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Tittabawassee River Assessment

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and
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EXECUTIVE SUMMARY

This is one in a series of river assessments prepared by the Michigan Department of Natural Resources, Fisheries Division for Michigan rivers. This report describes the physical and biological characteristics of the Tittabawassee River, details those human activities that have influenced the Tittabawassee River watershed, and serves as an information base for future management goals.

River assessments are intended to provide a comprehensive reference for citizens and agency personnel seeking information about a river. The information contained in this assessment is a compilation of not only river related problems but opportunities as well. The relationship between human influence and river status necessitates public awareness and involvement. This river assessment serves as a tool which can be used to assist the management decision process and increase public understanding and foster their involvement in management decisions. This cooperative stewardship by professional managers and the public will benefit the resource, and ultimately, the future generations of people that will live and recreate within the river watershed.

This document consists of four parts: Introduction, River Assessment, Management Options, and Public Comments (with our responses). The River Assessment is the nucleus of the report. It provides a description of the Tittabawassee River and its watershed in thirteen sections: Geography, History, Geology, Hydrology, Soils and Land Use, Channel Morphology, Dams and Barriers, Water Quality, Special Jurisdictions, Biological Communities, Fisheries Management, Recreational Use, and Citizen Involvement.

The Management Options section identifies a variety of actions that could be taken to protect, restore, rehabilitate, or better understand the Tittabawassee River. These management options are organized according to the main sections of the river assessment. They are intended to provide a foundation for public discussion, priority setting, and ultimately planning the future of the Tittabawassee River.

The Tittabawassee River watershed is centrally located in the Lower Peninsula of Michigan. The watershed encompasses a land area of 2,471 mi^2 and is the fifth largest in Michigan. All or part of Arenac, Bay, Clare, Gladwin, Gratiot, Isabella, Mecosta, Midland, Montcalm, Ogemaw, Osceola, Roscommon, and Saginaw counties lie within the Tittabawassee River watershed. The Tittabawassee River main stem is 91 miles long, and the network of contributing tributaries total 621 miles. There are 217 lakes greater than 10 acres within the watershed.

For analysis and descriptive purposes the main stem Tittabawassee River has been divided into three segments based on differences in channel features and soil types, surficial geology, and topography within the watershed. The headwaters segment is composed of the Middle, East, and West branches of the Tittabawassee River. All three branches begin as coldwater streams and quickly transition into coolwater. The middle segment begins at the upper end of the Secord Lake and extends south 36 miles to the Sanford Dam. This segment is a relatively large warmwater system that is greatly influenced by four hydropower dams: Secord, Smallwood, Wixom, and Sanford. The Sugar, Molasses, and Tobacco rivers enter the main stem within this segment. The mouth segment extends 35 miles from the Sanford Dam to the confluence with the Saginaw River. This segment is a large warmwater system with relatively low gradient. Major tributaries include Carroll Creek Drain (also referred to as Carrol Creek Drain); Sturgeon and Bullock creeks; and the Salt, Chippewa, and Pine rivers.

The natural resources of the Tittabawassee River watershed have played a prominent role in the history of human activities in the region. Native Americans and European settlers were drawn to the Tittabawassee River area because of the abundance of fish and wildlife. By the mid-1800s, the lumber era was underway sparked by the abundant stands of white pine and other valuable trees in the region. Agriculture flourished following deforestation of the watershed and the discovery of brine and oil deposits led to industrial development. Human activity in the watershed has increased economic value and has resulted in serious environmental effects in portions of the watershed.

Soils and land use patterns have a major influence on the hydrology, water temperature, and water quality in the Tittabawassee River watershed. Soils in the northern and western portions of the watershed are highly permeable, are less suitable for agriculture, and produce stable flow, cold- to cool-water streams of good water quality. Soils in the central portions of the watershed have low permeability, support intensive agriculture, and produce flashy, warmwater streams of poorer water quality. The majority of urban areas are located in the central and eastern portion of the watershed. Together, agricultural (e.g., channelization, drainage of wetlands, and installation of artificial drainage systems) and urban (e.g., conversion to impervious surfaces) land use practices have altered flow stability, thermal regimes, and water quality especially in the central and eastern portion of the watershed.

Mean gradient (4.7 ft/mi) within the main stem Tittabawassee River is steep relative to other Michigan rivers and varies from 0.9 ft/mi near the mouth to 68.8 ft/mi in the headwaters. Rivers typically have steep gradient in their headwaters with more moderate gradient further downstream. In the Tittabawassee River, however, gradient remains quite steep within the central portion of the main stem. High gradient reaches in the main stem lie beneath impoundments making these rare and valuable habitats unavailable to stream biota.

Channel cross-section of the Tittabawassee River watershed is normal in most reaches, except the Pine River where widths were greater than expected. Excessively wide channel widths in the Pine River occur below areas with excessive field tiling and high concentrations of county drain systems. Both field tiling and county drains contribute to extreme peak flow events that cause the stream to adjust channel shape through bank erosion.

There are 143 dams registered with MDEQ in the Tittabawassee River watershed. There are 6 listed for hydroelectric generation, 3 are retired hydroelectric dams, 86 for recreation, and the remainder for farm ponds, irrigation, or water supply. Dams in the Tittabawassee River watershed have altered historical fish communities by blocking migration routes, elevating stream temperatures, and inundating high quality, steep-gradient habitats.

Water quality in the Tittabawassee River watershed is influenced by human uses of land and water including agriculture, industry, and suburban development. Aquatic habitat and water quality varies throughout the watershed, with some areas being quite healthy, while other areas are seriously degraded and incapable of supporting designated uses. The Tittabawassee River watershed has historically suffered from poor water quality due to unregulated discharges by industries and municipalities. Although there are three superfund sites in the Tittabawassee River watershed, water quality in the watershed is improving, and virtually all point source discharges are regulated. Major effects on water quality continue to be dioxins, contaminated sediments, nonpoint source pollution, and adjacent sites of contamination. Along the lower Tittabawassee River, elevated levels of dioxins and furans have been found in the sediments of the Tittabawassee River beginning downstream of Midland. The levels of dioxins found at these location exceeds Michigan's generic residential direct-contact clean-up criteria and may exceed the action level of 1,000 parts per trillion (ppt) established by the Centers for Disease Control's Agency for Toxic Substances and Disease Registry.

The present day fish fauna of the Tittabawassee River watershed is composed of 75 native species, 14 introduced or colonized species, and 4 additional species where the status of distribution is unknown. Cisco and lake whitefish were formerly indigenous, but are believed to be extirpated. Lake sturgeon were historically very common and are now a threatened and rare species. The pugnose shiner is the only fish listed as a species of special concern. Most of the upper stream reaches in the northern and western portions of the Tittabawassee River watershed support coldwater fish communities dominated by trout and sculpin. Further downstream waters transition into cool- and warm-water habitats supporting a mixture of esocids (e.g., northern pike), percids (e.g., walleye, yellow perch, and darters), centrarcids (e.g., smallmouth bass, largemouth bass, and sunfishes), and cyprinids (minnows). In addition to water temperature, fish distributions are influenced by dams, water quality, streamflows, and proximity to Lake Huron.

Fisheries management in the Tittabawassee River watershed dates back to 1927. Management to improve the recreational fishery has been vigorous at times, generally concentrating on isolated areas or tributaries. Early fish stocking in rivers and lakes included a variety of species such as brook and brown trout, yellow perch, bluegills, northern pike, largemouth bass, smallmouth bass, and walleye. Most of these early stocking locations, and the species stocked there, have been discontinued or modified. These changes in stocking are the result of advancing fisheries and management methods. Current management focuses on the compatibility of a given species, the water type, and potential of that system (e.g., trout stocking in coldwater streams where reproduction is limited).

In headwater systems water quality is generally good with temperatures cool to cold and many are classified as Type 1 trout streams. Management actions include monitoring of naturally reproducing trout populations. Stocking in recent years has been minimal and occurs at limited locations. Riverine waters in middle sections are typically cool or warm water. Here management consists of monitoring current populations with limited stocking. The middle segment of the main stem is almost completely impounded. Management has been focused on requiring run of the river operation of hydroelectric dams that fragment this section. This requires frequent monitoring to minimize negative effects of dams. Walleye and northern muskellunge are currently stocked in Secord, Smallwood, Wixom, and Sanford impoundments. Runs of potamodromous species are blocked by these impoundment dams as well as the Dow Dam. Thus, additional appropriate management actions are eliminated for the Tittabawassee River system, and sport fishing opportunities are lost. Lower river sections are warm water and management consists of monitoring existing stocks. Both the middle and lower river sections are negatively influenced by agricultural practices. Many river and stream sections are designated drains and field tiling is common. Management here is in the form of educating citizens to minimize land and river practices that negatively affect the watershed.

The Tittabawassee River watershed offers a variety of water-based recreational use. Opportunities for hunting, fishing, swimming, camping, picnicking, boating, and wildlife viewing exist at various locations. Limited public access and the publics' awareness and perception of polluted waters and sediments hinder potential recreational use, particularly on the Pine River downstream from Alma and the Tittabawassee River downstream from Midland.

Citizen involvement in management of the Tittabawassee River and its tributaries occurs through interactions with government and citizen organizations to: manage water flows, water quality, animal populations, land use, and recreation. Continued cooperative and focused efforts between governmental and citizen agencies are necessary to maintain viable resources and to rehabilitate those resources which have been severely degraded.

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TITTABAWASSEE RIVER ASSESSMENT

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INTRODUCTION

This river assessment is one of a series of documents being prepared by the Michigan Department of Natural Resources (MDNR), Fisheries Division, for rivers in Michigan. We have approached this assessment from an ecosystem perspective, as we believe that fish communities and fisheries must be viewed as parts of a complex ecosystem. Our approach is consistent with the mission of MDNR, Fisheries Division, namely to "protect and enhance the public trust in populations and habitat of fishes and other forms of aquatic life, and promote optimum use of these resources for benefit of the people of Michigan".

As stated in the Fisheries Division Strategic Plan, our aim is to develop a better understanding of the structure and functions of various aquatic ecosystems, to appreciate their history, and to understand changes to systems. Using this knowledge, we will identify opportunities that provide and protect sustainable aquatic benefits while maintaining, and at times rehabilitating, system structures or processes.

Healthy aquatic ecosystems have communities that are resilient to disturbance, are stable through time, and provide many important environmental functions. As system structures and processes are altered in watersheds, overall complexity decreases. This results in a simplified ecosystem that is less able to adapt to additional change. All of Michigan's rivers have lost some complexity due to human alterations in the channel and on surrounding land. Therefore, each assessment focuses on ecosystem maintenance and rehabilitation. Maintenance involves either slowing or preventing losses of ecosystem structures and processes. Rehabilitation is putting back some of the original structures or processes.

[1] Retired

River assessments are based on ten guiding principles in the Fisheries Division Strategic Plan. These are: 1) recognize the limits on productivity in the ecosystem; 2) preserve and rehabilitate fish habitat; 3) preserve native species; 4) recognize naturalized species; 5) enhance natural reproduction of native and desirable naturalized fishes; 6) prevent the unintentional introduction of invasive species; 7) protect and enhance threatened and endangered species; 8) acknowledge the role of stocked fish; 9) adopt the genetic stock concept, that is protecting the genetic variation of fish stocks; and 10) recognize that fisheries are an important cultural heritage.

River assessments provide an organized approach to identifying opportunities and solving problems. They provide a mechanism for public involvement in management decisions, allowing citizens to learn, participate, and help direct decisions. They also provide an organized reference for Fisheries Division personnel, other agencies, and citizens who need information about a particular aspect of the river system.

The nucleus of each assessment is a description of the river and its watershed, using a standard list of important ecosystem components. These include:

Geography–a brief description of the location of the river and its watershed; a general overview of the river from its headwaters to its mouth, including topography. This section sets the scene.

History–a description of the river as seen by early settlers and a history of human uses and modifications of the river and watershed.

Geology–a description of both the surficial and bedrock geology of the area.

Hydrology–patterns of water flow, over and through a landscape. This is the key to the character of a river. River flows reflect watershed conditions and influence temperature regimes and habitat characteristics.

Soils and Land Use Patterns–soils and land use in combination with climate determine much of the hydrology and thus the channel form of a river. Changes in land use often drive change in river habitats.

Channel Morphology–the shape of a river channel: width, depth, and sinuosity. River channels are often thought of as fixed, apart from changes made by people. However, river channels are dynamic, constantly changing as they are worked on by the unending, powerful flow of water. Diversity of channel form affects habitat available to fish and other aquatic life.

Dams and Barriers–affect almost all river ecosystem functions and processes, including flow patterns, water temperature, sediment transport, animal drift and migration, and recreational opportunities.

Water Quality–includes temperature, and dissolved or suspended materials. Temperature and a variety of chemical constituents can affect aquatic life and river uses. Degraded water quality may be reflected in simplified biological communities, restrictions on river use, and reduced fishery productivity. Water quality problems may be due to point-source discharges (permitted or illegal) or to nonpoint-source runoff.

Special Jurisdictions–stewardship and regulatory responsibilities under which a river is managed.

Biological Communities–species present historically and today, in and near the river; we focus on fishes, however associated mussels, mammals and birds, key invertebrate animals, special concern, threatened and endangered species, and pest species are described where possible. This component is the foundation for the rest of the assessment. Maintenance of biodiversity is an important goal of natural resource management. Species occurrence, extirpation, and distribution are important clues to the character and location of habitat problems.

Fishery Management–goals are to provide diverse and sustainable game fish populations. Methods include management of fish habitat and fish populations.

Recreational Use–types and patterns of use. A healthy river system provides abundant opportunities for diverse recreational activities along its mainstem and tributaries.

Citizen Involvement–an important indication of public views of the river. Issues that citizens are involved in may indicate opportunities and problems that Fisheries Division or other agencies should address.

Throughout this assessment we use data and shape files downloaded from the Michigan Geographic Data Library, maintained by the Michigan Center for Geographic Information (MDNR 2004). These data provide measures of watershed surface area for numerous categories (e.g., soil types, land use, surficial geology), measures of distance (e.g., stream lengths), and creation of associated figures. We used Arc View GIS 3.2a or Arc GIS (Environmental Systems Research Institute, Inc.; Copyright) to display and analyze these data, and create the landscape figures presented in this report. Unless otherwise referenced, all such measures and associated figures reported within the sections of this report were derived from these data.

Management options follow the river assessment sections of this report, and list alternative actions that will protect, rehabilitate, and enhance the integrity of the river system. These options are intended to provide a foundation for discussion, setting priorities, and planning the future of the river system. Identified options are consistent with the mission statement of Fisheries Division.

Copies of the draft assessment were distributed for public review in fall 2008. Three public meetings were held: Midland Chippewa Nature Center on October 17, 2008, 4 people attended; Mt. Pleasant Public Library on October 22, 2008, 1 person attended; and Gladwin Riverwalk Place on October 30, 2008, 13 people attended. By request, a fourth public meeting was added on January 22, 2009 at the Mt. Pleasant Library, Twenty-one people attended. Written comments were received through February 22, 2009. Comments were responded to in the Public Comment and Response section.

A fisheries management plan will now be written. This plan will identify options chosen by Fisheries Division, based on our analysis and comments received. In general, a Fisheries Division management plan will focus on a shorter time, include options within the authority of Fisheries Division, and be adaptive.

Individuals who review this assessment and wish to comment should do so in writing to:

Michigan Department of Natural Resources
Fisheries Division
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Bay City, MI 48706

Comments received will be considered in preparing future updates of the Tittabawassee River Assessment.

RIVER ASSESSMENT

Geography

The Tittabawassee River watershed is centrally located in the Lower Peninsula of Michigan (Figure 1). It drains a land area of 2,471 mi^2 and is the fifth largest watershed in Michigan. This river is the largest of four main tributaries of the Saginaw River which drains into Saginaw Bay, Lake Huron. All or part of Arenac, Bay, Clare, Gladwin, Gratiot, Isabella, Mecosta, Midland, Montcalm, Ogemaw, Osceola, Roscommon, and Saginaw counties lie within the Tittabawassee River watershed. The main stem is 91 miles long and the network of contributing tributaries total 621 miles.

The topography of the eastern and southeastern part of the basin is flat, with little relief. The western and northern portions of the watershed are hilly and rolling (WRC 1960). Ground elevations vary from 1,574 ft in the headwaters to 577 ft above mean sea level near the mouth. Mean elevation within the basin is 725 ft.

There are 414 lakes within the watershed, with 217 ≥10 acres (Table 1), and 26 >100 acres. Included in this list are four major hydroelectric impoundments (Secord, Smallwood, Wixom, and Sanford), which are located on the main stem (Figure 1) and vary in size from 370 to 1,401 acres. Collectively, these hydroelectric projects impound more than 22 river miles of the main stem and alter considerably more miles of river (see also **Dams and Barriers**).

For analysis and descriptive purposes the main stem Tittabawassee River watershed has been divided into three segments (Figure 2) based on differences in channel features and soil types (see also **Soils and Land Use**), surficial geology, and topography (see also **Geology**) within the watershed (Seelbach et al. 1997). These landscape characteristics influence groundwater flow which, in turn, shapes patterns of streamflow, water temperature, and ultimately fish species composition. Consequently, the segments represent distinctive ecosystem types and therefore provide a simple and ecologically meaningful framework to describe the main stem reaches of the Tittabawassee River. The number of tributaries within the watershed are too numerous to address individually in this document. Instead, descriptions will be primarily limited to major tributaries.

Headwaters

The headwaters are composed of the Middle, East, and West branches of the Tittabawassee River. All three branches begin as coldwater streams and quickly transition into coolwater. The Middle and East branches begin in southern Ogemaw County and the West Branch begins in southern Roscommon County. All three branches flow south for a relatively short distance (15 to 20 miles) before entering Secord Lake. For discussion in this document, the point where the headwaters reach Secord Lake impoundment is considered the downstream boundary of this segment.

Middle

The middle segment begins at the upper end of the Secord Lake impoundment and extends south 36 miles to Sanford Dam. This segment is a relatively large warmwater system that is greatly influenced by four hydropower dams: Secord, Smallwood, Wixom, and Sanford (see also **Dams and Barriers**). The Sugar, Molasses, and Tobacco rivers enter the main stem within this segment. The Sugar and Tobacco rivers begin as coldwater streams draining glacial till and become warmer as they flow through impoundments and across land composed of less permeable materials. The Molasses River and its tributaries are small- to medium-sized coolwater streams with relatively lower gradient. Like most of the other streams in this segment, the Molasses River is also influenced by several impoundments.

Mouth

The mouth segment extends 35 miles from the Sanford Dam to the confluence with the Saginaw River. This segment is a large warmwater system with relatively low gradient. Major tributaries include Carroll Creek Drain (also referred to as Carrol Creek Drain), Sturgeon and Bullock creeks, and the Salt, Chippewa, and Pine rivers. Carroll Creek Drain, Sturgeon, and Bullock creeks are small low-gradient warmwater streams that have been heavily influenced by channelization and artificial drainage due to settlement and agriculture (see also **Land Use**). Salt River is a medium size low-gradient warmwater stream that drains predominantly agricultural land. Flows are generally surface-water driven. Chippewa River is a large river of medium to high gradient. Chippewa River headwaters begin in glacial till and many tributaries and some upper reaches support coldwater species. The upper mid-reach to lower Chippewa River is a larger to medium-size, coolwater stream that flows through though the City of Mt. Pleasant and terminates at its confluence with the Tittabawassee River in the City of Midland. Major tributaries to the Chippewa River are generally low-gradient, cool- to warm-water streams and drainages. The Pine River shares similar geology with the upper Chippewa River. Headwaters and tributaries to the upper Pine River include small cool- to cold-water streams. The mid-reaches are large- to medium-sized and include a large impoundment and dam at St. Louis (see also **Dams and Barriers**). The lower reaches of the Pine River are medium to large and generally warm water with moderate to low gradient. The Pine River empties into the Chippewa River in the very lower reaches, just prior to confluence with the Tittabawassee River in Midland. This segment and tributaries are influenced by urban development and industrial activities such as by Dow Chemical Company on the Tittabawassee River and Velsicol on the Pine River (see also **Water Quality**).

History

The Tittabawassee River watershed was formed by the Saginaw lobe of the Wisconsinan glacier (Farrand 1988). The course of the main stem from north to south was determined by deposition of the Port Huron moraine; the main stem paralleled the face of the moraine. The Port Huron moraine in central Michigan was subsequently washed over and redistributed during the time of glacial Lake Warren (WRC 1960). About 4,000 BP (before present), postglacial rebound changed the location of the outlet of the upper Great Lakes from North Bay in northeastern Lake Huron to the present location at Port Huron (Farrand 1988). Erosion of unconsolidated glacial till eventually lowered the elevations of the outlet and consequently the level of the lakes. The Great Lakes reached their present level about 3,200 BP when the St. Clair River shifted laterally from the bedrock sill to an area underlain by glacial till, which facilitated further downcutting of the channel (Dorr and Eschman 1970). Lowering of Great Lake levels increased tributary gradients. The Tittabawassee River and its tributaries eroded deep channels in the glacial till and lake plain soils of the watershed, thereby creating the downcut channels evident throughout much of the watershed today (WRC 1960).

Presettlement vegetation in the Tittabawassee River watershed was variable, depending upon the soils and rate of natural drainage. Clay soils supported beech–sugar maple forests, with wetter sites supporting hemlock, white pine, burr oak, swamp white oak, red ash, and American elm. One of the state's largest pineries occurred here on the somewhat poorly drained sand and clay soils (Albert 1994). To the west and north, ground moraines and end moraines in headwater areas supported beech–sugar maple forests, with black maple, pignut hickory, basswood, red oak, and white ash common. Poorly drained areas supported swamp forests dominated by American elm, red oak, silver maple, and swamp white oak. Presettlement records indicate tamarack was also present (Albert et al. 1986; see also **Soils and Land Use**).

Native Americans may have occupied the Tittabawassee River watershed as early as 10,000 BCE, as evidenced by the fluted spear points unearthed at various locations in the watershed. These Paleo-

Indians hunted mastodons, mammoths, giant beaver, deer, elk, and caribou (Quimby 1960). Analysis of 874 prehistoric archaeological sites in the watershed indicates the presence of Native American peoples more or less continuously throughout the Archaic (7000–500 BCE) and Woodland (500 BCE–1700 CE) periods. A total of 1,001 prehistoric and historic archaeological sites are known to exist in the Tittabawassee River watershed (Tables 2 and 3).

Principal Native American tribes occupying the Saginaw Valley (of which the Tittabawassee River watershed is a large component) were the Sauk, Chippewa or Ojibwa, and Potawatomi. *Saginaw* is a corruption of either the Chippewa term *O-sag-e-non* or the Algonquin term *Sauk-i-non*, both of which mean "place of the Sauk" (Smith and Kilar 1987). The Sauk were a warlike people, constantly attacking other tribes. Around 1520 CE, the other tribes formed an alliance and annihilated the Sauk in a series of actions including the Battle of Skull Island (on the Saginaw River near present day Bay City). For nearly 200 years thereafter the entire Saginaw Valley was known as the "Forbidden Valley" and few if any Indians lived there for fear of violating the taboos of the ghosts of the Sauk tribe (Berriman 1970).

The first European contact with Native American peoples, in what is now central Michigan, took place in the mid-1600s. Father Henri Nouvel was the first European to visit the Tittabawassee River watershed. He wintered there in 1675–76 at the invitation of the Chippewa who had visited him at the Jesuit Mission at St. Ignace (Yates 1987). The Tittabawassee River takes its name from a European corruption of the Chippewa name *Thaw-tippe-a-waso-ach* which, according to Yates (1987) means "what place is the light" – in a dark forest. Other possible meanings include "the water that runs slowly" or "the water runs parallel to the shore" (Smith and Kilar 1987).

Most lands in the watershed were ceded to the United States government in the Treaty of Saginaw in 1819. The remainder of the watershed (and most of the rest of northern Michigan) was ceded in the Treaty of Washington in 1836 (Dunbar and May 1995).

Today, the Chippewa people maintain a strong presence in the watershed. The Treaty of 1855 set aside the equivalent of six townships in Isabella County for an Indian Reservation, allowed individual Indians to select acreage and stake a claim, and to eventually receive a government patent. While most land was subsequently resold to European settlers and speculators, the Saginaw Chippewa Tribe still occupies substantial holdings in Isabella County and operates a large successful casino and hotel complex just east of Mt. Pleasant (Keenan 2005).

Early interactions between Europeans and Native Americans were primarily for fur-trading. John Jacob Astor's American Fur Company established a trading post at the Forks (where the Tittabawassee and Chippewa rivers converge, near present day downtown Midland) in 1824, but the establishment was short-lived. In 1827, Louis Compau set up a trading post a short distance upstream from the Forks on the banks of the Tittabawassee River at what is now Emerson Park in Midland. The first European settlers came to the watershed in the 1830s, just prior to Michigan's statehood (Yates 1987).

The Tittabawassee and Saginaw rivers teemed with fish in the early 1800s, providing an important source of food for Indians and European settlers alike. Lake sturgeon, some weighing in excess of 100 lb, were called "Saginaw Beef" by the settlers. The Tittabawassee River also provided trout (lake trout), pickerel (pike), mullet (suckers), whitefish, perch, black bass, catfish, and walleyed-pike (walleye) (Yates 1987).

Settlement in Michigan was slow compared to some other areas of the Old Northwest Territory, as reports of early surveyors described Michigan as "nothing but miasmatic marshes and bogs infested with mosquitoes, fit only for muskrats, Indians, and rattlesnakes" (Yates 1987). Early settlers found the Tittabawassee River watershed to be a vast forest with incredible stands of white pine and other valuable trees. Lumber companies began operating in the watershed about 1847 (Ederer 1999). Lumbermen came to Michigan from the east as New England's timber resources were exhausted. Most sawmills were located on the Saginaw River, but major pineries were located proximate to the Tittabawassee River and its major tributaries, including the Chippewa, Pine, Salt, Sugar, Molasses, and Tobacco rivers. These rivers acted as highways down which the pine logs were floated each spring to sawmills in Saginaw and Bay City (Yates 1987).

The business of sorting logs coming down rivers in spring was handled by booming companies who sorted logs by their marks, connected them in rafts, and delivered them to various mills. The first booming company on the lower Tittabawassee River was the Charles Merrill Co. This company gave way to the Tittabawassee Boom Company which was formed in 1864. During its 30-year existence, the Tittabawassee Boom Company handled more than 11 billion board feet of lumber (Berriman 1970). The lumber era in the Saginaw Valley and the Tittabawassee River watershed lasted approximately 43 years, from 1847 to 1890, although some operations continued as late as 1897 (Ederer 1999). Derelict pine sawlogs are still commonly found along the bottom and banks of the Tittabawassee River and its tributaries.

The lumber era facilitated a subsidiary and lucrative industry involving salt production from brine wells. Salt was a fairly rare and expensive commodity in the early 19th century, as it was produced in the State of New York and had to be shipped to the Great Lakes region via the Erie Canal. Exploration of salt deposits in the Tittabawassee River watershed began in 1838 when the Michigan Legislature authorized state geologist Dr. Douglas Houghton to begin boring for salt and appropriated $3,000 to fund the project. Houghton's first brine well was located on the bank of the Tittabawassee River about a mile below its confluence with the Salt River. This effort was largely unsuccessful. Houghton's well still exists on private land and can be observed on the river's edge (V. Barnard, Michigan Department of Environmental Quality, Office of Geological Survey, personal communication). Much better brine deposits were subsequently found in Midland and along the Saginaw River. Sawmill owners drilled brine wells adjacent to their mills and used the waste lumber to power steam pumps and boilers to evaporate the brine. Waste steam from sawmills was also used for this purpose. Commercial salt production began in the Saginaw Valley about 1859, fueled by wood from the Tittabawassee River watershed. Production of salt waxed and waned with the lumber market through the 1860s and 1870s and declined at the end of the lumber era as timber was exhausted, although some salt was produced in the early 20th Century as an adjunct of plate glass and chemical production (Ederer 1999; McMacken 2003). Salt production in the Saginaw Valley peaked in 1886 when more than 1.2 million barrels (280 lb of salt per barrel) were produced by 52 salt works (Ederer 1999). By 1880, Michigan accounted for more than 40 percent of total U.S. salt production (Dunbar and May 1995).

The plow followed the axe into the Tittabawassee River watershed, as settlers bought cutover lands from lumber companies. The southern and western parts of the watershed proved to be good farm land and farmers planted corn, wheat, oats, potatoes, and sugar beets. Farmlands in the northern watershed were used to grow hay and pasture livestock. Some areas of the central and northern parts of the watershed had poor sandy soils. Many lands reverted to state ownership after settlers went broke and could not pay their taxes. Some lands were permanently retained in state ownership and became part of Michigan's state forests. Both lumbering and agriculture had significant negative effects on the hydrology and channel morphology of the Tittabawassee River mainstem and its tributaries (see also **Factors Affecting Fish Communities.)**

Brine springs and wells in the Midland area were found to contain substantial concentrations of bromine, and by 1888 Midland had become the largest producer of bromine in the world. In 1888, Herbert H. Dow, a native of Ohio and a chemist with a degree from the Case School of Applied Sciences in Cleveland, came to Midland to study brines. He returned in 1890 and rented a brine well to test a new process he was developing to extract bromine using electrolysis. After several abortive (and explosive) attempts that earned him the nickname “Crazy Dow,” he succeeded in extracting bromine without first making salt. (Salt, by that time, was a drug on the market.) Further experimentation (and explosions) produced a process to extract chlorine gas, and Dow began producing household bleaching powders. From these modest beginnings the Dow Chemical Company eventually grew into one of the largest producers of chemicals in the world. Business boomed during World War I when Dow produced many chemicals previously available only from Germany, which were made unavailable by the British blockade of German shipping. In addition, Dow produced mustard gas to aid the war effort. During World War II, Dow made airplane parts from magnesium extracted from seawater using processes developed in Midland. Dow also produced styrene for synthetic rubber (the supply of natural rubber having been cut off by the Japanese).

During the Vietnam War, Dow found itself the target of protests because it made napalm, a mixture of gasoline and plastic thickeners used in incendiary aerial bombs. Dow also produced Agent Orange, a defoliant herbicide used in Vietnam to clear trees and bush that hid enemy forces. Many Vietnam veterans sued Dow over health problems allegedly caused by exposure to Agent Orange. The company settled out of court for a payment of $180 million. Dow was the subject of further controversy beginning in 1983 when concern mounted over dioxin, an unwanted trace by-product of herbicide manufacture. Dow and the Michigan Department of Natural Resources in 1986 agreed to a wastewater discharge limit of 10 parts per quadrillion. Concerns regarding dioxin contamination of the Tittabawassee River and its floodplain are ongoing today (see also **Water Quality**).

Dow Chemical’s Michigan Division continues to be a major presence and employer in the watershed, producing hundreds of different chemicals and plastics. The brine wells that had supplied Dow’s basic raw materials played out by the late 1980s and the company now obtains its raw materials from other sources (Yates 1987).

Brine deposits also led to the establishment of the Michigan Chemical Company, later renamed Velsicol Chemical Company, on the Pine River in St. Louis. The company was established in 1935 on the site of an earlier salt works. At first it produced salt, bromine, and a compound used to settle dust on dirt roads. During World War II, a DDT (dichlorodiphenyltrichloroethane) plant was constructed, and tons of DDT were manufactured for the military. DDT production continued for the civilian market after the war. Velsicol also produced a polybrominated biphenyl (PBB) fire-retardant compound which accidentally was mixed with cattle feed in 1973, leading to sickness and birth defects in many Michigan cattle herds. Meat from contaminated cattle had been shipped statewide before the problem was discovered, leading to exposure of nearly all citizens in the Lower Peninsula to PBB contamination. Velsicol Chemical Company closed its St. Louis plant in 1978 (McMacken 2003). Concern over DDT pollution of the Pine River remains to the present (see also **Water Quality**).

In addition to the chemical industry, petroleum deposits were discovered in the watershed in the mid-1920s. The resulting oil boom largely saved central Michigan from the worst effects of the Great Depression (McMacken 2003). Oil refineries operated in Mt. Pleasant, Alma, and St. Louis, fed by pipelines from oil fields. Oil production in the watershed continues to the present, but only in a limited way. Most oil fields are played out and modern efforts are directed at secondary recovery (Yates 1987). The last remaining oil refinery, at Alma, closed in the late 1990s.

The most prominent human modifications of the Tittabawassee River main stem are the four hydropower dams creating Sanford, Wixom, Smallwood, and Secord lakes. These four impoundments form a continuous chain of lakes 35 miles in length and flood approximately 6,000 surface acres. All four dams were built by the Wolverine Power Company, formed in 1923 by Frank I. Wixom, for whom Wixom Lake impoundment is named. All dams were completed by 1925 (Yates 1987). The four dams continue to produce electricity to this day under the ownership of Synex-Wolverine, LLC.

Two additional hydropower projects continue to operate within the watershed: Ross Impoundment on the Tobacco River at Beaverton, and St. Louis Impoundment on the Pine River at St. Louis. Both projects are owned by the local municipalities. Retired hydroelectric projects include Chappel Dam which impounds Wiggins Lake on the Cedar River near Gladwin, and the Harris Dam on the Chippewa River in Mt. Pleasant. Wiggins Lake impoundment is now a recreational body of water with a fixed-crest dam. The Harris Dam in Mt. Pleasant was removed in 2002.

Dow Chemical Company constructed a low-head dam on the Tittabawassee River main stem at the site of its Midland plant in 1939. This dam was built to maintain hydraulic head at Dow's water intakes to ensure an adequate supply of water for the plants' operations. The Dow Dam is located the furthest downstream on the main stem and is a significant impediment to fish passage.

The Tittabawassee River watershed today bears the scars of 150 years of human influence. Deforestation, effects of agriculture, channel modification, draining of wetlands, and urban development have increased surface runoff and dramatically altered the hydrology of the main stem and its tributaries. Dams have blocked fish passage and further altered the hydrology of the main stem through peaking operations. Persistent toxic contamination of various reaches as a result of chemical production and petroleum refining continues to linger, limiting or precluding fish consumption by humans and causing concerns for the rest of the food web. On the positive side, water quality improvements resulting from passage of the Clean Water Act of 1972 have facilitated the return of valuable walleye fisheries in the main stem and natural reproduction of walleye has been well documented (Fielder 2002). The main stem and its tributaries are currently valued more for the recreational opportunities they provide than for commercial and industrial purposes.

Geology

Geology is composed of bedrock geology and surficial geology. Bedrock is a geologic formation below surficial materials and may be at or near land surface or hundreds of feet below. During glacial advances and retreats across Michigan, glaciers scoured across and into bedrock formations. Hence, bedrock is often referred to as "glacial pavement." Surficial geology refers to the materials immediately atop bedrock. Surficial geology is composed primarily of bedrock materials scoured and deposited by glaciers with materials varying from fine clays to huge boulders (i.e., erratics).

Bedrock Geology

The Tittabawassee River watershed bedrock geology is composed of seven layers (by formation age, newest to oldest): Red Beds, Grand River Formation, Saginaw Formation, Bayport Limestone, Michigan Formation, Marshall Formation, and Coldwater Shale (Milstein 1987; Table 4). Red Beds consist of sandstone, shale, and gypsum. Grand River Formation and Saginaw Formation are marine and nonmarine sandstone, shale, limestone, and coal. The remaining formations (Bayport Limestone, Michigan Formation, Marshall Formation, and Coldwater Shale) include Bedford Shale, Berea Sandstone, and Sudbury Shale (Bucklund 2005).

These layers are the product of sea level fluctuations and sediments were precursors to these layers. Sediments were deposited by chemical precipitation, accumulation of coral reefs, plant and animal remains, and deposition of mud, silt, and sand from streams flowing into seas. Compaction and cementation formed shale, dolomite, and limestone. Sediments were carried to the center of the basin and general down warping and uplifting of the land caused seas to be entombed. These briny pockets still exist today.

The majority of the watershed (55.83%) is the Saginaw Formation especially the lower Tittabawassee River and the northeastern area of the watershed except for the tip (Figure 3). The northeastern tip is Michigan Formation and the extreme northeastern tip is of Marshal Formation. The south-central and southwest portions of the basin are Red Bed (41.51% of the watershed) and Saginaw Formation mixed.

Surficial Geology

Glacial advances shaped the surficial geology of the Lower Peninsula of Michigan. During the Pleistocene Epoch major glaciers came and went approximately 20 times. Most glacial advances and retreats in Michigan occurred during the Wisconsinan phase of glaciation (10,000 to 18,000 years BP)**.** Final glacial advances within the Tittabawassee River watershed and along its margins occurred 12,500 years BP and 13,500 years BP (Figure 4; Farrand 1988). By about 10,000 years BP Michigan was glacier free (Farrand and Eschman 1974).

Surficial materials help define the characteristics of a river system by determining its source of river water. River systems draining permeable surficial materials and varying land elevation are mostly fed by groundwater. In contrast, systems draining less permeable materials and areas with less variation in land elevation are primarily supplied by surface runoff. Rivers receiving a large proportion of their flow as groundwater tend to be colder and more stable hydrologically and thermally (especially during temperature extremes of summer and winter) than rivers that are dominated by surface runoff. Typically, surface runoff is warmer in summer than the underlying groundwater, and is frozen and unavailable to a river during winter. Temperature of groundwater is correlated to mean annual air temperatures. Collins (1925) found that groundwater temperature is ±1.8°F of the mean annual air temperature. Mean annual air temperature at Gladwin (approximately centrally located within the watershed) is 44.9°F (MSU 2005b), thus estimated groundwater flow temperature is 43.1–46.7°F (see also **Climate**). Snowmelt and rainwater that flow over the land surface (surface runoff-fed) gets to a river quickly and increases flow variability. If the permeability rates are high, such as in groundwater-fed streams, then rivers receive water at a steady rate resulting in more stable flows. These groundwater-fed streams only receive water as surface runoff when the groundwater system becomes saturated, or water is received faster than it can infiltrate soils (Wiley and Seelbach 1997).

Surficial materials described within this report were taken from Farrand (1982) and their permeability rates from Morris and Johnson (1967) and Baker et al. (2003). Classification into permeability type (high or medium) follows Madison and Lockwood (2004). Relationship of surficial materials (i.e., soils) to land use and vegetation (e.g., forest type, agriculture) are described in **Soils and Land Use.**

The western portion of the basin has extensive ridges of glacial till (moraines) deposited along the glacial front (Figure 4). Thickness of glacial drift varies from 400 to 600 feet (WRC 1960). This material is composed of sorted or stratified lenses of permeable sand and gravel. Outwash was deposited in front of the morainic ridges by meltwater. The eastern section of the basin consists of glacial lake deposits composed of fine sand with imbedded clay layers. Moving upstream from the main stem mouth, the Tittabawassee River follows the western border of the Port Huron moraine, which is characterized by low relief and interbedding of glacial till with lake sediments (WRC 1960). Thickness of glacial drift in the eastern section is thinner and varies from 200 to 400 feet.

Much of the watershed (60.2%) is composed of highly permeable materials and associated with the most variable topography within the watershed (Table 5). These materials and varying topography are found along the northern and western headwater portions of the watershed (Figure 5). The central and eastern portions of the watershed are composed predominantly of materials of medium permeability (39.8%) and less diverse topography.

Hydrology

Climate

Climate, by location, within the watershed is relatively consistent. Day-to-day weather is controlled by pressure systems moving across the nation, thus prolonged periods of hot, humid weather in summer and extreme cold during winter are rare. The center of the watershed is approximately 87 miles from Lake Michigan and 38 miles from Saginaw Bay on Lake Huron. Winds are predominantly west-southwest at about 10 mph. As a result, some lake effect weather from Lake Michigan occurs primarily along the western watershed boundary. These westerly winds minimize lake effect weather from Lake Huron. Most precipitation occurs in the form of rain (>87%). Summer precipitation comes in afternoon showers and thundershowers. Thunderstorms occur about 33 days per year (MSU 2005b). For years 1950 through 1995, 802 tornadoes were sighted in Michigan, 102 (12.7%) of these were sighted within the watershed's counties (Tornado Project 2005).

Temperature averages from the Mt. Pleasant weather station were used to characterize the watershed. The original Mt. Pleasant weather station was established in April 1887 and was moved several times prior to 1916. On October 5, 1916 the station was relocated at the Central State Teachers College (now Central Michigan University) and moved again on June 1, 1962 approximately 0.4 mi to its current location at Central Michigan University's power plant. Temperature and precipitation averages presented here are for years 1951–80.

The mean annual temperature was 46.8°F. During summer months temperatures exceed 90°F nine days. Temperatures are at or below 32°F 158 days, and at or below 0°F 11 days. The average last date of freezing temperatures during spring was May 11 and the average first date of freezing temperatures during fall was October 3. A record high temperature of 99°F was recorded September 1953 and again August 1955. Record low temperature of -23°F was recorded January 1951 and again February 1951. The average freeze-free days were 144. Growing degree-days defined as days between 50°F and 86°F were 2,582 (MSU 2005b).

Four weather stations are located at towns within the watershed: Midland, Gladwin, Alma, and Mt. Pleasant (Figure 1). Precipitation is similar for each station (Table 6). Mean annual rain fall is 25.8–27.5 inches; snow fall is 36.3–51.6 inches, with total liquid 28.7–31.5 inches.

While precipitation and temperatures are similar within the watershed, drought conditions vary east to west. Drought data are not available for any of weather stations, however conditions at Midland and Gladwin are considered similar to those for Lupton (located approximately 15 mi north-northeast of the watershed), and Alma and Mt. Pleasant to those for East Lansing (MSU 2005b). Evaporation exceeded precipitation during months May to October by 32% for Midland and Gladwin and during months April to October by 94% for Alma and Mt. Pleasant. Palmer Drought Index indicated drought conditions reached extreme severity 3% of the time at Midland and Gladwin and 6% at Alma and Mt. Pleasant. For all locations, soil moisture replenishment (precipitation exceeds evaporation) occurs during winter months.

Annual Streamflow

The United States Geological Survey (USGS) has maintained up to nine gauge sites for varying intervals since 1930 within the watershed (Table 7 and Figure 6). Gauge data were available for the tributaries of the middle segment and for the tributaries and main stem reach of the mouth segment. No USGS streamflow data were available for streams in the headwater segment or for the main stem portion of the middle segment. Five gauge sites are currently operational with flow data available through September 30, 2003. For the remaining four gauge sites, only data from previous years are available. All flow measures reported in this document were summarized by water year, October 1 through September 30 (USGS 2005).

Mean annual discharge varies considerably from 74.2 ft^3/s in the South Branch of the Tobacco River to 1,702.1 ft^3/s in the main stem segment at Midland (Table 7). Variation in mean annual discharge among sites is primarily determined by differences in catchment area, with sites draining smaller catchments having lower mean annual discharge. Because catchment area has such a prominent effect on streamflow, dividing mean annual discharge by catchment area to estimate yield provides a means to directly compare streamflow among different location in a stream network. Yield or the amount of streamflow per square mile, for most of the Tittabawassee River gauging sites was relatively similar (0.71 to 0.81 $ft^3/s/mi^2$). The South Branch of the Tobacco River (0.46 $ft^3/s/mi^2$) and the Salt River ($ft^3/s/mi^2$), however, had relatively lower yields. Streams located higher in the network along the northern and eastern portions of the watershed drain more permeable soils (Figure 5), have a greater potential for groundwater discharge (Figure 7), and are expected to have relatively higher yields than the sites where gauge data were available.

The annual pattern of high and low flows is similar across the watershed (Figure 8). A period of high discharge begins near the end of February, peaks in April, and subsides by the end of May. This peak in streamflow during early spring results because storm water and snowmelt cannot percolate into the frozen ground and are delivered relatively rapidly to the stream channel. A second, smaller peak in streamflow begins in late fall, peaks in mid-December, and subsides by mid-January. This smaller peak in streamflow probably results from the reduction in evapotranspiration that occurs when trees lose their leaves in fall. When leaf drop occurs, the portion of rainfall typically used by plants during the growing season gets routed to the stream channel. The drop in this peak in January probably coincides with the period when the majority of precipitation occurs as snow.

Seasonal Flow

Flow duration curves are plots that describe the percentage of time that streamflow is exceeded. The shape of flow duration curves, especially in the lower and upper tails, provides information about streamflow behavior and catchment characteristics. The lower tail of the curve depicts streamflows that are exceeded the majority of time and characterizes the type of low-flow conditions that a stream exhibits during late summer. The upper tail of the curve depicts streamflows that are rarely exceeded and characterizes the type of high flow conditions that a stream exhibits during early spring. Streams draining permeable soils and receiving significant contributions of groundwater typically have relatively flat flow duration curves with high base flows and low peak flows. Streamflows in these systems are very stable and are unresponsive to precipitation events. Streams draining less permeable soils and receiving significant contributions of surface runoff typically have relatively steep flow duration curves with low base flows and high peak flows. Streamflows in these systems are considered “flashy” and respond relatively quickly to precipitation events.

Flow duration curves were calculated for all gauge sites except the Tittabawassee River at Freeland because of the brief and out-of-date period of record at this site (Table 7). These curves were standardized by catchment area to create yield duration curves which allows for direct comparison among sites having different catchment size. Yield duration curves for sites in the Tittabawassee River watershed were compared with data from the Sturgeon River (Cheboygan River watershed) and the Shiawassee River. These rivers were chosen to represent the diversity of stream types in Michigan. The Sturgeon River has substantial groundwater flow and, consequently, is a stable-flow, coldwater system. The Shiawassee River receives substantial surface runoff and is characterized by more variable streamflows and is a warmwater system.

Sites in the Tittabawassee River have yield duration curves that are indicative of less stable, warmwater systems such as the Shiawassee River (Figures 9 – 13). Low-flow yields at sites in the Tobacco (Figure 9), Chippewa (Figure 10), and the Pine rivers (Figure 11) were relatively higher than those in the Shiawassee River. The elevated base flows observed in these Tittabawassee River tributaries results from groundwater accrual especially in the upper portions of these tributary catchments where soils are highly permeable (Figure 5) and the probability of groundwater discharge is relatively high (Figure 7). Despite these groundwater flows, peak flows in Tobacco (except the South Branch of the Tobacco River), Chippewa, and Pine rivers have relatively high peak flow events indicating that these tributaries receive significant contributions of surface runoff during storm events. High surface runoff likely results from rapid routing of precipitation to the channel caused by agricultural (field tiling) and urban land use practices (impervious surfaces) in the catchment. In the South Branch of the Tobacco River, base flow yields were high but peak flow yields were very low (Figure 9). This yield duration curve parallels the pattern seen in the Sturgeon River and suggests that streamflow in the South Branch of the Tobacco River is buffered against precipitation events. Buffering in the South Branch of the Tobacco River may result from surface storage of precipitation in wetlands, storage of water in the channel created by the impounded waters that extend upstream from Ross Lake, or both. The Salt River had the lowest base flow yields of any Tittabawassee River site and was lower than base flow yields in the Shiawassee River (Figure 12). Despite having low base flow yields, peak flow yields in the Salt River were nearly as high as peak flow yields in other Tittabawassee River tributaries. The shape of the yield duration curve for the Salt River indicates that water in this system is routed to the channel very quickly as surface runoff during precipitation events and that there is little water remaining in the catchment, and consequently the stream channel, during drier portions of the year. The flashy nature of the Salt River can be attributed, in part, to the relatively flat, impermeable soils within the catchment. Flashiness in the Salt River is also likely exacerbated by agricultural practices such as county drains and field tiling that rapidly move water from the landscape to the stream channel. Yield duration curve for the main stem Tittabawassee River at Midland was identical to the yield duration curve for the Shiawassee River (Figure 13).

Streamflow at Hydropower Facilities

Flow duration curves, operational ranges, and allowable head fluctuation are presented for the four major reservoirs located within the middle segment of the main stem Tittabawassee River. These flow data and the associated turbine operating ranges are for water years 1977–91.

The Secord Dam operates one electric generating turbine (Figure 14). This turbine was operational for flows of 300–450 ft^3/s with an optimal flow of 380 ft^3/s (FERC 1998a). For the period of record, this turbine was potentially operational 8% of the time. Mean annual flow for period of record was 171 ft^3/s. During operation impounded head may be increase 0.4 ft and decreased 0.3 ft.

The Smallwood Dam operates one electric generating turbine (Figure 15). This turbine was operational for flows of 500 – 720 ft^3/s with an optimal flow of 600 ft^3/s (FERC 1998a). For the period of record, this turbine was potentially operational 7% of the time. Mean annual flow for period of record was 279 ft^3/s. During operation impounded head may fluctuate 0.7 ft.

The Edenville Dam (Wixom Lake impoundment) operates two electric generating turbines (Figure 16). Both turbines are operational for flows of 900–1,940 ft^3/s with an optimal flow of 1,600 ft^3/s (FERC 1998a). For the period of record, these turbines were potentially operational 15% of the time. Only one turbine was operational for flows of 450 – 970 ft^3/s with an optimal flow of 800 ft^3/s. For the period of record, this turbine was potentially operational 29% of the time. One or two turbines are operational for flows of 900 – 970 ft^3/s. This flow range occurred 1% of the time. This dam potentially produced electricity 45% of the time during the period of record. Mean annual flow for period of record was 803 ft^3/s. During operation impounded head may be increased 0.4 ft and decreased 0.3 ft.

The Sanford Dam operates three electric generating turbines (Figure 17). All three turbines are operational for flows of 1,530–2,190 ft^3/s with an optimal flow of 1,950 ft^3/s (FERC 1998a). For the period of record, these turbines were potentially operational 7 % of the time. Two turbines were operational for flows of 1,030–1,470 ft^3/s with an optimal flow of 1,300 ft^3/s. For the period of record, these turbines were potentially operational 9% of the time. Only one turbine was operational for flows of 530 – 750 ft^3/s with an optimal flow of 650 ft^3/s. For the period of record, one turbine was potentially operational 15% of the time. This dam potentially produced electricity 31% of the time during the period of record. Mean annual flow for period of record was 831 ft^3/s. During operation impounded head may be increase 0.4 ft and decreased 0.3 ft.

Daily Streamflow

Daily streamflows are affected by soil permeability, landscape elevation, and human alterations to the landscape and river system. In Michigan less variable elevation is correlated with less permeable soils (Madison and Lockwood 2004). Rivers flowing through such areas are more likely to receive water as surface runoff rather than as groundwater flow and have more variable flows. Removal of riparian vegetation exacerbates potential problems and increases transfer of surface water to the river. Similarly, channelization of streams (i.e., county drains), agricultural tiling, and runoff from hard surface roads and parking lots each contribute to variable flows. Unstable flows limit aquatic species and cause flooding of adjacent lands. Such flood events result in destruction of property, crops, and loss of human life.

In September 1986 a major rainfall event occurred across central Lower Michigan and within the watershed (Deedler 2005). Excessive rainfall, surface runoff, and human alterations all contributed to the devastating effects of this weather system. Rainfall began on September 9 as the system moved slowly from west to east across central Lower Michigan. Within the Tittabawassee River watershed, this system produced rainfall from September 10 to September 12 with most of the rain falling during a 12 hour period on September 11. Rainfall during this 3 d period averaged 6–12 inches by location with isolated rainfalls of 14 inches. At the Tittabawassee River gauge site at Midland (04156000) the mean daily flow at this site for the period of record is 1,702.1 ft^3/s. On September 9 the mean daily flow was 573 ft^3/s; by September 10 mean daily flow had increased to 1,610 ft^3/s. The river continued to rise with mean daily flow of 14,000 ft^3/s on September 11 and a peak mean daily flow of 31,200 ft^3/s on September 13. An hourly peak flow of 38,640 ft^3/s was recorded at 0600 h on September 13 (Figure 18). The river began to slowly recede after that. During the 54 hour period beginning September 11 at 0100 h to September 13 at 0600 h discharge increased by a factor of 5.5. Within a 22 county area, 10 people died, 100 people were injured, and property damage was estimated at 400 to 500 million dollars.

Flooding or Floodplains

Flooding and the movement of river water onto floodplains are a natural part of river systems (Junk et al. 1989, Wohl 2000). These flooding events serve to redistribute sediment and nutrients within a river channel and onto surrounding floodplains. Floodplains create spawning and feeding areas for stream biota. Each of these is important to individual species life cycles and to maintaining species diversity within a river system.

Flooding also redistributes and deposits large woody structure. Within a river, woody structure serves as a food source for invertebrates, thus providing a food source for fish and other higher level predators. Woody structure also provides essential habitat for numerous fish species.

Efforts to prevent flooding typically reduce and destroy essential habitat. They also compound flood waters and transfer their effects downstream. For example, field tiling prevents percolation of water into groundwater aquifers (see also **Soils and Land Use),** increases transfer of water from the land to the river, and increases the magnitude and frequency of flooding events. Creation of county drains, channelization, and straightening of rivers and drains then becomes necessary to handle the increased volume of storm water delivered to the channel. Further downstream, seawalls and levees are often constructed in an attempt to reduce and prevent increased flooding. Ultimately, this process destroys river habitat, reduces species diversity, and increases destruction of riparian properties.

Bank stabilization methods, such as the use of sheet piling, destroy shoreline feeding and spawning habitat and reduce species diversity. Better alternatives to sheet piling are log and rock riprap, tree revetments, and vegetation (Alexander et al. 1995). These alternatives provide bank stabilization, habitat, and maintain species diversity.

Dams similarly disrupt natural flooding cycles and redistribution of sediment and nutrients. Impoundments trap sediments and nutrients often creating anoxic conditions in the deeper, colder bottom waters. Large woody structure is trapped by dams, thus decreasing potential habitat and food sources in downstream waters (see also **Dams and Barriers**).

Currently 30 communities within the watershed participate in the National Flood Insurance Program (Table 8). An additional community, Coldwater Township (Isabella County) currently does not participate in the program, but has been identified as a special flood hazard area (MDEQ 2005a). Communities participating in the program determine 100 and 500 year flood boundaries. Appropriate planning, development, and flood insurance within these boundaries are necessary to maintain health of aquatic organisms and to ensure public safety and well being.

Consumptive Water Use

During calendar year 2001, 6,152 gallons/day/mi^2 of water were drawn from surface, ground, and Great Lakes sources for irrigation, municipal, commercial, and residential use (Table 9; MDEQ 2005b). Of this, 62% was taken from groundwater sources, 38% from surface water, and <1% from the Great Lakes. Approximately 15% (942 gallons/day/mi^2) of the 2001 water use was for agriculture (Table 10; MDEQ 2005c). Most water for agricultural use came from groundwater sources (752 gallons/day/mi^2 or 80% of agricultural water withdrawal). As of 1997, 31 farms (≥14 acres) irrigated 4,528 acres.

Relative to other Michigan watersheds, relatively little water is removed from the Tittabawassee River watershed. On the partial list presented in Table 9, the Tittabawassee River ranks 7th and well behind more populous watersheds and is similar to the Flint and Manistique river watersheds.

Consumptive water use is the difference between the amount of water withdrawn from a resource and the amount of water returned to that resource. For example, in 2001 942 gallons/day/mi^2 of water were withdrawn for agricultural use. Of that 942 gallons/day/mi^2, 90% or 848 gallons/day/mi^2 were lost to evapotranspiration (Bedell and Van Til 1979). While a greater amount of water was removed for municipal, commercial, and residential use (5,210 gallons/day/mi^2) only a small fraction of this water was consumed and not returned to the resource. Water consumption for thermoelectric production is 98.7% efficient (only 1.3% lost to evaporation and not returned to the resource) and other uses such as industrial were 90% efficient (MDEQ 1998). Consequently, agriculture consumed 848 gallons/day/mi^2 while the remaining major water users consumed 68–521 gallons/day/mi^2.

Soils and Land Use

Soils and land use patterns have great influence on the character of a stream. Soils of the Tittabawassee River watershed result from geological influence (see also **Geology**) and land use is influenced by climate, slope, erosional forces, and human activities.

As discussed in **Geology**, permeability affects hydrology and channel morphology of a stream. Soil particle size and texture determines permeability rate. More coarse textured sands and gravels will be more highly permeable than the fine textured silts and clays (Leonardi 2001). Sandy or gravelly soils associated with moraines are highly permeable and streams flowing through them have more stable flow regimes and are cooler. Less permeable, finer clay rich soils, produce greater surface water runoff, have more variable flows, and tend to be warmer.

The northern and western portions of the Tittabawassee River watershed are characterized by light, porous, well-drained soils (Albert 1995). Such soils act as a groundwater reservoir and contribute to the stability of stream discharge. In contrast, the southern and eastern regions have heavier, less porous, poorly drained soils containing a significant percentage of clay. These soils are well suited to agricultural uses, but often require artificial drainage (e.g., tiling, ditching) to facilitate tillage. Drainage accelerates the rate of surface runoff and causes the water to reach the river faster rather than over a prolonged period. Consequently, rivers in extensively drained regions tend to be flashier and more flood prone than those in regions less anthropogenically altered (Dodge 1998). Drainage of wetland areas adjacent to streams results in displacement of wetland-dependent wildlife species and destroys important spawning and nursery habitat for fish.

The Natural Resource Conservation Service (NRCS) classifies soil associations into major land resource areas based on features such as soils, land use, elevation, topography, climate, water, and potential natural vegetation (NRCS 2005). These classifications are used for environmental modeling and ecosystem management. The Tittabawassee River basin falls into 5 classifications (Figure 19). Forty-three percent of the watershed, 1,042 mi^2, is classified as Southern Michigan and Northern Indiana Drift Plain (SMNIDP). The Northern Michigan and Wisconsin Sandy Drift (NMWSD) comprises 30% of the watershed, 740 mi^2. Similarly, Erie-Huron Lake Plain (EHLP) accounts for 22% of the watershed, 530 mi^2. Smaller areas are classified as Western Michigan and Northeastern Wisconsin Fruit Belt (MNWFB), 2% of the watershed, 60 mi^2; and Indian and Ohio Till Plain (IOTP) 1% of the watershed, 27 mi^2.

Southern Michigan and Northern Indiana Drift Plain is a land resource area that has deep, medium, and moderately coarse textured soils. These soils have mesic temperature regimes. The plain is deeply mantled by till and outwash. Topography is nearly level to gently rolling and elevations vary from 656 to 984 feet. There are intermixed belts of morainic hills with relief as much as 80 to 160 feet. Groundwater is abundant in deep glacial drift. Most lands in this classification are used for farming. Small acreages are in state forests. Principal crops include corn and feed grains for dairy cattle and livestock, cash crops such as soft winter wheat, dry beans, fruits, and vegetables. This classification supports deciduous forest. Hickory, white oak, red oak, black oak, sugar maple, and beech are dominant tree species. Red maple, white oak, and American basswood grow in wetter soils.

Northern Michigan and Wisconsin Sandy Drift are areas with soils that are deep, coarse, and moderately coarse textured materials formed in sandy or loamy glacial drift. These soils have frigid temperatures regimes and mixed mineralogy. These soil associations are formed in organic depressions and are poorly drained. In morainic areas relief can be quite varied. Within the watershed, areas of Northern Michigan and Wisconsin Sandy Drift vary in elevation from 688 to 1,574 ft. In areas of old lake bed, relief is level to gently rolling. These lands are largely national and state forests, with some in private ownership and used for farming forage, feed grains, and pastures. Groundwater is abundant in the deep glacial drift that covers nearly all the area. Large and small lakes frequently occur. The area supports deciduous and evergreen trees. Jack pine, red pine, and big tooth aspen are the dominant species on the sandy soils. Sugar maple, birch, beech, and hemlock are common on moist soils. Tamarack, black spruce, and northern white cedar are dominant on wet soils.

Erie-Huron Lake Plain has soils that are deep and fine to coarse textured. They have a mesic temperature regime. The dominant soils are somewhat poorly drained to very poorly drained. Many soils require artificial drainage (e.g., field tiles) before they can be used for crops. Elevation is about 656 feet increasing from the lakeshore inland. These areas are heavily farmed, mostly in cash crops. These include sugar beets, canning crops, winter wheat, soybeans, and hay. Some areas remain in woodlot and others are urbanized. Hickory, white oak, red oak, and black oak are dominant forest vegetation on upland soils. American basswood and quaking aspen are dominant on wetter soils.

Western Michigan and Northeastern Wisconsin Fruit Belt is characterized by deep to moderately deep, medium to coarse textured soils. They have a frigid temperature regime and mixed mineralogy. Soils often do not retain moisture in low precipitation years. Groundwater is abundant in deep sandy and loamy drift areas. The topography is generally rolling to hilly moraines and beach ridges. In areas of medium moisture the dominant vegetation includes sugar maple, yellow birch, beech, and hemlock. On sandy soils jack pine, red pine, and white pine grow. In lowlands mixed hardwoods and conifers such as elm, soft maple, black ash, and white cedar dominate.

Indian and Ohio Till Plain soils account for only a small portion of the watershed. This classification has deep, medium to fine textured soils with mesic temperature regimes and are formed in calcareous loamy glacial till. They are a gently sloping till plain broken in places by hilly moraines and outwash terraces. Elevations vary from 656 to 984 feet, generally increasing from east to west. Most soils are in farm crops such as soy beans, corn, and feed grains, with some used for dairy cattle. A few small woodlots are found. Hardwood vegetation like white oak, poplar, beech, sugar maple, and white ash are dominant on well-drained soils.

Each of these major land resource areas are further partitioned into smaller more specific soil associations. The major land resource areas (Figure 19) and smaller more specific soil associations are further described for each individual catchment.

Soils

Headwaters

The catchment of the headwaters is classified into three major land resource areas. Most (89%) is SMNIDP and the remainder classified as WMNWFB (10%) and EHLP (1%). The northwestern part is dominated by loamy soils interspersed with sandy soils. The Grayling–Montcalm soil association is the most common association (MSU 1981). These deep soils vary from well-drained to excessively drained sandy soils on gently sloping to moderately steep topography. They have low available water capacity and rapid permeability. The Middle Branch and East Branch Tittabawassee rivers have Nester–Kawkawlin–Sims soil associations. These are deep, well-drained to very poorly drained loamy soils intermixed by clayey soils and underlain by sand and gravel. They are on nearly level to strongly sloping topography. They have a high available water capacity and moderately slow or slow permeability. Intermixed are Iosco–Allendale–Brevort soil associations. These are deep, poorly to very poorly drained sandy loam or sand over clayey soils on nearly level to gently sloping topography. They have low available water capacity and slow to moderate permeability. The West Branch of the Tittabawassee River drains medium textured soils. The most common soil association is the Iosco–Allendale–Brevort association.

Middle

This catchment, excluding the Tobacco River drainage is classified as 62% NMWSD, 27% EHLP, and 11% WMNWFB. The area around the upper three impoundments, from Secord down to Wixom, has soils dominated by wet sand and organic materials. The Iosco–Allendale–Brevort association is the most common soil association around the upper impoundments. These soils are generally deep, poorly to very poorly drained loamy or sandy soils on nearly level to gently sloping terrain with slow to moderate permeability. The areas east and west of the impoundments have deep poorly drained sandy soils. Most of these soils are over loamy or clayey sub soils on nearly level to gently sloping topography with slow to moderate permeability. Pipestone–Kingville–Saugatuck–Wixom soil associations are found in the lower end of this catchment, below Wixom Lake impoundment. These are deep soils dominated by wet sand and wet loamy soils underlain by sand and gravel. The topography is depressional to gently sloping. These soils have low to moderate water capacity and rapid permeability. The other less dominant soil association, Belleville–Selfridge–Metea, consists of deep, poorly drained sandy soils underlain by loamy material. They are level to strongly sloping, have low to moderate water capacity, and have moderately slow permeability rates.

Most (79%) of the Tobacco River drainage is classified as NMWSD. Areas of SMNIDP (13%) are located along the southeast and southwest edges. South-central and southeast edges are classified as EHLP (7%). Three small areas of WMNWFB are found scattered within this catchment (2%). The catchment is dominated by loamy soils interspersed with sandy soils. The Grayling–Montcalm association and the Nester–Menominee–Montcalm are common. These are deep, somewhat well-drained to excessively drained sandy soils on gently sloping to moderately steep topography. They have low available water capacity and rapid permeability. Much less dominant are loamy soils that are well-drained, with sandy over loamy soils on level or steep topography. These soils have high available water capacity and slow to rapid permeability. The more central portion of the Tobacco River catchment has Nester–Kawkawlin–Sims soil associations. These soils are deep, poorly drained to well-drained loamy soils on nearly level to strongly sloping topography. They have high available water capacity and moderately slow to slow permeability.

Mouth

Roughly 80% of this main stem catchment excluding the major tributaries which will be discussed individually is classified as EHLP. The remaining area (20%) is SMNIDP and mostly located in the stem in the southern end. The upper portion flows through areas dominated by wet sandy soils and wet loamy soils underlain by sand and gravel. The most common soil association is the Belleville–Selfridge–Metea association. These are deep, poorly drained sandy soils underlain by loamy material. They have low to moderate water capacity and moderately slow to moderate permeability. Progressing southward, the area becomes dominated by wet loamy soils and some wet clayey soils. These Kibbie–Colwood associations are deep, poorly drained, stratified loamy soils on nearly level to gently sloping topography. They have high available water capacity and slow to moderate permeability. A portion of the river also flows through the Lenawee–Toledo–Del Rey association. These deep soils are somewhat poorly to poorly drained loamy and clayey soils on depressional to gently sloping topography. They have moderate to high available water capacity, and moderately slow to slow permeability.

In the Salt River drainage, the headwaters are SMNIDP (56%) and the lower end is EHLP (44%). The most common soil association in the upper Salt is the Perrinton–Ithaca association. These are deep, poorly to well-drained loamy soils on nearly level topography. They have high available water capacity and moderately slow permeability. In the central portion of the catchment the most common soil association is the Belleville–Selfridge–Metea association. These are deep, poorly drained sandy soils underlain by loamy material. They are level to strongly sloping, have low to moderate water capacity, and have moderately slow permeability rates. In the lower end of the catchment the dominant soil association is the Pipestone–Kingsville–Saugatuck–Wixom. These are deep somewhat poorly drained loamy and sandy soils. The topography is depressional to gently sloping. These soils have low to moderate water capacity and rapid permeability. Slopes are generally higher in the west than the flatter lake plain to the east.

Most of the upper Chippewa River catchment is also classified as SMNIDP (79%); the remainder is classified as NMWSD (1%) and EHLP (20%). The upper and middle watershed is dominated by sandy soils. The most common associations include the Oakville–Tedrow–Granby, the Gratton association, and the Spinks–Perrinton–Ithaca Association. The characteristics of these associations vary, but are generally deep, very poorly drained to well-drained sandy soils on nearly level to steep topography. They have very low to low available water capacity and rapid to very rapid permeability. Toward the mouth of the Chippewa River, in the lower quarter of the catchment, the dominant soil associations are Pipestone–Kingsville–Saugatuck–Wixom. These soils are deep somewhat poorly drained loamy and sandy soils. The topography is depressional to gently sloping. These soils have low to moderate water capacity and rapid permeability. Also found in this area are Belleville–Selfridge–Metea associations which are deep, poorly drained sandy soils underlain by loamy material. They are level to strongly sloping, have low to moderate water capacity, and have moderately slow permeability rates. Similar to the Salt River, slopes are generally higher in the west and flatter in the lake plain to the east.

The Pine River catchment is largely classified as SMNIDP (78%), much like the Chippewa River. In lesser amounts are EHLP (16%) and IOTP (6%). The headwaters originate in areas dominated by loamy soils underlain by sand and gravel. The dominant soils association here is the Spinks–Oshtemo–Boyer. These are deep, well-drained, loamy, and sandy soils on nearly level to strongly sloping topography, with low to moderate available water capacity and moderate to rapid permeability. Also found is the Oakville–Tedrow–Granby soil association. These are generally deep, very poorly drained to well-drained sandy soils on nearly level to steep topography. They have very low to low available water capacity and rapid to very rapid permeability. The Tedrow–Tedrow, Loamy Substratum–Selfridge association consists of deep, somewhat poorly drained soils on nearly level to gently sloping topography. They typically have low to moderate water capacity and rapid to slow permeability. Similar to the Salt River, slopes are generally higher in the west than the flatter lake plain in the east.

Land Use

Land use and vegetation in the Tittabawassee River watershed have been altered by human activities and artificial drainage from their presettlement (prior to 1800) condition. Prior to 1800, land within the watershed was completely forested (Table 11). The predominant forests were beech–sugar maple–hemlock forest (25.4%), hemlock–white pine forest (20.8%), and beech–sugar maple forest (19.1%). Swamps and wetlands covered 20.8% of the watershed (514 mi^2).

Today, most of the forests have been cut and vast acreages have been developed or cleared for farming. Currently only 34.8% of the watershed is forested while 44.8% is agricultural (Table 12; Figure 20). One quarter of all wetland (133 mi^2) has been artificially drained and extensive field tiling exists throughout agricultural land (Figure 21). Artificial drainage is mostly confined to the southern and eastern portion of the watershed where agricultural land use predominates. Artificial drainage allows soils to be drained more quickly and results in more direct discharges into streams with minimal percolation into the water table. Artificial drainage results in greater fluctuations in streamflow (flashier streams), greater temperature fluctuations, and increases the rate of sedimentation.

Land use within the Tittabawassee River basin today is predominantly agricultural in nature, with small- to medium-size towns and cities scattered throughout the basin (Table 12). Agricultural activities are most intense in the southern and central portions of the basin, where cash crop production (corn, soybeans, wheat) predominates. Dairy farming is widely practiced in the northern part of the basin. Within recent years, 125,148 acres are in pasture and hay production, and 583,148 acres are in row crops (Table 13).

Present land use is developed, commercial, upland, grassland, wetland, open water, and agricultural. Overall, 44.8% of the watershed is classified as agricultural. Upland represents 34.8 % and 15.4% is classified as wetland. Lesser land uses include open water (1.7%), developed (1.2%), commercial (0.8%), and grassland (1.3%).

Headwaters

Predominate land use in the catchment of the headwaters is upland (53.7%) with wetland the second greatest land use (26.9%). Presettlement estimates indicate that 25.5% of this catchment was wetland (Table 11; Figure 21). The third largest land use is agriculture (12.0%). Less frequent land uses include grassland (4.5%) and commercial (0.5%). Agriculture use consists of dairy farming, general farming, and pasture land. Agricultural usage is 7,304 acres in pasture and hay, and 6,728 acres in row crops (Table 13).

Middle

Like the headwaters, the middle catchment, excluding the Tobacco River, is mostly composed of upland (37.9%). Presettlement estimates indicate that 36.2% was wetland (Table 11) and estimates for present day are 34.3% (Figure 21). Agricultural use occupies 21.2%. Relative to the other major segments and tributaries, this catchment has more open water due to large impoundments (3.3%). Riparian development is common around the large impoundments. A similar proportion is grassland (3.0%). Agricultural use includes general farming and specialty crops. Agricultural usage is 12,438 acres in pasture and hay, and 29,135 acres in row crops (Table 13). Many soils in the ELHP major land resource area require artificial drainage before they can be farmed or developed, including the eastern quarter of Midland County.

The Tobacco River is one of the largest drainages contributing to the Tittabawassee River middle drainage. The dominant land uses are upland (47.7%) and agriculture (36.2%). The greatest reduction in wetlands has occurred within this catchment (51.8%; Figure 21). Presettlement estimates indicate that 22.8% was wetland (Table 9) and estimates for present day are only 11.0%. Smaller proportions are in grassland (2.4%) and open water (1.5%). Developed and commercial land use makes up 0.6% and 0.5%, and collectively is attributed to the towns and villages of Clare, Farwell, and Harrison. Agricultural use is general farming and pasture land. Agricultural usage is 26,687 acres in pasture and hay, and 85,408 acres in row crops (Table 13).

Mouth

Land use, excluding catchments of the major tributaries which are discussed separately, is predominantly agricultural (38.7%). Many wetlands have been drained to augment farming. Presettlement estimates indicate that 23.1% of this catchment was wetland (Table 11) and estimates for present day are 18.8% (Figure 21). This represents an 18.6% reduction in wetlands. Uplands comprise 30.8%. This segment has the greatest amount of development (6.5%) and commercial land use (3.4%), including the City of Midland, some of the larger villages, and industrial developments such as the Dow Chemical Company. Agricultural uses include general farming (5,777 acres in pasture and hay) and row crops (56,228 acres; Table 13). Much of this catchment basin has been artificially drained to facilitate farming and development.

The Salt River catchment like the Mouth catchment is dominated by agricultural land use (61.0%). Uplands cover 24.1%. Wetlands have been reduced by 14.8% (Figure 21). Presettlement estimates indicate that 16.2% was wetland (Table 11) and estimates for present day are only 13.8%. Agricultural use is primarily in the eastern portion where much land has been artificially drained to facilitate farming and development. Agricultural usage is 9,440 acres in pasture and hay, and 76,866 acres in row crops (Table 13).

Similar land use patterns are also characteristic to the Chippewa River catchment basin. The catchment is predominantly agriculture (54.4%). Uplands account for 32.3%. Almost one-third of all wetlands have been destroyed (Figure 21). Presettlement estimates indicate that 14.4% was wetland (Table 11) and estimates for present day are only 9.8%. Open water covers 2.0%. Developed and commercial land use occupies 0.8% and 0.6% and is concentrated in the city of Mt. Pleasant. Artificial drainage is used in the eastern end to facilitate farming and development with 34,513 acres in pasture and hay and 175,670 acres in row crops (Table 13).

Although the catchment of the Pine River is smaller, land use patterns almost mirror the Chippewa River. The dominant land use is agriculture (67.8%). Uplands occupy 21.4%. Almost half of the wetlands have been destroyed (Figure 21). Presettlement estimates indicate that 15.7% was wetland (Table 11) and estimates for present day are only 8.6%. Developed (1.0%) and commercial (0.4%) land use are primarily attributed to the communities of St. Louis and Alma. Agricultural use is general farming and is facilitated in the eastern portion by artificial drainage. Agricultural usage is 28,990 acres in pasture and hay, and 153,246 acres in row crops (Table 13).

The Pine River exhibits an unusual hydrologic phenomenon attributed to the soils through which it flows and extensive artificial drainage (WRC 1960). The USGS gauging stations indicate that the lower reaches have higher discharge rates per square mile of drainage area than the upper reaches (Table 7). The Pine River headwaters are composed of light sand and gravel soils of glacial moraines and outwash plains of the western edge of the basin. It then flows through clay soils in the eastern portion of the catchment (old lake bed) where artificial drainage is extensive.

Bridges and Other Stream Crossings

The Tittabawassee River watershed has 5.59 road stream crossings per square mile. The number varies by segment, but generally there are more crossings in the southern part of the watershed or near population centers. Culverts and bridges are typically paved, gravel, sand, or soil surfaced. Culverts and bridges typically affect stream habitat at crossings, but also can have cumulative effects on a stream and its biological communities. They can also greatly affect stream hydrology.

In most instances, banks and slopes on or near crossings are cleared and direct erosion into a stream often results. These sediments cover up and destroy fish habitat, bury and suffocate fish eggs and larvae, and destroy or alter habitat for invertebrates or less mobile aquatic organisms. Sediments and runoff from road crossings also carry contaminants such as oils, antifreeze, and other pollutants.

Many culverts, especially older ones, are improperly designed. Problems vary from improper alignment, sizing, depth or slope setting, or a combination of these. This can result in hydrology problems such as downcutting or damming affects, blowing out banks, complete road washouts, and accelerated erosion. Downcutting and perched and improperly-sized culverts can fragment habitat by creating a barrier to fish movement.

Similar to culverts, bridges can also have design flaws. Improperly-sized bridges can cause velocity increases and current changes immediately upstream and downstream of a bridge. Piers and pillars of bridges also affect stream hydraulics and can act to collect debris and block water flow. These flow alterations can cause erosion, destabilize banks, and in some instances prevent movement of fish.

Road stream crossing inventories have been completed in several parts of the watershed by the nonpoint source unit of the Michigan Department of Environmental Quality (MDEQ) Water Bureau, Saginaw Bay Resource Conservation and Development, local Soil Conservation Districts, and volunteer groups. Many have been completed on the main stem Tittabawassee River including the impoundments, the North and South branches of the Salt River, the North Branch of the Chippewa River, and the Cedar River. These inventories detail specific crossings, but many are limited to describing erosion issues and do not include habitat fragmentation.

Oil and Gas Development

There are 398 oil and gas operations located in the Tittabawassee River watershed (Figure 22; Table 14). There is activity in every major catchment, but most operations are concentrated in clusters. Most wells occur in the Salt River drainage (117 wells), which also has the greatest concentration of wells, 0.53 wells per mi^2. The other two main areas are the Chippewa River drainage (96 wells or 0.16 wells per mi^2) and Pine River drainage (66 wells or 0.16 wells per mi^2). In both catchments, operations are concentrated in the lower reaches. Fewer wells are located in the main stem Middle (45 wells or 0.15 wells per mi^2) and Mouth (38 wells or 0.15 wells per mi^2), excluding the tributaries, Tobacco River (34 wells or 0.07 wells per mi^2) and the Upper main stem (2 wells or 0.01 wells per mi^2).

In many cases (160), oil and gas wells are located along the margins of Red Beds and Saginaw Formation (see also **Geology**; Figure 3). In Michigan, these geologic materials are considered major hydrocarbon-bearing rocks (MSU 2005a).

State oil and gas development and private lands where the state owns mineral rights is subject to restrictions outlined in the State Mineral Lease and State Land Forestry Land Use Permit Regulations and the restrictions from the Supervisor of Wells Part 615 Act 451 Natural Resources Environmental Protection Act (NREPA). New oil and gas wells drilled on state leases require a setback of ¼ mile from streams and water bodies. Additional permits, issued by MDEQ, Land and Water Management Division, are needed to develop areas in wetlands. Prior to property being leased for development, land parcels go through a leasing classification period. Many divisions of MDNR, including Fisheries Division, Forest Management, Wildlife, and Parks and Recreation provide comments to MDEQ at the leasing classification level. Here lands are classified as leasable, with or without restrictions, or nonleasable (V. Barnard, MDEQ, personal communication).

Private land gas and oil development is also overseen by MDEQ, Office of Geological Survey whose authority comes from Act 451, NREPA, Part 615, Supervisor of Wells and Administrative Rules. This allows for all regulation of oil and gas well operations including drilling, production, brine disposal, and plugging. Although there are no specific setbacks on private land from surface water, the rules empower the Supervisor of Wells to do whatever is necessary for the protection of natural resources (V. Barnard, MDEQ, personal communication). During the permit application review process the Office of Geological Survey may consult other divisions and agencies when special circumstances exist.

Oil and gas development adds roads, potential stream crossings, and clears forests or land which affects the permeability of soils and can cause accelerated erosion. Oil spillage is contained at the well site and cleaned up promptly by the well owner and operators. MDEQ, Office of Geological Survey maintains the records of all oil and gas wells and is the regulatory authority for oil and gas operations. Well sites and facilities are inspected by Office of Geological Survey Field geologists or geological technicians on a regular basis for compliance with Act 451, NREPA, Part 615, Supervisor of Wells and Administrative Rules (V. Barnard, MDEQ, personal communication).

Channel Morphology

Erosion, deposition, and channel movement are natural river processes. These processes maintain equilibrium between water energy and river margins. As energy increases, for example, downcutting, lateral movement, and channel widening can occur. When downcutting occurs, river velocity is decreased (i.e., energy) by reducing channel gradient. Similarly, lateral movement increases sinuosity thus increasing river length and reducing gradient. Channel widening increases the volume capacity within the channel thus decreasing velocity.

Within this section we present three river measures that describe flow and stability of the Tittabawassee River main stem and its tributaries. They are: gradient, specific power, and channel cross section.

Gradient

Gradient is the measure of channel slope over river length and is reported in feet per river mile. We calculated gradient using elevation contours. River gradient generally follows land (elevation) contours; however, gradient is strongly influenced by surficial materials. For example, in areas of erodible materials, such as sand, gradient may easily change as flow varies. Typically, rivers flowing through sand have lower gradient. Rivers flowing across less erodible materials (e.g., rock) have greater gradient and gradient is less likely to change as flow varies.

Gradient determines the type and diversity of river habitats (Table 15). Free flowing river sections, that are not impounded, with gradient class “Excellent” (gradient = 10.0 to 69.9 ft/mi) are rare in Michigan since dams are typically constructed in areas of highest gradient (Wesley and Duffy 1999). Dams, and their impounded waters, reduce hydraulic diversity and consequently aquatic species diversity (Wesley and Duffy 1999).

The main stem Tittabawassee River drops 440 ft from 1,017 ft above sea level at its headwaters to 577 ft above sea level at the mouth. Mean gradient within the main stem is 4.7 ft/mi and varies from 0.9 ft/mi near the mouth to 68.8 ft/mi in the headwaters. Tittabawassee River gradient is steep relative to other Michigan rivers of similar size. For example gradient of the Au Sable River is 3.9 ft/mi (Zorn and Sendek 2001), Kalamazoo River is 3.0 ft/mi (Wesley 2005), Manistee (Rozich 1998) and Huron (Hay-Chmielewski et al. 1995) rivers are each 2.95 ft/mi, Flint River is 2.9 ft/mi (Leonardi and Gruhn 2001), Muskegon River is 2.6 ft/mi (O’Neal 1997), and the St. Joseph River is 2.5 ft/mi (Wesley and Duffy 1999). Rivers typically have steep gradient in their headwaters with more moderate gradient further downstream. However, gradient remains quite steep within the central portion of the main stem (approximate 40 mi stretch from Sanford Dam to Secord Dam). The close proximity of the dams within the middle segment is a good indicator of the steep gradient in this portion of the Tittabawassee River.

Specific Power

Specific power of a river is a function of its width, rate of discharge, and gradient. Specific power is reported in watts/m^2 and provides a measure of the potential energy supplied to a river channel and its banks. Power is the rate at which work is done (e.g., moving a 1 oz stone 30 ft in 15 min) and specific power is an important measurement necessary to understanding the dynamics of a river system. Specific power is expressed as:

$$\omega = \frac{pgQ_f s}{w},$$

where *p* is water density, *g* is gravitational acceleration, *Q* is discharge at percent exceedence *f*, *s* is channel slope in meters, *w* is cross-sectional bank-full width in meters. The product of *p* and *g* is approximated at 10 (Wiley and Gough 1995).

Because of Michigan's glacial history, the Tittabawassee River watershed is composed of areas of coarse- (e.g., sand) and fine-textured materials (e.g., clayey materials). Materials, whether they are rocks or clays, may be eroded and transported by a river. Sand particles are more erodible than larger particles (e.g., gravel or cobble) or smaller clayey materials (Figure 23). Clay materials are less easily eroded due to their cohesive nature. However, once clay materials are in suspension they are more easily transported than sand and remain in suspension even in still water.

Rivers, regardless of the materials they flow through, are dynamic in nature and move laterally within their meander belt (valley corridor). The location of a present day stream bed is different from its location in previous millennia. Remnants of earlier stream bed locations are evident in the form of oxbow lakes and silted oxbows found within their meander belt (Schiefer 2001). When a river moves laterally, the outside bank is eroded. Easily transported materials (sand, etc.) are carried and deposited within a river system. Coarser materials, such as rock or gravel, are deposited in the streambed. As a river moves laterally off of its present channel within the meander belt, these coarse materials form veins. Through time a river rediscovers these older veins and the coarse materials once again become components of the riverbed (Hansen 1971).

Michigan rivers flowing through sand become dynamic when specific power reaches 15 watts/m^2 (M. Wiley, University of Michigan, personal communication). That is, they may begin to erode, increase sinuosity, downcut, overflow their banks, or a combination of these. The result of these actions is a reduction in specific power. Rivers flowing through clay materials require greater specific power to begin the erosion process. Essential to the point at which a river becomes erosive is the shape of the channel. In 1776, Chezy published a manuscript entitled "Formula to find the uniform velocity that the water will have in a ditch or in a canal of which the slope is known" (Khoury 2004). His formula showed that as the ratio of the canal area to the wetted perimeter increased there was less friction due to the canal bottom and margin (Russell 1942). Consequently, water moves faster through a canal or river that has a greater area to wetted perimeter ratio. For example, unaltered rivers have channels with cross-sectional shape presented in the left portion of Figure 24. River channels with this unaltered shape have lower specific power, are less likely to produce flooding, and have fewer erosion problems. However, when rivers are dredged and straightened (i.e., county drains) their shape and the ratio of area to wetted perimeter increases. Typical county drains are channels with cross-sectional shape presented in the right portion of Figure 24. River channels with this altered shape have greater specific power, produce more flooding in downstream areas, and have greater erosion problems.

Channel Cross Section

Similar to gradient, channel cross section is a measure of channel complexity and quality of aquatic habitat. In unaltered river systems, sinuosity and pool-riffle complexes contain many habitat types and support greater number of aquatic organisms. When channels are altered (e.g., straightened, dredged) habitat complexity and consequently, biodiversity are often reduced.

Measured channel (bank full) width compared to predicted width is an indicator of channel alterations and riparian land practices. In unaltered river systems, channel width typically increases downstream although depth can be quite variable. Overly narrow channels are generally the result of channel dredging or bank alterations in the immediate area. Channel alterations in upstream areas often result in unstable flows and wider than predicted channels in downstream areas. Unstable flows are typically caused by land practices (e.g., field tiling) and channel degradation upstream (e.g., county drains). As a result of unstable flows, channels become excessively wide given their mean low flow discharge (*Q* at 95% exceedence).

We calculated mean expected widths and their upper and lower 95% confidence bounds (G. Whelan, MDNR, Fisheries Division, unpublished data) for each USGS gauge site using available flow data. Mean expected width $\overline{W}$ was calculated as:

$$\overline{W} = 10^{(0.741436+(0.498473 \cdot \log Q))},$$

where Q is the discharge at 95% exceedence. Upper 95% confidence bound for expected width $\overline{W}$ was calculated as:

$$\overline{W}_{upper} = 10^{(0.819976+(0.525423 \cdot \log Q))}$$

and lower 95% confidence bound for expected width $\overline{W}$ was calculated as:

$$\overline{W}_{lower} = 10^{(0.662895+(0.471522 \cdot \log Q))}.$$

Headwaters

The overall mean gradient for the headwater segment is 14.5 ft/mi (Figure 25) and classified as excellent. Within this segment, 45.0% is classified as excellent, 20.0% each as good and fair (3.0–4.9 ft/mi), 10% as fair (70.0–149.9 ft/mi), and the remaining 5.0% as low (Table 16). The river drops 273 ft from its headwaters elevation of 1,017 ft above sea level to 744 ft above sea level at the upper end of the Secord Lake impoundment (Figure 26).

No USGS gauge stations were located within this subwatershed; specific power and expected channel width were not calculated.

Middle

Mean gradient for the middle segment of the Tittabawassee River is 3.2 ft/mi (Figure 25) and classified as fair. However, most of the channel gradient is impounded (see also **Dams and Barriers**). Gradient is classified as low for 61.1% and fair for 38.9% (Table 16). The river drops 121 ft from 744 ft above sea level at the upper end of the Secord Lake impoundment to 623 ft above sea level at the Sanford Dam (Figure 26).

No USGS gauge stations were located within the main stem; specific power and expected channel width were not calculated.

Mean gradient for the Tobacco River is 9.9 ft/mi (Figure 27) and classified as good. Most, 53.1% is classified as excellent, 15.6% as good, and 31.3% as fair (Table 16). The Tobacco River drops 46 ft from 984 ft above sea level at the headwaters to 656 ft above sea level at the mouth (Figure 28).

Mean gradient for the South Branch of the Tobacco River is 8.7 ft/mi (Figure 30) and classified as good. This river is classified as low for 34.2%, good for 39.5%, and excellent for 26.3% of its total length (Table 16). This segment drops 328 ft from 1,049 ft above sea level at the headwaters to 721 ft above sea level at the mouth (Figure 31).

Yield was measured at two USGS stations:

- Tobacco River at Beaverton (USGS station no. 04152500)

  Specific power was 3.2 watts/m^2 at 5% exceedence and 0.5watts/m^2 at 95% exceedence (Figure 29). Specific power was 15 watts/m^2 at 4,731 ft^3/s (0.05% exceedence) and this flow was equaled or exceeded 6 of 35 years. Measured channel width of 92.2 ft was within expected range (Table 17). Short duration of peak flow events likely cause the river to overflow its banks and retreat quickly. These peak flow events of short duration limit the river's ability to reshape or move its channel.

- South Branch of the Tobacco River near Beaverton (USGS station no. 04152238)

  Specific power was 2.2 watts/m^2 at 5% exceedence and 0.6 watts/m^2 at 95% exceedence (Figure 32). Specific power was 15 watts/m^2 at 855 ft^3/s (0.2% exceedence) and this flow was equaled or exceeded 5 of 17 years. Measured channel width of 55.1 ft was within expected range (Table 17). Short duration of peak flow events likely cause the river to overflow its banks and retreat quickly. These peak flow events of short duration limit the river's ability to reshape or move its channel.

Mouth

Mean gradient of the Tittabawassee River is 1.3 ft/mi (Figure 25) and 100% is classified as low (Table 16). The river drops 46 ft from 623 ft above sea level at the Sanford Dam to 577 ft above sea level at the mouth (Figure 26).

Specific power and expected channel width were calculated only for the USGS station at Midland. Data from the gauging station at Freeland were not used because of the brief period of record and the out-of-date information (see also **Hydrology**):

- Tittabawassee River at Midland (USGS station no. 04156000)

  Specific power was 8.8 watts/m^2 at 5% exceedence and 0.5 watts/m^2 at 95% exceedence (Figure 33). Specific power was 15 watts/m^2 at 9,519 ft^3/s (1.5% exceedence) and this flow was equaled or exceeded 51 of 68 years. This indicates that peak flows are short, but occur almost annually. Numerous factors can contribute to these peak flows. For example, dams release excessive amounts of water to maintain impoundment levels (see also **Dams and Barriers**). Impervious surfaces (e.g., roads, parking lots) speed transfer of precipitation to the river. Similarly, county drains prevent retention of precipitation and increase river flows. Measured channel width of 216.8 ft was within expected range (Table 17). However, river banks are heavily stabilized with rock and concrete rubble at this gauge site and lateral movement of channel is prevented.

Mean gradient for the Salt River is 3.5 ft/mi (Figure 34) and classified as fair. Most, 66.7% is classified as low and 33.3% as good (Table 16). The Salt River drops 65 ft from 688 ft above sea level at the headwaters to 623 ft above sea level at the mouth (Figure 35). One USGS gauging station was located on the Salt River (see also **Hydrology**):

- Salt River near North Bradley (USGS station no. 04153500)

  Specific power was 5.16 watts/m^2 at 5% exceedence and 0.1 watts/m^2 at 95% exceedence (Figure 36). Specific power was 15 watts/m^2 at 872 ft^3/s (1.4% exceedence) and this flow was equaled or exceeded 32 of 38 years. Measured channel width of 60.8 ft was within expected range (Table 17). This tributary is dominated by agriculture (see also **Soils and Land Use**) and has a high concentration of country drains (see also **Special Jurisdictions**). Tiling of fields and faster transfer of water via country drains correlates with frequency of peak flows. Thus, modest precipitation events produce peak flows on an almost annual occurrence. Appropriate channel width coupled with frequent peak flows indicates that the river peaks, overflows its banks, and then recedes quickly. Tiling and county drains have compounding effects and serve to increase flooding potential in downstream areas.

Mean gradient for the Chippewa River is 3.8 ft/mi (Figure 37) and classified as fair. This river is classified as low for 31.5%, fair for 43.8%, and good for 24.7% of its total length (Table 16). The river drops 361 ft from 984 ft above sea level at the headwaters to 623 ft above sea level at the mouth (Figure 38). Yield was measured at two USGS stations within the Chippewa River (see also **Hydrology**):

- Chippewa River near Mt. Pleasant (USGS station no. 04154000)

  Specific power was 2.4 watts/m^2 at 5% exceedence and 0.3 watts/m^2 at 95% exceedence (Figure 39). Specific power was 15 watts/m^2 at 5,018 ft^3/s (0.009% exceedence) and this flow was equaled or exceeded 1 of 74 years. Measured channel width of 84.8 ft was within expected range (Table 17). This gauge is located just downstream from an area of highly permeable soils (see also **Geology**) where few county drains have been established (see also **Special Jurisdictions**). Consequently, precipitation easily percolates through the soil and rarity of channelized county drains minimizes fast transfer to the river.

