE
9411	ADMINISTRATION OF EDUCAT PROG
9431	ADMIN OF PUB HEALTH PROGRAMS
9441	ADM OF SOCIAL/HUMAN RESOURCE
9451	ADM OF VET AFFAIRS, EX HEA/INS
9511	AIR & WATER RES & SOL WSTE MGT
9512	LAND, MIN, WILDLIFE/FOREST CON
9531	ADMIN OF HOUSING PROGRAMS
9532	ADM OF URB PLAN/COMM/RURL DEV
9611	ADMIN OF GENERAL ECONOMIC PRO
9621	REG & ADMIN OF TRANS PROGRAMS
9631	REG & ADM OF COMMS, ELEC, GAS
9641	REG OF AGRI MARKETING & COMMOD
9651	REG, LIC & INSP OF COMM SECTOR
9661	SPACE RESEARCH AND TECHNOLOGY
9711	NATIONAL SECURITY
9721	INTERNATIONAL SECURITY
9999	NONCLASSIFIABLE ESTABLISHMENTS

Table IV-14. Median Phosphorus Soil Test Levels (pounds per acre) for Counties in the Saginaw Bay Drainage Basin, 1972-1990 (MDNR, 1985; Warncke, 1987; MDNR, 1991).

COUNTY	YEAR 1962	1967	1972	1976-1977	1979-1980	1982-1983	1984	1985	1986	1987	1990
Arenac	19	21	46	88	130	102	119	108	90	108	67
Bay	27	51	74	88	130	147	194	182	222	170	132
Clare	--	--	--	41	66	76	66	61	60	83	60
Genesee	17	27	33	54	107	98	98	80	62	76	79
Gladwin	17	18	17	41	45	61	40	67	67	53	46
Gratiot	19	31	52	66	98	107	124	131	100	122	102
Huron	28	25	23	17	68	104	95	109	90	97	92
Iosco	--	31	27	38	77	67	85	57	78	68	65
Isabella	18	32	48	62	12[illegible]	106	109	94	92	97	95
Lapeer	22	19	35	38	[illegible]	62	80	68	72	68	64
Livingston	44	32	36	62	9[illegible]	96	98	114	80	90	92
Midland	26	30	45	51	1[illegible]	128	165	130	99	204	127
Ogemaw	--	83	27	45	6[illegible]	74	56	49	60	67	65
Shiawassee	16	25	36	41	82	97	90	100	63	80	81
Tuscola	18	29	38	56	82	93	112	97	117	96	94
AVERAGE	23	32	38	53	90	95	102	96	90	99	86

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

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	Nitrate	TKN	Total Phosphorus	Chloride
	Parameter			
1982				
Bay City	322	302	4.9	327
Port Austin	341	599	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

SAGINAW BAY WATERSHED MANAGEMENT UNITS (mgmt.units in PERMANENT)
Potential for Stream Bank Erosion (recl.streros in PERMANENT)

Watershed #	Description	Acres	Percent	Severe/Moderate Percent	Rank (H,M,L)
0	no data differences between two data layers	5,952,570			
	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	5,945,526 2,966 3,337 742			
10101	0 No data available 1 Severe Potential 3 Slight Potential	6,118 83,050 33,121	68% 27%	68%	H
10102	0 1 Severe Potential 3 Slight Potential	618 50,485 43,008	54% 46%	54%	M
10103	1 Severe Potential 2 Moderate Potential 3 Slight Potential	52,277 1,359 101,774	34% 1% 65%	35%	M
10104	0 1 Severe Potential 3 Slight Potential	927 21,442 16,252	56% 42%	56%	M
10105	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	185 136,317 27,683 78,663	56% 11% 32%	67%	H
10201	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	1,854 26,509 865 37,323	40% 1% 56%	41%	M
10202	0 1 Severe Potential 3 Slight Potential	5,005 39,239 55,861	39% 56%	39%	M
10203	1 Severe Potential 3 Slight Potential	39,795 26,015	60% 40%	60%	M
10204	1 Severe Potential 3 Slight Potential	30,341 47,581	39% 61%	39%	M
10301	0 1 Severe Potential 3 Slight Potential	4,511 24,285 47,457	32% 62%	32%	M
10302	0 1 Severe Potential 3 Slight Potential	62 15,325 40,289	28% 72%	28%	L

SAGINAW BAY WATERSHED MANAGEMENT UNITS (mgmt.units in PERMANENT)
Potential for Stream Bank Erosion (recl.streros in PERMANENT)
Continued

Watershed #	Description	Acres	Percent	Severe/Moderate Percent	Rank (H,M,L)
10303	0 1 Severe Potential 3 Slight Potential	556 20,330 31,453	 39% 60%	39%	M
10304	1 Severe Potential 3 Slight Potential	8,898 57,468	13% 87%	13%	L
10305	0 1 Severe Potential 3 Slight Potential	247 11,123 35,284	 24% 76%	24%	L
10306	1 Severe Potential 2 Moderate Potential 3 Slight Potential	11,803 20,145 68,405	12% 20% 68%	32%	M
10307	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	62 12,359 22,307 51,350	 14% 26% 60%	40%	M
10308	0 1 Severe Potential 3 Slight Potential	1,854 6,365 85,769	 7% 91%	7%	L
20101	1 Severe Potential 3 Slight Potential	102,577 16,746	86% 14%	86%	H
20102	1 Severe Potential 2 Moderate Potential 3 Slight Potential	42,205 1,854 6,056	84% 4% 12%	88%	H
20103	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	62 8,095 5,067 30,093	 19% 12% 69%	31%	M
20104	1 Severe Potential 2 Moderate Potential 3 Slight Potential	6,303 9,825 1,483	36% 56% 8%	92%	H
20105	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	185 50,115 18,476 43,564	 45% 16% 39%	61%	H
20106	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	309 26,509 7,601 14,027	 55% 16% 29%	71%	H
20107	1 Severe Potential 2 Moderate Potential 3 Slight Potential	39,548 73,102 18,785	30% 56% 14%	86%	H