- Chippewa River near Midland (USGS station no. 04154500)

  Specific power was 8.1 watts/m^2 at 5% exceedence and 0.8 watts/m^2 at 95% exceedence (Figure 40). Specific power was 15 watts/m^2 at 2,404 ft^3/s (1.1% exceedence) and this flow was equaled or exceeded 18 of 26 years. Measured channel width of 205.5 ft was wider than expected, minimum and maximum expected widths were 80.0 and 159.1 ft (Table 17). Measurements at this gauge reflect soil types and human activities. The approximate lower one-half of the Chippewa River flows through soils of medium permeability with minimal variability in elevation (see also **Geology**). Consequently, precipitation is more likely to flow across the land into tributaries rather than percolate into the ground. Agricultural practices in this eastern portion of the catchment have resulted in extensive field tiling (see also **Soils and Land Use**) and concentrations of county drains (see also **Special Jurisdictions**). These have all contributed to short-duration peak flows which occur almost annually and a wider than expected channel width.

Mean gradient for the Pine River is 4.1 ft/mi (Figure 41) and classified as fair. This river is classified as low for 47.9%, fair for 28.1%, good for 18.8%, and excellent for 5.2% of its total length (Table 16). The river drops 394 ft from 1,017 ft above sea level at the headwaters to 623 ft above sea level at the mouth (Figure 42). Yield was measured at two USGS stations (see also **Hydrology**):

- Pine River at Alma (USGS station no. 04155000)

Specific power was 5.2 watts/m^2 at 5% exceedence and 0.5 watts/m^2 at 95% exceedence (Figure 43). Specific power was 15 watts/m^2 at 1,822ft^3/s (0.2% exceedence) and this flow was equaled or exceeded 18 of 74 years. Measured channel width of 80.3 ft was within expected range (Table 17). Land above this gauge site is composed of highly permeable soils (see also **Geology**), and has minimal influence from field tiling and county drains (see also **Soils and Land Use** and **Special Jurisdictions**). These all contribute to stable flows.

- Pine River near Midland (USGS station no. 04155500)

  Specific power was 8.4 watts/m^2 at 5% exceedence and 0.6 watts/m^2 at 95% exceedence (Figure 44). Specific power was 15 watts/m^2 at 1,689 ft^3/s (1.3% exceedence) and this flow was equaled or exceeded 43 of 59 years. Measured channel width of 183.0 ft was wider than expected, minimum and maximum expected widths were 69.4 and 135.9 ft (Table 17). This gauge is located in the eastern end of the catchment. This area is composed of medium permeable materials, less variable elevation (see also **Geology**), and land use is primarily agricultural (see also **Soils and Land Use**). As a result of agricultural practices, much of the land is tiled and county drains are concentrated in this eastern portion (see also **Special Jurisdictions**). These all contribute to frequency of peak flows and excessively wide channel.

Dams and Barriers

There are 143 dams in the Tittabawassee River basin registered with MDEQ (Table 18 and Figures 45–48). Dams are maintained for a variety of purposes: six are listed for hydroelectric generation (see also **Hydrology**), 3 are retired hydroelectric dams, 86 are for recreation, and the remainder are for farm ponds, irrigation, or water supply.

Most dams in the basin are small and impound a relatively small amount of water. The majority (60) are less than 10 ft in height. Fifty-five dams range from 10 to 20 ft and only 10 dams have heights that are greater than 20 ft. Impoundments created by most dams (66) are less than 10 acres. Of the remaining dams, 44 impound 10–99.0 acres, 24 impound 100–999.9 acres, and three impound more than 1,000 acres.

Dams were important in the early development of the basin. The first dams were built to power saw mills or grist mills. Today, many of these dams are now maintained for recreational purposes. Most of the hydroelectric dams were constructed from 1900 to 1925. A number of dams were constructed in the 1940s to create habitat for wildlife. Dams constructed between the 1950s and 1990s were primarily for maintaining lake levels, often driven by increasing residential development.

Dams are regulated under Michigan's Dam Safety, Part 315 of the Natural Resources and Environmental Protection Act (P.A. 451, 1995) as amended and the Federal Energy Regulatory Commission (FERC) Regulation 18 of Part 12 of the Code of Federal Regulations (Leonardi and Gruhn 2001). Most existing hydroelectric dams in the basin are under FERC authority and operating agreements exist between the federal and state management agencies and the dam's owners (Appendix A).

All dams and barriers require some type of maintenance. If not maintained properly, the structural integrity of a dam is compromised and there could be a threat to property damage, environmental damage, and potential for loss of life. According to FEMA 1999 (as reported by Public Sector Consultants, Inc., 2002), the average life expectancy of a dam is 50 years. Dams in the watershed vary in age from 37 to 135 years. By 2020, most of the larger dams in the Tittabawassee River watershed will have outlived their normal design life, making repair or removal imminent.

From Sec 31503 and Sec 31504, Part 315, NREPA, hazard ratings are assigned based on the consequences of dam failure. High hazard dams are located in an area where failure may cause serious damage to inhabited homes, agricultural buildings, campgrounds, recreational facilities, industrial or commercial buildings, public utilities, main highways, or class I carrier railroads, or where environmental degradation would be significant, or where danger to individuals exists with the potential for loss of life. A significant hazard rating means a dam is located in an area where its failure may cause damage limited to isolated inhabited homes, agricultural buildings, structures, secondary highways, short line railroads, or public utilities where environmental degradation may be significant, or where danger to individuals exists. A low hazard rating mostly includes low head dams located in more remote areas where failure may cause damage limited to agriculture, uninhabited buildings, structures or township or county roads, where environmental degradation would be minimal, and where danger to individuals is slight or nonexistent. There are 11 dams with hazard rating of high and 9 dams with hazard rating of significant. Most (119) have hazard rating of low. Four dams do not currently have hazard ratings.

Dams, regardless of their intended use or origin, have major effects on river ecosystems. By impounding rivers, dams reduce water velocity changing flowing waters to more lentic or lake-type habitats. This reduction in water velocity causes nutrients and sediments to be trapped in impoundments which leads to excessive algae and vascular plant growth and disrupts natural sediment transport. Reduced water velocity and increased surface area created by impoundments allows for increased absorption of direct solar radiation which causes an increase in water temperatures. Warm surface water from impoundments can alter the thermal regime of receiving waters for a long distance before cooler groundwater, if available, can restore temperatures to more natural conditions (Lockwood et al. 1995). Fish communities are limited in these types of stretches to more warmwater tolerant species, and certain aquatic species including fishes may be eliminated (Wesley and Duffy 1999). Warm water has less physical potential to carry oxygen than cold water, and therefore fish that survive in low oxygen environments are often inhabitants of impoundments. Carp, channel catfish, and bullheads are all commonly found in many impoundments of the Tittabawassee River. The increased surface are in impoundments also results in increased evaporation rates. Increased evaporation can lower base flows in streams below dams especially during summer. Discharges from the upper layers of impoundments have also been observed to cause dense growths of filamentous algae below dams causing changes in the fauna (Hynes 1970).

Rapidly varying flows or peaking downstream from hydroelectric facilities can reduce abundance, diversity, and productivity of riverine organisms (Cushman 1985). Peaking operations occur when water is stored in a reservoir at night and released through turbines to satisfy increased electrical demand during the day. Peaking can reduce biotic diversity directly by displacing organisms or indirectly by reducing habitat suitability through changes in water depth, temperatures, or substrate. Downcutting of the main channel below a dam can also occur as a result of the erosive power of water associated with peaking. Downcutting of the channel can eliminate river connections to floodplains and side channels, critical habitats for fishes and invertebrates.

Dams fragment habitat by blocking upstream and downstream movement of fishes and invertebrates. Many fish species from within a stream and from Saginaw Bay migrate upstream to spawn. Fishes may also move to feed, find protective cover, and to escape extreme temperatures. Only limited migrations are possible today and access to different habitats within the watershed is severely limited by dams. As with fish, many insects reproduce upstream of larval areas and drift downstream. Fish and insect larvae produced upstream of impoundments may be trapped in impoundments while migrating downstream.

Downstream recruitment of natural vegetation and large woody material is also prevented by dams. Large woody material provides a source of nutrients for production, cover for fishes, and adds increased diversity in depth, velocity, and lighting conditions within the stream (Zorn and Sendek 2001). Eliminating recruitment of woody material reduces habitat complexity and nutrients in the sections downstream from dams.

Many dams are lake-level control structures and are often operated in a manner that benefits the riparians along lake-frontage at the expense of the biological communities and habitat of the lake and outlet stream. Often times these structures maintain a constant water level which eliminates the natural fluctuation between seasons and years. This leads to losses in wetland riparian habitats that require these natural fluctuations to survive. The loss of lakeside wetland shoreline habitats such as cattails and other emergent vegetation reduces the quality of critical spawning habitats for fishes and invertebrates. Constant water levels also encourage more residential shoreline development. Some control structures allow the removal of boards during high water periods. Rapid drawdowns can trap fish in the shallows and wetlands and destroy wetlands. Less mobile species such as clams, snails, and aquatic insects are eliminated during these dewatering activities. In addition, outlet streams may experience erosion during these quick draw downs. During drought conditions lake-level control structures allow water to be held back. This further reduces the water available to outlet streams and intensifies low water situations.

Dams can also interfere with navigation and recreational use of rivers. Dams are obstacles for boaters, canoers, and kayakers and although some have portages, many are poorly marked. There is some access to the tailwaters below the major dams on the Tittabawassee River and all FERC orders during the last relicensing addressed the need for more access and better signage.

The operation of hydropower dams can affect fish populations through entrainment and turbine mortality. Environmental assessments were conducted for several years (Freshwater Physicians 1988) in conjunction with the relicensing of the hydroelectric dams on the main stem Tittabawassee River (FERC 1998a). The estimated total annual mortality rate for all species of larval fish was 1.97 million at Secord Dam, 13.9 million at Smallwood Dam, 3.4 million at Edenville Dam, and 8 million at Sanford Dam. Highest mortality occurred in spring during high flows. Total juvenile and adult mortality was also estimated for the major hydro dams. Estimated losses were 144,847 at Secord Dam, 411,622 at Smallwood Dam, and 169,699 at Edenville Dam. No estimate was calculated for Sanford Dam. Annual monetary replacement costs were estimated to be $550 in 1998 at Secord Dam, $3,530 at Smallwood Dam, $840 at Edenville Dam, and $3,830 at Sanford Dam.

Most of the larger dams in the Tittabawassee River basin were built on the higher gradient habitats to create the highest hydraulic head possible for the lowest cost. These areas were probably fast riffles to small waterfalls. Historically, these areas provided spawning areas for a wide variety of species including lake sturgeon and walleye from Lake Huron. These areas are no longer accessible and quality habitat has been lost.

Dams do provide some positive human benefits. Dams and the impoundments they create provide necessary water supplies for industry, municipalities, and riparian owners. In some areas, impounded waters provide recreational opportunities such as boating, swimming, hunting, and fishing that are different from those on free flowing reaches. Often times, these impoundments are more accessible and usable to the public. Dams also create barriers blocking the upstream migration of undesired species such as lamprey and carp. Finally, some contaminated sediments become trapped behind dams which prevents them from being transported downstream.

Headwaters

There are 34 dams in this segment that are listed with MDEQ (Table 18). The earliest listed, a Benmark Club Dam on the West Branch of the Tittabawassee River was built in 1940 for recreation. Rau Lake Dam on Rau Creek is the newest dam and was constructed in 1970. Eleven dams have unknown construction dates. All dams in the headwaters are of low hazard type and most were built for or are being used for recreational purposes. Ten dams have no information under purpose indicating that the reason for maintaining the dam is unknown or that the dam may serve no purpose. Most of these dams are water control structures creating small ponds ranging in size from 1 to 65 acres, but most are less than 5 acres. Elk Lake, in Roscommon County, is the largest impoundment and was created by impounding Elk Lake Creek, a tributary to the Middle Branch Tittabawassee River. All dam types are earth, gravity, earth/gravity (see also **Glossary**), or other (wooden stop-logs or cobble). There is no upstream fish passage from any waters below Secord Dam.

Middle

This river segment has the largest dams and most impounded water. Tributaries to the middle segment including the Sugar, Tobacco, and Cedar rivers are also impounded. There are 4 dams on the main stem, 8 on the Sugar River, 6 on the Molasses, and 42 on the Tobacco and Cedar river systems that are listed with MDEQ. The oldest, Farewell Millpond was built in 1909 on the South Branch of the Tobacco River. There are 4 active hydroelectric dams on the main stem including Secord, Smallwood, Edenville, and Sanford dams. Edenville was constructed first in 1924 followed by the other main stem hydroelectric producing dams in 1925. They were all built in high gradient areas and are earth-gravity type. With the exception of Sanford Dam, these hydroelectric projects were last licensed under FERC in 1998 and are up for relicensing in 2028. Sanford Dam actually went through relicensing in 1987, but an amendment in 1998 made the relicensing of Sanford Dam coincide with the other projects. All hydroelectric dams were privately owned licensed by Wolverine Power Company. The company transferred the FERC licenses of all these projects to Synex-Wolverine LLC on June 23, 2004. There was another name change in 2007, and they are all now operated under the name Boyce Hydropower, LLC (Kyle Kruger, personal communication). All of these hydroelectric dams are listed as high hazard dams meaning that failure would result in potential loss of life and extensive property damages.

Operational specifications are the same for Secord, Smallwood, Edenville, and Sanford dams. Except during emergencies and winter drawdown, operations of the project may not fluctuate more than 0.4 ft below or 0.3 ft above normal pool elevation. With the relicensing in 1998, Synex-Wolverine was ordered to have a plan to monitor water quality standards, address an erosion control program, monitor shoreline erosion caused by the project operations, and to provide pedestrian access. Access plans are to include signs, a barrier-free restroom, a canoe portage, and access paths to tailwater, dike areas, restroom, canoe portage, and parking areas.

Secord Dam, the uppermost of the large hydroelectric dams, is located north of the Village of Wooden Shoe in Gladwin County, T 19N, R1E, Sec 15, just below the confluences of the East, West, and Middle branches of the Tittabawassee River. Secord Dam has three sections that span a total of 2,085 ft. The dam has a dam height of 55 ft, hydraulic head of 46 ft, and impounds 895 acres and creates 69 miles of shoreline at normal pool height (750.8 ft National Geodetic Vertical Datum (NGVD)). There is a reinforced multiple arch spillway with an ogee crest and two Taintor gates. The powerhouse is equipped with one Francis vertical-axis turbine generator with an installed capacity of 1.2 MW (FERC 1998b). There is a 47-ft long intake leading to the powerhouse. During winter drawdown, December 15 and January 15, the level may not fall below 747.8 ft NGVD.

Smallwood Dam, the second hydroelectric dam in the series on the main stem, is located 10 miles downstream of Secord Dam in the Village of Wooden Shoe in Gladwin County, T 18N, R 1E, Sec 15. Smallwood Dam has a height of 36 ft and hydraulic head of 28 ft. It impounds 402 acres, creating a 25-mile shoreline at normal pool elevation (704.8 ft) NGVD. The dam has a reinforced concrete hollow gravity spillway dam about 52 ft long and 50 ft wide at the base. There are two steel Taintor gates on top of the right-side earth embankment, about 100 ft long by a maximum of 40 ft high. There is a 25 ft long intake leading to the powerhouse. The powerhouse has a single turbine with an installed capacity of 1.2 MW (FERC 1998c). Except during winter drawdown, December 15 and January 15, the level may not fall below 701.8 ft NGVD. There currently is no official public access site on Smallwood Lake impoundment.

Edenville Dam, the third in series of hydroelectric dams, is located 13 miles down from Smallwood Dam in the village of Edenville in Gladwin County, T 17N, R1W, Sec 35. The dam width consists of three sections totaling about 6,600 ft. Edenville Dam has a height of 54.5 ft, hydraulic head of 44 ft, and impounds the most water with 2,600 acres, creating 49 miles of shoreline at full pool, in Wixom Lake impoundment. There is a 50 ft long intake and the powerhouse has an installed capacity of 4.8 MW. The project creates a 0.4-mile bypassed reach on the Tobacco River that extends from the dam to the point where the Tobacco River meets the Tittabawassee River. The Tobacco River arm bypass has a minimum flow of 40 CFS winter and 66 CFS summer (FERC 2000). The Tobacco River arm is essentially on the west and the Tittabawassee River arm is on the east side of the impoundment (FERC 1998d). Normal pool elevation is 675.8 ft NGVD. During winter drawdown, December 15 and January 15, the level may not fall below 672.8 ft NGVD. Railed barrier free fishing piers are supposed to be located near the tailwater area of the Tittabawassee River outlet and an improved and railed shoreline pier is to be provided at the Tobacco River outlet.

The last in the series of hydroelectric dams, Sanford Dam is located 10 miles downstream of Edenville dam in the Village of Sanford in Midland County, T15N, 1W, Sec 24. It has a dam height of 36 ft and hydraulic head of 26 ft. It impounds 1,528 acres above it, in Sanford Lake impoundment. The dam has a controlled crest length of 1,579 ft, and a spill width of 139 ft. Sanford Dam was licensed under FERC in 1987, but amended to be included for relicensing with the above three dams in 2028 (FERC 1998e, and FERC 2004). The minimum flow requirement for downstream release is 210 ft^3/s, except during walleye spawning season when the minimum flow requirement is 650 ft^3/s. This flow requirement is not as beneficial as run of the river, but it does provide for an increase in the amount of available downstream aquatic habitat than would be available under peaking operations. This FERC order again called for plans for development of public access to the reservoir and downstream, short- and long-term needs for recreational facilities, and associated construction plans.

There are 42 dams in Tobacco River system listed with MDEQ (Table 18). Five of these are high hazard dams and the others are small, low hazard dams. These dams were constructed from 1909 to 1971 and all are of earth, gravity or other construction.

Chappel Dam is located on the Cedar River in Gladwin County northwest of the City of Gladwin. This is a high hazard dam with an earthen embankment, approximately 870 ft long and 32 ft high. The dam was originally constructed in 1910 for logging, but is presently listed as a retired hydroelectric dam in the MDEQ database. The existing spillway consists of a 100 ft fixed crest Ogee-shaped concrete spillway (filled with sand), a 15 ft Taintor gate with a radial diameter of 12 ft, and a powerhouse with stop logs. The powerhouse is currently not operational; therefore, the system is being run at “run of the river”. Because the dam failed to meet minimum requirements set forth by the MDEQ Dam Safety Unit, Spicer Engineering group was contracted in 2002 to provide engineering cost–benefit analyses for dam improvements, repair, and reconstruction options for the Gladwin County Drain Commissioner (Anonymous 2002a). The proposed actions are under permit review by MDEQ Permit 07-26-0009-P (MDEQ 2007).

Shamrock Lake Dam is listed as a high hazard dam and was constructed in 1962 on the South Branch of the Tobacco River just on the north end of the City of Clare. It is an earthen structure that was built for the purposes of recreation with a height of 20 ft and 12 ft of head. It is listed by MDEQ as impounding 120 acres of water known as Shamrock Lake, but MDNR Fisheries Division lake files list the impoundment size at 62 acres.

The Lake 13 Dam is located on Runyon Creek and is listed as a high hazard dam due to its proximity to the city of Clare. It is an earthen dam, constructed in 1948, and with a height of 19 feet and a 15 ft hydraulic head. It has a crest length of 75 ft and a controlled spillway of 6 ft. The dam impounds 88 acres in Lake Thirteen and is used for recreational purposes.

Surrey Lake Dam is a high hazard dam located just above Farwell on Elm Creek, a tributary to the South Branch of the Tobacco River. The privately owned dam was constructed in 1965 for recreational purposes; it has a 300 ft crest length with a controlled 4 ft spillway length. The height is 19 ft and it has 15 ft of hydraulic head, impounding 234 acres in Surrey Lake. In 1993 a legal-lake level was established and is set at 956.1 ft NGVD.

Beaverton Dam is a high hazard dam located in the City of Beaverton, Gladwin County. It is located at the confluence of the Cedar River and the branches of the Tobacco River. The dam was built in 1919 by the Ross Brothers as a hydroelectric facility. It was sold to Consumers Power and operated to generate electricity until the mid-1960s. Consumers Power sold the dam to the City of Beaverton in 1967. From 1967 to 1984, the dam was only operated for flood control. Beaverton Dam is 30 ft high and has a hydraulic head of 23 ft. This gravity dam has a crest length of 218 ft and a controlled 113 ft spillway width and according to the MDEQ database has an installed capacity of 1,200 kW. The dam creates Ross Lake, an impoundment of 270 acres. There is a normal lake level of 710 ft NGVD established and this corresponds to a hydro staff gauge level of 19.6 in winter and 19.8 in summer. FERC inspections have been conducted in the past and Beaverton Dam now has an Exempt License issued on December 31, 1981 (K. Kruger, MDNR, personal communication). This license does not expire and is granted in perpetuity. Ultimate authority for safety and regulation will lie with the city of Beaverton. In 1984, new turbines were installed and the dam is operated by Catalyst Energy Development, a company based out of New York. After the new turbines were installed, stream fluctuations became an issue, especially during droughts in 1987 and 1988 (MDNR, Fisheries Division, files). Minimum flows of 200 ft^3/s or the flow equivalent were not met and damages to the resources were noted. This dam has a long history of compliance issues and damages caused during operations. In winter, 2006-07, the dam experienced issues concerning undermining of the spillway which required significant repair. They have also installed an “emergency” siphon to protect aquatic resources in the tailrace if the unit experiences a shutdown.

Mouth

Dow Dam was constructed in 1939 to increase the hydraulic head available for the Dow Chemical Company. According to MDEQ database, the dam has 4 ft of normal head, with a structural height of 7 feet and a crest width of 325 feet. The impoundment is essentially contained within the river channel, so there is no good estimate of storage volume. Modifications were made to the dam in 1970 to convert it from a hydraulically-controlled structure to a concrete fixed-crest dam. A vertical-slot fishway was also installed in 1971 to facilitate fish passage, but this ladder failed to pass the intended species. Unfortunately it did pass the undesired sea lamprey. Fish passage is of great concern at this site because it would open up miles on the main stem Tittabawassee River to Sanford Dam, the Chippewa River to Lake Isabella, and the Pine River up to St. Louis. Modifications were made in 1984 because of safety issues and drownings. Large rock riprap was added at the foot of the dam to eliminate back eddies. This rock placement once again allowed the sea lamprey to migrate up the system. The fishway was closed in 1990. In 1993, Dow cooperated with the USFWS to install a portable lamprey trap at the fishway. In 1997, the fishway was opened for conducting engineering studies to again try to make a feasible fishway to pass desired species such as walleye and lake sturgeon. At present time, many fish, including sea lamprey can get over the dam during periods of high water, but this doesn’t always coincide with the spawning runs.

There are only three dams listed in the MDEQ database in the Salt River system. All three, located on Bluff Creek or Bluff Creek tributaries, were built for recreational purposes, and are considered low hazard dams.

There are 32 dams listed with MDEQ in the Chippewa River watershed. The oldest, Harris Dam, was built in 1870 and is the only dam in the Tittabawassee River watershed that has been recorded as being removed. The most recent dam to have been constructed was Long Lake dam in 1993. The only high hazard dam listed in this subwatershed is Lake Isabella. Four dams are listed as significant hazard dams including Barryton, Winchester, Weidman Pond, and Weidman Mill dams. Barryton Dam is a retired hydroelectric dam and the others were constructed to provide recreation.

The Lake Isabella Dam is located on the main stem Chippewa River upstream of Mt. Pleasant. The earthen dam is privately owned, constructed in 1967, and has a 3,030-ft crest length and a spill width of 130 ft. It is 45 ft in height, has a hydraulic head of roughly 42 ft, and impounds 730 acres in Lake Isabella. Legal summer and winter lake levels were established in 1982 and are 895 ft NGVD and 885 ft NGVD respectively. Lake Isabella has no public access other than via the Chippewa River channel.

The Barryton Dam, a retired hydroelectric dam, is located near the village of Barryton on the West Branch of the Chippewa River. The dam was constructed as earth/gravity type in 1920 and is a controlled fixed crest having an approximate crest length of 502 ft and a spill width of 61 ft. Barryton Dam has a height of 15 ft and approximately 6 ft of hydraulic head that impounds 46 acres, but is more riverine than lentic. The dam is listed as significant hazard due to the downstream proximity of Mount Pleasant.

The Winchester Dam was constructed in 1954 on the West Branch of the Chippewa River. This dam is owned by the State of Michigan and was built for recreation. The 1,420 acres it impounds make up the Martiny Flooding State Game Area. The Winchester dam is listed as a significant hazard due to its proximity to the Village of Barryton. The dam is 13 ft high and has a hydraulic head of 8 ft. In 1954 a legal lake level of 993.8 ft NGVD was established.

The Weidman Pond Dam is another significant hazard dam and is located on Walker Creek, a tributary to the Coldwater River. The dam was constructed in 1968 for the purpose of recreation. The dam is 14 ft high and has a 14 ft of hydraulic head, impounding 50 acres in Lake of the Hills. The dam is privately owned by the lake association. The outflow of Lake of the Hills combines with the Coldwater River to form Weidman Mill Pond.

The Weidman Mill Dam, a significant hazard dam, on the Coldwater River and was built in 1900 for use as a grist mill. The dam is listed as recreational and is privately owned. It is 12 ft high and has 12 ft of hydraulic head, impounding 65 acres of water. A legal lake level was established in 1987 and is set at 885.4 ft NGVD.

There are 12 dams listed with MDEQ in the Pine River watershed. The oldest, St. Louis Dam, was built in 1938 on the Pine River and is the only hydroelectric dam in the system. There are no high-hazard dams in the Pine River, but there are two significant-hazard dams: State Street and St. Louis dam.

The State Street dam is located on the Pine River in Gratiot County. The dam was built in 1938 and is owned by the city of Alma. It is a controlled gravity structure built for municipal water supply. The dam has a crest length of 355 ft and a height of 18 ft, creates 9 ft of head, and impounds approximately 140 acres. There is a restricted consumption advisory on carp due to PCBs in the Alma Impoundment (MDCH 2007; see also **Water Quality**).

The St. Louis dam is downstream of the State Street dam on the Pine River in Gratiot County. The dam is owned by the city of St. Louis and is a controlled gravity structure built for hydroelectric generation. The dam is FERC licensed. According to the FERC order issued in November 2001, the dam has a height of 21 ft and provides 12 ft of head (FERC 2001). It is a 126 ft long reinforced concrete dam surmounted by six 19 ft wide, 8 ft high radial gates, a 60 ft long left embankment, and a 55 ft long center embankment. It impounds approximately 1,575 acres of water at normal water elevation of 719 ft NGVD. There is a powerhouse containing two generating units for a total capacity of 425 kW. Currently the dam is being operated at run-of-the river. The project is considered part of the Velsicol Chemical Superfund Site (see also **Water Quality**). There is an all species no consumption advisory due to PCBs and DDT on the Pine River from Alma dam downstream (MDCH 2007). Currently the project is in noncompliance with several FERC Order articles including 406, 408, 409, 410, and 411 (C. Freiburger, MDNR, personal communication). The city of St. Louis is failing to monitor run-of-the-river operating mode and erosion control. This facility also has issues with passage of organic materials and disposal of materials from trash racks. In addition, the city is in noncompliance as they have not produced an approved wildlife plan, a monitoring plan for control of purple loosestrife and Eurasian milfoil, or an outreach program. The Habitat Unit of Fisheries Division, MDNR, will be following up with the numerous FERC noncompliance issues.

Water Quality

Water quality in the Tittabawassee River watershed is influenced by human uses of land and water including agriculture, industry, and suburban development. Specifics on Historic land use practices and development of the watershed can be found in the **History** section discussed earlier.

State and federal laws (e.g., Natural Resources Environmental Protection Act 1994 PA 451) have been developed to protect water quality (Legislative Council, State of Michigan 2006). Michigan Water Quality Standards (Part 31 of 1994 PA 451) protects each of the surface waters in the Tittabawassee River watershed for the following designated uses: warm and coldwater fisheries, other aquatic life, and wildlife; agriculture, industrial, and municipal water supply; navigation; and recreation. Waters of the state designated as trout streams by the Director of MDNR (Table 19) have more stringent dissolved oxygen and temperature standards to protected coldwater fish (Tables 20 and 21). Regulatory agencies monitor river water quality and water uses in a watershed to ensure minimum water quality standards are met, to determine compliance with the law, and to document water quality conditions in the watershed. MDEQ, Water Division is the lead regulatory agency for water quality in Michigan with assistance from Waste and Hazardous Materials and Remediation and Redevelopment divisions. MDEQ, Water Division has conducted biological and chemical surveys of a number of streams in the Tittabawassee River watershed. Aquatic habitat and water quality varies throughout the watershed. Some areas are quite healthy, while other areas are seriously degraded and are not supporting designated uses (Table 22).

The Clean Water Act (CWA) requires Michigan to prepare a biennial report on the quality of its water resources as the principal means of conveying water quality protection and monitoring information to the United States Environmental Protection Agency (USEPA) and the United States Congress. The Integrated Report satisfies the listing requirements of Section 303(d) and the reporting requirements of Section 305(b) and 314 of the CWA. The Section 303(d) list includes Michigan water bodies that are not attaining one or more designated uses and require the establishment of Total Maximum Daily Loads (TMDLs) to meet and maintain Water Quality Standards.

The Tittabawassee River watershed has historically suffered from poor water quality due to unregulated discharges by industries and municipalities. Water quality in the watershed is improving, and virtually all point source discharges are regulated. Major sources of water quality impairments continue to be dioxins, contaminated sediments, and nonpoint source pollution. Many studies on water quality have been completed for the Tittabawassee River watershed (Appendix B).

Dioxin Contamination

One of the current and most serious water quality issues in the watershed is the presence of elevated levels of dioxins and furans (a type of dioxin) in the lower Tittabawassee River. Higher than normal levels of dioxins have been found in Tittabawassee River sediment, floodplain soils, fish, and wild game animals harvested from the Tittabawassee River floodplain downstream of Midland. The following information is based on MDEQ (2006a), A. Taylor (MDEQ, personal communication), and K. Groetsch (MDCH, personal communication).

Dioxin is a group of 419 chlorinated chemicals with generally similar structures and chemical properties. This group includes chlorinated dioxins, furans, and polychlorinated biphenyls. Dioxins are formed as unwanted by-products of certain industrial manufacturing and burning activities. Pesticide manufacturing, chlorine manufacturing, burning household trash, and burning of industrial and medical waste products are major sources of dioxins. Because dioxins are usually found as mixtures and they share a similar mode of toxicity, the total toxicity of twenty-nine of the dioxin-like chemicals is usually evaluated together and expressed as a single toxic equivalent concentration (MDCH 2001).

Dioxins are very stable chemicals that can last in the environment for many years especially if buried in the sediments and not exposed to sunlight. MDEQ refers to them as persistent bioaccumulative compounds. Dioxins released from airborne sources usually settle out locally. When released into lakes and rivers, most dioxins accumulate in the sediment and biota. Dioxins attach to soil particles and persist for a long time, where they can be rereleased into the environment in the future (MDCH 2001).

Exposure to low levels of dioxins can cause cancer, liver damage, and disruption the endocrine system. Humans are mainly exposed to dioxins by eating animals and animal products (milk, eggs, etc.) that contain dioxins. People who regularly consume fish, fatty meats, or high-fat dairy may be exposed to higher levels of dioxins. Most dioxins taken in by humans and other animals are stored in fatty tissues and remain there for many years. Additional information on the potential health effects of dioxins are found in MDEQ (2006a).

Locations of Higher Dioxin Levels

The MDEQ has found higher than normal levels of dioxins in the soil and sediment samples taken from the channel and floodplain of the lower Tittabawassee River, downstream from Midland. Along the lower Tittabawassee River, elevated levels of dioxins and furans have also been found in sediments of the Tittabawassee River beginning downstream of Midland. Floodplain soil samples were taken from private property and from public parks including: West Michigan Park, Imerman Park, Freeland Festival Park, and property adjacent to Caldwell Boat Launch. The levels of dioxins found at these locations exceed Michigan’s generic residential direct contact clean up criteria and may exceed the action level of 1,000 parts per trillion (ppt) established by the Centers for Disease Control’s (CDC) Agency for Toxic Substances and Disease Registry (ATSDR). The elevated levels of dioxins in the sediments and floodplain soils are thought to be responsible for the increased levels of dioxin in the fish and wild game from the Tittabawassee River and floodplain (MDEQ 2006a). Elevated levels of dioxins have also been found in Saginaw River and Saginaw Bay sediments

Sources of Dioxin

The Dow Chemical Company (Dow), which has manufacturing in this area, is a source for the increased levels of dioxins and furans in the Tittabawassee River. Dow was incorporated in 1897 in

Midland, Michigan. Initially the company extracted chlorides and bromides from brine deposits under Midland and produced bleach and bromine. Today Dow is one of the largest chemical manufacturers in the world, producing a wide range of chemicals used in plastics, pesticides, and other products. Historically, at Dow's Midland facility, waste generated from production was stored on-site in large ponds which were periodically discharged to the Tittabawassee River. Dow currently operates on-site wastewater treatment facilities. Current emissions of dioxins from Dow's Midland facility are not thought to contribute significantly to the existing elevated levels of dioxins in and along the Tittabawassee River. Today, the major sources of dioxin contamination in the Tittabawassee River are the contaminated floodplain soils and river sediments that remain from Dow's past releases. There are dioxin removal actions currently being undertaken under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) program by EPA.

The Tittabawassee River is a "flashy" river that often overflows its banks (see also **Hydrology** resulting in the deposition of contaminated material onto the floodplain and in the redistribution of contaminated sediments. The presence of elevated levels of dioxins at depth in soils (down to 10 feet in some areas near the river's bank) indicates that contaminated soils and sediments have been accumulating for an extended period of time (ATSDR 2005).

Dioxin Contamination

On June 12, 2003, MDEQ issued a Hazardous Waste Management Facility Operating License to Dow for its Midland, Michigan Plant Site. The operating license requires Dow to address off-site releases of dioxins, and contaminated river sediments and floodplain soils of the Tittabawassee and Saginaw rivers.

The operating license also requires that Dow undertake Interim Response Activities (IRAs) to control exposures and limit recontamination until the full extent of the floodplain contamination can be determined and remediated (MDCH 2005). This is a very large and complex site of environmental contamination and it will take several years to identify and implement final corrective actions.

Michigan Department of Environmental Quality, MDCH, Michigan State University, and Dow are in the process of conducting extensive sediment sampling, and ecological risk assessment in the lower Tittabawassee and Saginaw river floodplains. Results to date can be found at MDEQ (2006a).

Dioxin-like compounds in the soil and sediments appear also to have entered the human food chain, as indicated by elevated dioxin concentrations in local domesticated animals (e.g., chicken eggs of free ranging chickens from the floodplain of the Tittabawassee River), wild game (turkeys, deer and squirrels) (MDCH 2005) and Tittabawassee River fish (ATSDR 2005). Michigan Department of Community Health (MDCH) has issued "no consumption" advisories on several species of fish and wild game on and around the floodplain (ATSDR 2005).

Natural Resource Damage Assessment

The Natural Resource Damage Assessment (NRDA) was created by Congress as part of the hazardous substances cleanup process. The purpose of NRDA is to restore, replace, or acquire the equivalent of natural resources that have been injured by hazardous substances and to compensate the public for past and future lost uses of the resources through additional restoration. In the NRDA process, government agencies act on behalf of the public to replenish the common store of natural resources for public use and enjoyment. These agencies are referred to as trustees for natural resources.

The NRDA trustees for the Tittabawassee River are the director of MDNR; the director of MDEQ; the attorney general of the State of Michigan; the U.S. Department of the Interior, represented by the U.S. Fish and Wildlife Service and the Bureau of Indian Affairs; and the Saginaw Chippewa Indian

Tribe of Michigan (http:www.fws.gov/midwest/TittabawasseeRiverNRDA). The trustees are assessing injuries to natural resources that have resulted from Dow. They will determine how much and what types of restoration are appropriate based on injuries to natural resources in the past and those that might be expected in the future.

The trustees are coordinating with the cleanup process for the river by integrating trustee concerns and data needs into cleanup investigations. The trustees will develop restoration plans in coordination with planning for river cleanup and will be responsible for oversight and implementation of these plans.

Point Source Pollution

There are 103 industrial storm water permits and 55 municipal and industrial discharges permitted to the surface waters in the Tittabawassee River watershed (Tables 23 and 24). These discharges are point source pollution since the source of the pollutants is distinct. Discharges are permitted by the State of Michigan through the National Pollution Discharge Elimination System (NPDES), which regulates discharges to surface waters.

Discharges to the Tittabawassee River include effluent from municipalities: wastewater treatment plants, water treatment facilities, and storm sewers; industrial discharges: contact and noncontact cooling waters, process wastewater, sanitary wastewater, groundwater remediation sites; and miscellaneous discharges from trailer parks, campgrounds, concentrated animal feeding operations, and highway rest areas. Permits issued to these dischargers contain limits for parameters of concern (e.g., metals, organics, dissolved oxygen (DO), carbonaceous biochemical oxygen demand, solids, nutrients, oil and grease, temperature, and chlorine) and are specific to each discharge. Limits for these parameters are based on the assimilative capacity of the receiving water and may incorporate mixing zones in rivers. Permits are issued for five years, and are reviewed by MDEQ Water Bureau staff before being reissued. Permits in the Tittabawassee River watershed were reviewed in 2003. In general, permitted dischargers were in compliance with specified limits.

As part of the NPDES system, any violations of these permits are required to be reported. There are also records of combined sewer overflows and storm sewer overflows maintained by MDEQ. Updated site information is available at MDEQ (2006b). Although there are occasional releases, most are of partially treated water (J. Bloemker, MDEQ Water Bureau, personal communication).

Nonpoint Source Pollution

Nonpoint source pollution does not originate from a specific point and enters surface water through atmospheric deposition or water transport. Nonpoint source pollutants in aquatic systems include sediments, nutrients, bacteria, organic chemicals, or other inorganic chemicals including metals. These pollutants derive from agricultural fields, livestock feedlots, surface runoff from construction sites, parking lots, urban streets, uncontrolled septic seepage, groundwater contamination, open dumps, industrial sites, and inadvertent chemical spills (Wesley 2005).

Nonpoint source pollutants have a variety of effects on aquatic systems. Many pollutants use oxygen during their breakdown process. This can limit or eliminate oxygen needed by fish and other aquatic organisms. Nutrients can lead to excessive aquatic vegetation growth which further depletes oxygen concentrations through decay and bacterial respiration. Metals, pesticides, and other toxics can accumulate in the aquatic food chain and have harmful effects on fish or lead to consumption advisories for anglers. Increased sedimentation can limit fish and macroinvertebrate habitat by covering gravel riffles and filling pools. Sediment particles often have nutrients attached to them.

Urban and agricultural runoff contributes significantly to water quality problems in the Tittabawassee River. In the Saginaw River/Bay Area of Concern, nonpoint source sediment pollution is listed as one of the contributing factors leading to impairments in fisheries habitat in Saginaw Bay and possible declines in the fisheries (Public Sector Consultants, Inc. 2002).

Construction activities can also be a source of nonpoint pollution along rivers. Michigan Department of Environmental Quality, Land and Water Management Division regulate construction activities adjacent to waterways and in floodplains. The biggest threat to the watershed from construction activities is sedimentation from uncontrolled runoff. Erosion control permits are required under Part 91 of the Michigan Natural Resources and Environmental Quality Protection Act (1994 PA 451), but too often local administrators of the law do not enforce permit conditions, do not monitor construction, or work is simply done without required permits.

Section 319 of the Federal Clean Water Act provides funding to address nonpoint source problems. Grants to local agencies or organizations are awarded and administered by the Water Division of the MDEQ. There are currently twelve completed and five ongoing Section 319 Grants within the watershed (Table 25). Many are associated with agriculture, road stream crossings, and general watershed projects. There are Section 319 projects in the Tittabawassee, Cedar, Salt, and Coldwater rivers, and Sturgeon Creek (C. Bauer, MDEQ, personal communication).

Storm Water Control

Storm water sewers, open road ditches, and drainage ditches collect both point and nonpoint sources of pollution and discharge them to the river. These discharges can have high chloride concentrations (from road salt), high nutrient and sediment loads, and can increase biological oxygen demand in the receiving stream. They also contribute oils, grease, and tars from roadways. Because storm water sewers usually drain large paved areas, during storm events they can contribute a significant portion of the flow in small streams. This can have short-term effects on aquatic communities in these streams, consequently developing into long-term effects. Increased discharges from several small sewer-influenced streams can have cumulative effects downstream by increasing flows to larger receiving rivers. National Pollution Discharge Elimination System permits are required for storm water discharges where large municipalities and industrial activities exist. There are 55 permitted industrial storm water and municipal discharges within the watershed (Table 24).

Sites of Environmental Contamination (Part 201 Sites)

Michigan Department of Environmental Quality, Remediation and Redevelopment Division, has identified 137 sites of environmental contamination within the Tittabawassee River watershed (Table 26). These sites are regulated under Part 201 of the Natural Resources and Environmental Protection Act, 1994 PA 451. Part 201 provides laws and promulgated rules for the identification and remediation of sites of environmental contamination, determines liable party responsibilities, and provides the regulatory framework for the remediation of these sites. These sites are leaking underground storage tanks, spills of waste products from industries, leaking solid waste management facilities, or improperly constructed wastewater treatment facilities. Such sites contaminate soils and groundwater. Ultimately, there is high potential for groundwater contaminants to migrate to the river and tributaries, especially in reaches with high groundwater flows. Long-term monitoring is required to assess any ecological effects to the system (Wesley 2005). Several cleanup projects have been started but will take many years to complete. Some cleanups will result in a discharge of treated groundwater to surface waters, under NPDES permit. There is the potential for trace amounts of contaminants to be discharged into the Tittabawassee River system through these clean up efforts. Accumulation of these trace amounts is of concern.

Michigan Department of Environmental Quality also maintains lists and oversees response activities for underground and aboveground storage tank facilities. These are separate from the known leaking sites discussed above. In 2006, there were 776 permitted facilities with underground storage tanks in the Tittabawassee River watershed. Records identify the number of tanks per facility, the number still in use, the number of releases, and whether releases are still open or closed. If they are closed, the risk to human health and the environment have been fully addressed. In April 2006, there were 770 tanks in use. These tanks store mostly petroleum and other hazardous products but not hazardous waste. Also in April 2006, there were 426 reported releases, of which 201 are still classified as open. These spills or releases have potential to migrate to groundwater and surface waters. There are a large number of underground storage facilities in the lower Tittabawassee, Tobacco, Chippewa, and Pine river watersheds.

Superfund Sites

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) provides a federal "Superfund" to cleanup uncontrolled or abandoned hazardous waste sites as well as accidents, spills and other emergency releases of pollutants and contaminants into the environment. The Superfund Program involves a state and federal partnership to cleanup some of the most complex and controversial sites in Michigan. The U.S. Environmental Protection Agency (EPA) has primary authority under CERCLA. Locations designated as Superfund sites have been nominated to be on the national priorities list by the state, in order to be eligible for federal superfund funding for cleanup. The state also is responsible for a 10% match to this funding and assumes long-term operation and maintenance responsibilities for CERCLA sites (MDEQ 2007a).

There are three Superfund sites within the watershed including the Velsicol site, the Gratiot County Landfill on the Pine River, and the Clare water supply in the Tobacco River drainage. Velsicol was proposed for the Superfund program in 1982 and accepted in 1983. The Clare water supply was also proposed for the program in 1982 and accepted in 1984. The Gratiot County Landfill was proposed and accepted in 1982.

Dissolved Oxygen, Temperature, Nutrients, and Bacteria

Temperature and oxygen are important components of fish habitat and determine where given fish species can survive. Fish live in temperature regimes that are generally characterized as warm and cold water. Warmwater species can be found in waters with mean water temperatures >70 °F (21 °C) during summer months; whereas, coldwater species require mean water temperatures <70 °F (21 °C) during summer months. In addition, most fish require moderate levels of DO (above 3 mg/l) in order to survive. Standards for DO and other parameters have been established to protect fish and other aquatic organisms. These standards are included in Part 4 Water Quality Standards in the Clean Water Act (Part 31 of 1994 PA 451), and are used to develop permit limits for NPDES permitted discharges. The water quality standard for DO in warmwater streams is 5.0 ppm (Table 21).

Michigan Department of Natural Resources, MDEQ, and USGS have collected stream temperature data for several tributaries in the watershed. Many of the parameters that MDEQ collects are stored in Storet. Fisheries Division has been deploying recording thermometers and the mean, minimum, and maximum July stream temperatures have been summarized in Table 27 (unpublished MDNR, Fisheries Division files

Bacteria are also important as they are potential hazards to human health and animals. Higher levels of certain bacteria can indicate the presence of untreated human or animal waste and can suggest the presence of other pathogenic microorganisms. County health departments are the lead agencies for monitoring bacteria. The species most often monitored for is *Escherichia coli.* High presence of *E. coli* may indicate failing septic tanks or other sources of waste entering water bodies. The Water Quality Standard for *E. coli* is a 30-day geometric mean of 130 counts/100 ml for total body recreation (MDEQ 1997). Health Departments will advise against body contact when daily samples exceed counts of 1,000 counts/100 ml. Some of the larger impoundments have had high *E. coli* counts in the past (Charles Bauer, MDEQ, personal communication). Areas that have bacterial issues will be discussed by individual subwatershed below.

Tainting of Fish

In the 1940s through the 1970s, there were frequent complaints and reports of chemical odors and tastes associated with fish harvested from the Tittabawassee River, Saginaw River, and Saginaw Bay. Sources of these tainting problems were directly related to the discharge of certain industrial chemicals such as phenols. In 1989, MDNR Water Quality Division conducted a fish flavor impairment study (Masterson 1989). Results from this study suggested that there was no significant flavor impairment in walleye from the Tittabawassee River. In 2000, MDEQ received no fish tainting reports. While this information suggests that the reports decreased, there has been no systematic effort since 1995 to verify the absence of tainting (Public Sector Consultants, Inc. 2002).

River Classification by MDNR, Fisheries Division

In 1967 Fisheries Division developed a Stream Classification System for the purpose of fisheries management. This classification characterized stream reaches with similar temperatures, water characteristics, and sport fish characteristics. Classification is largely based on presence and absence of sport fish. However, nonsport fish such as sculpin sp. and certain dace sp. are indicative of good water quality. Streams were identified as: 1) top quality coldwater streams capable of supporting self sustaining populations of trout; 2) second-quality coldwater streams that contain significant trout populations maintained by stocking; 3) top quality warmwater streams that contain self sustaining warmwater (and coolwater) sport fish; and 4) second-quality warmwater streams that have limited sport fish populations due to pollution, contamination, inadequate natural reproduction, or lack of suitable habitat (Figure 49). Most of the headwater streams are classified as either top or second quality coldwater streams. The classification is directly associated with geology, hydrology, and channel morphology. Top quality and second quality trout waters are often located in areas with glacial moraines, high rates of infiltration, and good groundwater flow. The remaining unclassified drainages and areas (Figure 49) are generally warmwater streams. Designated trout streams (Table 19) are discussed further in **Special Jurisdictions.**

Due to the limitations of simply describing stream segments by sport fish species and temperature, Seelbach et al. (1997) developed a system that was more landscape based for rivers of Lower Michigan including the Tittabawassee River. As described in **Geography**, valley segments are based on homogeneous portions of the river channel that share common features and flow through specific landscape units. These valley segments are highly influenced by geology, topography, and landform type. This system also considers predictable changes in physical parameters such as flow patterns, temperature, and energy; biological community; and stream size.

Consumption Advisories

The Fish Contaminant Monitoring Program is part of MDEQs comprehensive water quality monitoring strategy. The Michigan Fish Contaminant Monitoring Program consists of fish collections from streams and lakes, and caged fish studies. MDCH is responsible for establishing, modifying, and removing sport fish consumption advisories for Michigan's surface waters. Fish samples are analyzed for contaminants and compared to the fish consumption advisory trigger levels (Table 28). When concentrations of contaminants exceed a trigger level, a consumption advisory is issued for that species and water body. There are fish consumption advisories currently for the Tittabawassee River downstream of Midland and for the Pine River at Alma Impoundment and downstream of the Alma Dam (MDCH 2007; see also **Water Quality**).

In addition, there is a mercury advisory for all inland lakes and reservoirs in Michigan. No one should eat more than one meal per week of rock bass, yellow perch, or crappie over nine inches in total length; or more than one meal per week of bass, walleye, northern pike, or muskellunge of any size. Mercury is an airborne pollutant that can contaminate lakes and reservoirs regardless of the environmental health of a watershed. Advisories have also been put on wild game and soils for the floodplain (http://www.michigan.gov/deq/0,1607,7-135-3307_29693_21234-43808--,00.html#Wild_Game_Information).

Procedure 51

Rapid, qualitative biological assessments of wadable streams and rivers are conducted using the Great Lakes and Environmental Assessment Section Procedure 51, which compares fish and benthic invertebrate communities at a site to the communities that are expected at an unaffected reference site. This is a key tool used by MDEQ to determine whether water bodies are attaining Michigan Water Quality Standards. The biosurvey protocols evaluate the macroinvertebrate community, fish community, and habitat quality. Any one or combination of the three categories can be evaluated. The biological integrity of a stream is based on results of fish and macroinvertebrate communities. These protocols can become the yardstick used to measure effectiveness of Best Management Practices in controlling watershed-wide nonpoint source effects, and can help to predict potential intrawatershed or regional trends, and can help to determine the degree of use attainability of individual water bodies.

Biological and habitat data collected are part of five-year watershed surveys and are summarized in watershed reports (Appendix B). A list of reports is available on the MDEQ, Surface Water Quality Division's web site.

Summary of Water Quality Issues by River Section

Headwaters

Water quality is generally good. Portions of the East, Middle, and West branches of the Tittabawassee rivers and most of their tributaries are designated trout waters (Table 19). July temperatures are generally favorable for supporting trout. Especially cold tributaries include Cooks and Brick creeks, both on the East Branch of the Tittabawassee River. The upper West Branch of the Tittabawassee River had colder temperatures than the other two branches. Sedimentation is the primary factor affecting water quality (Table 22). There are agricultural programs designed to reduce sedimentation including fencing off livestock, cattle crossings, filter strips, and others which are encouraged and offered through the County Soil Conservation Districts. There are only four NPDES permits issued for industrial or municipal storm water discharge and no industrial discharges. MDEQ also maintains a list of part 201 sites under state lead (Table 26).

Middle

Water quality is generally good. A few tributaries are designated trout streams including Sugar Creek, the Sugar River, and its tributaries (Table 19). The Little Molasses River, Fish Creek, and the lower Sugar River all have somewhat warmer temperatures that no longer support trout (Table 27). Most of the main branches of the Tobacco and Cedar river systems are also designated trout streams and support excellent July temperatures (Tables 19 and 27). Like the main stem Tittabawassee River, the waters below Chappel Dam on the Cedar River and Beaverton Dam on the Tobacco River become too warm to support trout (Table 27). The main stem Tittabawassee River becomes highly influenced by the four major hydroelectric dams (Secord, Smallwood, Wixom, and Sanford) and the backwaters they create. The water becomes considerably warmer as the amount of surface area is increased and the flow is decreased. These impoundments have lake characteristics and are more subject to water recharge and extreme manipulations in water level and flow. Main stem water quality (i.e., pollutant) is not deteriorated due to industry. Here, major problems include sedimentation, riparian shoreline development, septic systems and enrichment, and erosion due to recreational use. Failing septic tanks have also been identified as a major problem. There are four storm water discharges and four industrial discharges permitted in this reach. The Tobacco River watershed also has issues which include livestock access, road stream crossings, and stream bank erosion that contribute to sediment loading to the system (Table 22). The Tobacco River and tributaries have potential to receive contamination through an additional 11 permitted storm water and 8 industrial discharges.

There is one Superfund Site in this part of the watershed. The Clare Water Supply was accepted for listing as a Superfund Site in 1984. The site covers most of downtown Clare and includes the city’s municipal wellfield. Two of the four municipal wells are contaminated with low levels of chlorinated hydrocarbons such as benzene. The aquifers are contaminated by an adjacent industrial park with sources including leaking underground storage tanks, above ground waste piles, sludge lagoons, and vapor degreasers that leaked through floor drains (EPA 2007b). MDEQ also maintains a list of part 201 sites under state lead (Table 26).

Mouth

The water quality of the Tittabawassee River from Sanford Dam down to the mouth is highly influenced by the hydroelectric dam operation and industrial discharges (both historic and present). The river here is a warmwater system with highly flashy flows. Due to inappropriate operation of the dams, the water can fluctuate several feet in a day. Stream bank erosion is prevalent, resulting in sedimentation problems.

In this reach, the influence of industry and development are reflected in the large number of permitted discharges (23 permitted storm water discharges and 18 permitted industrial discharges). Urban runoff from Midland also contributes storm water pollutants to the river. Urban runoff carries various pollutants such as sediments, nutrients, pesticides, bacteria, and toxic contaminants. The most severe water quality issue in this reach is dioxin contamination (see also **Water Quality**).

Water quality in the Salt River watershed is fair to good. Flashy flows and sedimentation due to agricultural drainages are the major deterrent to appropriate water quality. There are 10 storm water discharge permits and 5 industrial discharge permits in the Salt River watershed.

Water Quality in the Chippewa River watershed is good. It is somewhat influenced by agriculture and the development associated with the City of Mt. Pleasant. Artificial drainage is common in the eastern end of the watershed to facilitate farming and development. There are several drainages listed as not having enough data to positively assess whether designated uses are being met (Table 22). The Coldwater River is listed as having a threatened biological community from Littlefield Lake outlet to Vernon Road. There are 27 permitted storm water discharges and 9 permitted industrial discharges in the Chippewa River watershed. Most of these occur around the City of Mt. Pleasant.

Water quality of the upper part of the Pine River watershed is generally good. The Pine from St. Louis downstream is affected by agricultural practices, development, industrial development, and road stream crossings. The Pine River has 22 storm water discharge permits and 11 industrial discharge permits.

Water quality of the main stem Pine River is impaired and of particular concern from St. Louis to its confluence with the Tittabawassee River. Sediments around the St. Louis area have been contaminated with a variety of chemicals including DDT, PBB, and HBB resulting from the activities of the Velsicol Chemical Corporation and its predecessor the Michigan Chemical Corporation. Due to the complexity of the cleanup and chemicals involved, the Velsicol Site was nominated and declared a Superfund Site in 1983 (EPA 2007a).

As a result of this contamination, fish consumption advisories have been placed on fish from Alma Impoundment and all waters downstream of Alma Dam. On Alma Impoundment, women and children should not eat more than 1 meal per week of carp ranging from 6 to 26 inches, and no more than one meal per month of larger carp. Carp have been found to have high concentrations of PCB. Downstream from Alma Dam there is a no consumption advisory on any species of fish due to high levels of PBB and DDT.

There is an additional Superfund Site in the Tittabawassee River watershed, the Gratiot County Landfill that is located in the Pine River watershed. This landfill was operated in 1971 by the Gratiot County Board of Public Works for disposal of domestic, commercial, and industrial solid waste. Prior to 1977, the Michigan Chemical Corporation, later purchased by Velsicol Chemical Corporation, disposed of various wastes including PBBs at the landfill. These wastes leached into aquifers and nearby ponds and also contaminated a deeper aquifer, supplying drinking water to the region (EPA 2006). MDEQ also maintains a list of part 201 sites under state lead (Table 26).

Special Jurisdictions

Many agencies and governmental units have statutory jurisdiction over segments of the Tittabawassee River and lands within the watershed.

Navigability

The question of "navigability" has often come up in reference to statutory authority, recreational activity, and development and activity in the riparian corridor. The United States Army corps of Engineers has declared the Tittabawassee River to be navigable from the Dow Dam in Midland downstream to the mouth (MDNR 1993). The Michigan Supreme Court, in the resolution of more than a dozen cases, indicated that the Tittabawassee River and all of its major tributaries floated logs on a commercial basis during the lumbering era. Specifically mentioned are Tittabawassee River main stem, the Chippewa and Pine rivers, the main stem of the Tobacco River, and the North, Middle, and South branches of the Tobacco River.

Waters of the state are "presumed navigable" if (MDNR 1993):

> Flow exceeds 41 cubic feet per second, greater than 30 feet width and depth is greater than 1 foot or capable of floating loose logs, ties or similar products seasonally; used by fishing public for extended periods of time; stocked with fish by the state of Michigan; or waters susceptible to navigation by boats for commerce or travel.

All other tributaries of the aforementioned streams are presumed to be navigable. No waters within the Tittabawassee River watershed are specifically designated as non-navigable (MDNR 1979). The public has common right trespass on submerged soil but not the adjacent uplands, and has the right of fishing in navigable streams, subject to state regulation.

Federal Authority

The United States Army Corps of Engineers (USACE) has regulatory authority for the Tittabawassee River up to Dow Dam (W. Leiteritz, USACE, personal communication). This authority is mandated under Section 9 of the River and Harbors Act of 1899 to regulate activities in all waterways and wetlands (USACE 2005a). This gives the USACE the authority to oversee bridge, causeway, dams, and dike projects, and the discharge or fill materials associated with these projects under section 404 of the Clean Water Act.

Section 10 of the Rivers and Harbors Act of 1899 also gives the authority to USACE to oversee any structure or work in or over any navigable waters of the United States (USACE 2005b). This includes small floating docks, riprap, groins, beach nourishment, levees, and temporary measures such as cofferdams and storage and work areas.

Coastal Zone Management

The Tittabawassee River is not located in the Coastal Zone Management Area. Coastal Zone Management only has authority or jurisdiction in areas at the coast of Lake Huron or up to 1,000 ft inland. Authority or grants are also issued with waters of equal elevation. The nearest area under Costal Zone Management is the Saginaw River at the Bay and Saginaw county line, well downstream of where the Tittabawassee River enters the Saginaw River (D. Kenaga, MDEQ Water Bureau, personal communication).

Federally Regulated Dams

Jurisdiction by FERC in the Tittabawassee River is determined by the definition of navigability or by having been established by the Michigan Supreme Court. As such any hydroelectric dams in these reaches come under FERC licensing. These licenses cover the operation of hydroelectric dams and include protecting the resources by ensuring that projects adhere to quality standards and monitoring parameters including water temperatures, DO, contaminants, and sediments. These licenses also cover fish passage, project boundaries, studies, and public access issues. Dams within the Tittabawassee River falling under FERC jurisdiction include Secord, Smallwood, Edenville, and Sanford dams on the Tittabawassee River main stem; Chappel Dam on the Cedar River; Beaverton Dam on the Tobacco River; and the St. Louis Dam on the Pine River (see also **Dams and Barriers**).

Federal Emergency Management Agency (FEMA)

The primary mission of the Federal Emergency Management Agency is to reduce loss of life and property and protect the nation from all hazards, including natural disasters, acts of terrorism, and other human-made disasters, by leading and supporting the nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation. In the context of the Tittabawassee, FEMA oversees the National Flood Insurance Program (NFIP) and would have the ultimate oversight of each community's participation in the NFIP including local floodplain management and permits.

United States Fish and Wildlife Service–Lamprey Control

The Great Lakes Fishery Commission was established by the Convention on Great Lakes Fisheries between Canada and the United States, and was ratified in 1955. One primary responsibilities assigned to the Commission was to formulate and implement a program to eradicate sea lamprey populations in the Great Lakes. The Commission currently has an integrated pest management approach including use of lampricide to destroy larval sea lampreys (D. Lavis, USFWS, Ludington, personal communication).

The Convention on the Great Lakes Fisheries of 1955 also authorized the Commission under articles V and VI to "take measures and install devices on Great Lakes tributaries for the purpose of lamprey control" and to make use of official agencies of the federal government, Canadian provinces, and bordering states.

Sea lamprey control in the Tittabawassee River watershed is currently limited to periodic lampricide treatments of several tributaries including Carroll Drain, Bluff Creek, and Big Salt, Little Salt, Chippewa, Coldwater, and Pine rivers. These treatments potentially affect native biological communities and are particularly hazardous to invertebrate populations (D. Lavis, USFWS, Ludington, personal communication).

The Tittabawassee River at Dow Dam has been the subject of additional sea lamprey control activity in recent years. The site is routinely trapped in spring to capture migrating lamprey for use in the sterile male release program. Dow Dam ranks second in the numbers of adult lampreys trapped out of 161 potential sea lamprey control trapping areas considered by USFWS (D. Lavis, USFWS, Ludington, personal communication).

Natural and Scenic River Designation

No portion of the Tittabawassee River system has been designated by the state as a natural or scenic river under the Natural Rivers Act Part 305 of Public Act 451 of 1994 (Legislative Council, State of Michigan 2006). No portion of the Tittabawassee River is federally designated as a wild and scenic river under Wild and Scenic Rivers Act, PL 90-542 of 1968 (D. Pearson, Fisheries Division, personal communication).

County Authorities

County Drain Commissioners have authority to establish designated county drains under the Drain Code (P.A. 40 of 1956). This authority allows for construction, maintenance, inspection, and improvement of all designated drains. Maintenance and improvement activities include deepening, straightening, widening, relocating, dredging, and enclosing. Activities carried out under the authority of this act are not subject to MDEQ approval if applied to drains designated before 1972 (see also **Soils and Land Use** and **Water Quality**). The Salt, Chippewa, and Pine rivers have the most designated drains (see Table 29 for designated drains, length of individual drains, and their dates of establishment by subwatershed).

Maintenance and operations of many lake-level control structures also falls under the responsibility of the Drain Commissions, particularly those set by Part 307 of the Natural Resources and Environmental Protection Act (1994 PA 451), formerly the Inland Lake Level Act (PA 146 of 1961). Methods of operations, set by court orders, are at the discretion of each drain commissioner. In addition, MDEQ has jurisdiction for resource issues. This is also discussed in **Dams and Barriers**.

County road commissions also have the ability to affect the watershed by the design and maintenance of county roads. Road crossings can negatively affect drainages by increasing sedimentation, preventing migration of aquatic species (e.g., perched drains), accelerating delivery of precipitation to the channel (causing high flow events), and allowing transport of chemicals (e.g., oil and gasoline) to rivers (see also **Soils and Land Use** for additional information).

State Government

Water Quality

Michigan Department of Environmental Quality administers the Federal Water Pollution Control Act (Federal Clean Water Act, Section 404) under the Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, part 31. This authority allows the state to protect and conserve Michigan's water resources and to control pollution of surface or underground waters. Specifics are discussed in **Water Quality**.

Dredge and Fill Activities

Michigan Department of Environmental Quality also administers parts 301 and 303 of the Federal Water Pollution Control Act. Part 301 authorizes the state to regulate activities including: dredge or fill of bottomlands; construction in bottomlands; marina construction and operations; creation, enlargement or reduction of inland lakes or streams; construction or dredging of wetlands within 500 ft of the ordinary high water mark of an existing lake or stream; and connecting any natural or artificial waterway with any existing water body. Part 303, wetland protection, regulates activities in wetlands including placement of fill, removal of soils; construction; and draining surface waters.

Designated Trout Streams

The Department of Natural Resources has the authority to regulate hunting, fishing, boating, and other recreational activities. MDNR, Fisheries Division has categorized segments of streams and tributaries as either warm or cold water. Some coldwater streams are capable of supporting trout based on temperature, water quality, and habitat. MDNR, Fisheries Division has designated some streams and tributaries in the Tittabawassee River watershed as trout streams—Upper main stem, Tobacco, Chippewa, and Pine rivers (Table 19; MDNR, Fisheries Division, Director's Field Order 210.04). This designation sets water quality standards for specific reaches and governs fishing seasons and fishing gear types.

Tribal

In 2007 a consent decree was signed between the five tribes of the 1836 Treaty area, the State of Michigan, and the United States government. This decree stipulates that tribal members can exercise certain hunting, fishing, and gathering rights. The five tribes federally recognized in the 1836 Treaty area are the Bay Mills Indian Community, Sault Ste. Marie Tribe of Chippewa Indians, the Grand Traverse Band of Ottawa Indians, the Little River Band of Odawa Indians, and the Little Traverse Bay Band of Ottawa Indians. A portion of the Tittabawassee River watershed is located within the 1836 Treaty area (Figure 50). The upper Tobacco River and its tributaries, the upper Chippewa River and tributaries, and the upper Pine River and tributaries fall within this tribal boundary. There are also several lakes that fall within this area. Details of the Decree are available at the MDNR Fisheries Division website: http://www.michigan.gov/dnr/0,1607,7-153-10364_47864---,00.html.

The Isabella Indian Reservation is located within the Tittabawassee River watershed. The reservation covers an area of 214.3 square miles (137,179 acres) and occupies a large portion of the Chippewa and Salt river watersheds (Figure 50). Under the Treaty of 1855, members of the Saginaw Chippewa tribe were deeded land and encouraged to file land claims within the tribal boundary (see also

History). Before and during the lumber era many claims were sold. Today, the reservation boundary covers a six township area, but there are many private landholdings intermixed. The Saginaw Chippewa Tribe follows state and federal regulations that govern hunting and fishing activity. Members of this tribe are stakeholders and participate in watershed and other activities involving the Tittabawassee River.

Public Lands

There are 165,753 acres of public land in the Tittabawassee River watershed (Table 28), approximately 10% of the watershed. The majority of public land in the watershed is owned by the State of Michigan and maintained as state forest (Figure 51). Most of these state forest lands are concentrated in the headwater and middle segments of the main stem. In addition, there are numerous township, village, county and city parks.

Wilson State Park is the only state park in the Tittabawassee River watershed. There are four state game areas: Martiny State Game Area and Haymarsh Lake State Game Area in the Chippewa River watershed, and Vestiberg State Game Area and the Edmore State Game Area in the Pine River watershed. The only federally owned land is the Shiawassee National Wildlife Refuge, located in the main stem mouth segment.

Biological Communities

Original Fish Communities

Presettlement and early settlement species assemblages are not available for the Tittabawassee River watershed. Estimates of the original fish community are based on historic writings and the assumption of connectivity with the Great Lakes.

The Tittabawassee River watershed historically provided spawning, nursery, and refuge habitat for potamodromous fishes migrating up from Saginaw Bay, Lake Huron. Based on commercial fishing records from the 1900s Cleland (1966) listed the following species as historically present in the Saginaw Valley: lake sturgeon, longnose gar, bowfin, longnose sucker, white sucker, silver redhorse, golden redhorse, shorthead redhorse, yellow bullhead, brown bullhead, channel catfish, northern pike, lake trout, white bass, rock bass, smallmouth bass, largemouth bass, yellow perch, walleye, and freshwater drum. All of these species historically had access to the Tittabawassee River watershed and likely used the main stem and its tributaries to complete a portion of their lifecycle.

Early settlement revolved around fisheries. As described in **History**, the Tittabawassee and Saginaw rivers teemed with fish in the early 1800s, providing an important source of food for Indians and European settlers alike. Lake sturgeon earned the nickname “Saginaw Beef” by settlers. Records indicate that the river was inhabited by lake trout, pike, suckers, whitefish, perch, black bass, catfish, and walleye in the early 1800s (Yates 1987). The Saginaw basin fish trade was estimated at $40,000 in 1858 and included lake sturgeon, lake trout, muskellunge, walleye, sucker species, whitefish, perch, sunfish species, black bass, gar, and catfish (Mills 1918; Fox 1958).

Factors Affecting Fish Communities

The Tittabawassee River watershed changed dramatically during European settlement. Effects of damming, logging, development, sedimentation, and pollution are discussed in greater depth in **Geology**, **Hydrology**, **Channel Morphology**, **Soils and Land Use**, and **Water Quality.** Human activities that affected the landscape and water affected the fish community. Invasive pest species and introduced species have also affected the fish community.

Stream fish often require different habitats for spawning, feeding, and refuge and must be able to migrate between these habitats to complete their lifecycles (Schlosser 1991). Human activities that alter spawning, feeding, or refuge habitat or that limit access to these critical habitats can negatively affect fish communities by disrupting a portion or all of a species lifecycle.

The original fish habitat was greatly altered by European settlers and their activities. Presettlement vegetation along the banks originally provided shading and bank stabilization. This vegetation consisted largely of stands of white pine, hemlock, beech, sugar maple, and swamp forests (Albert et al. 1986). Downed trees and logs in the presettlement era provided an abundance of fish habitat both directly and by creating undercut banks. With stabilized banks and ample wetland complexes, the river had a stable flow, good groundwater recharge, and more filtered surface runoff. This stable system provided spawning, nursery, and refuge habitat for native species and potamodromous fish of Saginaw Bay.

The logging era denuded much of the landscape and most of the major tributaries and the main stem Tittabawassee River were used to transport logs which had major affects for the fish community. With this industry came removal of bank vegetation and habitat, destabilization of banks, scouring from log drives, dams, mills, soil erosion and sedimentation, and temperature changes. Negative effects on fish communities resulted from loss of critical habitat and reduced water quality. Due to lack of vegetative cover and log drives, flashiness of flow became common. Sawdust and sedimentation caused fish and fish eggs to be suffocated. Direct contribution of pollutants from sawmills and other industries also caused degradation of water quality. Potamodromous fish runs and even local fish runs were blocked by damming of rivers. Dams degraded the higher quality and higher gradient water needed by a variety of fish species and warmed water temperatures. Dams created unfavorable conditions that altered fish communities to favor fewer more tolerant species (Cushman 1985). Additionally, potamodromous fish often collect below dams and are more vulnerable to harvest.

Agricultural development was next to affect the fish community. Draining swamps, plowing, increased sedimentation, and direct influence of pesticides all negatively altered the fish community and reduced diversity. Reduced canopy cover, and functional wetlands and ditching and draining caused increased flashiness in the river system. Altered flow regimes resulted in warmer and more variable water temperatures favoring more tolerant species. Channelization (dredging) reduced habitat by eliminating natural pool-riffle-run sequencing and meanders of streams. The erosion that came from agricultural practices also buried gravel, cobble, and rock spawning substrates. By the late 1800s, the effects of logging industry, settlement, and agriculture coincided with the extirpation of the river spawning populations of lake trout, lake sturgeon, lake herring, and lake whitefish in the Saginaw River basin (Leonardi and Gruhn 2001). Saginaw Bay supported early commercial walleye fisheries dating back to the 1830s and this fishery was largely supported by reproduction in the watershed’s rivers and Saginaw Bay’s offshore reefs. Lumbering and agricultural activities resulted in degradation of habitat and consequently river-based reproduction was lost (Fielder and Baker 2004).

Development of the chemical industry was next to scar and degrade the fish community. Dow Chemical Company formed along the Tittabawassee River in Midland and produced a wide variety of chemicals, compounds, and products. Dow has been the subject of controversy for many years and at present dioxin is the largest contamination issue surrounding the company and the watershed. This subject is discussed in detail in **Water Quality** and **History**. Direct discharges, damming, and development all have resulted in less diversity with more tolerant species dominating. Dow Dam is the first dam on the system which during most of the year prevents fish from migrating upstream of

Midland and entering the Chippewa, Pine, or Salt rivers. A second chemical company, the Michigan Chemical Company (renamed Velsicol) was constructed along the Pine River in St. Louis. This company produced the pesticide DDT and the fire retardant PBB. Additional information can be found in **History** and **Water Quality**. Again species tolerance to these pollutants is reflected in the distribution of the present fish community.

Of the changes caused by humans, dams have had the greatest effects on fish communities. Construction and operation of the four major hydroelectric dams on the main stem Tittabawassee River (1923–25), the hydroelectric dam on the Tobacco River at Beaverton, the St. Louis Dam on the Pine River, and the retired Chappel Dam on the Cedar River near Gladwin all degraded the fish community. Effects of the dams on the habitat and fish community are discussed more thoroughly in **Dams and Barriers**. Hydrology, temperature, sedimentation, channel diversity, direct blockages, inundation of critical high gradient habitat result in reduced diversity and degraded fish habitats. The impoundments these dams create provide some atypical recreational benefits. The fish community is more lentic and typically provides substandard fisheries (see also **Dams and Barriers**).

Development of dense population centers also affected fish communities. Urbanization and industrialization increased the discharges of human wastes and synthetic pollutants into the river, degrading water quality. Road systems and impermeable surfaces resulted in accelerated surface water loading, less stable flows, warmer temperatures, and nutrient loading. The degraded water quality, flow instability, and habitat loss favors only the most tolerant, less desirable species.

Riparian development has greatly affected fish communities. Riparian frontage on lakes, streams, and impoundments was developed for housing and valued for its aesthetic appeal. Riparian development has been accompanied by reductions and changes in riparian vegetation that can result in increased run-off, increased water temperatures because of decreased shading, and contamination from pesticides and fertilizers used on lawns and gardens near the water. In addition riparian residences often incorporate septic systems and when these systems are faulty or fail, they can add nutrients and pathogens directly to the river. Riparian development also has been associated with increased construction of lake-level control structures that have resulted in loss of critical spawning habitats for fish and disruption of fish migration (discussed in **Dams and Barriers**).

Species that have colonized the area or been introduced have also greatly affected fish communities. Carp was introduced into Michigan waters in 1885 (Leonardi and Gruhn 2001). Problems with carp are well documented. Where populations are high, aquatic vegetation is lost and water quality is reduced. Other introduced species and colonized nonindigenous species in the watershed include zebra mussel, rusty crayfish, goldfish, sea lamprey, alewife, rainbow smelt, white perch, round gobies, grass carp, and flathead catfish. Many times introduced or colonized species tend to out compete and displace native fish species (see also Aquatic Nuisance Species).

Present Fish Communities

Based on Bailey et al. 2004 and Michigan Department of Natural Resource, Michigan Department of Environmental Quality, and US Fish and Wildlife Service survey records, the present fish community of the Tittabawassee River is composed of 75 native species, 14 introduced or colonized species, and 4 additional species where the status of distribution is unknown because there have been no recent findings or surveys (Table 31). Two species formerly indigenous to the Tittabawassee River watershed are believed to be extirpated: cisco and lake whitefish. Lake sturgeon, historically very common, are listed as threatened and have been known to be caught on occasion in the Tittabawassee River main stem. The pugnose shiner, listed as a species of special concern, has not been found recently and the status of this species is unknown. Detailed current distribution maps of each species are found in Appendix C.

Headwaters

Portions of the East, Middle, and West branches of the Tittabawassee River are designated trout waters (Table 19). These reaches are generally above impounded water and are located in permeable glacial moraines. These reaches typically support coldwater species including resident brown trout and, in the upper headwaters, brook trout. Other expected species, include blacknose dace, creek chubs, darters, northern redbelly dace, log perch, and mottled sculpin.

Some stream reaches in the headwaters segment are also influenced by some human-made lakes, natural lakes, and connected ponds. The dominant species in these reaches, like sunfishes and minnow species, are tolerant of warmer water and generally prefer more lentic conditions.

Middle

Water quality of the main stem–middle river segment is highly affected, by the four large hydroelectric dams on the main stem and also by several other large dams on some tributaries (see also **Dams and Barriers**). Altered temperatures, fragmentation, and altered habitat and flow have dramatically changed fish assemblages in many reaches.

All four of the large impoundments on the main stem (Secord, Smallwood, Wixom, and Sanford lakes) have similar fish communities dominated by cool- to warm-water fishes that are more indicative of lake rather than the riverine environments. These impoundments are dominated by sunfishes including crappie (both black and white), bluegill, pumpkinseed sunfish, green sunfish, and rock bass. Largemouth bass, smallmouth bass, northern pike, northern muskellunge, walleye, and channel catfish are the top predators in these systems. Yellow perch are also present in the impoundments although population sizes are typically low. Impoundments on the main stem also have sizable populations of a variety of redhorse sucker species, white sucker, carp, and black, brown, and yellow bullhead.

Wiggins Lake is an impoundment of the Cedar River, Ross Lake an impoundment at the confluence of the Tobacco and Cedar rivers, and Lake Lancer is an impoundments of the Sugar Rivers. These water bodies share the fish community characteristics described above for the main stem impoundments. The only difference is in management of predator species. Northern muskellunge have been stocked and are established in Ross Lake. Wiggins Lake and Lake Lancer impoundments are not stocked currently with muskellunge, but have good populations of northern pike.

Sugar Creek and the upper Sugar River support populations of brook and brown trout as well as a mix of more thermally-tolerant species, indicating connections to lakes or impoundments. Much of Sugar River is affected by Lake Lancer. Downstream of Lake Lancer water temperatures typically exceed 70°F in summer making this section of river unsuitable for trout. Prior to construction of the impoundment, the Sugar River likely supported trout from the headwaters to the confluence with the main stem Tittabawassee River. Fish species present in the impoundment are more typical of lentic conditions and are able to tolerate warmer temperatures.

The upper Middle, North, and South branches of Tobacco River, Cedar River, and many tributary headwater streams are also designated trout streams (Table 19). These coldwater streams, like the coldwater streams found in the Headwater segment, are above impounded water and are located in permeable glacial moraines. Headwater streams are typically dominated by brook trout. As these systems get bigger and somewhat warmer, brown trout dominate and sculpin, dace, and darter species may be present. Presence of warmwater species like bass and stonecats in the lower Tobacco and Cedar rivers suggests the influence and connectivity to warmer stream habitat created by Ross and Wiggins lakes.

Other tributaries including the Little Molasses River, Fish Creek, and lower Sugar River have relatively lower flows of groundwater, are slightly warmer, and support northern pike, brown bullhead, largemouth bass, smallmouth bass, pumpkinseed sunfish, and rock bass.

Mouth

This segment of the main stem is a very large warmwater system. The fish population is influenced by several factors including effects of the hydroelectric dam at the Village of Sanford, tributary flows, Village of Sanford, City of Midland, development associated with these municipalities, and directly by the Dow Dam in Midland.

The river reach from the Village of Sanford to Dow Dam has varying substrate with a substantial amount of cobble and gravel. Surveys and fishing reports indicate that a variety of species typical of large cool to warmwater rivers inhabit this area. Fish species present upstream from Dow Dam include smallmouth bass, rock bass, yellow perch, walleye, and redhorse species. From Dow Dam downstream, the bottom becomes dominated by sand and clay. Fish habitat in the form of woody structure and channel pilings is also common in the lower river. The main stem Tittabawassee River is dominated by a variety of species including carp, channel catfish, white suckers, freshwater drum, emerald shiners, golden redhorse, gizzard shad, northern hog suckers, northern pike, rock bass, shorthead redhorse, smallmouth bass, walleye, white bass, yellow perch, longnose gar, logperch, and quillback. Flathead catfish were first documented in this reach in 2005. A number of species seasonally migrate from Saginaw Bay into this section of river including walleye, northern pike, white bass, sucker species, gizzard shad, and others. Upstream movement of these species is limited by Dow Dam, but seasonal flooding does allow for some passage. If Dow Dam was removed or continuous passage was provided, many species whose distribution and numbers are restricted by the dam could gain access to additional habitat for spawning, nursery, and feeding in the miles of tributary waters and main stem that would be available. Lake sturgeon, a threatened species, historically migrated up the Tittabawassee River, but now their upstream progress is limited by Dow Dam. There is also a huge walleye run in the Tittabawassee River, and streamflow during this run often isn’t great enough to allow fish to pass upstream of Dow and into the Chippewa and Pine rivers. Providing consistent passage would improve walleye spawning success and would result in more walleye recruitment in Saginaw Bay.

The fish community of the Salt River is more typical of a medium-size warmwater system. Many tributaries entering the Salt River are agricultural drains. Fisheries Division has little survey data on smaller drainages. Species collected and expected are indicative of warmwater, more lentic systems.

Chippewa Lake covers 770 acres and is the headwaters of the West Branch of the Chippewa River. Primary game fish species in Chippewa Lake include walleye, black crappie, bluegills, largemouth bass, smallmouth bass, northern pike, rock bass, tiger muskellunge, warmouth, and yellow perch. Surveys in 1987 and 1988 also showed a presence of bowfin, golden shiners, grass pickerel, longnose gar, bullheads, and white suckers. No reports of tiger muskellunge catches have been received since the tiger muskellunge stocking program ended.

The outflow of Chippewa Lake forms Chippewa Creek which flows in Martiny Lake flooding in north-central Mecosta County. The flooding is a large complex of relatively shallow warmwater lakes and, together with the surrounding lands, is managed as a state game area. Lakes in this flooding include Big Evans, Lower Evans, Lost, Tubbs, Saddlebag, Dogfish, Boon, Bass, and Diamond lakes. The first survey of the entire complex was completed in 2005. Species inventoried included black crappie, bluegill, bluntnose minnow, bowfin, brown bullhead, lake chubsucker, white sucker, golden shiner, grass pickerel, hybrid sunfish, largemouth bass, central mudminnow, northern pike, pumpkinseed sunfish, rainbow darter, rock bass, warmouth, yellow perch, and yellow bullhead.

From the outlet of Martiny Lake (Winchester Dam) the river is a medium-sized warmwater stream. Michigan Department of Environmental Quality surveys in 1994 revealed presence of central mudminnow, hornyhead chub, creek chub, common shiner, blacknose dace, white sucker, northern hog sucker, stonecat, rock bass, green sunfish, pumpkinseed sunfish, bluegill, warmouth, and johnny darter

The North Branch of the Chippewa West River originates in southwestern Clare County and flows west to southeastern Osceola County, south to Mecosta County to the town of Barryton where it converges with the West Branch of the Chippewa River. Topography and geology in the area make this branch and its tributaries a coldwater stream. The West Branch of the Chippewa River and its tributaries are designated trout streams (Table 19). Temperature data from the North Branch of the Chippewa West River and tributaries show they are capable of supporting a coldwater fish community (Table 27). Michigan Department of Environmental Quality conducted a fish survey on the North Branch of the Chippewa West River just above Barryton. Species collected included brook trout, grass pickerel, hornyhead chub, creek chub, common shiner, mottled sculpin, white sucker, hog sucker, rock bass, pumpkinseed sunfish, bluegill, rainbow darter, fantail darter, johnny darter, and blackside darter. Little data are available on smaller tributary waters.

From the confluence of the North Branch of the Chippewa West River and the West Branch of the Chippewa River to Lake Isabella, the main stem of the Chippewa River is roughly 35–45 ft wide and is considered a warmwater stream at this point. The MDEQ 1992 fish survey collected lamprey ammocoetes, central stoneroller, hornyhead chub, creek chub, common shiner, fathead minnow, northern redbelly dace, blacknose dace, river chub, white sucker, northern hog sucker, stonecat, rock bass, smallmouth bass, pumpkinseed sunfish, green sunfish, black crappie, largemouth bass, rainbow darter, Iowa darter, fantail darter, and blackside darter.

Lake Isabella is a semiprivate impoundment that is only accessible from the river inlet and outlet. The lake supports a warmwater fishery and has never been surveyed. According to reports from MDNR Law Division, the lake has largemouth bass, smallmouth bass, black crappie, bluegill, northern pike, and walleye. Correspondence files (1970–present) indicate black bullhead, yellow perch, pumpkinseed sunfish, warmouth, brown bullhead, carp, and green sunfish to be present.

The Coldwater River originates above Littlefield Lake in northern Isabella County and flows through Littlefield Lake, Coldwater Lake, and then enters the main stem Chippewa River below Lake Isabella. The Coldwater River from Littlefield Lake to Weidman Pond (Lake of the Hills east) is a small coolwater stream. Recent surveys are limited, but the system should support a variety of minnow species. MDNR surveys conducted in 1962 found brook trout, northern pike, pumpkinseed sunfish, largemouth bass, hog sucker, creek chub, hornyhead chub, blacknose dace, rainbow darter, blackside darter, johnny darter, common shiner, central stoneroller, and mottled sculpin. From Weidman Pond to Coldwater Lake, the river is warmer and wider. In addition to minnow species, this stretch gets a spawning run of walleye from Coldwater Lake, and possibly from adjoining lakes. Other fish species that may be present include white sucker, redhorse, black bullhead, northern hog sucker, and carp. From Coldwater Lake to the confluence of the Chippewa River, the Coldwater River supports a warmwater fish community, much like the main stem Chippewa River.

Historically, Littlefield Lake (183 acres) supported trout, cisco, and smelt populations. Beginning in the 1950s, lake trout, splake, rainbow, and brown trout were all stocked into the lake at various times. The lake supported a “two story” fishery with the above mentioned species in the lower deep cold layers and warmwater species in the shallow warm layers of the lake. These warmwater species included: largemouth bass, bluegill, longear sunfish, yellow perch, white sucker, rock bass, northern pike, common shiner, hornyhead chub, johnny darter, Iowa darter, and bluntnose minnow. Trout stocking was discontinued in 1991 and walleye stocking was initiated. The most recent survey, 1995, found black crappie, bluegill, largemouth bass, northern pike, and walleye. The smelt fishery appears to have collapsed due to predation and a beaver dam blockage of Sucker Creek, a tributary to the lake that was a primary spawning area. Today's fish population is probably a mix of warm and coolwater species. In recent years, no smelt, trout, or cisco have been reported in any surveys or by anglers.

Weidman Pond is an 80 acre impoundment (Mill Pond Dam) on the Coldwater River. The most recent fish survey, 1994, found 13 species including northern pike, smallmouth bass, largemouth bass, black crappie, bluegill, pumpkinseed sunfish, channel catfish, carp, white sucker, yellow bullhead, black bullhead, brown bullhead, and golden shiner.

Coldwater Lake is a 294 acre impoundment located in the downstream reaches of the Coldwater River. Fishing reports and the last several fish surveys indicate the presence of walleye, northern pike, largemouth bass, smallmouth bass, black crappie, bluegill, redhorse, common shiner, carp, bowfin, white sucker, rock bass, yellow perch, hornyhead chub, and logperch.

Below Coldwater Lake the main stem Chippewa River is free flowing and unimpounded. This stretch of river supports excellent smallmouth bass populations. Additionally northern pike, walleye, rock bass, and sucker species are abundant. Michigan Department of Environmental Quality's survey of 1992 also found rainbow trout, central mudminnow, central stoneroller, hornyhead chub, finescale shiner, fathead minnow, longnose dace, river chubs, white sucker, northern hog suckers, black redhorse, golden redhorse, stonecat, rock bass, green sunfish, pumpkinseed sunfish, bluegill, black crappie, smallmouth bass, rainbow darters, fantail darter, johnny darter, blackside darter, logperch, creek chub, rosyface shiner, pearl dace, and brown bullhead. The rainbow trout found were probably resulting from a steelhead stocking program (see also **Fisheries Management**). A survey was conducted in 1993 with the fish toxicant, rotenone, to assess the fish population and to compare with other survey collection methods. A total of 33 species were collected, game fish represented 6.8% of the total catch by weight and the river had a biomass of 283.7 lbs per acre. Additional species found not recorded in other surveys included shorthead redhorse, northern redbelly dace, sand shiner, spotfin shiner, bluntnose minnow, channel catfish, brown trout, carp, and brook stickleback. The Natural Features inventory lists the pugnose shiner, a species of special concern, as occurring within this watershed.

The North Branch of the Chippewa East River flows through a highly agricultural area and has a warmwater fish community more typical of heavily channelized agricultural drains. A MDEQ survey in 1997 collected American brook lamprey, central mudminnow, central stoneroller, hornyhead chub, creek chub, golden shiner, common shiner, blacknose shiner, bluntnose minnow, blacknose dace, mottled sculpin, white sucker, northern hog suckers, golden redhorse, tadpole madtom, brook stickleback, rock bass, green sunfish, largemouth bass, rainbow darter, Iowa darter, fantail darter, and johnny darter. The geology of this area has less morainal influence and is dominated by a higher percentage of less permeable soils (see also **Geology**). Stevenson Lake is connected to this river segment and contains similar species.

The Little Salt River enters the Chippewa River from the south, approximately 8 miles upstream of the Pine River. A MDEQ survey in 1992 found central mudminnow, central stoneroller, hornyhead chub, creek chub, common shiner, bluntnose minnow, suckermouth minnow, river chubs, white sucker, northern hog sucker, golden redhorse, stonecat, rock bass, green sunfish, smallmouth bass, rainbow darter, fantail darter, johnny darter, and blackside darter. The Little Salt River is a medium-sized warmwater stream.

Most tributaries to the Pine River in Isabella and Montcalm counties are designated trout streams (Table 19). These small streams support populations of brown and brook trout, and minnow species indicative of small cold headwater streams. The upper headwater streams like Skunk Creek, Stoney

Brook, and Cedar Creek are dominated by brook trout. A 1996 MDEQ fisheries survey of Stoney Brook found blacknose dace, brook trout, central mudminnows, creek chubs, and rosyface shiners. Species not recorded, but probably present include northern redbelly dace and mottled sculpin.

The main stem Pine River supports a good brown trout population through most of Isabella County and is a designated trout stream until it flows into Gratiot County. MDNR, Fisheries Division has conducted many trout surveys and the river is dominated by brown trout. A few brook trout have been collected as well, probably migrating from upstream tributaries. Also captured were a variety of sucker species and coldwater minnow species. A more complete survey in 1992 found redbelly dace, brown trout, brook trout, creek chub, white sucker, common shiner, northern hog sucker, blacknose dace, bluntnose minnow, pearl dace, brook stickleback, lamprey, central stoneroller, hornyhead chub, johnny darter, central mudminnows, rock bass, and blacknose shiner. From Gratiot County downstream, the Pine River warms and supports cool and warmwater species.

Alma Impoundment, 140 acres, has the typical fish community found in most central Michigan warmwater impoundments. Species captured in the MDNR, Fisheries Division survey in 1995 include black crappie, bluegill, bullhead, carp, channel catfish, largemouth bass, northern pike, pumpkinseed sunfish, rock bass, smallmouth bass, white sucker, and yellow perch. No minnow species were sampled, but those common to warmwater steams and lakes are presumably present. Effects of dams are discussed in the **Dams and Barriers** section including fragmentation, alteration of riverine habitat, and warming. The fish community in impoundments is more similar to that of a lake than a river.

St. Louis Impoundment, 1,575 acres, has contamination issues and numerous fish advisories (discussed in **Water Quality)**. This generally is not limiting presence or abundance of fish species. A MDNR, Fisheries Division survey in 1995 captured black crappie, bluegill, brown bullhead, common carp, channel catfish, catfish, white suckers, green sunfish, white suckers, northern pike, pumpkinseed sunfish, rock bass, smallmouth bass, and yellow perch.

From St. Louis Impoundment downstream, the Pine River is a large warmwater stream. There is also a no consumption advisory on this stretch (see also **Water Quality**). A MDEQ 2002 survey rated the fish community as excellent. Sixteen species including central mudminnow, golden shiner, spottail shiner, carp, hornyhead chub, common shiner, rosyface shiner, spotfin shiner, mimic shiner, bluntnose minnow, brook stickleback, white sucker, northern hog sucker, golden redhorse, shorthead redhorse, yellow bullhead, stonecat, rock bass, green sunfish, bluegill, smallmouth bass, rainbow darter, and johnny darter were identified. A MDNR, Fisheries Division survey in 2002 also confirmed the above species and additionally recorded brassy minnow, channel catfish, common stone roller, emerald shiner, gizzard shad, longear sunfish, and sand shiner.

Aquatic Invertebrates

MDEQ, Water Bureau and specifically the Great Lakes and Environmental Assessment Section (GLEAS) conducts surveys to assess the condition of waters based on abundance and diversity of fish, macroinvertebrates, and habitat of the survey site. The methods used (Procedure 51) are discussed in **Water Quality.** Macroinvertebrates included in these evaluations are sponges, moss animals, worms, arthropods (scuds, sow bugs, spiders, crayfish, insects), and mollusks. Besides being water quality indicators, macroinvertebrates are also an important food source for fish, birds, mammals, reptiles, and amphibians.

MDEQ conducted Procedure 51 surveys on the Tittabawassee, Chippewa, Tobacco, Cedar, and Salt rivers in 1997 and on the Pine River in 2002. Many stations were evaluated for macroinvertebrates (Tables 32–38). A bibliography of these reports can be found in Appendix B.

The Natural Features Inventory maintains a list of endangered, threatened, or special concern species (Table 39). This watershed has one endangered invertebrate, the snuffbox mussel *Epioblasma triquetra*. This mussel has been found in the main stem mouth segment and in the Salt and Chippewa rivers. There are also 11 species of special concern.

Mammals

The Tittabawassee River watershed supports a variety of mammal species. The river and its riparian corridor provide diverse habitat for migration, feeding, and reproduction. Forty-eight species either once inhabited or still inhabit the Tittabawassee River watershed (Table 40). Eastern elk are extinct and woodland caribou, lynx, cougar, and gray wolves are considered extirpated from the watershed. The woodland vole is the only species listed as special concern (Table 39). Watershed development has greatly altered natural habitat by reducing, fragmenting, and degrading it. Many mammal species have had to learn to coexist with humans.

MDNR, Wildlife Division is charged with management of games and nongame species. Wildlife Division strives to maintain balanced mammal populations and to avoid conflicts between humans and mammals. Wildlife Division actively manages a variety of mammal game species in the watershed including deer, beaver, squirrel, and rabbit. Populations are controlled by hunting and trapping seasons and other management methods such as relocation or special permits.

Beaver populations are capable of affecting stream habitat and water quality by damming up streams. These activities can cause warming of tributaries and subsequent loss of rare coldwater habitats. The flooding and subsequent destruction or breeching of beaver dams can cause sedimentation by slowing waters initially causing settling and then when breached causing erosion and subsequent downstream settling of silt and sediments. Dams can block fish migration and alter flow regimes causing assemblages of fish and aquatic invertebrates to shift toward more warmwater lentic species. Wildlife Division helps keep beaver population in balance by setting trapping seasons and by issuing necessary nuisance trapping permits.

Birds

The Shiawassee National Refuge, located just south of the Tittabawassee River watershed keeps records of migratory birds including raptors, shore and wading birds, and songbirds that visit the refuge annually. The refuge's maintained list includes 277 species (USFWS 2006).

According to the Atlas of Breeding Birds of Michigan, there are at least 146 birds that breed within the Tittabawassee River watershed (Table 41). Additionally, there are many birds that stop or migrate through the watershed. Several species of ducks, geese, and mergansers nest and forage along the river. Other species such as Woodcock, Grouse, and Turkeys forage and travel within the riparian corridors. Stream edge habitats are used by several species of shorebirds and wading birds such as Blue Herons. Several rare raptors also occur such as Bald Eagles and Red-shouldered Hawks. There are eight bird species listed under special concern (Table 39). The Bald Eagle was listed as threatened by both the federal government and the State of Michigan, but the federal government has delisted this species and the State of Michigan now lists it as a species of special concern.

Amphibians and Reptiles

There are 11 frog and toad species, 7 salamander species, 10 turtle and lizard species, and 15 snake species that occur within the Tittabawassee River watershed (Table 42). Of these, 3 turtles, and 1 snake are on the special concerns species list; and 1 turtle and 1 snake species are listed as threatened (Table 39). Many amphibians and reptiles rely on the aquatic environment for habitat, reproduction, and food. They are also an important food source for a variety of species including fish, mammals, and birds. Primary threats include road kills, alteration and loss of wetland habitats, nest predation, and collection as pets (Harding 1997).

Natural Features of Concern

MSU, Natural Features Inventory maintains a listing of all endangered, threatened, and otherwise significant plant and animal species, plant communities, and other features (Table 39). Plant communities and geological features within the Tittabawassee River watershed are of special concern as development threatens their existence. Some of these features, such as bogs, prairie fens, and kames provide unique habitat for many animals.

Aquatic Nuisance Species

Aquatic nuisance species are plants, animals, and microscopic organisms that have been intentionally or inadvertently introduced and cause serious problems in aquatic ecosystems and threaten biodiversity and ecosystem function (NOAA 2006a). A MDNR–MDEQ report submitted to the Michigan Legislature indicated that since the 1800s approximately 160 nonindigenous aquatic species have been introduced into the Great Lakes basin (Anonymous 2002b). The number of species discussed in this assessment will be limited to nuisance species affecting the Tittabawassee River watershed. These include carp, goldfish, white perch, round goby, sea lamprey, zebra mussels, rusty crayfish, Eurasian milfoil, purple loosestrife, and the parasite *Myxobolus cerebralis* (whirling disease).

Sea lamprey are parasitic eel-like fish that are native to North American and European coastal regions of the Atlantic Ocean. They entered the Great Lakes through the Welland Canal in the 1920s. Sea lamprey prey on native fish and have had a major effect on the Great Lakes ecosystem. Sea lamprey are potamodromous and live as adults in the Great Lakes but use accessible tributaries such as the Tittabawassee, Chippewa, Pine, and Salt rivers to reproduce and for habitat during their larval nonparasitic phase. Sea lamprey are able to traverse Dow Dam, but are blocked by Sanford Dam. The USFWS, Lamprey Control unit surveys and treats tributaries within the Tittabawassee River watershed on an approximate five-year rotation using the lampricide TFM (3-trifluoromethyl-4-nitrophenol). Tributaries that have been treated include Carroll and Bluff creeks, Big Salt, Chippewa, North Branch of the Chippewa East, and Coldwater rivers. The Tittabawassee River at Dow Dam has also been the location of additional sea lamprey control activity in recent years. The site is routinely trapped in spring to capture adult lampreys for use in a sterile male release program. The dam ranks high on the potential project list for establishment of an effective sea lamprey barrier (D. Lavis, USFWS, personal communication). The lampricide TFM can also affect local aquatic communities. Studies have shown a temporary reduction in mayflies after treatments. Mudpuppies, tadpoles, and salamanders are very susceptible to TFM treatments. Besides lampreys, channel catfish, rainbow trout and lake sturgeon juveniles are particularly sensitive to TFM (Wesley 2005).

Zebra mussels, barnacle-like mollusks native to the Caspian Sea region of Asia, were introduced into the Great Lakes ecosystem via ballast waters from freighters and attach to hard objects such as rocks, dock pilings, and native clams and mussels. They cause significant environmental and economic affects by reducing native mussels and clams, by altering aquatic food webs, and by clogging municipal and industrial water intakes. These mussels are easily spread to other inland waters by boating activities because the larval stage is easily transported (NOAA 2006b). Zebra mussels have been documented in many Tittabawassee River watershed impoundments and lakes including Secord, Smallwood, Wixom, Sanford, Coldwater, and Pratt (USGS 2006). They are probably established in the lower Tittabawassee River (USGS 2006).

The rusty crayfish is native to the Ohio River basin and is considered a threat to Michigan's native crayfish populations and could have environmental and economic effects on local areas. Rusty crayfish were introduced as a result of releases by anglers using them as bait. Rusty crayfish are voracious feeders and feast on aquatic plants, invertebrates, aquatic insects, and other crustaceans. Detritus, fish eggs, and small fish complete their diet. Rusty crayfish can dramatically reduce aquatic plant beds and can affect species, especially fishes that rely on these resources for food, shelter, and reproduction. Records of sightings and surveys are not readily available for most of the Tittabawassee River watershed, but rusty crayfish are probably dispersed throughout (MDNR 2006b).

Eurasian milfoil is a submerged aquatic plant commonly used in the aquarium trade and thought to have been introduced by a pond culture. Eurasian milfoil spreads by fragmentation and grows very quickly, often out competing and displacing native aquatic plant species. Eurasian milfoil forms thick mats in shallow areas of lakes and streams which can alter fish and aquatic invertebrate populations, interfere with recreation, and once established can be difficult to eradicate. Heavy infestations of Eurasian milfoil are often treated with chemicals. These chemical treatments also affect fish and invertebrate populations. Chemical treatments are often not selective, and kill all vegetation including native species, thus reducing native habitat availability. Decomposition of aquatic plants also causes a reduction in oxygen as they decompose. Nutrients released by decaying plants may cause undesirable algal blooms. Eurasian milfoil is common in many watershed lakes and impounded waters.

Purple loosestrife is a tall flowering plant native to Europe and has invaded many North American wetlands including those in the Tittabawassee River watershed. This plant forms thick stands and blocks access to water, overtakes native wetland plants, and causes a reduction in food and habitat for wildlife (NOAA 2006c). It is currently found sparsely distributed in the watershed.

The protozoan *Myxobolus cerebralis* became established in the Tittabawassee River watershed in approximately 1968, causing whirling disease in trout and salmon (Tody 2003). The disease entered Michigan as a result of fish escapement from a private hatchery to the headwaters of the Tobacco River in Clare County. Fish from this facility were also sold to private fish ponds throughout the state, allowing for spread of the disease. This protozoan has a two-host lifecycle involving benthic tubifex worms and fish. The free swimming triactinomyxon phase enter the fish host through the skin or by ingestion. Ultimately, the parasite damages cartilage in the head and spine which results in loss of equilibrium and consequently erratic (whirling) swimming. Rainbow trout are most susceptible to this disease followed by brook trout, Chinook and coho salmon, and brown trout (Faisal and Garling 2004). Whirling disease has been identified in the North Branch of the Tobacco River, Spikehorn, and Jose creeks (Tobacco River watershed).

Recently, the watershed has also experienced an outbreak of viral hemorrhagic septicemia (VHS). The disease is caused by a rhabdovirus, but it is incapable of replicating in warm-blooded animals and therefore poses no risk to humans. The virus is most active in cold water ranging from 2–9°C. Viral hemorrhagic septicemia has plagued fish farms in Europe and wild salmon populations in the Pacific west coast. It was discovered in the U.S. waters of the Great Lakes in 2005. Fish from Lake Huron have tested positive for VHS but, to date, no fish from the Tittabawassee River have tested positive. An isolated case of VHS was recently found in Budd Lake within the watershed. Testing of fish collected in Budd Lake during a 2007 spring fish kill investigation indicated that VHS was a factor in mortality. This virus can easily be transported and spread by moving infected fish, transporting and using infected baitfish, and releasing fishing boat live-well water.

Several species of fish are considered nuisance species in the Tittabawassee River watershed. Originally native to Europe, common carp are now in the entire Great Lakes region, including the Tittabawassee River watershed. Carp are known for their undesirable effects on aquatic plant and fish communities. This species tends to dominate overall fish biomass, reduce aquatic rooted plants, increase turbidity, and reduce water quality. The lower Tittabawassee River and some lakes and impoundments, including Sanford, Wixom, and Ross lakes, have fairly substantial carp populations.

White perch, native to the Atlantic drainage, are also considered an introduced aquatic nuisance species which can potentially outcompete yellow perch. At present time white perch are confined to the lower reaches of the Tittabawassee, Pine, and Chippewa rivers and do not appear to be causing major problems.

The most recent invader to have colonized in the Tittabawassee River watershed is the round goby. The round goby, native to Black and Caspian Sea, also entered the Great Lakes in ballast water of ocean vessels. Though not documented, round gobies are believed to inhabit the lower Tittabawassee River below Dow Dam. This species achieves high densities and has the potential to threaten native darters through competition (Leonardi and Gruhn 2001).

Other Pest Species

Other pest species in the Tittabawassee River watershed include: gypsy moth, emerald ash borer, Japanese beetle, forest tent caterpillar, spruce budworm, mosquitoes, deer and horse flies, and occasionally local populations of mute swans, Canada geese, deer, beaver, muskrats, raccoons, feral swine, Norway rats, and mouse and mole species.

Fisheries Management

Historical Fisheries management in the Tittabawassee River watershed dates back to 1927 (MDNR Fisheries Division files). Fish were probably stocked before 1927, but documentation is lacking. Management to improve the recreational fishery has been vigorous at times, generally concentrating on isolated areas or tributaries. The entire watershed is subject to fishing regulations as contained in Michigan law. Laws and regulations are fisheries management tools designed to protect, preserve, and enhance a fishery resource. Below is a discussion of historical and current fisheries management of the Tittabawassee River watershed by river segments. Emphasis is placed on current and historical fisheries management, fisheries management limitations, and potential fisheries enhancements.

Early management records also included miscellaneous angler survey data collected from 1928 through 1965 for the Tittabawassee River, its tributaries, and watershed lakes (Appendix D). Most of these angler survey records came from general creel census data collected by MDNR Conservation Officers. Limitations of these data are discussed in Appendix D. These data provide insight to species distribution and information on recreational opportunities for anglers.

Headwaters

Portions of the East, Middle, and West branches of the Tittabawassee River are designated trout waters (Table 19). These are all classified as Type 1 streams and have an 8-inch size limit on both brook and brown trout for these streams and a 10-inch size limit on rainbow trout (MDNR 2006a).

Fish were stocked into the West Branch of the Tittabawassee River as early as 1937. Brook trout and yellow perch were stocked for a few years. Bluegills were also stocked on one occasion in 1941. No stocking occurred again until 1976 when brown trout were stocked for two consecutive years. No stocking has occurred since 1977. Stocking records for the East and Middle branches are not available.

The Middle, West, and East branches of the Tittabawassee River were surveyed in 1969 and previously (see also **Biological Communities**). Management records for the Middle and East branches of the Tittabawassee River are not available. Present management activities on the Middle, West, and East branches of the Tittabawassee River include habitat protection through permit reviews, evaluation of fisheries and habitat through MDNR, Fisheries Division Status and Trends Monitoring Program and discretionary surveys, and enforcement of Type 1 fishing regulations.

Middle

Several tributaries to the main stem are designated trout streams (Table 19) including Sugar Creek, Sugar River, and the upper Cedar River and upper branches of the Tobacco River. Fish Creek, the Little Molasses, and lower Sugar rivers all have warmer temperatures and are unable to support trout.

The Sugar River was stocked annually with brook trout from 1937 to 1951, in 1954, and from 1957 to 1959. Brown trout were also stocked in 1937. Prior to 1960 700–725 legal brook trout were stocked monthly from April through August. In 1960 stocking rates changed to 1,000 legal brook trout per year. In 1961 stocking was to be discontinued until a trout survey could be completed. This survey, completed in 1968, found fair populations of brook trout, exceptional populations of brown trout, and good natural reproduction. There are no additional records of fish stocking. In 1971, Fisheries Division used index stations to monitor the fish populations. Population estimates were conducted for brown trout at several locations from 1978 to 1988. The estimated brown trout population was 600 to 1,800 fish per acre. Temperature data were also monitored in 1968 and 1972. Temperatures in 1968 ranged from 60ºF to 74ºF on a warm mid-July day. The Butman, Hockaday, and Richie road crossings were all over 70ºF on two occasions. In 1972 water temperatures ranged from 63ºF to 67ºF (with 83ºF air temperatures) in the morning in all locations tested from Sugar River Road downstream to Hockaday Road. The Sugar River was dammed in 1977 to create the Sugar Spring residential development around Lake Lancer and Lake Lancelot. Presently, there is no active management aside from monitoring the fish community and habitat conditions, including brook and brown trout, and habitat protection through MDEQ permit reviews.

Lake Lancer is a 685 acre impoundment of the Sugar River and is managed by MDNR, Fisheries Division as a warmwater lake. There is a fish passage structure on the dammed outlet of the impoundment; however, this structure does not work well for warmwater species due to excessive velocities and the design. Currently, the impoundment is being actively managed for walleye. MDNR, Fisheries Division has stocked walleye spring fingerlings since 1984 (Table 43). The impoundment is scheduled for triennial plants of 34,250 fingerlings (50/acre), but has often received walleye biennially when fingerlings were available. Several surveys (1986, 1992, 1993, 1995, 1998, and 2000) have been conducted to assess the success of the walleye stocking program. A good walleye population was documented in the 1993 survey. General fish population surveys were conducted in 1986, 1993, and 2000 to assess species composition and balance. The species complex remained similar in all surveys. Relative abundance of some species have changed. Bluegill and largemouth bass abundance increased in recent years. Also common in 2000 were pumpkinseed sunfish and rock bass. In contrast to 1993, the number of black crappie and northern pike declined. Walleye catches in 2000 were similar or slightly lower than previous years. The lake association has been actively working to monitor and improve water quality and has contracted out water quality studies. They have also dug sand traps in tributaries above the impoundment to minimize sedimentation to the lake. The lake has a history of chemical aquatic vegetation treatments.

The Sugar River below Lake Lancer is now a warmwater stream that is not actively stocked or managed by MDNR, Fisheries Division. If sufficient flow of cold temperature could be restored, it may be possible to manage the lower Sugar River as a trout stream. Presently, active fisheries involvement in this river reach is for MDEQ permit reviews, MDNR Forest Compartment reviews, and fisheries surveys. There is a lack of inventory data on the lower Sugar River and scheduling additional discretionary surveys would be helpful as well as monitoring temperatures.

Minimal information is available on the Molasses River, Little Molasses River, and Fish Creek tributaries. Temperature data indicate these streams have warm water with average July temperatures approaching 80ºF. MDNR, Wildlife Division operates five floodings on the Molasses River for waterfowl. These floodings provide limited fishing for yellow perch, bluegill, sunfish, and bullhead. MDNR acquired the land in the early 1900s and created the first dam around 1949. The others, five in all, were built from 1949 to 1962 (T. Reis, MDNR Wildlife Division, personal communication). These streams were warmwater prior to creating the floodings, so the effect to the system is mostly due to changes in flow, fragmentation, and fish passage up and downstream. There are no major fish runs in these systems. There is little fishing activity in these steams, and there may actually be an increase in the activity resulting from these floodings and the increased access.

The Tobacco River watershed includes many designated trout streams (Table 19). These are all classified as Type 1 and follow an open season and possession for trout from the last Saturday in April to September 30. There is an 8-inch size limit on both brook and brown trout and a 10-inch size limit on rainbow trout. Most of these streams are sustained by natural reproduction and additional stocking is not necessary. Rivers stocked in this watershed include Newton Creek, South Branch of the Tobacco River, and North Branch of the Cedar River (Table 43).

Population surveys were conducted on many of these tributaries in the 1980s. The North Branch of the Tobacco River is a fixed site sampled regularly through the Status and Trends Program. Trout populations at this site are quite variable and are attributed to variability in streamflow.

A sediment trap has been operated at Newton Creek at Hatchery Road since 1981. The trap was cleaned out in 1999 and 2000 and is presently full. Cleanout is scheduled for 2008. See Madison and Lockwood (2004) for a more thorough discussion on effective and ineffective placement of sand traps.

Whirling disease, discussed in **Biological Communities**, has been previously identified in the North Branch of the Tobacco River, Spikehorn, and Jose creeks. The North Branch of the Tobacco River was closed to fishing because of whirling disease on April 25, 1970. The stream was treated with 500 ppm chlorine to eradicate fish and treat for the disease. Cages containing rainbow trout were placed in the stream to check for the presence of whirling disease. These fish continued to test positive. The stream was treated with rotenone and chlorine in 1971 and 1972. Files indicate that whirling disease monitoring surveys were conducted from 1970 to 1974. There were no additional fishing closures or treatments after 1974. Currently, the North Branch of the Tobacco River has an excellent trout population. Recent random monitoring of many tributaries has found little clinical signs for whirling disease. No evidence was found in MDNR, Fisheries Division files documenting disease activity in other tributaries.

Wiggins Lake is a 234 acre impoundment created by damming the Cedar River in 1910 to provide for hydroelectric generation. It is located in Sage and Grout townships northwest of Gladwin. Similar to other impoundments in the area, a variety of fish species were stocked from 1937 to 1944. These included yellow perch, walleye fry, bluegill, northern pike, largemouth bass, and smallmouth bass. Early inventories, made in 1951 and 1960, indicated low sport fish abundance and high rough fish abundance. In 1962, Wiggins Lake impoundment was treated with rotenone in an attempt to eradicate all fish. Following rotenone treatment, the impoundment was stocked intermittently with trout and subsequently stocked with walleye and northern muskellunge fry or fingerlings. Surveys conducted in 1963 and 1965 documented poor success of the chemical treatment as the fish community composition was very similar to that prior to treatment. After 1965, management focused on developing a better predator base and exploration into creation of a northern pike marsh. A northern pike marsh was developed in 1974 and operated nearly every year through 1999. Channel catfish and white bass were stocked in 1987 and 1988 (Table 43). Bluegill, largemouth bass, and yellow perch were also stocked by the lake association under private permit. Walleye fingerlings have been stocked since 1989 and are currently planted biennially at the rate of 50/acre.

The most recent fish survey of Wiggins Lake impoundment was conducted in 1999. Fish community characteristics remain very similar to 1994. Bluegill and black crappie numbers and growth appeared good, rough fish were not dominating the catch, and diversity of game fish species was good.

Anglers and lake association members believed that northern pike were more plentiful than the 1999 survey indicated. Consequently, their complaints promulgated a change in the northern pike fishing regulations. Northern pike spearing was prohibited in years when the pike marsh was in operation. The spearing ban was removed in 2004.

Ross Lake was formed by impounding both the of the Cedar and Tobacco rivers in 1919. There have been numerous documented downstream river flow problems especially prior to 1989. These included stream channel water level drops that caused stranding of game fish and other fish species resulting in documented fish mortalities. A FERC inspection in 1989 revealed a number of violations and outlined corrections. File data thereafter is sketchy; however, complaints have diminished. The FERC inspection also pointed out a need to improve recreational access to the tailwater area of the facility. Most noted problems did not have direct influence on the impoundment except for the establishment of a specific range of water levels.

Although management records for Ross Lake are scant, bluegills, largemouth bass, yellow perch, and some walleye fry were stocked from 1937 to 1944. The first survey on record was in 1951. The lake was treated with rotenone in 1967 to remove rough fish, but a gill net survey conducted in 1971 documented the reestablishment of rough fish. In 1976 a more thorough rotenone treatment was carried out which included the South Branch of the Tobacco River downstream of Clare and the Cedar River downstream from Gladwin. An excellent, if not total kill, was realized in the treated waters. However, the size and complexity of the watershed made it impractical to treat the entire watershed. Channel catfish, steelhead, largemouth bass, crappie, brown trout, and bluegill were subsequently stocked. An electrofishing survey in 1977 revealed that numerous young-of-the-year carp were still present. Recommendations were made for a follow-up antimycin treatment in 1978, but there is no documentation indicating that this treatment was administered.

A netting survey was conducted on Ross Lake in 1981 to assess the fish community following the 1976 treatment. The summary mentions that the carp and bullhead levels had returned to pretreatment levels. Crappie sp., catfish sp., and northern pike were fairly abundant and of decent size, while panfish and the remainder of the game fish populations appeared poor. In 1987 a prescription was written to address the problem of low numbers of predator species and overabundance of rough fish. The prescription included stocking 2,000 northern muskellunge fingerlings annually and stocking 300 adult white bass for three consecutive years. Northern muskellunge had previously been stocked as early as 1984 and stocking of walleye fingerlings began in 1987. The lake has been managed with walleye and northern muskellunge ever since. A netting survey conducted in 1987 revealed a species complex similar to that of 1981. Four white bass and one walleye were netted, and rough fish numbers were still high. Golden shiner, common shiner, and creek chub were the forage species noted. Sizes and numbers of panfish appeared to have improved. Eighty-one percent of the bluegill were of catchable size (≥6 in); however predator numbers were still low. Growth of panfish was only slightly below state average. A subsequent night electrofishing showed largemouth bass to be growing 1.9 inches above state average. Two walleye, one northern pike, and six smallmouth bass were also captured.

In 1995 a netting survey was conducted on Ross Lake to again evaluate the status of the fish community, and the walleye and northern muskellunge stocking programs. Only 2 walleye and 10 northern muskellunge were captured during the survey. Management recommendations were to continue the stocking program and to increase walleye stocking rates.

The last survey, 2003, was a Status and Trends Program netting survey. Results indicate that Ross Lake had a well-balanced fish community. The highlight appears to be the crappie population. Both black and white crappie are numerous and there are many large-sized fish. The predator population appears diverse and growth is above state average for largemouth bass and northern pike. Walleye recruitment or survival of young-of-the-year appears to be fair. The bluegill population is acceptable, but they are on the small side even though growth is 0.5 above state average. Twenty-nine percent of the bluegills surveyed in the 2003 assessment were of desirable angling size (≥6 in). Bluegill captured in the trap nets averaged 5.4 inches. Based on this information, the predator population appears to be controlling the panfish population. The electrofishing survey indicated that the walleye year-class of 2002 is surviving; 4 northern muskellunge were also captured. Continued management of Ross Lake is for muskellunge and walleye.

Downstream of the confluence of the three branches of the main stem Tittabawassee River, the water quality and fish populations are influenced by the four hydroelectric dams. Management of each of these impoundments will be discussed individually. Because of their proximity to one another, there is little riverine habitat between impounded areas.

Secord Lake impoundment was stocked from 1937 to 1944 with a variety of fish species including bluegills, yellow perch, largemouth bass, smallmouth bass, and walleye (“pike-perch”). The first general fisheries survey was in 1951. Predominantly warmwater species were captured and no management recommendations were made. In the early 1960s, concerns grew over increased carp numbers and recommendations were to draw down the impoundment to control them. However, there is insufficient information to know if this happened. Channel catfish were stocked from 1963 to 1965.

To provide additional predation, perhaps on young carp, MDNR, Fisheries Division developed and operated a northern pike marsh. This marsh was completed in 1972 and northern pike were stocked through 1988. Records also indicate that one planting of white bass was made in 1988, perhaps in an effort to diversify the fishery and provide additional predators. An earlier netting survey (1967) collected age and growth information. Panfish exhibited slow growth, while largemouth bass and northern pike were growing near state average (Schneider et al. 2000). In 1980 the species complex appeared to be similar. Carp were not excessively abundant. The steep drop-offs and lake contours made netting difficult and few fish were caught. Only 11 species were netted, a total of 187 fish or 91 lb. By1992 northern pike, black crappie, and yellow perch were growing below state average, while largemouth bass growth appeared above state average. Rough fish (white suckers, redhorse suckers, carp, black, brown, and yellow bullheads) still represented 1/3 of the total biomass. Recommendations were to discontinue northern pike stocking and initiate a northern muskellunge stocking program to help control rough fish. Due to the popularity of walleye, their stocking was also continued. Northern muskellunge stocking began in 1994 and continues to present. Currently, the Secord Lake impoundment is managed as a warmwater lake with emphasis on controlling rough fish populations and increasing panfish growth by stocking walleye and northern muskellunge. The last survey, in 1998, indicated improved growth of panfish. This survey failed to document an established northern muskellunge fishery and showed only limited success for walleye. Anglers report catches of walleye and, on rare occasions, northern muskellunge. Limited success of northern muskellunge is probably due to production inconsistency in the muskellunge rearing program. Muskellunge are also more tolerant of warmer waters than pike and generally have been known to do well in impoundments.

Smallwood Lake impoundment is the second hydroelectric dam in the series on the main stem. Like Secord Lake impoundment, fisheries management of Smallwood Lake impoundment began with sporadic stocking of a variety of species from 1937 to 1944. These included smallmouth bass, largemouth bass, northern pike, bluegills, walleye, and yellow perch. The first biological inventory was completed in 1951 and no management recommendations were made. White bass were introduced in 1954.

General fisheries surveys were conducted in 1951 and 1967. Fish populations appeared to be healthy and no comments were included. In 1983, a survey showed good populations of black and white crappie, northern pike, largemouth bass, and large channel catfish. Bluegill growth appeared to be slow and sizes were small. Walleye stocking became regular starting in 1985 with the minimum of triennial plants of walleye fingerlings at a rate range of 50 to 100 per acre. Northern pike were stocked from 1974 to 1990 and discontinued in favor of stocking northern muskellunge. Northern muskellunge stocking began in 1994 to diversify fishing opportunities and to provide another predator. To date, northern muskellunge have not been fully stocked at the prescribed rates because of limitations in hatchery production. Surveys in 1991 and 1999 indicate fair to good survival of walleye, limited northern muskellunge survival, and a good warmwater fish community. Present management strategy for Smallwood Lake impoundment includes stocking northern muskellunge and walleye, working with FERC for dam operation, MDEQ permit reviews, and Status and Trends Program surveys.

A variety of fish species were stocked in Wixom Lake impoundment from 1937 to 1944. Species stocked included bluegill, walleye fry, yellow perch, smallmouth bass, and largemouth bass. No active management was performed from 1944 to 1951. A biological inventory was completed in 1951. Species collected included black crappie, yellow perch, bluegill, pumpkinseed, largemouth bass, smallmouth bass, bluntnose minnow, fathead minnow, golden shiner, common shiner, mimic shiner, sand shiner, spotfin shiner, brassy minnow, hornyhead chub, stoneroller, logperch, Johnny darter, Iowa darter, blackside darter, white sucker, black bullhead, brown bullhead, and yellow bullhead. Rock bass and walleyes were reported as rare. An aquatic plant survey was also conducted. Common plant species included *Anacharis, Ceratophyllum, Juncus, Lemna minor, Myriophyllum,* several *Potamogeton species, Scirpus, Sparangium,* and *Typha*.

Fingerling (1 in) channel catfish were stocked in Wixom Lake impoundment from 1963 to 1966. A northern pike marsh was operated cooperatively with a local sportsman’s club around 1963 and 1964, but production records are scant.

Wixom Lake impoundment was surveyed in 1967. The survey caught most of the fish listed from the 1951 survey, with the addition of channel catfish and northern pike. No walleye were caught. Bluegill and northern pike were growing above state average, while perch, smallmouth bass, and black crappie were growing somewhat below state average. Wixom Lake impoundment has experienced occasional winter kills, mostly in back channels and isolated areas.

A survey in 1985 of Wixom Lake impoundment captured species similar to earlier surveys. A number of walleyes were taken and channel catfish were shown to be well established. Growth data was kept separate for the two arms of Wixom Lake impoundment. Bluegills, black crappie, and yellow perch were growing above state average in both arms. The Tittabawassee River arm had slightly better growth. Northern pike were growing slowly in the Tobacco River arm. Too few fish were captured from the Tittabawassee River arm to calculate a growth index.

A regular walleye stocking of a targeted 75,000 fingerlings biennially began in 1985 and continues to the present. Walleye were locally popular and provided additional predation on panfish. This resulted in improved growth and health of the panfish population. Further surveys and fall walleye evaluations were conducted in 1985, 1994, and 2002. In 1985, 39 walleye representing seven different year classes were captured. The 1994 walleye evaluation showed excellent survival of both young of the year and older fish, with over 63 walleyes captured during fall electrofishing. Only 19 were collected in the 2002 survey and 24 during fall electrofishing surveys. Management for northern muskellunge began with the first stocking in 1996. Northern muskellunge production and frequency of stocking has limited the ability to successfully establish a northern muskellunge population. However, northern muskellunge are also stocked above Wixom Lake impoundment and they have the ability to move down through the system. The 2002 survey documented survival and excellent growth of several northern muskellunge. Fishing reports indicate more northern muskellunge are being seen and caught.

The 2002 survey showed the impoundment to have a well-balanced fish population with adequate growth. The predator population appeared diverse. Northern muskellunge were present in low numbers and not well-established. Walleye recruitment appears to be fair. Large channel catfish are becoming very numerous. Our experience with other similar impoundments suggests a decline in walleye numbers as catfish abundance increases. Panfish, northern pike, and largemouth bass were numerous; each present in proportionally appropriate numbers.

Wixom Lake impoundment continues to be managed for current composition of species, development of the northern muskellunge fishery, and continuation of the walleye stocking program. Both stocking programs are very popular locally. With the establishment of zebra mussels, water clarity and the amount of aquatic vegetation has increased. Chemical vegetation treatments have been increasing. Changes in clarity may be limiting walleye populations and may favor those species preferring more clear water and submergent aquatic vegetation such as bass and panfish.

The last in the series of main stem impoundments is the 1,528-acre Sanford Lake impoundment. Similar to other impoundments, stocking of bluegill, walleye fry, smallmouth bass, and largemouth bass took place from 1937 to 1944. Biological inventories were also made in 1951 and 1967. Management strategies were similar to other impoundments. Channel catfish were stocked in 1963 and 1964. Developing a northern pike marsh was a priority and a permanent outlet was completed in 1970. MDNR, Fisheries Division records indicate that the marsh was in operation from 1967 to 1971. Northern pike were stocked through 1988. Stocking of northern muskellunge started in 1984 (Table 43) and has a fairly well-established population. Management for northern muskellunge continues today. Walleye stocking began in 1986 and continues to present (Table 43).

Surveys and stocking evaluations were conducted in 1986, 1997, 1999, 2000, 2001, 2003, and most recently in 2007. Six walleye were captured in spring 1986 and an additional 35 during fall, with the majority being young of the year. Walleye (n=59) in 1997 were found to be growing at 1.5 inches above state average. Five year classes were represented in the aged fish. The 1999 netting survey captured 19 adult walleye. In March, 2000, the spawning run was evaluated by a shocking survey at Edenville Dam. Fifty-four walleye were captured representing 8 year classes. The 2001 fall electrofishing survey was conducted to assess natural reproduction in a nonstocked year. Only 8 walleye were captured and only 4 of these were young of the year. This indicated limited natural reproduction or a very weak year class for 2001. The 2003 survey also indicated a week year class with only five young of the year captured. Water temperatures and changes in clarity may be to blame for this. A Status and Trends netting survey was conducted most recently in 2007. This survey also showed low walleye catch rates. Thirty-four walleyes were captured during the netting and summer shocking, and only 3 were captured during fall evaluation during a nonstocked year.

Netting surveys indicate that the impoundment has a good balance of game fish to rough fish and predators to prey. Sanford Lake impoundment has a diverse species complex including bluegill, crappie, largemouth bass, smallmouth bass, large channel catfish, walleye, northern pike, and northern muskellunge. Similar to Wixom Lake impoundment, water clarity has increased due to zebra mussels. The reduced turbidity has allowed for more sunlight penetration and therefore an increase in aquatic macrophyte growth. These macrophytes interfere with recreation and landowners and associations often recommend and treat to reduce these aquatic plants. The increased water clarity may limit the walleye population as walleyes are generally less light tolerant and prefer darkness or turbidity. Species that may benefit are those associated with submergent aquatic vegetation such as bass, pike, and panfish. Management of Sanford Lake impoundment continues for current species composition, including the northern muskellunge fishery and continuation of the walleye stocking program. Both the northern muskellunge and walleye programs are very popular with local anglers. There have been no recent creel surveys conducted to assess fishing pressure or success of muskellunge and walleye stocking.

Mouth

Walleye typically migrate into a river from winter to early spring and congregate to spawn in late March to early April. To protect and maintain vulnerable walleye stocks, walleye fishing season is closed from March 16 through the last Saturday in April. Due to enforcement issues, total fishing closures are in effect from below Sanford Dam to the mouth of the Salt River, and from Dow Dam down to the Gordonville boat launch. During this closure, there is also a gear restriction which prohibits artificial lures typically used to target walleyes, while allowing natural baits to be used for other species. In some years depending on river flows and timing of spring flooding, walleyes are able to ascend the river above Dow Dam. During such periods additional walleye spawning habitat is available from the City of Midland to the Village of Sanford and other tributaries such as the Pine and Chippewa rivers.

Very few complete surveys have been conducted on the river reach from Sanford Dam to Dow Dam. A Fisheries Division survey was conducted in 2004 in the river reach above Dow Dam and just above the confluence of the Chippewa River. The flow at the time was 201.27cfs. Fourteen warmwater species were collected. The only other survey was conducted in 2005 just below Sanford Dam shocking 1 mile downstream. Flow was low that day, and the water was extremely clear. Only 8 warmwater species were collected.

A creel survey was conducted in the lower Tittabawassee River from Dow Dam to the confluence with the Saginaw River. This survey was initiated to assess fishing pressure and catch rates and to relate these to overall walleye population dynamics for Saginaw Bay. Catches were highly dependent on spring weather conditions and the timing of the spawning run. From 1999 to 2003 anglers spent an average of 33,808 angler hours annually and caught an average of 11,062 walleyes annually from the lower Tittabawassee River (David Fielder, MDNR, personal communication). Other species recorded included white sucker, channel catfish, white bass, and yellow perch. The river reach at Center Road was also surveyed in 2003 and 2005. Discharge was 443.83 cfs in 2003 and 15 warmwater species were collected. The 2005 survey captured 14 warmwater species and for the first time ever, a flathead catfish was collected.

As part of a project to evaluate Saginaw Bay walleye population dynamics and movement, walleye have been tagged annually at Dow Dam and a few individuals have been tagged upstream at Sanford Dam. Currently, Fisheries Division’s database has over 88,000 records of tagged walleye from the Tittabawassee River, Saginaw River, and Saginaw Bay walleye since 1981. The majority, over 88%, are from the Tittabawassee River at Dow Dam. These data demonstrate the importance of the Tittabawassee River to the Saginaw Bay walleye fishery.

Dow Dam has also been the site of walleye egg take. Fish congregate below Dow Dam and are easily collected. The Tittabawassee River strain has been used for Lake Huron management since 1995. Eggs and milt are taken on site at Dow Dam, fertilized, transported to Wolf Lake Hatchery for incubation, and then brought back to ponds in the management units for growing to fingerling size. The fingerlings are then planted out within the management unit.

A few lake sturgeon have been caught and released over the past several years and the USFWS has been conducting research on lake sturgeon population dynamics and reproduction. The USFWS is also evaluating the Dow Dam for passage of lake sturgeon.

Sea lamprey also ascend the river in spring to spawn. Sea lamprey are one of the few species able to ascend the dam. The USFWS has operated a trap at Dow Dam and continues to monitor and treat for lamprey in tributaries above this dam.

Management in this lower reach of the main stem is for the aforementioned species. These are managed using current Lower Peninsula fishing regulations including size limits, possession limits, and fishing seasons. Critical to management of these species is protection of habitat and water quality. Protection efforts include reviewing MDEQ permits, working with MDEQ and their water quality programs, and working with FERC to improve management of licensed dams.

The Salt River contains a warmwater fish community (see also **Biological Communities**) and is managed accordingly. Active management includes MDEQ permit review, supporting nonpoint source programs, and surveying through the Status and Trends Program. The Salt River is also on the USFWS larval sea lamprey treatment schedule (see also **Biological Communities**). MDNR, Fisheries Division has conducted several fisheries surveys to assess recolonization following a fish kill event in 1998. Another fisheries survey was conducted in 2003. This survey documented 15 species and recorded a water temperature of 76ºF and an alkalinity of 171 ppm. The South Branch of the Salt River was surveyed in 2007 as a random site for the Status and Trends survey program. Thirteen warmwater species were recorded. MDEQ also surveyed the river in 1992.

Herrick Ponds are located in a park operated by the Isabella County Park System. There are three warmwater ponds as part of this park. These small ponds have received much attention due to their proximity to Central Michigan University. Fish populations have been studied since the 1980s. MDNR has records of fish being stocked as early as 1984 (Table 43): brown trout, largemouth bass, and channel catfish. Several surveys were conducted in the early 1990s and the population consisted of bluegill, black crappie, yellow perch, and northern pike.

In the early 1990s Isabella County park personnel became interested in a total reclamation project for all three ponds. A complete chemical treatment using rotenone was done in 1994 followed up by interim stocking of rainbow trout and then stocking of northern pike, largemouth bass, and bluegill. However, after creating the interim trout fishery complaints from park patrons indicated they preferred the species composition prior to the reclamation project. Stocking of trout was subsequently halted and a 1998 survey indicated that the ponds had reverted back to a warmwater fishery with a species complex similar to the prereclamation program.

The upper Chippewa River has several designated trout streams in Mecosta, Osceola, and Isabella counties (Table 19). These are all classified as Type 1 and follow those regulations. There are limited data available on the fish communities in many of these systems.

Chippewa Lake has been managed as a warmwater fish community. It was stocked with largemouth bass, smallmouth bass, walleye, perch, and bluegills from 1930 to 1944. The Department of Conservation management card indicates that there was an interest in providing spawning access for pike in streams with culverts, but no evaluations were discussed. This project was done in conjunction with the Mecosta County Rod and Gun Club. Tiger muskellunge were stocked once in 1980. Little survival was noted in the 1987 and 1988 surveys, or from angler reports, so stocking was discontinued and walleye stocking was initiated in 1988. The lake has received large numbers of walleye (up to 148,000 fingerlings) biennially or annually. Stocking evaluations in 1997, 2000, and 2003 failed to document large populations of these fish despite high stocking rates. Stocked fish in the past were often very small, ranging from 1.0 to 1.4 inches in total length. Present emphasis is now being placed on stocking fewer but larger-size walleye rather than high numbers of smaller walleye. The stocking rate of larger walleye will be 50 per acre.

Martiny Lake flooding is a large complex of several relatively shallow, warmwater lakes and together with the surrounding lands are managed as a state game area and administered by MDNR, Wildlife Division. These lakes include Big Evans, Lower Evans, Lost, Tubbs, Saddlebag, Dogfish, Boom, Bass, and Diamond. The first survey of the entire complex was completed in 2005 with the cooperation of Fisheries and Wildlife division personnel. The fish community appears well balanced in terms of predator to prey ratios and also game fish to rough fish ratios. The dominant predators are largemouth bass and northern pike. Management continues for species present and no stocking or active management is being done.

The North Branch of the Chippewa West River and its tributaries are designated trout streams (Table 19). Historically, brook, rainbow, and brown trout were stocked sporadically from 1947 to 1971. An evaluation in 1971 showed poor survival of stocked fish and stocking was discontinued. The water temperature at Evergreen Rd on July 21, 1972 was 73ºF (marginal for supporting trout). A reach at Hoover Road was also surveyed in 1973 and no trout were captured. The water temperature during the 1973 survey in July was 68–70ºF, capable of supporting trout yet none were captured. MDEQ conducted a fish survey on the North Branch of the Chippewa West River just above Barryton in 1992. Brook trout, grass pickerel, hornyhead chub, creek chub, common shiner, blacknose dace, mottled sculpin, white sucker, hogsucker, rock bass, pumpkinseed sunfish, bluegill, rainbow darter, fantail darter, johnny darter, and blackside darter were collected. Many of these species show the influence of Barryton dam and the more lentic conditions.

From the confluence of the North Branch of the West Chippewa River and the West Branch of Chippewa River to Lake Isabella, the Chippewa River is considered a warmwater stream. A survey of the North Branch of the Chippewa River at 10^{th} Avenue was conducted in 1991. Twenty warmwater species were captured. MDEQs 1992 fish survey recorded an array of warmwater species. This section of river has no active fisheries management. Fisheries Division continues to work with MDEQ in permit review.

Lake Isabella is a semiprivate impoundment that supports a warmwater fishery, but has never been surveyed by MDNR, Fisheries Division. Reports from MDNR, Law Division are the only documentation of fish community present. Residents follow current state fishing regulations. Fisheries Division has no active management programs on Lake Isabella.

The Chippewa River below Lake Isabella has been managed for steelhead since the early 1980s. Annual stocking of 10.000 steelhead began in 1988 in the upper Chippewa River near Mt. Pleasant. In 1996, the number stocked was increased to 12,650 annually (Table 43). Besides having a steelhead run, the Chippewa River is managed for other species present including smallmouth bass, walleye, northern pike, and rock bass.

The Coldwater River, from Littlefield Lake to Lake of the Hills (east), is a small coolwater stream. From Weidman Pond (Lake of the Hills east) to Coldwater Lake, the river is warmer and wider. In addition to minnow and chub species, this stretch receives a spawning run of walleye from Coldwater Lake. Historically, brown trout were stocked from 1944 to 1946. From Coldwater Lake to the confluence of the Chippewa River, the river has a warmwater fish community. The Coldwater River was surveyed in 1962 and 1972. Both surveys found the stream to be marginal for trout. Water temperatures recorded in 1972 were 76ºF and 82ºF. These temperatures are too high to support trout especially when there are no cold springs or refuges available. The Coldwater River is managed for the natural warmwater fish community and the only active management is to protect habitat and water quality by reviewing MDEQ permits.

Historically, Littlefield Lake supported trout, cisco, and smelt. Littlefield Lake was stocked with bluegill, yellow perch, and largemouth bass from 1939 to 1944. Beginning in the 1950s, lake trout, splake, rainbow, and brown trout were stocked at various times. The lake supported a “two story” fishery with the above mentioned species in the hypolimnion and warmwater species in the upper layers. Both rainbow smelt and cisco were found in a 1960 fish survey. At that time the lake provided a unique opportunity for inland smelt fishing which was very popular. Trout stocking was discontinued in 1991 because of low trout survival and increases in the northern pike population as documented in 1990 and 1991 surveys. Walleye stocking began in 1991 at the rate of 50 fingerling per acre. The most recent survey, 1995, indicated black crappie, bluegill, largemouth bass, northern pike, and walleye were all established. The smelt population appeared to have collapsed by 1995 and was probably due to predation by northern pike and walleye and a beaver dam blockage of Sucker Creek, a tributary to the lake that was the primary spawning area. Today’s fish population is probably a mix of warm to coolwater species. No smelt, trout, or cisco have been reported in any surveys or by anglers in recent times. At present 9,000 spring walleye fingerlings will be stocked triennially.

Weidman Pond is an 80 acre impoundment (Mill Pond Dam) on the Coldwater River. The dam washed out in 1977, but was reconstructed in 1987 and a legal lake-level was established. From 1987 to 1989 northern pike, largemouth bass, and yellow perch were transferred into Weidman Pond following the restoration of the lake level. The most recent fisheries survey, 1994, indicated that 13 species were present. The warmwater fish community appears in balance of rough fish to game fish species, although panfish are somewhat slow growing. This is probably due to abundant aquatic vegetation and ineffectiveness of predation. Weidman Pond is highly eutrophic. There is no active management on this lake at this time.

Fish were stocked into Coldwater Lake from 1935 to 1942, including largemouth bass, walleye fry, and bluegill. No natural reproduction of walleye was found in 1946. In 1956 an experimental walleye stocking program was initiated. Six thousand walleye fingerlings were stocked in 1957 and 1962. An artificial spawning reef was placed in the northeast end of the lake in 1959 by a local sportsmen club. In 1961, rainbow trout were stocked for two years and then terminated due to lack of success. Walleye stocking was reinitiated in 1963 and 1964, but in early years walleye production was very unstable. General surveys were conducted in 1959, 1961, 1966, and 1974. A more regular walleye stocking program began in 1984 and walleye are now stocked biennially or triennially if available. More recent surveys in 1985, 1988, 1995 to 1997, and 1999 indicate a well-established walleye population and a well-balanced ratio of predators to prey and game fish to rough fish populations. Northern pike were also stocked in 1993 and 1995 to provide additional predation. Current management recommendations for Coldwater Lake call for stocking 10,000 spring fingerling walleye triennially and 3,000 spring fingerling northern pike.

The upper parts and tributaries of the Pine River in Isabella, Montcalm and Gratiot counties include designated trout streams (Table 19). These are all classified as Type 1. The upper Pine River has been managed for trout for many years. Both rainbow and brown trout were stocked in the Pine River in Gratiot and Montcalm counties in 1980–86, 1990, and 1991. However, survival has been fair to poor and the system has been dominated by rough fish. The stream was chemically treated with rotenone in 1957. By 1959 the Pine River was dominated by rough fish and was once again chemically treated with rotenone in 1964. Due to low trout survival and increased competition from rough fish and creek chubs, the Pine River was chemically treated in 1980 to eradicate all fish and stocked with trout. Although anglers enjoyed good trout fishing for a few years, the river quickly reverted back to being a very marginal trout fishery. Temperatures were monitored in 1988, and Gratiot County waters were found to be marginal to exceptionally warm, often reaching 80ºF. In 1988, Fisheries Division decided to manage for species present and cancelled further rotenone treatment and trout stocking. The Upper Pine River was surveyed by MDEQ, Water Division in 2002.

The Pine River in Isabella County is the only section of the river that is being actively managed for trout. An initial population survey was conducted in 1962 where a limited trout population was encountered. Additional surveys were conducted in 1966, 1969, 1971, 1972, and 1979. Brown trout stocking was initiated in 1980. The Pine River in Isabella County is stocked presently at four locations with about 1,200 yearling brown trout at each location. More recent trout stocking evaluations were made in 1991, 1994, 1997, and 1998. These indicated that trout in this section have limited competition with rough fish and indicated fair to good survival and carryover.

Alma Impoundment, roughly 140 acres, was surveyed by MDNR Fisheries Division in 1990 and 1995. These surveys found a warmwater fish community that is typical in these large impoundments. These species appear to be well balanced and no active fish management is taking place.

St. Louis Impoundment (1,575 acres) has been heavily polluted and consequently has numerous fish advisories (see also **Water Quality**). The fishery of St. Louis Impoundment is essentially a "catch-release" fishery. The species complex is much like that of Alma Impoundment. Fish species were collected in 1995 contaminant analysis. No active management is being done at this time.

From St. Louis Impoundment downstream, the Pine River is a large warmwater stream. There is also a no consumption advisory on all fish in this river reach (see also **Water Quality**). Topography of the lower Pine River is relatively flat to gently undulating and is heavily used for agriculture, but the river has a high quality warmwater fishery with a high diversity of species. MDEQ has done numerous aquatic surveys for both macroinvertebrates and fish in this reach (Appendix B). Fisheries Division conducted a survey in 2002 and 25 warmwater fish species were captured indicating excellent species diversity. No fish are being stocked in this river reach. The only management is MDEQ permit reviews and working with other agencies and groups on projects to benefit the stream.

Recreational Use

The Tittabawassee River watershed offers a variety of water-based recreational use. Opportunities for hunting, fishing, swimming, camping, picnicking, boating, and wildlife viewing exist at various locations. Limited public access and public awareness and perception of polluted waters and sediments hinder potential recreational use, particularly on the Pine River downstream from Alma and the Tittabawassee River downstream from Midland. Although water quality has improved since the 1970s, the public remains skeptical of the safety of the river. Human health risks need to be continuously monitored and communicated to help keep the public informed of current conditions (see also **Water Quality)**.

From 1928 to 1964, conservation officers recorded catch and effort data from anglers at several locations in the watershed (Appendix D). Records indicate preferred fish species sought by anglers and gives some indication of species distribution and abundance. Access to the river, its tributaries, and lakes in the watershed was probably greater during that time than what exists at the present.

Most land within the watershed is under private or corporate ownership. Large tracts of state land open for public recreational use include the Au Sable State Forest and Edmore State Game Area. County-operated parks in Isabella, Midland, and Saginaw counties also have substantial tracts of land open for public recreation and most provide water access. Also, a number of small parks and nature areas are maintained by local government units. Outdoor educational facilities include the Chippewa Nature Center and Green Point Nature Center.

There are 39 public boat launches in the Tittabawassee River watershed (Table 44). Boating activities that require launches with sufficient water depths for safe operation are limited to inland lakes and impoundments and to the Tittabawassee River main stem from Midland downstream.

The Tittabawassee River main stem is canoeable from the upstream reaches of Secord Lake impoundment to the mouth, with portages at the four hydroelectric dams and Dow Dam. The Chippewa and Pine rivers are also canoeable through most of their main stems. Several canoe liveries operate on the Chippewa River in the vicinity of Mount Pleasant. In addition, the Isabella County Parks and Recreation Department operates three river access areas on the Chippewa River west of Mount Pleasant and the City of Mount Pleasant provides a take-out point at the site of the old Harris Dam. While the Pine River main stem is certainly large enough to be canoeable for most of its length, it is likely that public perception of chemical contamination causes most canoeists to seek out other rivers.

Headwaters

The upper reaches of all three branches of the Tittabawassee River, as well as many of their tributaries, are designated trout streams with resident populations of brown trout. Brook trout are also present in the smaller tributaries. Fishing access is severely limited, as most of the land is privately owned. However, some tributaries flow through state-owned lands in northern Gladwin and southern Ogemaw counties and provide small stream trout fishing opportunities for anglers with a penchant for orienteering and a general disregard for blood-sucking insects.

Middle

Secord, Smallwood, Wixom, and Sanford lake impoundments all provide excellent fishing opportunities for a wide variety of warmwater fish species including largemouth and smallmouth bass, northern pike, northern muskellunge, walleye, channel catfish, bluegill, black and white crappie, and other sunfish species. Sanford Lake impoundment contains a resident population of white bass. Public access sites operated by MDNR or county parks departments exist on Secord, Wixom, and Sanford lake impoundments. The public can launch for a fee at two private boat ramps on Smallwood Lake impoundment.

The Sugar River upstream from Lake Lancer is a designated trout stream and supports a self-sustaining population of brown trout. Lake Lancer is an impoundment of the Sugar River, and supports largemouth bass, northern pike, walleye, bluegills, and several other warmwater species. The Sugar River downstream from the dam is a warmwater stream populated by various minnow and sucker species.

The Molasses River is a warmwater stream, sustaining populations of minnows, suckers, and a few northern pike. Impoundments on the upper Molasses River created as waterfowl habitat by MDNR, Wildlife Division provide angling opportunities for yellow perch, sunfish, and bullhead species.

The North, Middle, and South branches of the Tobacco River, Cedar River, and their tributaries are designated trout streams with resident populations of brown trout. Brook trout are also found in the colder tributaries. Most reaches these streams are relatively narrow and brushy, lending themselves more readily to bait and spin fishing techniques rather than fly fishing. However, fly fishing is possible on certain reaches of each stream. Public access exists on Newton Creek, a tributary of the South Branch of the Tobacco River in Clare County, and through state forest lands on the North Branch of the Cedar River and main stem of the Cedar River in Gladwin County. Informal access exists at many rural-road stream crossings and some private landowners allow fishing access to streams. The South Branch of the Tobacco River downstream from Old US–27 flows into Shamrock Lake in Clare. Shamrock Lake supports largemouth bass, northern pike, bluegill, black crappie, suckers, and bullheads. A public launch ramp maintained by the City of Clare is located at the east end of the lake near the dam.

The South Branch of the Tobacco River downstream from Shamrock Lake is a transitional warmwater stream mainly supporting minnow and sucker species. However, a few large brown trout are occasionally taken by local anglers in this reach. It is believed that these trout find thermal refuge during summer months in small, colder tributary streams and live in the South Branch of the Tobacco River when water temperatures are suitable.

The designated trout waters of the Cedar River terminate just upstream from Wiggins Lake impoundment in Gladwin County. Wiggins Lake was originally impounded for hydroelectric generation, but now remains as a recreational body of water. Wiggins Lake impoundment supports largemouth bass, northern pike, walleye, bullhead, and assorted panfish species. A public boat launch is located near the dam.

The Cedar River downstream from Wiggins Lake impoundment is a warmwater stream providing fishing opportunities for smallmouth bass, rock bass, and a variety of nongame species.

Ross Lake supports a variety of warmwater fishing opportunities for largemouth bass northern pike, northern muskellunge, walleye, black crappie, and channel catfish.

The Tobacco River downstream from Ross Lake is not well known for its fishing. Peaking operations at the Beaverton hydroelectric project result in wide flow variations and public access to the river is quite limited.

Mouth

The Tittabawassee River from Sanford Dam downstream to Midland has excellent fishing for smallmouth bass. Northern pike, rock bass, and the occasional walleye and northern muskellunge are also taken. Boat launches are located in Sanford Village Park below the Sanford Dam and in Emerson Park in Midland, both of which facilitate float trips. Anglers, canoeists, and kayakers should pay particular attention to the operation of the Sanford hydroelectric project when planning float trips. River flows decline markedly when the hydroelectric plant ceases power generation and increases rapidly when power generation is initiated.

The Tittabawassee River downstream from the Dow dam in Midland supports major seasonal migrations of many cool and warmwater fish species from Saginaw Bay and Lake Huron. The Dow Dam is a barrier to upstream migration of warmwater fishes and concentrates fish in the reach immediately downstream. This reach is the site of a world-class walleye fishery each spring, as large numbers of postspawn walleye remain in the river when the season opens on the last Saturday of April. Spring walleye fishing tapers off by mid-May as the fish leave the river and return to Saginaw Bay. Walleye fishing picks up again in late fall and winter as prespawn fish move up the river. Winter fishing can be very productive if ice conditions permit boat launching. This reach does not freeze sufficiently to permit safe ice fishing. The Tittabawassee River downstream from Midland has some consumption advisories as discussed in **Water Quality**. Advisories are listed for carp, catfish, smallmouth bass, white bass, walleye and other species because of elevated levels of PCBs and dioxins.

Spawning migrations of steelhead, suckers, and white bass also ascend the lower Tittabawassee River providing seasonal fisheries. Smallmouth bass can be found in the river year round in proximity to woody structure and rocky substrate.

Carroll, Bullock, and Sturgeon creeks are small tributaries primarily supporting minnow species and a few northern pike. They provide some fishing opportunity. Public access is very limited.

The headwaters of the Salt River, the Herrick Park Ponds provide fishing for largemouth bass, bluegill, and bullhead sp. These four small ponds, the largest being 13 acres, are remnants of a gravel mining operation. They are owned by the Isabella County Parks and Recreation Commission, which operates a county park at the site.

Small and hydrologically unstable, the Salt River is not noted for its fishery. The fish community consists of northern pike, rock bass, and a variety of sucker and minnow species as well as some carp. The Salt River downstream from Delwin provides some fishing opportunities to local youths and is also a favorite destination for commercial minnow seiners.

Chippewa Lake is located at the headwaters of Chippewa Creek, which flows southeast into the Martiny Flooding. Chippewa Lake supports a warmwater fish community that includes largemouth bass, smallmouth bass, northern pike, walleye, bluegill, black crappie, yellow perch, and bullheads. A state-owned public access site is located on the east side of the lake.

The South Branch of the Chippewa River flows out of the Martiny Lake Flooding in north-central Mecosta County. This complex of relatively shallow warmwater lakes sustains excellent fishing opportunities for largemouth bass, northern pike, bluegills, crappies, and bullheads. The Martiny Lake Flooding is surrounded by a state game area of the same name which includes several public boat launches and camping areas. The South Branch of the Chippewa River downstream from the Martiny Lake Flooding to the town of Barryton supports a warmwater fish community.

The North Branch of the Chippewa West River and its tributaries are designated trout streams until they reach the upper end of the old impoundment in Barryton, where it joins with the South Branch of the Chippewa River to form the Chippewa River main stem. Temperature data suggests suitable habitat for trout, but survey data is lacking at this time. Public access above Barryton is very limited, as the North Branch of the Chippewa West River and its tributaries flow through private lands.

The Chippewa River downstream from Barryton is a warmwater stream with excellent fishing for smallmouth bass and rock bass. Some walleye, northern pike, and sucker species are also taken. The Chippewa River main stem is impounded in western Isabella County to form Lake Isabella, a recreational development with a fixed crest dam. Lake Isabella supports excellent bass fishing (both largemouth and smallmouth) as well as northern pike, walleye, black crappie, and bluegills (Lt. R.W. Utt, MDNR, Law Division, personal communication). There is no public boat launch on Lake Isabella, but some shore and ice fishing access is available through Gilmore Park, which is owned and maintained by the Isabella County Parks and Recreation Commission.

Downstream from Lake Isabella, the Chippewa River main stem is free-flowing to the City of Mt. Pleasant. Two major tributaries join the main stem between Lake Isabella and Mount Pleasant: the Coldwater River and the North Branch of the Chippewa East River.

The Coldwater River has its source in Littlefield Lake in north-central Isabella County. Littlefield Lake is very deep with a fish community that includes: largemouth bass, northern pike, walleye, bluegill, black crappie, and yellow perch. Littlefield Lake once had a productive winter fishery for rainbow smelt, but extensive beaver activity in Sucker Creek, a coldwater tributary of the lake, eliminated spawning habitat and smelt were extirpated.

The Coldwater River flows south from Littlefield Lake for several miles and enters Weidman Pond, a small impoundment at the confluence of the Coldwater River and Walker Creek. Walker Creek is also impounded to form Manitonka and Windoga lakes and Lake of the Hills; all small private developments. Weidman Pond is shallow and heavily vegetated with a fish community consisting of largemouth bass, northern pike, sunfish species, bullhead, and carp. Shore–fishing opportunities exist at the auxiliary spillway near the dam.

From Weidman Pond, the Coldwater River continues south and enters Coldwater Lake in Nottawa Township. Coldwater Lake offers excellent fishing for largemouth and smallmouth bass, walleye, northern pike, bluegill, black crappie, rock bass, and yellow perch. A public boat launch is on the lake's east side in Coldwater Lake County Park and is operated by the Isabella County Parks and Recreation Commission.

From Coldwater Lake, the Coldwater River continues southward to join the Chippewa River main stem. This reach of Coldwater River is large enough to fish without constantly fighting brush and offers fishing opportunities for smallmouth bass, rock bass, and other warmwater species.

The North Branch of the Chippewa East River has its origins in the south end of the Dead Man Swamp in southern Clare and northern Isabella counties. A warmwater stream with water quality problems, primarily related to agricultural practices, the North Branch of the Chippewa East River is not noted for fishing opportunities. Nearby Stevenson Lake is tributary to the North Branch of the Chippewa East River via Willow Lake and Gilbert drains. Stevenson Lake supports largemouth bass, northern pike, bluegill, black crappie, and bullheads. A state-owned public access site is located at the end of Whiteville Road on the south side of the lake.

After the confluence of the North Branch of the Chippewa East River with the main stem, the Chippewa River continues to Mount Pleasant. The Harris Dam in Mount Pleasant was modified in 2002 to facilitate fish passage and floatage for recreational watercraft. As a result, the Chippewa River main stem is now, for practical purposes, unimpounded from Lake Isabella downstream to the confluence with the Tittabawassee River in Midland. Throughout this reach smallmouth bass fishing is excellent. Rock bass, northern pike, sucker species and a few walleye, are also available. Park lands owned by the City of Mount Pleasant and the Isabella County Parks and Recreation Commission provide good public access to the river at several locations between Lake Isabella and Mount Pleasant. Downstream from Mount Pleasant public access to the river is more limited, but some parcels of state forest land abut the river and Manitou Park in Midland County provides fishing and canoeing access. Some informal access also exists at various road stream crossings.

Most tributaries of the Pine River in Isabella and Montcalm counties are designated trout streams. While the small coldwater tributaries support populations of brown and brook trout year round, the main stem becomes too warm during summer months and the trout move into tributaries. The Pine River main stem is a marginal trout stream which supports large numbers of minnow and sucker species and a few large brown trout. The trout designation ends at Lumberjack Road in northwestern Gratiot County. Downstream from this point, minnow and sucker species dominate the fish community until the river flows into Alma Impoundment.

Alma Impoundment sustains a fish community similar to other warmwater impoundments in central Michigan. Largemouth and smallmouth bass, northern pike, bluegill, pumpkinseed, black crappie, rock bass, yellow perch, channel catfish, bullheads, suckers, and carp are available in good numbers and sizes. The City of Alma maintains a boat launch and a shore fishing platform on Alma Impoundment. Contrary to popular local perception, fish taken in Alma Impoundment are not contaminated and all species except carp are approved for unlimited consumption by the MDCH.

Downstream from Alma dam, all fish species in the Pine River are heavily contaminated with PBB and DDT. MDCH has issued advisories recommending that no one should eat any species of fish taken from the Pine River downstream from the Alma dam to the confluence with the Chippewa River in Midland County (see also **Water Quality**). Catch-and-release fishing can be quite productive, however. Bass tournaments are held every summer in the St. Louis Impoundment, which is just downstream from Alma in the City of St. Louis. Largemouth and smallmouth bass are present in good numbers and grow to substantial size. Northern pike and black crappie also grow large due to minimal fishing pressure and no harvest. Several other sunfish species, channel catfish, bullheads, suckers, and carp are present. The City of St. Louis maintains a park and a boat launch on St. Louis Impoundment.

The Pine River from St. Louis downstream receives very little fishing pressure due to the contamination problems and public access to the stream is quite limited. The fish community consists of smallmouth bass, rock bass, a few northern pike, and a variety of minnow and sucker species.

Citizen Involvement

Citizen involvement in management of the Tittabawassee River and its tributaries occurs through interactions with government agencies that manage water flows, water quality, animal populations, land use, and recreation. Government agencies include: MDNR, MDEQ, United States Fish and Wildlife Service, United States Department of Agriculture, Natural Resource Conservation Service, soil conservation districts, county drain commissioners, and community governments.

The Little Forks Conservancy, based in Midland County, works to protect open spaces that provide diverse natural and cultural resources, including riparian habitat in the Tittabawassee River watershed, especially on the 95 miles of rivers and creeks flowing through the county. This group works cooperatively with landowners to establish conservation easements, maintains nature preserves, sponsors seminars, conducts research, and provides educational materials regarding land use issues (Little Forks Conservancy, 2006).

The Chippewa Watershed Conservancy, founded in 1985, protects land within the Chippewa River watershed through land acquisition, conservation easements, and educational projects. The Conservancy owns five land parcels that it manages as nature preserves and assists landowners in establishing conservation easements to preserve the natural character of the land (Chippewa Watershed Conservancy 2006).

The Pine River Superfund Citizen Task Force, based at Alma College, focuses on environmental issues and community restoration efforts occurring on the Pine River in Gratiot County. In 1983 the United States Environmental Protection Agency designated the old Velsicol Chemical Company plant site on the Pine River in St. Louis, another site west of the plant, and the nearby Gratiot County landfill as superfund sites. The Pine River Superfund Citizen Task Force was formed to provide local citizens and other interested organizations a voice in the cleanup of these sites (Alma College 2006).

Chippewa Nature Center is a nonprofit organization whose mission is to facilitate enjoyment and understanding of natural and cultural resources relevant to Saginaw Valley's ecosystems and to promote environmental awareness and foster responsible stewardship. Located in Midland County at the confluence of the Pine and Chippewa rivers, the Center controls over 1,200 acres of land, has a staff of 40, and provides a wide variety of programs to over 50,000 visitors each year (Chippewa Nature Center 2006).

The Leon P. Martuch chapter of Trout Unlimited, based in Midland, has been actively involved in several stream improvement projects on the Cedar River over the past several years. The chapter also owns and manages a parcel of land on the West Branch of the Cedar River in Clare County. The public can gain access to the river from this parcel.

Several other organizations have interests in the watershed (Table 45). These groups are generally associated with outdoor recreation or environmental concerns. The Tittabawassee River watershed is a very significant part of the larger Saginaw River watershed and thus draws the attention of organizations interested in the larger watershed as well as Saginaw Bay and Lake Huron.

MANAGEMENT OPTIONS

The Tittabawassee River is a fairly healthy system characterized by warmwater habitats and communities in the lower reaches and cool- and cold-water habitats and communities in most upper reaches. In many river reaches, however, fish populations and habitat are degraded and in need of attention. The management options presented are designed to address the most important problems that are now understood and to help establish priorities for further investigation.

Dewberry (1992) outlined measures that were important in the protection of healthy river ecosystems. These revolved around protection and rehabilitation of headwater streams, riparian areas, and floodplains. It is vital to reconnect streams and floodplains wherever possible. The river system should be viewed holistically, for the functionality and important elements of fish habitat are governed by whole system processes.

The mission statement of Fisheries Division is to protect and enhance public trust in populations and habitat of fishes and other forms of aquatic life, and to promote optimum use of these resources for the benefit of the people of Michigan. In particular, the Division seeks to: protect and maintain healthy aquatic environments and fish communities and rehabilitate those now degraded; provide diverse public fishing opportunities to maximize the value to anglers; and foster and contribute to public and scientific understandings of fish, fishing, and fishery management. The management options listed below are organized according to the sections in this assessment. Their function is to provide a framework for use in public discussion and comment.

Four types of options for correcting problems in the watershed are presented: 1) options to protect and preserve existing resources; 2) options requiring additional surveys; 3) opportunities for rehabilitation of degraded resources; and 4) opportunities to improve an area or resources, above and beyond the original condition.

History

Archaeological sites can be damaged or destroyed by any activity that disturbs soil. Most sites lie in the upper 1 ft of soil, though some are buried more deeply. The Office of the State Archaeologist maintains records of archaeological sites and can advise regarding management of them. Archaeological artifacts cannot be removed without permission of the landowner. Permits are required for investigation of sites on federal and state lands.

Option: Protect existing and future archaeological and historical sites by contacting the Office of the State Archaeologist before any major earth moving or river restoration projects are initiated.

Option: Survey for and identify animal artifacts at archaeological sites to further understanding of the historical presence of animals within the watershed.

Geology and Hydrology

The Tittabawassee River watershed has stable flows in its headwaters. These are areas with good groundwater flow created by porous surficial materials, varying landscape elevation, and appropriate land use practices. The middle and lower reaches have less groundwater flow because of less porous surficial materials and a flatter landscape. These reaches are influenced by land use practices that affect the river by causing flashiness, accelerated runoff, and reduced infiltration. Much of the land has been tiled and there are high concentrations of county drains. Tiles and artificial drains destabilize river flows and contribute to almost annual flooding and low flow events.

Option: Protect all existing coldwater, stable streams from effects of land use changes, channelization, creation of country drains, irrigation, and construction of dams and other activities that may disrupt the hydrologic cycle, by working with land managers, planners, and MDEQ permit approvals.

Option: Protect and rehabilitate the function of wetlands and floodplains as water retention areas and groundwater recharge areas. Inventory existing wetlands and identify potential areas for creation of wetlands.

Option: Protect natural lake outlets by opposing construction of new lake-level control structures. When possible, remove existing lake-level control structures and rehabilitate or install riverine habitat necessary to retain river connectivity. Modify existing lake-level control structures as fixed-crest structures with minimum flow requirement capabilities.

Option: Install additional flow gauges in rivers and streams that are currently not monitored. Installation of gauges will provide crucial flow regime data necessary for appropriate management of these systems.

Option: Monitor surface and groundwater withdrawals and establish minimum flow requirements for the main stem and all tributaries. Support programs that promote conservation and regulation of surface and groundwater withdrawals.

Option: Monitor flows and water quality below main stem and tributary dams and lake-level control structures to determine if minimum flow or run-of-river flow requirements are necessary.

Option: Rehabilitate floodplains by removing buildings, dams, and road crossings that interfere with natural river function. Explore alternatives to channelization to allow streams to reestablish a natural streambed and water course. Work toward zoning requirements that prevent development in floodplains.

Option: Rehabilitate flow stability by working with county drain commissioners to incorporate flow patterns into criteria for drain design and maintenance and storm water management.

Option: Rehabilitate flow stability by removing or plugging drain tile fields that are no longer needed for land drainage.

Option: Protect groundwater and streamflows by ground-truthing the hydrologic and biological components of the Water Withdrawal Assessment Tool for the Tittabawassee River watershed and providing the information back to DEQ.

Option: Protect groundwater and streamflows by forming water user groups to discuss problems, and concerns about water allocation and potential conservation strategies. This is fulfilling the vision for local governance found in the water withdrawal assessment process established under the 2008 Water Management Law.

Option: Support agricultural best management practices and storm water management education with emphasis towards: area school districts, contractors, developers, and farmers.

Soils and Land Use Patterns

Land use practices in the past and present have affected Tittabawassee River resources. Loss of wetlands, converting permeable soils to impervious soil surfaces, constructing land drainage systems, converting agricultural lands to urban and industrial uses, and destroying naturally forested areas along river corridors all negatively affect the river resource.

Option: Protect natural areas by working with local governments and planners, zoning boards, agricultural agencies, and groups to implement best management practices.

Option: Protect developed and undeveloped lands through land use planning and zoning guidelines that emphasize protection of critical areas, minimize impervious surfaces, improve storm water management for quality and quantity, and maximize infiltration.

Option: Protect remaining wetlands, especially small "unregulated" wetlands, by working with local governments and planners, zoning boards, agricultural agencies, and groups.

Option: Protect and rehabilitate forested corridors along the river and its tributaries. Encourage additional tree planting and reforestation throughout the watershed.

Option: Support enforcement of soil sedimentation and erosion control laws to protect productivity of land and prevent siltation of instream aquatic habitat.

Option: Protect and rehabilitate critical areas through maintenance of current storm-water management systems and retrofitting areas that are in need of storm-water management systems.

Option: Protect the functionality of the watershed through legislation that preserves rural lands by controlling urban sprawl and industrial development.

Option: Protect natural river functionality through the purchase of flooding rights within the floodplain (i.e., similar to conservation easements by public and private organizations).

Option: Survey watershed to locate crossings that are degrading streams through sedimentation, disruption of streamflow, or creation of barriers to fish passage.

Option: Rehabilitate any crossings identified above through erosion control measures, reconstruction of poorly placed crossings, and replacing perched and narrow culverts. When possible, bridges are preferred over culverts. New culverts should be properly sized and placed to insure fish passage and minimize disturbances in streamflow.

Channel Morphology

Much of the Tittabawassee River watershed has high channel gradient. However, large hydro dams were constructed in these areas and the high gradient is now under flooded impoundments. Also, county drains and agricultural field tiling have degraded many natural channel characteristics. These alterations have increased flow variability, altered channel shapes, and the erosive potential has affected habitat diversity.

Option: Educate and develop necessary relationships with county drain commissioners and riparian land owners to reduce effects of county drains and field tiling. Where possible, reduce field tiling and reduce number of county drains. These actions will maintain channel shape and width where appropriate, and rehabilitate shape and width in degraded areas to reduce flooding events.

Option: Protect channel morphology by promoting use of bridges or properly sized culverts at road–stream crossings.

Option: Protect existing large woody structure in stream channels by educating riparian property owners and drain commissioners of the value of this structure.

Option: Restore and maintain greenbelts along river corridors to minimize surface runoff and erosion of adjacent lands, and to retain valuable top soils.

Option: Undesignate drains and restore streams where no longer needed.

Dams and Barriers

There are 143 dams in the watershed and many have significant negative effects on aquatic resources. Dams fragment habitat for resident fish, impede fish movements, impound high gradient areas, trap sediments and woody structure, cause flow fluctuations, cause fish mortalities (e.g., entrainment by hydroelectric dams), and block navigation. Lake-level control structures alter natural water regimes and impair downstream aquatic habitat. Some dams, however, provide impoundments with existing and future potential for fisheries and other recreational uses not provided by flowing water.

Option: Protect and improve biological communities by providing upstream and downstream fish and large-woody structure passage at dams to mitigate habitat fragmentation.

Option: Protect remaining connectivity of the river system by opposing construction of dams and instream storm water detention basins.

Option: Protect and restore angler access rights to the Tittabawassee River by working through FERC to ensure that Boyce Hydropower, LLC implements approved plans in their FERC license to develop and improve public access and recreational opportunities at the four major projects on the main stem.

Option: Protect fishery habitat and river functionality through active opposition to hydroelectric facilities development within the Tittabawassee River watershed. If hydroelectric development cannot be avoided, DNR should forcefully pursue mitigation of all project effects on the resource.

Option: Survey and develop an inventory of barriers to fish passage, such as culverts, and explore options to correct any problems.

Option: Survey and develop a watershed list of the most environmentally damaging dams and barriers to fish passage in the river and make recommendations to mitigate damages where possible.

Option: Monitor water temperatures above and below dams to determine the effects of dams on coldwater systems.

Option: Survey to determine number, location, and potential effects of small unregistered dams.

Option: Rehabilitate free-flowing river conditions by encouraging dam owners to make appropriate financial provisions for future dam removal and seek legislation to require dam owners to establish such funds.

Option: Rehabilitate free-flowing river conditions by removing dams, requiring dam owners to operate at run-of-river flows, and modifying all possible dams to fixed-crest structures. Fish passage and dam removal will be most beneficial for the most downstream dams in the watershed for the short term, as fish could gain access to more habitat upstream. However, any dam requiring repair or extensive maintenance should be considered for removal.

Option: Rehabilitate river functionality through foundation support and appropriations to create a dam removal fund that local communities can use to help remove unwanted dams.

Option: Rehabilitate river navigability by constructing canoe portages and upstream and downstream access launches at dam locations on the main stem and major tributaries.

Option: Rehabilitate natural water levels by requiring all lake-level control structures to be operated to maintain existing seasonal water level fluctuations. Lake-level control structures should be removed or converted to fixed crest to accomplish this.

Water Quality

Tittabawassee River water quality has improved since the establishment of the NPDES program according to the Clean Water Act of 1973. Continued improvement is needed with storm sewers and nonpoint sources, which have significant bacteria, nutrient, and dissolved oxygen effects on the river, especially in the middle segment of the main stem. The many contaminated (Part 201) sites in the watershed raise concern about possible future and current loading of toxic materials to the river and groundwater. Dioxin contaminated sediments continue to be the main impediment to fisheries management in the Tittabawassee River below Midland, and PBB in the St. Louis Impoundment and Lower Pine River.

Option: Protect and rehabilitate water quality by implementing improved storm water and nonpoint source best management practices watershed wide.

Option: Protect and rehabilitate water quality through effective use of regulatory tools (enforcement) by DEQ and federal agencies (e.g., United States Environmental Protection Agency and Army Corp of Engineers).

Option: Protect and rehabilitate water quality by supporting the existing phosphorous TMDL project and any future TMDL projects.

Option: Protect water quality and fish habitat by ensuring enforcement and compliance of erosion control permits under Part 91 of the Michigan Natural Resources and Environmental Quality Protection Act (1994 PA 451).

Option: Protect water quality by conserving existing wetlands and riparian corridors, rehabilitating former wetlands, and maximizing use of natural and constructed wetlands as natural filters.

Option: Protect river quality by supporting educational programs for farmers, land developers, and other resource users that teach land and water management practices that prevent further degradation of aquatic resources.

Option: Protect and rehabilitate water quality by promoting use of non-phosphorous fertilizers near streams, lakes, and impoundments. Work with local governments, zoning boards, and agricultural agencies and support legislation to ban fertilizers that contain phosphorous near any stream, lake, or impoundment.

Option: Protect major aquifers by promoting hydrogeologic studies to characterize groundwater and by promoting programs aimed at preventing groundwater contamination.

Option: Protect and rehabilitate water quality by continuing to improve pollution prevention for storm water discharge or regulated industrial sources.

Option: Survey the watershed to determine areas with contaminated fish. System-wide sampling will provide baseline information on areas with no or limited data.

Option: Survey loading of nutrients and sediments to the river and develop strategies to reduce nonpoint source pollution problems by working with MDEQ, MDA, and local Natural Resource Conservation Service offices.

Option: Protect and rehabilitate water temperatures by maintaining and enhancing riparian corridors to be fully vegetated. Encourage removal of unnecessary dams. Protect wetlands and sources for infiltration to encourage groundwater recharge over surface runoff.

Option: Investigate the role of dams in elevating natural water temperatures to determine where effects are greatest.

Option: Rehabilitate and protect water quality by supporting the Lower Tittabawassee River NRDA and efforts to clean up dioxins and other contaminants.

Option: Rehabilitate and protect water quality of the Pine River, Velsicol Site by continuing to support efforts of MDEQ, Remediation and Redevelopment Division.

Option: Use and support local zoning as an instrument to control urbanization and non-point sources of runoff.

Option: Support legislation and efforts to require mandatory septic system inspection when property changes hands.

Special Jurisdictions

Natural resources and environmental quality are managed by the State of Michigan through the departments of Natural Resources and Environmental Quality. The Federal Energy Regulatory Commission licenses active hydropower facilities. County drain commissioners have authority over designated drains and many lake-level control structures. Township and city officials control zoning and ordinances that can have an effect on the quality of a river system. Public ownership and management of land in the Tittabawassee River watershed is minimal except in a few subwatersheds.

There are also many road and stream crossings in the watershed that have negative effects on streams (similar to the negative effects of dams). They can potentially block upstream movements of fish and aquatic organisms, cause erosion, destroy high gradient areas, impede woody structure transport, and cause sedimentation. They also interfere with navigation and recreational activities.

Option: Protect recreational access to streams by continuing to advocate and work toward legislative adoption of the recreational definition of navigability (e.g., a stream is legally navigable if it can be navigated by canoe or small boat).

Option: Protect and rehabilitate the river system by supporting cooperative planning and decision making.

Option: Protect coldwater tributaries by designating appropriate reaches as trout streams to ensure proper management and environmental protection.

Option: Protect the quality of wetlands, streams, and lakes through rigorous enforcement of Parts 31, 91, 301, and 303 of the NREPA Act of 1994.

Option: Survey and identify river reaches for natural river designation. The lower and middle main stem segments could be considered for this designation.

Option: Rehabilitate designated drains by encouraging drain commissioners to use stream management approaches that protect and rehabilitate natural processes rather than traditional deepening, straightening, and widening practices that emphasize moving water quickly with little consideration for the effect on a stream or biota.

Option: Rehabilitate designated drains by supporting efforts to rewrite the drain code.

Option: Rehabilitate lake outlet streams by encouraging run-of-river management at lake-level control structures.

Option: Reconnect fragmented riverine habitat by working with road commissions to replace perched culverts that block movement of fish and aquatic organisms, woody structure, and sediment, with structures that allow preservation of the natural stream bottom.

Option: Work with MDEQ, citizens groups, and other agencies to conduct stream crossing surveys to identify sources of pollutants in the watershed.

Option: Work with county road commissioners to install bridges that span the entire flood way without placing supporting structures in the flood way.

Option: Work with county road commissioners to prevent erosion by stabilizing road surfaces and embankments and by diverting surface water runoff to retention areas for sediment and contaminant deposition. Maintain retention areas by cleaning and transporting undesirable sediments and nutrients to appropriate locations away from the floodplain.

Option: Work with Michigan Department of Transportation by providing early review and comments of road and bridge projects to protect fisheries habitat and water quality.

Option: Increase groundwater recharge by directing roadway runoff into wetlands and retention areas.

Biological Communities

The biological communities of the Tittabawassee River have improved significantly since the 1970s due to water quality improvements. Certain problems, however, are still present. Aquatic habitat has been lost to sediment deposition, to impounding of high gradient areas, and to channelization. There has also been a loss of potamodromous species that historically used the river for spawning (e.g., lake sturgeon). These species have been cut off from spawning habitats by dams on the main stem and tributaries. Channelization and stream clearing has degraded channel morphology and removed woody structure used for habitat and raised stream temperature. Mussel and aquatic invertebrate species have declined because of poor water quality, sedimentation, and the inundation of riverine habitats by impoundments. Decline of amphibians and reptiles coincide with loss of wetlands.

Option: Protect remaining stream margin habitats, including floodplains and wetlands, by encouraging setbacks and vegetation buffer strips in zoning regulations, controlling development in the stream corridor, and acquiring additional greenbelts through agricultural set aside programs, conservation easements, or direct purchases from conservation organizations or government agencies.

Option: Protect remaining high gradient and naturally graveled habitats.

Option: Protect native aquatic species from predation, competition, and habitat destruction from invasive species (e.g., sea lamprey, gobies, zebra mussels, rusty crayfish, and purple loosestrife), by suppressing the spread and population expansion of pest species through education and chemical or biological control (TFM, beetles, or species specific bacteria) when feasible.

Option: Protect native mussels by removing dams so less lentic habitat is available for zebra mussels.

Option: Protect and rehabilitate cold- and cool-water thermal habitat areas and their unique biological communities including East Branch of the Tittabawassee River, West Branch of the Tittabawassee River, Sugar River and Creek, Tobacco River, Cedar River and all branches, and upper Pine and Chippewa rivers.

Option: Protect and rehabilitate upland habitats for native plant and wildlife diversity.

Option: Survey and map biological community distributions using advanced technology including global positioning and geographic information systems.

Option: Work with MDEQ, Water Bureau to survey distribution and status of aquatic invertebrate (mussels and insects) and fish fauna. Many drainages have no survey data (e.g., Bullock Creek, Carroll Drain, and Mud Creek).

Option: Survey distribution and status of amphibians and reptiles and protect critical habitats.

Option: Survey distribution and status of species of concern, develop protection and recovery strategies for those species, and explore options to protect critical habitat.

Option: Support USFWS programs to evaluate use of the Tittabawassee River by lake sturgeon for spawning and habitat. Work with other agencies and the Dow Chemical Company for fish passage over Dow Dam so lake sturgeon may eventually have access to additional habitat for spawning.

Option: Assess the fish community and habitat in the lower main stem, lower Pine River, and lower Chippewa River.

Option: Rehabilitate rare, high-gradient and fragmented habitats by removing unnecessary dams.

Option: Rehabilitate populations of potamodromous fish by removal of unnecessary dams and by installing upstream and downstream passage at other dams and barriers. Passage facilities should consider the migration of salmonids as well as cool- and warm-water species (e.g., smallmouth bass, walleye, flathead catfish, lake sturgeon, redhorse, and suckers).

Fishery Management

Moderately stable, groundwater-moderated flows and coarse substrates represent key values of the headwaters segment of the main stem, the Tobacco River, and the Upper Pine and Chippewa rivers. The middle and mouth segments of the Tittabawassee River main stem have the potential to support substantial populations of cool- and warm-water fishes along much of their length. Angling opportunities could be expanded through more concerted management and careful review of existing management practices.

Sport fish populations and biological communities will improve with continued improvements in water quality. Therefore, controlling point and nonpoint source pollution is critical for rehabilitation and protection of fish habitats, fish populations, and for greater and safer public use of aquatic resources.

Future fisheries management should account for physiographic features of the watershed as well as human alterations and influences.

Option: Protect headwater habitats by promoting best management practices such as buffer strips and conservation easements.

Option: Protect coldwater habitats and self-sustaining brook and brown trout populations by seeking alternatives to land development, or by encouraging sensible development that will include buffer strips, shading, and wetlands.

Option: Protect urban streams in the lower and middle segments by instituting ecologically smart development techniques.

Option: Protect existing wetlands (e.g., northern pike spawning and nursery habitat) in the lower Tittabawassee, Pine, and Chippewa rivers.

Option: Protect and identify high quality trout streams by including these identified streams on the MDNR, Beaver Management Policy stream list for active beaver trapping and removal.

Option: Protect the fishery in Tittabawassee River mouth reach, Pine River, and Chippewa River through habitat protection that maintains natural reproduction of smallmouth bass and northern pike.

Option: Survey fish populations and inventory habitat in waters lacking recent or any data (e.g., Upper Pine River and tributaries, Upper Chippewa River and tributaries, Salt River and Creek, and many drainages and tributaries to the middle and lower Tittabawassee River).

Option: Survey and evaluate existing walleye populations in the main stem mouth segment. Continue to tag walleyes at Dow Dam and monitor population dynamics and growth of this spawning population.

Option: Survey habitat for rehabilitation of lake sturgeon spawning runs, especially in the main stem mouth reach.

Option: Rehabilitate habitat continuity by removing unnecessary dams. Require upstream and downstream fish passage as well as bottom-draw release on those dams that remain. Fish passage and dam removal will be most beneficial at the most downstream dams for the short term, as fish could gain access to upstream habitat. However, any dam requiring repair or extensive maintenance should be considered for removal.

Option: Rehabilitate historical populations of Great Lakes muskellunge in the main stem mouth in conjunction with management program of Saginaw Bay

Option: Rehabilitate angling opportunities by continued improvement and acquisition of public access property.

Option: Rehabilitate potamodromous fish movements by developing a fish passage plan for the Tittabawassee River that considers a sea lamprey barrier, lake sturgeon passage, and cool- and warm-water fish passage.

Option: Enhance fishing opportunities through stocking programs. Stocked waters should continue to be surveyed to evaluate fish populations and angler use to justify future stocking (e.g., Sanford, Wixom, Wiggins impoundments, and Tobacco and Pine rivers).

Option: Rehabilitate and improve fish habitat at road crossings by minimizing erosion, sediment loading, and perched culverts.

Option: Determine the recreational fishing value of the four large impoundments in the main stem middle reach by conducting creel surveys.

Option: Monitor effects of aquatic invasive species (e.g., zebra mussels, VHS, etc.) on native fish populations.

Option: Continue to monitor sea lamprey reproduction in the Tittabawassee River watershed. Work with the USFWS, Lamprey Control to implement necessary control measures.

Recreational Use

The watershed offers a wide variety of recreational opportunities in publicly owned areas including fishing, hunting, swimming, camping, picnicking, boating, and wildlife viewing. Limited public access and the publics' perception of polluted waters and sediments hinder potential recreational use, particularly on the Pine River downstream from Alma and the Tittabawassee River main stem downstream from Midland.

Option: Support efforts to rehabilitate contaminated reaches, remove dams that no longer serve a purpose, and maintain a natural river corridor with continuous public access.

Option: Protect, encourage, and support existing parks and recreation areas, and promote responsible management for riparian areas in public ownership.

Option: Improve public access through land acquisition by all levels of government (i.e., state, county, and township) and other private organizations.

Option: Protect recreational use of small tributaries by supporting establishment of a "recreational" definition of navigability as opposed to a "commercial" definition.

Option: Develop and support programs, similar to MDNR, Wildlife Division's Hunter Access Program, that offer financial incentives for private landowners to permit public access.

Citizen Involvement

Citizen involvement in the watershed is increasing. Several groups have developed with specific goals. It is important that all interest groups communicate with each other as well as with other groups around the state to develop educated and effective management strategies toward watershed improvements.

Option: Assure MDNR, Fisheries Division involvement with interest groups by attending meetings, reviewing project proposals, and providing information regarding watershed issues.

Option: Support communication between interest groups in the Tittabawassee River watershed.

Option: Implement strategies to educate the community to the benefits of river ecosystems, wetlands, and floodplains by supporting local conservation organizations.

Option: Rehabilitate river habitat by encouraging and supporting habitat improvement projects conducted by sports groups.

Option: Promote citizen use of the river by supporting programs that encourage use and contact with the river.

PUBLIC COMMENT AND RESPONSE

The draft of the Tittabawassee River Assessment was distributed for public review in fall 2008. Electronic copies were available on the State of Michigan, MDNR web site. Statewide MDNR press releases were issued in conjunction with release of this draft.

Three public meetings were held to receive comments concerning the river assessment draft. Midland Chippewa Nature Center, October 17, 2008 (4 people attended); Mt. Pleasant Public Library, October 27, 2008 (1 person attended) ; Gladwin Riverwalk Place, October 30, 2008 (13 people attended); and by request, a fourth public meeting was added, also at the Mt. Pleasant Library (January 22, 2009; 21 people attended).

The public comment period for the river assessment draft ended February 22, 2009. This was an extension of the original comment period due to the addition of an extra public meeting. All comments received were considered. Where Fisheries Division agreed with comments, changes were made. Where Fisheries Division disagreed with comments, reasons why are stated in our response.

Entire Document

Comment: Many comments were received complimenting us on an excellent compilation of information describing the Tittabawassee River system and suggesting that this document should become important for future decision making and be a reference for watershed issues for years to come.

> Response: Thank you.

Comment: Many comments were received regarding the public presentations and how much information they provided.

> Response: Thank you.

Comment: Several generic grammatical and spelling errors were noted.

> Response: Corrections have been made.

Comment: The theme for dam removal shows up an excessive number of times and appears to be a theme of the document. Many are concerned that removal of dams is the preferred option and would solve many of the current problems.

> Response: Removal of dams is only one option for the river. While it is true that it would solve many problems and also restore the original river functionality, it is not necessarily the only solution. The decision to remove dams is ultimately going to be determined by societal needs including financial and situational obligations. We realize that many of these dams create impoundments which have high riparian development and are economically important to communities.

Comment: Several groups have requested to be added to the Citizens interest groups in Table 45.

Response: These groups have been added to Table 45.

Comment: Will there be a watershed management plan to follow this?

Response: Fisheries Division will complete the writing of a 5 year Fisheries Management Plan to accompany this assessment. It is hoped that other groups will act on options in their area of interest.

Executive Summary

Comment: An editing suggestion was received to replace the word "restore" with the word "utilize" in the sentence "The Management Options Section identifies a variety of actions that could be taken to protect, restore, rehabilitate, or better understand the Tittabawassee River."

Response: Although recognition of the present state is important, restoring functionality is an important theme in the river assessment. There are interpretations of all those words that would provide improvements even for the current state of the impoundments. This word change was not made. Utilization is not necessarily the same goal.

Geography

Comment: The headwaters of some tributaries should not have been included in the Middle and Mouth segments, as they are more similar to the Headwater segment.