SAGINAW BAY WATERSHED MANAGEMENT UNITS (mgmt.units in PERMANENT)
Potential for Stream Bank Erosion (recl.streros in PERMANENT)
Continued

Watershed #	Description	Acres	Percent	Severe/Moderate Percent	Rank (H,M,L)
20108	1 Severe Potential 2 Moderate Potential 3 Slight Potential	48,879 27,992 64,821	34% 20% 46%	54%	M
20109	1 Severe Potential 3 Slight Potential	71,433 29,908	70% 30%	70%	H
20110	1 Severe Potential 3 Slight Potential	20,083 20,763	49% 51%	49%	M
20111	1 Severe Potential 3 Slight Potential	30,217 680	90% 2%	90%	H
20112	1 Severe Potential 3 Slight Potential	7,477 12,297	38% 62%	38%	M
20113	1 Severe Potential 3 Slight Potential	35,099 34,481	50% 50%	50%	M
20201	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	371 64,636 112,093 2,225	 36% 63% 1%	99%	H
20202	2 Moderate Potential	13,286	100%	100%	H
20203	1 Severe Potential 2 Moderate Potential	14,151 37,447	27% 73%	99%	H
20204	0 1 Severe Potential 2 Moderate Potential	185 21,566 91,269	 19% 81%	100%	H
20205	1 Severe Potential 2 Moderate Potential 3 Slight Potential	4,387 8,033 4,573	26% 47% 27%	73%	H
20206	1 Severe Potential 2 Moderate Potential 3 Slight Potential	56,170 47,025 21,875	45% 38% 17%	83%	H
20207	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	124 20,515 62,968 1,730	 24% 74% 2%	98%	H
20208	1 Severe Potential 2 Moderate Potential 3 Slight Potential	14,830 13,038 43,626	21% 17% 61%	38%	M
20301	1 Severe Potential 3 Slight Potential	33,369 55,985	37% 63%	37%	M

SAGINAW BAY WATERSHED MANAGEMENT UNITS (mgmt.units in PERMANENT)
Potential for Stream Bank Erosion (recl.streros in PERMANENT)
Continued

Watershed #	Description	Acres	Percent	Severe/Moderate Percent	Rank (H,M,L)
20302	1 Severe Potential 3 Slight Potential	10,752 9,454	53% 47%	53%	M
20303	1 Severe Potential 2 Moderate Potential 3 Slight Potential	8,898 309 36,149	20% 1% 80%	21%	L
20304	1 Severe Potential 2 Moderate Potential 3 Slight Potential	13,718 6,983 41,958	22% 11% 67%	33%	M
20305	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	62 70,321 2,719 40,660	 62% 2% 36%	64%	H
20306	1 Severe Potential 3 Slight Potential	27,251 53,081	34% 66%	34%	M
20307	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	124 28,919 37,756 14,274	 36% 47% 18%	83%	H
20308	0 1 Severe Potential 2 Moderate Potential 3 Slight Potential	62 16,808 58,704 8,342	 20% 70% 10%	90%	H
20309	0 1 Severe Potential 2 Moderate Potential	309 5,561 83,977	 6% 93%	99%	H
20310	0 1 Severe Potential 2 Moderate Potential	124 32,689 109,869	 23% 77%	100%	H
20401	1 Severe Potential 2 Moderate Potential 3 Slight Potential	28,858 46,716 37,570	26% 41% 33%	67%	H
20402	1 Severe Potential 2 Moderate Potential 3 Slight Potential	61,114 51,041 20,701	46% 38% 16%	84%	H
20403	1 Severe Potential 2 Moderate Potential 3 Slight Potential	8,342 51,350 14,089	11% 70% 19%	81%	H
20404	1 Severe Potential 2 Moderate Potential 3 Slight Potential	3,460 41,278 7,292	7% 79% 14%	86%	H

SAGINAW BAY WATERSHED MANAGEMENT UNITS (mgmt.units in PERMANENT)
Potential for Stream Bank Erosion (recl.streros in PERMANENT)
Continued