Response: The watershed could be divided in various ways, as the system is large and dendritic in nature. We chose the system we used because it maintained a direct relationship with the Tittabawassee Mainstem and we believe this provided the best continuity and consistency. Changing valley segment organization would not alter the conclusions or management options of this assessment.

History

Comment: In the first paragraph of this section: "Great Lakes" should probably be "upper Great Lakes".

Response: This change was made in reference to the location of the outlet.

Comment: Consider adding information on the impacts that logging and agricultural eras had on the river, similar to the information in **Biological Communities**.

Response: A reference to this information was added.

Water Quality

Comment: Several editorial suggestions were made for the paragraph regarding *Sources of Dioxins*.

Response: All changes were incorporated.

Comment: Several editing suggestions were given to change the *Natural Resources Damage Assessment* section.

> Response: All suggestions have been incorporated and an additional reference has been added.

Comment: Add a new heading for the paragraph dedicated to consumption advisories.

> Response: A heading called *Consumption Advisories* was added.

Comment: Add additional references to wild game consumptions advisories and soil advisories to the floodplain.

> Response: These references were added.

Comment: Add a statement to make mention of the additional contamination sites under state authority (Part 201 sites) and to reference Table 26 to draft page 43.

> Response: Changes were made. This reference has been added to the river reach sections.

Comment: Several suggestions were given to edit the Natural Resources Damage Assessment Section.

> Response: Most changes were incorporated into the text in this section.

Comment: Several editorial suggestions were made for the *Sites of Environmental Contamination (Part 201 Sites)* section.

> Response: Most editorial changes were made. Dates were added for the section regarding underground and aboveground storage facilities and the section was clarified. All changes were made in the *Superfund* Section.

Comment: Who measures heavy metals in the watershed?

> Response: Heavy metals are regulated by MDEQ.

Comment: What is the 1967 Stream Classification?

> Response: In 1967, the MDNR Fisheries Division classified streams based on temperature, habitat quality, size, and riparian development. It was not necessarily dependent on presence or absence of fish species. MDNR Fisheries Division is currently working on an improved classification system to add fisheries survey data to ground truth the old data.

Special Jurisdictions

Comment: Regarding the navigability laws, can you go around obstructions and wade up streams?

> Response: Yes, you need to be wading (get your feet wet), but you may step around obstructions and return back to the water. You may not enter uplands adjacent to the stream except to go around an obstruction using the shortest practical route.

Comment: Add Federal Emergency Management Agency (FEMA) to the **Special Jurisdictions** section

> Response: A section has been added.

Biological Communities

Comment: Several editing suggestions were given to change the *Factors Affecting Fish Communities* section.

> Response: Most editorial comments were incorporated into the text. Rainbow trout, brown trout, coho salmon, and Chinook salmon were not included with the colonized or exotic species because they were intentionally stocked and naturalized early on.

Comment: It was suggested that it would be helpful if the species distribution figures in Appendix C had additional information regarding the status of the species (native, introduced, or colonized).

> Response: This information is already covered in Table 31.

Comment: A question was asked regarding whether the term “colonized” was the standard used by the DNR versus terms such as “exotic” or “invasive”.

> Response: Colonized is a term used for fish that have become established, and this term generally is less negatively construed. Exotic or invasive introduction infers an unintentional establishment that is generally problematic.

Comment: An editorial suggestion was made in the *Bird* section.

> Response: This change has been made.

Comment: It was pointed out that common names of bird species should be always capitalized. Several inconsistencies occur in both the text and associated tables.

> Response: The text has been corrected and all capitalized. Tables 39 and 41 have been corrected.

Comment: List feral swine as an exotic species.

> Response They have been added to the list in **Biological Communities** under the section on Pest Species.

Biological Communities

Comment: It was suggested that a statement regarding fish consumption advisories be added along with a website citation in the **Recreation** section.

> Response: A sentence has been added regarding advisories and directing the readers to the section where they are discussed in **Water Quality**.

Comment: It was suggested to be consistent and add the information regarding the advisory downstream of Midland on the Tittabawassee as was done for the sections of the Pine River.

> Response: This has been added.

References

Comment: "Landscaping for Wildlife and Water Quality by Henderson, Dindof, and Rozumalski, Nongame Wildlife Program—Section of Minnesota Department of Natural Resources" was suggested to be added for inclusion as a reference.

> Response: This reference was not used in the preparation of this assessment and as a result cannot be included in our references section. It is included here as another potential source of information.

Management Options

Entire Draft

Comment: It is disturbing to continually see only management options that refer to restoration of the natural riverbed. Another option should be added to include planning for sustainable utilization of key impoundments (lakes) including support of their dam infrastructure with shorelines.

> Response: Values of the impoundments are covered in several of the other management sections, especially in the **Dams and Barriers** and **Recreation** sections. Their fisheries and recreational value are recognized. Many options suggest restoring to more free flowing conditions, restoring connectivity, etc. The management options are not meant to necessarily be all or none. As stated in the **Entire Draft** regarding dams, removal is ultimately a decision which will be based on many factors of society including economics and needs. We recognize the investments of citizens, businesses, and taxpayers. No separate management option was added to specifically support sustaining the infrastructure.

Dams and Barriers

Comment: A sentence should be added to clarify that some dams, in particular hydroelectric dams, provide impoundments with values and have become highly developed with homes and are therefore important to local businesses and government, and that removal would create a major economic impact to the surrounding areas and governments.

> Response: No sentence was added. Dam removal is an option. It is not the only option. As stated in the **Entire Draft** comments, ultimately these decisions will be based on society's needs. Due to the condition of many of the larger hydroelectric dams, decisions will need to be made and capital will need to be invested. More general discussions and information can be found in the **Dams and Barriers** section.

Comment "[F]ish migration should be prioritized for restoration to the middle and upper tributaries of the Tittabawassee: Tobacco R/Cedar R, Sugar R., and Chippewa R."

> Response: The importance of fish migration and passage is discussed in many places in the assessment. In the **Management Options** section it is covered under the **Dams and Barriers** section. Providing passage wherever we can is priority and refers not just to fish but also woody structure and other components, and not just for those reaches mentioned above. Restoring connectivity of the system is priority.

Comment A statement should be included in any Tittabawassee River Management plan saying "All dams located upstream of Secord Dam (mostly Sugar R. system) and all dams on the Tobacco R. watershed should be slated for removal."

> Response: A DNR Fisheries management plan will be written following the completion of this assessment. As the management options indicated, dam removal is one option. Priorities and where this can be accomplished will be determined by circumstances, opportunity, economics, and ultimately the priorities of society.

Comment: "Include the Chippewa River Headwaters in dam removal. Most of these are probably lake control structures or city-owned dams that have zero or limited value anymore and inhibit the coldwater habitat that is most valuable".

> Response: All dams are included with the options for removal where feasible. The reasons for removal are also discussed in **Dams and Barriers**. See also the general comment on dams discussed in the **Comment and Response** Section.

Comment: Have all hydroelectric dams been re-licensed?

> Response: Yes, they have all been re-licensed. This is discussed in the **Dams and Barriers** section and in Appendices A1- A4.

Comment Add a management option to the *Dams and Barriers* section to show that there is a need to monitor water temperature to determine the effects of dams on coldwater streams.

> Response: A management option has been added.

Comment: Is there direct evidence on any dam removal in the Tittabawassee watershed to show the benefits.

Response: No research has been done on any specific dam in the watershed, but there is much evidence from other studies in other locations to suggest the benefits, see **Dams and Barriers** section. This type of demonstration project (on a specific dam removal) would be very worthwhile for local documentation and support.

Water Quality

Comment: Add an option to protect and rehabilitate water quality by promoting the use of non phosphorous fertilizers near streams, lakes and dams by working with local governments, zoning boards, and agricultural agencies and by supporting legislation to ban fertilizers that contain phosphorous near any stream, lake or dam.

Response: A management option has been added.

Comment: Add an option to "[p]rotect water quality by reducing the nonpoint source pollution coming from septic systems of the large urban communities surrounding the hydroelectric dams by working with local governments and the state legislature to install sewer systems".

Response: Conversion from septic to sewer systems could help water quality, but may be expensive. It should also be noted that properly functioning or sited septic systems do not necessarily contribute adversely as a non-point source. The regulation of septic systems ultimately falls under the jurisdiction of the County Health Department.

Comment: MDEQ Remediation and Redevelopment Division is responsible for the Velsicol site, not Water Bureau.

Response: This change has been made to the Management Options.

Comment: There is a need to emphasize zoning as an instrument to control urbanization or non-point source runoff.

Response: We agree. A management option has been added to the water quality section noting this.

Comment: Add a management option to require mandatory septic system inspection when a property changes hands.

Response: This has been added as a management option under the *water quality* section. Regulation for this ultimately falls under County Health Departments.

Biological Communities

Comment: There is a management option needed to promote beaver control in coldwater streams.

Response: Beavers have a place within the watershed and their management is guided by the MDNR Beaver Management Policy. Many of our coldwater streams have been identified in this policy as places where beaver trapping would be encouraged and where nuisance beaver trapping permits may be issued. The beaver management policy guides issuances of nuisance permits and provides guidance for stream setbacks for timber management.

GLOSSARY

alluvium – detrital material such as clay, silt, sand, or gravel deposited by running water

ammocoetes – larval (juvenile) stage of lamprey; eyeless, toothless

base flow – portion of streamflow attributable to groundwater

BCE – "before the common era"; period of time measured prior to year 1 of the Gregorian calendar; the years are the same as we know them now

BP – "before present"; years before CE 1950 of the Gregorian calendar; most commonly used in reference to geology and archeology dates

calcareous – consisting or containing calcium carbonate

carapace – exterior calcium skeleton covering the head and upper portion of the thorax on crayfish and other crustaceans (shrimp, crab, lobster, etc)

CE – common era; period of time measured beginning with year 1 of the Gregorian calendar

DDT – dichloro-diphenyl-trichloro-ethane; an insecticide toxic to vertebrates, known to accumulate in ecosystems

deciduous – vegetation that sheds its foliage annually

detritus – loose material found on a lake or river bottom consisting of disintegrating organic particles

earthen dam – a dam with the embankment made up of dirt

earth/gravity dam – a dam with an earthen embankment and a concrete gravity spillway

entrainment – the movement of fish, either voluntary or involuntary, into the intake structure of a hydroelectric facility

evapotranspiration – loss of water from the soil by both evaporation and transpiration from growing plants

exceedence – a yield (flow) amount that is exceeded by the stream for a given percentage of time; for example, for 90% of the year the stream's yield is greater than its 90% exceedence yield value; consequently, the 90% exceedence yield represents a stream's summer low (drought) yield Help me here…this is Roger's

fauna – the animals of a specific region or time

FERC – Federal Energy Regulatory Commission

fixed-crest – a dam that is fixed at an elevation and has no ability to change from that elevation

frigid temperature regimes – At a soil depth of 20 inches: mean soil temperature is 33.8°F to 44.6°F and mean summer soil temperatures differ from mean winter soil temperatures by more than 41°F

gradient – the rate of descent of a river from an upstream location to a downstream location

gravity dam – a dam where the weight of the dam (usually concrete) is what keeps it in place. This is opposed to an arch dam or a buttress dam where there is a more engineered design keeping it in place rather than weight.

growing-degree day – growing degree days take aspects of local weather into account and involve the amount of accumulated heat required for organisms to flourish. and complete their growth and development.

height (as referring to the height of a dam) – the difference between the lowest point of the top of the dam to the lowest point of the streambed just downstream from the dam

hydraulic head – The difference between the impoundment elevation (headwater) and the elevation of the water at the outlet (tailwater), at normal flow, in feet

hydrology – the study of water

hypolimnion – bottom portion of a thermally stratified lake; immediately below metalimnion; characterized as having cold temperatures which remain relatively constant with depth

impoundment – water of a river system that has been held up by a dam, creating an artificial lake

installed capacity – a dam's hydroelectric generating ability given in Kilowatt hours

invertebrates – animals without a backbone

lacustrine – relating to or living in lakes

large woody structure – trees, logs, and logjams that are in a stream

larval – early life stage beyond the embryo and prior to juvenile

lentic – nonflowing water; for example, lentic fishes are in a nonflowing water or lake environment

littoral – an interface zone between the land of a drainage basin and the open water of a lake

loam – soil consisting of varying proportions of clay, silt, and sand

lotic – flowing water; for example, lotic habitats are habitats present in a flowing water environment

LWMD – Land and Water Management Division (MDEQ)

main stem – primary river channel, also known as mainstream

MDEQ – Michigan Department of Environmental Quality

MDCH – Michigan Department of Community Health

MDNR – Michigan Department of Natural Resources

mesic – characterized by, relating to, or affected by moisture

mesic temperature regimes – At a soil depth of 20 inches: mean soil temperature is 46.4°F to 59.0°F and mean summer soil temperatures differ from mean winter soil temperatures by more than 41°F

moraine – a mass of rocks, gravel, sand, clay, etc. carried and deposited directly by a glacier

mph – miles per hour

MSU – Michigan State University

NOAA – National Oceanic and Atmospheric Administration

NRCS – National Resource Conservation Service, United States Department of Agriculture

outwash – glacial deposits that have been sorted by flowing water; outwash deposits typically consist of sand, gravel, and larger substrates, with the finer-textured silts and clays having been washed away

Palmer Drought Index – developed by W. C. Palmer in 1965, this index of drought conditions is based on the supply-and-demand concept of the water balance equation, taking into account moisture conditions that were standardized so that comparisons could be made between locations and between months

PBB – polybrominated biphenyl; a toxic fire-retardant compound know to cause sickness and birth defects in mammals

peaking – operational mode for a hydroelectric project that maximizes economic return by operating at maximum possible capacity during peak demand periods (generally 8 a.m. to 8 p.m.) and reducing or ceasing operations and discharge during nonpeak periods; in other words, streamflows alternate between flood and drought on a daily basis

permeability – the ability of a substance to allow the passage of fluids; soils containing sands and gravels have high permeability because water readily moves through them

Pleistocene-Epoch – also know as Ice Age; period from 1,600,000 BP to 10,000 BP

potamodromous – fish that migrate from freshwater lakes up freshwater rivers to spawn

Precambrian period – includes about 90% of all geologic time; from the beginning of the earth, about 4.5 billion years BP, to 544 million years BP

refugia – an area of relatively unaltered climate inhabited by plants and animals during a period of continental climatic change (e.g., glaciation); an area from which a new dispersion and speciation may take place after climatic readjustment

riparian – of or pertaining to the bank of a natural course of water; adjacent to, or living on, the bank of a river

riverine – of or pertaining to a river; a reach or portion of a river that is freely flowing and not impounded by dams

run-of-river – instantaneous flow of water to an impoundment equals instantaneous outflow of water; on impounded systems this flow regime mimics the natural flow regime of a river

spatial – occupying or relating to physical space

specific power – rate at which potential energy is supplied to a stream channel bed and banks; specific power of a river is a function of its width, rate of discharge, and gradient; measured in watts/m^2

surficial – referring to something on the surface

tailrace – the region of high velocity water flow below the turbine discharge of a hydroelectric facility; the channel conveying water away from a powerhouse

till – unstratified, unsorted glacial deposits of clay, sand, boulders, and gravel

Type 1–7 trout stream – trout streams in Michigan are managed with 1 of 7 regulation types, ranging from more liberal to more conservative; see the Michigan Inland Trout and Salmon Guide for individual stream designations

USDA – United States Department of Agriculture

USFWS – Department of the Interior, United States Fish and Wildlife Service

USGS – United States Geological Survey

watershed – an area of the earth's surface that drains toward a receiving body of water (such as a lake or stream) at a lower elevation

yield – river flow per square mile of drainage area

FIGURES

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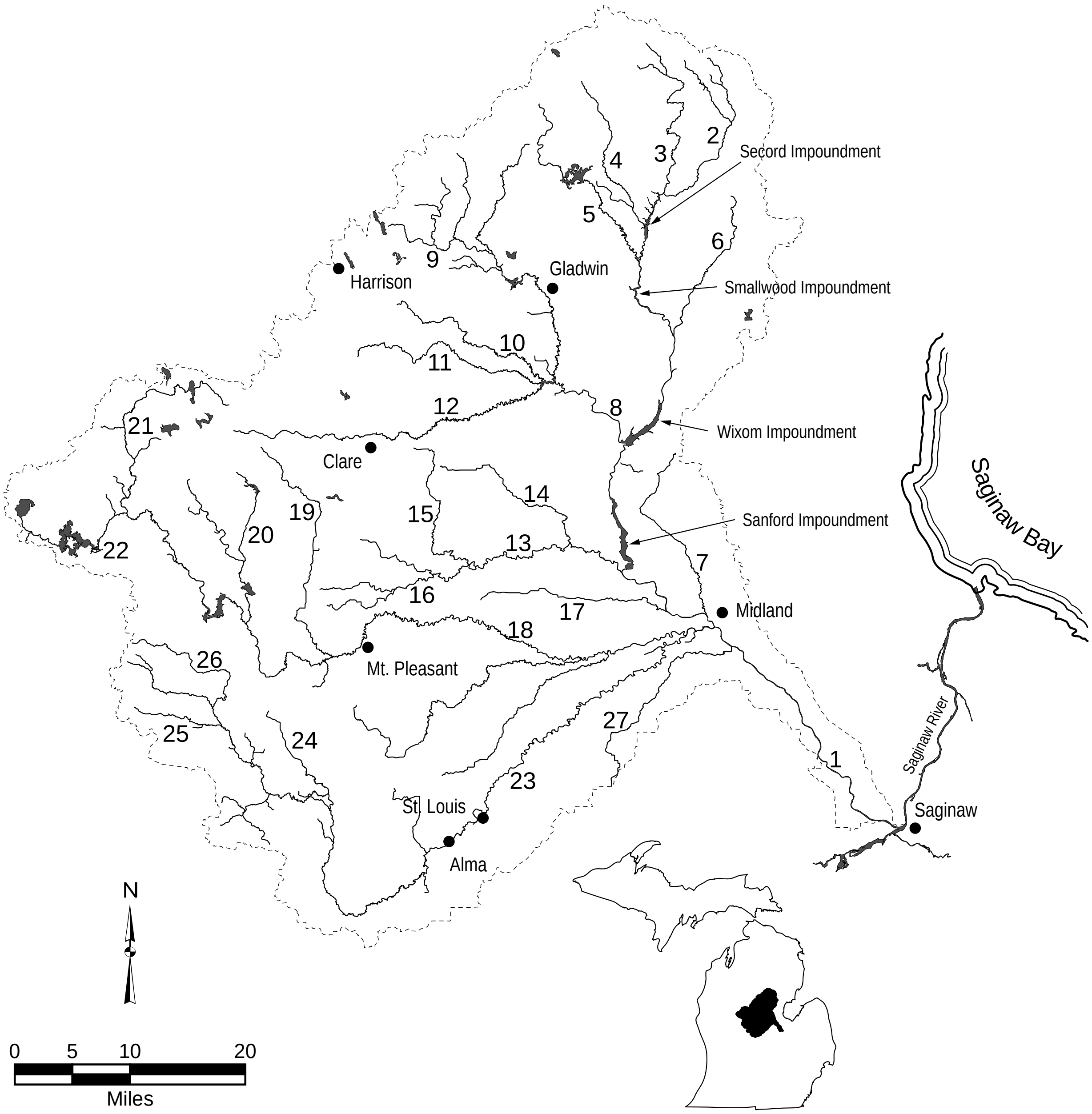

1 – Tittabawassee River
2 – East Branch Tittabawassee River
3 – Middle Branch Tittabawassee River
4 – West Branch Tittabawassee River
5 – Sugar River
6 – Molasses River
7 – Sturgeon Creek
8 – Tobacco River
9 – Cedar River
10 – North Branch Tobacco River
11 – Middle Branch Tobacco River
12 – South Branch Tobacco River
13 – Salt River
14 – Bluff Creek
15 – North Branch Salt River
16 – South Branch Salt River
17 – Carroll Creek Drain
18 – Chippewa River
19 – North Branch Chippewa East River
20 – Coldwater River
21 – North Branch Chippewa West River
22 – West Branch Chippewa River
23 – Pine River
24 – North Branch Pine River
25 – South Branch Pine River
26 – Pony Creek
27 – Bullock Creek

Figure 1.–Tittabawassee River system and its watershed boundary.

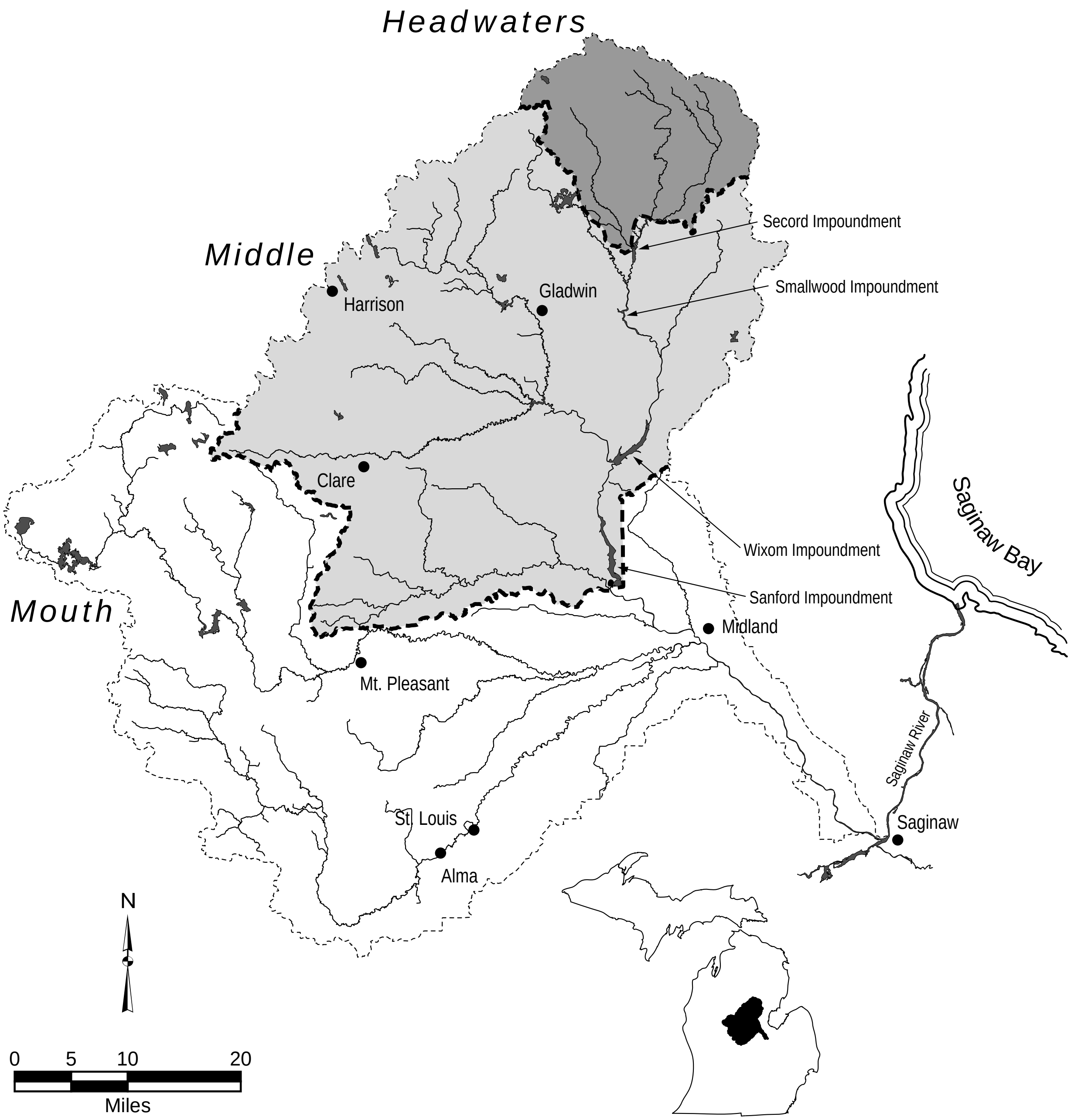

Figure 2.–Main stem valley segments of the Tittabawassee River.

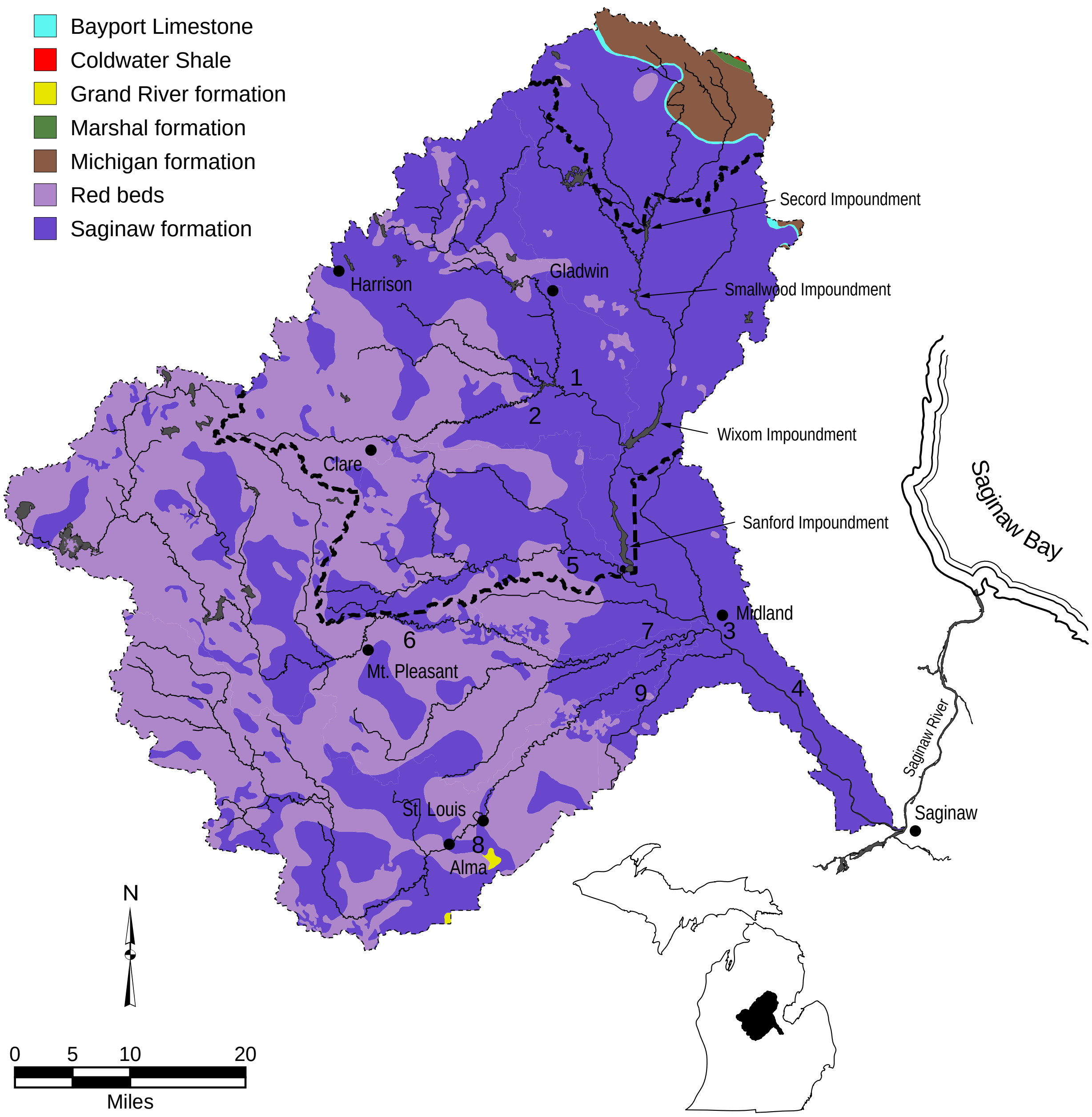

Figure 3.–Bedrock geology of the Tittabawassee River watershed.

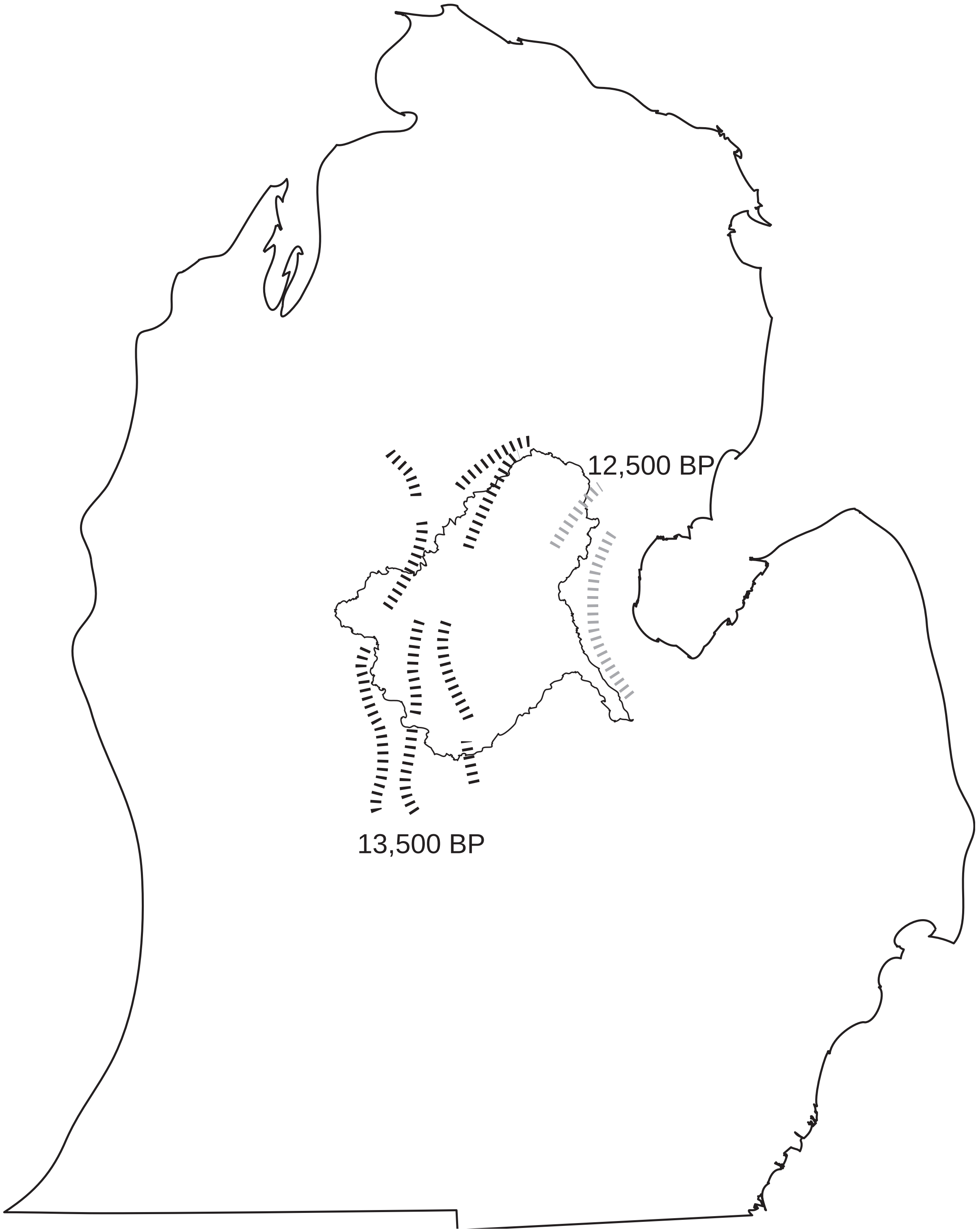

Figure 4.–Glacial advance borders (hash marks) forming the Tittabawassee River watershed (modified from Farrand 1988). Advance borders (dark hash) along the western edge of the watershed occurred approximately 13,500 years before present (BP) and the borders (light hash) along the eastern edge of the watershed occurred approximately 12,500 years BP.

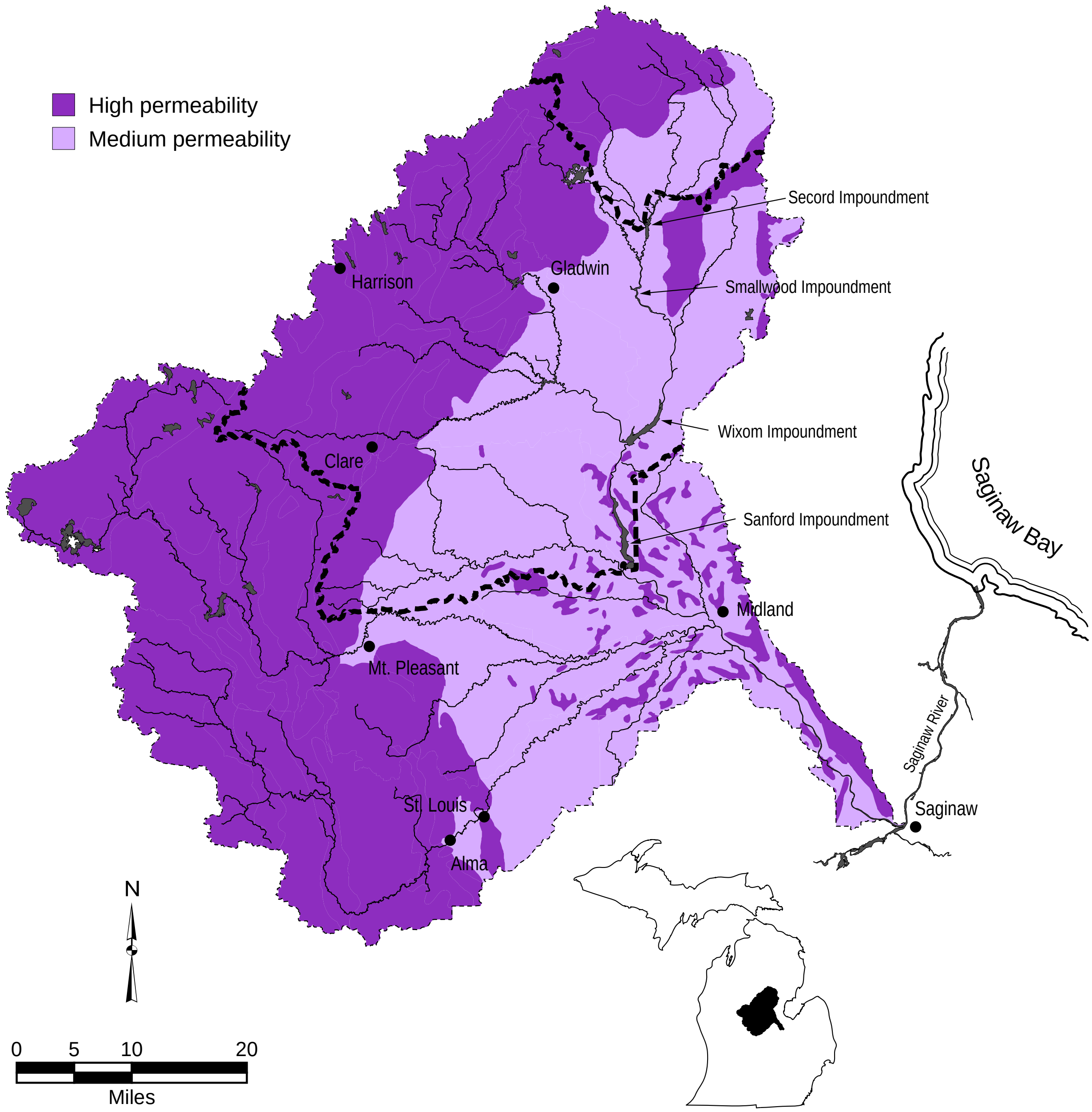

Figure 5.–Permeability of surficial deposits in the Tittabawassee River watershed.

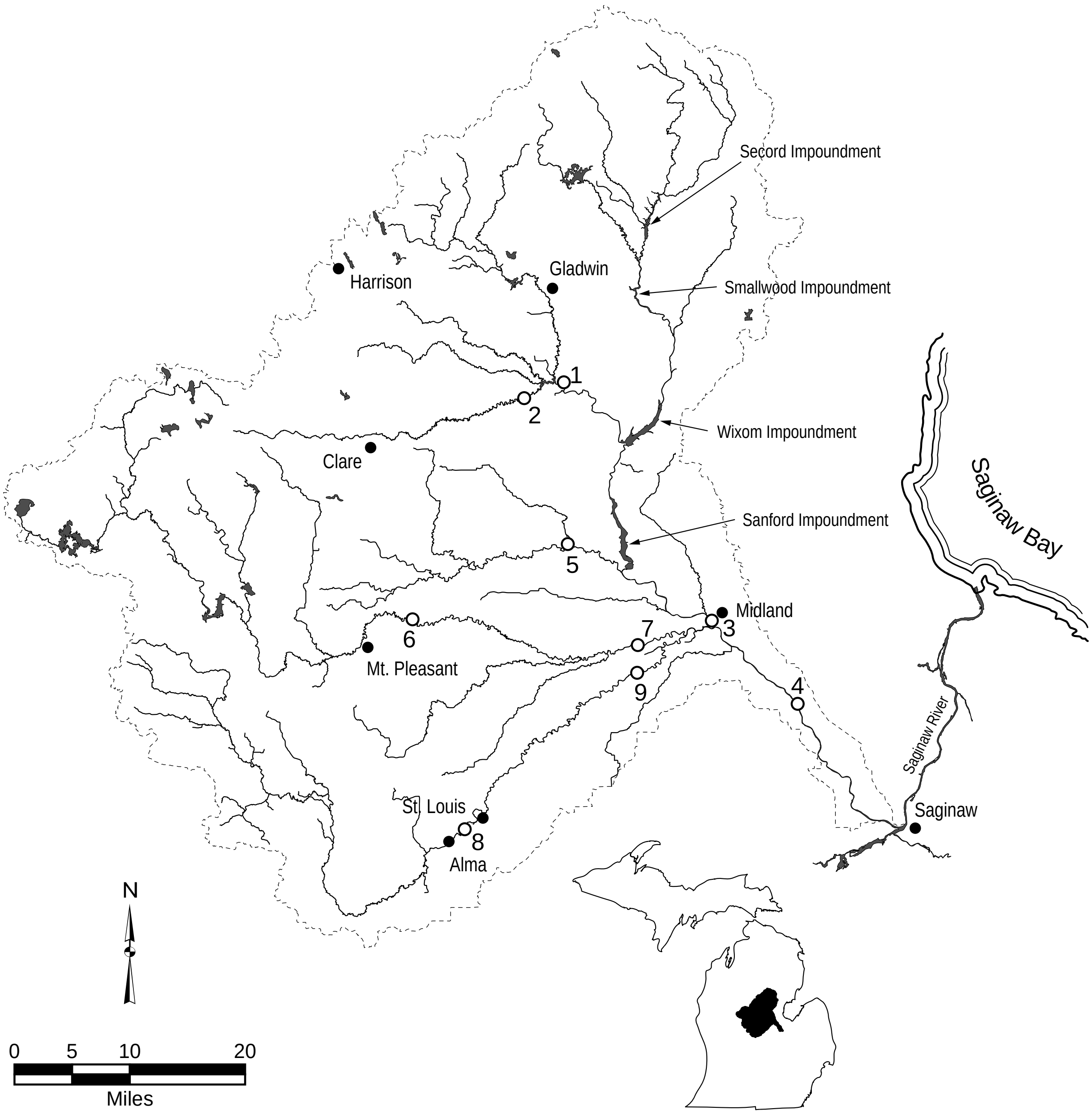

Figure 6.–United States Geological Survey gauge sites in the Tittabawassee River watershed. See Table 7 for gauge site descriptions.

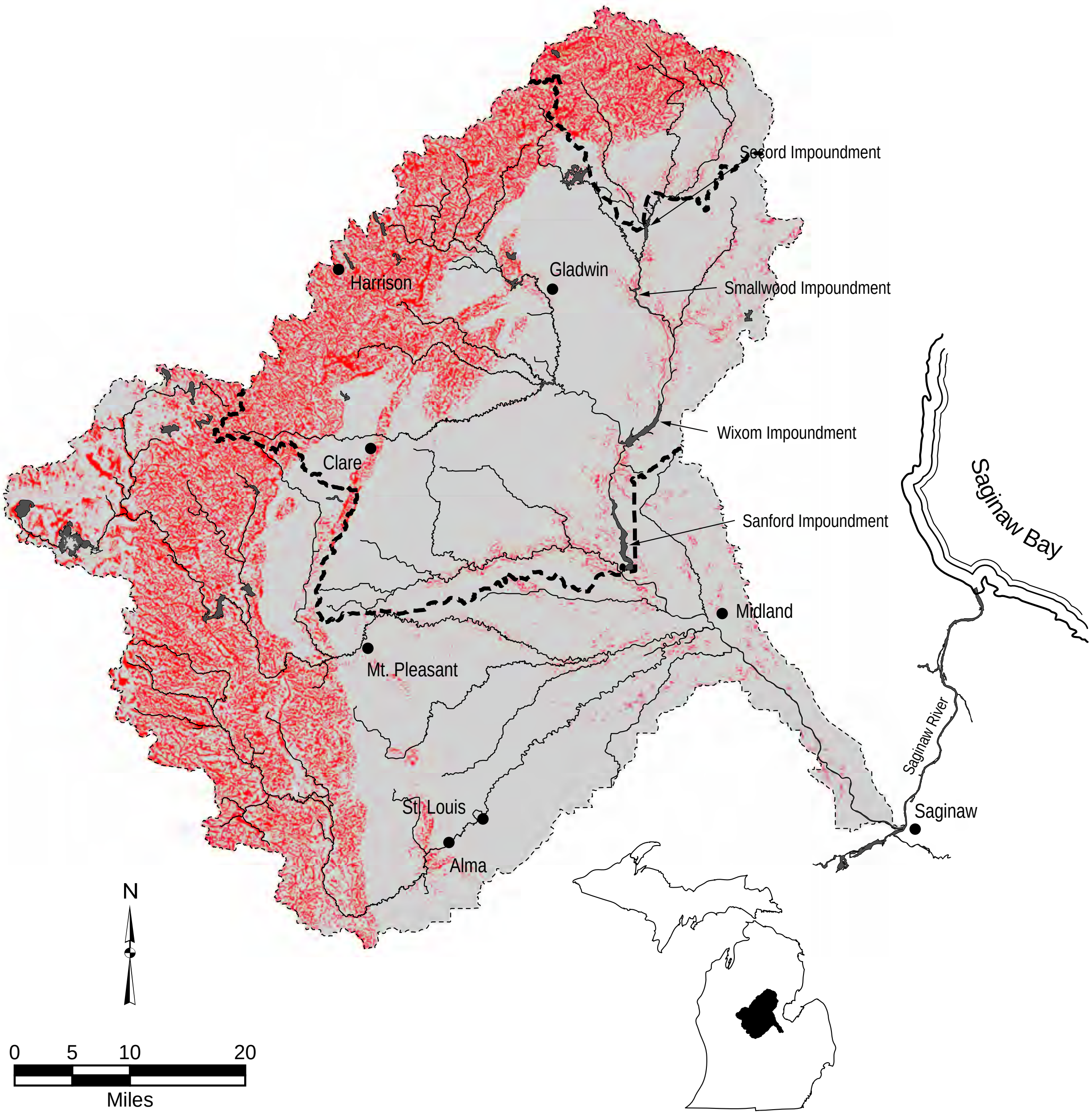

Figure 7.–Areas of groundwater recharge and discharge in the Tittabawassee River watershed. Areas where groundwater recharge is high are shown in grey and areas where groundwater discharge is high are shown in red.

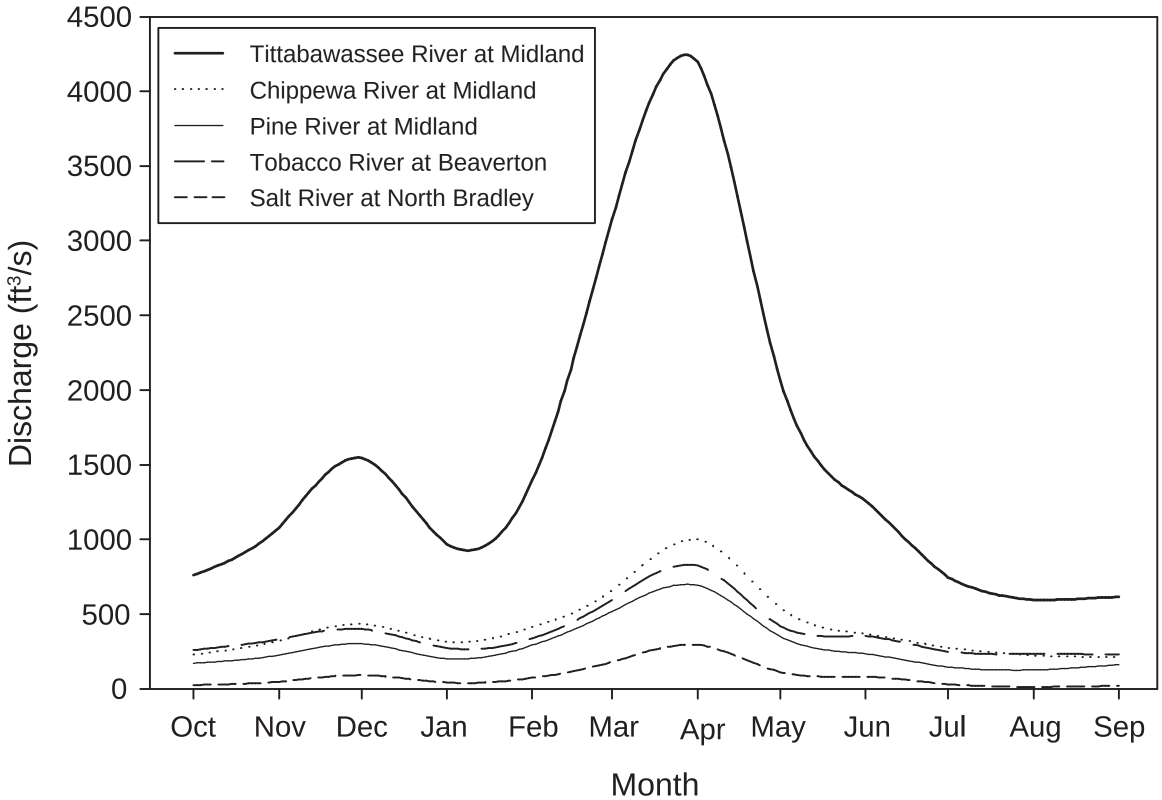

Figure 8.–Mean monthly discharge for selected locations in the Tittabawassee River watershed for years 1963–71. Data from United States Geological Survey.

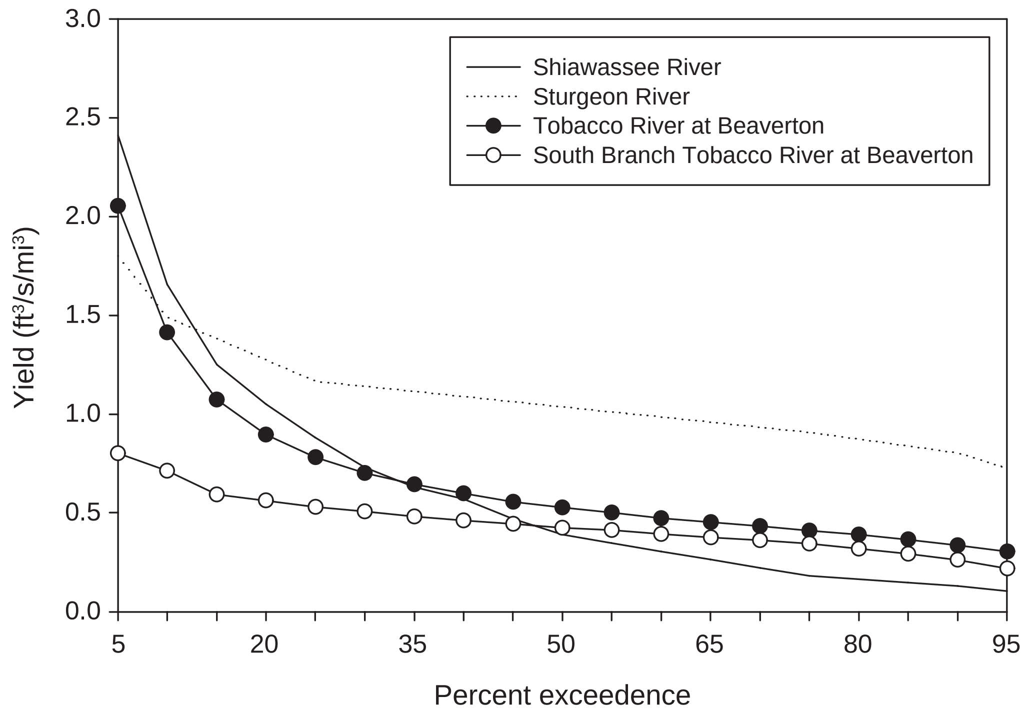

Figure 9.–Yield ($ft^3/s/mi^2$) exceedence curves for the Tobacco River (Tobacco River at Beaverton and South Branch of the Tobacco River at Beaverton). Comparison exceedence curves are given for the Shiawassee and Sturgeon rivers. Exceedence curve represents the frequency of a discharge exceeding a given rate. Data from the Unived States Geological Service for period of record.

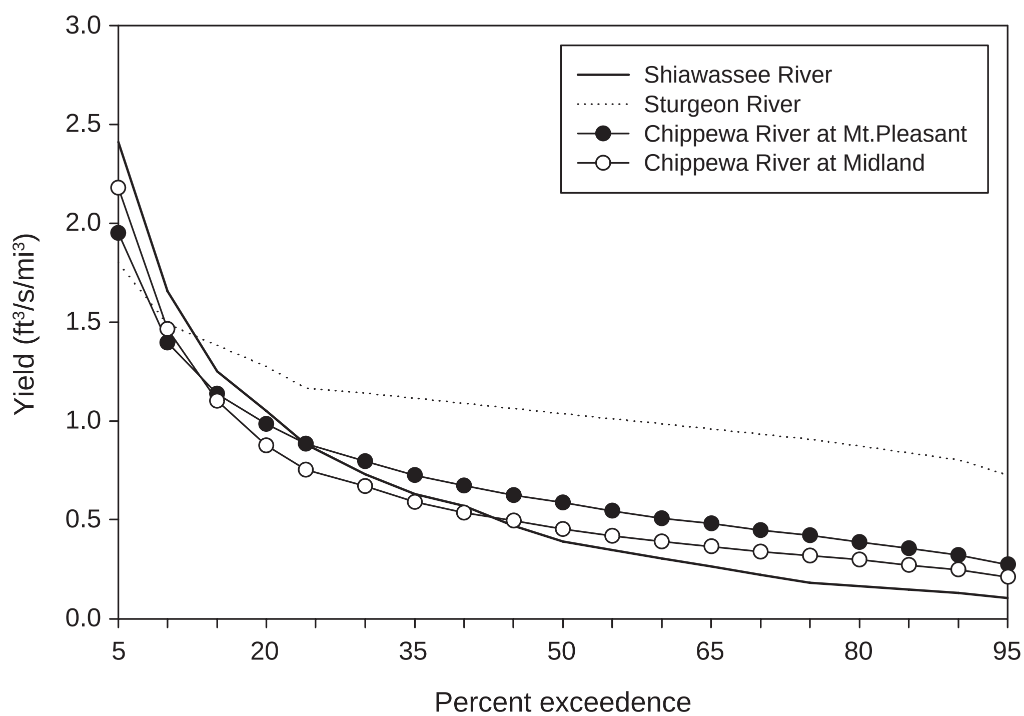

Figure 10.–Yield ($ft^3/s/mi^2$) exceedence curves for the Chippewa River (Chippewa River at Mt. Pleasant and Chippewa River at Midland). Comparison exceedence curves are given for the Shiawassee and Sturgeon rivers. Exceedence curve represents the frequency of a discharge exceeding a given rate. Data from the Unived States Geological Service for period of record.

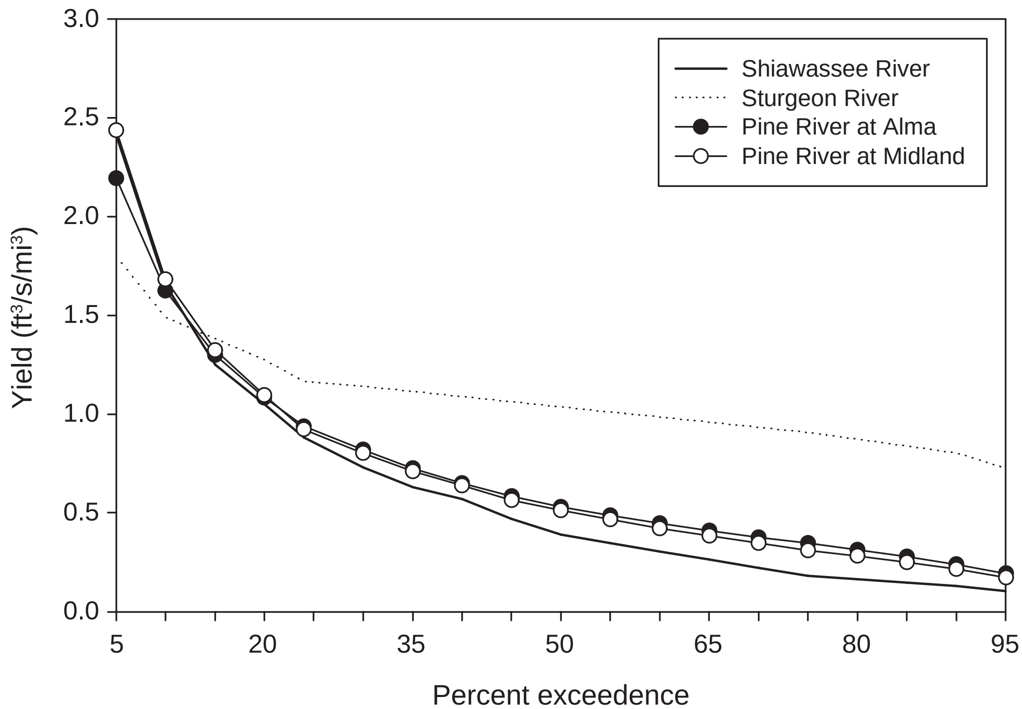

Figure 11.–Yield (ft^3/s/mi^2) exceedence curves for the Pine River (Pine at Alma and Pine at Midland). Comparison exceedence curves are given for the Shiawassee and Sturgeon rivers. Exceedence curve represents the frequency of a discharge exceeding a given rate. Data from the Unived States Geological Service for period of record.

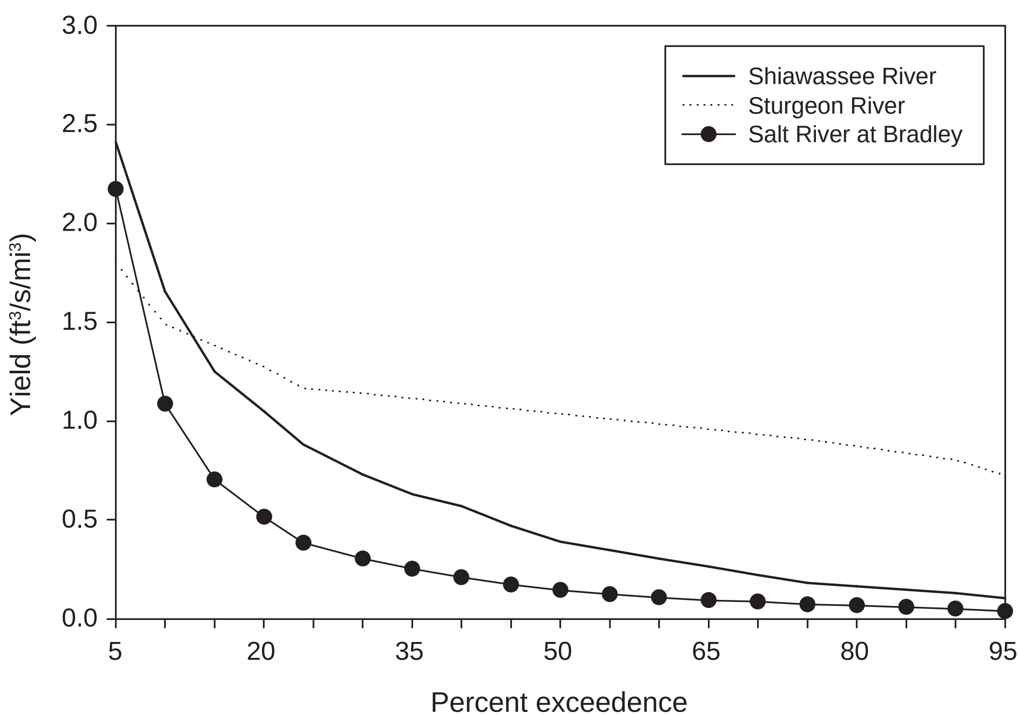

Figure 12.–Yield (ft^3/s/mi^2) exceedence curves for the Salt River (Salt near North Bradley). Comparison exceedence curves are given for the Shiawassee and Sturgeon rivers. Exceedence curve represents the frequency of a discharge exceeding a given rate. Data from the Unived States Geological Service for period of record.

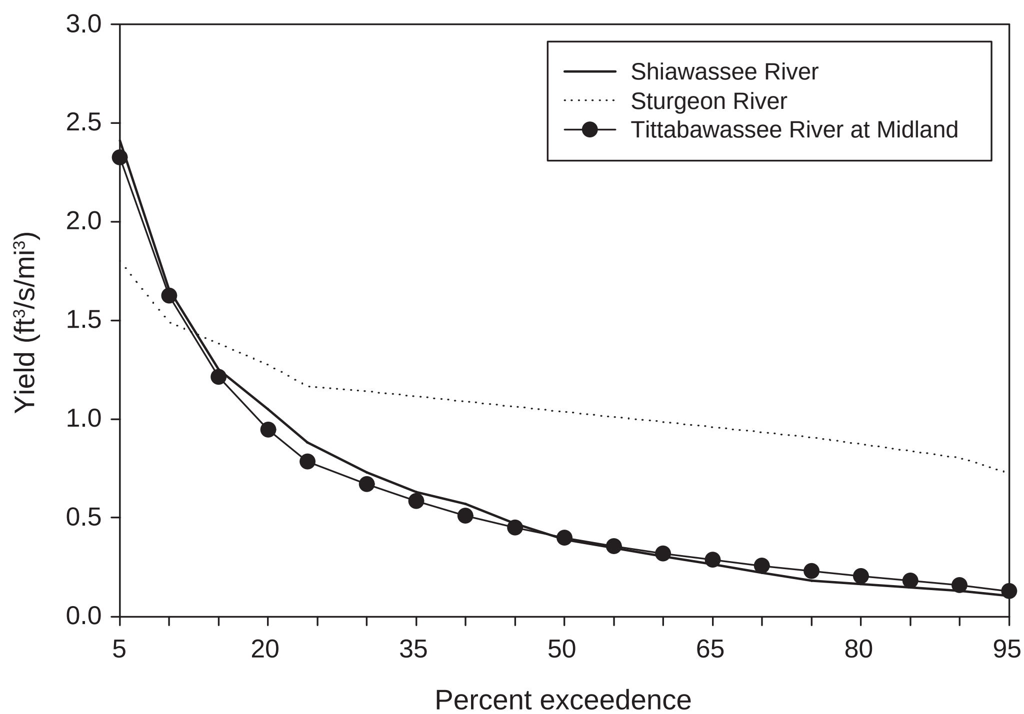

Figure 13.–Yield (ft^3/s/mi^2) exceedence curves for the mouth segment (Tittabawassee River at Midland). Comparison exceedence curves are given for the Shiawassee and Sturgeon rivers. Exceedence curve represents the frequency of a discharge exceeding a given rate. Data from the Unived States Geological Service for period of record.

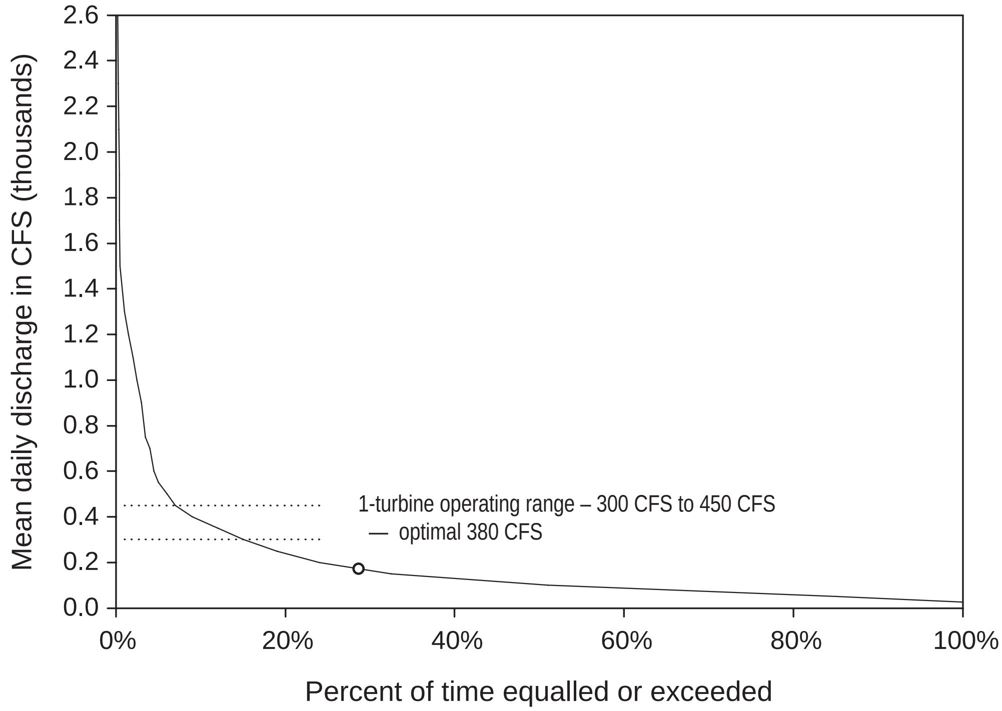

Figure 14.–Percentage of operational times by mean monthly discharge for Secord Dam turbine. Mean annual discharge is indicated by a circle. Data are from FERC (1998a). Period of record is for water years 1977–91.

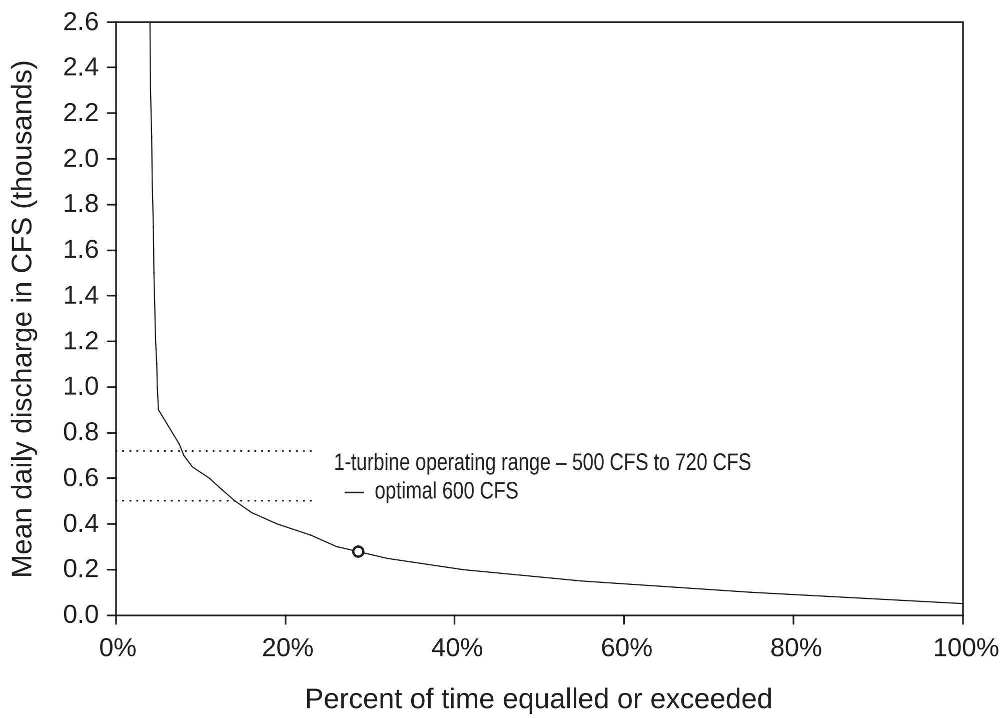

Figure 15.–Percentage of operational times by mean daily discharge for Smallwood Dam turbine. Mean discharge is indicated by a circle. Data are from FERC (1998a). Period of record is for water years 1977–91.

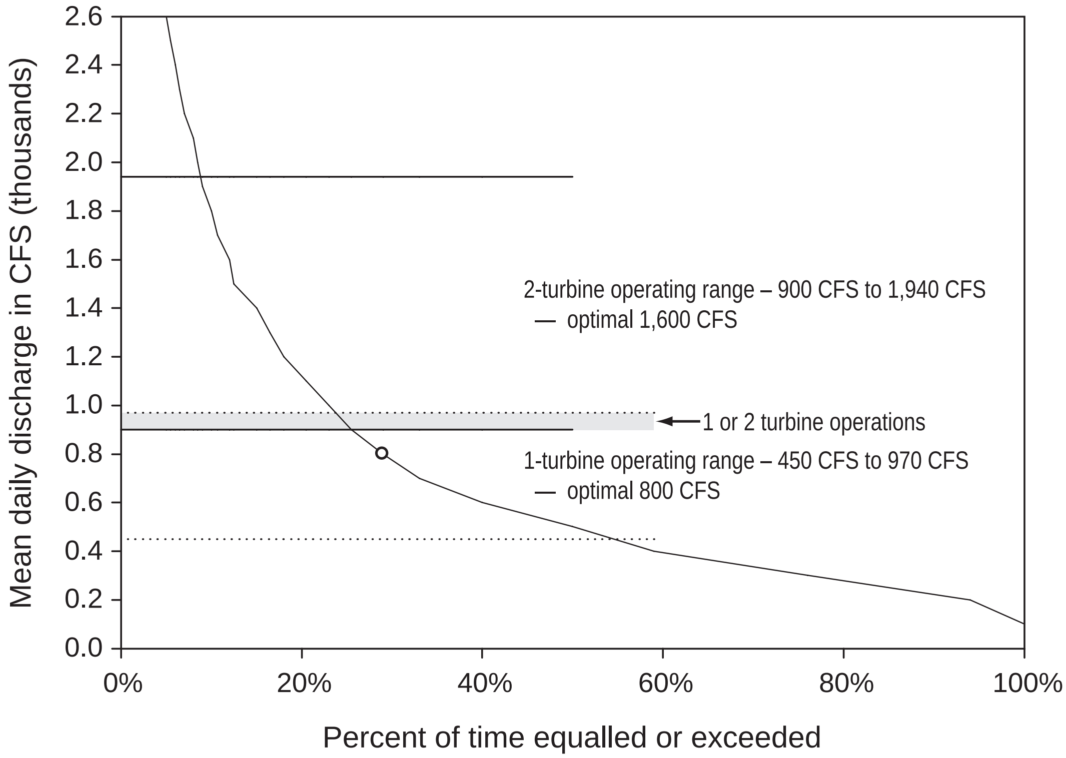

Figure 16.–Percentage of operational times by mean daily discharge for Edenville Dam (Wixom Lake impoundment) turbines. Mean discharge is indicated by a circle. Data are from FERC (1998a). Period of record is for water years 1977–91.

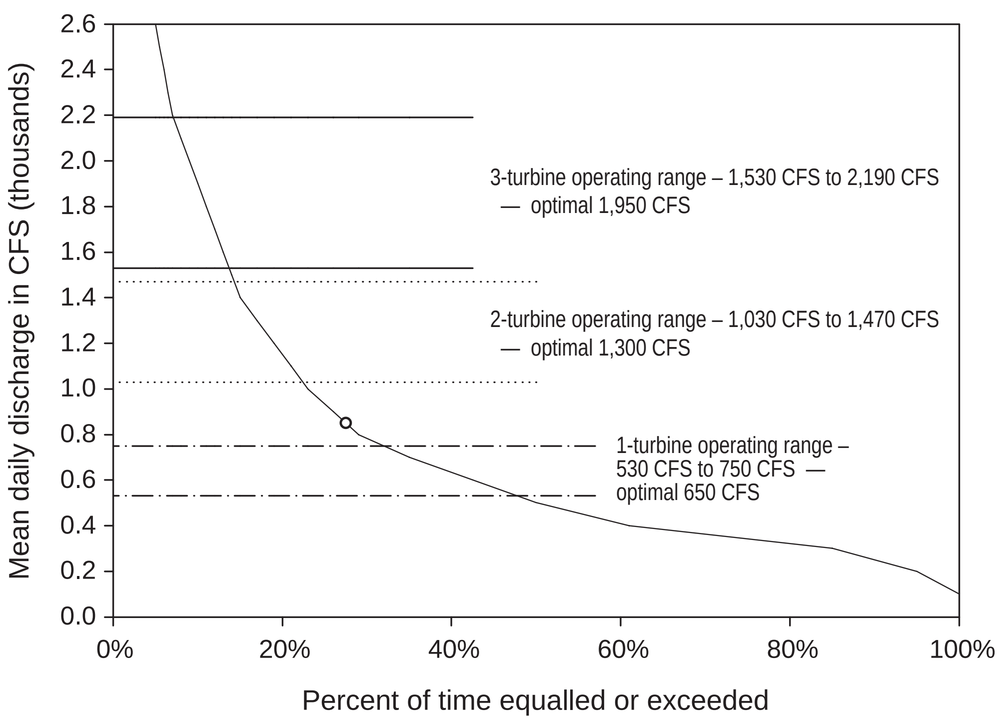

Figure 17.–Percentage of operational times by mean daily discharge for Sanford Dam turbines. Mean discharge is indicated by a circle. Data are from FERC (1998a). Period of record is for water years 1977–91.

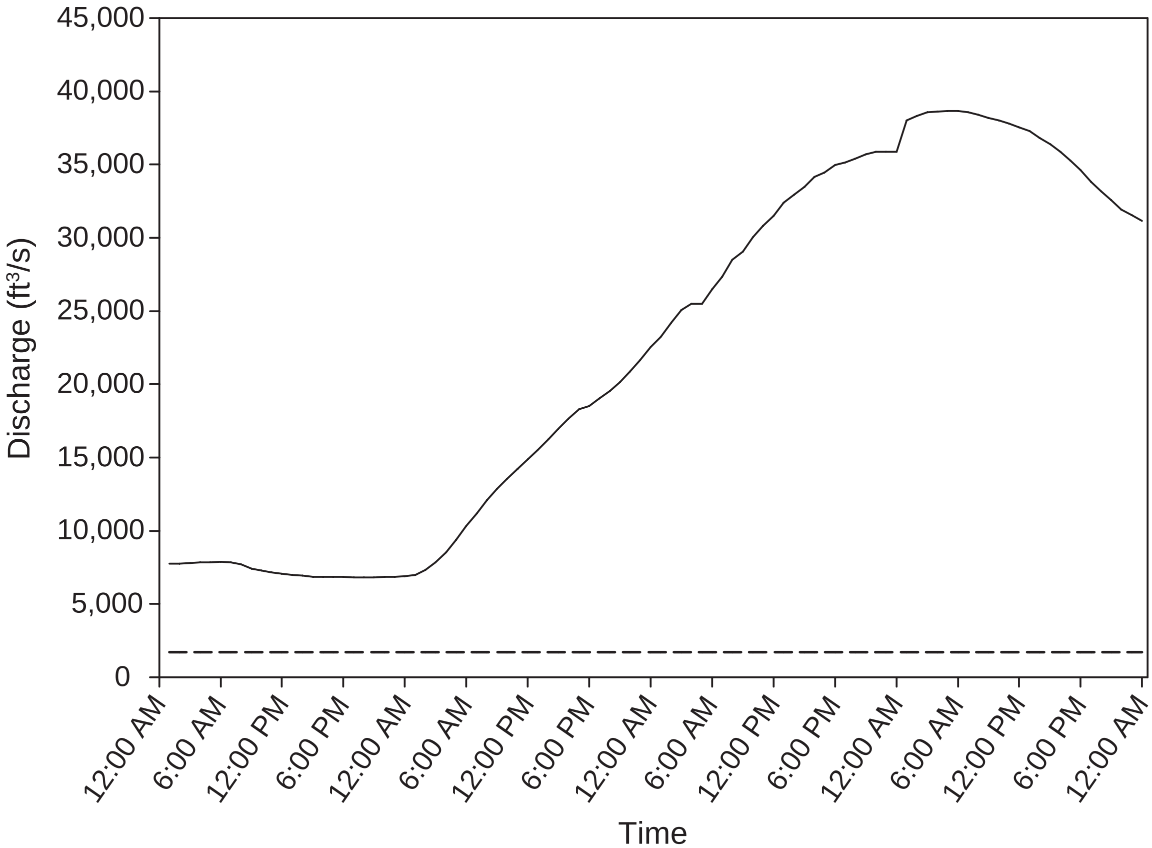

Figure 18.–Instantaneous discharge of the Tittabawassee River at Midland from September 10 to 13, 1986 and mean flow for the period of record 1936–2003. Data from United States Geological Survey.

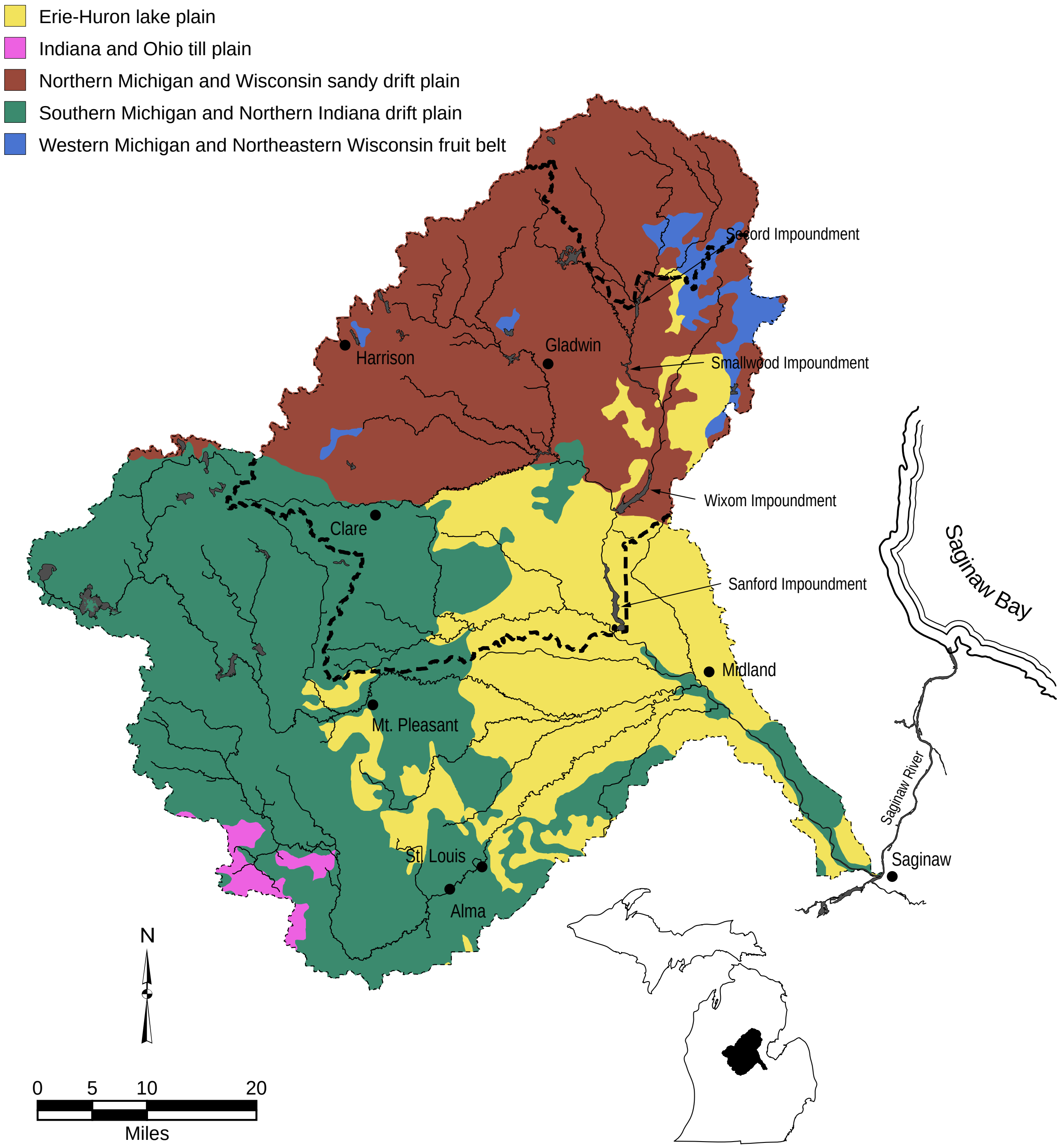

Figure 19.–Major land resource areas of the Tittabawassee River watershed.

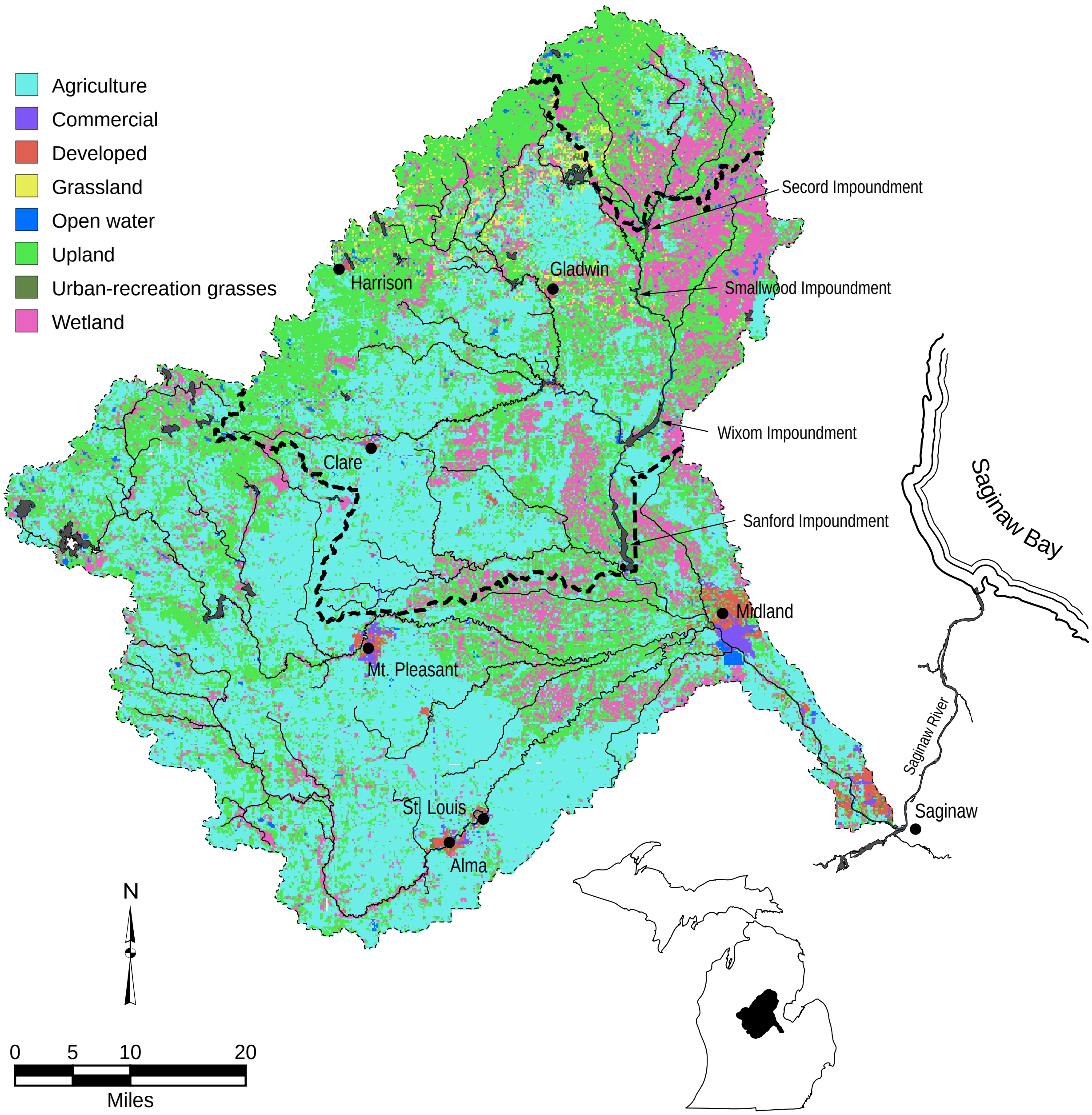

Figure 20.–Land use types within the Tittabawassee River watershed.

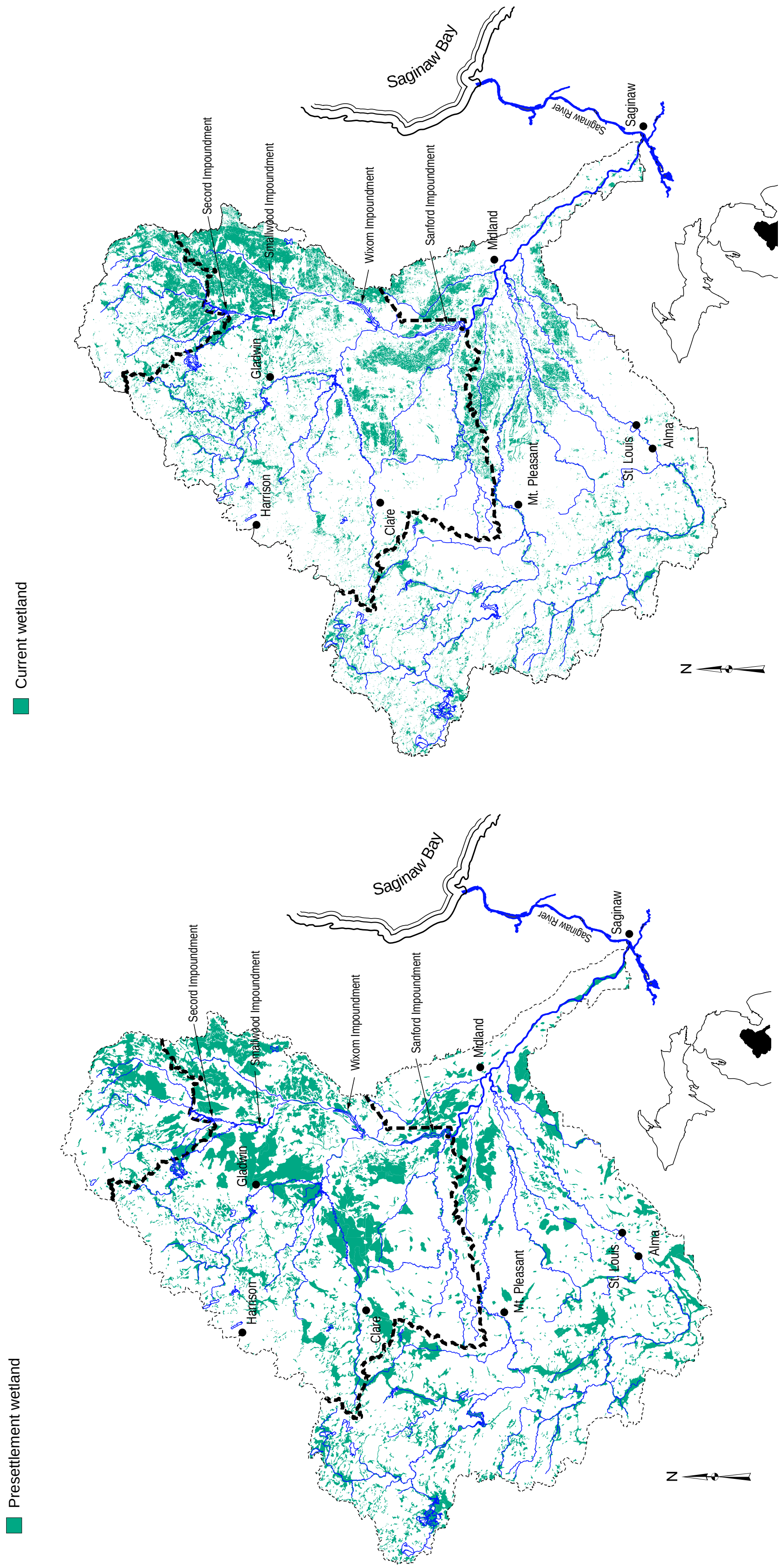

Figure 21.–Tittabawassee River watershed wetlands: presettlement (left) and current (right).

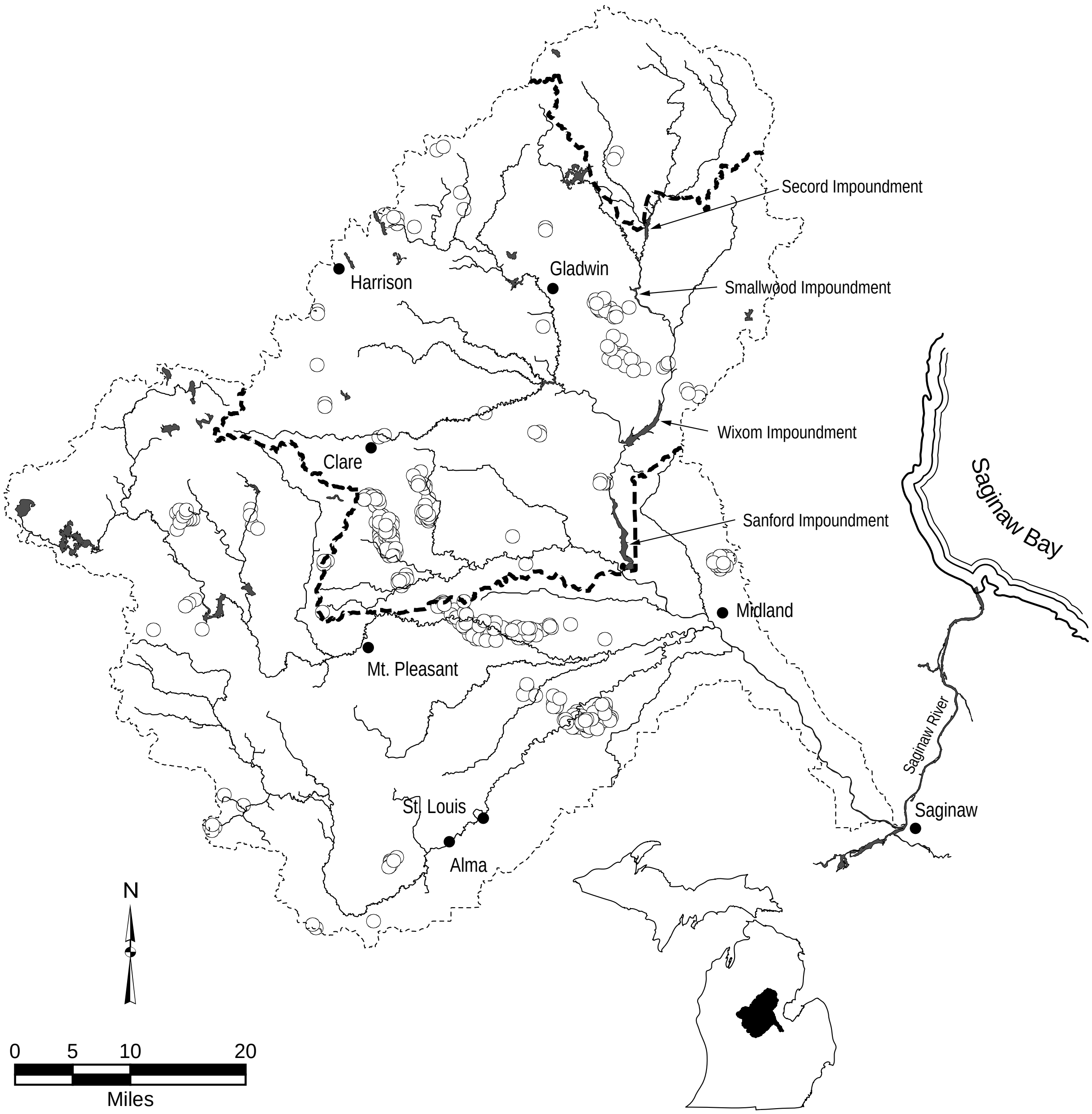

Figure 22.–Oil and gas well operations within the Tittabawassee River watershed.

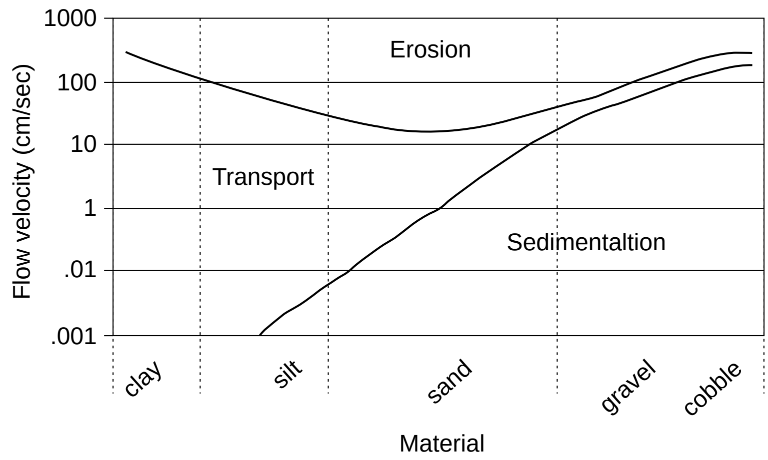

Figure 23.–Flow velocities at which various soil materials are eroded, transported, or sediment (from Hjulstrom 1935). Material size increases along the X axis with clay materials the smallest and cobbles the largest.

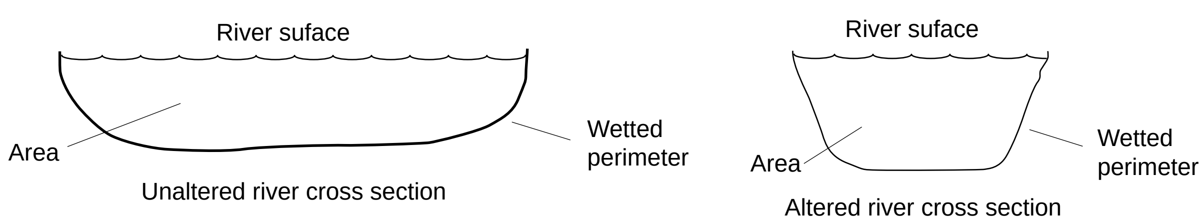

Figure 24.–Unaltered and altered river cross sections (from Wiley and Gough 1995). Unaltered cross section is typical of natural rivers while altered cross section is typical of county drains which have been dredged and straightened.