Watershed #	Description	Acres	Percent	Severe/Moderate Percent	Rank (H,M,L)
20405	0	185		95%	H
	1 Severe Potential	9,887	15%		
	2 Moderate Potential	50,980	80%		
	3 Slight Potential	2,843	4%		
20406	1 Severe Potential	19,959	15%	72%	H
	2 Moderate Potential	75,821	57%		
	3 Slight Potential	36,582	28%		
20407	1 Severe Potential	4,017	10%	67%	H
	2 Moderate Potential	22,493	57%		
	3 Slight Potential	13,038	33%		
20408	0	247		66%	H
	1 Severe Potential	13,904	14%		
	2 Moderate Potential	50,424	52%		
	3 Slight Potential	32,194	33%		
20409	1 Severe Potential	22,925	23%	65%	H
	2 Moderate Potential	42,576	42%		
	3 Slight Potential	36,273	36%		
20410	1 Severe Potential	14,521	32%	100%	H
	2 Moderate Potential	30,959	68%		
	3 Slight Potential	62	0%		
20501	1 Severe Potential	32,009	60%	71%	H
	2 Moderate Potential	5,623	11%		
	3 Slight Potential	15,510	29%		
20502	1 Severe Potential	30,711	42%	89%	H
	2 Moderate Potential	34,481	47%		
	3 Slight Potential	8,280	11%		
20503	1 Severe Potential	40,537	71%	88%	H
	2 Moderate Potential	9,640	17%		
	3 Slight Potential	7,106	12%		
20504	1 Severe Potential	26,386	53%	91%	H
	2 Moderate Potential	19,218	38%		
	3 Slight Potential	4,573	9%		
20505	1 Severe Potential	35,902	39%	100%	H
	2 Moderate Potential	55,491	61%		
20506	1 Severe Potential	27,931	47%	76%	H
	2 Moderate Potential	16,931	29%		
	3 Slight Potential	14,089	24%		
20507	0	62		100%	H
	1 Severe Potential	24,408	56%		
	2 Moderate Potential	19,218	44%		

SAGINAW BAY WATERSHED MANAGEMENT UNITS (mgmt.units in PERMANENT)
Potential for Stream Bank Erosion (recl.streros in PERMANENT)
Continued

Watershed #	Description	Acres	Percent	Severe/Moderate Percent	Rank (H,M,L)
20508	0 1 Severe Potential 2 Moderate Potential	371 27,127 105,791	 20% 79%	99%	H
20509	1 Severe Potential 2 Moderate Potential	2,966 16,870	15% 85%	100%	H
20601	1 Severe Potential 3 Slight Potential	10,937 29,846	27% 73%	27%	L
20602	1 Severe Potential 3 Slight Potential	38,312 81,506	32% 68%	32%	M
TOTAL		11,479,507			

Table IV-6. Phosphorus Loads from Major Municipal Wastewater Treatment Plants to Surface Waters in the Saginaw Bay Watershed, 1974, 1979-1986, and 1992.

Year	Load (metric tons/year)
1974	800
1979	211
1980	220
1981	232
1982	200
1983	141[a]
1984	125[a]
1985	114[b]
1986	169[c]
1992	108

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

[b] Includes phosphorus load from Mt. Pleasant WWTP (3 mt). Data not available for Saginaw Township WWTP.

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

Table 4. Total Phosphorus Loads from Major Municipal Point Source Dischargers in the Saginaw Bay Watershed.

Municipal Facility	1982 Flow (mgd)	1982 Load (mt/yr)	1992 Flow (mgd)	1992 Annual Avg Conc (mg/l)	1992 Load (mt/yr)
Alma	2.23	3.08	2.35	.54	1.72
Bay City	9.45	13.06	9.19	.59	7.48
Bridgeport	1.23	1.70	1.49	.35	0.96
Buena Vista	1.77	2.45	1.91	.50	1.20
Flint	47.93	66.22	33.24	.68	29.88
Flushing	2.23	3.08	1.73	.51	1.19
Frankenmuth	1.09	1.51	1.14	.60	0.91
Genesee County - Ragnone	20.96	28.96	25.99	.40	14.80
Genesee County #3	3.48	4.81	5.85	.51	4.42
Howell	1.23	1.70	1.27	.33	0.58
Lapeer	1.29	1.78	1.90	.55	1.39
Midland	6.41	8.86	8.87	.21	2.61
Mt. Pleasant	2.98	4.12	3.78	.57	2.96
Owosso	3.77	5.21	4.29	.33	1.89
Saginaw Township	4.17	5.76	5.28	.73	5.47
Saginaw	27.65	38.20	26.69	.69	26.84
West Bay County	4.30	5.94	4.41	.54	3.47
Zilwaukee Region	2.35	3.25	0		0
	145.80	199.69	142.38		107.77

Table 5. Total Point Source and Nonpoint Source Phosphorus Loads (mt/yr) to Saginaw Bay for 1982, 1991 and 1992.

Category	G.Lakes Task Force Estimate (Late 70s avg)	MDNR Estimates 1982	MDNR Estimates 1991	MDNR Estimates 1992
Point Sources				
Major Municipal WWTPs	200		108	108[a]
Minor Municipal WWTPs	25		10	10[a]
Municipal Sewage Lagoons	8		22	22[a]
Industrial Facilities	56		20	20[a]
Combined Sewer Overflows	28		28[b]	28[b]
Total Point Sources	317	317	188	188
Nonpoint Sources	348[c]	1527[d]	1970	758
Total Load	665[c]	1844[d]	2158	946
% Nonpoint	52%	83%	91%	80%
GL Task Force Target Load	440			

[a] 1992 Point source discharges were essentially unchanged from 1991, therefore 1991 estimates were used.

[b] Lacked reliable method to estimate 1992 loads, therefore 1982 estimates were used for 1992 as well.

[c] Average load for the preceding several years used to represent baseline.

[d] Actual calculated load for 1982.

Table 6. Total Phosphorus Loading to Saginaw Bay by Watershed, 1992.