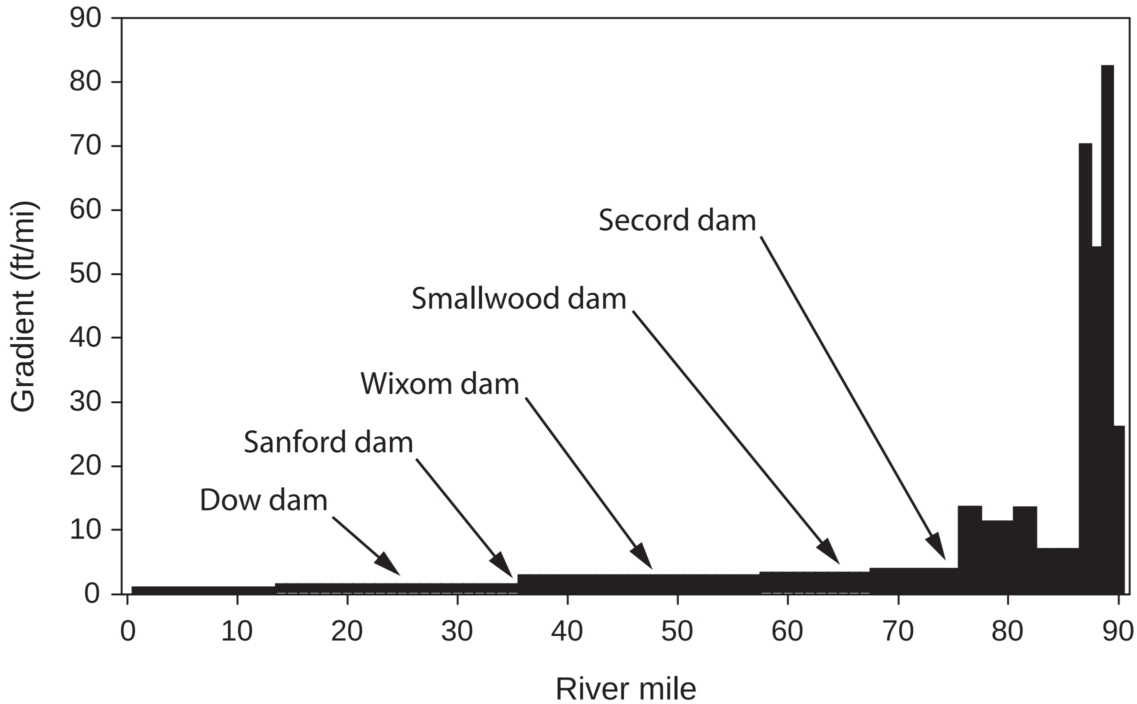

Figure 25.–Main stem Tittabawassee River channel gradient per river mile and location of major dams.

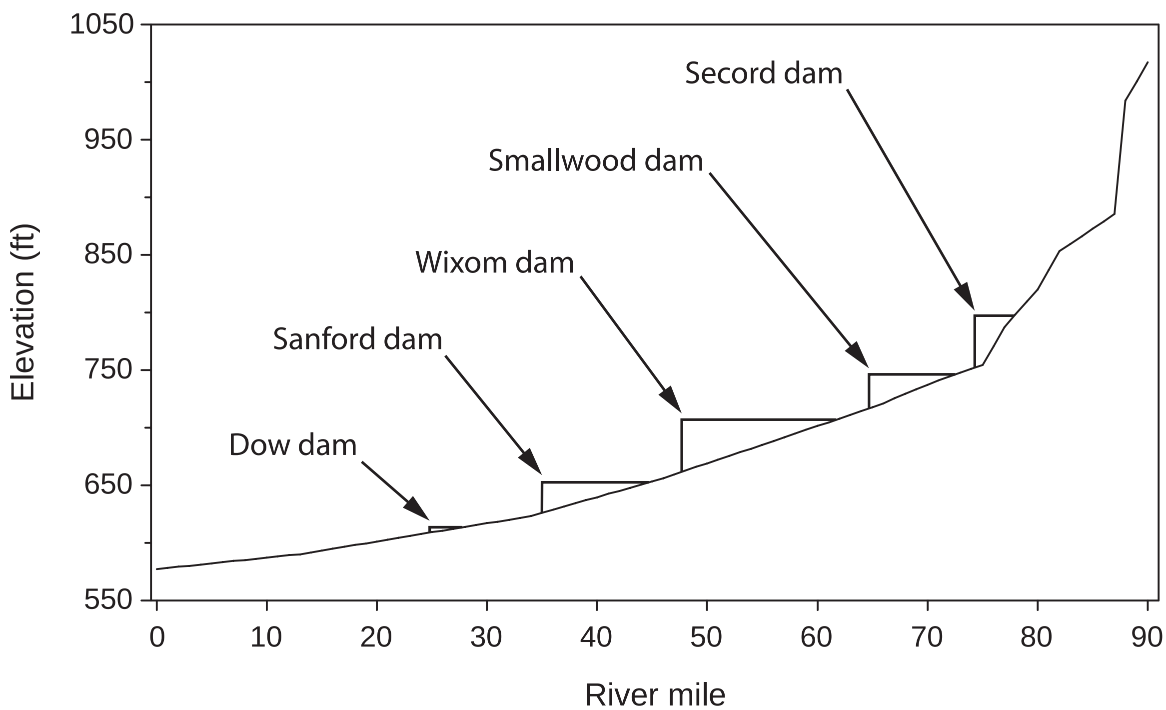

Figure 26.–Main stem Tittabawassee River channel elevation per river mile and location of major dams.

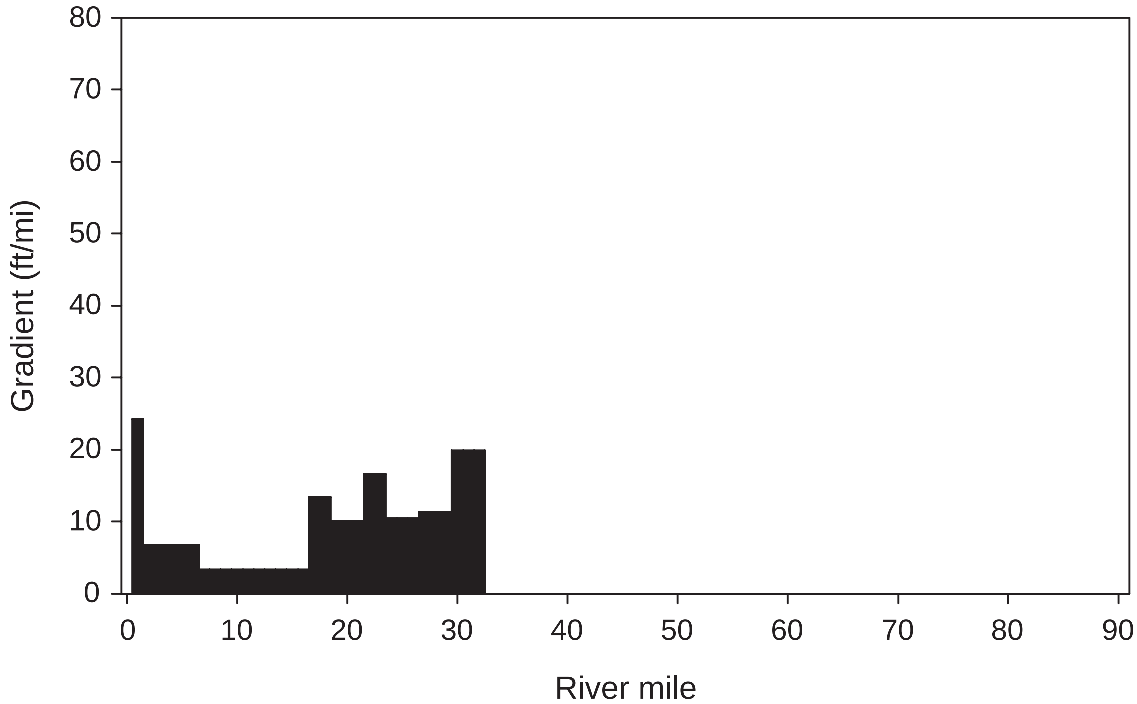

Figure 27.–Tobacco River channel gradient per river mile.

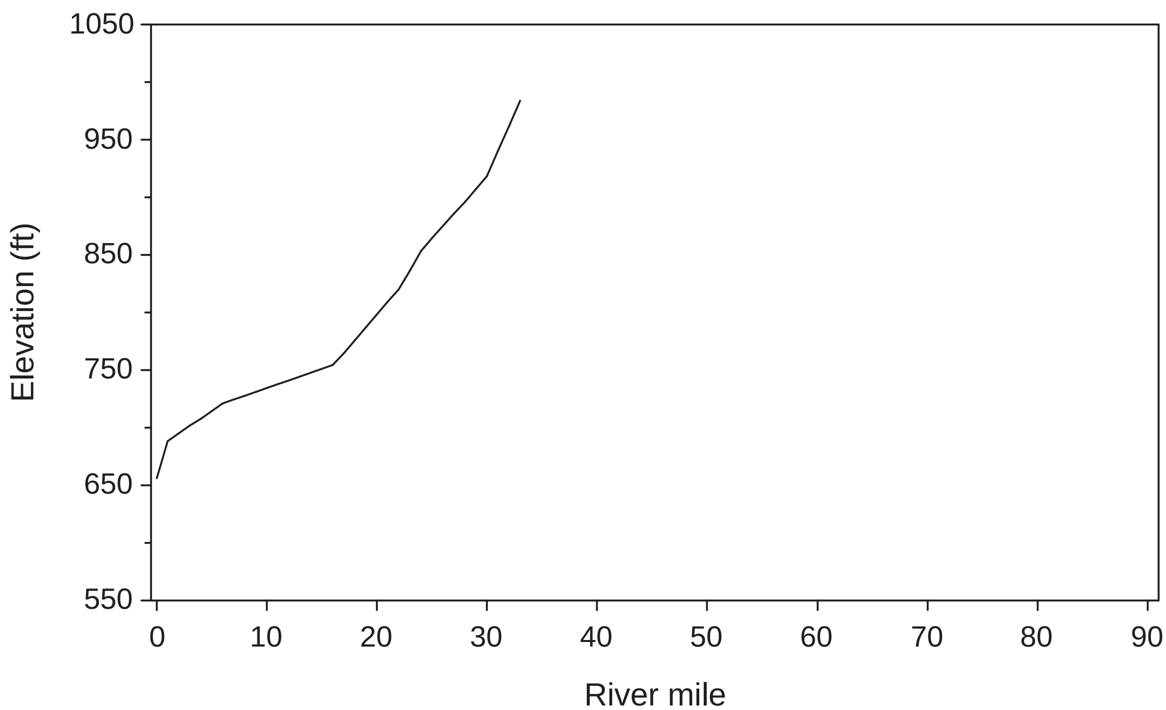

Figure 28.–Tobacco River channel elevation per river mile.

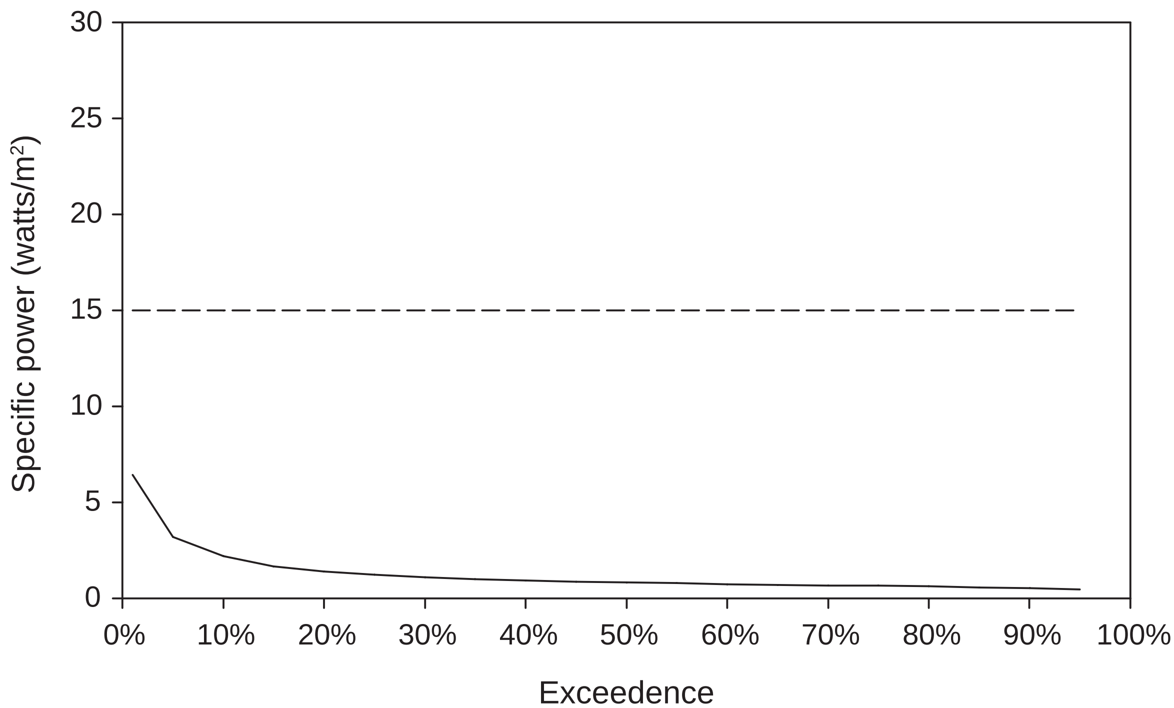

Figure 29.–Specific power for the Tobacco River at Beaverton. Dashed line indicates the specific power (15 watts/m^2) at which the channel of a river flowing through sand becomes dynamic.

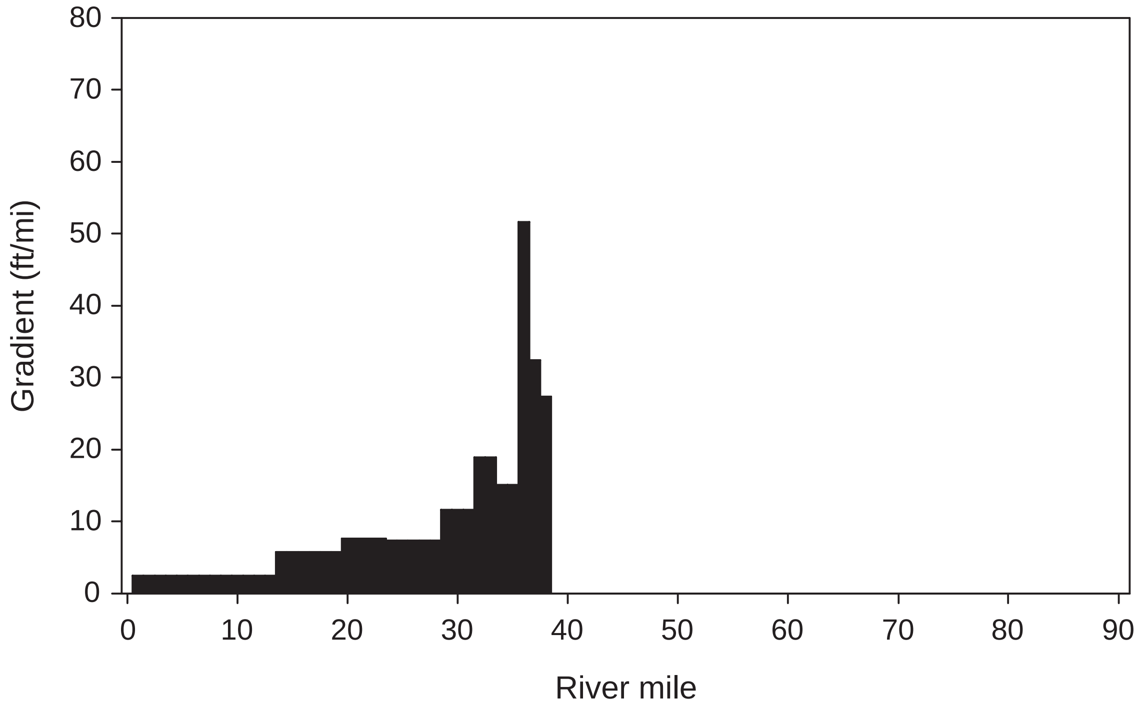

Figure 30.–South Branch of the Tobacco River channel gradient per river mile.

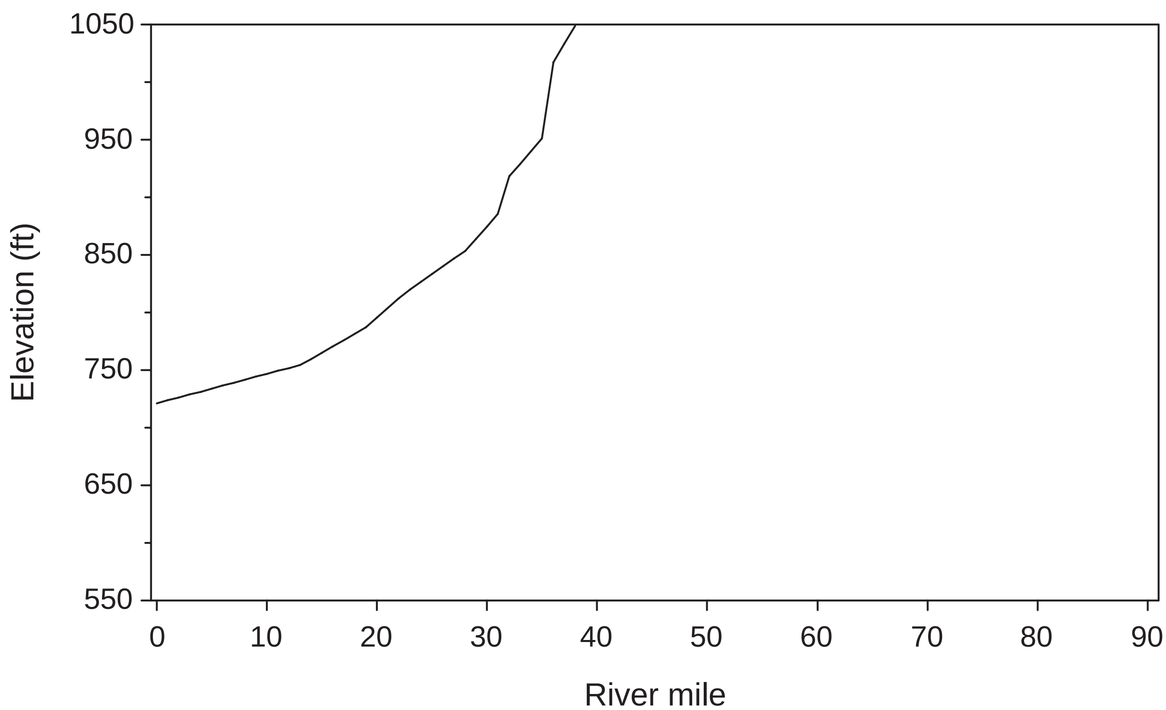

Figure 31.–South Branch of the Tobacco River channel elevation per river mile.

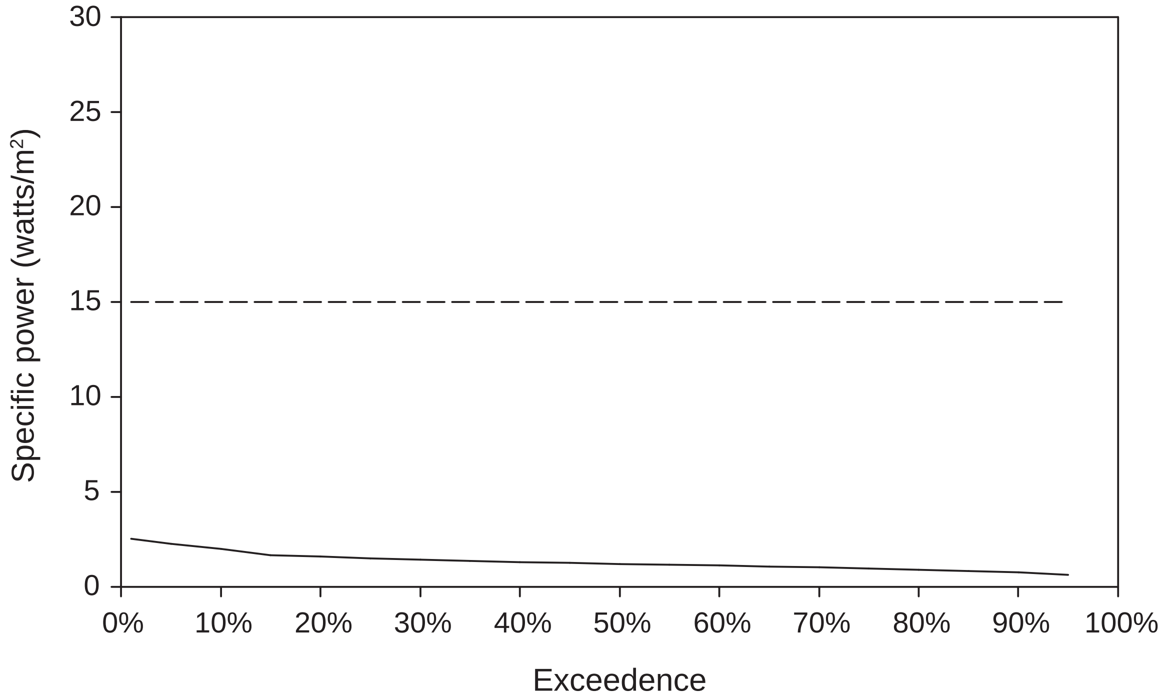

Figure 32.–Specific power for the South Branch of the Tobacco River near Beaverton. Dashed line indicates the specific power (15 watts/m^2) at which the channel of a river flowing through sand becomes dynamic.

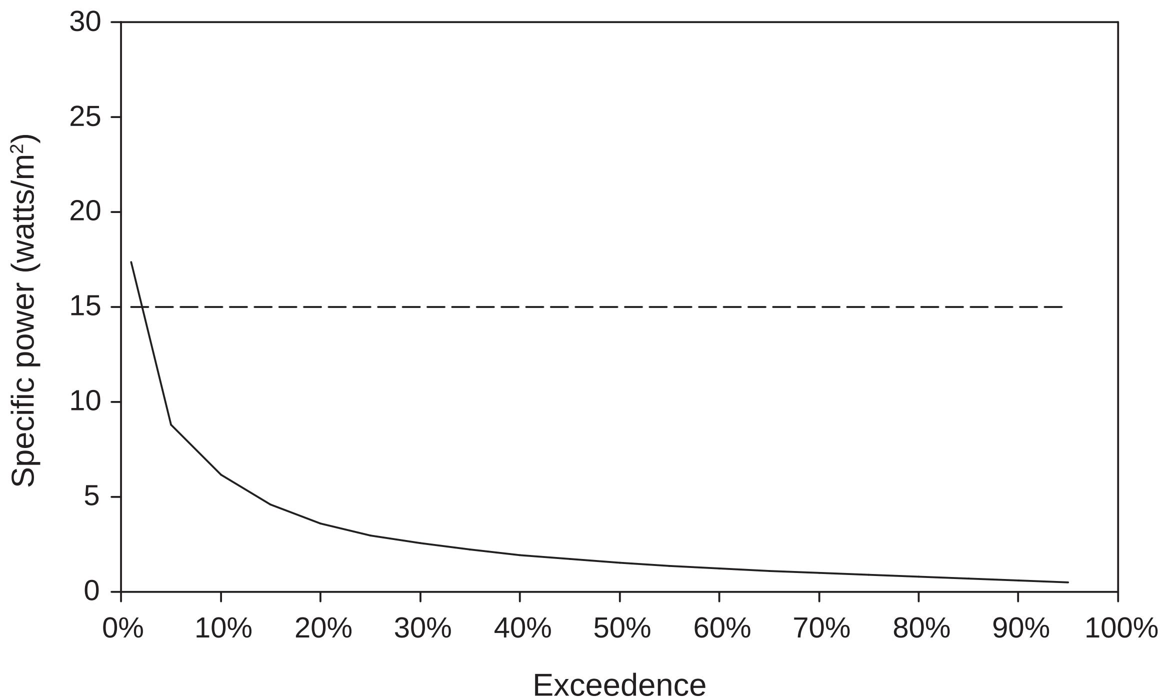

Figure 33.–Specific power for the Tittabawassee River at Midland. Dashed line indicates the specific power (15 watts/m^2) at which the channel of a river flowing through sand becomes dynamic.

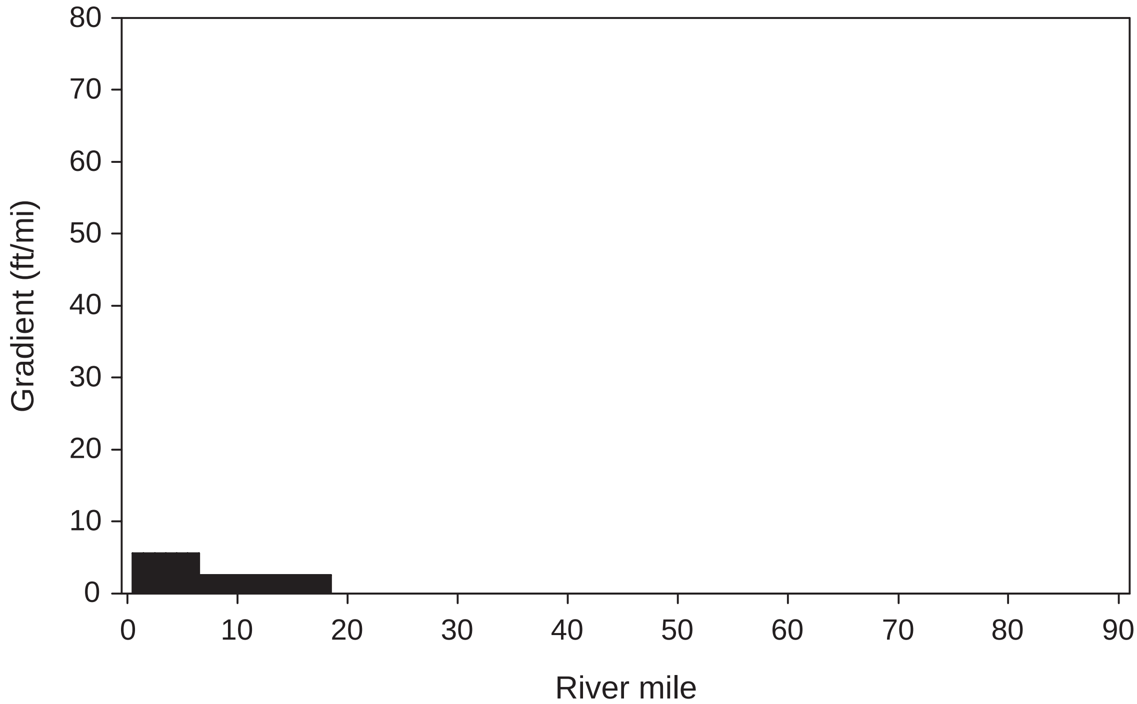

Figure 34.–Salt River channel gradient per river mile.

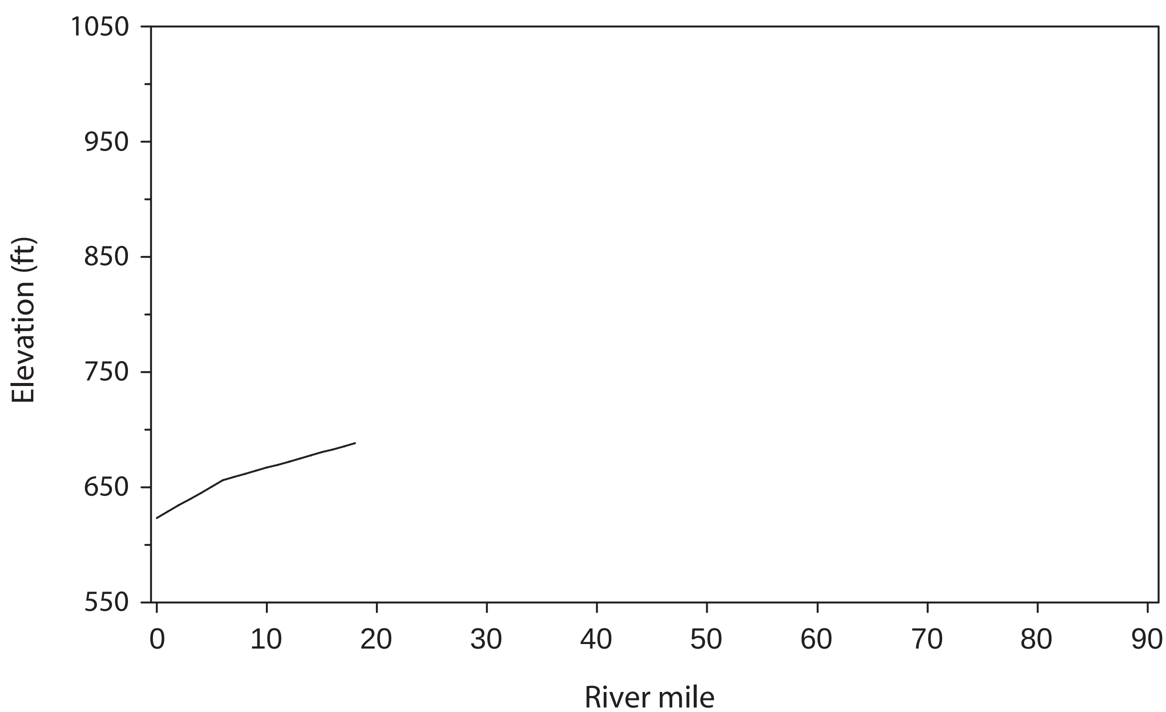

Figure 35.–Salt River channel elevation per river mile.

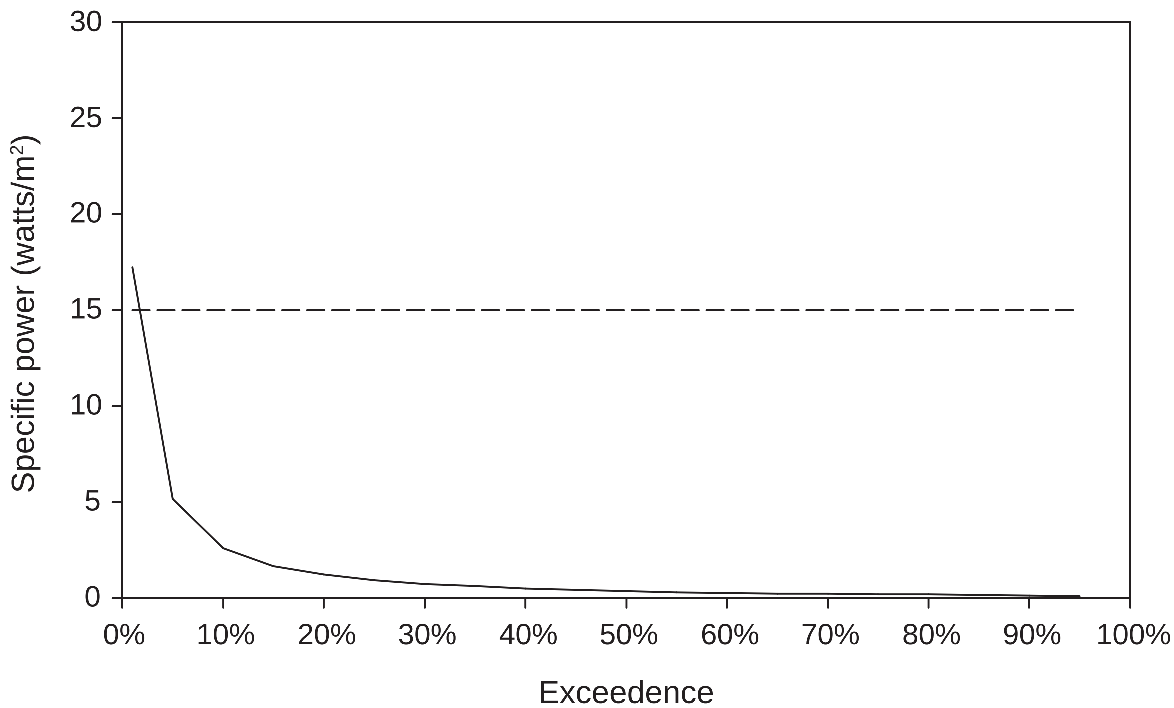

Figure 36.–Specific power for the Salt River near Beaverton. Dashed line indicates the specific power (15 watts/m^2) at which the channel of a river flowing through sand becomes dynamic.

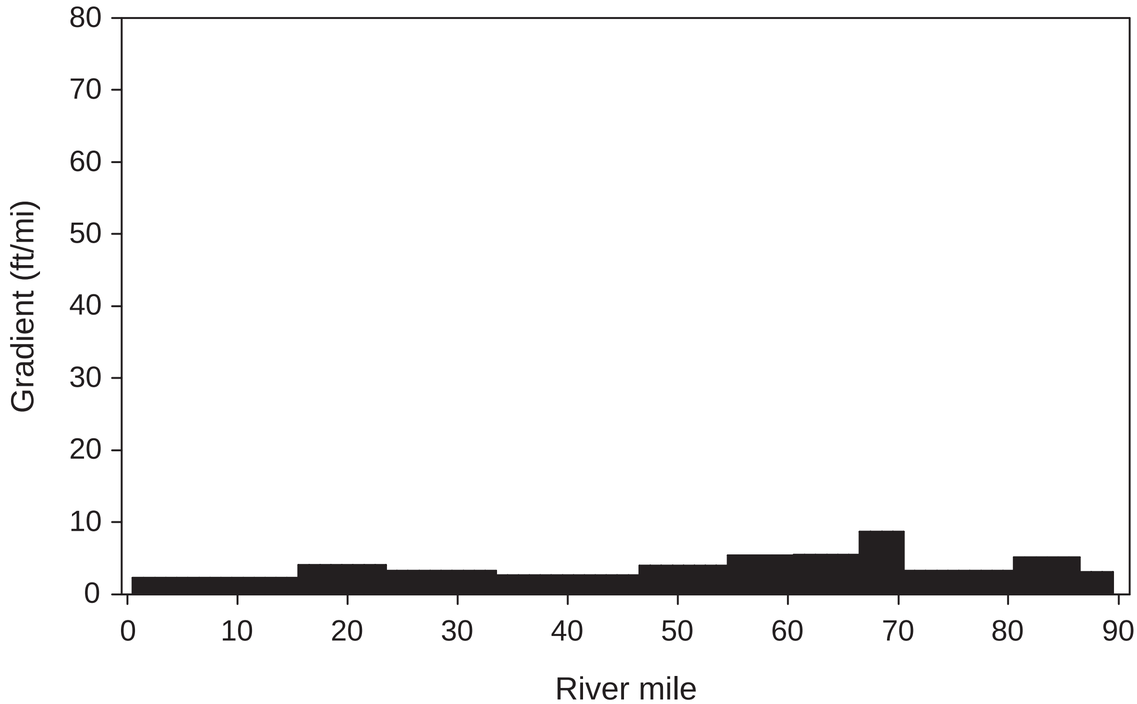

Figure 37.–Chippewa River channel gradient per river mile.

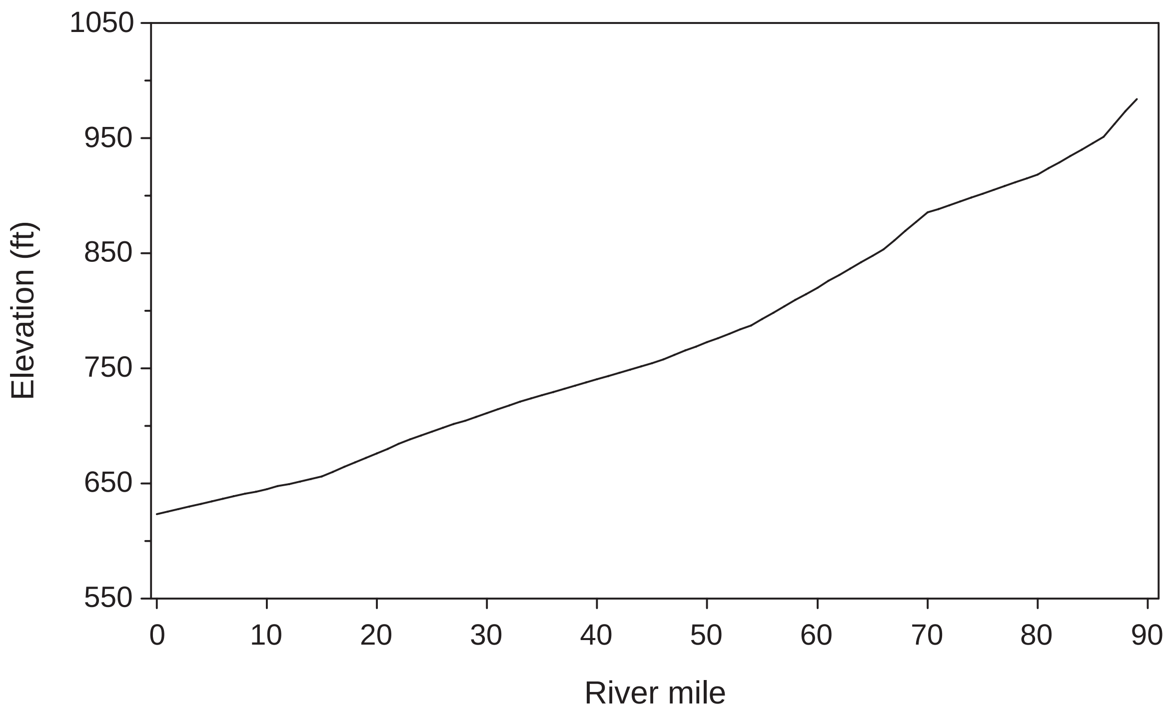

Figure 38.–Chippewa River channel elevation per river mile.

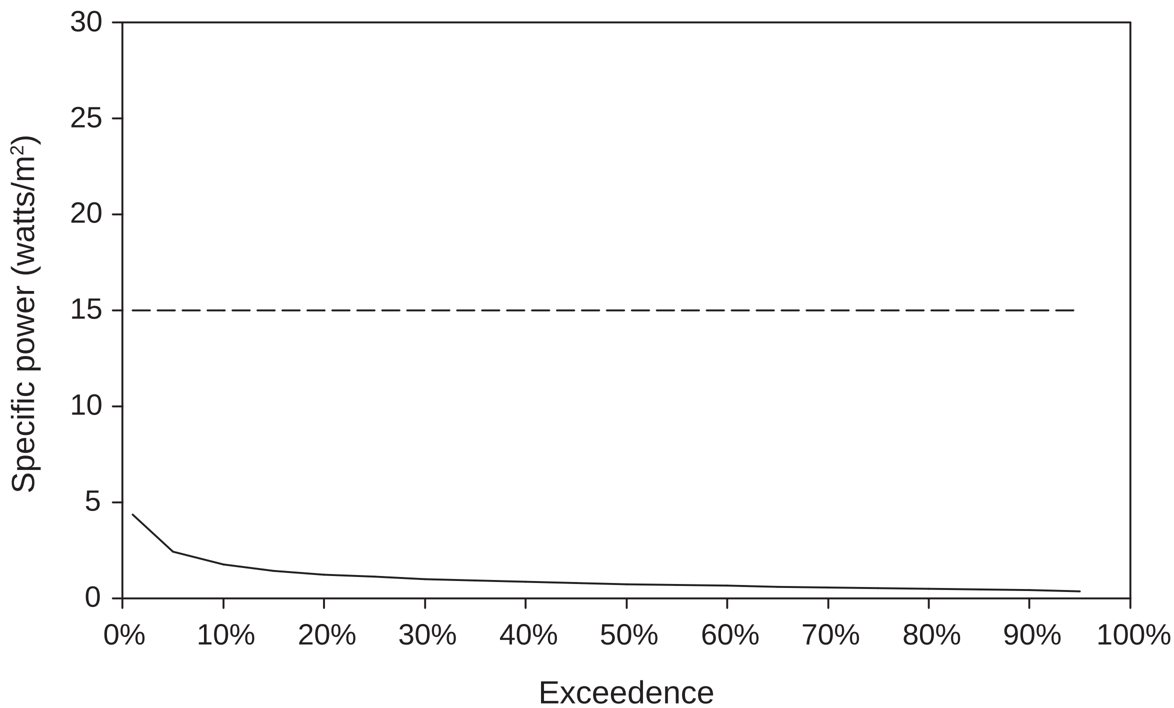

Figure 39.–Specific power for the Chippewa River near Mt. Pleasant. Dashed line indicates the specific power (15 watts/m^2) at which the channel of a river flowing through sand becomes dynamic.

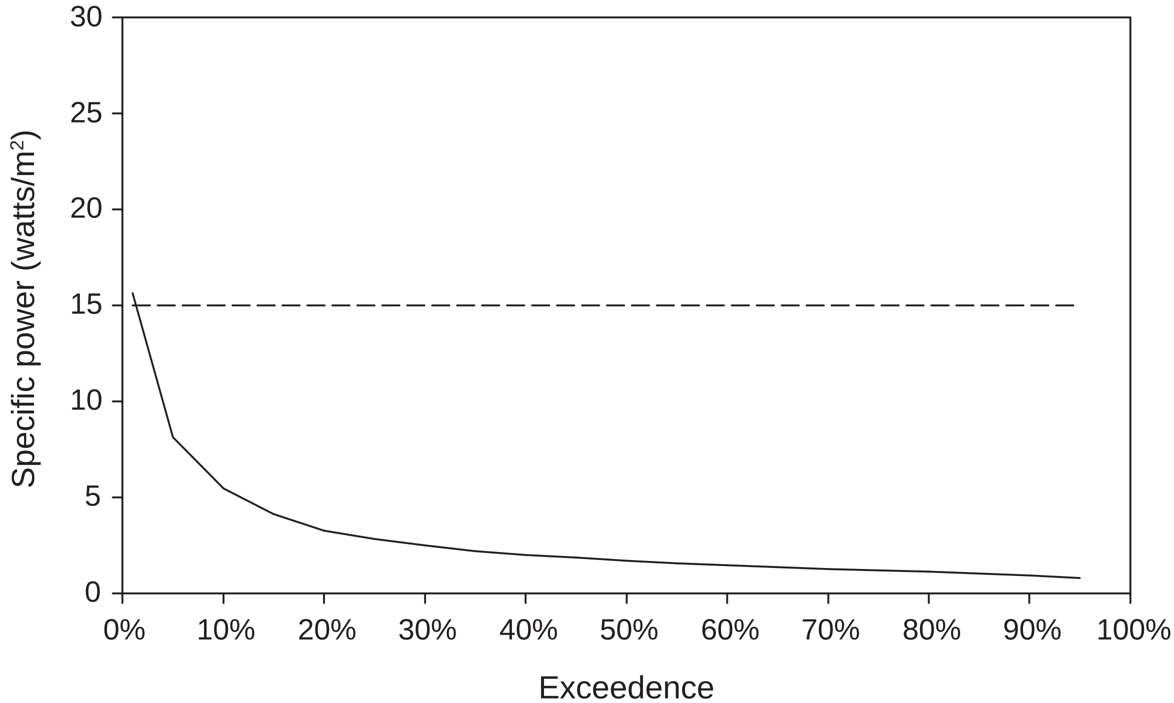

Figure 40.–Specific power for the Chippewa River near Midland. Dashed line indicates the specific power (15 watts/m^2) at which the channel of a river flowing through sand becomes dynamic.

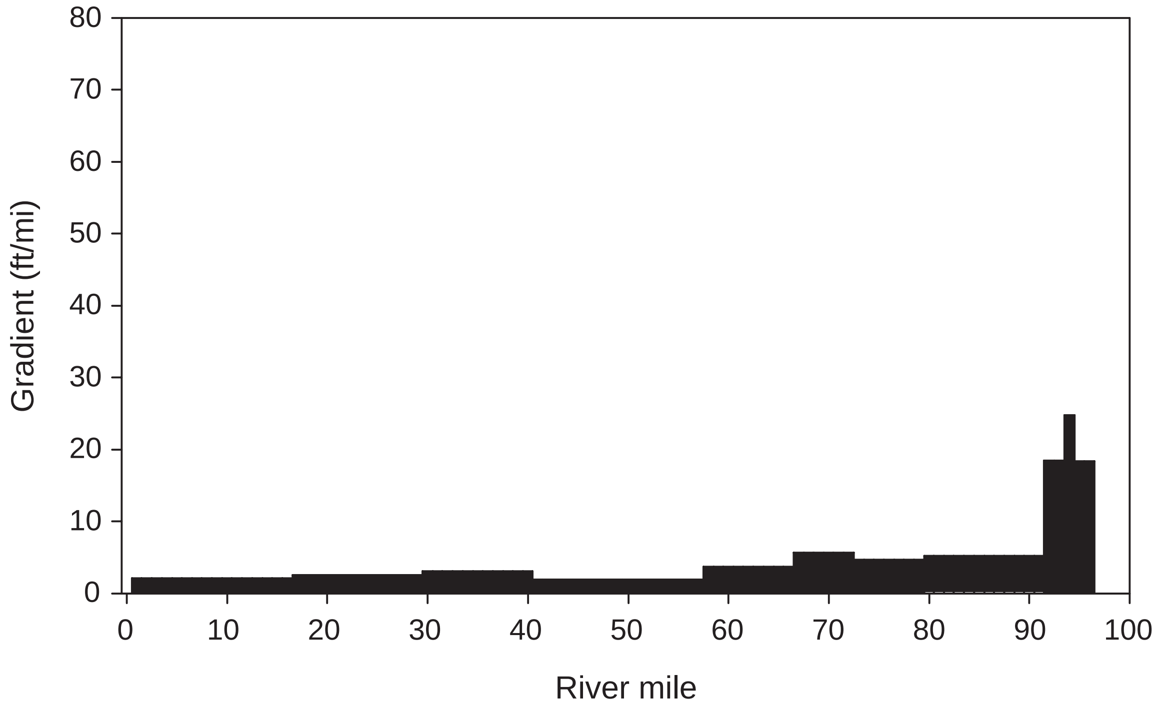

Figure 41.–Pine River channel gradient per river mile.

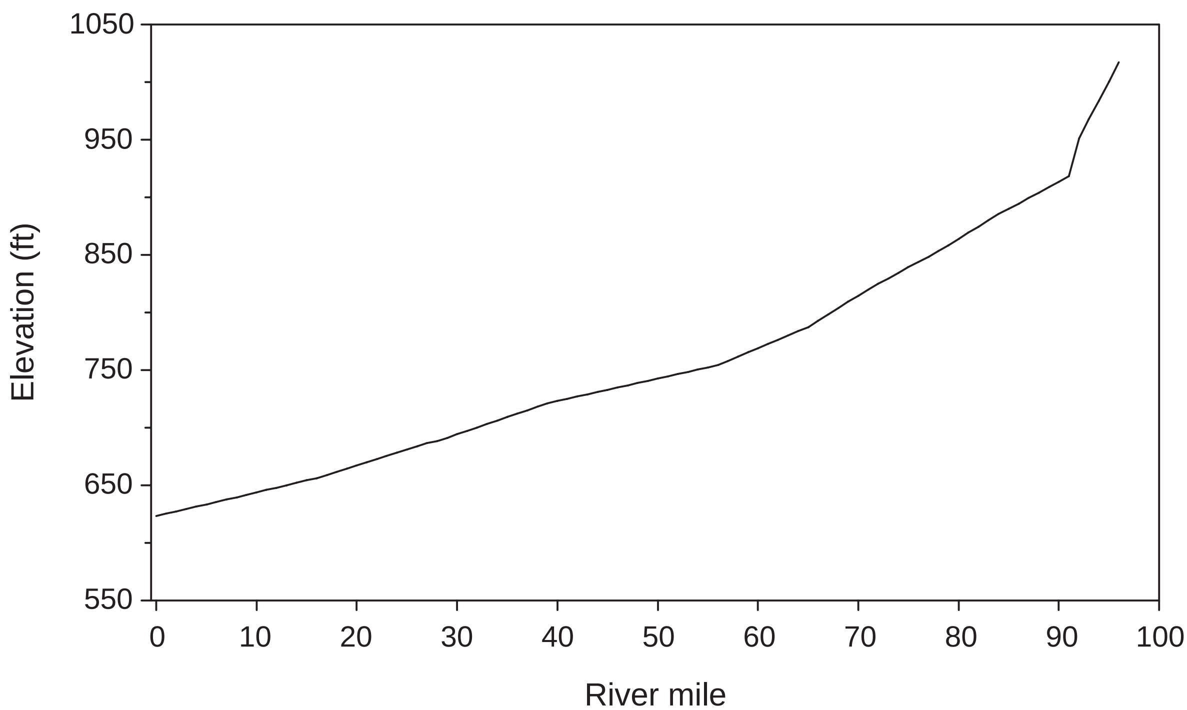

Figure 42.–Pine River channel elevation per river mile.

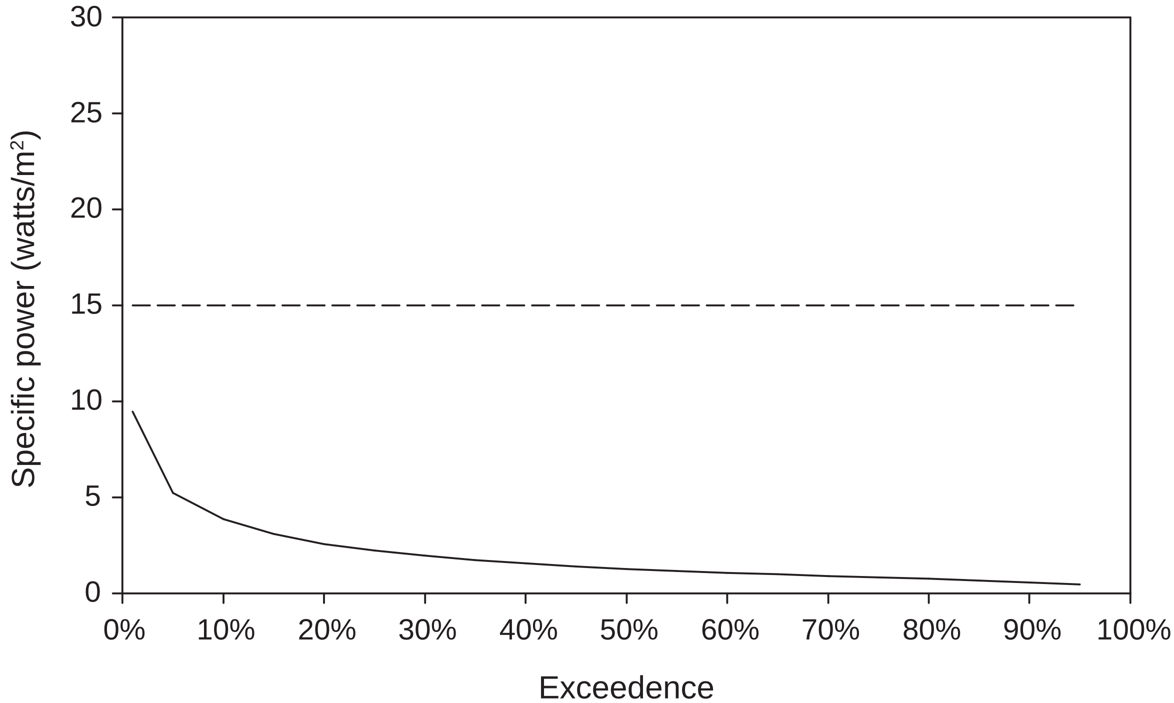

Figure 43.–Specific power for the Pine River at Alma. Dashed line indicates the specific power (15 watts/m^2) at which the channel of a river flowing through sand becomes dynamic.

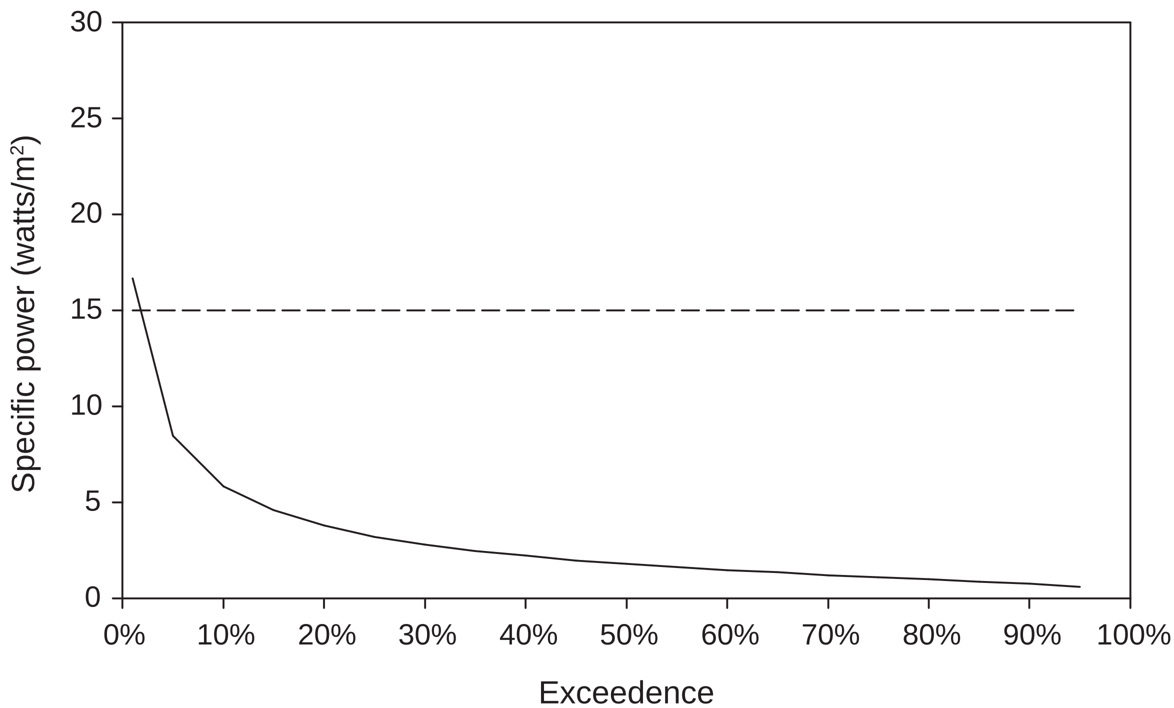

Figure 44.–Specific power for the Pine River near Midland. Dashed line indicates the specific power (15 watts/m^2) at which the channel of a river flowing through sand becomes dynamic.

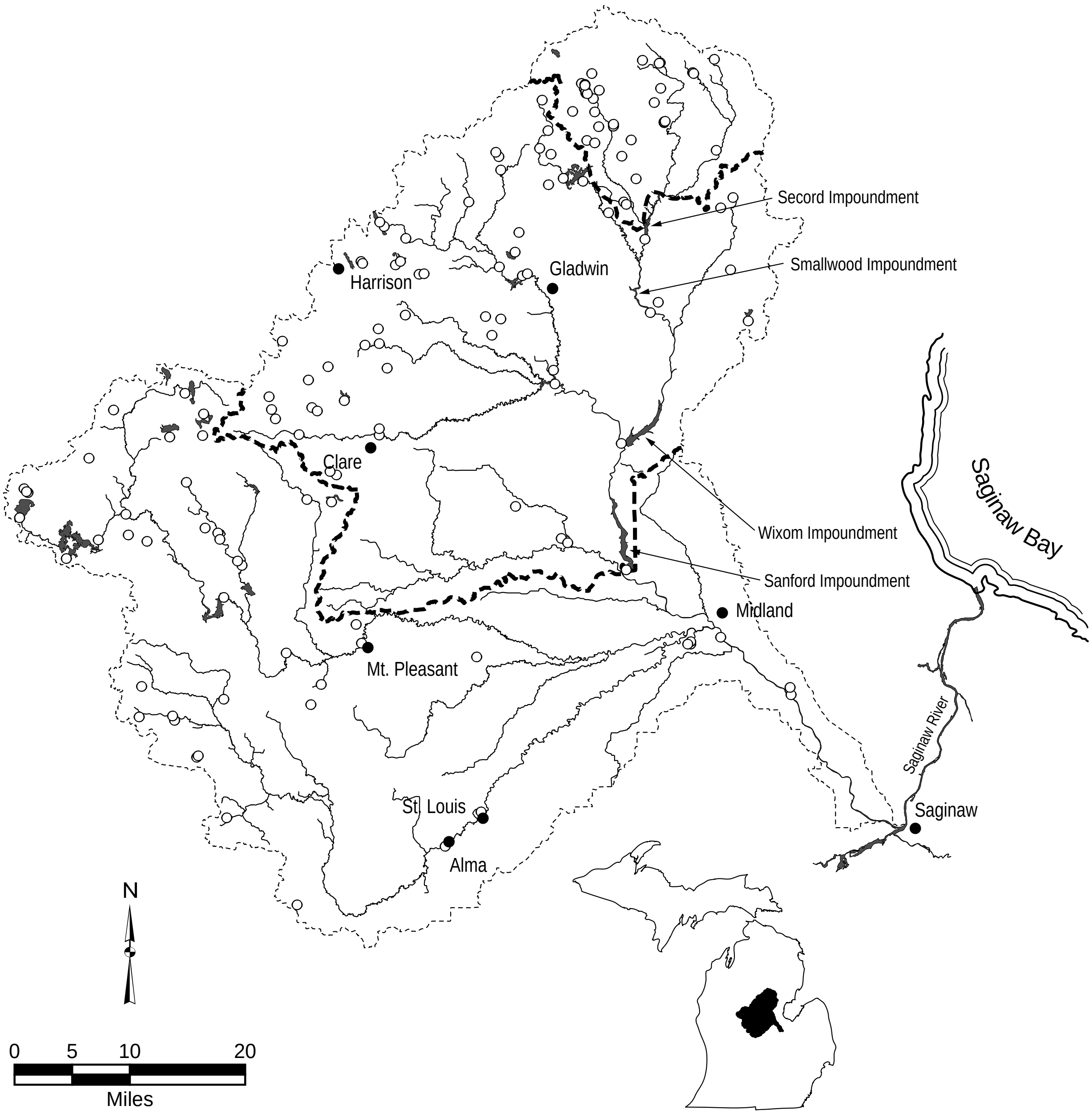

Figure 45.–Dams and water control structures in the Tittabawassee River watershed.

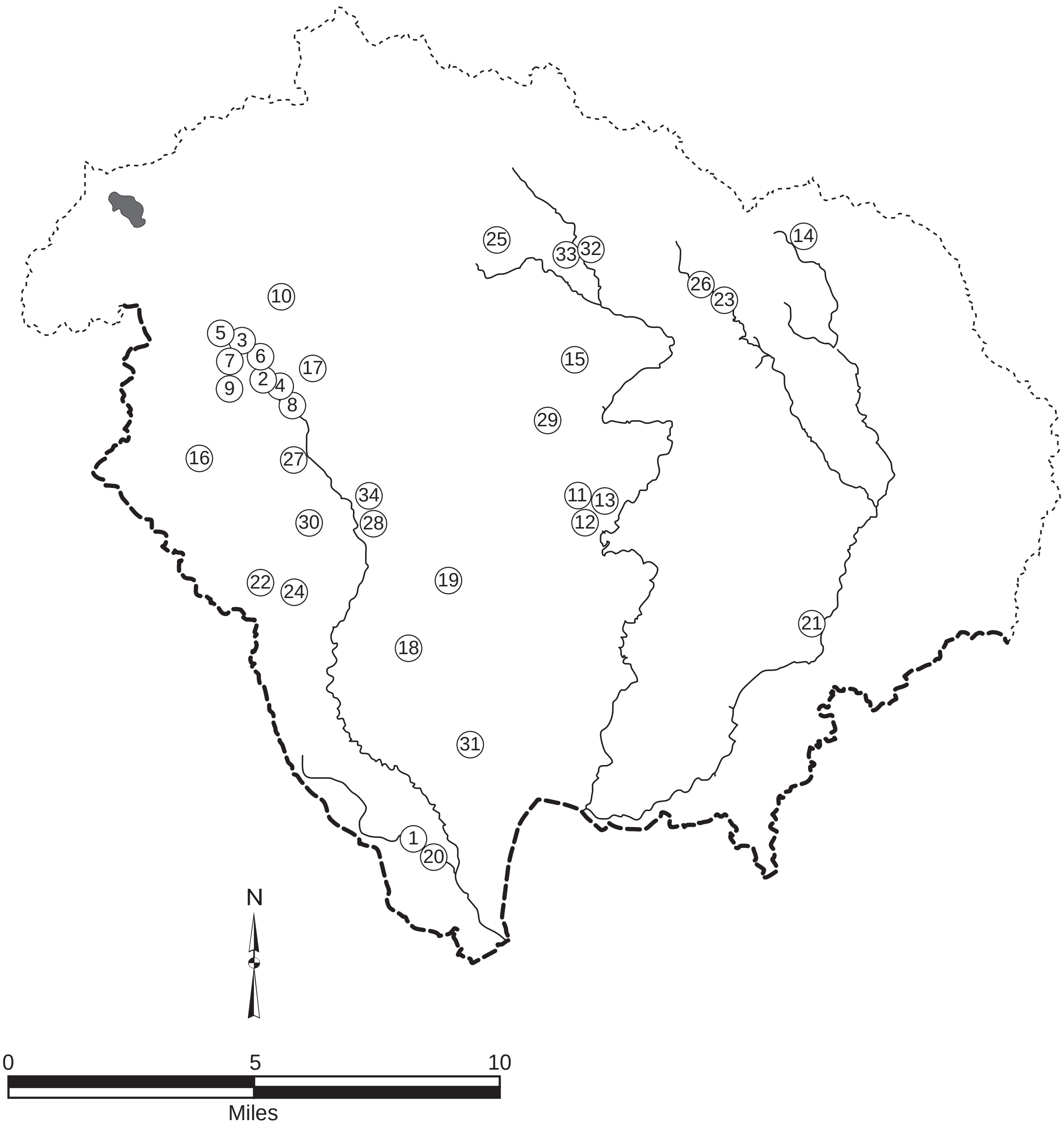

Figure 46.–Dams located within the headwaters segment of the Tittabawassee River watershed. See Table 18 for dam names and descriptions.

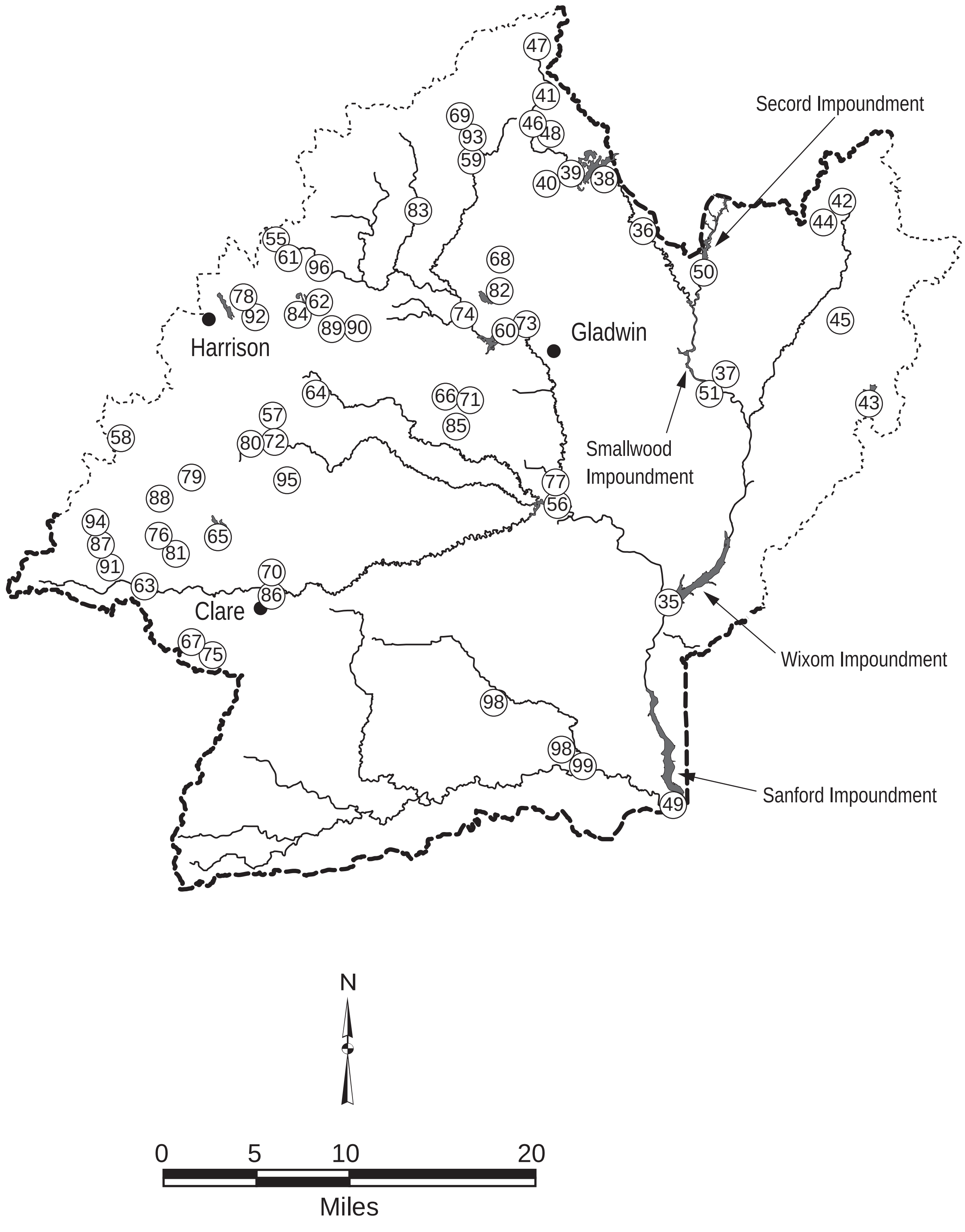

Figure 47.–Dams located within the middle segment of the Tittabawassee River watershed. See Table 18 for dam names and descriptions.

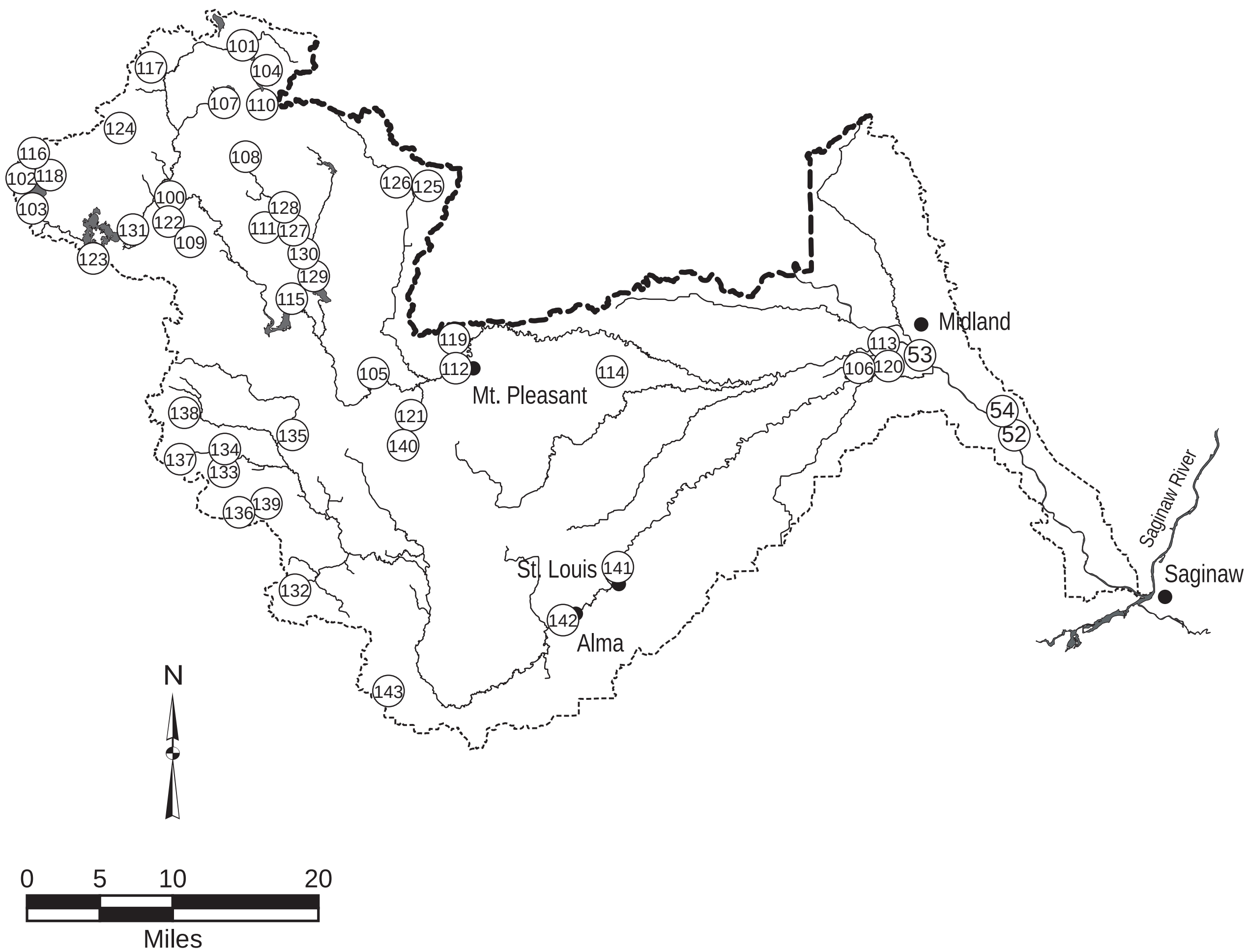

Figure 48.–Dams located within the mouth segment of the Tittabawassee River watershed. See Table 18 for dam names and descriptions.

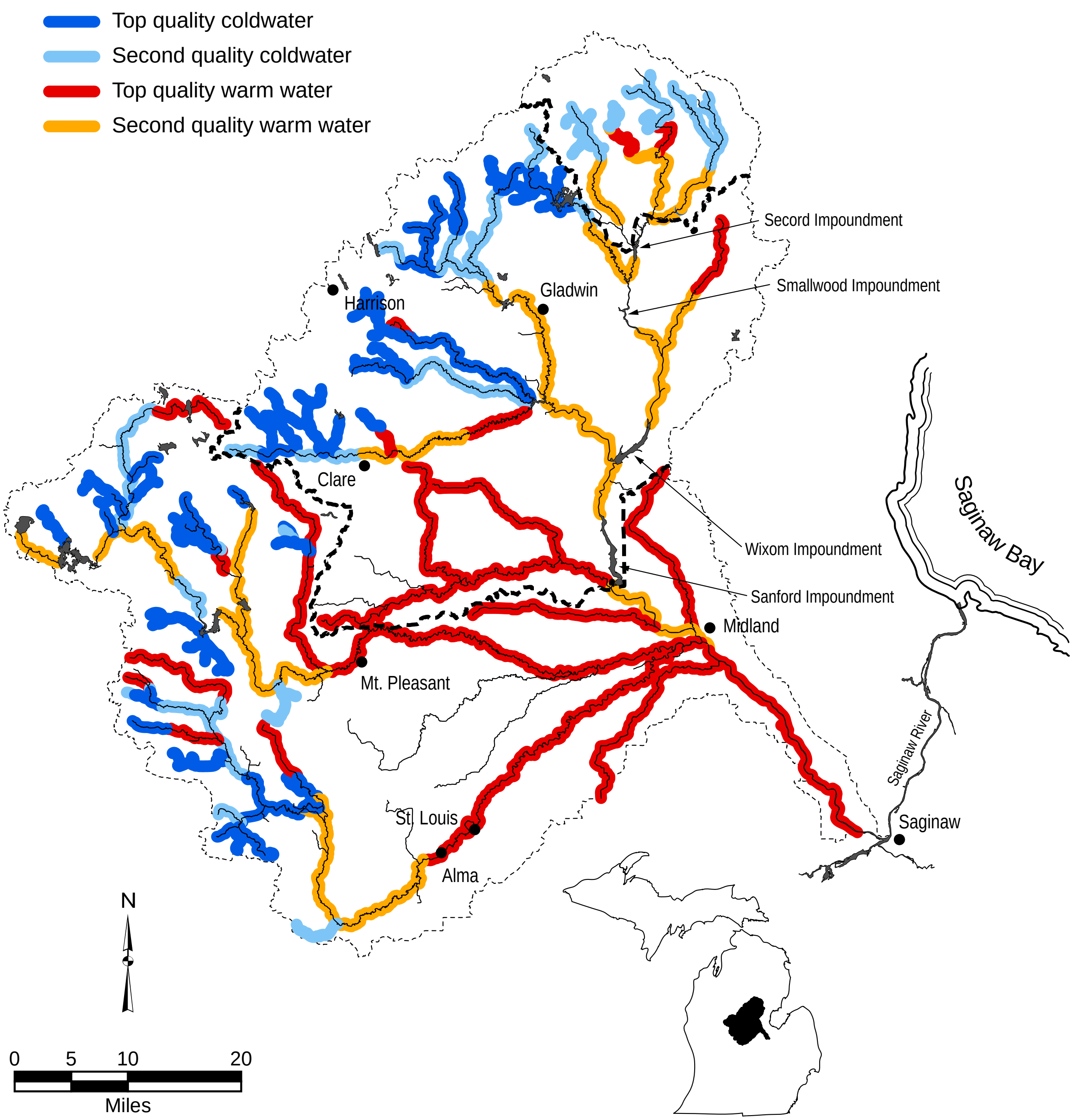

Figure 49.–Water quality within the Tittabawassee River watershed.

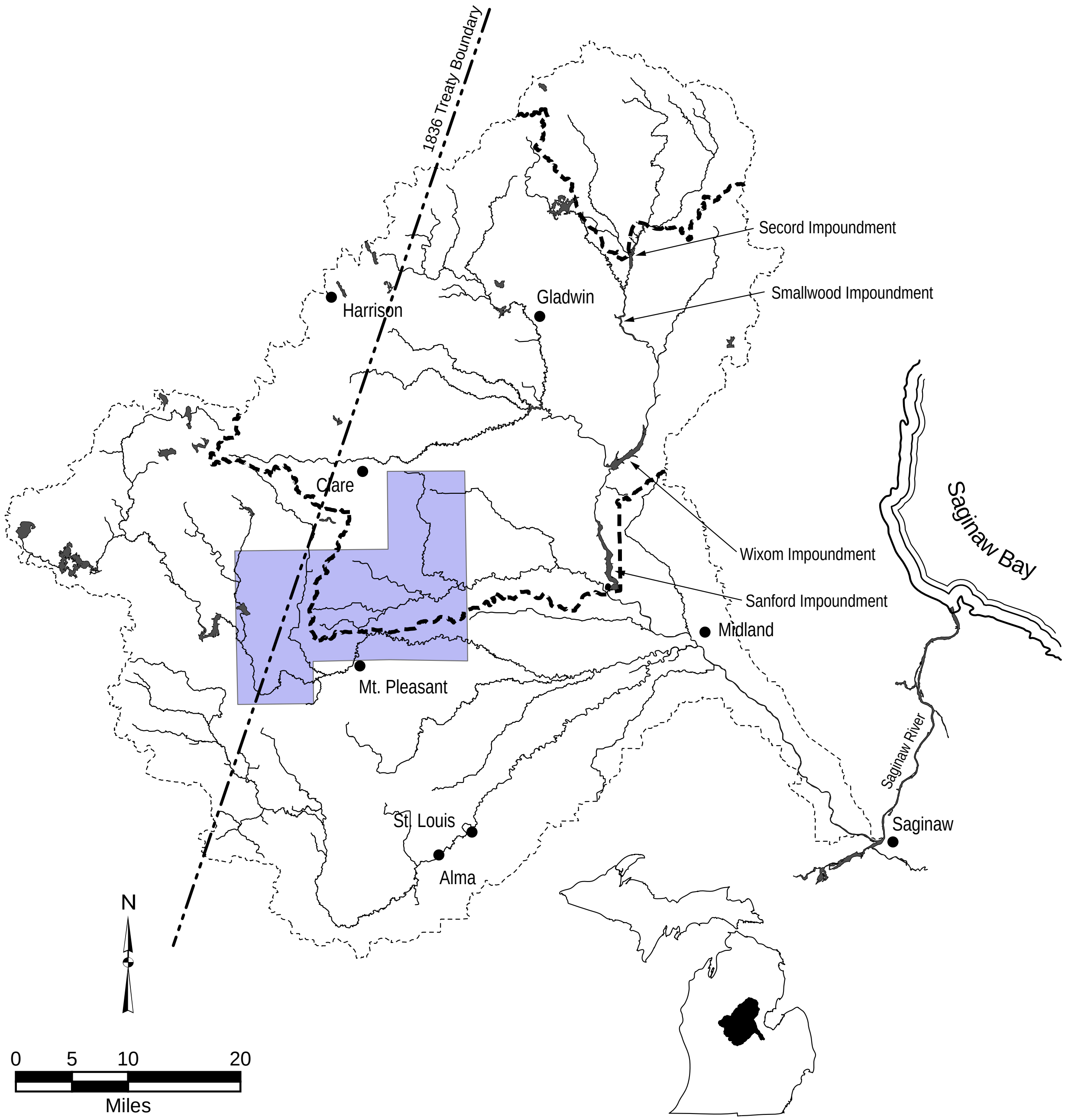

Figure 50.–Isabella Indian Reservation, Treaty of 1855, and location of the 1836 Treaty boundary within the Tittabawassee River watershed.

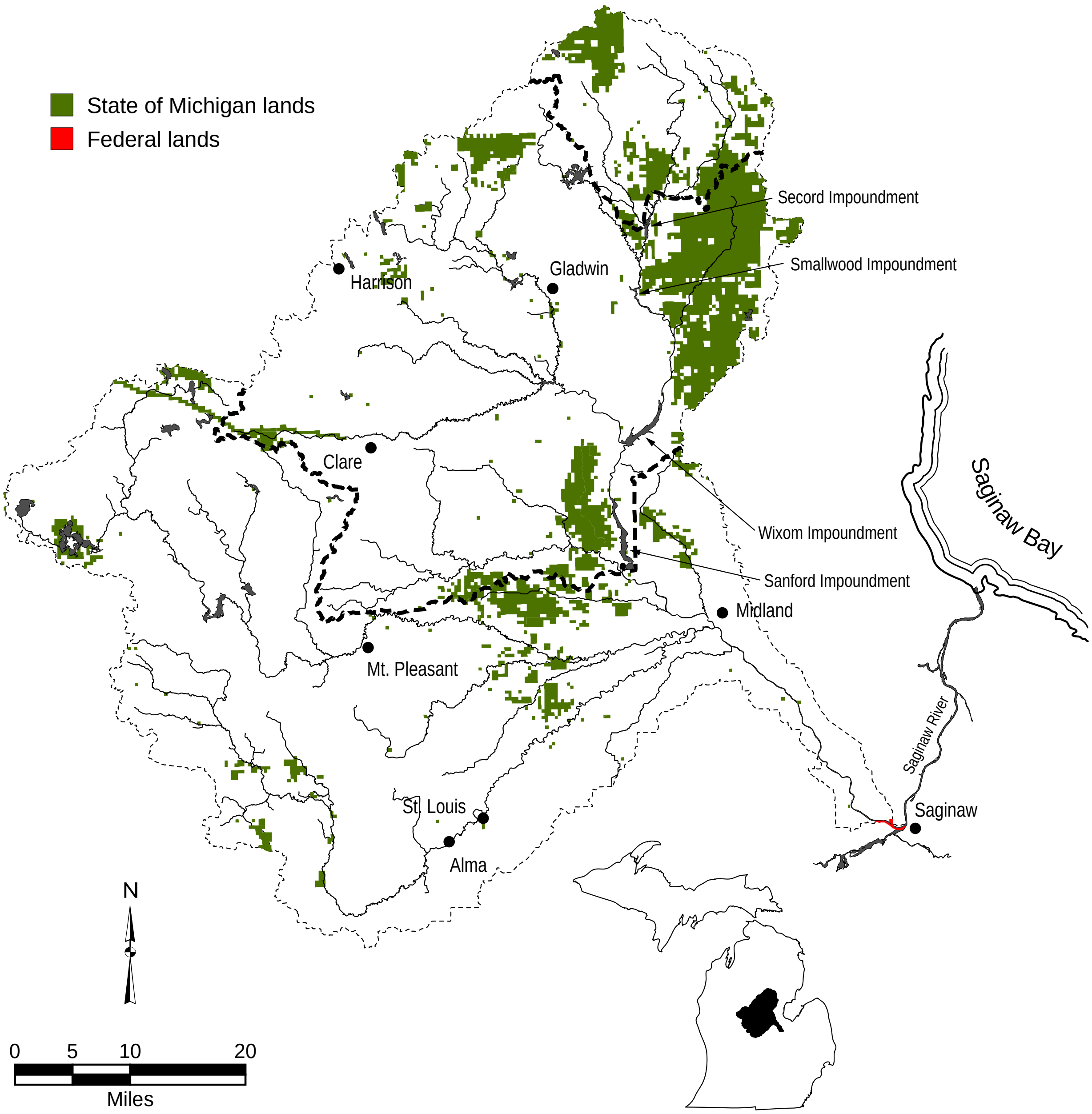

Figure 51.–State of Michigan and federal lands within the Tittabawassee River watershed.

TABLES

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Table 1.–Name, size, and location of lakes and impoundments 10 acres or greater in the Tittabawassee River watershed.

Lake name	Size (acres)	County	Latitude	Longitude
Arnold Lake	121.3	Clare	44.069500°	-84.752000°
Atchel Lake	16.3	Roscommon	44.183500°	-84.520333°
Bailey Lake	38.3	Clare	43.891667°	-84.651500°
Barrytown	46.7	Mecosta	43.746333°	-85.146667°
Bass Lake	101.1	Montcalm	43.402500°	-84.927333°
Bass Lake	55.8	Clare	43.867500°	-85.072667°
Beebe Lake	49.7	Clare	43.945500°	-84.759000°
Bentley Marsh	303.3	Gladwin	44.014333°	-84.170500°
Bertha Lake	35.7	Clare	43.932167°	-84.892667°
Big Cranberry Lake	310.5	Clare	43.883000°	-85.038667°
Big Eldred Lake	12.0	Isabella	43.598000°	-85.070667°
Big Mud Lake	230.9	Clare	43.900333°	-85.074333°
Blanchard Millpond	14.9	Isabella	43.523333°	-85.075167°
Blue Lake	24.4	Gladwin	44.122500°	-84.561167°
Bluegill Lake	11.7	Mecosta	43.697000°	-85.226000°
Bluff Lake	41.8	Clare	43.833000°	-84.977333°
Boathouse Lake	50.0	Clare	44.025500°	-84.722000°
Boyles Creek	287.7	Clare	43.847500°	-85.014833°
Brine Pond	868.6	Midland	43.576000°	-84.221333°
Brine ponds	375.9	Midland	43.590167°	-84.237333°
Budd Lake	173.7	Clare	44.020333°	-84.794333°
Bungo Lake	18.7	Clare	43.940333°	-84.910333°
Camelot Lake	55.6	Isabella	43.584333°	-84.610167°
Campbell Lake	14.8	Roscommon	44.191833°	-84.045833°
Cedar Lake	10.2	Gladwin	44.137500°	-84.349500°
Chatman Lake	61.2	Ogemaw	44.167500°	-84.341000°
Chippewa Lake	791.3	Mecosta	43.754500°	-85.298167°
Clear Lake	52.4	Clare	43.894167°	-84.941500°
Clear Lake	65.8	Roscommon	44.230000°	-84.488167°
Coldwater Lake	285.3	Isabella	43.661167°	-84.956000°
Cranberry Lake	162.9	Clare	44.057500°	-84.743667°
Deaner Lake	25.4	Montcalm	43.392167°	-84.875667°
Deer Lake	19.1	Clare	44.020833°	-84.757333°
Diamond Lake	85.7	Mecosta	43.723000°	-85.204500°
Dodge Lake	23.4	Clare	44.021333°	-84.712833°
Dunham Lake	19.1	Roscommon	44.209667°	-84.403667°
East Twin Lake (East)	16.5	Roscommon	44.246667°	-84.451000°
East Twin Lake (West)	52.9	Roscommon	44.246167°	-84.456000°
Eddy Lake	18.7	Roscommon	44.239833°	-84.465167°
Edwards Lake	56.0	Ogemaw	44.193833°	-84.304000°
Eight Point Lake	415.6	Clare	43.840000°	-85.073500°
Elbow Lake	23.7	Clare	44.134167°	-84.662000°
Elk Lake	68.3	Gladwin	44.157833°	-84.359833°
Emerald Lake	13.6	Mecosta	43.800833°	-85.247333°
Lake Enola	17.9	Clare	43.932833°	-84.752333°
Eureka Lake	14.3	Clare	43.926333°	-84.881667°

Table 1.–Continued.

Lake name	Size (acres)	County	Latitude	Longitude
Five Lakes	118.7	Clare	43.872500°	-84.801833°
Lake Four	58.8	Gladwin	44.155000°	-84.445667°
Frost Lake	52.2	Ogemaw	44.181167°	-84.352333°
Gear Lake	31.6	Ogemaw	44.236167°	-84.334500°
Lake George	91.9	Ogemaw	44.209167°	-84.247667°
Glass Lake	24.9	Isabella	43.784167°	-84.857000°
Gorrel Lake	29.9	Mecosta	43.799667°	-85.160333°
Grass Lake	91.5	Gladwin	44.116333°	-84.459000°
Grass Lake	24.8	Gladwin	44.117000°	-84.584833°
Gray Lake	61.9	Clare	43.827833°	-85.015333°
Grewes Lake (East)	11.7	Isabella	43.616833°	-84.729333°
Grewes Lake (West)	41.3	Isabella	43.617167°	-84.734333°
Gut Lake	40.6	Clare	43.881667°	-84.821000°
Half Moon Lake	72.0	Gratiot	43.456167°	-84.823667°
Halfmoon Lake	24.9	Mecosta	43.695333°	-85.200333°
Halls Lake	69.1	Isabella	43.580833°	-85.066500°
Hannah Lake	28.2	Mecosta	43.682500°	-85.126500°
Haven Lake	11.5	Clare	44.024833°	-84.710333°
Hills Lake	13.2	Mecosta	43.752000°	-85.227333°
Hoister Lake	22.9	Gladwin	44.141667°	-84.566833°
Howland Lake	20.3	Clare	43.997000°	-84.650167°
Indian Lake	49.8	Gladwin	44.151667°	-84.352333°
Island Lake	39.4	Gladwin	44.123333°	-84.576000°
Jacks Lake	26.7	Mecosta	43.774500°	-85.223667°
Johnson Pond	13.3	Isabella	43.478000°	-85.035667°
Kerswill Lake	47.9	Gladwin	43.955333°	-84.560667°
Lake Contos	12.3	Gladwin	44.014333°	-84.564333°
Lake Isabella	701.2	Isabella	43.653500°	-84.995667°
Lake of the Hills (central)	13.2	Isabella	43.692833°	-84.969667°
Lake of the Hills (east)	79.7	Isabella	43.692000°	-84.963667°
Lake of the Hills (west)	74.2	Isabella	43.694167°	-84.972667°
Lake Thirteen	91.5	Clare	43.860833°	-84.860333°
Lake Twenty	124.0	Gladwin	43.940500°	-84.578333°
Lake Windaga	26.1	Isabella	43.718667°	-84.997667°
Lake Lancer	853.5	Gladwin	44.111833°	-84.444333°
LaStrange Lake	13.3	Isabella	43.476167°	-84.759833°
Lifter Lake	11.4	Mecosta	43.803833°	-85.216500°
Little Frost Lake	15.7	Ogemaw	44.182833°	-84.363167°
Little Lake George	10.8	Ogemaw	44.200000°	-84.250667°
Little Long Lake	68.2	Clare	44.026333°	-84.785167°
Little Loon Lake	12.1	Clare	43.878667°	-84.883500°
Littlefield Lake	139.8	Isabella	43.772500°	-84.945167°
Lake Lochbrae	85.6	Gladwin	44.103000°	-84.495333°
Long Lake	21.3	Isabella	43.700333°	-85.082833°
Long Lake	62.7	Mecosta	43.780500°	-85.300167°
Loon Lake	71.2	Clare	43.901167°	-84.821167°
Madison Lake	11.4	Gratiot	43.427833°	-84.736167°
Lake Maloy	46.2	Osceola	43.864667°	-85.157667°

Table 1.–Continued.

Lake name	Size (acres)	County	Latitude	Longitude
Marl Lake	19.3	Montcalm	43.406167°	-84.952833°
Marl Lake	11.2	Roscommon	44.164167°	-84.571000°
Martiny Lake	1,663.3	Mecosta	43.717833°	-85.183333°
McGilvery Lake	69.0	Gladwin	44.069167°	-84.601000°
McWatty Lake	23.5	Clare	44.033333°	-84.790167°
Merrill Lake	84.9	Mecosta	43.808667°	-85.155667°
Mill Pond	22.1	Clare	43.833000°	-84.877333°
Moiles Lake	22.3	Mecosta	43.687833°	-85.136833°
Molasses River Flooding #2	46.7	Gladwin	44.074167°	-84.225167°
Molasses River Flooding #3	203.6	Gladwin	43.949500°	-84.187000°
Molasses River Flooding	18.3	Gladwin	44.004167°	-84.188000°
Mud Lake	11.0	Mecosta	43.705833°	-85.207333°
Mud Lake	15.5	Gladwin	44.040000°	-84.552667°
Mud Lake	29.8	Gladwin	44.149500°	-84.363167°
Mud Lake	17.1	Ogemaw	44.193667°	-84.255333°
Mystic Lake	45.5	Clare	43.862833°	-85.042833°
Nestor Lake (East)	13.5	Clare	43.967333°	-84.656833°
Nestor Lake (West)	29.6	Clare	43.960167°	-84.656000°
no name	15.8	Gladwin	44.090000°	-84.257000°
no name	23.6	Gratiot	43.294833°	-84.767833°
no name	11.1	Gratiot	43.381667°	-84.624000°
no name	17.6	Gratiot	43.391167°	-84.615500°
no name	21.7	Saginaw	43.445167°	-84.057833°
no name	18.9	Isabella	43.584667°	-84.942333°
no name	17.3	Midland	43.595167°	-84.224667°
no name	11.8	Isabella	43.623167°	-84.622667°
no name	17.1	Midland	43.638000°	-84.485667°
no name	15.8	Midland	43.705333°	-84.426167°
no name	11.3	Midland	43.706833°	-84.437167°
no name	19.8	Midland	43.708667°	-84.394833°
no name	20.5	Midland	43.720833°	-84.437333°
no name	22.7	Isabella	43.724333°	-85.001000°
no name	32.0	Midland	43.747500°	-84.455167°
no name	37.0	Midland	43.753500°	-84.549833°
no name	10.7	Mecosta	43.756667°	-85.237333°
no name	12.0	Midland	43.762333°	-84.423833°
no name	30.0	Mecosta	43.774333°	-85.267167°
no name	10.5	Isabella	43.776000°	-84.875833°
no name	31.7	Isabella	43.787333°	-84.820000°
no name	18.7	Isabella	43.799167°	-84.719500°
no name	10.2	Isabella	43.804000°	-84.722333°
no name	26.1	Mecosta	43.808833°	-85.222000°
no name	26.2	Clare	43.818833°	-84.690833°
no name	14.2	Midland	43.827333°	-84.329000°
no name	13.6	Clare	43.837833°	-84.752333°
no name	19.6	Osceola	43.842833°	-85.179333°
no name	22.9	Osceola	43.846167°	-85.184167°
no name	12.2	Clare	43.852833°	-84.773167°

Table 1.–Continued.