Watershed	Acres	Mt/Year	Mt/10,000 acres
WEST COASTAL BASIN			
Tawas River	204,800	18.2	0.9
Whitney Drain	89,600	15.8	1.8
AuGres	140,000	24.5	1.7
Rifle	236,160	38.8	1.6
Big Creek	25,024	2.2	0.9
Pine River	58,816	12.7	2.2
Saganing Creek	18,112	7.6	0.9
Pinconning	16,576	2.4	1.4
Kawkawlin River	144,000	23.4	1.6
EAST COASTAL BASIN			
Quanicassee River	96,000	58.8	6.1
Northwest Drain	33,920	20.8	6.1
Allen Drain	15,168	7.7	5.1
Wiscoggin Drain	28,160	9.0	3.2
State Drain	39,680	12.8	3.2
Columbia Drain	24,320	4.3	1.8
Shebeon Creek	18,240	4.9	2.7
Mud Creek	6,099	6.4	10.5
Pigeon River	80,000	13.7	1.7
Pinnebog River	90,880	17.7	1.9
Taft Drain	32,320	6.1	1.9
Bird Creek	14,272	2.8	2.0
SAGINAW RIVER	3,995,000	591	1.5

Table 3. Acres of Conservation Tillage in Saginaw Bay Basin Counties, 1993.

County	1993 Conservation Tillage Surv[1] (Acres)	Total Cropland[2] (Acres)	% County in Basin	% Cropland in Conservation Tillage 1986	% Cropland in Conservation Tillage 1993
Arenac	15,428	68,355	100	24	23
Bay	13,005	161,143	100	19	8
Clare	1,978	50,215	54	28	4
Genesee	54,450	134,134	100	26	41
Gladwin	5,208	52,844	100	15	10
Gratiot	18,669	248,451	63	31	8
Huron	60,550	384,598	63	26	16
Iosco	15	35,022	66	16	<1
Isabella	46,140	159,774	100	29	29
Lapeer	58,300	178,853	71	27	33
Livingston	24,275	103,952	43	34	23
Mecosta	10,000	93,022	24	35	11
Midland	17,350	72,404	100	7	24
Montcalm	63,550	183,585	13	4	35
Oakland	10,935	50,530	18	33	22
Ogemaw	2,250	46,970	79	8	5
Osceola	8,050	76,293	5	20	11
Roscommon	0	3,391	11	4	0
Saginaw	78,780	282,524	100	30	[illegible]
Sanilac	68,100	391,182	32	13	17
Shiawassee	90,708	203,254	57	32	45
Tuscola	56,500	301,425	100	19	19
Total	704,241	3,281,921	67		21

[1] Includes no-til, ridge till, and mulch till.

[2] From Bureau of Census, 1984 (in 1988 Saginaw River/Bay Remedial Action Plan).

[3] From 1988 Saginaw River/Bay Remedial Action Plan.

Table III-27. Progress toward the Michigan Phosphorus Reduction Goals in Saginaw Bay through May 1991.

Source	Progress to Date (MT)[1]	Expected Reduction (MT)
Point Sources		
Municipal	35.5	4.5
Industrial	32.5	6.9
Nonpoint Sources		
Residue Management	120.5	182.2
Resource Management Systems	60.1	---
Fertilizer Management	25.0	30.8
Accelerated Soil Savings	16.4	---
Animal Waste Management	10.9	4.4
Total	300.9	228.8
Phosphorus Reduction Goal		225.0

[1] MT - Metric Tons

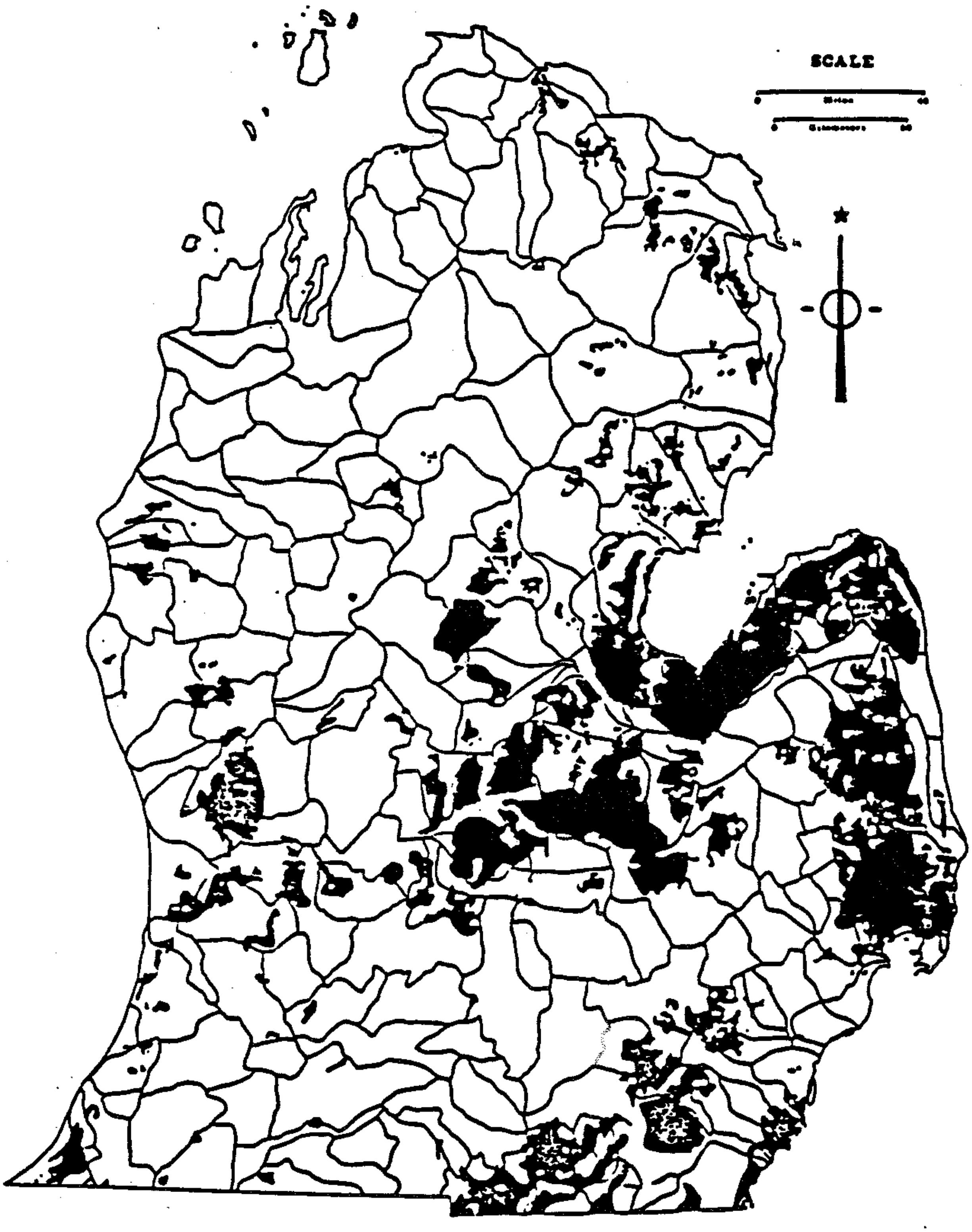


Figure IV-3. Cropland on high clay, low infiltration rate, soils in the Saginaw Bay drainage basin (Yocum et al., 1987).

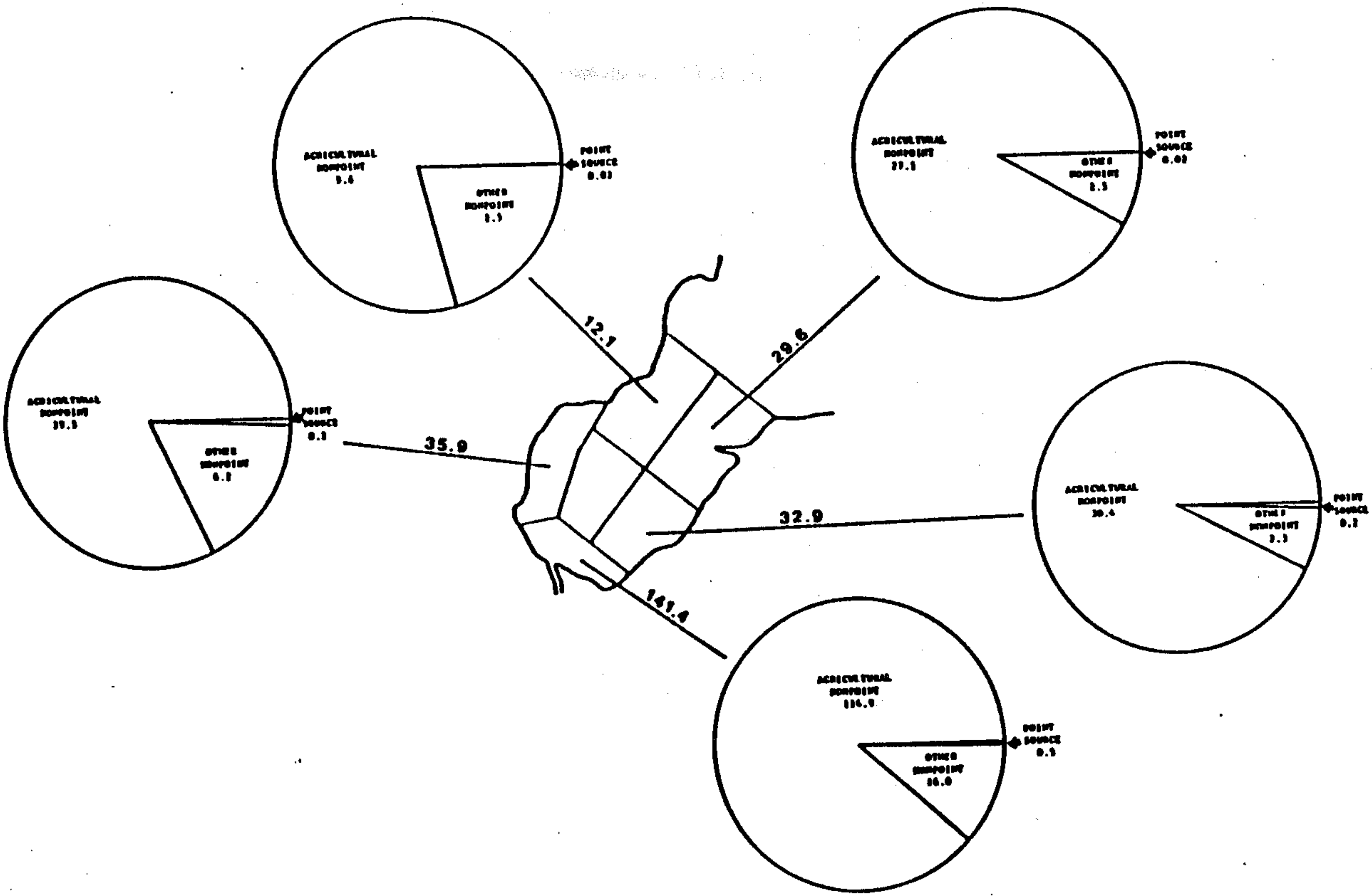


Figure IV-2. Distribution of annual suspended solid loads (1000 metric tons) to inner Saginaw Bay in 1980 (LTI, 1983).