Lake name	Size (acres)	County	Latitude	Longitude
no name	11.4	Clare	43.866500°	-84.896333°
no name	53.4	Gladwin	43.893833°	-84.235333°
no name	12.2	Clare	43.899333°	-84.631333°
no name	14.0	Clare	43.904667°	-84.828667°
no name	15.6	Gladwin	43.918333°	-84.508500°
no name	22.3	Clare	43.919667°	-84.892500°
no name	22.8	Clare	44.016333°	-84.713167°
no name	12.8	Gladwin	44.122167°	-84.331333°
no name	17.5	Roscommon	44.170333°	-84.375000°
no name	11.9	Ogemaw	44.202000°	-84.296333°
no name	15.6	Ogemaw	44.222667°	-84.301500°
Otter Lake	20.8	Clare	43.859667°	-84.842833°
Peas Lake	13.4	Isabella	43.555500°	-84.846833°
Perch Lake	16.7	Isabella	43.691333°	-84.986500°
Perch Lake	47.7	Clare	43.849167°	-85.001833°
Perch Lake	25.0	Clare	43.921167°	-84.930333°
Pine Lake	19.1	Bay	43.583000°	-85.141167°
Pine Lake	19.8	Mecosta	43.785333°	-85.284833°
Pine River	76.6	Gratiot	43.040167°	-84.668833°
Pine River	136.0	Gratiot	43.413500°	-84.606833°
Pratt Lake	188.1	Gladwin	44.025000°	-84.547000°
Pretty Lake	116.4	Mecosta	43.696167°	-85.234833°
Puro Lake	10.8	Gladwin	44.037000°	-84.563500°
Rattail Lake (Lower)	23.3	Mecosta	43.809333°	-85.196500°
Rattail Lakes	50.7	Osceola	43.816167°	-85.204333°
Robbins Lake	15.3	Montcalm	43.400333°	-84.848667°
Rock Lake	51.2	Montcalm	43.408333°	-84.942833°
Rollway Lake	54.3	Roscommon	44.186333°	-84.553500°
Ross Lake	249.4	Gladwin	43.883833°	-84.484000°
Round Lake	21.3	Isabella	43.697500°	-85.080167°
Round Lake	91.2	Clare	43.898833°	-84.641500°
Round Lake	26.3	Gladwin	44.085833°	-84.485167°
Russell Lake	20.7	Isabella	43.807500°	-85.009000°
Russell Lake	11.8	Clare	43.867000°	-84.953667°
Sand Lake	24.3	Clare	44.020000°	-84.720667°
Sanford Lake	1,401.6	Midland	43.677000°	-84.380167°
Scott Lake	16.2	Isabella	43.717833°	-84.936000°
Secord Lake	399.5	Gladwin	44.041667°	-84.341833°
sewage disposal pond	13.8	Gratiot	43.362500°	-84.668000°
sewage disposal pond	10.3	Isabella	43.532333°	-84.673333°
Shamrock Lake	61.7	Clare	43.831167°	-84.760833°
Smallwood Lake	370.5	Gladwin	43.960333°	-84.336000°
South Lake	18.2	Clare	43.868833°	-84.793500°
Spillway Lake	14.7	Clare	43.873667°	-85.025167°
Spring Lake	16.0	Roscommon	44.236333°	-84.497833°
Spring Lake	11.6	Roscommon	44.262833°	-84.437667°
Springwood Lakes (east)	23.9	Clare	44.006667°	-84.683833°
Springwood Lakes (west)	65.6	Clare	44.008333°	-84.690000°

Table 1.–Continued.

Lake name	Size (acres)	County	Latitude	Longitude
Stevenson Lake	156.6	Isabella	43.762833°	-84.821167°
Streaked Lake	10.4	Gladwin	44.129167°	-84.554500°
Strong Lake	11.9	Mecosta	43.704500°	-85.094833°
Surrey Lake	41.8	Clare	43.850500°	-84.911167°
Sutherland Lake	76.2	Clare	44.024667°	-84.769333°
Tanner Creek Flooding	58.3	Mecosta	43.716000°	-85.110167°
Tee Lake	42.1	Ogemaw	44.208333°	-84.350167°
Three Lake	72.9	Clare	43.886667°	-84.995333°
Tower Lake	15.8	Isabella	43.775333°	-84.958667°
Town Line Lake	12.4	Mecosta	43.791167°	-85.207333°
Townline Lake	31.9	Clare	44.029167°	-84.727667°
Trout Lake	19.8	Clare	44.134500°	-84.630667°
Trout Lake	26.4	Gladwin	44.136167°	-84.565167°
Tubs Lake	35.4	Osceola	43.855833°	-85.114833°
Twin Lake	10.4	Montcalm	43.378333°	-84.871833°
Wahl Lake	12.2	Isabella	43.802500°	-84.872000°
Wallic Lake	21.6	Gladwin	44.118833°	-84.519167°
Waterworks Reservoir	20.9	Midland	43.607833°	-84.195000°
West Twin Lake (East)	139.4	Roscommon	44.248667°	-84.479000°
West Twin Lake (West)	68.6	Roscommon	44.249000°	-84.482833°
Wiggins Lake	293.1	Gladwin	43.996167°	-84.543667°
Willing Lake	16.3	Roscommon	44.187333°	-84.524000°
Wing Lake	11.7	Isabella	43.553667°	-84.864333°
Wixom Lake	1,141.9	Gladwin	43.817000°	-84.384833°
Woodruff Lake	31.2	Isabella	43.558833°	-84.970167°
Woods Lake	33.5	Roscommon	44.234167°	-84.483167°

Table 2.–Archaeological sites within the Tittabawassee River watershed by county and township. Data from B. Mead, Department of State, Office of the State Archaeologist, personal communication.

County	Township	Number of sites
Arenac	19N 06E	1
Bay	14N 03E	1
Clare	17N 03W	1
	17N 04W	2
	17N 05W	3
	17N 06W	3
	18N 04W	1
	19N 03W	3
	19N 04W	14
	20N 03W	1
	20N 04W	5
Gladwin	18N 01E	1
	18N 02E	2
	19N 02E	2
Gratiot	10N 03W	1
	10N 04W	1
	11N 03W	23
	11N 04W	25
	12N 01W	7
	12N 02W	14
	12N 03W	23
	12N 04W	16
Isabella	13N 03W	1
	13N 04W	14
	13N 06W	3
	14N 03W	4
	14N 04W	5
	15N 03W	1
	15N 04W	7
	15N 05W	1
	15N 06W	2
	16N 04W	1
	16N 05W	2
	16N 06W	1
Mecosta	13N 07W	3
Midland	13N 01E	7
	13N 01W	39
	13N 02E	52
	13N 02W	27
	14N 01E	53
	14N 01W	41
	14N 02E	174
	14N 02W	10

Table 2.–Continued.

County	Township	Number of sites
	15N 01E	3
	15N 01W	37
	15N 02E	20
	15N 02W	9
	16N 01E	7
	16N 01W	24
	16N 02E	3
	16N 02W	1
Ogemaw	21N 01E	5
Roscommon	21N 01W	1
	23N 01W	4
	23N 02W	1
Saginaw	11N 03E	8
	11N 04E	16
	12N 02E	1
	12N 03E	73
	12N 04E	81
	13N 02E	1
	13N 03E	31
	13N 04E	1
	14N 03E	1

Table 3.–Prehistoric and historic archeological sites within the Tittabawassee River watershed. Cultural area is Eastern Woodlands. Data from B. Mead, Department of State, Office of the State Archaeologist, personal communication.

Era	Period Phase	Number of sites
Prehistoric	Specified period	
	Paleo-Indian	17
	Archaic	
	Early	9
	Middle	6
	Late	49
	Unspecified	4
	Total	68
	Woodland	
	Early	30
	Middle	29
	Late	78
	Unspecified	94
	Total	231
	Mississippian	2
	Specified period total	318
	Unspecified period	556
Total		874
Historic	Specified period	
	Seventeenth century	2
	Eighteenth century	7
	Nineteenth century	55
	Twentieth century	29
	Specified period total	93
	Unspecified period	34
Total		127

Table 4.–Bedrock layers, period of their formation, and composition within the Tittabawassee River watershed.

Bedrock layer	Period of formation	Area mi^2	Percent of watershed
Red Beds	Late Jurassic	1,025.68	41.51
Grand River Formation	Late Pennsylvanian	1.50	0.06
Saginaw Formation	Early Pennsylvanian	1,379.76	55.83
Bayport Limestone	Late Mississippian	4.36	0.18
Michigan Formation	Late Mississippian	58.04	2.35
Marshall Formation	Early Mississippian	1.67	0.07
Coldwater Shale	Early Mississippian	0.18	0.01

Table 5.–Percent of the Tittabawassee River watershed covered by various surficial materials and permeability rates.

Material	Percent of watershed	Permeability ([ft/day]*1,000)
High permeability		
Ice-contact outwash sand and gravel	4.7	328.08
End moraines of coarse-texture till	38.0	98.43
Dune sand	3.0	65.62
Glacial outwash sand and gravel and postglacial alluvium	14.5	65.62
Medium permeability		
Lacustrine sand and gravel	39.8	32.81

Table 6.–Annual precipitation by weather station within the Tittabawassee River watershed, 1951-80.

	Precipitation (inches)			
Form	Midland	Gladwin	Alma	Mt. Pleasant
Rain	25.8	27.5	26.3	27.4
Snow	37.7	51.6	41.8	36.3
Total	28.7	31.5	29.6	30.2

Table 7.–United States Geological Survey gauging stations within the Tittabawassee River watershed. Station numbers are referenced in Figure 6. Included in this table are period of record for each station, mean discharge, watershed area, and mean yield.

Segment name, map number–river	Location	Latitude Longitude	USGS station no.	Period of record	Mean discharge (ft^3/s)	Watershed area (mi^2)	Mean yield ($ft^3/s\ mi^2$)
Middle							
1–Tobacco	Beaverton	43.879500° -84.473833°	04152500	1948–82	373.8	487	0.77
2–South Branch Tobacco	Beaverton	43.867000° -84.545333	04152238	1987–03	74.2	160	0.46
Mouth							
3–Tittabawassee	Midland	43.595333° -84.235500°	04156000	1936–03	1,702.1	2,400	0.71
4–Tittabawassee	Freeland	43.522000° -84.125333°	04156500	1930–36	1,265.6	2,530	0.50
5–Salt	North Bradley	43.702833° -84.470500°	04153500	1934–71	75.7	138	0.55
6–Chippewa	Mt. Pleasant	43.625500° -84.707833°	04154000	1930–03	322.9	416	0.78
7–Chippewa	Midland	43.594500° -84.369500°	04154500	1947–72	426.5	597	0.71
8–Pine	Alma	43.379500° -84.655500°	04155000	1930–2003	228.2	288	0.79
9–Pine	Midland	43.564500° -84.369167°	04155500	1934–38 1948–97 2000–03	316.0	390	0.81

Table 8.–Communities participating in the National Flood Insurance Program by county and their date (month/day/year) of entry into the program.

County	Community name	Date of entry
Bay	Midland (City)	06/15/1984
	Williams (Township)	02/01/1986
Clare	Clare (City)	02/05/1992
Gladwin	Butman (Township)	07/30/1999
	Hay (Township)	12/31/1997
	Secord (Township)	01/29/1997
Gratiot	Alma (City)	03/01/1982
	St. Louis (City)	01/18/1989
Isabella	Broomfield (Township)	08/05/1991
	Chippewa (Township)	01/07/1998
	Coe (Township)	07/16/1991
	Coldwater (Township) [a]	01/07/1998
	Deerfield (Township)	01/07/1998
	Denver (Township)	07/16/1991
	Fremont (Township)	10/16/1991
	Isabella (Township)	04/16/1991
	Mount Pleasant (City)	08/16/1982
	Nottawa (Township)	05/02/1991
	Rolland (Township)	09/14/1990
	Sherman (Township)	10/16/1991
	Union (Township)	02/15/1991
	Vernon (Township)	02/05/1992
	Wise (Township)	09/18/1991
Mecosta	Fork (Township)	05/25/1984
Midland	Homer (Township)	05/14/1997
Saginaw	James (Township)	09/04/1991
	Saginaw (City)	11/16/1983
	Saginaw (Township)	07/02/1979
	Spaulding (Township)	06/15/1979
	Thomas (Township)	01/19/1983
	Tittabawassee (Township)	02/01/1987

[a] Currently not enrolled in National Flood Insurance Program, but an area where a special flood hazard has been identified.

Table 9.–Year 2001 water withdrawal from the Tittabawassee River watershed, select watersheds, and statewide. Units are in gallons/day/mi^2 (MDEQ 2005b).

Watershed	Water source			Total
	Great Lakes	Surface water	Groundwater	
Au Sable	0	322	1,851	2,173
Cheboygan	0	369	2,764	3,133
Clinton	8,618	4,177	26,505	39,300
Flint	0	1,902	5,840	7,742
Huron	697	29,154	20,089	49,940
Kalamazoo	0	8,242	43,710	51,952
Manistique	0	4,130	53	4,184
Muskegon	109,623	3,104	9,572	122,298
Thunder	93,186	520	1,599	95,306
Tittabawassee	28	2,326	3,798	6,152
Statewide	164,473	7,545	8,727	180,745

Table 10.–Irrigated agriculture 1997, estimated agricultural water withdrawal 2001, and total water withdrawal within the Tittabawassee River watershed (MDEQ 2005c).

Land use	1997		2001 (gallons/day/mi^2)			
	No. farms ≥14 acres	Irrigated acres	Great Lakes	Surface water	Groundwater	Total
Agriculture	31	4,528	0	190	752	942
Nonagriculture			28	2,136	3,046	5,210
Total			28	2,326	3,798	6,152

Table 11.–Presettlement land cover (circa 1800) by percentage of area for the Tittabawassee River watershed and for catchments of the main stem segments and their major tributaries. Catchment summaries for a segment represent the local landscape that contributes water to the segment and do not represent the cumulative upstream landscape.

Cover type	Watershed	Headwaters	Middle	Tobacco	Mouth	Salt	Chippewa	Pine
Aspen–birch forest	0.9	0.8	0.6	0.0	1.9	3.4	0.7	0.5
Beech–sugar maple forest	19.1	0.0	0.0	0.2	20.9	29.7	25.6	46.9
Beech–sugar maple–hemlock forest	25.4	21.6	20.0	48.9	9.2	24.9	33.9	1.5
Black ash swamp	1.0	0.6	1.1	2.0	0.8	1.3	0.8	0.4
Cedar swamp	6.0	19.5	14.1	9.1	0.0	4.4	2.0	0.9
Hemlock–white pine forest	20.8	30.3	38.3	12.1	43.8	24.8	15.4	6.1
Jack pine–red pine forest	0.3	1.2	1.5	0.1	0.0	0.0	0.0	0.0
Lake/river	0.8	1.1	0.5	0.8	0.6	0.1	1.5	0.5
Mixed conifer swamp	8.6	4.1	16.0	9.4	11.5	6.0	7.8	5.0
Mixed hardwood swamp	4.4	0.7	2.9	1.6	10.1	4.3	2.9	9.1
Muskeg/bog	<0.1	0.0	0.0	0.0	0.0	0.0	<0.1	<0.1
Oak/pine barrens	0.2	0.0	0.0	1.1	0.0	0.0	0.0	0.0
Oak–hickory forest	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Pine barrens	0.5	6.4	0.0	0.2	0.0	0.0	0.0	0.0
Shrub swamp/emergent marsh	0.8	0.6	2.1	0.7	0.7	0.2	0.9	0.3
White pine–mixed hardwood forest	5.9	0.0	0.0	0.0	0.0	0.0	7.7	23.9
White pine–red pine forest	4.0	13.2	3.1	11.9	0.4	0.9	0.8	0.0
White pine–white oak forest	1.2	0.0	0.0	1.9	0.0	0.0	0.0	4.8

Table 12.–Current land use by percentage of area for the Tittabawassee River watershed and for catchments of the main stem segments and their major tributaries. Catchment summaries for a segment represent the local landscape that contributes water to the segment and do not represent the cumulative upstream landscape.

Land use	Watershed	Headwaters	Middle	Tobacco	Mouth	Salt	Chippewa	Pine
Agriculture	44.8	12.0	21.2	36.2	38.7	61.0	54.4	67.8
Commercial	0.8	0.5	0.1	0.5	3.4	0.5	0.6	0.4
Developed	1.2	0.0	0.2	0.6	6.5	0.3	0.8	1.0
Grassland	1.3	4.5	3.0	2.4	0.2	0.2	0.1	0.1
Open water	1.7	2.3	3.3	1.5	1.6	0.1	2.0	0.6
Upland	34.8	53.7	37.9	47.7	30.8	24.1	32.3	21.4
Wetland	15.4	26.9	34.3	11.0	18.8	13.8	9.8	8.6

Table 13.–Agricultural use by acres for the Tittabawassee River watershed and for catchments of the main stem segments and their major tributaries. Catchment summaries for a segment represent the local landscape that contributes water to the segment and do not represent the cumulative upstream landscape.

Agricultural use	Watershed	Headwaters	Middle	Tobacco	Mouth	Salt	Chippewa	Pine
Grassland/Herbaceous	18,829	5,400	5,914	7,515				
Pasture/Hay	125,148	7,304	12,438	26,687	5,777	9,440	34,513	28,990
Row crops	583,282	6,728	29,135	85,408	56,228	76,866	175,670	153,246
Total acres	727,258	19,432	47,487	119,611	62,004	86,303	210,183	182,236

Table 14.–Number of oil and natural gas wells and wells per mi^2 for the Tittabawassee River watershed and for catchments of the main stem segments and their major tributaries.

Number of oil & gas wells	Watershed	Upper	Middle	Tobacco	Mouth	Salt	Chippewa	Pine
Wells	398	2	45	34	38	117	96	66
Wells/mi^2	0.16	0.01	0.15	0.07	0.15	0.53	0.16	0.16

Table 15.–Classification of gradient and the channel characteristics associated with each. Data from G. Whelan, MDNR, Fisheries Division, unpublished data.

Gradient class	Value (ft/mi)	Channel characteristics
Low	0.0–2.9	Mostly run habitat with low hydraulic diversity
Fair	3.0–4.9	Some riffles with modest hydraulic diversity
Good	5.0–9.9	Riffle-pool sequences with good hydraulic diversity
Excellent	10.0–69.9	Established, regular riffle-pool sequences with excellent hydraulic diversity
Fair	70.0–149.9	Chute and pool habitats with only fair hydraulic diversity
Poor	>150	Falls and rapids with poor hydraulic diversity

Table 16.–Percent of river miles in each gradient class for the Tittabawassee River watershed. Total miles of river for each segment and tributary in parentheses.

Gradient (ft/mi)	Percentage							
	Upper (20)	Middle (36)	Tobacco (34)	S. Br. Tobacco (38)	Mouth (35)	Salt (18)	Chippewa (89)	Pine (94)
0.0–2.9	5.0	61.1		34.2	100.0	66.7	31.5	47.9
3.0–4.9	20.0	38.9	31.3				43.8	28.1
5.0–9.9	20.0		15.6	39.5		33.3	24.7	18.8
10.0–69.9	45.0		53.1	26.3				5.2
70.0–149.9	10.0							
>150								

Table 17.–United States Geological Survey gauging stations within the Tittabawassee River watershed. Station numbers are referenced in Figure 6. Included in this table are record period for each station, measured bank full widths, expected lower 95% estimated width, expected mean width, and expected upper 95% upper width. Measured bank-full widths outside of the lower and upper 95% widths are noted with "*".

Segment name, map number–river	Location	USGS station no.	Period of record	Width (ft) Measured	Lower 95%	Expected mean	Upper 95%
Middle							
2–Tobacco	Beaverton	04152500	1948–82	92.2	75.2	105.6	148.5
3–South Branch Tobacco	Beaverton	04152238	1987–03	55.1	35.1	47.2	63.5
Mouth							
9–Tittabawassee	Midland	04156000	1936–03	216.8	153.6	224.9	329.3
4–Salt	North Bradley	04153500	1934–71	60.8	35.4	47.7	64.2
5–Chippewa	Mt. Pleasant	04154000	1930–03	84.8	70.1	98.2	137.5
6–Chippewa	Midland	04154500	1947–72	205.5*	80.0	112.8	159.1
7–Pine	Alma	04155000	1930–03	80.3	59.6	82.6	114.6
8–Pine	Midland	04155500	1934–38 1948–97 2000–03	183.0*	69.4	97.2	135.9

Table 18.–Dams and water control structures in the Tittabawassee River watershed. Data from Department of Environmental Quality, Land and Water Management Division, Dams Safety Unit. Hazard ranking: low, significant, high. High hazard = loss of life would occur; significant hazard = large amounts of property damage would occur. Blank indicates no data available. Dam no. corresponds to Figures 46-48. Dam type “other” includes stop logs and rock rip-rap. Sig = significant; hydro = hydroelectric producing.

Dam no.	Segment Tributary Dam name	River	Latitude	Longitude	Built	Owner	Type	Height	Acres	Surface acres	Purpose	Hazard
	Headwaters											
	Main Stem											
1	Baker	Wheeler Drain	44.082886°	-84.372730°	1962	Private	Earth	19	7	40	Recreation	Low
2	Benmark	West Branch Tittabawassee	44.205928°	-84.428034°	1945	Private	Gravity	12	1	10	Recreation	Low
3	Benmark	West Branch Tittabawassee	44.213272°	-84.428756°	1945	Private	Gravity	6	3	10	Recreation	Low
4	Benmark	West Branch Tittabawassee	44.203607°	-84.427422°	1945	Private	Other	5	2	4	Recreation	Low
5	Benmark	West Branch Tittabawassee	44.214564°	-84.434322°	1945	Private	Gravity	10	4	16	Recreation	Low
6	Benmark	West Branch Tittabawassee	44.212195°	-84.429431°	1945	Private	Other	9	4	14	Recreation	Low
7	Benmark	West Branch Tittabawassee	44.208451°	-84.430189°	1945	Private	Gravity	12	2	30	Recreation	Low
8	Benmark	West Branch Tittabawassee	44.197318°	-84.416622°	1945	Private	Gravity	6	2	5	Recreation	Low
9	Benmark	West Branch Tittabawassee	44.203287°	-84.425817°	1940	Private	Earth	7	1	0	Recreation	Low
10	Blackhurst	West Branch Tittabawassee	44.225007°	-84.418029°	1967	Private	Earth	9	4	18	Recreation	Low
11	Bowsher	West Branch tributary	44.170518°	-84.308542°		Private		3	1	0		Low
12	Bowsher	West Branch tributary	44.169488°	-84.308761°		Private		3	1	0		Low
13	Bowsher	West Branch tributary	44.170843°	-84.307023°		Private		3	1	0		Low
14	Bunting	Cooks Creek	44.238445°	-84.229488°	1970	Private	Earth	7	1	0	Water supply	Low
15	Cahoon	Mansfield tributary	44.207300°	-84.313093°		Private	Earth	8	2	0	Recreation	Low
16	Cushoff	West Branch tributary	44.184044°	-84.448461°	1966	Private	Other	7	2	0	Recreation	Low
17	Dunham	West Branch tributary	44.206356°	-84.406969°	1961	Private	Earth	5	19	100	Recreation	Low
18	Ed Klemac	West Branch tributary	44.133348°	-84.374968°	1961	Private	Earth	11	1	0	Other	Low
19	Elk Lake	Elk Lake Creek	44.151269°	-84.360072°		Private		1	65	0		Low
20	Good News	Wheeler Drain	44.079947°	-84.369127°	1964	Private	Earth	12	2	8	Recreation	Low
21	Hill	East Branch tributary	44.137794°	-84.229657°		Private			5			Low
22	Hoffman	Lake Four	44.151360°	-84.427749°	1964	Private	Earth	19	3	29	Farm Pond	Low
23	Horgewski	East Branch tributary	44.222808°	-84.261811°	1949	Private	Gravity	3	1	2	Recreation	Low
24	Huston	Lake Four Creek	44.148518°	-84.415525°		Private		19	3	0		Low
25	Morris Lake	Parren Creek tributary	44.238745°	-84.339724°	1965	Private	Earth	21	15	181	Recreation	Low
26	Rau Lake	Rau Creek	44.223948°	-84.263605°	1970	Private	Earth	0	0	0	Recreation	
27	Sanislow	West Branch tributary	44.182757°	-84.414830°	1960	Private	Earth	34	4		Recreation	Low

Table 18.–Continued.

Dam no.	Segment Tributary Dam name	River	Latitude	Longitude	Built	Owner	Type	Height	Acres	Surface acres	Purpose	Hazard
28	Soloskey	West Branch Tittabawassee	44.166684°	-84.386685°	1951	Private	Gravity	6	2	0		Low
29	Stillwagon	Mansfield tributary	44.191685°	-84.323334°		Private	Earth	6	1	0	Recreation	Low
30	Timmeck	West Branch tributary	44.166301°	-84.409405°	1969	Private	Gravity	15	2	0	Recreation	Low
31	Toutant	Elk Lake Creek	44.108335°	-84.353410°		Private		3	3	0		Low
32	Winter	Perry's Creek	44.235010°	-84.314208°		Private		3	1	0		Low
33	Winter	Perry's Creek	44.235474°	-84.313204°		Private		3	1	0		Low
34		West Branch Tittabawassee tributary	44.168877°	-84.386145°								
	Middle											
	Main Stem											
35	Edenville	Tittabawassee	43.816298°	-84.384026°	1924	Private	Earth, gravity	54	2250	66200	Hydro	High
36	Frayer	Sugar River tributary	44.071162°	-84.397029°	1972	Private	Earth	26	4	90	Farm Pond	Low
37	Heil	Black Creek	43.971529°	-84.323234°	1970	Private	Earth	23	10	140	Recreation	Low
38	Lake Lancer	Sugar River	44.106394°	-84.435254°	1976	Private	Earth	36	977	17500	Recreation	High
39	Lake Lancelot	Sugar River tributary	44.110302°	-84.465114°	1976	Private	Earth	17	250	2100	Recreation	Low
40	Lake Lochbrae	Long Lake Creek	44.103548°	-84.487378°	1968	Private	Earth	14	82	700	Recreation	Sig
41		Sugar River tributary	44.163425°	-84.486906°		Private	Earth	7	1	30		Low
42	Molasses	Molasses	44.085164°	-84.205473°	1949	State	Earth	5	83	276	Recreation	Low
43	Molasses	Little Molasses	43.948641°	-84.186840°	1955	State	Earth	12	590	4100	Recreation	Low
44	Molasses	Molasses	44.074126°	-84.224654°	1959	State	Earth	12	228	2000	Recreation	Low
45	Molasses	Molasses tributary	44.005288°	-84.211966°	1962	State	Earth	9	195	1240	Other	Low
46	Morey	Sugar River	44.143719°	-84.500011°	1912	Private	Earth	6	2		Recreation	Low
47	Priddy Lake	Sugar River tributary	44.196946°	-84.495490°	1968	Private	Earth	16	9	80	Recreation	Sig
48	Russell	Sugar River tributary	44.136948°	-84.483488°	1950	Private	Earth	17	4	50	Recreation	Low
49	Sanford	Tittabawassee	43.676807°	-84.380246°	1925	Private	Earth, gravity	36	1528	34500	Hydro	High
50	Secord	Tittabawassee	44.041171°	-84.341817°	1925	Private	Earth, gravity	57	894	51000	Hydro	High
51	Smallwood	Tittabawassee	43.960012°	-84.335796°	1925	Private	Earth, gravity	36	402	9000	Hydro	High
	Tobacco River											
52	Arnold Lake	Cranberry Creek	44.065277°	-84.746942°	1966	Private	Earth	4	118	190	Recreation	Low
53	Beaverton	Tobacco	43.883272°	-84.483444°	1919	Local gov	Gravity	30	270	2390	Hydro	High

Table 18.–Continued.

Dam no.	Segment Tributary Dam name	River	Latitude	Longitude	Built	Owner	Type	Height	Acres	Surface acres	Purpose	Hazard
54	Bebee Lake	Clear Creek	43.947315°	-84.752160°	1938	Private	Earth	22	51	800	Recreation	Low
55	Bertha Lake	South Branch Tobacco tributary	43.935419°	-84.898715°	1967							
56	Blue Lake	North Branch Cedar tributary	44.120892°	-84.560200°	1961	Private	Earth	17	33	0	Other	Low
57	Chappel	Cedar	44.003353°	-84.530054°	1910	Private	Earth, gravity	32	435	4650	Hydro (ret.)	High
58	Cranberry	Cranberry Creek	44.060498°	-84.740487°		Local gov	Other	4	106		Other	Low
59	Dodge Lake	Mostellar Creek Drainage	44.021731°	-84.716354°			Other		24		Recreation	
60	Farwell Mill Pond	South Branch Tobacco	43.831944°	-84.874714°	1909	Private	Earth	18	32	350	Hydro (ret.)	Low
61	Ferrel	North Branch Tobacco	43.962476°	-84.710343°	1927	Private	Earth	6	1	3	Recreation	Low
62	Five Lake	Five Lake Creek	43.868704°	-84.805622°	1958	Private	Gravity	8	117	0	Other	Low
63	Haines	Tobacco River tributary	43.959322°	-84.588003°		Private	Earth	18	2		Recreation	Low
64	Hamlin	South Branch Tobacco tributary	43.791032°	84.828820°	1967	Private	Earth	25	4	29	Farm Pond	Low
65	Hayward	Cedar River tributary	44.051462°	-84.534209°		Private	Earth, gravity	5	5	0	Recreation	Low
66	Hoister Lake	North Branch Cedar tributary	44.140136°	-84.567635°	1955	State	Earth	15	22	620	Recreation	Low
67	James B.	South Branch Tobacco tributary	43.837390°	-84.752506°	1971	Private	Earth	12	14	155	Recreation	Low
68	Kerswill	Kerswill Drain	43.956338°	-84.564645°	1967	Private	Earth	12	52	315	Recreation	Low
69	Klienhart	Middle Branch Tobacco tributary	43.931195°	-84.750933°	1963	Private	Earth	20	5	36	Farm Pond	Low
70	Krahner	Silver Creek	44.005872°	-84.522330°	1958	Private	Earth, gravity	6	3	0	Recreation	Low
71	Lake Contos	North Branch Cedar tributary	44.013987°	-84.565180°	1950	Private	Earth	12	15	150	Recreation	Low
72	Lake Pond	Duncan Drain	43.787050°	-84.818646°	1967	Private	Earth	27	36	472	Recreation	Low
73	Lake Thirteen	Runyon Creek	43.861594°	-84.854701°	1948	Private	Earth	19	88	1100	Recreation	High
74	Lang	Tobacco River tributary	43.898675°	-84.485473°		Private	Earth, gravity	13	3	0	Recreation	Low
75	Little Long Lake	North Branch Tobacco River	44.021997°	-84.776255°	1968	Local gov	Earth, gravity	5	43	85	Recreation	Low
76	McKays	Loon Lake Creek	43.906388°	-84.829167°	1940	Private	Earth	13	96	600	Recreation	Low
77	No. Two	Middle Branch Tobacco tributary	43.929877°	-84.772791°	1953	Private	Earth	14	2	11	Recreation	Low
78	Otter Lake	South Branch Newton Creek	43.858058°	-84.846371°	1976			4				Low
79	Pratt Lake	Foran Drain	44.029467°	-84.540457°	1989	Local gov	Earth	5	180	350	Recreation	Low
80	Presspitc	Middle Branch Cedar River	44.085883°	-84.610121°	1947	Private	Gravity	9	4	0	Recreation	Low
81	Sand Lake	Mostellar Creek	44.017592°	-84.723858°		Private	Earth	7	118	300	Recreation	Low
82	Scottish	Lake Twenty Creek	43.938408°	-84.578550°	1974	Private	Earth	14	128	2100	Recreation	Low

Table 18.–Continued.

Dam no.	Segment Tributary Dam name	River	Latitude	Longitude	Built	Owner	Type	Height	Acres	Surface acres	Purpose	Hazard
83	Shamrock	South Branch Tobacco	43.830474°	-84.753006°	1962	Local gov	Earth	20	120	882	Recreation	High
84	Sikkema	Elm Creek	43.860165°	-84.916564°	1963	Private	Earth	10	4	0	Other	Low
85	Spring Valley	Newton Creek	43.892007°	-84.859915°	1956	Private	Earth	6	4	0	Other	Low
86	Springwood	North Branch Cedar tributary	44.007158°	-84.688047°	1959	Private	Earth	18	70	230	Recreation	Low
87	Springwood	North Branch Cedar tributary	44.007776°	-84.680241°	1959	Private	Earth	11	32	320	Recreation	Low
88	Surrey Lake	Elm Creek	43.850045°	-84.910654°	1965	Private	Earth	16	234	1800	Recreation	High
89	Sutherland Lake	North Branch Tobacco	44.019772°	-84.774311°	1968	Private	Earth	9	78	230	Recreation	Low
90	Trout Lake	North Branch Cedar tributary	44.135562°	-84.562775°	1961	State	Earth	19	25	240	Recreation	Low
91	Valdaloch	Overton Creek	43.874386°	-84.920109°	1963	Private	Earth	14	10	0	Other	Low
92	Walter W.	Middle Branch Tobacco tributary	43.904077°	-84.738873°		Private	Earth	5			Other	Low
93	Warner	Cranberry Creek	44.047212°	-84.707772°	1966	Private	Earth	9	9	0	Recreation	Low
	Mouth											
94	Cole	Tittabawassee tributary	43.535175°	-84.134103°	1949	Private	Earth	16	3	15	Recreation	Low
95	Dow	Tittabawassee	43.599994°	-84.238957°	1939	Private	Gravity	7	0		Other	Low
96	Lincoln’s	Tittabawassee tributary	43.543183°	-84.135329°	1951	Private	Earth	7	11	0	Recreation	Low
	Salt River											
97	Coleman B.	Bluff Creek tributary	43.749096°	-84.546788°		State						Low
98	Gregor	Bluff Creek tributary	43.712976°	-84.478252°		Private	Earth	6	1	0		Low
99	Marcus	Bluff Creek tributary	43.707920°	-84.468949°	1975	Private	Earth	20	3	0	Recreation	Low
	Chippewa River											
100	Barryton	West Branch Chippewa	43.746479°	-85.140520°	1920	Local gov	Earth, gravity	15	46	260	Hydro (ret.)	Sig
101	Big Cranberry	North Branch Chippewa	43.879550°	-85.048447°	1961	Private	Earth	6	293		Other	Low
102	Birch Lake	Long Lake Creek tributary	43.772556°	-85.291243°	1985	Private	Earth		11		Recreation	Low
103	Chippewa	Chippewa Creek	43.743591°	-85.302234°		Private		3	770	0		Low
104	Crooked Lake	North Branch Chippewa tributary	43.856404°	-85.020257°	1976							Low
105	Deerfield	Chippewa River tributary	43.591099°	-84.899263°	1960	State	Earth	14	3	11	Other	Low
106	Dragonfly	West Branch Chippewa	43.593198°	-84.284958°	1992	Private	Earth	6	17		Other	Low
107	Eight Point	Eight Point Creek	43.831388°	-85.072008°	1966	Private	Gravity	4	388	615	Recreation	Low
108	Forbes	Delaney Creek	43.780893°	-85.047783°		Private	Earth, gravity	2	3	0	Recreation	Low
109	Georgia J.	Tanner Creek	43.716082°	-85.108542°	1972	Private	Earth	15	45	348	Recreation	Low
110	Gray Lake	North Branch Chippewa tributary	43.832313°	-85.021895°			Other		61		Recreation	Low

Table 18.–Continued.

Dam no.	Segment Tributary Dam name	River	Latitude	Longitude	Built	Owner	Type	Height	Acres	Surface acres	Purpose	Hazard
111	Grey's	Walker Creek tributary	43.730217°	-85.020220°	1959	Private	Earth, gravity	5	1	8	Irrigation	Low
112	Harris (removed)	Chippewa	43.600887°	84.784778°	1870	Private	Earth	16	2	150	Recreation	Low
113	Heron	West Branch Chippewa	43.595793°	-84.284353°	1992	Private	Earth	8	10		Other	Low
114	Lake Camelot	Black Creek	43.583594°	-84.609733°	1971	Private	Earth	19	85	855	Irrigation	Low
115	Lake Isabella	Chippewa	43.653379°	-84.992598°	1967	Private	Earth	45	730	13500	Recreation	High
116	Long Lake	Long Lake Creek tributary	43.775826°	-85.295036°	1993	Local gov	Other	6	75		Other	Low
117	Maloy Lake	North Branch Chippewa tributary	43.861566°	-85.157209°	1962	Private	Earth	5	40	180	Recreation	Low
118	Maple Lake	Long Lake Creek tributary	43.771307°	-85.288793°	1985	Private	Earth	11	4		Recreation	Low
119	Mission Creek	Mission Creek	43.621645°	-84.792591°	1950	Private	Earth	12	0	95	Recreation	Low
120	Muskrat	West Branch Chippewa	43.593514°	-84.289127°	1992	Private	Earth	6	10		Other	Low
121	Peas Lake	Johnson Creek	43.555666°	-84.846607°	1961	Private	Earth	18	10	165	Recreation	Low
122	Phillips	Bamber Creek tributary	43.723629°	-85.136969°		Private	Earth	5	4	0		Low
123	Pretty Lake	West Branch Chippewa tributary	43.698321°	-85.231744°	1992	Local gov	Other	6	116		Recreation	Low
124	Siebecker	Rattail Creek	43.808976°	-85.195823°	1978	Private	Earth	21	28	315	Recreation	Low
125	Stevenson	North Branch Chippewa tributary	43.757368°	-84.826924°	1975	Private	Earth, gravity	5	113	340	Recreation	Low
126	Thompson	North Branch Chippewa	43.760225°	-84.864314°		Private	Earth, gravity	13	22	160	Recreation	Low
127	Walker Creek	Walker Creek	43.717681°	-84.997996°	1965	Private	Earth	17	41	850	Recreation	Low
128	Walker Creek	Walker Creek	43.724872°	-85.000228°	1968	Private	Earth	18	42	900	Recreation	Sig
129	Weidman Mill	Coldwater	43.688715°	-84.964217°	1900	Private	Earth	12	65	300	Recreation	Sig
130	Wiedman Pond	Walker Creek	43.693673°	-84.971438°	1968	Private	Earth	14	50	420	Recreation	Sig
131	Winchester	West Branch Chippewa	43.718365°	-85.182989°	1954	State	Earth	13	1420	7500	Recreation	Sig
	Pine River											
132	Archer	South Branch Pine tributary	43.410060°	-84.992325°		Private		11	2	0		Low
133	Babcocks	South Branch Pine tributary	43.518238°	-85.069934°	1973	Private	Earth	18	9	66	Recreation	Low
134	Blanchard	North Branch Pine tributary	43.523086°	-85.072599°	1978	Private	Earth	12	13	300	Recreation	Low
135	Fitzgeral	Pony Creek	43.540912°	-84.994606°	1965	Private	Earth, gravity	5	3	0	Recreation	Low
136	Johnson Pond	Skunk Creek tributary	43.477118°	-85.037000°		Private		6	1	0		Low
137	Mason	Decker Creek tributary	43.522415°	-85.123100°	1977	Private	Earth	14	2	12	Recreation	Low
138	Millbrook	Pine Creek	43.556086°	-85.119337°	1915	Private	Other	7	1	25		Low

Table 18.–Continued.

Dam no.	Segment Tributary Dam name	River	Latitude	Longitude	Built	Owner	Type	Height	Acres	Surface acres	Purpose	Hazard
139	Peterson	Skunk Creek tributary	43.478762°	-85.034651°	1948	Private	Earth	12	10	0	Irrigation	Low
140	Schafer	Thatcher Creek	43.533550°	-84.862915°	1969	Private	Earth	10	3	60	Recreation	Low
141	St Louis	Pine	43.412628°	-84.607385°	1887	Local gov	Gravity	21	71	1000	Hydro	Sig
142	State Street	Pine	43.375107°	-84.662165°	1938	Local gov	Gravity	18	140	1500	Water supply	Sig
143	Stevens Lake	Carpenter Creek tributary	43.313097°	-84.887808°		Private	Gravity	4	7	0	Recreation	Low

Table 19.–Designated trout streams (as of 2006) in the Tittabawassee River watershed. Streams are designated upstream of the town, range, and section number unless specified otherwise. Data are from MDNR (2005).

Segment County Stream	Location
Headwaters	
Ogemaw	
East Br. Tittabawassee River	from T21N, R2E, S32 upstream
Spring Creek	(T21N, R2E, S32)
Cooks Creek	(T21N, R2E, S20)
Rau Creek	(T21N, R1E, S13)
Brick Creek	(T21N, R1E, S13)
Middle Br. Tittabawssee tributaries.	
Mansfield Creek	(T21N, R1E, S22)
Parren Creek	(T21N, R1E, S10)
Perrys Creek	(T21N, R1E, S10)
Gladwin, Roscommon	
W. Br. Tittabawassee and tributaries	From T20N, R1W, S23 upstream and tributaries Except: Lake Four Outlet (Gladwin County)
Roscommon	
Muma Creek	(T21N, R1W, S35)
W. Br. Tittabawassee River	(T21N, R1W, S22)
Roscommon, Ogemaw	
Unnamed tributary	(T21N, R1W, S24)
Middle	
Gladwin, Roscommon	
Sugar Creek	(T21N, R1W, S24)
Gladwin	
Sugar River and tributaries	upstream from T20N, R1W, S19
Sugar River	(T20N, R1W, S22 and 27)
Gladwin, Clare	
Cedar River	T19N, R2W, S20 upstream
N. Br. Tobacco and tributaries	(T17N, R2W, S1)
Middle Br. Tobacco	(T17N, R2W, S11)
Clare	
Middle Br. Cedar and tributaries	(T19N, R3W, S14)
West Branch Cedar River	(T19N, R3W, S15)
Cranberry Creek	(T19N, R3W, S15)
Popple Creek	Creek (T20N, R3W, S34)
Mostellar Creek	downstream (T18N, R4W, S1), upstream (T19N, R4W, S25)
Jose Creek	(T18N, R4W, S12)
Spike Horn Creek	(T19N, R4W, S35)
Unnamed tributary	(T18N, R3W, S32)
Clear Creek	(T18N, R3W, S30)
S. Br. Tobacco River	T17N, R4W, S27)

Table 19.–Continued.

Segment County Stream	Location
Clare–continued	
Sanford Creek	(Tl7N, R4W, S13)
Five Lakes Creek	(T17N, R4W, S33)
Loon Lake Creek	(T17N, R4W, S6)
Newton Creek	(Tl7N, R4W, S30)
Runyon	Creek (T17N, R5W, S13)
Overton Creek	(T17N, R5W, S26)
Elm Creek	(T17N, R5W, S16)
Two unnamed tributaries	(T17N, R5W, S28)
Mouth	
Mecosta, Osceola	
North Branch Chippewa River	(T16N, R7W, S27)
Butts Creek (Devil Creek)	(T16N, R7W, S11)
Benjamin Creek	Creek (T16N, R7W, S2)
Mecosta	
Rattail Creek	(T16N, R7W, S22)
Brown Creek	(T16N, R7W, S28)
Roundybranch Creek	(T16N, R8W, S35)
Isabella	
Jewell Creek	(T13N, R6W, S18)
Squaw Creek	(T14N, R6W, S3)
Indian Creek	(T14N, R6W, S3)
Jewell Creek S18)	(T14N, R6W, S3)
Johnson Creek	(T14N, R4W, S30)
Colley Creek	(T16N, R6W, S34)
Delaney Creek	(T16N, R6W, S34)
Walker Creek and tributaries	above T16N, R6W, S35
Cedar Creek	(T14N, R5W, S27)
Sucker Creek	(T16N, R5W, S18)
Gratiot, Montcalm, Isabella, Mecosta	
Pine River mainstream	mainstream from Lumberjack Road (T12N, R4W, S18) upstream to 10th Avenue (T14N, R7W, S26)
Gratiot, Montcalm, Isabella	
North Branch Pine River	from confluence with mainstream of Pine to Coe Road (T13N, R5W, S34)
Isabella, Mecosta	
Skunk Creek	(T13N, R6W, S25)
Mecosta	
Miller Creek	(T14N, R7W, S36)
Isabella	
Pony Creek	from confluence with Pine River upstream to S2, T13N, R6W
Decker Creek	(T13N, R6W, S18)

Table 20.–Monthly maximum river temperatures (°F) allowed in selected streams. These standards are applied to all permitted stream discharges and are given a 2–5 °F variance as shown in Table 8b. Data from Michigan Department of Environmental Quality, Water Bureau.

	Month											
Stream type	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	Temperature (°F)											
Coldwater	38	38	43	54	65	68	68	68	63	56	48	40
Warmwater	41	40	50	63	76	84	85	85	79	68	55	43

Table 21.–Dissolved oxygen (mg/l) and temperature (°F) standards for designated uses of the Tittabawassee River and tributaries. Temperatures represent allowable degrees of increase from the monthly river maximum. Data from Michigan Department of Environmental Quality, Water Bureau.

Designated use	Minimum dissolved oxygen (mg/l)	Temperature (°F)
Warmwater fish	5.0	5
Coldwater fish		
Designated trout	7.0	2
Designated migratory route	5.0	5

Table 22.–Areas not attaining designated uses (303d listings as of 2004) in the Tittabawassee River by segment. u/s = upstream; d/s = downstream.

Segment and stream	Category [a]	Problem	Location
Headwaters			
E. Br. Tittabawassee River	2	Sedimentation	Herner Road crossing SW of Greenwood Road
Middle Branch Tittabawassee River	2	Sedimentation	Boensch Road crossing, W. of Greenwood Road
W. Br. Tittabawassee River	2	Sedimentation	Fitzwater Road crossing, NE of Sugar Rapids
Middle			
Black Creek	2		E. of Woodenshoe at M61 upstream
Larabee Creek	2		At Weiman Road crossing, W. of Highwood
Sugar River	2	Suspended Solids	At M30 upstream
Little Sugar River	2		Sugar River confluence u/s to M18
Little Tobacco River	2	Habitat and bank erosion	At drain crossing NW of Wooden Shoe
Molasses River	2	Habitat and bank erosion	At M61 crossing, E of Wooden Shoe
Tittabawassee River	2	Sedimentation	Fitzwater Crossing, NE of Sugar Rapids
Sanford Lake	5	FCA-PCBs and fish tissue mercury	NW of Midland at Sanford
Little Cedar River	2		At Dale Road SE of Beaverton
Middle Branch Cedar River	2		Confluence with Cedar River u/s
N. Br. Cedar River	2		Confluence with Cedar River u/s
W. Br. Cedar River	2		Cranberry Creek confluence u/s
Budd Lake	3		Vicinity of Harrison
Cranberry Lake	3		NE of Harrison
N. Br. Tobacco River	2		Grout Road u/s to Clarwin Road
Middle Branch Tobacco River	2		McCullough Road u/s to Hoover Avenue
Black Creek	3		Sanford Lake Confluence, West River Road
S. Br. Tobacco River	2		Grout Road u/s to Rodgers Road
S. Br. Tobacco River	2		Grant Road u/s of Clare
N. Br. Tobacco River	3	Erosion	Ross Lake Confluence u/s
Middle Branch Tobacco River	3		Ross Lake Confluence u/s
Tobacco River			Shock Road u/s to Ross Lake Outlet
Cedar River	5	CSO and pathogens	Vicinity of Gladwin (M61) u/s to Howard Oil Field Road
Mouth			
Viscar Drain	2		TWP 17, 18
Black Creek	3		Sanford Lake Confluence, West River Road
Carrol Creek Dr.	2	Habitat	At Meridian Rd, NW of Midland
Sturgeon Creek	3	Habitat	Tittabawassee confluence
Tittabawassee River	5	Untreated sewage discharge, pathogens	1 mile d/s of Dow Dam
Tittabawassee River	5	FCA-PCBs, TCDD (Dioxins), fish tissue-mercury, WQS exceedances for hg	Dow Dam to confluence with Saginaw River

Table 22.–Continued.

Segment and stream	Category[a]	Problem	Location
Bluff Creek	2	Habitat	Poseyville Road crossing
Salt River	2		Big Salt River at North Bradley to Rosebush Road
Cedar Creek	2		Chippewa River confluence u/s to Millbrook Road
Chippewa River	2		At S. Meridian Road crossing, SW of Mt. Pleasant
Chippewa River	2		At Meridian Road crossing, W. of Midland, E. of Little Salt Creek
Chippewa River	2		At Coldwater Road crossing, SW of Weidman
Chippewa River	2		M-20 u/s to Barryton (excluding Lake Isabella)
Chippewa River	2		Lincoln Road u/s of Mt. Pleasant, Jerome Twp, Sec. 24
Chippewa River, N. Br.	2		Coleman Road crossing u/s to Grass Lake outlet
Coldwater River	2	Temperature	At Baseline Road crossing, S. of Weidman
Hogg Creek	2		Hogg Creek is a tributary to N. Br. Chippewa River in Deerfield Twp.
Jewel Creek	2		Blanchard Millpod confluence u/s
Little Salt Creek	2		From confluence with Chippewa River W. of 8 Mile Road (T14N, R1W) u/s to Redstone Road
Hogg Creek	2		Hogg Creek is a tributary to N. Br. Chippewa River in Deerfield Twp.
N. Br. Chippewa River	2		Chippewa River at Barryton u/s
Walker Creek			Lake of the Hills inlet u/s (Section 11 Sherman Twp).
Chippewa River	3		At Mt. Pleasant
Chippewa River, S. Br.	3		SW of Barryton. 35th Avenue u/s to Winchester Dam (19th Avenue)
Crooked Lake	3		Vicinity of Lake Station S. of U.S. Rt. 10 West of Clare
Martiny Lake	3		SW of Barryton. u/s of Winchester Dam on the W. Br. Chippewa River
Potter Creek	3	Poor macroinvertebrates	Onion Creek confluence u/s
Salt Creek	3	Ammonia WQS exceedance (one grab sample)	Chippewa River confluence u/s
Coldwater River	4a	Biological community threatened	Vernon Road Crossing u/s to Outlet Lake (Littlefield Lake area).
Pine River	2		Harrison Road, SW of Alma, u/s to Pine Lake, S. of Remus
Pony Creek	2		Pine River confluence u/s
Halls Lake	3		3.5 miles SE of Remus. D/s of Wheatland Twp. WWSL and Pony Creek
Pine River, S. Br.	3		E. of Blanchard. Pine River confluence u/s

Table 22.–Continued.

Segment and stream	Category [a]	Problem	Location
Pony Creek	3		Wheatland Twp., E. of Remus on M-20
Rock Lake	3		NW of Vestaburg. E. of Pine Grove; E. of Pine Grove Road and N. of M-46
Sugar Creek	3	Poor macroinvertebrates	Pine River confluence u/s from the vicinity of Begole Road
Wolf Creek	3	Assess fish for mercury concentrations due to historical discharges of mercury	d/s of Hitachi Magnetics in Edmore. Pine River confluence u/s to Cedar
Pine River and St. Louis Impoundment	4b	FCA-PBBs, DDT	

[a] Water quality assessment and water quality attainment categories:

1 All designated uses met.
2 Some uses are met but there is insufficient data to determine if remaining uses are met.
3 Insufficient data to determine whether any uses are met.
4a WQS Nonattained (USEPA approved TMDL but unverified WQS restoration).
4b WQS Nonattained (Other corrective action used but unverified WQS restoration).
4c WQS Nonattained (Highly modified water body).
5 Water is impaired or threatened and a TMDL is needed.

Table 23.–National Pollution Discharge Elimination System permits issued in the Tittabawassee River watershed by Michigan Department of Environmental Quality, Surface Water Quality Division. Acronyms: WWTP = wastewater treatment plant, WWSL = wastewater sewage lagoon, WW = wastewater, * = major discharges.

Segment River Tributary	Facility name	City
Middle		
Main Stem		
Unnamed	Billings Township WWTP	Beaverton
Sugar River	Butman Township WWTP	Gladwin
Unnamed	Eggers Exc-Lakewood Estates	Freeland
Unnamed	Stockholm Forest Vil MHP	Bay City
Tobacco River		
Tobacco River	Brown Machine-Beaverton	Beaverton
Tobacco River	Brown Machine-Beaverton	Beaverton
South Branch Tobacco River	Clare PRP Committee	Clare
South Branch Tobacco River	Clare WWTP	Clare
Unnamed	Clare-Water Filtration Plant	Clare
Not listed	Farwell WWSL	Farwell
Cedar River	Gladwin WWTP	Gladwin
Bailey Creek	Packard Farms-CAFO	Clare
Mouth		
Main Stem		
Unnamed	Bullock Creek High School WWSL	Midland
Tittabawassee River*	Dow Chemical-Midland	Midland
Lingle Drain	Dow Corning Corp-Midland	Midland
Lingle Drain	Dow Corning Corp-Midland	Midland
Unnamed	Fisher Cont Co-Pardel Pit	Midland
Unnamed	Freeland MHP	Freeland
Tittabawassee River*	Midland Cogeneration Venture	Midland
Tittabawassee River*	Midland WWTP	Midland
Tittabawassee River	Old Oak Trails Est MHP	Sanford
Sturgeon Creek	Pats Gradall Stark Pit	Hope
Tittabawassee River*	Saginaw Township WWTP	Saginaw
Tittabawassee River	Saginaw Township-Center Road LF	Saginaw
Carrol Creek Drain	Sterling Manor MHP	Midland
Tittabawassee River	Tittabawassee Township WWTP	Freeland
Not listed	James Township MS4-Saginaw	Saginaw
Not listed	Saginaw Township MS4-Saginaw	Saginaw
Not listed	Tittabawassee Township MS4-Saginaw	Freeland
Not listed	Thomas Township MS4-Saginaw	Saginaw
Salt River		
Jordon Creek	Country Place Park MHP	Mt. Pleasant
Unnamed	Rosebush WWSL	Rosebush
Bluff Creek	Coleman WWSL	Coleman
Bluff Creek, Mud Creek	Robinson Industries Inc	Coleman
Bluff Creek	Huhtamaki Plastics Inc	Coleman

Table 23.–Continued.

Segment River Tributary	Facility name	City
Mouth–continued		
Chippewa River		
Upton Drain	CMU-Central Energy Facility	Mt. Pleasant
Chippewa River	Isabella Co Landfill	Mt. Pleasant
Onion Creek	Isabella Reservation WWTP	Mt. Pleasant
Not listed	MDOT-Mt Pleasant-Dobias ROW	Mt. Pleasant
Chippewa River	Mi Reutilization	Mt. Pleasant
Chippewa River	Mt Pleasant WWTP	Mt. Pleasant
Chippewa River	Nartker-Wyman Apts	Mt. Pleasant
Salt Creek	Shepherd WWSL	Shepherd
Not listed	TPI-Mt Pleasant	Mt. Pleasant
Pine River		
Pine River*	Alma Products I Inc	Alma
Pine River	Alma WWTP	Alma
Sucker Creek	Breckenridge WWSL	Breckenridge
Not listed	Edmore WWSL	Edmore
Not listed	Great Lakes Adventist Academy	Cedar Lake
Wolf Creek	Hitachi Magnetics Corp	Edmore
Wolf Creek	Hitachi Magnetics Corp	Edmore
Little Salt Creek*	Mibelloon Dairy-CAFO	St. Louis
Pine River	St. Louis WWTP	St. Louis
Pine River	TPI Petroleum Inc-Alma	Alma
Thatcher Creek	Morey Foundation	Shepherd

Table 24.–Industrial storm water permits issued (as of 2006) by Michigan Department of Environmental Quality, Surface Water Quality Division, in the Tittabawassee River watershed.

Segment River Tributary	Facility name	Location
Headwaters		
Main Stem		
Cooks Creek	Bunting Sand Gravel Products, Incorporated	West Branch
Rau Creek	Flash Wood Products	West Branch
Unnamed tributary to Rau Creek	West Branch Concrete Products	West Branch
Rau Creek	Woodstock Incorporated	West Branch
Middle		
Main Stem		
Lorrabee Creek	Frito-Lay	Gladwin
Tittabawassee River	International Engineering & Manufacturing Incorporated	Edenville
Lorrabee Creek	JVS Auto Salvage, Incorporated	Gladwin
Round Lake	Pine Tech, Incorporated	Gladwin
Tobacco River		
Little Tobacco Drain	Campbell Printing, Incorporated	Clare
Conham Drain	Dura Automotive Sys-Gladwin	Gladwin
Doone Creek	Elmer's Concrete of Beaverton	Beaverton
Cedar River	Frank's Auto Salvage	Gladwin
Conham Drain	Gladwin Tank Manufacturing Incorporated	Gladwin
Not listed	JD Metalworks, Incorporated	Clare
Not listed	JD Metalworks, Incorporated	Clare
Little Tobacco Drain	Johnson Auto Parts-Clare	Clare
Little Tobacco Jt. Drain	Letherer Truss, Incorporated	Clare
Little Tobacco Drain	Pilot Industries	Clare
Overton Creek	Renosol Corporation/Renosol Seating LLC	Farwell
Tobacco River	Rockcrete Transit Mix, Incorporated	Clare
Unnamed Ditch to Tobacco River	Stage Right Corporation	Clare
Tobacco River	Spartech Plastics-Mideast	Clare
Wetlands	Waste Management of Michigan Incorporated	Harrison
Mouth		
Main Stem		
Tittabawassee River	Airgas Great Lakes, Incorporated	Midland
Sarle Drain	Anthony Gushow & Sons, Incorporated	Freeland
Harris Drain	B & B Pick Up Salvage	Hope
Lingle Drain	Cabot Corporation	Midland
Yates Drain	Carroll Excavating Incorporated	Sanford
Tittabawassee River	Case Systems Incorporated	Midland
Tittabawassee River	Dendritech Incorporated	Midland
Tittabawassee River	Dow Chemical Sludge Dewatering Facility	Midland
Tittabawassee River	Dow Chemical	Midland
Martinus Drain	FedEx Freight East	Midland
Sturgeon Creek	Fisher Property Account	Midland
Tittabawassee River	J Pomranky Incorporated	Midland
Jacobs Drain	Jack Barstow Airport	Midland
Unnamed tributary to Ashby Drain	Lake Painting, Incorporated	Midland
Jacobs Drain	Midland Armory-OMS22	Midland
Tittabawassee River	Midland-Municipal Service Ctr	Midland
Sturgeon Creek	Pats Gradall Stark Road Pit	Midland

Table 24.–Continued.

Segment River Tributary	Facility name	Location
Mouth–continued		
Tittabawassee River	Quebecor World Midland	Midland
Newell Drain	Sova Auto Sales and Parts	Midland
Tittabawassee River	Specialty Manufacturing, Incorporated	Saginaw
Jacobs Drain	Three Rivers Construction Company	Midland
Lingle Drain	Transport Service Company	Midland
Unnamed tributary to Tittabwawassee River	Willsie Lumber Company	Freeland
Salt River		
Howard Drain #11	C & M Rubber Technologies Incorporated	Coleman
Curtis Drain	G & D Auto Sales	Coleman
Curtis Drain	Homestead Tool & Machine, Incorporated	Coleman
Curtis Drain	Homestead Tool & Machine, Incorporated	Coleman
Unnamed tributary of Howard Creek	Mark-1 Flooring, Incorporated	Coleman
Bluff Creek	Robinson Industries	Coleman
Chippewa River		
Chippewa River	4-D an Oldcastle Co-Midland	Midland
Duncan Drain	Fair Salvage Company	Clare
Chippewa River	Fisher-Whitman Dr Sand & Clay	Midland
North Branch Chippewa River	Bandit Industries Inc-Remus	Remus
Chippewa River	Central Asphalt Incorporated	Mt. Pleasant
Unnamed Ditch	Central Concrete Products	Mt. Pleasant
Potter Creek	CME Corporation	Mt. Pleasant
Chippewa River	Delfield Company	Mt. Pleasant
Salt Creek	Dice’s Auto Scrap-Plus	Shepherd
Graves Lake	EaglePicher Automotive	Mt. Pleasant
Graves Lake	EaglePicher Automotive	Mt. Pleasant
Chippewa River	Elmer’s Concrete of Mount Pleasant	Mt. Pleasant
Chippewa River	Frito-Lay	Mt. Pleasant
Salt Creek	Highland Plastics Incorporated	Shepherd
Chippewa River	ITW Foil	Mt. Pleasant
Coldwater River	Maeder Brothers, Incorporated	Weidman
Unnamed tributary to Chippewa River	McGuirk Sand and Gravel, Incorporated	Mt. Pleasant
Chippewa River	Mt. Pleasant Central Concrete, Inc.	Mt. Pleasant
Chippewa River	Mt. Pleasant Minicipal Airport	Mt. Pleasant
Halstead Drain	Oil City Auto Salvage Incorporated	Shepherd
Chippewa River	Randell Manufacturing	Weidman
Chippewa River	Snowmobile-Motorcycle Salvage	Mt. Pleasant
Chippewa River	TB Woods Incorporated	Mt. Pleasant
Chippewa River	United Parcel Service	Mt. Pleasant
Chippewa River	W. Wing Auto Parts & Recycling	Mt. Pleasant
Chippewa River	Waste Management of Michigan	Mt. Pleasant
Wagner Drain	Weber Brothers Sawmill Incorporated	Mt. Pleasant
Pine River		
Pine River	Alma Concrete Products	Alma
Pine River	Alma Iron & Metal Co Inc	Alma
Pine River	Alma Products I Inc	Alma
Pine River	Alpha Plastics-St Louis	St. Louis
Riggle Marsh Drain	Apex Marine	St. Louis
Pine River	Bear Truss & Components Co	St. Louis
Horse Creek	Brinks Machine Co Inc-Alma	Alma

Table 24.–Continued.

Segment River Tributary	Facility name	Location
Mouth–continued		
Brady Creek	C & S Steel Service Co Inc	Ithaca
Brady Creek	Craig Frames Incorporated	Ithaca
St. Louis Storm Drain	Crippen Manufacturing Co Inc	St. Louis
Brady Creek	Davis Machine & Manufacturing	Ithaca
Pine River	Lear Corp-Alma	Alma
Horse Creek	Liquid Transport Trucking Inc	Alma
Pine River	Mich Chloride Sales-St Louis	St. Louis
Pine River	Oxford Automotive-Alma	Alma
Pine River	Plasti-Paint Incorporated	St. Louis
Pine River	Playbuoy Pontoon Mfg-Alma	Alma
Pine River	Powell Fabrication & Mfg Inc	St. Louis
Pine River	SPX Contech-Alma	Alma
Pine River	Terry Materials of Mich-Alma	Alma
Pine River	US EPA-Velsicol	St. Louis

Table 25.–Michigan Department of Environmental Quality 319 Grants to address nonpoint source issues. CL-project closed OP–project is open.

Project	Status	Goals of project/Cost
Dundas Road Reconstruction	CL	As a result of this road stabilization project, 269 tons of sediment per year were eliminated from entering Wixom Lake. 7100 cubic yards of gravel and 2654 tons of asphalt pavement were installed to reduce erosion and sedimentation into the Tittabawassee River watershed. $437,671.70
Cedar River Road Crossings	CL	This project resulted in the stabilization of 5 eroding road-stream crossings. $116,563.00
Cedar River Watershed Project	CL	The goal of the project is to complete a comprehensive nonpoint source watershed management plan, which will identify, document, quantify, and prioritize nonpoint pollution sources within the watershed. $101,995.00
North Branch Salt River	CL	This project resulted in the installation of 5.5 miles of exclusionary fencing, 15 grade stabilization structures, 10 livestock crossings/watering practices, 5.5 acres of critical area treatment and 1 diversion. During this project, EQIP practices were installed, including manure management and upland wildlife habitat improvement. Also installed during this project were Conservation Reserve Enchancement Program (CREP) practices, including filter strips, shallow water wildlife ponds, and animal exclusionary fencing/crossings. EQIP and CREP practices were not eligible nor counted as match. Advisory Committee meetings were held throughout this project to update partners. $390,559.20
Sturgeon Creek Watershed Plan (Midland County)	CL	The goal of this project is to develop a comprehensive watershed management plan. $170,801.00
Cedar River Implementation	OP	The goal of the Cedar River project is to restore the environmental integrity and the state's designated uses of warmwater fishery, coldwater fishery and partial body contact recreation of the Cedar River watershed. $394,502.97
Saginaw Bay Watershed Livestock Exclusion	OP	The goal of this project is to improve water quality by reducing nutrient and sediment input into the small creeks and flood plains, excluding livestock, providing stable crossings, restoring critical areas and providing stable watering facilities. $633,338.00
Sturgeon Creek Transition/Implementation I	OP	To upgrade watershed plan to meet EPA's 9 elements and begin implementation of priority BMPs to address priority pollutants of concern. $121,234.50
Sturgeon Creek Watershed Implementation	OP	Contract is to stabilize 7 stream banks, 5 storm drain outlets and restore a 5-acre wetland. $374,212.16
Cedar River Watershed Permanent Easement Acquisition Program	OP	The goals of this project include improving water quality and wildlife habitat, and protecting key natural features, by obtaining permanent conservation easements. $563,145.80
North Branch Chippewa River	CL	–Workshop seminar, Kellogg Center, MSU –Bi-weekly monitoring of selected physical and chemical parameters $38,000.00

Table 25.–Continued.

Project	Status	Goals of project/Cost
North Branch Chippewa River	CL	–Streambank=2,470.14 ft –Fencing=12,380 ft –Filter strips=8 acres –Diversions=833 ft –Critical Area seeding=7.2 acres $200,000.00
North Branch Chippewa River	CL	–Grade stabilization structures==14 units –Diversions==50 feet –Streambank stabilization==1626.63 feet –Filter strips==2.71 units –Agricultural waste storage==1 unit –Critical area planting==1.37 acres $130,842.00
South Branch Salt River	CL	–erosion control structures –filters strips –animal exclusionary fencing –grassed waterways –critical area seeding –diversions –stream bank stabilization –agricultural waste management $43,012.00
South Branch Salt River	CL	Planning only. $47,500.00
South Branch Salt River	CL	BMP's implemented as a result of this project include: 39 erosion control stuctures, 5,962 feet of animal exlusionary fencing, two demonstration farms, and 3.18 acres of filter strips. In addition, information and education activities included a "Twilight Tour" of the demonstration farms for local interested parties, and the development of a newsletter and a photo journal. $130,738.00
South Branch Big Salt River	CL	As a result of this project, thirteen erosion control structures, 7,900 feet of fencing, five animal crossings, 20, 746 feet of animal exclusionary fencing, and eleven grade stabilization structures were installed. In addition, three animal crossings were repaired. $261,476.00
Coldwater River TMDL Project	OP	The project goal is to achieve a habitat rating of "acceptable" by reducing sediment inflows. Achievement of project objectives should result in removal from the TMDL list. $150,429.94

Table 26.–Natural Resources Environmental Protection Act Part 201 Contamination sites in the Michigan portion of the Tittabawassee River watershed, by segment. Acronyms: BTEX = benzene, toluene, ethylbenzene, and xylene; DCA = dichloroethane; DCE = dichloroethylene; DDE = dichlorodiphenyldichloroethylene; MTBE = methyl tertiary butyl ether; DDT = Dechlorodiphenyltrichloroethane; PCB = polychlorinated biphenyl; PCE or PERC = perchloroethylene; PNAs = polynuclear aromatic hydrocarbons; TCA = trichloroethane; TCE = trichloroethylene; TPH = total petroleum hydrocarbons; LF = landfill.

Segment Tributary Site	Location	Pollutant
Headwaters		
Main Stem		
Zettel Drive	West Branch	Fuel oil , heating oil
Middle		
Main Stem		
Buckeye Oil Field		Brine/chloride, crude oil
Elm Street Spill	Gladwin	Ethylbenzene, xylenes, home heating oil
Rabb, Mary 12		Condensate-BTEX, crude oil, brine, chloride
D and G Laundromat	Sanford	PCE, dichloroethane, bromodichlorometha
Tobacco River		
Buckeye Twp Dump Closed	Gladwin	Trace pesticides, landfil
D and B Disposal Closed	Beaverton	Domestic Comm
Elliot Gas and Oil Co	Gladwin	Fuel oil
Gladwin Bulk Oil Plant State St	Gladwin	BTEX
Gladwin City of LF Closed	Gladwin	Arsenic, cadmium chromium, lead
Gladwin Co Road Comm	Gladwin	salt
Ruby Dr Residential Leaking Pipeline	Gladwin	Fuel oil
Sage Twp Dump Closed	Gladwin	Domestic Comm
Tobacco Twp Refuse Closed	Beaverton	Landfill
Chovich #1	Gladwin	brine/chloride
Maier J 1	Gladwin Co.	Condensate BTEX, crude oil
Buckeye Oil Field T&E Investment	Gladwin Co.	Condensate BTEX, crude oil, brine/chloride
American Dry Cleaners	Clare	Xylene, Tetrachloroethylene, carbontetrachloride
Arthur Twp Dump	Gladwin	Domestic Comm
Clare Co MDOT Bulk Storage Site	Clare	Benzene xylene, ethylbenzene, toluene
Clare Co Rd Comm Mansiding Rd	Harrison	Salt
Clare LF Closed City of	Clare	Domestic Comm
Clare Municipal Wells City of	Clare	PCE TCE 1,2 DCE, 1,1,1 TCA
Clare Sanitary LF City of	Clare	Chloroform, trichloroethylene, cadmium
Dodge Lake Dump	Harrison	Landfill
GW Contamination Meredith	Gladwin	PERC, BTX
Harrison Lagoon System City of	Harrison	Ammonia nitrate
Harrison LF City of	Harrison	Domestic Comm
Hoover Universal Funnell Prop	Farwell	Cr, Mn, Ni, Cu, As, beta-BHC
Renosol Plant	Farwell	Ethylhexylphthalate
Residential Well Farwell	Farwell	Nitrates
Surrey Twp LF	Farwell	PERC, Cis 1,2-DCE
Tuscola Saginaw Bay RR Derail	Farwell	Diesel fuel
Valcast Inc	Clare	Manufacturing waste
Crichton Property	Harrison	DDE, DDD, DDT, copper
Hamilton Compressor Station	Clare Co.	Condensate BTEXs
Mid Michigan Recyclers	Clare	PCB Lead, toluene
Gleason, Agnes J. 1	Clare Co.	Natural gas, chloride

Table 26.–Continued.

Segment Tributary Site	Location	Pollutant
Middle–continued		
McDonald Property	Clare	benzene, xylenes, ethylbenzene
Residential Contam Curtis Road	Edenville	BTEX
Mouth		
Main Stem		
Dow Chemical Rockwell Landfill	Midland	Benzene, ethylbenzene, chlorophenol phenol
SCA Saginaw Twp LF	Saginaw	C-66 endrin aldehyde, cadmium chromium
Shields Ziebart	Midland	Mineral spirits
Saginaw Community Hospital	Saginaw	Fuel oil
Dow Chem Brine Pipeline Spills	Several	Brine
Dow Corning	Midland	Toluene
Mostly Mopars	Midland	Toluene, methylene chloride
Oil Field Area Andreason Residential	Midland	Chlorides
Dow Poseyville Land Fill	Midland	Benzene, pentachlorophenol, PCE
Residential Contam W Isabella Road	Midland	BTEX
Tittabawassee River	Midland	2,3,7,8 Tetrachloro-, dibenzo-p-dioxin
Tridge Area	Midland	Domestic Comm
Dow Chemical Midland Plant	Midland	2,3,7,8 Tetrachloro-, dibenzo-p-dioxin
Dalton Pesticide Spill-Midland	Midland	2,4-D, gasoline
Transport Services	Midland	BTEX 1,1 DCE PERC, DCB 1,1,1 TCE, trichlorobenzene
Dow Corning Benzene	Midland	Benzene
Midland Co Bldg LUST	Midland	Fuel oil
Midland Co Bldg PCE	Midland	Tetrachloroethylene
Midland Painting	Midland	MEK Xylene, ethylbenzene toluene, dichlorobenzene
Hary Herron Domestic Well	Midland	Brine/chloride
State B 2 Flowline Johnson Site	Midland	Crude oil, brine/chloride
Howland 3 and TB	Midland	Condensate-BTEX, crude oil, brine/chloride
Tittabawassee River	Midland	Not listed
Salt River		
Michigan Ohio Pipeline Co	Mt. Pleasant	Petroleum products
Residential Well Loomis	Loomis	Benzene, ethylbenzene, toluene, xylenes
Wise Twp LF	Rose Bush	Hg As Cd Cr PERC TCA, 1,2-DCE
Harry Tope No 3	Beaverton	Brine
Warren Township Dump	Midland Co.	Nickel , arsenic, Mn, BEHP
Chippewa River		
Dana Corp	Mt. Pleasant	PCE TCE, methylene chloride
Fussman Race Track	Mt. Pleasant	Brine
Gilmore Twp Sanitary LF	Gilmore	Phthalates chrysene, Chromium Arsenic, Aluminum
Isabella Co Sanitary LF	Mt. Pleasant	Phthalates
Mich Wisconsin Pipeline Co	Weidman	Hydrocarbons
Mt Pleasant, City of	Mt. Pleasant	Benzene, ethylbenzene, toluene xylenes
Mt Pleasant Tar Pit	Mt. Pleasant	Chromium, lead, phenol, benzene, cyanide, As, PNAs
Residential Well Nottawa	Coldwater Lake	Gasoline, lubricating oil
Residential Well Schutt	Mt. Pleasant	Gasoline
Stanley Oil Co	Shepherd	Gasoline
Total Petroleum Inc Roosevelt	Mt Pleasant	Lead, oils
Dalton 24D Spill Isabella Co	Isabella Co.	2,4-D
Shepherd Village DPW	Shepherd	Salt
Rodgers, John 2	Isabella Co.	Crude oil BEXT, chloride

Table 26.–Continued.

Segment Tributary Site	Location	Pollutant
Mouth–continued		
Watkins, Andrew 1	Isabella Co.	Crude oil BEXT, chloride
Sides, Russell 2	Isabella Co.	Crude oil BEXT, chloride
Dague, Robert 0 1	Isabella Co.	Crude oil BEXT, chloride
Hoffman, Fred L. 1	Isabella Co.	Crude oil BEXT, chloride
Rodgers, J W 1	Isabella Co.	Crude oil BEXT, chloride
Dague, Robert O 2	Isabella Co.	Crude oil BEXT, chloride
Cummings, John 5	Isabella Co.	Crude oil BEXT, chloride
Cummings John 4	Isabella Co.	Crude oil BEXT, chloride
CMU/MDOT	Mt. Pleasant	Crude oil BEXT, chloride
Gordonville Road	Midland	Benzo(a)pyrene, Cr, Cu, chrysene Pb PNAs
Midland Iron Works	Midland	Heavy mfg
Residential Well Bradford Road	Midland Co.	Sodium chloride
Shepard Road Dump	St Louis	PCB, Cr, Cd, pyrene chrysene
St Jasper and Baker 1-2	Midland Co.	Brine/chloride
Conley and St Jasper 1-3	Midland Co.	Brine/chloride
Reed, Emma O C-1	Midland Co.	Condensate-BTEX, crude oil, brine/chloride
Bond Root 12, 18, 19 and TB	Midland Co.	Condensate-BTEX, crude oil, brine/chloride
Rayner D2, B3,B4 and Bond B RaynerTB	Midland Co.	Condensate-BTEX, crude oil, brine/chloride
Bond Root 7	Midland Co.	Condensate-BTEX, crude oil, brine/chloride
Rayner, John B D-7	Midland Co.	Condensate-BTEX, crude oil, brine/chloride
Rayner, J B 1	Midland Co.	Condensate-BTEX, crude oil, brine/chloride
Jasin Property	Garden City	BTEX
Ullom Residence	Mecosta	BTEX
Pine River		
Wickes Agriculture	Blanchard	Nitrate (Nitrogen), urea
Alma City of	Alma	Phenol
Alma Iron Metal Smith Property	Alma	Lead, chromium, PCB, Nickel, PBB
Alma Products	Alma	Cyanide, toluene, TCE
Total Petroleum Alma	Alma	Methylene, chloride, phenols
Lobdell-Emery	Alma	Lead, benzene, tetrachloroethene
Total Petroleum Present Refinery	Alma	BTEX
Admiral Petroleum	Alma	PNA’S, cyanide, BTEX, Pb, Cd, As, Ni
Midwest Refinery	Alma	BTEX, Chloroform, PCE, PNA’s, Acetone, Pb,Cd As, Cr
Total Petro Lansing Product Line	Alma	Gasoline
Vining Welding	Riverdale	Hydrocarbons
Gratiot County LF	St Louis	PBB
City of St. Louis, Electric Dept	St. Louis	PNAs, PCE, benzene, pesticides 1,4-DCB
Pat’s Service	Sumner	Benzene, toluene, lead
Velsicol Chemical Corporation	St. Louis	Benzene, DDT, DDD, chromium, PBB
Crystal Oil Field	Montcalm Co.	Brine/chloride
Hitachi Magnetics	Edmore	Trichloroethene(TCE), mercury, PCBs
Residential Wells Vestaburg	Vestaburg	Salt, brine
Gallaher Tank Battery	Home Twp	Oil, brine
Staffen, Glen Et Al 1	Montcalm Co.	BTEX Brine/Chloride, crude oil
Sackett, Raymond 2	Montcalm Co.	BTEX Brine/Chloride, crude oil
Graham, Harold 2	Montcalm Co.	BTEX Brine/Chloride, crude oil
Graham, Harold 1	Montcalm Co.	BTEX Brine/Chloride, crude oil
Lamphier Frank 2	Montcalm Co.	BTEX Brine/Chloride, crude oil

Table 26.–Continued.

Segment Tributary Site	Location	Pollutant
Middle–continued		
Marzig, Max C 1	Montcalm Co.	BTEX Brine/Chloride, crude oil
North 10 Mile	Montcalm Co.	Chloride
Campbell Lease	Midland Co.	Crude oil
Howard 7, 6, 2 and Howard TB	Midland Co.	Condensate-BTEX, brine/chloride
Root C-4, C-7, C-10 and Root C TB	Midland Co.	Condensate-BTEX, brine/chloride
TMT Petroleum Porter Field	Midland Co.	Condensate-BTEX, brine/chloride
Kleinhans TB and Kleinhans 1,2,3,4	Midland Co.	Condensate-BTEX, brine/chloride
Wager #2-12 DRLG 85-12-10	Midland Co.	Brine/chloride

Table 27.–July average stream temperature (°F) for the Tittabawassee River and tributaries. Blanks indicate missing information (MDNR, Fisheries Division, unpublished data).

				Temperature(°F)		
Stream	County	Site	Year	Minimum	Maximum	Mean
Main Stem Headwaters						
Mid. Br. Tittabawassee	Gladwin	M30/BoenschRd	2004	62.4	79.4	69.2
W. Br. Tittabawassee	Roscommon	Dunham Road	2004	52.8	68.2	58.8
E. Br. Tittabawassee	Ogemaw	Cook Road	2005	60.6	83.7	73.6
Mid. Br. Tittabawassee	Ogemaw	Beardslee Road	2004	63.9	80.1	70.7
Brick Creek	Ogemaw	Lehman Road	2004	53.5	67.5	59.4
Cooks Creek	Ogemaw	Lehman Road	2004	54.6	68.4	60.2
Main Stem Middle						
Little Molasses	Gladwin	Grim Road	2005	54.0	80.9	68.1
Molasses Flooding 3	Gladwin	Grim Road	2005	55.1	77.6	67.5
Fish Creek	Gladwin	Wildwood Road	2005	44.8	78.1	66.7
Sugar River	Gladwin	Above L. Lancer	2002	57.0	74.2	65.8
Sugar River	Gladwin	Below L. Lancer	2002	67.6	79.1	72.6
Bailey Creek	Clare	Surrey Road	2005	57.3	74.4	67.2
N. Br. Tobacco	Clare	Rodgers Road	2004	53.3	68.7	59.7
Sanford Creek	Clare	Elderhart Road	2004	53.9	68.4	60.0
Cedar River**	Gladwin	Above Wiggins L	2002	74.6	86.1	80.2
Cedar River	Gladwin	Below Wiggins L	2002	59.8	78.1	68.8
Main Stem Mouth						
Carroll Creek	Midland	Meridian Road	2005	57.3	75.6	75.6
Sturgeon Creek	Midland	Letts Road	2005	49.0	84.8	70.3
McDonald Drain	Isabella	Battle Road	2004	64.0	81.2	71.6
N. Br. Salt River	Isabella	Vernon Road	2005	59.2	79.4	70.5
S. Br. Salt River	Isabella	Leaton Road	2005	60.6	77.2	69.3
Big Salt River	Midland	Castor Road-Down	2004	60.8	80.9	70.4
Big Salt River	Midland	Castor Road-Up	2005	63.5	84.3	74.1
Big Salt River	Midland	Coleman Road	2004	57.3	75.6	67.8
Big Salt River	Midland	Coleman Road	2005	62.8	79.2	71.1
Cedar Creek	Isabella	Tyler Road	2004	54.9	69.9	61.8
Coldwater River	Isabella	Baseline Road	2005	67.9	86.4	77.2
Delaney Creek	Isabella	Rolland Road	2004	53.4	70.5	61.2
Indian Creek	Isabella	Wyman Road	2004	51.5	67.6	58.6
Johnson Creek	Isabella	Bluegrass Road	2004	53.2	66.6	59.0
N. Br. Chippewa River	Isabella	Glass Lake Road	2004	64.0	81.2	71.6
Walker Creek	Isabella	Vernon Road	2004	54.9	72.8	63.6
Brown Creek	Mecosta	20 Mile/40th	2005	58.3	67.2	63.0
Butts Creek	Mecosta	10th Avenue	2004	49.5	62.6	55.8
Jewell Creek	Mecosta	Harrison Road	2004	53.2	67.4	60.2
N. Br. Chippewa River	Mecosta	Hoover Road	2004	56.6	76.4	66.0
Rattail Creek	Mecosta	40th Avenue	2004	55.0	79.4	66.2
Roundybranch Creek	Mecosta	20 Mile	2004	57.3	73.0	64.8
South Branch Chippewa	Mecosta	19 Mile	2004	63.9	83.0	72.0
Benjamin Creek	Osceola	10th Avenue	2005	54.7	73.7	65.3
Honeyoey Creek	Gratiot	Madison Road	2004	55.8	73.7	65.0

Table 27.–Continued.

Stream	County	Site	Year	Temperature(°F) Minimum	Maximum	Mean
Main Stem Mouth–continued						
Pine River	Gratiot	Bridge Road	2004	66.2	83.5	74.5
Pine River	Gratiot	Lumberjack Road	2005	60.5	78.7	71.2
Pine River	Gratiot	Tyler Road	2004	55.6	104.1	71.5
Pine River	Midland	Redstone Road	2004	66.2	83.5	74.5
Pine River	Midland	Redstone Road	2005	68.4	85.8	78.5
N. Br. Pine River	Isabella	Coe Road	2004	53.9	73.0	63.8
Pine River	Isabella	Rolland Road	2004	55.1	74.9	65.2
S. Br. Pine River	Isabella	Pleasant Valley Rd	2005	46.8	93.9	69.4
Pony Creek	Isabella	Bridge	2004	56.2	74.3	65.2
Skunk Creek	Isabella	Brinton Road	2004	53.8	72.8	62.9
Decker Creek	Mecosta	10th Avenue	2004	52.7	67.3	59.8

Table 28.–Trigger levels for nine chemicals used by the Michigan Department of Community Health in the establishment of fish consumption advisories (ppm = parts per million; ppt = parts per trillion). Information from Wesley (2005).

Chemical	Advisory triggers
Total chlordane	0.3 ppm
Total DDT	5.0 ppm
Dieldrin	0.3 ppm
Toxic dioxin equivalents	10.0 ppt
Heptachlor	0.3 ppm
Mercury	0.5 ppm
Mirex	0.1 ppm
Total PCB	2.0 ppm
Toxaphene	5.0 ppm

Table 29.–Length (mi) and establishment date (Est.) of Tittabawassee River watershed designated county drains by subwatershed, county, and township. Information provided by county drain offices. Some drains are in more than one township and county. If so, this information is listed in parentheses following the drain name. N/A = not available.

Drain	Length (mi)	Est.
Headwaters		
Gladwin County		
• *Sherman Township*		
Busch Drain (Butman)	1.00	1922
Butman Township		
Busch Drain (Sherman)	1.00	1922
Hunt Drain	2.00	1918
• *Sherman Township* – continued		
Jadle Drain	1.50	1925
Wheeler Drain	5.00	1907
• *Clement Township*		
Elk Creek Drain	1.25	1909
Fornier Drain	1.25	1960
Middle		
Gladwin County		
• *Sherman Township*		
Foote Drain (Butman)	1.00	1922
Round Lake Drain (Sherman, Sage, Gladwin)	4.00	1902
• *Sage Township*		
Foran Drain	3.00	1923
Long Drain (Gladwin)	2.00	1909
Mud Lake Drain	2.00	1913
Round Lake Drain (Sherman, Butman, Gladwin)	4.00	1902
• *Butman Township*		
Foote Drain (Sherman)	1.00	1922
Round Lake Drain(Sherman, Sage, Gladwin)	4.00	1902
Shell Drain	3.00	1915
• *Gladwin Township*		
Bennington Drain	2.50	1912
Canham Drain (Buckeye)	4.00	1895
Humason Drain	1.00	1901
Johnson Drain	1.00	1917
Long Drain (Sage)	2.00	1909
Little Sugar Drain	3.00	1894
Round Lake Drain(Sherman, Sage, Butman)	4.00	1902
Weir Drain	2.00	1899
• *Buckeye Township*		
Arkwright Drain	2.00	1920
Canham Drain (Gladwin)	4.00	1895
Dam Drain	2.00	1918
Heth Drain	2.50	1911
Larabee Creek Drain (Hay)	7.00	1916
Oard Drain (Hay)	2.00	1914
Van Horn Drain	3.00	1911
• *Secord Township*		
Sheridan Drain (Grim)	4.00	1917
• *Hay Township*		
Babcock Drain	1.00	1919
Emmott Drain	2.00	1919
Larabee Creek Drain (Buckeye)	7.00	1916
• *Hay Township* – continued		
LeClear Drain (Billings)	2.00	1911
McMahon Drain	1.50	1917
Oard Drain (Buckeye)	2.00	1914
Robbins Drain	1.00	1914
Thompson Drain	0.50	1918
• *Billings Township*		
LeClear Drain (Hay)	2.00	1911
Leuenberger Drain	4.00	1922
Abbott & Ware Drain (Jerome)	6.99	1901
Edd Drain	0.63	1916
Ervin Drain	2.04	1897
Lee Drain	0.96	1908
Mason Drain (Hope)	1.26	1892
Meridian Drain (Hope)	2.48	1890
Raymond Drain (Hope)	4.01	1906
Snyder Drain	0.45	1929
Stone Drain	0.45	1916
• *Hope Township*		
Davids Drain	3.60	1903
Fowley Drain	2.90	1914
Hess Drain	1.78	1909
Meridian Drain (Edenville)	2.48	1890
Raymond Drain (Edenville)	4.01	1906
• *Jerome Township*		
Abbott & Ware Drain (Edenville)	6.99	1901
Crosby Drain	3.85	1995
Flanders Beach Tile	0.21	1965
Francis Drain	1.45	1919
Francis Grove Sub. Tile	0.08	1965
Perry Drain (Lincoln, Jerome)	1.20	1914
Midland County		
• *Geneva Township*		
Carroll Creek (Jerome, Homer)	15.50	1912
Custer Drain	1.50	1914
Russ Drain	2.50	1917

Table 29.–Continued.

Drain	Length (mi)	Est.
Mouth		
Midland County		
• *Greendale Township*		
South Br. Carroll Creek (Jerome)	9.00	1915
Prairie Creek Drain (Homer, City)	5.50	1908
• *Jerome Township*		
Black Creek	4.00	1902
Carroll Creek (Geneva, Homer)	15.50	1912
Falk Tile	0.50	1915
Irish Reed Drain (Homer)	3.25	1915
Knapp Drain (Lee, Homer)	4.20	1904
Sanford Tile	0.75	1966
South Br. Carroll Creek (Greendale)	9.00	1915
Zilski Drain	0.75	1915
• *Lee Township*		
Grace & Waltz Drain	3.00	1903
Knapp Drain (Homer, Jerome)	4.20	1904
Knapp Drain Cutoff	6.25	1917
Prairie Creek Drain (Homer, City, Greendale)	5.50	1908
• *Porter Township*		
Bullock Creek (Gratiot Cty, Mt. Haley, Homer)	11.20	1925
Corbat Drain	3.00	1905
Dowd Drain	1.70	1898
Hood Drain	2.00	1947
Howley Drain	1.00	1897
Kneeland Drain (Mt. Haley)	8.00	1913
Oliver Drain	2.00	1908
Ryan Drain	2.50	1895
• *Hope Township*		
Boyle Drain (Mills, Larkin, Lincoln)	7.50	1913
Clark Drain	1.00	1913
Harris Drain(Lincoln)	1.34	1906
Kelly Drain	2.50	1989
McCoy Drain	2.22	1908
Schoolhouse Drain (Lincoln)	2.30	1913
Weaver Br. 1	3.62	1906
Weaver Drain	1.95	1907
• *Lincoln Township*		
Averill Drain	2.00	1901
Beck Drain	0.39	1905
Bensch Drain (City)	4.28	1900
Boyle Drain (Mills, Hope, Larkin)	7.50	1913
Ditmar Drain	9.53	1905
Harris Drain (Hope)	1.34	1906
Inman Drain	3.85	1896
Lincoln Estates Drain	0.20	1984

Drain	Length (mi)	Est.
• *Lincoln Township* – continued		
State Drain (Homer, City)	2.52	1902
Stearns Drain	4.00	1894
Weaves Cutoff	1.30	1891
• *Mt. Haley Township*		
Bullock Creek (Gratiot County, Porter, Homer)	11.20	1925
Duncan Brooks Drain (Homeer)	7.00	1891
Kneeland Drain (Porter)	8.00	1913
Mt. Haley 16	0.70	1956
Valler & Rose Drain	3.40	1966
• *Homer Township*		
State Drain (Lincoln, City)	2.52	1902
Bullock Creek (Gratiot Cty, Porter, Mt. Haley)	11.20	1925
Carroll Creek (Jerome, Homer)	15.50	1912
Colon Drain	1.50	1910
Draves Drain	1.00	1918
Duncan Brooks Drain (Mt. Haley)	7.00	1891
Feaster Drain	1.00	1915
Gleason Tile	0.50	1946
Haywood Drain	1.25	1913
Irish Reed Drain(Jerome)	3.25	1915
Knapp Drain (Lee, Jerome)	4.20	1904
Prairie CreekDrain (Greendale, Lee, City)	5.50	1908
Rose Drain	5.00	1914
Schrade Drain	0.25	1961
Youngs Drain	1.50	1937
State Drain (Lincoln, City)	2.52	1902
• *Mills Township*		
Boyle Drain (Larkin, Hope, Lincoln)	7.50	1913
Morris Drain	3.50	1905
Whitmer Drain (Larkin)	5.00	1950
• *Larkin Township*		
Balcirak Drain	0.63	1917
Boyle Drain (Mills, Hope, Lincoln)	7.50	1913
Demski Drain	2.73	1908
Hahn Drain (City)	2.00	1902
Jacobs Drain (City)	6.13	1899
Jebert Drain (City)	3.50	1903
Kohtz Drain (City)	0.79	1946
Kruse Drain	0.71	1923
Lathrope Drain	1.73	1906
Miller Drain	2.33	1901
Newell Drain (City)	11.90	1895
Pluss Drain	6.33	1898

Table 29.–Continued.