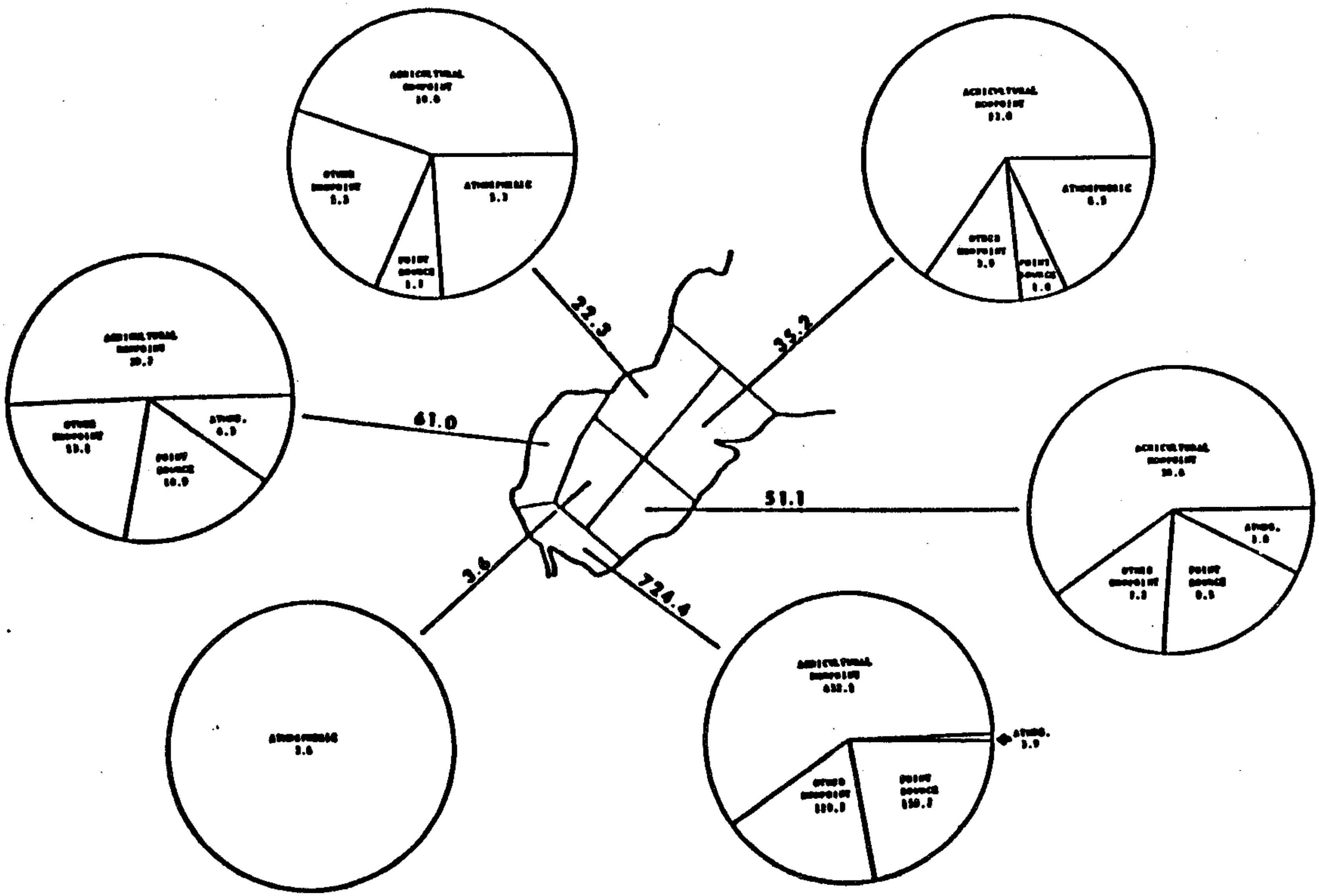
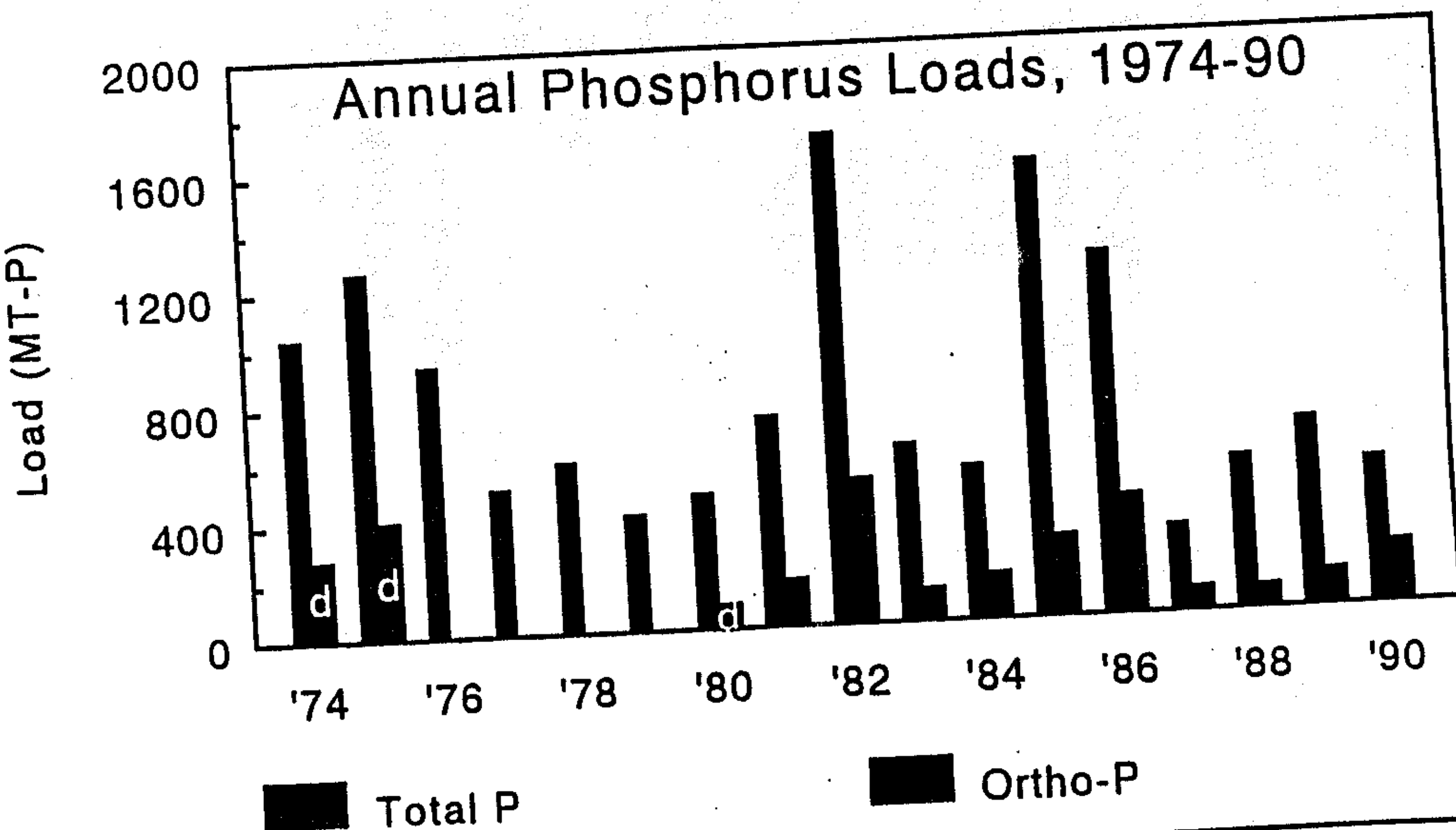


Figure IV-4. Source distribution of annual total phosphorus loads (metric tons) to inner Saginaw Bay in 1980 (LTI, 1983).

presenta

LOAD CALCULATION

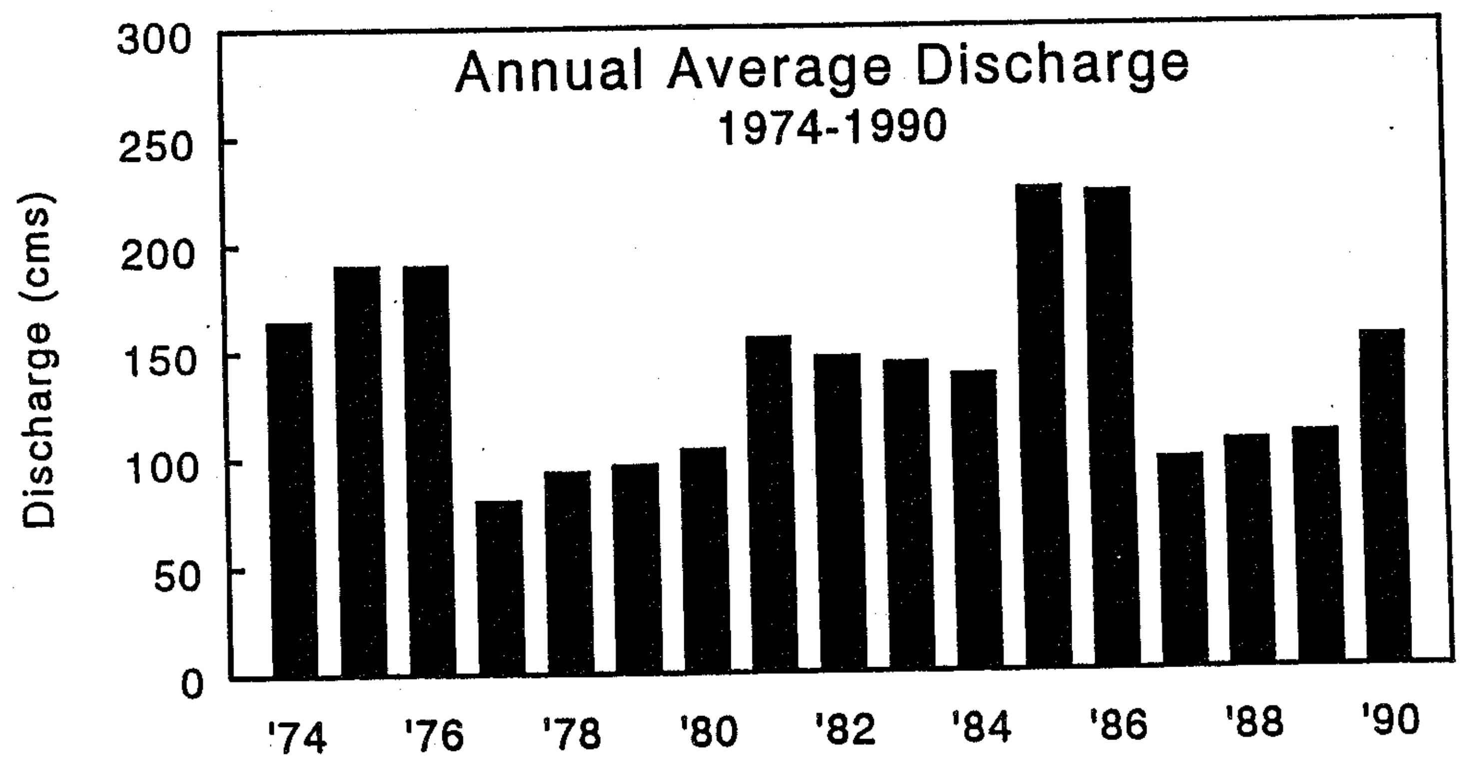


LTI, Limno-Tech, Inc.

d = dissolved orthophosphate

283

LOAD CALCULATION

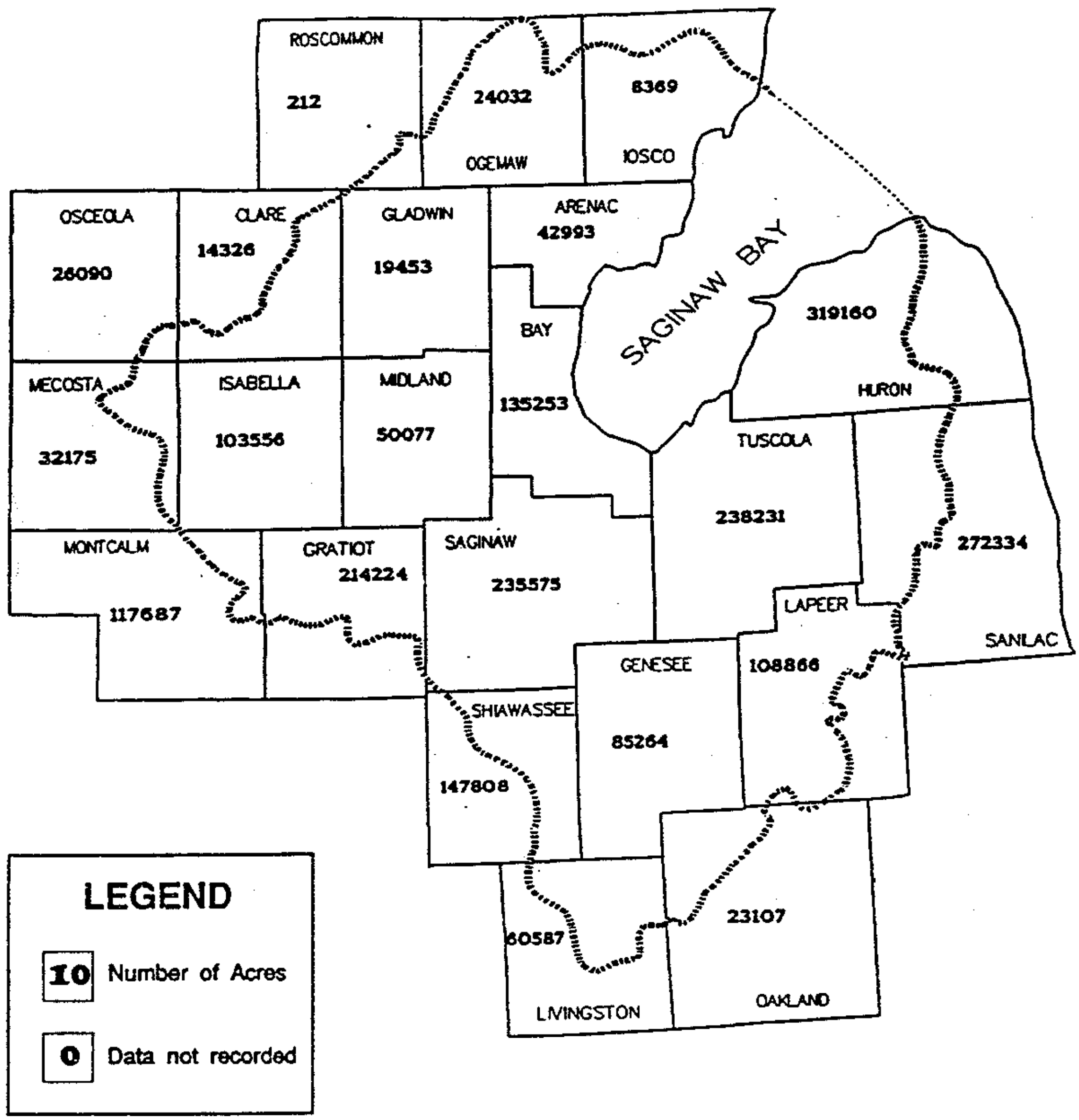


LTI, Limno-Tech, Inc.

Map 6-2

Number of Acres with Fertilizer Applications - 1987

by county



Saginaw Bay Drainage Basin

Saginaw Bay Watershed Land Use and Zoning Study

Map prepared using Michigan Databases, Institute for Public Policy and Social Research, Michigan State University, and U.S. Census TIGER maps.	SCALE 1:1,462,150	N

Map prepared by the Planning & Zoning Center, Inc.