Drain	Length (mi)	Est.
Mouth, *Midland County*–continued		
• *Larkin Township* – continued		
Venner Drain	2.41	1904
Whitmer Drain (Mills)	5.00	1950
Wisgar Drain	3.09	1896
• *Ingersoll Township*		
Cane Drain (City)	2.50	1998
Haley Drain (City)	3.50	1884
DeBolt Drain (City)	3.70	1882
• *City Township*		
Ames Drain (Saginaw & Bay cnties; Ingersoll)	2.00	1922
Ashby Main	0.75	1914
Beck Drain (Lincoln)	0.39	1903
Bensch Drain (Lincoln)	4.28	1900
Cane Drain (Ingersoll)	2.50	1998
Carter Drain	1.50	1941
DeBolt Drain (Ingersoll)	3.70	1882
Hahn Drain (Larkin)	2.00	1902
Haley Drain (Ingersoll)	3.50	1884
Irelan Drain	0.50	1938
Jacobs Drain (Larkin)	6.13	1899
Jebert Drain (Larkin)	3.50	1903
Kohtz Drain (Larkin)	0.79	1946
Lalk Drain	0.13	1951
Lingle Drain	1.50	1903
Martinus Drain	1.00	1914
Miller Relief	0.50	1962
Moore Drain	0.25	1954
Newell Drain (Larkin)	11.93	1895
Prairie Drain (Homer, Lee)	5.5	1908
Rockwell Drain	0.50	1897
State Drain (Lincoln, Homer)	2.52	1902
Bay County		
• *Williams Township*		
Ames Drain (Saginaw & Midland cnties)	1.14	1923
Saginaw County		
• *Tittabawassee Township*		
Ames Drain (Bay County)	2.10	1919
Brown & Mills Drain (Midland County)	2.86	1900
Freeland Tile	0.80	1926
Hackett Drain	1.20	1928
Lentz Drain	1.00	1946
• *Tittabawassee Township* – continued		
Macomber Drain (Thomas)	3.14	1895
New Freeland Tile	0.80	1956
Ostrander Drain	1.14	1915
Parker Swamp Drain	4.29	1912
Ralph Drain	1.14	1968
Sarle Drain	2.40	1920
Trickey Drain	2.86	1917
• *Thomas Township*		
Dutch Garey Drain (Saginaw)	1.71	1916
Hager 1	1.00	1927
Hoffman Drain	2.86	1903
Hunters Ridge Drain	2.14	1992
Kastorf Drain	3.86	1916
Macomber Drain (Tittabawassee)	3.14	1895
Metzler Drain (Saginaw)	1.00	1960
Monk Tile (Saginaw)	2.50	1916
Reineke Drain (Saginaw)	3.71	1899
TKS Drain (Saginaw, Kochville)	6.14	1899
Wagner Drain (Saginaw)	0.80	1964
• *Kochville Township*		
TKS Drain (Saginaw, Thomas)	6.14	1899
• *James Township*		
Thompson 2 Drain	1.71	1915
• *Saginaw Township*		
Allenhurst Drain	1.20	1969
Amanda Drain	0.71	1970
Center Road Drain	3.71	1957
Companion Tile	0.50	1998
Dutch Garey Drain (Thomas)	1.71	1916
Gemple Drain	0.50	1921
Metzler Drain (Thomas)	1.00	1960
Monk Tile (Thomas)	2.50	1916
Otto Tile	1.57	1972
Reineke Drain (Saginaw)	3.71	1899
Seidel Drain	2.86	1946
Stroeble Drain	2.29	1931
TKS Drain (Thomas, Kochville)	6.14	1899
Wagner Drain (Thomas)	0.80	1964
Winterstein Drain	3.14	1900
Tobacco River		
Clare County		
• *Lincoln Township*		
Bertha Lake Drain	N/A	1997
Ross Drain	N/A	N/A
• *Surrey Township*		
Allen Drain (Grant)	1.69	1915
Cut-off Drain	N/A	1992
Farwell Drain (Village of Farwell)	0.54	1920

Table 29.–Continued.

Drain	Length (mi)	Est.
Tobacco River, *Clare County*–continued		
• *Hatton Township*		
Lower Drain(Grant, Arthur)	0.48	1916
• *Grant Township*		
Allen Drain (Surrey)	1.69	1915
Gilmore Jt. Drain (City of Clare)	2.00	1898
Herring Drain (Isabella County)	0.56	1901
Jordan Drain (Sheridan))	1.47	1914
Little Tobacco Dr (Isabella Cnty, City of Clare)	2.27	1897
Lloyd Drain	1.02	1921
Lower Drain(Hatton, Arthur)	0.48	1916
Ness Drain	0.91	1913
State Trunkline Drain (City of Clare)	1.50	1922
Tobacco Drain	3.00	N/A
Whitbeck Drain (City of Clare)	N/A	1989
• *Franklin Township*		
Nash Drain (Gladwin County)	0.75	N/A
• *Arthur Township*		
Ackney Drain	1.74	1914
Coates Drain	0.89	1918
Cook Drain (Sheridan)	2.13	1915
Cornwell Drain	0.38	N/A
Hutchinson Drain (Arthur)	0.61	N/A
Leitner Drain	0.88	N/A
Lower Drain(Hatton, Grant)	0.48	1916
Mark & Brand Drain	0.41	1909
Tonkin Drain	0.62	N/A
Tonkin Jt. Drain	3.50	N/A
• *Sheridan Township*		
Bailey Drain	2.03	N/A
Carrow Drain	0.92	N/A
Cook Drain (Arthur)	2.13	1915
Harvey Drain	0.90	1921
Howe Dr (Isabella, Gladwin, & Midland cnties)	N/A	1910
Hutchinson Drain (Arthur)	0.61	N/A
Jordan Drain (Grant)	1.47	1914
Larson-Elliot Drain	0.16	1918
Loomis Jt. Drain	0.05	N/A
McGivern Drain	1.70	1901
Rilette Jr. Drain (Gladwin County)	3.00	1920
Warner Drain	0.97	N/A
Gladwin County		
• *Sherman Township*		
Nash IC Drain (Clare County)	1.00	1916
• *Sage Township*		
Bendle Drain	2.50	1914
Foran Drain	3.00	1923
Grams Drain	1.00	1914

Drain	Length (mi)	Est.
• *Sage Township* – continued		
Van Drain	6.00	1895
• *Grout Township*		
Carr Drain	2.50	1916
Dickens Drain(Beaverton)	2.00	1918
Doane Creek Drain (Beaverton)	3.50	1903
Flynn Drain	1.00	1900
Grams Drain	1.00	1914
Huber Drain (Beaverton)	1.50	1913
Lee Farm Creek Drain	2.00	1894
Longstretch Drain (Buckeye)	2.00	1923
Lucas Drain	2.50	1916
Mills Drain	1.00	1901
Stroman Drain (Beaverton)	1.00	1909
Tobacco Drain	1.25	1895
Tubbs Drain	0.50	1919
Walker I. C. Drain (Clare County)	1.00	1998
Whitman Drain	1.00	1899
Carr Drain	2.50	1916
Dickens Drain(Beaverton)	2.00	1918
Doane Creek Drain (Beaverton)	3.50	1903
Flynn Drain	1.00	1900
Grams Drain	1.00	1914
Huber Drain (Beaverton)	1.50	1913
Lee Farm Creek Drain	2.00	1894
Longstretch Drain (Buckeye)	2.00	1923
Lucas Drain	2.50	1916
Mills Drain	1.00	1901
Stroman Drain (Beaverton)	1.00	1909
Tobacco Drain	1.25	1895
Tubbs Drain	0.50	1919
Walker I. C. Drain (Clare County)	1.00	1998
Whitman Drain	1.00	1899
• *Beaverton Township*		
Baker Drain	0.50	1921
Bear Creek Drain (Tobacco)	5.00	1902
Bell Drain	0.50	1921
Burleson Drain	3.00	1915
Davidson Creek Drain	3.00	1913
Dickens Drain (Grout)	2.00	1918
Doane Creek Drain (Grout)	3.50	1903
Dopp Drain	2.50	1901
Dopp Drain Ext.	1.00	1910
Dow Drain (Tobacco)	8.00	1903
Dunbar I.C. Drain (Midland County)	3.00	1916
Huber Drain (Grout)	1.50	1913
Long/Scott Drain (Tobacco)	4.50	1908

Table 29.–Continued.

Drain	Length (mi)	Est.
Tobacco River, *Clare County*–continued		
• *Beaverton Township*–continued		
Lyle Drain	7.00	1912
McKimmy Drain (Tobacco)	1.50	1913
Nestor Creek Drain (Beaverton)	6.00	1915
Quillet Drain (Tobacco)	2.50	1919
Spencer Drain	3.50	1918
Stroman Drain (Grout)	1.00	1909
Taylor Drain	1.00	1917
• *Gladwin Township*		
Little Tobacco Drain	3.50	1908
Ogg Drain	4.00	1903
Sampson Drain	3.00	1912
Van Drain	6.00	1895
Warner Drain	1.00	1918
• *Buckeye Township*		
Bennett Drain	3.00	1917
Canham Drain (City of Gladwin)	4.00	1895
Dow Drain (Tobacco)	8.00	1903
Duby DRAIN	1.50	1902
Flynn/Nash Drain	0.75	1917
Graham Drain	7.75	1914
Hoy Drain (Tobacco, Billings, Hay)	3.00	1907
Longstretch Drain (Grout)	2.00	1923
Martin Drain	2.50	1900
Pete Drain	4.00	1918
Venison Creek Drain	4.50	1913
• *Hay Township*		
Hoy Drain (Tobacco, Billings, Tobacco)	3.00	1907
• *Billings Township*		
Brushaber Drain (Tobacco)	1.00	1921
Hoy Drain (Buckeye, Tobacco, Hay)	3.00	1907
• *Tobacco Township*		
Bear Creek Drain (Beaverton)	5.00	1902
Brooks Drain	0.50	1898
Brushaber Drain (Billings)	1.00	1921
Coolidge Drain	2.00	1914
Crockett Drain	1.00	1910
Dow Drain (Buckeye)	8.00	1903
Hay Drain (Buckeye, Billings, Hay)	3.00	1907
Hoover Drain	2.00	1917
Hoy Drain (Buckeye, Billings, Hay)	3.00	1907
Kaake Drain	1.25	1908
Long/Scott Drain (Beaverton)	4.50	1908
McKimmy Drain (Beaverton)	1.50	1913
Nestor Creek Drain (Beaverton)	6.00	1915
Ottgen Drain	2.00	1908
Quillet Drain (Beaverton)	2.50	1919
Ray Drain	1.00	1920
Rich Drain	2.00	1905
Smith/Chris Drain	1.50	1917
Snyder Drain	2.00	1912
Tremaine Drain	1.50	1904
Wagner Drain	1.00	1929
Woodby Drain	1.00	1917
Salt River		
Gladwin County		
• *Beaverton Township*		
Bliss 1 Drain (Midland County)	2.00	1901
Bliss 2 Drain (Midland County)	0.50	1901
Sage IC Drain (Midland County)	2.00	1918
• *Tobacco Township*		
Curtice IC Drain (Midland County)	2.00	1920
Isabella County		
• *Nottawa Township*		
Garvin Drain (Union, Isabella)	1.22	1894
John Neff Drain (Union, Isabella, Deerfield)	7.96	1904
Jordan Creek Drain (Isabella)	12.6	1903
• *Vernon Township*		
Crowley Drain	1.19	1919
Dixon Drain	4.65	1901
Gilmore Drain (Clare County)	0.54	1898
Howland Drain	1.90	1906
• *Vernon Township* – continued		
Jennings Drain (Wise)	3.95	1916
Killenbeck Drain (Isabella, Wise, Denver)	6.68	1914
Lamphere Drain (Wise)	8.08	1967
Loomis Drain (Clare Cnty, Vernon, Wise)	8.30	1904
McConnell Drain (Isabella)	0.89	1819
Ouderkirk Drain	0.61	1907
Seeley Drain	1.91	1899
Seiter Drain (Isabella)	0.77	1915
Sharp Drain	2.56	1968
Spring Creek Drain (Denver, Isabella)	8.20	1951
Wager Drain (Isabella)	2.43	1915
Wing Drain (Isabella)	3.03	1897
• *Isabella Township*		
Bloom Drain	0.77	1914
Bradley Drain	0.52	1921
Bullard Drain	1.79	1926

Table 29.–Continued.

Drain	Length (mi)	Est.
Salt River, *Isabella County*–continued		
• *Isabella Township* – continued		
Burr & Thompson Drain	0.79	1916
Calkins Drain	3.96	1900
Cameron Drain	1.16	1918
Carpenter Drain	0.72	1906
Clare Drain	0.63	1913
Conway Drain	2.14	1907
Dimond Drain (Denver, Union, Chippewa)	3.64	1918
Dock Bryant Drain	1.01	1911
Ege Drain (Union)	1.83	1921
Elliot Drain	0.53	1907
Fall Drain	0.78	1916
Fitzpatrick Drain	0.51	1911
Garvin Drain (Union, Nottawa)	1.22	1894
Harrison Drain (Denver)	2.25	1916
House Drain	3.88	1918
John Neff Drain (Nottawa, Union, Deerfield)	7.96	1918
Johnson Drain	2.35	1915
Jordan Creek Drain (Nottawa)	12.58	1903
Killenbeck Drain (Wise, Vernon, Denver)	6.68	1914
Lewis Drain (Denver)	8.52	1904
McConnell Drain (Vernon)	0.89	1819
McDonald Drain (Union)	0.78	1919
McKay Drain (Denver)	6.65	1916
Pelcher Drain	0.27	1943
Phillips Drain	0.23	1920
Seiter Drain (Vernon)	0.77	1915
Spring Creek Drain (Vernon, Denver)	8.20	1951
Vincent Drain	3.44	1894
Wager Drain (Vernon)	2.43	1915
Walton Drain	1.15	1915
West Drain (Denver)	2.82	1916
Wing Drain (Vernon)	3.03	1897
• *Union Township*		
Dimond Drain (Denver, Isabella, Chippewa)	3.64	1918
Ege Drain (Isabella)	1.83	1921
Garvin Drain (Isabella, Nottawa)	1.22	1894
McDonald Drain (Isabella)	0.78	1919
• *Wise Township*		
Bagley Drain	1.07	1917
Bickerton Drain (Midland County)	2.74	1903
Brock Drain (Denver)	0.28	1944
Burns Drain	2.33	1911
Butler Drain	1.08	1917
Curtiss Drain	2.96	1905
Gibson Drain	0.80	1930
High Drain (Midland County)	3.40	1915
Howe Jt. Drain (Mecosta County)	2.50	1910
• *Wise Township* – continued		
Jennings Drain (Vernon)	3.95	1916
Killenbeck Drain (Isabella, Vernon, Denver)	6.68	1914
King Drain	2.31	1915
Klashak Drain	1.92	1915
Knipe Drain	2.19	1951
Lamphere Drain (Vernon)	8.08	1967
Lennox Drain (Denver)	0.60	1917
Loomis Drain (Clare County, Vernon)	8.30	1904
Lowe Drain (Midland County, Denver)	3.18	1915
Menery DRAIN	1.60	1911
Methner Drain	2.05	1913
Morrison Drain	0.80	1913
Sealey Drain	1.91	1899
Sharp Drain (Vernon)	2.50	1968
Wise Drain (Midland County, Denver)	3.26	1900
• *Denver Township*		
Bender Drain	0.38	1946
Boone Drain	2.85	1913
Brock Drain (Wise)	0.28	1944
Cluley Drain	1.95	1918
Dimond Drain (Isabella, Union, Chippewa)	3.64	1918
Epple Drain	1.49	1932
Harrison Drain (Isabella)	2.25	1916
Killenbeck Drain (Isabella, Vernon, Wise)	6.68	1914
Kirkey Drain	0.99	1918
Kreiner Drain	1.99	1918
Leaton Drain	0.74	1945
Lennox Drain (Wise)	0.60	1917
Lewis Drain (Isabella)	8.52	1904
Lowe Drain (Midland County, Wise)	3.18	1915
McKay Drain (Isabella)	6.65	1916
Raymond Drain	0.70	1915
Spring Creek Drain (Vernon, Isabella)	8.20	1951
Stuber Drain	1.67	1916
Welnack Drain (Chippewa)	5.62	1916
West Drain (Isabella)	2.82	1916
Wise Drain (Midland County, Wise)	3.26	1900
• *Chippewa Township*		
Dimond Drain (Isabella, Union, Denver)	3.64	1918
Welnack Drain (Denver)	5.62	1916
Midland County		
• *Warren Township*		
Babcock Drain (Edenville, Jerome)	1.50	1912
Bickerton Drain	5.00	1903
Bliss 1 Drain (Gladwin County)	10.00	1900
Bliss 2 Drain (Gladwin County)	3.00	1901
Bluff Creek	4.00	N/A

Table 29.–Continued.

Drain	Length (mi)	Est.	Drain	Length (mi)	Est.
Salt River, *Midland County*–continued					
• *Warren Township* – continued			• *Geneva Township* – continued		
Childs Drain (Geneva)	3.40	1900	Lamping Drain	1.00	1914
Coleman Drain	3.30	1902	Lowe Drain (Isabella County)	0.50	1915
High Drain (Isabella County)	3.20	1900	Macnelly Drain	0.20	N/A
Home Drain (Isabella County)	6.50	1900	May Drain	1.50	1923
Howard Drain(Geneva)	5.50	1886	Middleton Drain	0.30	N/A
Johnson Drain	0.70	1915	Roth Drain	0.50	1973
McCumber Drain	0.75	1921	Smith Drain	1.00	1915
Nelson Drain	2.20	1916	Stemple Drain (Warren)	3.40	1904
Russell Drain	1.00	1917	Teed Drain (Jerome)	12.00	1904
Sage Drain (Gladwin County)	0.70	1918	Tigner Drain	2.00	1909
Stemple Drain (Geneva)	3.40	1904	Vanderveen Drain	1.00	1918
Tripp Drain (Edenville)	4.30	1912	• *Edenville Township*		
• *Geneva Township*			Curtis Drain (Gladwin County)	8.50	1898
Childs Drain (Warren)	3.40	1900	Babcock Drain (Jerome, Warren)	1.50	1912
Dawe Drain	0.25	1916	Tripp Drain (Warren)	4.30	1912
Green Drain	1.00	1916	• *Jerome Township*		
Haller Drain	1.50	1915	Babcock Drain (Edenville, Warren)	1.50	1912
Haulk Jt. Drain (Isabella County)	2.50	1962	Durbin Drain	9.00	1919
Housholder Drain	1.70	1921	Teed Drain (Geneva)	12.00	1904
Howard Drain (Warren)	5.50	1886	Vane Drain	2.00	1911
Chippewa River					
Osceola County			• *Gilmore Township* – continued		
• *Orient Township*			Larrance Drain (Vernon Nottawa, Isabella)	1.43	1916
Orient Drain #4 and #5	2.27	1906	Love Drain(Nottawa)	9.90	1915
Orient Fork Jt. Drain (Mecosta County)	0.97	1929	Scholfield Creek	4.60	1898
Mecosta County			Scutt Lake Drain (Nottawa)	6.60	1913
• *Martiny Township*			Seymour Drain	1.50	1907
Martiny and Br.1 Drain	1.70	1916	Willow Lake Drain (Vernon)	3.13	1896
• *Fork Township*			• *Nottawa Township*		
Orient Fork Drain (Osceola County)	0.60	1928	Blesch Drain (Gilmore)	3.15	1920
Barryton Drain	3.10	1920	Burgess Drain(Gilmore)	3.44	1915
• *Sheridan Township*			Foerst Drain	3.90	1903
Mark/Meeker Drain	2.83	1907	Fox Drain	1.26	1921
Green Drain	1.53	1916	Garrett Drain	2.38	1947
Sheridan Drain	3.23	1917	Hagerman Drain (Deerfield)	0.38	1913
Moyer Drain	1.60	1907	Kennedy Drain	0.93	1918
Isabella County			Larrance Drain(Vernon, Gilmore Isabella)	1.43	1916
• *Coldwater Township*			Lawens Drain	0.57	1917
Buger Drain	2.21	1912	Love Drain(Gilmore)	9.90	1915
Conley Drain	0.20	1925	Martin Drain (Deerfield)	5.10	1912
Reynolds Drain	1.48	1917	Pitts Drain	0.23	1905
• *Sherman Township*			Schafer Drain	0.95	1917
Denslow Drain	1.88	1919	Scutt Lake Drain (Gilmore)	6.60	1913
• *Gilmore Township*			Simmer Drain	3.37	1917
Blesch Drain (Nottawa)	3.15	1920	Smith Drain (Deerfield)	1.03	1896
Burgess Drain(Nottawa)	3.44	1915	Tilman Drain	1.51	1919

Table 29.–Continued.

Drain	Length (mi)	Est.	Drain	Length (mi)	Est.
Chippewa River, *Isabella County*–continued					
• *Nottawa Township* – continued			• *Union Township* – continued		
Wagner Drain	2.83	1906	Bufford Drain	0.38	1918
Weber/Mill Drain	0.29	1917	Cahoon Drain (Lincoln)	2.30	1915
Weidman Drain	1.03	1884	Carroll Drain	1.58	1924
White Imp. Drain	2.51	1901	Cole Drain	1.29	1920
Wichenhiser Drain	1.40	1922	Dorris Drain	1.25	1917
Yonker Drain	3.97	1912	Dumas Drain	0.28	1952
Zucker Drain (Deerfield)	1.00	1925	Fitzgerald Drain	2.37	1919
• *Deerfield Township*			Gordon/Meyers Drain (Deerfield)	0.50	1912
Barnard Drain (Union)	1.82	1915	Hance Drain (Chippewa)	4.60	1909
Boettner Drain	0.48	1915	Hunter Drain (Chippewa)	2.10	1910
Bunker Drain	0.68	1929	Jefford Drain	0.70	1906
Davis Drain	2.76	1917	LaPoe Drain (Chippewa)	1.10	1941
Fowler Drain	2.34	1915	Log Cabin Drain	0.40	1935
Gordon/Meyers Drain (Union)	0.50	1912	Mead Creek	1.11	1916
Hagerman Drain (Nottawa)	0.38	1913	Miser Drain (Chippewa)	6.17	1905
Hein Drain	1.60	1913	Mission Creek	5.47	1904
Martin Drain (Nottawa)	5.10	1912	Oberlin Drain (Chippewa)	0.85	1888
McCarthy Drain	1.16	1913	Onion Creek Drain (Chippewa, Lincoln)	6.15	1907
Murphy Drain	0.63	1908	Paisley Drain	0.99	1909
Page Drain	1.02	1911	Peterson Drain	0.56	1923
Rhodes Drain (Union)	0.67	1915	Pope Drain	0.50	1918
Smith Drain (Nottawa)	1.03	1896	Potter Brodie Drain (Coe, Lincoln, Chippewa)	8.63	1908
Starkweather Drain(Fremont)	4.02	1922	Quarterline Drain (Chippewa)	2.27	1973
Urie Drain	0.95	1914	Reserve Drain (Chippewa)	N/A	N/A
Walker Drain (Union)	1.96	1919	Sponsteller Drain	0.2	1938
Young Drain	3.03	1913	Sterling Drain	0.89	1910
Zucker Drain (Nottawa)	1.00	1925	Stillwell (Lincoln)1.71	0.89	1895
• *Vernon Township*			Theirs Drain	1.00	1918
Bogan Drain	0.94	1915	Tice Drain	2.28	1904
Duncan Drain	6.88	1897	Travis Drain	0.49	1922
Flood Drain	0.28	1904	Turney Drain	0.10	1929
Gilbert Drain	1.53	1903	Upton Drain (City)	2.47	1964
Gorr Drain	0.79	1900	Welsch Drain (Lincoln)	1.25	1911
Larrance Drain (Gilmore, Nottawa, Isabella)	1.43	1916	Wheeler Drain (Lincoln)	3.60	1918
McKinnen Drain	2.27	1899	Woodin Drain (Lincoln)	1.33	1921
McMillan Drain	0.28	1916	• *Lincoln Township*		
Nevills Drain	2.39	1900	Bass Lake Drain (Gratiot County)	3.00	1910
Snear Drain	1.42	1950	Bellinger/Schooley Drain (Union)	1.69	1917
Willow Lake Drain (Gilmore)	3.13	1896	Bowman Drain	0.23	1925
• *Isabella Township*			Brenner Drain	0.85	1921
Larrance Drain (Gilmore, Nottawa, Vernon)	1.43	1916	Brody Drain (Union)	4.20	N/A
• *Union Township*			Bronson Drain (Coe)	0.67	1914
Beckett Drain	0.59	1936	Burdick Drain	0.58	1901
Bellinger/Schooley Drain (Lincoln)	1.69	1917	Cahoon Drain (Union)	2.30	1915
Beltnick Drain	0.48	1919	Campbell Drain (Coe)	2.10	1906
Bollman Drain	0.94	1946	Childs Drain (Coe)	2.10	1906
Brody Drain (Lincoln)	4.20	N/A	Coe & Lincoln Drain (Coe)	2.06	1894

Table 29.–Continued.

Drain	Length (mi)	Est.
Chippewa River, *Isabella County*–continued		
• *Lincoln Township* – continued		
Crim Drain	0.56	1905
Dubois Drain	2.68	1908
Ervans Drain	1.17	1913
Figg Drain	11.77	1903
Fisher Drain	0.95	1911
Garber Drain	0.61	1912
Irishtown Drain (Gratiot County)	0.60	1956
Jerseyville Drain	N/A	N/A
Kenny Drain	0.34	1944
Key Drain (Coe)	2.37	1918
Keys Drain (Lincoln)	2.37	1918
Kirconnell Drain	0.50	1915
Krick Drain (Midland County, Fremont, Coe)	0.52	1916
Kyser Drain	0.2	1927
Little Salt Dr (Midland & Gratiot cnties; Coe)	1.40	1906
Mead Drain	1.16	1925
Millett Drain (Gratiot County)	0.69	1919
Mud Lake Drain	4.22	1916
Onion Creek Drain (Union, Lincoln)	6.15	1907
Parcher Drain	2.45	1907
Piatt Drain	0.48	1919
Potter Brodie Drain (Coe Union Chippewa)	8.63	1908
Roberts Drain (Gratiot County)	0.71	1917
Root Drain	1.61	1914
Rowlader Drain	0.54	1919
Salt River Drain (Coe)	6.00	1900
Saunders Drain	3.80	1906
Stillwell (Union)	1.71	1895
Tomlinson Drain	0.54	1913
Tripp Drain (Coe)	2.11	1916
Van Lieu Drain	2.36	1923
Welsch Drain (Union)	1.25	1911
Wheeler Drain (Union)	3.60	1918
Wilberding Drain	0.77	1930
Woodin Drain (Union)	1.33	1921
Wyant Drain	2.80	1899
• *Denver Township*		
Mitchell Drain (Chippewa)	4.03	1903
• *Chippewa Township*		
Chamberlain Drain	6.04	1912
Church Drain (Coe)	3.69	1906
Deputy Drain	2.43	1903
Durfee Drain	2.28	1908
Froggett & Fitzgerald Drain (Coe)	0.21	1922
Gillspie Drain	1.43	1911
Granger Drain	3.78	18.99
Halstead Drain (Midland County)	3.00	1906
• *Chippewa Township* – continued		
Hammond Drain	0.61	1914
Hance Drain (Union)	4.60	1909
Hentz Drain	0.12	1924
Hickson Drain	2.12	1973
Hill Drain (Midland County)	1.26	1903
Hunter Drain (Chippewa)	2.10	1910
John Dibble Drain	0.68	1914
Kempter Drain	1.31	1901
Kern Drain (Coe)	1.67	1915
Landon Drain	1.52	1910
Maurice Drain	1.55	1953
Miles Drain	1.24	1910
Miley Drain (Coe)	0.61	1915
Miser Drain (Union)	6.17	1905
Mitchell Drain (Denver)	4.03	1903
Neff Drain	5.90	1910
Oberlin Drain (Union)	0.85	1888
Onion Creek Drain (Union, Lincoln)	6.15	1907
Potter Brodie Drain (Coe, Lincoln, Union)	8.63	1908
Powers Drain	1.23	1912
Quarterline Drain(Union)	2.27	1973
Richmond Drain	1.16	1914
Ripley Drain	0.50	1918
Salisbury Drain	1.93	1911
Servoss Drain	0.33	1914
Stacey Drain	0.76	1912
• *Coe Township*		
Adams Drain	0.54	1961
Adgate Drain	1.3	1909
Alexander Drain	0.54	1914
Atwater Drain (Midland County)	3.90	1956
Barden & Ross Drain	2.78	1905
Bell Drain	1.12	1928
Best Drain	2.69	1902
Bronson Drain (Lincoln)	0.67	1914
Campbell Drain (Lincoln)	2.10	1906
Childs Drain (Lincoln)	2.10	1906
Church Drain (Chippewa))	3.69	1906
Cline Drain	1.03	1916
Coe & Lincoln Drain (Lincoln)	2.06	1894
Conley Jt. Drain (Gratiot)	0.59	1914
Countyline Drain(Gratiot)	1.04	1912
Dubois Drain (Lincoln)	2.68	1908
Dutt & Hart Drain(Midland County)	1.64	1906
Ewing Drain (Midland County)	1.00	1900
Feltman Drain	0.50	1937
Froggett & Fitzgerald Drain (Chippewa)	0.21	1922

Table 29.–Continued.

Drain	Length (mi)	Est.
Chippewa River, *Isabella County*—continued		
• *Coe Township* – continued		
Frost Drain (Midland County)	1.76	1905
Gallagher Drain (Midland County)	0.76	1950
Girvin Drain	1.25	1916
Hall Drain (Midland County)	0.05	1914
Hannett Jt. Drain (Midland County)	0.75	1904
Kent & Northrup Drain	2.40	1927
Kern Drain (Chippewa)	1.67	1915
Keys Drain (Lincoln)	2.37	1918
Kinter Hannett Drain	2.57	1912
Krick Drain (Midland County)	0.52	1916
Leonard Drain	3.43	1912
Little Salt Dr (Midland & Gratiot cnties; Lincoln)	1.40	1906
McClintic Drain	0.51	1916
McFarren Drain (Midland County)	0.70	1906
Mellville Drain	1.18	1920
Miley Drain (Chippewa)	0.61	1915
Miller & Occonner Drain	1.13	1924
Myers Drain	1.65	1916
Nilson Drain	0.27	1918
Petoskey Drain	2.80	1929
Potter Brodie Drain (Lincoln, Union, Chippewa)	8.63	1908
Salt River Drain (Lincoln)	6.00	1900
Stahlman Drain	1.21	1911
Stuble Drain	0.63	1914
Swain Jt. Drain (Midland County)	0.38	1930
Taylor Drain	1.02	1897
Throop Drain	0.47	1905
Tripp Drain (Lincoln)	2.11	1916
Turner Jt. Drain (Midland County)	0.88	1911
Turnwald Drain	1.29	1954
VanVraken Drain	0.16	1915
Walling Drain	0.40	1912
Way & Childs Drain	2.18	1913
Midland County		
• *Greendale Township*		
Caywood Drain (Jasper, Porter, Lee)	2.00	1961
Dickensen Drain (Isabella County)	0.50	N/A
Emma Drain (Lee)	1.00	2000
Halstead Drain (Isabella County)	1.00	N/A
Hill Drain (Isabella County)	1.50	1900
Krick Drain (Isabella County, Jasper)	0.52	1916
Lawson Drain (Lee)	4.00	1917
Prairie Drain (Lee)	9.00	1908
Purtell Drain	2.50	1956
Unnamed Drain (Isabella County)	1.00	N/A
• *Jasper Township*		
Alspaugh Drain	5.00	1913
Atwater Drain (Isabella County)	1.10	1907
Barnes Drain	0.50	1914
Caywood Drain(Greendale Porter, Lee)	2.00	1961
Cronk Drain (Gratiot County)	7.00	1895
Davison Drain	1.00	1909
Dolan Drain	1.30	1911
Dutt & Hart Drain (Isabella County)	2.00	1906
Ewing Drain (Isabella County)	2.60	1904
Frost Drain (Isabella County)	2.00	1905
Hall Drain (Isabella County)	3.00	1894
Hanlet Drain	2.50	1912
Hannett Drain (Isabella County)	2.50	1903
Harlon Drain	0.10	1917
Hevel Drain	2.50	1912
Holton Drain	0.30	1953
Jasper Coe 1 Drain (Isabella County)	0.60	1913
Jasper Coe 2 Drain	0.50	1893
Krick Drain (Isabella County, Jasper)	0.52	1916
Little Salt Creek (Isaballa County)	7.00	1882
Martin Drain	1.00	1911
McFarren Drain (Isabella County)	3.00	1900
Murry Drain	0.60	N/A
Old Cronk Drain	3.00	1895
Sehler Drain	0.50	1945
Sinif Drain	2.80	1913
Sparks Drain	1.50	1914
Swain Drain (Isabella County)	3.00	1894
Turner Drain (Isabella County)	2.00	1911
• *Lee Township*		
Baker Drain(Homer)	3.60	1902
Caywood Drain(Greendale Jasper, Porter)	2.00	1961
Emma Drain (Greendale)	1.00	2000
Frank Drain (Porter)	1.00	1919
Herrill Drain	3.00	1915
Hoxie Drain (Porter)	4.80	1902
Huber Drain (Porter, Homer)	5.50	1913
Lawson Drain (Greendale)	4.00	1917
Prairie Drain (Greendale)	9.00	1908
Turkey Creek (Porter)	14.00	1914
Unnamed Drain	3.00	N/A
Wilson Drain 2 (Homer)	3.00	1899
• *Porter Township*		
Caywood Drain(Greendale Jasper, Lee)	2.00	1961
Frank Drain (Lee)	1.00	1919

Table 29.–Continued.

Drain	Length (mi)	Est.	Drain	Length (mi)	Est.
Chippewa River, *Midland County*–continued					
• *Porter Township* – continued			• *Homer Township* – continued		
Hoxie Drain (Lee)	4.80	1902	Dice Drain	4.00	1903
Huber Drain (Lee, Homer)	5.50	1913	Huber Drain (Porter, Lee)	5.50	1913
Turkey Creek (Lee)	14.00	1914	Wilson Drain 2 (Lee)	3.00	1899
Wilson Drain	2.50	1889	• *CityTownship*		
• *Homer Township*			Burgoon Drain (Homer, City)	2.00	1909
Baker Drain(Lee)	3.60	1902	Hepner Drain	0.50	1913
Burgoon Drain (Mills, City)	2.00	1909	O'Conner Drain	1.00	1951
Pine River					
Mecosta County			• *Fremont Township* – continued		
• *Wheatland Township*			Russell Drain	2.11	1923
Pine Lake Drain	1.90	1911	Stanley	5.10	1900
Martin Drain	3.05	1917	*Montcalm County*		
Cummins Drain	0.54	1921	• *Home Township*		
Millbrook Jt. Drain(Isabella County)	1.47	1918	100 (Richland, Ferris)	3.78	1901
Gingrich Drain	0.79	1912	Dallavo Drain	0.64	1898
• *Millbrook Township*			Edmore Sewer	0.63	1940
Blanchard Jt. Drain (Isabella)	1.26	1916	Parmeter Drain	N/A	N/A
Isabella County			Wilson Drain	1.62	1898
• *Broomfield Township*			100 (Richland, Ferris)	3.78	1901
Millbrook Jt. Drain (Mecosta County)	3.05	1919	Dallavo Drain	0.64	1898
Riggle Marsh Drain (Rolland, Fremont)	4.00	1904	• *Richland Township*		
• *Rolland Township*			Erskin Drain	0.95	1916
Blanchard Drain (Mecosta County)	3.70	1915	Fisk and Johnson Drain	0.66	1898
Delo Drain	1.04	1915	Galvin Drain	2.79	1952
Foster Drain (Fremont)	1.28	1916	Lacey and Hall Drain	1.11	1904
Guy Drain	0.10	1916	Montc/Isabella Drain (Isabella County)	0.75	N/A
Howard Drain (Fremont)	1.50	1905	Richland Drain	0.80	1944
Masters Drain (Fremont)	1.49	1916	100 (Home, Ferris)	3.78	1901
Moody Drain	1.70	1917	• *Ferris Township*		
Riggle Marsh Drain (Broomfield)	4.00	1904	Corbin Creek	11.9	1893
Stanley Drain (Fremont)	5.10	1900	Ext. 131 (Gratiot County, Crystal)	5.29	1916
• *Fremont Township*			Ferris Creek and Brs.	5.27	1900
Bundy Drain	1.24	1883	Howe Drain	2.12	1923
Delo Drain(Rolland)	1.04	1915	Kneer/Robinson (Gratiot County, Crystal)	3.00	1893
Demlow Drain	1.41	1907	Whetsone (Crystal)	3.02	1952
Foster Drain (Rolland)	1.28	1916	*Gratiot County*		
Masters (Rolland)	1.49	1906	• *Seville Township*		
Howard Drain (Rolland)	1.50	1905	96 (Sumner, Pine River, Arcada)	8.32	1894
Bundy Drain	1.24	1883	105 (Pine River, Bethany)	5.25	1998
Delo Drain(Rolland)	1.04	1915	174	6.60	1900
Demlow Drain	1.41	1907	176	5.20	1901
Foster Drain (Rolland)	1.28	1916	177	0.80	1902
Masters (Rolland)	1.49	1906	178 (Montalm County)	0.26	1903
Howard Drain (Rolland)	1.50	1905	226	1.80	1902
Richardson Drain	0.95	1898	243 (Pine River, Arcada, Seville, Bethany)	0.60	1909
Riggle Marsh Drain(Broomfield, Fremont)	4.00	1904	290 (Sumner, Arcada)	5.80	1912

Table 29.–Continued.

Drain	Length (mi)	Est.	Drain	Length (mi)	Est.
Pine River, *Gratiot County*–continued					
• Seville Township – continued			• Newhaven Township – continued		
321	1.60	1914	303 (Sumner)	1.50	1912
507	0.25	1954	557 (Montcalm County, Sumner)	1.13	1950
553 (Isabella County)	1.00	1943	• *Pine River Township*		
556 (Isabella County)	1.10	1918	21 (Emerson, Arcada)	2.00	1882
• *Sumner Township*			52 (Emerson, Arcada)	6.20	1898
36 (Newhaven)	1.83	1890	73 (Arcada)	11.60	1906
70	5.40	1902	96 (Seville, Sumner, Arcada)	8.32	1894
96 (Seville, Pine River, Arcada)	8.32	1894	104 (Bethany)	4.18	1898
97	2.00	1904	105 (Pine Rr, Seville, Sumner)	5.25	1998
111 (Newhaven, Arcada)	17.40	1887	160 (Arcada)	5.50	1888
112	4.76	1898	180	0.50	1996
113	6.60	1898	218 (Bethany, Emerson)	7.78	1880
126 (Newhaven)	1.15	1889	199	2.29	1906
147	0.63	1890	231(Midland County, Bethany)	5.00	1884
166	5.50	1901	232 (Bethany)	1.64	1892
167	3.90	1901	243 (Arcada,Sumner,Bethany, Seville)	1.50	1909
189	0.26	1905	251 (Midland County, Bethany)	1.75	1894
243 (Arcada, Seville, Bethany, PineR)	1.50	1909	254	2.25	1911
263	1.40	1910	283 (Bethany)	9.00	1911
290 (Seville, Arcada)	5.80	1912	319	2.47	1913
291	4.00	1912	335 (Arcada)	1.80	1915
303 (Newhaven)	1.50	1912	339	4.96	1915
318	1.50	1914	343 (Bethany)	0.60	1909
337	3.00	1915	374	1.01	1917
366	3.15	1916	384 (Midland)	1.00	1914
367	0.70	1915	398	1.60	1918
388	0.50	1883	418 (Arcada)	4.48	1920
420	1.00	1920	424 (Bethany)	0.65	1923
443	0.46	1928	432 (Arcada)	0.28	1925
557 (Montcalm County, Newhaven)	1.13	1950	441	0.57	1927
263	1.40	1910	445	0.88	1928
290 (Seville, Arcada)	5.80	1912	463	0.40	1930
291	4.00	1912	464	1.40	1930
303 (Newhaven)	1.50	1912	470	0.56	1926
318	1.50	1914	486	0.52	1969
337	3.00	1915	491	0.62	1948
366	3.15	1916	497	2.15	N/A
367	0.70	1915	501	0.44	1952
388	0.50	1883	539 (Midland County)	1.14	1913
420	1.00	1920	• *Arcada Township*		
443	0.46	1928	1	4.30	1894
557 (Montcalm County, Newhaven)	1.13	1950	8	1.20	1879
• *Newhaven Township*			21 (Emerson, Pine River)	2.00	1882
36 (Sumner)	1.83	1890	24	3.29	1888
110 (Arcada, Sumner, Newark)	7.73	1915	52 (Emerson, Pine River)	6.20	1908
111 (Newhaven, Arcada)	17.40	1887	73 (Pine River)	11.60	1906
126 (Sumner)	1.15	1889	96 (Seville, Sumner, Pine River)	8.32	1894

Table 29.–Continued.

Drain	Length (mi)	Est.
Pine River, *Gratiot County*–continued		
• *Arcada Township* – continued		
108	0.75	1898
110 (Newhaven, Newark)	7.73	1915
144 (Emerson)	7.40	1988
160 (Pine River)	5.50	1888
235	1.60	1905
243 (Pine River, Sumner, Bethany, Seville)	1.50	1909
264	1.40	1910
285	2.26	1910
290 (Sumner, Seville)	5.80	1912
291 (Sumner)	4.00	1912
320	0.64	1914
335 (Pine River)	1.80	1915
418 (Pine River)	4.48	1920
432 (Pine River)	0.28	1925
437	1.26	1927
450	1.20	1928
504	0.94	1954
519	0.30	1960
• *Newark Township*		
110 (Newhaven, Arcada)	7.73	1915
• *Emerson Township*		
3 (Midland County, Bethany)	11.65	1881
21 (Arcada, Pine River)	2.00	1882
22 (Bethany)	4.14	1889
29 (Bethany)	2.85	1891
52 (Arcada, Pine River)	6.20	1908
128 (Emerson)	3.96	1898
144 (Arcada)	7.40	1988
218 (Pine River)	7.78	1880
320	0.65	1914
338	1.39	1915
• *Bethany Township*		
3 (Midland County, Emerson)	11.65	1881
22 (Emerson)	4.14	1889
29 (Emerson)	2.85	1891
3 (Midland County, Bethany)	11.65	1881
21 (Arcada, Pine River)	2.00	1882
22 (Bethany)	4.14	1889
29 (Bethany)	2.85	1891
52 (Arcada, Pine River)	6.20	1908
128 (Emerson)	3.96	1898
144 (Arcada)	7.40	1988
218 (Pine River)	7.78	1880
320	0.65	1914
338	1.39	1915
41	4.60	1925
78	0.83	1908
• *Bethany Township* – continued		
86 (Midland County)	2.16	1889
89 (Midland County)	5.10	1903
93 (Midland County)	0.89	1903
94	1.48	1903
104 (Pine River)	4.18	1898
105 (Pine River, Seville, Sumner)	5.25	1998
116	6.03	1898
128 (Emerson)	3.96	1898
148	0.80	1900
170 (Wheeler)	2.39	1888
202 (Midland County)	1.93	1905
218	7.78	1880
231(Midland County, Pine River)	5.00	1884
232 (Pine River)	1.64	1892
246 (Midland County)	0.42	1892
251 (Midland County, Pine River)	1.75	1894
265	2.52	1910
283 (Pine River)	9.00	1911
329	2.44	1902
371	1.00	1915
372 (Wheeler)	1.05	1917
373	0.70	1916
384	0.54	1916
415	0.50	1921
424 (Pine River)	0.65	1923
568	1.89	1929
595	0.75	1890
• *Wheeler Township*		
31 (Midland County)	10.00	1887
42	7.68	1889
208 (Midland County)	3.70	1905
372 (Bethany)	1.05	1917
381	2.40	1885
478 (Midland County)	1.70	1941
522	1.00	1965
554 (Midland County)	1.00	1930
575	1.80	1957
580 (Midland County)	2.50	1957
Midland County		
• *JasperTownship*		
Bear Head Drain (Gratiot County)	2.00	1902
Bush Drain (Gratiot County, Porter)	4.50	1914
Davis Drain	5.00	1912
Forest Drain	0.25	1966
Hagen Drain	1.50	1907
Irvin Drain	1.00	1912
Laning Drain	0.75	1911

Table 29.–Continued.

Drain	Length (mi)	Est.	Drain	Length (mi)	Est.
Pine River, Midland *County*–continued					
• *JasperTownship* – continued			• *Porter Township* – continued		
Nevins Drain	1.00	1903	Stoneman Drain (Gratiot County)	0.50	1968
Townline Drain (*Gratiot County*)	2.00	1905	Sucker Drain (Gratiot County)	7.00	1888
Wells Drain (*Gratiot County*)	0.50	1925	Townline Drain (Gratiot County, Jasper)	2.00	1905
• *Lee Township*			Wayne Drain	1.50	1911
Wilson Drain#2	2.50	1889	Whitney Drain	1.50	1906
• *Porter Township*			• *Homer Township*		
Brue Drain	3.50	1915	Brewer Drain .	2.00	1893
Bush Drain	4.50	1914	Frost Drain	2.00	1899
Bush Drain (Gratiot County)	2.80	1901	King Drain(Porter, Mt. Haley)	9.00	1901
Centerline Drain	4.80	1897	Rose Glenn	0.50	1993
Davis Drain(Jasper)	5.00	1912	Unknown Drain	1.50	N/A
Hastings Drain	2.00	1912	Woodcock Drain	0.50	N/A
Jackson Drain	2.00	1910	• *Mt. Haley Township*		
King Drain (Homer, Mt. Haley)	9.00	1901	King Drain(Porter, Homer)	9.00	1901
McNeill Drain	1.00	1904	Mt. Haley Drain	8.50	1902
Redstone Drain	2.00	1896			

Table 30.–State and Federal land areas (acres) within the Tittabawassee River watershed for catchments of the main stem segments and their major tributaries. Catchment summaries for a segment represent the local landscape that contributes water to the segment and do not represent the cumulative upstream landscape.

Owner Type	Headwaters	Middle	Tobacco	Mouth	Salt	Chippewa	Pine
Michigan							
State forest	27,199	68,915	12,551	15,498	12,849	8,291	52
Public - general	423	612	3,954	2,024	609	3,563	1,537
State game areas						4,126	3,340
State park			36				
Federal							
Nat. wildlife refuge				145			
Total public lands	27,622	69,527	16,540	17,667	13,458	15,980	4,929

Table 31.–List of fishes in the Tittabawassee River watershed. Origin: N = native, C = colonized, I = introduced. Status: O = extirpated, P = recent observations, U = historic record-current status unknown. Data from: University of Michigan records; Michigan Department of Natural Resources, Fisheries Division records; Michigan Department of Environmental Quality, Surface Water Quality Division records, Environmental Science & Engineering Consultants (1983); and United States Fish and Wildlife Service records.

Common name	Scientific name	Origin	Status
Lampreys			
northern brook lamprey	*Ichthyomyzon fossor*	N	P
American brook lamprey	*Lampetra appendix*	N	P
sea lamprey	*Petromyzon marinus*	C	P
Sturgeons			
lake sturgeon **(threatened)**	*Acipenser fulvescens*	N	P
Gars			
longnose gar	*Lepisosteus osseus*	N	P
Bowfins			
bowfin	*Amia calva*	N	P
Herrings			
alewife	*Alosa pseudoharengus*	C	P
gizzard shad	*Dorosoma cepedianum*	N	P
Carps and minnows			
central stoneroller	*Campostoma anomalum*	N	P
goldfish	*Carassius auratus*	I	P
spotfin shiner	*Cyprinella spiloptera*	N	P
common carp	*Cyprinus carpio*	I	P
brassy minnow	*Hybognathus hankinsoni*	N	P
common shiner	*Luxilus cornutus*	N	P
redfin shiner	*Lythrurus umbratilis*	N	U
pearl dace	*Margariscus nachtriebi*	N	P
hornyhead chub	*Nocomis biguttatus*	N	P
river chub	*Nocomis micropogon*	N	P
golden shiner	*Notemigonus crysoleucas*	N	P
pugnose shiner (**special concern**)	*Notropis anogenus*	N	U
emerald shiner	*Notropis atherinoides*	N	P
blackchin shiner	*Notropis heterodon*	N	P
blacknose shiner	*Notropis heterolepis*	N	P
spottail shiner	*Notropis hudsonius*	N	P
rosyface shiner	*Notropis rubellus*	N	P
sand shiner	*Notropis stramineus*	N	P
mimic shiner	*Notropis volucellus*	N	P
northern redbelly dace	*Phoxinus eos*	N	P
finescale dace	*Phoxinus neogaeus*	N	P
bluntnose minnow	*Pimephales notatus*	N	P
fathead minnow	*Pimephales promelas*	N	P
longnose dace	*Rhinichthys cataractae*	N	P
blacknose dace	*Rhinichthys obtusus*	N	P

Table 31.–Continued.

Common name	Scientific name	Origin	Status
Carps and minnows–continued			
creek chub	*Semotilus atromaculatus*	N	P
Suckers			
quillback	*Carpiodes cyprinus*	N	P
longnose sucker	*Catostomus catostomus*	N	P
white sucker	*Catostomus commersonii*	N	P
lake chubsucker	*Erimyzon sucetta*	N	P
northern hog sucker	*Hypentelium nigricans*	N	P
silver redhorse	*Moxostoma anisurum*	N	U
black redhorse	*Moxostoma carinatum*	N	P
golden redhorse	*Moxostoma erythrurum*	N	P
shorthead redhorse	*Moxostoma macrolepidotum*	N	P
greater redhorse	*Moxostoma valenciennesi*	N	U
Bullhead catfishes			
black bullhead	*Ameiurus melas*	N	P
yellow bullhead	*Ameiurus natalis*	N	P
brown bullhead	*Ameiurus nebulosus*	N	P
channel catfish	*Ictalurus punctatus*	N	P
stonecat	*Noturus flavus*	N	P
tadpole madtom	*Noturus gyrinus*	N	P
flathead catfish	*Pylodictis olivaris*	C	P
Pikes			
grass pickerel	*Esox americanus*	N	P
northern pike	*Esox lucius*	N	P
muskellunge	*Esox masquinongy*	N	P
Mudminnows			
central mudminnow	*Umbra limi*	N	P
Trouts			
lake herring **(threatened)**	*Coregonus artedi*	N	O
lake whitefish	*Coregonus clupeaformis*	N	U
rainbow trout	*Oncorhynchus mykiss*	I	P
coho salmon	*Oncorhynchus kisutch*	I	P
Chinook salmon	*Oncorhynchus tshawytscha*	I	P
brown trout	*Salmo trutta*	I	P
brook trout	*Salvelinus fontinalis*	I	P
lake trout	*Salvelinus namaycush*	N	P
Trout-perches			
trout-perch	*Percopsis omiscomaycus*	N	P
Pirate perches			
pirate perch	*Aphredoderus sayanus*	N	P
Killifishes			
banded killifish	*Fundulus diaphanus*	N	P

Table 31.–Continued.

Common name	Scientific name	Origin	Status
Silversides			
brook silverside	*Labidesthes sicculus*	N	P
Sticklebacks			
brook stickleback	*Culaea inconstans*	N	P
Sculpin			
mottled sculpin	*Cottus bairdi*	N	P
Smelt			
rainbow smelt	*Osmerus mordax*	C	P
Temperate basses			
white perch	*Morone americana*	C	P
white bass	*Morone chrysops*	N	P
Sunfishes			
rock bass	*Ambloplites rupestris*	N	P
green sunfish	*Lepomis cyanellus*	N	P
pumpkinseed	*Lepomis gibbosus*	N	P
bluegill	*Lepomis macrochirus*	N	P
longear sunfish	*Lepomis peltastes*	N	P
redear sunfish	*Lepomis microlophus*	I	P
smallmouth bass	*Micropterus dolomieu*	N	P
largemouth bass	*Micropterus salmoides*	N	P
white crappie	*Pomoxis annularis*	N	P
black crappie	*Pomoxis nigromaculatus*	N	P
Perches			
rainbow darter	*Etheostoma caeruleum*	N	P
Iowa darter	*Etheostoma exile*	N	P
least darter	*Etheostoma microperca*	N	P
fantail darter	*Etheostoma flabellare*	N	P
johnny darter	*Etheostoma nigrum*	N	P
yellow perch	*Perca flavescens*	N	P
logperch	*Percina caprodes*	N	P
blackside darter	*Percina maculata*	N	P
walleye	*Sander vitreus*	N	P
Drums			
freshwater drum	*Aplodinotus grunniens*	N	P
Gobies			
round goby	*Neogobius melanostomus*	I	P

Table 32.–Aquatic macroinvertebrates of the headwaters Tittabawassee River. Data code: X = present, blank indicates not collected. Data from Cooper (2002).

	Tittabawassee River sites (Road crossing)		
Taxa	Middle Branch (Bensch)	East Branch (Hemer)	West Branch (Fitzwater)
Porifera (sponges)	X		
Bryozoa (moss animals)		X	
Platyhelminthes (flatworms)			
Turbellaria	X		
Annelida (segmented worms)			
Hirudinea (leeches)		X	X
Oligochaeta (worms)	X	X	X
Arthropoda			
Crustacea			
Amphipoda (scuds)	X	X	X
Decapoda (crayfish)	X	X	X
Isopoda (sowbugs)			
Arachnoidea			
Hydracarina (mites)	X		X
Insecta			
Ephemeroptera (mayflies)			
Baeticidae		X	
Baetidae	X	X	X
Caenidae			
Ephemerellidae			
Ephemeridae	X	X	
Heptageniidae	X	X	X
Isonychiidae	X	X	X
Syphlomuridae			X
Potamanthidae			
Tricorythidae			
Odonata			
Anisoptera (dragonflies)			
Aeshnidae	X	X	
Cordulegastridae	X		
Gomphidae	X	X	X
Libellulidae	X		
Zygoptera (damselflies)			
Calopterygidae	X	X	X
Coenagrionidae			
Lestidae			
Perlodidae			
Plecoptera (stone flies)			
Perlidae	X	X	X
Pteronarcyidae			X

Table 32.–Continued.

Taxa	Tittabawassee River sites (Road crossing) Middle Branch (Bensch)	East Branch (Hemer)	West Branch (Fitzwater)
Insecta–continued			
Hemiptera (true bugs)			
Belastomatidae	X		
Corixidae	X	X	
Gerridae	X	X	X
Nepidae			
Notonectidae			
Pleidae			
Veliidae			
Saldidae			
Megaloptera			
Corydalidae (dobson flies)	X	X	X
Sialidae (alder flies)	X	X	
Trichoptera (caddisflies)			
Brachycentridae	X	X	X
Glossosmatidae	X		X
Helicopsychidae	X		X
Hydropsychidae		X	
Hydroptilidae	X		
Lepidostomatidae	X		
Leptoceridae		X	X
Limnephilidae	X	X	X
Molannidae			
Philopotamidae		X	
Phryganeidae	X	X	
Uenoidae		X	
Lepidoptera (moths)			
Nornidae			
Coleoptera (beetles)			
Amphizoidea			
Dryopidae			
Dyticsidae			
Elmidae			
Gyrinidae			
Haliplidae	X	X	
Psephenidae			
Scirtidae (adults)	X		X
Diptera (flies)			
Athericidae	X	X	X
Ceratopogonidae			
Culicidae		X	X
Chironomidae	X	X	X
Ephydridae			
Muscidae			
Sciomyzidae			
Simuliidae	X	X	
Stationyidae			
Tabanidae		X	
Tipulidae			

Table 32.–Continued.

Taxa	Tittabawassee River sites (Road crossing)		
	Middle Branch (Bensch)	East Branch (Hemer)	West Branch (Fitzwater)
Mollusca			
Gastropoda (snails and limpets)			
Ancylidae	X		
Lymnaeidae	X	X	
Physidae		X	
Planorbidae	X	X	
Bithyniidae			
Pleuroceridae			
Pomatiopsidae			
Vivaparidae			
Bivalvia (bivalves)			
Sphaeriidae	X		X
Unionidae		X	
Pisididae			

Table 33.–Aquatic macroinvertebrates of the tributaries to the middle segment Tittabawassee River. Data code: X = present, blank indicates not collected. Data from Cooper (2002).

	River or Creek sites (Road crossing)				
Taxa	Larrabee (Creel survey) (Weiman)	Molasses (M-61)	Black (M-61)	Sugar (M-30)	Little Tobacco (Drain)
Porifera (sponges)					
Bryozoa (moss animals)				X	
Platyhelminthes (flatworms)					
Turbellaria				X	
Annelida (segmented worms)					
Hirudinea (leeches)		X	X	X	X
Oligochaeta (worms)				X	
Arthropoda					
Crustacea					
Amphipoda (scuds)	X	X	X	X	X
Decapoda (crayfish)	X	X	X	X	X
Isopoda (sowbugs)					
Arachnoidea					
Hydracarina (mites)					
Insecta					
Ephemeroptera (mayflies)					
Baeticidae				X	
Baetidae	X	X	X	X	X
Caenidae		X		X	X
Ephemerellidae					
Ephemeridae				X	
Heptageniidae	X	X	X	X	X
Isonychiidae				X	
Syphlomuridae					
Potamanthidae					
Tricorythidae					
Odonata					
Anisoptera (dragonflies)					
Aeshnidae	X		X	X	
Cordulegastridae					
Gomphidae				X	
Libellulidae					
Zygoptera (damselflies)					
Calopterygidae	X	X	X	X	X
Coenagrionidae					
Lestidae					
Perlodidae					
Plecoptera (stone flies)					
Perlidae	X		X	X	
Pteronarcyidae				X	

Table 33.–Continued.

Taxa	River or Creek sites (Road crossing)				
	Larrabee (Creel survey) (Weiman)	Molasses (M-61)	Black (M-61)	Sugar (M-30)	Little Tobacco (Drain)
Insecta–continued					
Hemiptera (true bugs)					
Belastomatidae		X	X		X
Corixidae	X	X		X	X
Gerridae	X	X	X		X
Nepidae					
Notonectidae					
Pleidae					
Veliidae	X				
Saldidae					
Megaloptera					
Corydalidae (dobson flies)	X			X	X
Sialidae (alder flies)	X	X	X	X	
Trichoptera (caddisflies)					
Brachycentridae				X	
Glossosmatidae					
Helicopsychidae	X			X	X
Hydropsychidae		X		X	
Hydroptilidae				X	
Lepidostomatidae					
Leptoceridae	X		X	X	X
Limnephilidae	X	X		X	
Molannidae					
Philopotamidae			X		
Phryganeidae				X	
Uenoidae					
Lepidoptera (moths)					
Nornidae		X			X
Coleoptera (beetles)					
Amphizoidea					
Dryopidae					
Dyticsidae					
Elmidae	X	X		X	
Gyrinidae					
Haliplidae	X		X		
Psephenidae				X	X
Scirtidae (adults)		X	X		X
Diptera (flies)					
Athericidae			X	X	
Ceratopogonidae					
Culicidae		X			X
Chironomidae	X	X		X	X
Ephydridae					
Muscidae					
Sciomyzidae					

Table 33.–Continued.

Taxa	River or Creek sites (Road crossing)				
	Larrabee (Creel survey) (Weiman)	Molasses (M-61)	Black (M-61)	Sugar (M-30)	Little Tobacco (Drain)
Insecta–continued					
Simuliidae		X			X
Statiomyidae					
Tabanidae	X	X		X	X
Tipulidae	X	X		X	
Mollusca					
Gastropoda (snails and limpets)					
Ancylidae					
Lymnaeidae					
Physidae	X	X	X	X	X
Planorbidae	X				
Bithyniidae					
Pleuroceridae					
Pomatiopsidae					
Vivaparidae					
Bivalvia (bivalves)					
Sphaeriidae	X	X	X	X	X
Unionidae				X	
Pisididae					

Table 34.–Aquatic macroinvertebrates of the Tobacco River. Data code: X = present, blank indicates not collected. Data from Cooper (2002).

	River or creek sites (Road crossing)					
Taxa	Little Cedar (Dale)	Cedar (Campbell)	N. Br. Tobacco (Grout)	Mid. Br. Tobacco (McCollouch)	S. Br. Tobacco (Grout)	S. Br. Tobacco (Grant)
Porifera (sponges)	X					
Bryozoa (moss animals)		X				
Platyhelminthes (flatworms)						
Turbellaria		X				
Annelida (segmented worms)						
Hirudinea (leeches)					X	X
Oligochaeta (worms)	X		X	X		
Arthropoda						
Crustacea						
Amphipoda (scuds)	X	X	X	X	X	X
Decapoda (crayfish)	X	X	X	X	X	X
Isopoda (sowbugs)	X				X	
Arachnoidea						
Hydracarina (mites)			X	X		X
Insecta						
Ephemeroptera (mayflies)						
Baeticidae						
Baetidae	X	X	X		X	X
Caenidae		X	X		X	
Ephemerellidae					X	
Ephemeridae			X			
Heptageniidae	X	X	X	X	X	X
Isonychiidae		X	X	X	X	X
Leptophlebiidae						
Potamanthidae						
Tricorythidae						
Odonata						
Anisoptera (dragonflies)						
Aeshnidae	X	X		X	X	X
Corduliidae						
Gomphidae			X			
Libellulidae						
Zygoptera (damselflies)						
Calopterygidae	X	X	X	X	X	X
Coenagrionidae						
Lestidae						
Perlodidae						
Plecoptera (stone flies)						
Perlidae	X	X	X	X	X	X
Pteronarcyidae		X	X	X	X	

Table 34.–Continued.

Taxa	Little Cedar (Dale)	Cedar (Campbell)	N. Br. Tobacco (Grout)	Mid. Br. Tobacco (McCollouch)	S. Br. Tobacco (Grout)	S. Br. Tobacco (Grant)
	River or creek sites (Road crossing)					
Insecta–continued						
Hemiptera (true bugs)						
Belastomatidae						
Corixidae			X			
Gerridae	X	X	X	X	X	X
Mesoveliidae				X	X	X
Notonectidae						
Pleidae						X
Veliidae			X			
Saldidae						
Megaloptera						
Corydalidae (dobson flies)		X	X	X	X	X
Sialidae (alder flies)						
Trichoptera (caddisflies)						
Brachycentridae		X	X	X	X	X
Glossosmatidae						X
Helicopsychidae	X	X	X	X		X
Hydropsychidae		X	X	X	X	X
Hydroptilidae						
Lepidostomatidae		X				
Leptoceridae						X
Limnephilidae	X	X	X	X	X	X
Molannidae						
Philopotamidae		X	X			
Polycentropodidae						
Uenoidae		X	X	X		X
Coleoptera (beetles)						
Amphizoidea						
Dryopidae						
Dyticsidae		X				
Elmidae	X	X	X	X		
Gyrinidae		X			X	X
Haliplidae						
Psephenidae		X				X
Scirtidae (adults)						
Diptera (flies)						
Athericidae		X	X	X	X	
Ceratopogonidae						
Culicidae						
Chironomidae	X	X	X	X	X	X
Ephydridae						
Muscidae						
Sciomyzidae						
Simuliidae		X	X	X		
Statiomyidae						

Table 34.–Continued.

Taxa	Little Cedar (Dale)	Cedar (Campbell)	N. Br. Tobacco (Grout)	Mid. Br. Tobacco (McCollouch)	S. Br. Tobacco (Grout)	S. Br. Tobacco (Grant)
	River or creek sites (Road crossing)					
Insecta–continued						
Tabanidae		X				
Tipulidae			X	X		X
Mollusca						
Gastropoda (snails and limpets)						
Ancylidae	X	X	X			
Lymnaeidae						
Physidae					X	X
Planorbidae						
Bithyniidae						
Pleuroceridae						
Pomatiopsidae						
Vivaparidae	X	X	X			
Bivalvia (bivalves)						
Sphaeriidae	X	X		X	X	X
Unionidae			X			
Pisididae						

Table 35.–Aquatic macroinvertebrates of the tributaries to the mouth segment Tittabawassee River. Data code: X = present, blank indicates not collected. Data from Cooper (2002).

	River or Creek sites (Road crossing)	
Taxa	Carrol (Meridian)	Bullock (Poseyville)
Porifera (sponges)	X	
Bryozoa (moss animals)	X	
Platyhelminthes (flatworms)		
Turbellaria		X
Annelida (segmented worms)		
Hirudinea (leeches)		
Oligochaeta (worms)	X	
Arthropoda		
Crustacea		
Amphipoda (scuds)	X	X
Decapoda (crayfish)	X	X
Isopoda (sowbugs)		X
Arachnoidea		
Hydracarina (mites)		
Insecta		
Ephemeroptera (mayflies)		
Baeticidae	X	
Baetidae	X	X
Caenidae		
Ephemerellidae		
Ephemeridae		
Heptageniidae	X	X
Isonychiidae		
Syphlomuridae		
Potamanthidae		
Tricorythidae		
Odonata		
Anisoptera (dragonflies)		
Aeshnidae	X	X
Cordulegastridae		
Gomphidae	X	
Libellulidae		
Zygoptera (damselflies)		
Calopterygidae	X	X
Coenagrionidae		
Lestidae		
Perlodidae		
Plecoptera (stone flies)		
Perlidae		
Pteronarcyidae		
Hemiptera (true bugs)		
Belastomatidae		
Corixidae		X
Gerridae	X	X
Nepidae		X

Table 35.–Continued.

Taxa	River or Creek sites (Road crossing)	
	Carrol (Meridian)	Bullock (Poseyville)
Insecta–continued		
Notonectidae		
Pleidae		
Veliidae		
Saldidae		
Megaloptera		
Corydalidae (dobson flies)	X	X
Sialidae (alder flies)		
Trichoptera (caddisflies)		
Brachycentridae		
Glossosmatidae		
Helicopsychidae		
Hydropsychidae	X	
Hydroptilidae		
Lepidostomatidae		
Leptoceridae	X	
Limnephilidae	X	X
Molannidae		
Philopotamidae		
Phryganeidae	X	X
Uenoidae		X
Lepidoptera (moths)		
Nornidae	X	
Coleoptera (beetles)		
Amphizoidea		
Dryopidae		
Dyticsidae		
Elmidae	X	X
Gyrinidae		
Haliplidae		X
Psephenidae		
Scirtidae (adults)		
Diptera (flies)		
Athericidae		
Ceratopogonidae		
Culicidae		X
Chironomidae	X	X
Ephydridae		
Muscidae		
Sciomyzidae		
Simuliidae		
Stationyidae		
Tabanidae	X	
Tipulidae	X	X
Mollusca		
Gastropoda (snails and limpets)		
Ancylidae		
Lymnaeidae		
Physidae	X	X
Planorbidae		

Table 35.–Continued.

Taxa	River or Creek sites (Road crossing)	
	Carrol (Meridian)	Bullock (Poseyville)
Mollusca–continued		
Bithyniidae		
Pleuroceridae		
Pomatiopsidae		
Vivaparidae		
Bivalvia (bivalves)		
Sphaeriidae	X	X
Unionidae		
Pisididae		

Table 36.–Aquatic macroinvertebrates of the Salt River. Data code: X = present, blank indicates not collected. Data from Cooper (2002).

	River or Creek sites (Road crossing)	
Taxa	Bluff (Weinert)	Salt (Coleman)
Porifera (sponges)		
Bryozoa (moss animals)	X	X
Platyhelminthes (flatworms)		
Turbellaria		X
Annelida (segmented worms)		
Hirudinea (leeches)		
Oligochaeta (worms)		X
Arthropoda		
Crustacea		
Amphipoda (scuds)	X	X
Decapoda (crayfish)	X	X
Isopoda (sowbugs)		X
Arachnoidea		
Hydracarina (mites)	X	X
Insecta		
Ephemeroptera (mayflies)		
Baeticidae	X	
Baetidae	X	X
Caenidae		
Ephemerellidae		
Ephemeridae		
Heptageniidae	X	X
Isonychiidae		
Leptophlebiidae		
Potamanthidae		
Siphlonuridae		X
Tricorythidae	X	X
Odonata		
Anisoptera (dragonflies)		
Aeshnidae	X	X
Corduliidae		
Gomphidae	X	X
Libellulidae		
Zygoptera (damselflies)		
Calopterygidae	X	X
Perlodidae		
Plecoptera (stone flies)		
Perlidae		X
Pteronarcyidae		
Hemiptera (true bugs)		
Belastomatidae		X
Corixidae	X	X
Galastocoridae		X
Gerridae	X	X
Mesoveliidae		

Table 36.–Continued.

Taxa	River or Creek sites (Road crossing)	
	Bluff (Weinert)	Salt (Coleman)
Notonectidae		
Pleidae		
Veliidae		
Saldidae		
Megaloptera		
Corydalidae (dobson flies)	X	X
Sialidae (alder flies)	X	X
Trichoptera (caddisflies)		
Brachycentridae		
Glossosmatidae		
Helicopsychidae		X
Hydropsychidae	X	X
Hydroptilidae		
Lepidostomatidae		
Leptoceridae	X	X
Limnephilidae	X	X
Pharyganeidae		X
Philopotamidae		
Polycentropodidae		
Uenoidae	X	X
Coleoptera (beetles)		
Amphizoidea		
Dryopidae		
Dyticsidae		
Elmidae	X	X
Gyrinidae		
Haliplidae	X	X
Psephenidae	X	X
Scirtidae (adults)		
Diptera (flies)		
Athericidae	X	
Ceratopogonidae		
Culicidae		
Chironomidae	X	X
Dixidae		X
Muscidae		
Sciomyzidae		
Simuliidae	X	X
Statiomyidae		
Tabanidae	X	X
Tipulidae	X	X
Mollusca		
Gastropoda (snails and limpets)		
Ancylidae		
Lymnaeidae		X
Physidae	X	X
Planorbidae	X	

Table 36.–Continued.

Taxa	River or Creek sites (Road crossing)	
	Bluff (Weinert)	Salt (Coleman)
Bithyniidae		
Pleuroceridae		X
Pomatiopsidae		
Vivaparidae		
Bivalvia (bivalves)		
Sphaeriidae	X	X
Unionidae		X
Pisididae		

Table 37.–Aquatic macroinvertebrates of the Chippewa River. Data code: X = present, blank indicates not collected. Data from Cooper (2002).

	River or Creek sites (Road crossing)											
Taxa	Chippewa (Meridian)	Chippewa (M-20)	Chippewa (S.Meridian)	Chippewa (Coldwater)	L. Salt (McGruder)	L. Salt (9-Mile)	Salt (Alamondo)	N. Br. Chippewa east (S.Nottawa)	N. Br. Chippewa east (Rosebush)	N. Br. Chippewa east (Stevenson Lake)	Coldwater (Baseline)	Coldwater (Vernon)
Porifera (sponges)				X			X					
Bryozoa (moss animals)	X		X	X				X		X		
Platyhelminthes (flatworms)												
Turbellaria	X	X	X	X	X	X		X				
Annelida (segmented worms)												
Hirudinea (leeches)		X	X	X	X	X	X	X		X	X	X
Oligochaeta (worms)					X				X			
Arthropoda												
Crustacea												
Amphipoda (scuds)	X	X	X	X	X	X	X	X	X	X	X	
Decapoda (crayfish)	X	X	X	X	X		X	X	X	X	X	
Isopoda (sowbugs)	X				X			X	X	X	X	
Arachnoidea												
Hydracarina (mites)	X				X							
Insecta												
Ephemeroptera (mayflies)												
Baeticidae								X		X		
Baetidae	X	X	X		X	X	X	X	X	X	X	
Caenidae	X			X	X	X	X			X	X	
Ephemerellidae	X		X	X			X				X	
Ephemeridae		X		X			X					
Heptageniidae	X	X	X		X	X		X	X	X	X	
Isonychiidae	X	X	X									
Leptophlebiidae												

Table 37.–Continued.

Taxa	Chippewa (Meridian)	Chippewa (M-20)	Chippewa (S.Meridian)	Chippewa (Coldwater)	L. Salt (McGruder)	L. Salt (9-Mile)	Salt (Alamondo)	N. Br. Chippewa east (S.Nottawa)	N. Br. Chippewa east (Rosebush)	N. Br. Chippewa east (Stevenson Lake)	Coldwater (Baseline)	Coldwater (Vernon)
	River or Creek sites (Road crossing)											
Insecta–continued				X			X					
Potamanthidae			X									
Tricorythidae			X									
Odonata												
Anisoptera (dragonflies)												
Aeshnidae					X							
Corduliidae												
Gomphidae	X		X		X	X	X	X	X	X	X	
Libellulidae												
Zygoptera (damselflies)												
Calopterygidae	X	X	X		X	X	X	X	X	X	X	X
Coenagrionidae		X		X							X	X
Lestidae				X								
Perlodidae	X				X	X						
Plecoptera (stone flies)												
Perlidae	X	X	X		X	X	X	X		X	X	
Pteronarcyidae		X	X					X				
Hemiptera (true bugs)												
Belastomatidae												
Corixidae	X				X		X			X		
Gerridae	X	X	X		X		X		X	X	X	
Mesoveliidae												
Notonectidae												
Veliidae												
Saldidae												

Table 37.–Continued.

	River or Creek sites (Road crossing)											
Taxa	Chippewa (Meridian)	Chippewa (M-20)	Chippewa (S.Meridian)	Chippewa (Coldwater)	L. Salt (McGruder)	L. Salt (9-Mile)	Salt (Alamondo)	N. Br. Chippewa east (S.Nottawa)	N. Br. Chippewa east (Rosebush)	N. Br. Chippewa east (Stevenson Lake)	Coldwater (Baseline)	Coldwater (Vernon)
Insecta–continued				X			X					
Megaloptera												
Corydalidae (dobson flies)	X		X	X		X	X			X		
Sialidae (alder flies)												
Trichoptera (caddisflies)												
Brachycentridae	X		X									
Glossosmatidae	X											
Helicopsychidae	X	X	X	X	X	X	X			X	X	
Hydropsychidae	X	X	X	X	X	X	X	X	X	X	X	
Hydroptilidae			X									
Lepidostomatidae	X	X	X	X								
Leptoceridae							X					
Limnephilidae					X	X	X			X	X	X
Molannidae											X	
Philopotamidae			X									
Polycentropodidae							X	X				
Uenoidae	X	X	X		X		X			X	X	
Coleoptera (beetles)												
Amphizoidea						X						
Dryopidae												
Dyticsidae								X	X			
Elmidae		X	X	X	X	X	X	X	X	X	X	X
Gyrinidae	X	X	X	X		X			X	X	X	
Haliplidae	X				X							X
Psephenidae			X				X			X	X	
Scirtidae (adults)												

Table 37.–Continued.

Taxa	River or Creek sites (Road crossing)											
	Chippewa (Meridian)	Chippewa (M-20)	Chippewa (S.Meridian)	Chippewa (Coldwater)	L. Salt (McGruder)	L. Salt (9-Mile)	Salt (Alamondo)	N. Br. Chippewa east (S.Nottawa)	N. Br. Chippewa east (Rosebush)	N. Br. Chippewa east (Stevenson Lake)	Coldwater (Baseline)	Coldwater (Vernon)
Insecta–continued				X			X					
Diptera (flies)												
Athericidae												
Ceratopogonidae												
Chaoboridae												
Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X
Ephydridae												
Muscidae												
Sciomyzidae												
Simuliidae	X	X	X	X	X	X	X	X	X	X		
Statiomyidae											X	
Tabanidae												
Tipulidae	X					X						X
Mollusca												
Gastropoda (snails and limpets)												
Ancylidae							X	X				
Lymnaeidae			X								X	
Physidae		X	X	X		X	X	X	X	X	X	X
Planorbidae	X		X									
Bithyniidae												
Pleuroceridae			X				X					
Pomatiopsidae												
Vivaparidae												
Bivalvia (bivalves)												
Sphaeriidae	X	X	X	X	X	X	X	X	X	X	X	X
Unionidae	X		X	X			X				X	
Pisididae				X								

Table 38.–Aquatic macroinvertebrates of the Pine River. Data code: X = present, blank indicates not collected. Data from Cooper (2002).

	River or Creek sites {County} (Road crossing or approximate location)													
Taxa	Pine {Midland} (lower)	Pine {Midland} (middle)	Pine {Gratiot} (middle)	Pine {Gratiot} (upper)	Honey {Gratiot}	Unnamed {Gratiot} (Ely)	Pine {Montcalm}	N. Br. Pine {Montcalm}	Pony {Isabella}	Pine {Isabella}	Pony {Isabella}	S. Br. Pine {Isabella}	Jewell {Mecosta}	Wolf {Montcalm}
Porifera (sponges)				X							X			X
Bryozoa (moss animals)														
Platyhelminthes (flatworms)														
Turbellaria		X												
Annelida (segmented worms)														
Hirudinea (leeches)	X			X	X	X					X			
Oligochaeta (worms)	X	X	X		X	X		X			X	X	X	X
Arthropoda														
Crustacea														
Amphipoda (scuds)	X	X	X	X	X	X		X	X	X	X	X	X	X
Decapoda (crayfish)	X	X	X	X	X	X		X	X	X	X	X	X	X
Isopoda (sowbugs)					X									
Arachnoidea														
Hydracarina (mites)					X						X			
Insecta														
Ephemeroptera (mayflies)														
Baetidae	X	X	X	X	X			X	X	X	X	X	X	X
Caenidae	X	X	X	X	X	X				X	X			X
Ephemerellidae					X								X	X
Ephemeridae	X	X		X	X							X	X	X
Heptageniidae	X	X	X	X				X	X	X		X	X	X
Isonychiidae	X			X										
Leptophlebiidae										X				
Potamanthidae	X	X												
Tricorythidae	X	X	X					X	X	X			X	X

Table 38.–Continued.

Taxa	River or Creek sites {County} (Road crossing or approximate location)													
	Pine {Midland} (lower)	Pine {Midland} (middle)	Pine {Gratiot} (middle)	Pine {Gratiot} (upper)	Honey {Gratiot}	Unnamed {Gratiot} (Ely)	Pine {Montcalm}	N. Br. Pine {Montcalm}	Pony {Isabella}	Pine {Isabella}	Pony {Isabella}	S. Br. Pine {Isabella}	Jewell {Mecosta}	Wolf {Montcalm}
Insecta–continued														
Odonata														
Anisoptera (dragonflies)														
Aeshnidae			X		X			X	X	X	X	X	X	
Corduliidae													X	
Gomphidae	X			X					X	X				X
Libellulidae											X		X	
Zygoptera (damselflies)														
Calopterygidae	X	X		X		X			X	X		X	X	X
Coenagrionidae	X	X	X		X									
Perlodidae	X												X	
Plecoptera (stone flies)														
Perlidae	X	X	X	X	X			X	X	X		X	X	X
Pteronarcyidae		X		X										
Hemiptera (true bugs)														
Belastomatidae				X										
Corixidae	X	X	X	X	X	X	X					X		X
Gerridae		X	X	X	X	X	X	X	X	X	X	X	X	X
Mesoveliidae			X						X				X	
Notonectidae					X									
Veliidae	X	X		X										
Saldidae										X				
Megaloptera														
Corydalidae (dobson flies)		X					X			X			X	X
Sialidae (alder flies)				X						X			X	
Trichoptera (caddisflies)														
Brachycentridae					X		X	X	X	X	X	X		X
Glossosmatidae							X	X	X			X		X

Table 38.–Continued.

Taxa	River or Creek sites {County} (Road crossing or approximate location)													
	Pine {Midland} (lower)	Pine {Midland} (middle)	Pine {Gratiot} (middle)	Pine {Gratiot} (upper)	Honey {Gratiot}	Unnamed {Gratiot} (Ely)	Pine {Montcalm}	N. Br. Pine {Montcalm}	Pony {Isabella}	Pine {Isabella}	Pony {Isabella}	S. Br. Pine {Isabella}	Jewell {Mecosta}	Wolf {Montcalm}
Insecta–continued														
Helicopsychidae		X	X	X				X	X	X		X		X
Hydropsychidae	X	X	X				X		X	X	X	X	X	X
Hydroptilidae														
Lepidostomatidae												X		
Leptoceridae	X	X	X	X			X							X
Limnephilidae			X	X	X	X	X	X	X	X	X	X	X	X
Molannidae										X	X			
Philopotamidae														X
Polycentropodidae				X									X	
Uenoidae	X	X	X	X			X	X	X			X		X
Coleoptera (beetles)														
Dryopidae														
Dyticsidae	X	X	X	X							X		X	X
Elmidae	X	X	X	X	X		X	X	X					X
Gyrinidae	X	X	X		X	X				X				
Haliplidae				X	X			X						
Psephenidae	X		X											X
Scirtidae (adults)				X						X				X
Diptera (flies)														
Athericidae		X												
Ceratopogonidae	X	X	X	X	X		X						X	
Chaoboridae														
Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ephydridae	X	X	X											
Muscidae					X		X							
Sciomyzidae														
Simuliidae		X			X			X		X	X	X	X	X

Table 38.–Continued.

Taxa	Pine {Midland} (lower)	Pine {Midland} (middle)	Pine {Gratiot} (middle)	Pine {Gratiot} (upper)	Honey {Gratiot}	Unnamed {Gratiot} (Ely)	Pine {Montcalm}	N. Br. Pine {Montcalm}	Pony {Isabella}	Pine {Isabella}	Pony {Isabella}	S. Br. Pine {Isabella}	Jewell {Mecosta}	Wolf {Montcalm}
	River or Creek sites {County} (Road crossing or approximate location)													
Insecta–continued														
Statiomyidae	X								X					
Tabanidae							X							
Tipulidae	X										X		X	X
Mollusca														
Gastropoda (snails and limpets)														
Ancylidae				X			X	X	X					X
Lymnaeidae		X	X	X							X		X	
Physidae		X	X	X	X	X	X	X	X		X	X	X	X
Planorbidae			X	X			X	X						
Bithyniidae										X		X		
Pleuroceridae														X
Pomatiopsidae														
Vivaparidae				X										X
Bivalvia (bivalves)														
Sphaeriidae					X	X	X	X		X	X	X		X
Unionidae							X	X				X		
Pisididae	X	X	X						X					

Table 39.–Occurrence of natural features within the Tittabawassee River watershed. Data from Michigan Department of Natural Resources, Wildlife Division, Natural Features Inventory, May 2006. State status codes: E=endangered, T=threatened, SC=special concern (rare, may become E or T in the future), X=extirpated. Federal status codes: LT=listed threatened, PDL=proposed for de-listing, C=candidate to be listed.

		Status								
Common name or feature	Scientific name	Federal	State	Upper	Middle	Tobacco	Mouth	Salt	Chippewa	Pine
Vertebrate										
Bald eagle	*Haliaeetus leucocephalus*		SC	X	X	X	X		X	
Blanding's turtle	*Emys blandingii*		SC	X		X			X	X
Common loon	*Gavia immer*		T	X	X	X			X	
Common tern	*Sterna hirundo*		T				X			
eastern box turtle	*Terrapene carolina carolina*		SC						X	
eastern fox snake	*Elaphe vulpina gloydi*		T				X			
eastern massasauga	*Sistrurus catenatus catenatus*	C	SC			X				
Grasshopper sparrow	*Ammodramus savannarum*		SC							X
King rail	*Rallus elegans*		E						X	
lake sturgeon	*Acipenser fluvescens*		T				X			
Northern goshawk	*Accipiter gentilis*		SC		X					
Osprey	*Pandion haliaetus*		T			X			X	
pugnose shiner	*Notropis anogenus*		SC			X			X	
Red-shouldered hawk	*Buteo lineatus*		T		X	X	X		X	
spotted turtle	*Clemmys guttata*		T			X				
wood turtle	*Clemmys insculpta*		SC	X	X	X		X	X	X
woodland vole	*Microtus pinetorum*		SC			X				X
Invertebrate										
ebony boghaunter	*Williamsonia fletcheri*		SC						X	
elktoe	*Alasmidonta marginata*		SC	X	X	X	X			X
ellipse	*Venustaconcha ellipsiformis*		SC	X	X	X		X		
hickorynut	*Obovaria olivaria*		SC				X			
laura's snaketail	*Stylurus laurae*		SC	X						
rainbow	*Villosa iris*		SC							X
rapids clubtail	*Gomphus quadricolor*		SC						X	
riverine snaketail	*Stylurus amnicola*		SC						X	
round pigtoe	*Pleurobema coccineum*		SC							X
slippershell mussel	*Alasmidonta viridis*		SC	X	X	X		X		X
snuffbox	*Epioblasma triquetra*		E				X	X	X	
splendid clubtail	*Gomphus lineatifrons*		SC						X	

Table 39.–Continued.

Common name or feature	Scientific name	Status		Upper	Middle	Tobacco	Mouth	Salt	Chippewa	Pine
		Federal	State							
Vascular plant										
alleghany or sloe plum	*Prunus alleghaniensis var. davisii*		SC							X
beak grass	*Diarrhena americana*		T						X	X
blue-eyed-grass	*Sisyrinchium strictum*		SC							X
broad-leaved puccoon	*Lithospermum latifolium*		SC						X	X
calypso or fairy-slipper	*Calypso bulbosa*		T						X	
Cooper's milk-vetch	*Astragalus neglectus*		SC							X
Engelmann's spike-rush	*Eleocharis engelmannii*		SC		X					
false hop sedge	*Carex lupuliformis*		T							X
ginseng	*Panax quinquefolius*		T							X
Hayden's sedge	*Carex haydenii*		X					X		
lake cress	*Armoracia lacustris*		T							X
pale beard tongue	*Penstemon pallidus*		SC			X				
prairie fringed orchid	*Platanthera leucophaea*	LT	E							X
ram's head lady's-slipper	*Cypripedium arietinum*		SC						X	X
sedge	*Carex seorsa*		T				X		X	
showy orchis	*Galearis spectabilis*		T							X
slough grass	*Beckmannia syzigachne*		T							X
small love grass	*Eragrostis pilosa*		SC				X			
three-awned grass	*Aristida longespica*		T					X		
twinleaf	*Jeffersonia diphylla*		SC						X	
Virginia spiderwort	*Tradescantia virginiana*		SC						X	
whorled pogonia	*Isotria verticillata*		T							X
Plant community										
mesic southern forest							X			
dry-mesic northern forest								X		
rich conifer swamp										X
bog										X
Rookery										
Great Blue Heron	*Ardea herodias*			X	X			X	X	X

Table 40.–Mammals of the Tittabawassee River watershed. SC denotes mammals of special concern, mammals extirpated from the Tittabawassee River watershed are denoted * and extinct species **. Data from Burt (1957) and Evers (1994).

Common name	Scientific name
Pouched mammals	Marsupiala
opossum	*Didelphis virginiana*
Shrews, moles, and allies	Insectivora
eastern mole	*Scalopus aquaticus*
starnose mole	*Condylura cristata*
masked shrew	*Sorex cinereus*
shorttail shrew	*Blarina brevicauda*
Bats and flying mammals	Chiroptera
little brown myotis	*Myotis lucifugus*
keen myotis	*Myotis keeni*
silver-haired bat	*Lasionycteris noctivagans*
big brown bat	*Eptesicus fuscus*
red bat	*Lasiurus borealis*
hoary bat	*Lasiurus cinereus*
Rabbits, hares and picas	Lagamorpha
snowshoe hare	*Lepus americanus*
eastern cottontail	*Sylvilagus floridanus*
Rodents	Rodentia
eastern chipmunk	*Tamias striatus*
woodchuck	*Marmota monax*
thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*
eastern gray squirrel	*Sciurus carolinensis*
eastern fox squirrel	*Sciurus niger*
red squirrel	*Tamiasciurus hudsonicus*
southern flying squirrel	*Glaucomys volans*
beaver	*Castor canadensis*
white-footed mouse	*Peromyscus leucopus*
deer mouse	*Peromyscus maniculatus*
meadow vole	*Microtus pennsylvanicus*
woodland vole **(SC)**	*Microtus pinetorum*
muskrat	*Ondatra zibethicus*
southern bog lemming	*Synaptomys cooperi*
Norway rat	*Rattus norvegicus*
house mouse	*Mus musculus*
meadow jumping mouse	*Zapus hudsonius*
porcupine	*Erethizon dorsatum*
Flesh eaters	Carnivora
gray wolf*	*Canis lupus*
coyote	*Canis latrans*
red fox	*Vulpes vulpes*
gray fox	*Urocyon cinereoargenteus*
black bear	*Ursus americanus*
raccoon	*Procyon lotor*
marten*	*Martes americana*
long-tailed weasel	*Mustela frenata*
least weasel	*Mustela nivalis*
mink	*Mustela vison*

Table 40.–Continued.

Common name	Scientific name
American badger	*Taxidea taxus*
striped skunk	*Mephitis mephitis*
river otter	*Lutra canadensis*
cougar*	*Felis concolor*
lynx*	*Lynx canadensis*
bobcat	*Lynx rufus*
Even-toed ungulates	Artiodactyla
eastern elk**	*Cervus elaphus canadensis*
whitetail deer	*Odocoileus virginianus*
woodland caribou*	*Rangifer tarandus caribou*

Table 41.–Breeding bird observations in the Tittabawassee River watershed. Status codes in parentheses and bold (Brewer et. al. 1991).

Common name	Scientific name
Loon	Gaviidae
Common Loon **(threatened)**	*Gavia immer*
Grebe	Colymbidae
Pied-billed Grebe	*Podilymbus podiceps*
Herons	Ardeidae
Great Blue Heron	*Ardea herodias*
Green-backed Heron	*Butorides striatus*
American Bittern	*Botaurus lentiginosus*
Least Bittern (**threatened**)	*Ixobrychus exilis*
Swans, Geese, and Ducks	Anatidae
Mute Swan	*Cygnus olor*
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
American Black Duck	*Anas rubripes*
Blue Winged Teal	*Anas discors*
Wood Duck	*Aix sponsa*
Hooded Merganser	*Lophodytes cucullatus*
American Vultures	Cathartidae
Turkey Vulture	*Cathartes aura*
Hawks	Accipitridae
Northern Goshawk	*Accipiter gentilis*
Sharp-shinned Hawk	*Accipiter striatus*
Cooper’s Hawk	*Accipiter cooperii*
Red-tailed Hawk	*Buteo jamaicensis*
Red-shouldered Hawk (**threatened**)	*Buteo lineatus*
Broad-winged Hawk	*Buteo platypterus*
Bald Eagle **(special concern)**	*Haliaeetus Ieucicephalus*
Grouse	Tetraonidae
Ruffed Grouse	*Bonasa umbellus*
Pheasants and Quail	Phasianidae
Northern Bobwhite	*Colinus virginianus*
Ring-necked Pheasant	*Phasianus colchicus*
Turkeys	Meleagrididae
Wild Turkey	*Meleagris gallopavo*
Cranes	Gruidae
Sandhill Crane	*Grus canadensis*
Rails	Rallidae
Virginia Rail	*Rallus limicola*
Sora	*Porzana carolina*
American Coot	*Fulica americana*
Plovers	Charadriidae
Killdeer	*Charadrius vociferus*

Table 41.–Continued.

Common name	Scientific name
Sandpipers	Scolopacidae
American Woodcock	*Scolopax minor*
Common Snipe	*Gallinago gallinago*
Spotted Sandpiper	*Actitis macularia*
Upland Sandpiper	*Bartramia longicauda*
Pigeons and Doves	Columbidae
Mourning Dove	*Zenaida macroura*
Rock Dove	*Columba livia*
Cuckoos	Cuculidae
Yellow-billed Cuckoo	*Coccyzus americanus*
Black-billed Cuckoo	*Coccyzus erythropthalmus*
Barn Owls	Tytonidae
Eastern Screech-owl	*Otus asio*
Great Horned Owl	*Bubo virginianus*
Barred Owl	*Strix varia*
Short-eared Owl (**endangered**)	*Asio flammeus*
Whip-poor-will	*Caprimulgus vociferus*
Common Nighthawk	*Chordeiles minor*
Swifts	Apodidae
Chimney Swift	*Chaetura pelagica*
Hummingbirds	Trochilidae
Ruby-throated Hummingbird	*Archilochus colubris*
Kingfishers	Alcedinidae
Belted Kingfisher	*Ceryle alcyon*
Woodpeckers	Picidae
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Red-bellied Woodpecker	*Melanerpes carolinus*
Downy Woodpecker	*Picoides pubescens*
Hairy Woodpecker	*Picoides villosus*
Northern Flicker	*Colaptes auratus*
Pileated Woodpecker	*Dryocopus pileatus*
Flycatchers	Tyrannidae
Acadian Flycatcher	*Empidonax virescens*
Alder Flycatcher	*Empidonax alnorum*
Willow Flycatcher	*Empidonax traillii*
Least Flycatcher	*Empidonax minimus*
Great Crested Flycatcher	*Myiarchus crinitus*
Eastern Kingbird	*Tyrannus tyrannus*
Eastern Phoebe	*Sayornis phoebe*
Eastern Wood-pewee	*Contopus virens*
Larks	Alaudidae
Horned Lark	*Eremophila alpestris*
Tree Swallow	*Tachycineta bicolor*
Bank Swallow	*Riparia riparia*
Cliff Swallow	*Hirundo pyrrhonota*
Barn Swallow	*Hirundo rustica*

Table 41.–Continued.

Common name	Scientific name
Purple Martin	*Progne subis*
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
Jays and Crows	Corvidae
Blue Jay	*Cyanocitta cristata*
American Crow	*Corvus brachyrhynchos*
Titmice	Paridae
Black-capped Chickadee	*Parus atricapillus*
Tuffed Titmouse	*Parus bicolor*
Nuthatches	Sittidae
Red-breasted Nuthatch	*Sitta canadensis*
White-breasted Nuthatch	*Sitta carolinensis*
Creepers	Certhiidae
Brown Creeper	*Certhia americana*
Wrens	Troglodytidae
House Wren	*Troglodytes aedon*
Winter Wren	*Troglodytes troglodytes*
Sedge Wren	*Cistothorus platensis*
Marsh Wren	*Cistothorus palustris*
Mockingbirds and Thrashers	Mimidae
Northern Mockingbird	*Minnus polyglottos*
Brown Thrasher	*Toxostoma rufum*
Gray Catbird	*Dumetella carolinensis*
Thrushes	Turdidae
American Robin	*Turdus migratorius*
Wood Thrush	*Hylocichla mustelina*
Veery	*Catharus fuscescens*
Eastern Bluebird	*Sialia sialis*
Gnatcatchers and Kinglets	Sylviidae
Blue-gray Gnatcatcher	*Polioptila caerulea*
Golden-crowned Kinglet	*Regulus satrapa*
Waxwings	Bombycillidae
Northern Harrier	*Circus cyaneus*
American Kestrel	*Falco sparverius*
Common Moorhen	*Gallinula chloropus*
Cedar Waxwing	*Bombycilla cedrorum*
European Starling	*Sturnus vulgaris*
Solitary Vireo	*Vireo solitarius*
Yellow-throated Vireo	*Vireo flavifrons*
Warbling Vireo	*Vireo gilvus*
Red-eyed Vireo	*Vireo olivaceus*
Blue-winged Warbler	*Vermivora pinus*
Golden-winged Warbler	*Vermivora chrysoptera*
Nashville Warbler	*Vermivora ruficapilla*
Yellow Warbler	*Dendroica petechia*
Chestnut-sided Warbler	*Dendroica pensylvanica*
Black-throated Blue Warbler	*Dendroica caerulescens*

Table 41.–Continued.

Common name	Scientific name
Black-throated Green Warbler	*Dendroica virens*
Blackburnian Warbler	*Dendroica fusca*
Pine Warbler	*Dendroica pinus*
Prairie Warbler (**endangered**)	*Dendroica discolor*
Cerulean Warbler	*Dendroica cerulea*
Black-and-white Warbler	*Mniotilta varia*
American Redstart	*Setophaga ruticilla*
Ovenbird	*Seiurus aurocapillus*
Northern Waterthrush	*Seiurus noveboracensis*
Louisiana Waterthrush	*Seiurus motacilla*
Mourning Warbler	*Oporornis philadelphia*
Common Yellowthroat	*Geothlypis trichas*
Hooded Warbler	*Wilsonia citrina*
Canada Warbler	*Wilsonia canadensis*
Yellow-breasted Chat	*Icteria virens*
Scarlet Tanager	*Piranga olivacea*
Northern Cardinal	*Cardinalis cardinalis*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Indigo Bunting	*Passerina cyanea*
Dickcissel	*Spiza americana*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Chipping Sparrow	*Spizella passerina*
Clay-colored Sparrow	*Spizella pallida*
Field Sparrow	*Spizella pusilla*
Vesper Sparrow	*Pooecetes gramineus*
Savannah Sparrow	*Passerculus sandwichensis*
Grasshopper Sparrow	*Ammodramus savannarum*
Henslow's Sparrow (**threatened**)	*Ammodramus henslowii*
Song Sparrow	*Melospiza melodia*
Swamp Sparrow	*Melospiza georgiana*
Bobolink	*Dolichonyx oryzivorus*
Red-winged Blackbird	*Agelaius phoeniceus*
Eastern Meadowlark	*Sturnella magna*
Western Meadowlark	*Sturnella neglecta*
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*
Brewer's Blackbird	*Euphagus cyanocephalus*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*
Orchard Oriole	*Icterus spurius*
Northern Oriole	*Icterus galbula*
Purple Finch	*Carpodacus purpureus*
House Finch	*Carpodacus mexicanus*
Pine Siskin	*Carduelis pinus*
American Goldfinch	*Carduelis tristis*
House Sparrow	*Passer domesticus*

Table 42.–Amphibians and reptiles in the Tittabawassee River watershed. Data are from Harding and Holman (1990, 1992), Harding (1997) and Michigan Department of Natural Resources, Fisheries Division.

Common name	Scientific name
Salamanders	
mudpuppy	*Necturus maculosus maculosus*
eastern newt	*Notophthalmus viridescens*
spotted salamander	*Ambystoma maculatum*
blue-spotted salamander	*Ambystoma laterale*
eastern tiger salamander	*Ambystoma tigrinum tigrinum*
red-backed salamander	*Plethodon cinereus*
four-toed salamander	*Hemidactylium scutatum*
Frogs and toads	
eastern American toad	*Bufo americanus americanus*
Blanchard's cricket frog	*Acris crepitans blanchardi*
striped chorus frog	*Pseudacris triseriata*
northern spring peeper	*Pseudacris crucifer crucifer*
eastern gray tree frog	*Hyla versicolor*
Cope's gray tree frog	*Hyla chrysoscelis*
bullfrog	*Rana catesbeiana*
green frog	*Rana clamitans melanota*
wood frog	*Rana sylvatica*
northern leopard frog	*Rana pipiens*
pickerel frog	*Rana palustris*
Turtles and lizards	
common snapping turtle	*Chelydra serpentina serpentina*
common musk turtle	*Sternotherus odoratus*
spotted turtle	*Clemmys guttata*
eastern box turtle	*Terrapene carolina carolina*
Blanding's turtle	*Emydoidea blandingii*
common map turtle	*Graptemys geographica*
painted turtle	*Chrysemys picta*
red-eared slider	*Trachemys scripta elegans*
eastern spiny softshell turtle	*Apalone spinifera spinifera*
five-lined skink	*Eumeces fasciatus*
Snakes	
northern water snake	*Nerodia sipedon*
queen snake	*Regina septemvittata*
common garter snake	*Thamnophis sirtalis*
Butler's garter snake	*Thamnophis butleri*
northern ribbon snake	*Thamnophis sauritus septentrionalis*
brown snake	*Storeria dekayi*
northern red-bellied snake	*Storeria occipitomaculata*
smooth green snake	*Opheodrys vernalis*
blue racer	*Coluber constrictor foxi*
black rat snake	*Elaphe obsoleta obsoleta*
eastern fox snake	*Elaphe gloydi*
eastern milk snake	*Lampropeltis triangulum triangulum*
northern ring-necked snake	*Diadophis nunctatus edwardsii*
eastern hog-nosed snake	*Heterodon platirhinos*
eastern massasauga	*Sistrurus catenatus catenatus*

Table 43.–Fish stocking in the Tittabawassee River watershed, 1995–2005. Data from Michigan Department of Natural Resources, Fisheries Division.

County Location	Species	Years	Numbers	Comments
Clare				
Bertha Lake	bluegill	2001	400	private stocking
	hybrid sunfish	2005	200	private stocking
	largemouth bass	2001, 2004	610	private stocking
Budd Lake	northern muskellunge	1995, 1997, 2000, 2003	4,321	management stocking
	redear sunfish	2003, 2004	1,500	private stocking
	walleye	1995, 1996, 2004	52,694	management and private stocking
	yellow perch	2004	2,600	private stocking
Eightpoint Lake	black crappie	2005	900	private stocking
	largemouth bass	1989, 1992	700	private stocking
	walleye	2004	10,965	private stocking
	yellow perch	2003	20,000	private stocking
Lake Thirteen	bluegill	2004	800	private stocking
	hybrid sunfish	2003	1,000	private stocking
	walleye	1998, 2001, 2002, 2005	3,300	private stocking
	yellow perch	2003, 2004	1,800	private stocking
Little Long Lake	black crappie	2001	2,500	private stocking
	bluegill	2001	2,500	private stocking
	brown trout	1995–2004	10,991	discontinued 2005
	hybrid sunfish	2000	2,000	private stocking
	rainbow trout	2000–04	14,691	discontinued 2005
Newton Creek	brown trout	1995–2005	12,664	management stocking
S. Br. Tobacco River	brown trout	1995–2005	48,050	management stocking
Shamrock Lake	walleye	1996	53,433	management stocking, discontinued
Sutherland Lake	largemouth bass	1999	357	private stocking

Table 43.–Continued.

County Location	Species	Years	Numbers	Comments
Gladwin				
Blue Lake	rainbow trout	2004	500	private stocking
Lake Four	walleye	1998	522	private stocking
Lake Lancer	walleye	1995, 1996, 1998, 2000, 2002, 2004	357,480	ongoing management
N. Br. Cedar River	brown trout	1995–2005	22,945	management stocking
Pratt Lake	walleye	1996, 1998, 2000, 2002, 2004	119,237	management stocking
	yellow perch	1996	1,000	private stocking
Ross Lake	northern muskellunge	1997, 2000, 2003, 2000	5,828	management stocking
	walleye	2000, 2002, 2004	82,281	management stocking
Secord Lake	northern muskellunge	1995, 1996, 1997, 2000, 2001, 2004	101,977	management stocking
	walleye	1995, 1998, 2000, 2002, 2004	244,067	management stocking
Smallwood Lake	northern muskellunge	1995–1997, 2001, 2004	5,046	management stocking
	northern pike	2001	44	management stocking
	walleye	1995, 1996, 1998, 2000, 2003, 2005	244,440	management stocking
Trout Lake	rainbow trout	2000–02	2,480	management stocking
Wiggins Lake	bluegill	1999	1,300	private stocking
	largemouth bass	1995, 1996	1,840	private stocking
	northern pike	1996, 1999	3,600	management stocking
	walleye	1995, 1996, 1998, 2000, 2002, 2004	111,581	management stocking
	yellow perch	1999	2,231	private stocking
Wixom Lake	northern muskellunge	1996, 1998, 2004	7,202	management stocking
	walleye	1995, 1996, 1997, 2000, 2001, 2004	494,212	management stocking
Isabella				
Chippewa River	Chinook salmon	1998, 1999	87	private stocking
	rainbow trout (steelhead)	1995–2005	145,882	management stocking
	walleye	1995	2,964	rearing pond release
Coldwater Lake	northern pike	1995	3,000	management stocking
	walleye	1996, 1999, 2002	29,328	management stocking
Herrick Pond North	bluegill	1997	84	restocking
	largemouth bass	1995	37	restocking

Table 43.–Continued.

County Location	Species	Years	Numbers	Comments
Isabella–continued				
Herrick Pond South	northern pike	1999–2000	635	restocking
	rainbow trout	1995–98	4,230	interim fishery
	yellow perch	1996, 1997	128	restocking
Herrick Swimming Pond	largemouth bass	1997	163	restocking
Littlefield Lake	walleye	2002	9,317	management stocking
Pine River	brown trout	1995–2005	51,153	management stocking
Mecosta				
Chippewa Lake	walleye	1995, 1997, 1998, 2000, 2003	286,765	management stocking
Pretty Lake	redear sunfish	1999	1,800	management stocking
	walleye	1995, 2001, 2005	3,070	private stocking

Table 44.–Public boat launch sites in the Tittabawassee River watershed by county and water body (MDNR 1996).

County	Name of water body	Location	Ownership
Clare	Arnold Lake	T20N, R4W, SEC. 35	State
	Budd Lake	T19W, R4W, SEC. 21	State
	Cranberry Lake	T19N, R4W, SEC. 1	State
	Crooked Lake	T17N, R6W, SEC. 22	State
	Five Lakes	T17N, R4W,SEC. 9	State
	Little Long Lake	T19N, R4W, SEC. 22	State
	Big Mudd Lake	T18N, R6W, SEC. 31	State
	Nester Lake	T18N, R3W, SEC. 10	State
	Perch Lake	T17N, R6W, SEC. 23	State
	Shamrock Lake	T17N, R4W, SEC. 26	City
Gladwin	House Lake	T20N, R2W, SEC. 8	State
	Lake Four	T20N, R1W, SEC. 4	State
	Lake Lancer	T20N, R1W, SEC 21	Township
	Hoister Lake	T20N, R2W, SEC. 9	State
	Pratt Lake	T19N, R2W, SEC. 21	State
	Ross Lake	T17N, R2W, SEC. 12	Township
	Secord Lake	T19N, R1E, SEC. 9	State
	E. Branch Tittabawassee River	T20N, R2E, SEC. 29	State
	Trout Lake	T20N, R2W, SEC. 9	State
	Wiggins Lake	T19N, R2W, SEC. 34	State
	Wixom Lake	T17N, R1W, SEC. 36	State
Gratiot	Alma Impoundment	T11N, R1W, SEC. 3	City
	St. Louis Impoundment	T12N, R2W, SEC. 25	City
Isabella	Coldwater Lake	T15N, R5W, SEC. 30	County
	Halls Lake	T14N, R6W, SEC. 19	Township
	Littlefield Lake	T16N, R5W, SEC. 17	State
	Stevenson Lake	T16N, R4W, SEC. 19	State
Mecosta	Chippewa Lake	T16N, R8W, SEC. 20	State
	Big Evans (2)	T16N, R8W, SEC.35	State
	Lost Lake	T15N, R8W, SEC. 1	State
	Lower Evans	T15N, R8W, SEC. 3	State
	Pretty Lake	T15N, R8W, SEC. 14	State
	Tubbs Lake	T15N, R7W, SEC. 7	State
	Tubbs Lake	T15N, R7W, SEC. 5	State
Midland	Sanford Lake	T15N, R1W, SEC. 24	County
	Tittabawassee River	T14N, R2E, SEC. 17	City
	Tittabawassee River	T14N, R5E, SEC. 35	City
Montcalm	Rock Lake	T12N, R5W, SEC.29	Township
Saginaw	Tittabawassee River	T12N, R3E, SEC. 11	County
	Tittabawassee River	T12N, R4E, SEC. 32	County

Table 45.–Organizations with interests in the Tittabawassee River watershed.

Organization name
Ducks Unlimited
Gladwin County Walleye Association
Izaak Walton League
Little Forks and Chippewa Nature Conservancy
Lone Tree Council
Michigan B.A.S.S. Chapter Federation
Michigan Chapter of American Fisheries Society
Michigan Duck Hunters Association
Michigan Muskie Alliance
Michigan Trappers Association
Michigan United Conservation Clubs District #10
Midland County Sportfishing Association
Mt. Pleasant League of Women Voters
Natural Resource Conservation Service
Nature Conservancy
Pheasants Forever
Pikemasters
Saginaw Bay Walleye Club
Saginaw Field and Stream Club
Saginaw Bay Watershed Initiative Network
Sanford Lake Improvement Board
Sierra Club
Sugar Springs Property Owners Association
Trout Unlimited
Wixom Lake Association
Wixom Lake Improvement Board

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APPENDICES

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Appendix A.1

Federal Energy Regulatory Commission license covering Secord, Smallwood, Edenville, and Sanford hydroelectric dams. Dams are located in the middle segment of the main stem. The license was issued October 16, 1998.

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85 FERC ¶ 61,064

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Before Commissioners: James J. Hoecker, Chairman;
Vicky A. Bailey, William L. Massey,
Linda Breathitt, and Curt Hébert, Jr.

Wolverine Power Corporation) Project No. 10809-000

ORDER ISSUING MINOR LICENSE

(Issued October 16, 1998)

BACKGROUND

Wolverine Power Corporation (Wolverine) filed applications under Part I of the Federal Power Act (FPA) for original licenses for the continued operation and maintenance of four unlicensed hydroelectric projects located on the Tittabawassee River in Gladwin and Midland Counties, Michigan. Beginning furthest downstream, the projects are: the 3.3-megawatt (MW) Sanford Hydroelectric Project No. 2785, the 4.8-MW Edenville Project No. 10808, the 1.2-MW Smallwood Project No. 10810, and the 1.2-MW Secord Project No. 10809.

We issued a license for the Sanford Project No. 2785 in 1987. 1/ Rehearing requests of the license order have been held in abeyance while we analyzed all four projects together. 2/ We stayed parts of the license order for the same reason. In 1989, Wolverine filed license applications for its Edenville, Smallwood, and Secord Projects.

Notice of the applications was issued, and the State of Michigan Department of Natural Resources (Michigan DNR), the U.S. Department of the Interior (Interior), Donald J. Maladecki, and Terry Whittington filed timely motions to intervene in the three licensing proceedings. Maladecki and Whittington, local residents and recreational users of the project reservoirs, state that large fluctuations of reservoir levels adversely affect boaters and lake-front residences, and ask that any license issued limit such fluctuations.

The Commission staff prepared an Environmental Assessment (EA) that evaluates the impacts of all four projects on the

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1/ 41 FERC ¶ 62,192.

2/ The four projects comprise a single unit of development. See Section 3(11) of the FPA, 16 U.S.C. § 796(11).

environmental resources of the area. 3/ We are concurrently issuing an order on rehearing of the Sanford Project license, and orders issuing licenses for the other three projects. This order issues the license for the Secord Project No. 10809.

The license order for the Edenville Project No. 10808 addresses, among other matters, issues of pertinence to all four projects, notably including mode of operation, fluctuation of reservoir levels, and fish entrainment. The discussion in the Edenville license order is incorporated by reference herein.

PROJECT DESCRIPTION

The Secord Project is the most upstream of the four projects. The Secord Dam, which has three sections totaling about 2,085 feet in length and has a maximum height of 55 feet, creates Secord Lake, a 1,100-acre reservoir with a 69-mile shoreline at full pool. There is a 47-foot-long intake leading to the powerhouse, which is located at the dam and has an installed capacity of 1.2 MW. The license application does not propose any new construction or redevelopment.

WATER QUALITY CERTIFICATION

The State of Michigan waived water quality certification for this project by its failure to act on Wolverine's certification request within one year. 4/

SECTION 18 FISHWAY PRESCRIPTION

As requested by Interior, we are including a condition in this license (Article 405) that reserves our authority to require such fishways as Interior may prescribe pursuant to Section 18 of the FPA. 5/

ENDANGERED SPECIES

Bald eagles (federally listed as threatened) are known to forage along the Tittabawassee River, Sanford Lake, and probably

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3/ A draft EA was issued March 31, 1994; the final EA was issued August 14, 1998.

4/ See Order Issuing Original License for Project No. 10808.

5/ Id.

Smallwood Lake. As requested by FWS, Article 406 of the license requires Wolverine to prepare a bald eagle protection plan. 6/

RECOMMENDATIONS OF FEDERAL AND STATE FISH AND WILDLIFE AGENCIES

A. Section 10(j) Recommendations

Section 10(j)(1) of the FPA 7/ requires the Commission, when issuing a license, to include license conditions, based on recommendations of federal and state fish and wildlife agencies submitted pursuant to the Fish and Wildlife Coordination Act, for the protection of, mitigation of adverse impacts to, and enhancement of fish and wildlife resources (including related spawning grounds and habitat) affected by the project. 8/

Michigan DNR and Interior submitted ten recommendations that we have considered under Section 10(j): (1) run-of-river operation of the projects; (2) continued flow releases through the project during project shut-downs; (3) a gaging plan to monitor project operation; (4) establishment of target reservoir elevations and limitation on reservoir fluctuations to +/-0.2 feet; (5) maintenance of state water quality standards for temperature and dissolved oxygen (DO), and development of a monitoring plan; (6) a bald eagle protection plan; (7) a habitat protection plan for state-listed threatened or endangered species; (8) a nuisance flora monitoring and control plan; (9) a wildlife management and land use plan; and (10) an erosion control plan. 9/

6/ Id.

7/ 16 U.S.C. § 803(j)(1).

8/ If the Commission believes that any such recommendation may be inconsistent with the purposes and requirements of Part I of the FPA or applicable law, Section 10(j)(2) requires the Commission and the agencies to attempt to resolve any such inconsistency, giving due weight to the recommendations, expertise, and statutory responsibilities of such agencies. If the Commission then does not adopt a recommendation, it must explain how the recommendation is inconsistent with applicable law and how the conditions selected by the Commission adequately and equitably protect, mitigate damages to, and enhance fish and wildlife.

9/ The agencies submitted five other recommendations that we do not consider under Section 10(j), because they are not specific measures to protect, mitigate damages to, or enhance fish and wildlife. See, e.g., Mead Corp., 72 FERC (continued...)

We have included conditions in the Secord license consistent with five of the recommendations and portions of two others: (1) a gaging plan to monitor project operation (Article 405); (2) establishment of target reservoir elevations (Article 403); (3) maintenance of state water quality standards for dissolved oxygen (DO) and temperature downstream of the project, and development of a related monitoring plan (Article 402); (4) a bald eagle protection plan (Article 406); (5) a nuisance flora monitoring and control plan (Article 407); (6) an erosion control plan (Article 401); and (7) a wildlife management and land use plan (Articles 403 and 406). 10/

As explained in the license order for Project No. 10808, we decline to adopt the Section 10(j) recommendations for (1) run-of-river operation, (2) continuous flows from the project during project shutdowns, (3) a temperature change standard, and (4) a habitat protection plan for listed species.

B. Other Recommendations and Resource Issues

As discussed in the Project No. 10808 license order, we decline to include in the Secord license conditions requiring the licensee: (1) to study the costs of project retirement; (2) to perform additional entrainment and mortality studies, evaluate potential protection devices, and provide compensation for fish losses at the project; and (3) to modify project operations or facilities or to install fish passage facilities when so ordered by Michigan DNR.

As proposed by both Wolverine and Michigan DNR, the license requires recreation facility improvements. 11/

In response to comments received, we are including a condition in the Secord Project license that requires Wolverine

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9/ (...continued)
¶ 61,027. These recommendations are: (1) a turbine entrainment and mortality study; (2) a reservation of authority to Michigan DNR to order changes in project operations and facilities; (3) a reservation of authority to Michigan DNR to order preparation of an upstream fish passage plan; (4) a plan for recreation facilities; and (5) a plan for studying the costs of decommissioning and partial or complete project removal. We instead consider these recommendations under Section 10(a) of the FPA.

10/ See Order Issuing Original License for Project No. 10808.

11/ Id.; and EA at 60-70.

to draw down the projects' reservoirs in early-winter to no more than three feet below the target elevations. 12/

COMPREHENSIVE PLANS

Pursuant to Section 10(a)(2)(A) of the FPA 13/ we reviewed the comprehensive plans relevant to this project and found no conflicts. 14/

COMPREHENSIVE DEVELOPMENT

Sections 4(e) and 10(a)(1) of the FPA require the Commission, in acting on applications for license, to give equal consideration to the power and development purposes and to the purposes of energy conservation, the protection, mitigation of damage to, and enhancement of fish and wildlife, the protection of recreational opportunities, and the preservation of other aspects of environmental quality. Any license issued shall be best adapted to a comprehensive plan for improving or developing a waterway or waterways for all beneficial public uses. The decision to license this project, and the terms and conditions included herein, reflect such consideration.

The EA analyzed the effects associated with the issuance of an original license for the existing Secord Project. It recommends a number of measures to protect and mitigate environmental resources, which we adopt, as discussed herein and in the companion order issuing license for the Edenville Project No. 10808. These measures will establish target reservoir levels, limit reservoir fluctuations, and enhance recreational resources in the project area.

The electricity generated from renewable water power resources will be beneficial, because it will continue to offset the use of fossil-fueled, steam-electric generating plants, thereby conserving nonrenewable resources and reducing atmospheric pollution.

One of the public interest factors the Commission considers is the economic benefits of project power. Under our approach to evaluating the economics of hydropower projects, as articulated

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12/ See Order Issuing Original License for Project No. 10808; and EA at 35-36, 48-51, 69-70, and 75.

13/ 16 U.S.C. § 803(a)(2)(A).

14/ See Order Issuing Original License for Project No. 10808.

in Mead Corp., 15/ we employ an analysis that uses current costs to compare the costs of the project and likely alternative power, with no forecasts beyond the license issuance date concerning potential future inflation, escalation, or deflation. The basic purpose of the analysis is to provide a general estimate of the potential power benefits and the costs of a project, and reasonable alternatives to project power. The estimate helps to support an informed decision concerning what is in the public interest with respect to a proposed license.

In making our decision, we consider the project power benefits both with the applicant's proposed mitigation measures and with the Commission's proposed recommendations to the applicant's proposal. In addition, certain economic factors related to project decommissioning impinge on the decision to issue original licenses for existing projects that are not present in the licensing of unconstructed projects. If an existing project is not issued a license, or if its licensee declines to accept the license, the project generally will have to be retired in one form or another. This could range from simply removing the generator at the powerhouse to major environmental restoration varying from minor measures to dam removal.

As licensed by the Commission, the Secord Project will produce an average of about 4.0 GWh of energy, at an annual cost of about $104,000 (26.0 mills/kWh). The current annual value of the project's power would be $176,000 (44.0 mills/kWh). 16/ To determine whether the project is currently economically beneficial, we subtract the project's cost from the value of the project's power. Thus, the project, as licensed by the Commission would have a net benefit of about $72,000 (about 18.0 mills/kWh).

As explained in Mead, the economic analysis is by necessity inexact, and project economics is only one of many public interest factors considered in determining whether or not, and under what conditions, to issue a license. Wolverine is ultimately responsible and best able to determine whether continued operation of the existing project, with the conditions adopted herein, is a reasonable decision in these circumstances.

15/ 72 FERC ¶ 61,027 (1995).

16/ We base this value on the cost of alternative resources, which in this case is the cost of a new combined cycle and simple cycle combustion turbine plants, the regional cost of natural gas, and peak and off-peak energy values. The estimate of the value of project power is more completely described in the EA.

Based on our review of the comments on this project filed by agencies and the public, our review of the staff's evaluation of the environmental and economic effects of the project and its alternatives, and our analysis pursuant to Sections 4(e) and 10(a)(1), we find that the Secord Project, with our mitigative measures, will be best adapted to the comprehensive development of the Tittabawassee River for beneficial public uses.

LICENSE TERM AND ANNUAL CHARGES

The license for the Secord Project will be issued for a prospective 30-year term. 17/ In addition, the license will be conditioned upon payment of an additional amount equivalent to the charges that would have been collected, had Wolverine obtained a license for this project in a timely manner, to when it first was required, i.e., from April 1, 1962. 18/

The Commission orders:

(A) This license is issued to Wolverine Power Corporation (Licensee) for a period of 30 years, effective the first day of the month in which this order is issued, to operate and maintain the Secord Project. This license is subject to the terms and conditions of the Federal Power Act (FPA), which is incorporated by reference as part of this license, and subject to the regulations the Commission issues under the provisions of the FPA.

(B) The Secord Project consists of:

(1) All lands, to the extent of the Licensee's interest in those lands shown by exhibit G:

Exhibit G-	FERC No. 10809-	Showing
1	6	Secord Project Map

(2) Project works consisting of: (a) Secord Lake, an 1,100-acre reservoir with a gross storage of approximately 15,000 acre-feet at the normal pool elevation of 750.8 feet National Geodetic Vertical Datum; (b) a 1,400-foot-long earth embankment

17/ See Order Issuing Original License for Project No. 10808.

18/ Id. As of October 1, 1994, the Commission is not assessing annual charges for projects, like the Secord, with less than 1.5-MW authorized installed capacity. Therefore, the Secord Project will be assessed annual charges for the period April 1, 1962, through September 30, 1994.

section of the dam (maximum height of 55.0 feet) between the left abutment and the powerhouse; (c) a 600-foot-long earth embankment section of the dam between the spillway and the right abutment; (d) a reinforced concrete multiple arch spillway with an ogee crest and two Taintor gates; (e) a powerhouse integral with the dam, equipped with one Francis vertical-axis turbine-generator unit rated at 1.2 MW; (f) a 47-foot-long intake structure; and (g) appurtenant facilities.

The project works generally described above are more specifically shown and described by those portions of Exhibit A and F that also form a part of the application for license and that are designed and described as:

Exhibit A: The turbines and generators as described on page A-1 of the Exhibit A filed July 24, 1989.

Exhibit F Drawing	FERC No.	Description
F-1	10809-1	Secord Survey Plan
F-2	10809-2	Secord Plan View
F-3	10809-3	Secord Spillway Section
F-4	10809-4	Secord Powerhouse Section
F-5	10809-5	Secord Embankment Section

(3) All of the structures, fixtures, equipment, or facilities used to operate or maintain the project, all portable property that may be employed in connection with the project, and all riparian or other rights that are necessary or appropriate in the operation or maintenance of the project.

(C) The Exhibits A, F, and G as designated in ordering paragraph (B) above are approved and made part of the license.

(D) The following sections of the FPA are waived and excluded from the license for this minor project:

4(b), except the second sentence; 4(e), insofar as it relates to approval of plans by the Chief of Engineers and the Secretary of the Army; 6, insofar as it relates to public notice and to the acceptance and expression in the license of terms and conditions of the Act that are waived here; 10(c), insofar as it relates to depreciation reserves; 10(d); 10(f); 14, except insofar as the power of condemnation is reserved; 15; 16; 19; 20; and 22.

(E) This license is subject to the articles set forth in Form L-9 (October 1975), entitled, "Terms and Conditions of License for Constructed Minor Project Affecting Navigable Waters of the United States," and the following additional articles.

Article 201. The Licensee shall pay the United States the following annual charges:

(1) From April 1, 1962, through September 30, 1994, for the purpose of reimbursing the United States for the cost of administration of Part I of the Federal Power Act (FPA), a reasonable amount as determined in accordance with the provisions of the Commission's regulations in effect from time to time. The authorized installed capacity for that purpose is 1,200 kilowatts (kW).

(2) From October 1, 1998, through August 31, 2028, for the purpose of reimbursing the United States for the cost of administration of Part I of the FPA, as determined by the Commission, a reasonable amount as determined in accordance with the provisions of the Commission's regulations in effect from time to time. The authorized installed capacity for that purpose is 1,200 kW. Under the regulations currently in effect, projects with authorized installed capacity of less than or equal to 1,500 kW will not be assessed an annual charge.

Article 401. Within six months of license issuance, the Licensee shall file for Commission approval a plan for erosion control in order to minimize shoreline erosion and bank instability occurring in the project reservoir and the river area downstream from the project dam and tailrace. Erosion control measures in the plan shall adhere to the most recent version of the Michigan Department of Transportation standards, and shall be designed to allow pedestrian access while providing long-term stability.

The plan shall include at a minimum:

(1) a summary description of the existing erosion control program;

(2) a description of measures to monitor shoreline erosion and bank instability caused by project operations;

(3) descriptions, functional design drawings, and topographic map locations of proposed new and enhanced control measures;

(4) a description of how the control measures will allow pedestrian access while providing long-term stability;

(5) identification of the Michigan Department of Transportation standards used, and description of how the pertinent standards would be adhered to;

(6) an implementation schedule;

(7) provisions for the Licensee's periodic review and revision of the plan; and

(8) provisions for provide the results of its monitoring program to the Michigan Department of Natural Resources, other agencies, and property owners upon request.

The Licensee shall prepare the plan after consultation with the Michigan Department of Natural Resources and the Natural Resources Conservation Service. The Licensee shall include with the plan documentation of consultation, copies of comments and recommendations on the completed plan, and specific description of how the agencies' comments are accommodated by the plan. The Licensee shall allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the Licensee does not adopt a recommendation, the filing shall include the Licensee's reasons, based on project-specific information.

The Commission reserves the right to require changes to the plan. No land-disturbing or land-clearing activities shall begin until the Licensee is notified by the Commission that the plan is approved. Upon Commission approval, the Licensee shall implement the plan, including any changes required by the Commission.

Article 402. The Licensee must implement all reasonable and prudent measures to ensure that the following water quality standards are met whenever inflows to the projects are greater than or equal to the 95-percent-exceedance inflow:

(1) Dissolved oxygen (DO) concentrations in the project's tailwaters of not less than 5 milligrams per liter (mg/l) at all times; and

(2) monthly average temperatures downstream from the project of no greater than:

January ------	42°F
February -----	41°F
March --------	53°F
April --------	67°F
May ----------	78°F
June ---------	85°F
July, August -	86°F
September ----	80°F
October ------	69°F
November -----	56°F
December -----	44°F

These monthly average temperatures may be exceeded for short periods when natural water temperatures measured upstream of the project exceed the 90th percentile occurrence of water temperatures (i.e., the monthly average temperatures cited in item No. 2 minus 5°F).

Within six months of license issuance, the Licensee shall file for Commission approval a plan to monitor, and mitigate if necessary, DO and temperature levels of the Tittabawassee River downstream from the Secord Project. The plan shall include provisions for: (1) monitoring of DO and temperature above the Secord impoundment and downstream from Secord Dam with the sensor locations and monitoring frequency determined in consultation with the Michigan Department of Natural Resources (Michigan DNR) and the U.S. Fish and Wildlife Service (FWS); and (2) a description of operating procedures developed in consultation with Michigan DNR and FWS to alleviate water quality conditions which deviate from the above limits.

The Licensee shall prepare the plan after consultation with Michigan DNR and FWS. The monitoring plan shall include schedules for: (1) implementing the plan within 24 months of license issuance; (2) consulting with Michigan DNR and FWS on the results of monitoring; and (3) filing the results, agency comments, and Licensee's response to agency comments with the Commission.

The Licensee shall include with the plan documentation of consultation, copies of comments and recommendations on the completed plan, and specific descriptions of how the agencies' comments are accommodated by the plan. The Licensee shall allow a minimum of thirty days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the Licensee does not adopt a recommendation, the filing shall include the Licensee's reasons, based on project-specific information.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the Licensee shall implement the plan, including any changes required by the Commission.

Article 403. Within sixty days of the installation of reservoir level gages required by Article 405, the Licensee shall operate the Secord Project so that the project reservoir elevation does not fluctuate more than 0.4 foot below or 0.3 foot above the normal pool elevation of 750.8 feet National Geodetic Vertical Datum (NGVD) except during the winter drawdown. The Licensee shall begin the winter drawdown after December 15, and shall complete the winter drawdown by January 15 of each year. The Licensee shall complete the refill of the reservoir, thus ending the winter drawdown period, prior to the surface water temperature of the reservoir reaching 39°F. During the winter drawdown, the Licensee shall operate the Secord Project so that the reservoir level does not fall below 747.8 feet NGVD, and so that the daily fluctuation in reservoir elevation does not exceed 0.7 foot.

The required reservoir elevations may be temporarily modified if required by operating emergencies beyond the control of the Licensee, and for short periods for project maintenance purposes, upon mutual agreement between the Licensee and the Michigan Department of Natural Resources. If the reservoir level fluctuation is so modified, the Licensee shall notify the Commission as soon as possible, but no later than ten days after each such incident.

<u>Article 404</u>. The Commission reserves the authority to require the Licensee to construct, maintain, and operate or to provide for the construction, maintenance, and operation of such fishways as may be prescribed by the Secretary of the U.S. Department of the Interior.

<u>Article 405</u>. To ensure compliance with the reservoir elevation requirements of Article 403, the Licensee, within 180 days of license issuance, shall file for Commission approval a reservoir level gaging plan to monitor water surface elevations in Secord Lake at intervals of no greater than 15 minutes.

The plan shall include, but not be limited to, (1) details on the location, design, and calibration of the monitoring equipment; (2) the method of data collection; (3) provisions for compiling and storing the data; and (3) provisions for supplying the data to the U.S. Fish and Wildlife Service (FWS), the U.S. Geological Survey (USGS), and the Michigan Department of Natural Resources (Michigan DNR) within thirty days of the agency's request.

The monitoring plan shall also include a schedule for: (1) implementation of the program; (2) consultation with the appropriate federal and state agencies concerning the data from the monitoring; and (3) filing the data, agency comments, and the Licensee's response to agency comments with the Commission.

The Licensee shall prepare the plan after consultation with Michigan DNR, FWS, and USGS. The Licensee shall include with the plan, documentation of consultation, copies of comments and recommendations on the completed plan, and specific descriptions of how the agencies' comments are accommodated by the plan. The Licensee shall allow a minimum of thirty days for the agencies to comment and to make recommendations prior to filing the plan with the Commission. If the Licensee does not adopt a recommendation, the filing shall include the Licensee's reasons, based on project-specific information.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the Licensee shall implement the plan, including any changes required by the Commission.

Article 406. Within one year of license issuance, the Licensee shall file for Commission approval a Bald Eagle Management Plan to protect the federally listed as threatened bald eagle (*Haliaeetus leucocephalus*) and its habitat. The Commission reserves the right to require changes to the plan.

The plan shall be developed in consultation with the U.S. Fish and Wildlife Service (FWS) and the Michigan Department of Natural Resources (Michigan DNR), and include, but not be limited to the following:

(1) The results of a winter and breeding season survey of bald eagles and a bald eagle habitat assessment of project lands and waters, including descriptive and mapped identification of any existing and potential future eagle perching, roosting, nesting, and foraging habitat areas;

(2) A proposed protocol and an implementation schedule for an ongoing bald eagle monitoring program;

(3) Specific measures to maintain and protect any existing and potential eagle habitat areas on project lands and waters, including an implementation schedule;

(4) Specific measures to maintain and protect bald eagle perch and roost trees on project lands, including an implementation schedule; and

(5) Procedures for notifying the Commission if potential adverse impacts to eagles or their habitats arise as a result of project operation or activities on project lands or waters.

The Licensee shall include in the plan documentation of consultation, copies of agency comments and recommendations on the completed plan, and specific descriptions of how the agencies' comments are accommodated by the plan. The Licensee shall allow a minimum of thirty days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the Licensee does not adopt a recommendation, the filing shall include the Licensee's reasons, based on project-specific information.

Article 407. Within six months of license issuance, the Licensee shall, in consultation with the Michigan Department of Natural Resources (Michigan DNR), file for Commission approval a plan to monitor purple loosestrife and Eurasian watermilfoil in project waters. The Commission reserves the right to require changes to the plan.

The plan shall include, but not be limited to: (1) a description of the monitoring method; (2) a monitoring schedule; and (3) a schedule for providing the monitoring results to Michigan DNR; (4) documentation of agency consultation, including copies of comments and recommendations on the completed plan; and (5) specific descriptions of how the agencies' comments are accommodated by the plan. The Licensee shall allow a minimum of thirty days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the Licensee does not adopt a recommendation, the filing shall include the Licensee's reasons, based on project-specific information.

If at any time during the period of license, Michigan DNR demonstrates that purple loosestrife or Eurasian watermilfoil is significantly affecting fish and wildlife populations at the project and that control measures are needed, and the Commission agrees with those determinations, the Commission may require the Licensee to cooperate with Michigan DNR and to undertake reasonable measures to control or eliminate the weeds in project waters.

Article 408. The Licensee, before starting any land-clearing or land-disturbing activities within the project boundary, including recreation developments at the project, shall consult with the State Historic Preservation Officer.

If the Licensee discovers previously unidentified archeological or historic properties during the course of constructing or developing project works or other facilities at the project, the Licensee shall stop all land-clearing and land-disturbing activities in the vicinity of the properties and consult with the State Historic Preservation Officer.

In these instances, the Licensee shall file for Commission approval a cultural resource management plan prepared by a qualified cultural resource specialist after having consulted with the State Historic Preservation Officer. The plan shall include the following items: (1) a description of each discovered property indicating whether it is listed, or eligible to be listed, on the National Register of Historic Places; (2) a description of the potential effect on each discovered property; (3) proposed measures for avoiding or mitigating effects; (4) documentation of the nature and extent of consultation; and

(5) a schedule for mitigating effects and conducting additional studies.

The Licensee shall include with the plan documentation of agency consultation, copies of agency comments and recommendations on the completed plan, and specific descriptions of how the agencies' comments are accommodated by the plan. The Licensee shall allow a minimum of thirty days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the Licensee does not adopt a recommendation, the filing shall include the Licensee's reasons, based on site-specific information.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the Licensee shall implement the plan, including any changes required by the Commission.

Article 409. Within one year of license issuance, the Licensee shall file for Commission approval a recreation plan for the Secord Project. The Commission reserves the right to make changes to the plan.

The plan shall be prepared in consultation with the Michigan Department of Natural Resources (Michigan DNR) and shall include the following:

(1) A fishing access site at the Secord Project dam that shall include (a) directional signs; (b) a barrier-free restroom; (c) access paths to the tailwater and dike areas, restrooms, canoe portage, and parking areas; (d) parking for 15 vehicles with designated barrier-free parking spaces; (e) improved railed shoreline fishing pier at the tailwater; and (f) improved railed barrier-free fishing pier located on the dike shoreline near the dam;

(2) A canoe portage;

(3) Installation of signs that identify the project's recreational facilities;

(4) functional design drawings, costs for the improvements to, or construction of, the required facilities; and

(5) A schedule for completing construction of the required facilities within three years of license issuance.

The Licensee shall include with the plan documentation of agency consultation, copies of comments and recommendations on the completed plan, and specific descriptions of how the agencies' comments are accommodated by the plan. The Licensee shall allow a minimum of thirty days for the agencies to comment before filing the plan with the Commission. If the Licensee does not adopt a recommendation, the filing shall include the Licensee's reasons, based on project-specific information.

No land clearing or land-disturbing activities shall begin until the Licensee is notified by the Commission that the plan is approved.

Article 410. (a) In accordance with the provisions of this article, the Licensee shall have the authority to grant permission for certain types of use and occupancy of project lands and waters and to convey certain interests in project lands and waters for certain types of use and occupancy, without prior Commission approval. The Licensee may exercise the authority only if the proposed use and occupancy is consistent with the purposes of protecting and enhancing the scenic, recreational, and other environmental values of the projects. For those purposes, the Licensee shall also have continuing responsibility to supervise and control the use and occupancies for which it grants permission, and to monitor the use of, and ensure compliance with the covenants of the instrument of conveyance for, any interest that it has conveyed, under this article. If a permitted use and occupancy violates any condition of this article or any other condition imposed by the Licensee for protection and enhancement of the project's scenic, recreational, or other environmental values, or if a covenant of a conveyance made under the authority of this article is violated, the Licensee shall take any lawful action necessary to correct the violation. For a permitted use or occupancy, that action includes, if necessary, canceling the permission to use and occupy the project lands and waters and requiring the removal of any non-complying structures and facilities.

(b) The type of use and occupancy of project lands and waters for which the Licensee may grant permission without prior Commission approval are: (1) landscape plantings; (2) non-commercial piers, landings, boat docks, or similar structures and facilities that can accommodate no more than 10 watercraft at a time and where said facility is intended to serve single-family type dwellings; and (3) embankments, bulkheads, retaining walls or similar structures for erosion control to protect the existing shoreline.

To the extent feasible and desirable to protect and enhance the project's scenic, recreational, and other environmental values, the Licensee shall require multiple use and occupancy of facilities for access to projects lands or waters. The Licensee shall also ensure, to the satisfaction of the Commission's authorized representative, that the use and occupancies for which it grants permission are maintained in good repair and comply with applicable state and local health and safety requirements. Before granting permission for construction of bulkheads or retaining walls, the Licensee shall: (1) inspect the site of the proposed construction; (2) consider whether the planting of vegetation or the use of riprap would be adequate to control erosion at the site; and (3) determine that the proposed construction is needed and would not change the basic contour of the reservoir shoreline.

To implement this paragraph (b), the Licensee may, among other things, establish a program for issuing permits for the specified types of use and occupancy of project lands and waters, which may be subject to the payment of a reasonable fee to cover the Licensee's costs of administering the permit program. The Commission reserves the right to require the Licensee to file a description of its standards, guidelines, and procedures for implementing this paragraph (b) and to require modification of those standards, guidelines, or procedures.

(c) The Licensee may convey easements or rights-of-way across, or leases of, project lands for: (1) replacement, expansion, realignment, or maintenance of bridges and roads for which all necessary state and federal approvals have been obtained; (2) storm drains and water mains; (3) sewers that do not discharge into project waters; (4) minor access roads; (5) telephone, gas, and electric utility distribution lines; (6) non-project overhead electric transmission lines that do not require erection of support structures within the project boundary; (7) submarine, overhead, or underground major telephone distribution cables or major electric distribution lines (69-kV or less); and (8) water intake or pumping facilities that do not extract more than one million gallons per day from a project reservoir.

No later than January 31 of each year, the Licensee shall file three copies of a report briefly describing for each conveyance made under this paragraph (c) during the prior calendar year, the type of interest conveyed, the location of the lands subject to the conveyance, and the nature of the use for which the interest was conveyed.

(d) The Licensee may convey fee title to, easements or rights-of-way across, or leases or project lands for: (1) construction of new bridges or roads for which all necessary state and federal approvals have been obtained; (2) sewer or effluent lines that discharge into project waters, for which all necessary federal and state water quality certification or permits have been obtained; (3) other pipelines that cross project lands or waters but do not discharge into project waters; (4) non-project overhead electric transmission lines that require erection of support structures within the project boundary, for which all necessary federal and state approvals have been obtained; (5) private or public marinas that can accommodate no more than 10 watercraft at a time and are located at least one-half mile from any other private or public marina; (6) recreational development consistent with an approved Exhibit R or approved report on recreational resources of an Exhibit E; and (7) other uses, if: (i) the amount of land conveyed for a particular use is five acres or less; (ii) all of the land conveyed is located at least 75 feet, measured horizontally, from the edge of the project reservoir at normal maximum surface elevation; and (iii) no more than 50 total acres of project lands for the project development are conveyed under this clause (d)(7) in any calendar year.

At least forty-five days before conveying any interest in project lands under this paragraph (d), the Licensee must submit a letter to the Director, Office of Hydropower Licensing, stating its intent to convey the interest and briefly describing the type of interest and location of the lands to be conveyed (a marked exhibit G or K map may be used), the nature of the proposed use, the identity of any federal or state agency official consulted, and any federal or state approvals required for the proposed use. Unless the Director, within forty-five days from the filing date, requires the Licensee to file an application for prior approval, the Licensee may convey the intended interest at the end of that period.

(e) The following additional conditions apply to any intended conveyance under paragraph (c) or (d) of this article:

(1) Before conveying the interest, the Licensee shall consult with federal and state fish and wildlife or recreation agencies, as appropriate, and the State Historic Preservation Officer.

(2) Before conveying the interest, the Licensee shall determine that the proposed use of the lands to be conveyed is not inconsistent with any approved exhibit R or approved report on recreational resources of an exhibit E; or, if the project does not have an approved exhibit R or approved report on recreational resources, that the lands to be conveyed do not have recreational value.

(3) The instrument of conveyance must include covenants running with the land adequate to ensure that: (i) the use of the land conveyed shall not endanger health, create a nuisance, or otherwise be incompatible with overall project recreational use; and (ii) the grantee shall take all reasonable precautions to insure that the construction, operation, and maintenance of structures or facilities on the conveyed lands will

occur in a manner that will protect the scenic, recreational, and environmental values of the project.

(4) The Commission reserves the right to require the Licensee to take reasonable remedial action to correct any violation of the terms and conditions of this article, for the protection and enhancement of the project's scenic, recreational, and other environmental values.

(f) The conveyance of an interest in project lands under this article does not in itself change the project boundaries. The project boundaries may be changed to exclude land conveyed under this article only upon approval of revised exhibit G or K drawings (project boundary maps) reflecting exclusion of that land. Lands conveyed under this article will be excluded from the project only upon a determination that the lands are not necessary for project purposes, such as operation and maintenance, flowage, recreation, public access, protection of environmental resources, and shoreline control, including shoreline aesthetic values. Absent extraordinary circumstances, proposals to exclude lands conveyed under this article from the project shall be consolidated for consideration when revised exhibit G or K drawings would be filed for approval for other purposes.

(g) The authority granted to the Licensee under this article shall not apply to any part of the public lands and reservations of the United States included within the project boundary.

(E) The Licensee shall serve copies of any Commission filing required by this order on any entity specified in this order to be consulted on matters related to that filing. Proof of service on these entities must accompany the filing with the Commission.

(F) This order is final unless a request for rehearing is filed within thirty days of the date of its issuance pursuant to Section 313 of the Federal Power Act. The filing of a request for rehearing does not operate as a stay of the effective date of this order or of any other date specified in this order, except

Project No. 10809-000 -20-

as specifically ordered by the Commission. The Licensee's failure to file a request for rehearing shall constitute acceptance of this order.

By the Commission.

(S E A L)

David P. Boergers,
Secretary.

Appendix A.2

Federal Energy Regulatory Commission license covering the St. Louis Dam, Tributaries – Pine River. The license was issued November 29, 2001.

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97 FERC ¶ 62, 184
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

City of St. Louis, Michigan — Project No. 11428-000, Michigan

ORDER ISSUING ORIGINAL LICENSE
(Minor Project)
(November 29, 2001)

INTRODUCTION

Pursuant to Part I of the Federal Power Act (FPA)[1], the City of St. Louis, Michigan (City) filed an application for a minor license for operating the existing unlicensed 425-kilowatt Municipal Dam Hydroelectric Project No. 11428-000. The project is located on the Pine River[2] in the City of St. Louis, Gratiot County, Michigan.

BACKGROUND

On December 4, 1987, the Commission issued an order[3] determining that the St. Louis Municipal Dam Project was located on a stretch of the Pine River which was deemed to be navigable under Section 3(8) of the Federal Power Act, and was therefore subject to the Commission's licensing jurisdiction pursuant to Section 23(b) of the FPA. Accordingly, the Commission ordered the City to file a license or exemption application. The City filed its application for a minor license on August 5, 1993.[4]

The Commission issued a public notice accepting the application for filing on June 30, 1994. No motions to intervene were filed. The Commission then issued a public notice on December 31, 1996, indicating the project was ready for environmental

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[1] 16 U.S.C. §§ 791a - 825r.

[2] The Pine River is a navigable waterway of the United States. See 41 FERC ¶ 62,211 (1987). Therefore, Section 23 (b) (1) of the FPA, 16 U.S.C. § 817 (1), requires the project to be licensed.

[3] 41 FERC ¶62,211.

[4] A minor water power project means any licensed or unlicensed, existing or proposed water power project that would have a total installed generation capacity of 1.5 MW or less. 18 CFR § 4.30(b)(17).

analysis and soliciting comments, recommendations, prescriptions, and terms and conditions. The Commission received comments from the Michigan Department of Natural Resources (MDNR) and the U.S. Department of the Interior (Interior).

On July 13, 2001, the Commission's staff made available for public comment a draft environmental assessment (DEA). The DEA recommended that the project be licensed with certain additional environmental measures, and found that licensing the project would not constitute a major federal action significantly affecting the quality of the human environment. Comments on the DEA were filed by the MDNR, and the Commission's staff considered these comments in preparing the final environmental assessment (FEA), which is attached to this license. The comments filed by MDNR have been fully considered and addressed in this order in determining whether, and under what conditions, to issue this license.

PROJECT DESCRIPTION

The existing project consists of the following: (1) a 21-foot-high, 126-foot-long reinforced concrete dam surmounted by six 19-foot-wide, 8-foot-high radial gates; (2) a 60-foot-long left embankment, 55-foot-long center embankment, and 250-foot-long right embankment; (3) a 1,575-acre-foot reservoir at a normal water surface elevation of 719 feet; (4) a gated 18-foot-wide, 12-foot-deep intake flume; (5) a powerhouse containing two generating units for a total installed capacity of 425-kW; (6) a tailrace; (7) a short 2,400-volt transmission line; and (8) appurtenant electric and mechanical facilities. The project is described in greater detail in ordering paragraph (B)(2).

SUPERFUND SITE

The project area is part of the Velsicol Chemical Superfund Site. The St. Louis reservoir is currently under cleanup by the U.S. Environmental Protection Agency (EPA) and the Michigan Department of Environmental Quality (MDEQ).

Historically, heavy contamination from industrial sources led to severe degradation of water quality in the Pine River. Wastes discharged into the Pine River from Velsicol Chemical Plant (operated from 1936 to 1978), located on the St. Louis reservoir, include: polybrominated biphenyl (PBB), dichlorodiphenyl-trichloroethane (DDT), hexabromobenzene (HBB), and chlorobenzene. In 1982, the 56-acre Velsicol Chemical site was added to the EPA National Priorities List of sites eligible for cleanup under Superfund.

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In general, the contaminants are concentrated in bottom sediments of the St. Louis reservoir and immediately downstream, with surface and ground water samples in these areas showing little or no evidence of contamination. Additionally, reservoir sediments are heavily polluted with polycyclic aromatic hydrocarbons (PAHs) from abandoned petroleum refineries upstream of the reservoir. Bottom sediments have been reported to contain large amounts of oil as far back as 1967. Michigan Department of Health has continued to issue advisories for no consumption of fish in the Pine River at St. Louis and a 10-mile segment downstream from the reservoir since 1974 due to the DDT and PBB contamination.

The cleanup of the St. Louis reservoir is scheduled to be completed by 2002. From a site visit conducted on August 29, 2001, Scott Cornelius from the MDEQ stated that they were behind schedule because of a late start this season. Mr. Cornelius also stated that EPA and MDEQ have learned that the Velsicol Chemical land-site adjacent to the St. Louis reservoir may be leaking contaminants into the reservoir. This issue needs to be addressed before cleanup of the reservoir continues. Mr. Cornelius further added that they are in the process of receiving grants to assist with the cleanup of PAHs the Pine River upstream of the St. Louis reservoir (below Alma dam).

The City is currently restricting operations and has modified reservoir water level elevations at the request of the EPA and MDEQ. Accordingly, included in this license is a condition (Article 402) to modify project operations to assist in the cleanup and monitoring of contaminants, if so requested by EPA or MDEQ.

WATER QUALITY CERTIFICATION

Under Section 401(a)(1) of the Clean Water Act (CWA), the Commission may not issue a license for a hydroelectric project unless either the licensee obtains a water quality certificate (WQC) from the certifying agency of the state in which the project discharge will originate, or the certifying agency waives certification. Section 401(a)(1) states that certification is deemed waived if the certifying agency fails to act on a water quality certification request within a reasonable period of time, not to exceed one year.[7] Section 401(d) of the CWA provides that state certification shall set forth conditions

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[7] Section 401(a)(1) requires an applicant for a federal license or permit to conduct any activity that may result in any discharge into navigable waters to obtain from the state in which the discharge originates certification that any such discharge will comply with applicable water quality standards.

necessary to ensure that licensees comply with specific portions of the CWA and with appropriate requirements of state law.[6]

The City initially requested a WQC from MDNR on July 21, 1993. The MDNR reviewed and denied the request without prejudice on July 14, 1994 due to deficient data. The City reapplied for a WQC from MDNR on September 21, 1994. Since MDNR neither granted nor denied the applicant's certification request within one year of receiving that application, the WQC is deemed waived for the project.[7] Michigan Department of Environmental Quality (MDEQ)[8] issued a WQC on March 4, 1998 pursuant to a further request from the City on March 13, 1997. This later certification will not be considered valid because more than one year had elapsed since the September 21, 1994 request. Measures to protect water quality are included in this license (Articles 402, 403, 404, 405, 407, 408).

THREATENED AND ENDANGERED SPECIES

Section 7(a) of the Endangered Species Act of 1973 (ESA)[9] requires federal agencies to ensure that their actions are not likely to jeopardize the continued existence of federally listed threatened and endangered species, or result in the destruction or adverse modification of designated critical habitat. Interior determined that there are no federally listed threatened and endangered species. Therefore, we determined that the Municipal Dam Project would have no effect on federally listed species and further consultation per the ESA, as amended, is not needed.

FISHWAY PRESCRIPTIONS

Section 18 of the FPA[10] provides that the Commission shall require the construction, maintenance, and operation by a licensee of such fishways as the

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[6] 33 U.S.C. Section 1341(d).

[7] 18 CFR § 4.38 (f)(7)(ii).

[8] By Executive Order No. 1995-18, the Governor of the state of Michigan created the Michigan Department of Environment Quality, which was to take responsibility for WQC issuance as of October 1, 1995.

[9] 16 U.S.C. § 1536(a).

[10] 16 U.S.C. § 811.

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Secretaries of the U.S. Departments of Commerce and of the Interior may prescribe. By letter filed February 27, 1997, Interior requested the Commission to reserve Interior's authority to prescribe fish passage facilities for the project. Consistent with the Commission's policy, Article 401 of this license reserves the Commission's authority to require fishways that may be prescribed by Interior for the Municipal Dam Project.

RECOMMENDATIONS OF FEDERAL AND STATE FISH AND WILDLIFE AGENCIES

Section 10(j)(1) of the FPA[11] requires the Commission, when issuing a license, to include conditions based upon recommendations of federal and state fish and wildlife agencies submitted pursuant to the Fish and Wildlife Coordination Act,[12] to "adequately and equitably protect, mitigate damages to, and enhance fish and wildlife (including related spawning grounds and habitat)" affected by the project. If the Commission believes that any such recommendations may be inconsistent with the purpose and requirements of Part I of the FPA, or other applicable law, Section 10(j)(2) of the FPA requires the Commission and the agencies to attempt to resolve such inconsistencies, giving due weight to the recommendations, expertise, and statutory responsibilities of such agencies. If the Commission still does not adopt a recommendation, it must explain how the recommendation is inconsistent with Part I of the FPA or other applicable law and how the conditions imposed by the Commission adequately and equitably protect, mitigate damages to, and enhance fish and wildlife resources.

Interior and MDNR filed recommendations for license conditions that were considered in the Section 10(j) process in this proceeding.[13] Included in this license are conditions based on the agencies' recommendations, including requirements relating to maintaining state water quality standards (Article 403), a water quality monitoring plan (Article 404), run-of-river operation (Article 405), an operation and compliance plan (Article 406), a planned drawdown plan (Article 407), an erosion monitoring and control plan (Article 408), passing woody debris (Article 409), a wildlife management plan (Article 410), and a nuisance plant monitoring plan (Article 411).

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[11]16 U.S.C. § 803(j)(1).

[12]16 U.S.C. § 661 *et seq*.

[13]See letter filed February 27, 1997, for Interior recommendations submitted under Section 10(j) of the FPA. See letter filed March 3, 1997, for MDNR recommendations submitted under Section 10(j) of the FPA.

In the DEA, the Commission staff made an initial determination that the following recommendations made by Interior and MDNR may be inconsistent with the requirements of the FPA: (1) maintain state water quality standards; (2) develop and implement a water quality monitoring program; (3) periodically monitor contaminant concentrations in the reservoir and downstream of the dam; (4) maintain discharges within 10% of expected river flow during maintenance drawdown and refill; (5) provide funds to operate, maintain, and upgrade the upstream Alma USGS gage with telemetry; (6) install a continuous reservoir level recording device, equipped with telemetry; (7) maintain record of operation on a 30-minute basis and provide data to resource agencies upon request; (8) install a USGS gage downstream of the dam; (9) develop and implement an erosion monitoring and control plan; (10) improve downstream fish habitat by using large woody debris and restoring woody debris transport; and (11) develop and implement a wildlife management plan.

In letters dated July 23, 2001, the Commission staff sought to resolve the apparent inconsistency regarding Interior's and MDNR's recommendations by requesting a Section 10(j) meeting. In a letter commenting on the DEA from the MDNR filed August 6, 2001, MDNR disagreed with some of the Commission staff's recommendations. No comments were filed by Interior.

On August 30, 2001, the Commission staff convened a 10(j) meeting with a representative from MDNR (a representative from the U.S. Fish and Wildlife Service (FWS), representing Interior, did not attend the meeting). Resolution was achieved on most issues. Two issues (recommended by Interior) remain unresolved. Due to the EPA Superfund cleanup of the reservoir and the resultant increase in reservoir depth of 8 feet, Staff agreed to maintaining state water quality standards and 1 year of seasonal temperature and dissolved oxygen monitoring (with the possibility of a second year of seasonal monitoring due to extreme flow or temperature conditions, if requested by MDNR), to be conducted after the cleanup is completed (results of the monitoring would determine if further action was needed). The MDNR agreed that contaminant monitoring was not necessary, since contaminant monitoring is taking place through the EPA Superfund cleanup. The MDNR agreed that discharges during maintenance drawdowns and refills should be determined on a case by case basis, and not predetermined at 10% of expected river flow. The City agreed to add telemetry to the continuous reservoir level sensor and MDNR therefore withdrew USGS gaging recommendations. The MDNR agreed to records of operation maintained on an hourly basis (instead of every 30 minutes). The City stated it already conducts erosion surveys annually and repairs any erosional sites and therefore the Staff agreed to developing an erosion plan. The MDNR agreed to passing large woody debris over the dam, and clarified that they were not looking for additional habitat structures downstream (as stated in the original recommendation). The MDNR agreed to the wildlife management plan as modified by the Staff, without nesting structures for bluebirds and owls.

Commission staff were unable to resolve the Interior's recommendation to periodically monitor contaminant concentrations in the reservoir and downstream of the dam. As discussed in the FEA, there is no information that indicates project operations would alter the level of contaminants in the impoundment or downstream. Additionally, sufficient monitoring is taking place through the EPA Superfund Cleanup.

Commission staff were unable to resolve the Interior's recommendation to install a USGS gage downstream of the dam. As discussed in the FEA, installing a USGS gaging station is not necessary for compliance determination. Compliance will be based on reservoir elevation and demonstrated by powerplant recording data. As a result of Section 10(j) meeting with MDNR, telemetry will be added to the reservoir water level sensor and the turbine rating curves will be made available.

OTHER ISSUES

A. Administrative Conditions

Section 10(e) of the FPA[14] provides that the Commission shall assess licensees annual charges to reimburse the United States for the costs of administering Part I of the FPA. However, the Commission does not assess administrative annual charges for projects less than 1,500 kW authorized installed capacity[15]; accordingly, since the installed capacity for this project is 425 kW, no annual administrative charge will be assessed.

B. Cultural Resources

The Michigan State Historic Preservation Officer concludes that no cultural resources are listed or eligible for inclusion in the National Register of Historic Places are known to exist in the project area and that the project would have no effect on such resources. However, Article 413 of this license order provides guidance and protection if archeological or historic sites are discovered during: (1) upgrading recreation facilities; and (2) the future operation and maintenance of the project.

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[14] 16 U.S.C. § 803(e).

[15] 18 CFR § 11.(b)(1).

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C. Project Boundary Map

Minor license applicants are not required to file a project boundary map delineating the project works such as the dam, powerhouse, and reservoir. Therefore, no project boundary map is required for this project.

CONSISTENCY WITH COMPREHENSIVE PLANS

Section 10(a)(2)(A) of the FPA[16] requires the Commission to consider the extent to which a hydroelectric project is consistent with federal and state comprehensive plans for improving, developing, or conserving waterways affected by the project.[17] Under Section 10(a)(2)(A), federal and state agencies filed 64 comprehensive plans that address various resources in Michigan. Of these, the Commission staff identified and reviewed three plans relevant to this project.[18] No conflicts were found.

COMPREHENSIVE DEVELOPMENT

In determining whether a proposed hydroelectric power project will be best adapted to a comprehensive plan for developing a waterway for beneficial public uses, pursuant to Section 10(a)(1), the Commission considers a number of public interest factors, including the projected economic benefits of project power.

Under the Commission's approach to evaluating the economics of hydropower projects, as articulated in *Mead Corp.*,[19] the Commission employs an analysis that uses current costs to compare the costs of the project and likely alternative power, with no forecasts concerning potential future inflation, escalation, or deflation beyond the license issuance date. The basic purpose of the Commission's economic analysis is to provide a general estimate of the potential power benefits and the costs of a project, and of reasonable alternatives to project power. The estimate helps to support an informed decision concerning what is in the public interest with respect to a proposed license. In making its decision, the Commission considers the project power benefits both with the

[16]16 U.S.C. § 803(a)(2)(A).

[17]Comprehensive plans for this purpose are defined at 18 C.F.R. § 2.19 (1997).

[18]See Section IX of the FEA.

[19]72 FERC ¶ 61,027 (1995).

applicant's proposed measures and with the Commission's modifications and additions to the applicant's proposal.

Staff has analyzed the applicant's proposal. We find that the levelized annual cost of developing and operating the Municipal Dam Project would be about $54,000 or 34 mills per kilowatt-hour (kWh). The project would produce about 1,590,000 kWh annually, having a total value of about $51,000 or 32 mills per kWh in 2001 dollars, based on the average cost of alternative capacity and energy in the region.[20] Therefore in the first year of licensing, we estimate the project power would annually cost about $3,000 or 2 mills per kWh more than alternative power in the regional market.

Staff has also evaluated the applicant's proposal with staff-recommended enhancements that are valued at a total annual cost of $5,200 (see section VI of the FEA). The levelized annual cost of operating the project would be about $59,200 or 37 mills per kWh based on the average annual generation of 1,590,000 kWh. The project would produce generation valued at about $51,000 or 32 mills per kWh in 2001 dollars as stated above. Therefore in the first year of licensing, we estimate the project power would annually cost about $8,200 or 5 mills per kWh more than alternative power in the regional market. Thus, a comparison of the two proposals indicate that our recommended enhancements for the Municipal Dam Project would decrease annual benefits by about $5,200 when compared to the City's proposal. Both proposals would have no effect on project generation.

Our evaluation of the economics of the proposed action and the proposed action with additional staff-recommended measures shows that project energy would cost more

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[20]Our estimate of the cost of alternative power is based on the projected cost of energy generation in fossil-fueled electric generating plants in the East Central Area Reliability Coordination Agreement Region of the North American Electric Reliability Council plus a value of $114 per kilowatt year for the project's average annual capacity of 425 kW. We compute the regional energy value to be 24.8 mills/kWh and the capacity value to be 7.17 mills/kWh, for a total power value of 31.97 mills/kWh. Our estimate of the energy value is based on the cost of fuel that would be displaced by the hydroelectric generation in a combined-cycle combustion turbine plant fueled by natural gas, operating at a heat rate of 6,200 Btu/kWh. We estimate the cost of fuel based on the Energy Information Administration's reference-case estimate of average real natural gas costs for electric utilities, as published by the Energy Information Administration (EIA) in their Annual Energy Outlook for 2001 and its supplemental data on the EIA Internet Homepage.

than alternative energy. However, project economics is only one of the many public interest factors that is considered in determining whether or not to issue a license, and operation may be desirable for other reasons. For example, other public interest factors are to: (1) diversify the mix of energy sources in the area; (2) promote local employment; and (3) provide a fixed-cost source of power and reduce contract needs.

In analyzing public interest factors, the Commission takes into account that hydropower projects offer unique operational benefits to the electric utility system (ancillary benefits). These benefits include their value as almost instantaneous load-following response to dampen voltage and frequency instability on the transmission system, system-power-factor-correction through condensing operations, and a source of power available to help in quickly putting fossil-fuel based generating stations back on line following a major utility system or regional blackout.

Ancillary benefits are now mostly priced at rates that recover only the cost of providing the electric service at issue, which do not resemble the prices that would occur in competitive markets. As competitive markets for ancillary benefits begin to develop, the ability of hydropower projects to provide ancillary services to the system will increase the benefits of the projects.

Based on our independent review and evaluation of the Municipal Dam Project, recommendations from the resource agencies and other stakeholders, and the no-action alternative, as documented in the FEA, the Municipal Dam Project, with the staff-recommended measures, is the preferred alternative.

This alternative was selected because: (1) issuance of an original license would serve to maintain a beneficial, dependable, and an inexpensive source of electric energy; and (2) the required environmental measures would protect and enhance fish and wildlife, water quality, recreational, and cultural resources.

The preferred alternative includes the following measures:

(1) reserve the Commission's authority to require fishways as may be prescribed by Interior under Section 18 of the FPA (Article 401);

(2) cooperate with the EPA cleanup and monitoring efforts in the Pine River (Article 402);

(3) maintain state water quality standards for temperature and dissolved oxygen (Article 403);

(4) develop and implement a water quality monitoring plan (Article 404);

(5) operate the project in a run-of-river mode (Article 405);

(6) develop and implement an operation and compliance plan (Article 406);

(7) prepare drawdown plans, in consultation with MDNR, Interior, and EPA, for any protracted drawdowns (Article 407);

(8) develop and implement an erosion monitoring and control plan (Article 408);

(9) pass woody debris downstream of the project (Article 409);

(10) develop and implement a wildlife management plan (Article 410);

(11) develop and implement a plan to monitor nuisance plants (411);

(12) develop and implement a recreation and land use plan (412); and

(13) consult with the SHPO in the event that archeological or historic sites are discovered (Article 413).

LICENSE TERM

Section 6 of the FPA[21] provides that original licenses for hydropower projects shall be issued for a term not exceeding 50 years. The Commission's license term policy when issuing original licenses for existing projects that should have been licensed earlier is set forth in *City of Danville*.[22] A 30-year license is issued for projects with little or no redevelopment, new construction, or new environmental mitigation and enhancement measures; a 40-year license is issued for projects with a moderate amount of such activities; and a 50-year license is issued for projects with extensive measures.

This license authorizes a moderate amount of new environmental mitigation measures relative to the size of the project. Accordingly, this license will be issued for a term of 40 years, effective the first day of the month in which the license is issued.

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[21] 16 U.S.C. § 799.

[22] 58 FERC ¶ 61,318 at pp. 62,020-21 (1992).

SUMMARY OF FINDINGS

Background information, analysis of impacts upon the environment, and support for related license articles are contained in the FEA and in the record of this proceeding. Issuance of this license is not a major federal action significantly affecting the quality of the human environment.

The design of this project is consistent with the engineering standards governing dam safety. The project will be safe if operated and maintained in accordance with the requirements of this license.[23]

The Director orders:

(A) This license is issued to the City of St. Louis, Michigan (licensee) for a period of 40 years, effective the first day of the month in which this order is issued, to operate and maintain the Municipal Dam Hydroelectric Project. This license is subject to the terms and conditions of the Federal Power Act (FPA), which is incorporated by reference as part of this license, and subject to the regulations the Commission issues under the provisions of the FPA.

(B) The project consists of:

(1) All lands, to the extent of the licensee's interests in those lands, shown by Exhibit G filed March 11, 1994:

Exhibit G Drawing	FERC No.	Description
G - 1	11428-7	Project Location Map
G - 2	11428-8	Project Location Map

(2) Project works consisting of:

The project's principal features are three earthen embankments, a gated concrete gravity dam structure, an intake area leading to an integral powerhouse with a small tailrace area, a reservoir, a primary transmission line, and appurtenant facilities.

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[23]See Safety and Design Assessment issued for the St. Louis Municipal Dam Hydroelectric Project.

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In detail, from left to right, looking upstream, the existing unlicensed project consists of:

1. a left sandy silt earthen embankment, about 250 feet long by 7.5 feet high, with a top elevation of 723.5 feet national geodetic vertical datum (NGVD)[24];

2. an intake area leading to the powerhouse, which consists of (a) a reinforced concrete headrace, about 19 feet wide by 70 feet long; and (b) a concrete headgate flume, about 17 feet wide by 12 feet deep by 30 feet long, equipped with steel trashracks with 1 ½-inch spacings;

3. a center sandy silt earthen embankment, about 55 feet long by 10.5 feet high, with a top elevation of 723.5 feet, protected upstream by a steel sheet piling wall and downstream by a concrete retaining wall;

4. a concrete gravity dam, about 126 feet long by 10 feet high, with a sill elevation of 714.0 feet, topped with six radial gates, each measuring about 19 feet wide by 8 feet high, with a top of pier elevation of about 725.0 feet;

5. a right sandy silt earthen embankment, about 60 feet long by 4.0 feet high, with a top elevation of 723.5 feet, protected upstream by rip rap and downstream by a steel sheet piling wall;

6. a powerhouse, integral with the dam, equipped with 2 vertical Francis hydroelectric generating units, having (a) rated horsepower of 317 hp at 225kW and 290 hp at 200 kW for total installed capacity of 425 kW; (b) hydraulic capacity of 95 to 240 cfs; (c) average annual head of 12 feet; (d) power factor of 1.00 kW/kVA; and (e) tailrace channel about 35 feet long by 32 feet wide at the downstream face of the powerhouse, with a normal tailwater elevation of 706.5 feet;

7. a reservoir, with (a) normal pool elevation of 719.0 feet; (b) surface area of about 205 acres; (c) gross storage capacity of about 1,575 acre-feet; (d) useable storage capacity of 45 acre-feet, with a proposed 0.2-foot fluctuation; and (e) net storage capacity of 690 acre-feet, maintained

[24]All elevations are stated as NGVD, unless otherwise noted.

between the maximum pool elevation of about 722.0 feet and the normal pool elevation of about 719.0 feet;

8. a 2.4-kilovolt (kV), 80-foot-long overhead transmission line; and

9. appurtenant facilities.

The project works generally described above are more specifically described in Exhibit A of the application and shown by Exhibit F filed August 5, 1993:

Exhibit F Drawing	FERC No.	Showing
Sheet F-1	11428-1	Site Plan Sections
Sheet F-2	11428-2	Dam and Powerhouse Plans and Elevations
Sheet F-3	11428-3	Powerhouse Profiles
Sheet F-4	11428-4	Gated Spillway Cross Sections
Sheet F-5	11428-5	Earth Embankment Sections
Sheet F-6	11428-6	Powerhouse Plan View

(3) All of the structures, fixtures, equipment, or facilities used to operate or maintain the project, all portable property that may be employed in connection with the project, and all riparian or other rights that are necessary or appropriate in the operation or maintenance of the project.

(C) The Exhibits A, F, and G designated above are approved and made part of this license.

(D) The following sections of the FPA are waived and excluded from the license for this minor project:

4(b), except the second sentence; 4(e), insofar as it relates to approval of plans by the Chief of Engineers and the Secretary of the Army; 6, insofar as it relates to public notice and to the acceptance and expression in the license of terms and conditions of the FPA that are waived here; 10(c), insofar as it relates to depreciation reserves; 10(d); 10(f); 14, except insofar as the power of condemnation is reserved; 15; 16; 19; 20; and 22.

(E) This license is subject to the articles set forth in Form L-9 (October 1975), entitled "Terms and Conditions of License for Constructed Minor Project Affecting Navigable Waters of the United States," and the following additional articles:

Article 201. The licensee shall pay the United States the following annual charges effective the first day of the month in which this license is issued:

For the purposes of reimbursing the United States for the Commission's administrative costs, pursuant to Part I of the Federal Power Act, a reasonable amount as determined in accordance with the provisions of the Commission's regulations in effect from time to time. The authorized installed capacity for that purpose is 425 kilowatts (kW). Under the regulations currently in effect, projects with authorized installed capacity of less than or equal to 1,500 kW will not be assessed an annual charge.

Article 202. The licensee shall file, within 45 days of the license issuance, three sets of aperture cards of the approved exhibit drawings. The sets must be reproduced on silver or gelatin microfilm and mounted on type D (3 1/4" X 7 3/8") aperture cards.

Prior to microfilming, the FERC Drawing Numbers (11428-1 through 11428-8) shall be shown in the margin below the title block of the approved drawing. After mounting, the FERC Drawing Number must be typed on the upper right corner of each aperture card. Additionally the Project Number, FERC exhibits (e.g., F-1, G-1, etc.), Drawing title, and date of this order must be typed on the upper left corner of each aperture card. See Figure 1.

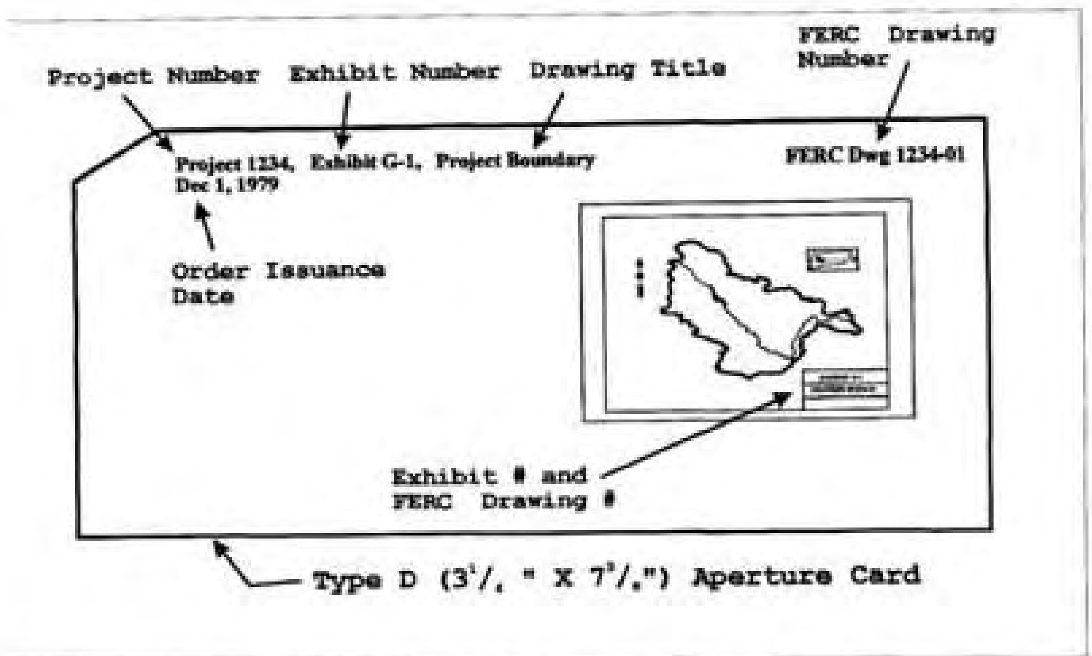

Figure 1. Sample Aperture Card Format

The original and one duplicate set of aperture cards shall be filed with the Secretary of the Commission, ATTN: OEP/DHAC. The remaining duplicate set of aperture cards shall be filed with the Commission's Chicago Regional Office.

Article 203. The licensee shall clear and keep clear to an adequate width all lands along open conduits and shall dispose of all temporary structures, unused timber, brush, refuse, or other material unnecessary for the purposes of the project which result from maintenance, operation, or alteration of the project works. All clearing of lands and disposal of unnecessary material shall be done with due diligence to the satisfaction of the authorized representative of the Commission and in accordance with appropriate federal, state, and local statutes and regulations.

Article 204. If the licensee's project was directly benefitted by the construction work of another licensee, a permittee, or the United States on a storage reservoir or other headwater improvement during the term of the original license (including extensions of that term by annual licenses), and if those headwater benefits were not previously assessed and reimbursed to the owner of the headwater improvement, the licensee shall reimburse the owner of the headwater improvement for those benefits, at such time as they are assessed, in the same manner as for benefits received during the term of this license.

Article 401. Authority is reserved to the Commission to require the licensee to construct, operate, and maintain, or to provide for the construction, operation, and maintenance of, such fishways as may be prescribed by the Secretary of the Interior under Section 18 of the Federal Power Act.

Article 402. The licensee shall cooperate, to the extent appropriate, with the U.S. Environmental Protection Agency (EPA) and Michigan Department of Environmental Quality (MDEQ) for the cleanup and monitoring efforts of the Velsicol Chemical Superfund Site. The licensee shall file, for Commission approval and after consultation with Michigan Department of Natural Resources (MDNR), U.S. Fish and Wildlife Service (FWS), MDEQ, and EPA, any proposed changes in project operation requested by EPA or MDEQ. Documentation of the request from EPA or MDEQ as well as proof of consultation with the agencies shall be provided.

The Commission reserves the right to require changes to the proposed changes in project operations. Upon Commission approval, the licensee shall implement the changes in project operations, including any changes required by the Commission.

Article 403. The licensee shall maintain the following state water quality standards for water temperature and dissolved oxygen (DO) at the Municipal Dam Hydroelectric Project when river discharges are greater than or equal to the 95 percent exceedence flow as follows:

(a) the average monthly temperatures downstream of the project shall not exceed the following temperatures (°F):

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
41	40	50	63	76	84	85	85	79	68	55	43

(b) the DO concentrations in the project tailwaters shall not be less than 5.0 milligrams per liter (mg/l) at any time;

(c) these condition shall not apply when the natural temperatures or DO of the Pine River upstream of the project exceed the standards listed.

<u>Article 404</u>. The licensee shall file, within 1 year after the completion of all river contaminant cleanup activity in the Pine River between the Alma and St. Louis dams, for Commission approval, a plan to sample water quality in the project area for one season. The plan shall include a description of the methods that will be used to collect dissolved oxygen (DO) and water temperature data upstream (upstream of the St. Louis reservoir) and downstream (tailrace) of the project from January 1 through December 31. The plan shall also contain provisions to measure the DO and water temperature profile in the deepest part of the reservoir every two weeks from May through October. Measurements shall be made at 0.5 meter increments or less.

Further, the plan shall include provisions for filing a summary of the monitoring data to the Commission, Michigan Department of Environmental Quality (MDEQ), U.S. Fish and Wildlife Service (FWS), Michigan Department of Natural Resources (MDNR), and the U.S. Environmental Protection Agency (EPA) within 60 days after the end of the water quality monitoring year.

The licensee shall prepare the plan after consultation with the MDEQ, FWS, MDNR, and EPA. The licensee shall include with the plan documentation of consultation, copies of comments and recommendations on the completed plan after it has been prepared and provided to the agencies, and specific descriptions of how the agencies' comments are accommodated by the plan. The licensee shall allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the licensee shall implement the plan, including any changes required by the Commission.

If the study year consists of higher than normal river flows or lower than average temperature conditions, MDNR may request the Commission to require the licensee to conduct a second year of water quality sampling. MDNR must provide the Commission with a written request within 60 days of receiving the summary report from the licensee, detailing the unusual river flows or temperatures that warrant another season of water quality sampling.

If results from the water quality sampling indicate that there are potential water quality problems in the St. Louis reservoir or in the tailrace, as determined by the Commission, the licensee shall consult with MDEQ, FWS, MDNR, and EPA on an action plan to continue monitoring water quality and implement changes in project operations to rectify the problems. The licensee shall allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the action plan with the Commission. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information.

The Commission reserves the right to require changes to the action plan. Upon Commission approval, the licensee shall implement the action plan, including any changes required by the Commission.

Article 405. The licensee shall operate the Municipal Dam Project in a run-of-river (R-O-R) mode for the protection of water quality, and aquatic and recreational resources, such that the St. Louis reservoir elevation is within plus or minus 0.2 feet of 719.0 feet National Geodetic Vertical Datum (NGVD).

The licensee shall at all times act to minimize the fluctuation of the reservoir surface elevation by maintaining a discharge from the project so that, at any point in time, flows, downstream of the project tailrace, approximate the sum of the inflows to the project reservoir. The licensee shall not use the operating band width for peaking purposes.

The R-O-R mode of operation may be temporarily modified if required by operating emergencies beyond the control of the licensee and for short periods (less than three weeks) upon mutual agreement between the licensee, the U.S. Fish and Wildlife Service and the Michigan Department of Natural Resources. If project operations are so modified, the licensee shall notify the Commission as soon as possible, but no later than 10 days after each incident.

Article 406. The licensee shall file, within one year of license issuance, for Commission approval, an operation and compliance plan to monitor the run-of-river (R-O-R) operating mode required by Article 405. The plan shall include, at a minimum, measures to implement the following:

(a) maintain a calibrated staff gage in the St. Louis reservoir at a location clearly visible to the public to show the minimum and maximum reservoir water surface elevations to the National Geodetic Vertical Datum;

(b) install, operate, and maintain an automated water surface elevation sensor in the St. Louis reservoir, record the reservoir water surface elevation on an hourly basis, and connect with telemetry;

(c) record operations data, including turbine start-up and shutdown times, and flows associated with project features.

The operation and compliance plan shall also include protocols for recording monitoring data, such as pond elevations and turbine flows, and provisions for maintaining and filing a log of naturally-occurring high flows and ice jams that may hinder compliance with R-O-R operations. The plan shall include a timetable for: (1) installing an automated headpond sensor and a staff-type gage that is clearly visible to the public on the St. Louis reservoir and (2) filing with the Commission summaries of monitoring data including, headwater water surface elevations, and project operations data to show compliance with R-O-R operations.

The licensee shall prepare the plan after consultation with the U.S. Fish and Wildlife Service and the Michigan Department of Natural Resources. The licensee shall include with the plan documentation of consultation, copies of comments and recommendations on the completed plan after it has been prepared and provided to the agencies, and specific descriptions of how the agencies' comments are accommodated by the plan. The licensee shall allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the licensee shall implement the plan, including any changes required by the Commission.

Article 407. At least 90 days before undertaking any planned drawdowns, for a time period greater than 3 weeks, of the St. Louis reservoir for construction or operations and maintenance purposes, the licensee shall file, for Commission approval, notification of the planned drawdown.

The licensee shall consult with the U.S. Fish and Wildlife Service (FWS), the Michigan Department of Natural Resources (MDNR), and the U.S. Environmental Protection Agency (EPA). The licensee shall provide a minimum of 30 days for the FWS, MDNR, and EPA to comment on any planned reservoir drawdown. The licensee shall file with the notification, a summary of resource agency comments, including how comments were addressed. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information. The Commission reserves the right to modify procedures for, and the execution of, any planned reservoir drawdowns.

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Article 408. The licensee shall file a plan, for Commission approval, to monitor and control erosion every 10 years in the St. Louis reservoir and downstream of the St. Louis dam for a distance of 200 yards within 5 years after the contaminant cleanup of the St. Louis reservoir.

The licensee shall prepare the plan after consultation with the U.S. Fish and Wildlife Service, the Michigan Department of Natural Resources, the Michigan Department of Environmental Quality, and the U.S. Environmental Protection Agency. The licensee shall include with the plan documentation of consultation, copies of comments and recommendations on the completed plan after it has been prepared and provided to the agencies, and specific descriptions of how the agencies' comments are accommodated by the plan. The licensee shall allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the licensee shall implement the plan, including any changes required by the Commission.

Article 409. The licensee shall pass all natural organic material over the St. Louis dam. The licensee shall remove and properly dispose of all other materials collected on the trashracks. The downstream passage of all natural organic material shall focus on material accumulating on project trashracks and other project structures, as safety and flow conditions allow.

The licensee shall file, within one year of license issuance, for Commission approval, the summary of consultation with the Michigan Department of Natural Resources (MDNR) regarding procedures for the disposition of woody debris not immediately passed downstream of the project, including the disposition of any large woody material requiring cutting or substantive non-manual efforts to pass downstream.

The licensee shall allow a minimum of 30 days for the MDNR to comment and to make recommendations before filing the summary with the Commission. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information. The Commission reserves the right to modify methods of woody debris disposition.

Article 410. The licensee shall file, within 3 years of license issuance, for Commission approval, a wildlife management plan. The plan shall include, but not be limited to the following:

(a) protection and enhancement of wildlife habitat, to the extent appropriate;

(b) protection of environmentally sensitive areas, to the extent appropriate;

(c) waterfowl enhancements consisting of wood duck boxes and mallard nesting structures;

(d) kestrel nest structures on project lands and rights of way;

(e) the protection and enhancement of habitat for any federal or state listed threatened or endangered species on project lands; and

(f) annual consultation with the resource agencies on the status of wildlife populations and measures to protect and enhance wildlife populations.

The licensee shall prepare the plan after consultation with the U.S. Fish and Wildlife Service (FWS) and the Michigan Department of Natural Resources (MDNR). The licensee shall include with the plan documentation of consultation, copies of comments and recommendations on the completed plan after it has been prepared and provided to the agencies, and specific descriptions of how the agencies' comments are accommodated by the plan. The licensee shall allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information.

If any of the measures prove unsuccessful, the plan shall provide for the inclusion of alternative measures or modifications to measures that are developed in consultation with the FWS and MDNR.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the licensee shall implement the plan, including any changes required by the Commission.

Article 411. The licensee shall file, within 3 years of license issuance, for Commission approval, a plan to monitor purple loosestrife (*Lythrum salicaria*) and Eurasian water-milfoil (*Myriophyllum spicatum*) in project lands and waters and to develop a public outreach program aimed at controlling the spread of these species. The plan shall include, but not be limited to the following:

(a) a description of the monitoring method and public outreach program;

(b) a monitoring schedule;

(c) a schedule for providing the monitoring results to the MDNR and FWS;

(d) an implementation schedule for the public outreach program; and

(e) documentation of agency consultation, including copies of comments and recommendations on the completed plan.

The licensee shall prepare the plan after consultation with the U.S. Fish and Wildlife Service (FWS) and the Michigan Department of Natural Resources (MDNR). The licensee shall include with the plan documentation of consultation, copies of comments and recommendations on the completed plan after it has been prepared and provided to the agencies, and specific descriptions of how the agencies' comments are accommodated by the plan. The licensee shall allow a minimum of 30 days for the agencies to comment and to make recommendations before filing the plan with the Commission. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information.

If at any time during the term of the license, the FWS or the MDNR demonstrate that purple loosestrife or Eurasian water-milfoil is significantly affecting fish and wildlife populations at the project and that control measures are needed, and the Commission agrees with those determinations, the Commission may require the licensee to cooperate with the FWS and MDNR to undertake reasonable measures to control or eliminate these weeds in project lands and waters.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the licensee shall implement the plan, including any changes required by the Commission.

Article 412. Within one year of the date of issuance of this license, the licensee, in consultation with the Michigan Department of Natural Resources (MDNR), shall file for the Commission's approval a recreation and land use plan for the project.

The plan shall include the final details of upgrades and enhancements to be made, maintenance schedule of facilities, a map of the existing and proposed facilities and City-owned lands, and a construction and implementation schedule. Further, the plan shall also include provisions for consultation with the Environmental Protection Agency for any construction that may disturb contaminated river sediments. Specifically, the licensee shall include measures for: (1) improvements for all project recreational facilities to be fully accessible to persons with disabilities, including improvements at Westgate Park to meet accessibility standards: the pier at the boat ramp, portable toilet, and walkway to the accessible picnic table; (2) improvements in the tailwater fishing area, including parking, toilet, picnic tables and grills; (3) signed, safe canoe portage around the dam at Mill Street within 5 years of license issuance; (4) signage improvements throughout the project area, including directional signage improvements in parking areas at Westgate, Prospect, and Michigan Avenue Parks with basic information such as: hours for recreation, nearest toilet facilities, nearest hospital, and a 911 emergency posting; and (6) "fish consumption" warning signs and "no swimming signs" posted in all areas where users have access to project waters.

The licensee shall prepare the plan after consultation with MDNR. The licensee shall include with the plan documentation of consultation, copies of comments and recommendations on the completed plan after it has been prepared and provided to MDNR, and specific descriptions of how MDNR's comments are accommodated by the plan. The licensee shall allow a minimum of 30 days for MDNR to comment and to make recommendations before filing the plan with the Commission. If the licensee does not adopt a recommendation, the filing shall include the licensee's reasons, based on project-specific information.

The Commission reserves the right to require changes to the plan. Upon Commission approval, the licensee shall implement the plan, including any changes required by the Commission.

Article 413. If archeological or historic sites are discovered during any future project modifications or construction that require land-disturbing activities, or during project operation or maintenance, or if the licensee plans any future modifications, other than routine maintenance, the licensee shall: (1) consult with the Michigan State Historic Preservation Officer (SHPO) about the discovered sites; (2) prepare a site-specific plan, including a schedule, to evaluate the significance of the sites and to avoid or mitigate any impacts to sites found eligible for inclusion in the National Register of Historic Places; (3) base the site-specific plan on recommendations of the SHPO and the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation; (4) file the site-specific plan for Commission approval, together with the written comments of the

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SHPO; and (5) take the necessary steps to protect the discovered archeological or historic sites from further impact until notified by the Commission that all of these requirements have been satisfied.

The Commission may require cultural resources surveys and changes to the site-specific plans based on the filings. The licensee shall not implement a cultural resources management plan, begin any land-clearing or land-disturbing activities in the vicinity of any discovered sites, or modify previously discovered sites until informed by the Commission that the requirements of this article have been fulfilled.

Article 414. (a) In accordance with the provisions of this article, the licensee shall have the authority to grant permission for certain types of use and occupancy of project lands and waters and to convey certain interests in project lands and waters for certain types of use and occupancy, without prior Commission approval. The licensee may exercise the authority only if the proposed use and occupancy are consistent with the purposes of protecting and enhancing the scenic, recreational, and other environmental values of the project. For those purposes, the licensee shall also have continuing responsibility to supervise and control the use and occupancies for which it grants permission, and to monitor the use of, and ensure compliance with the covenants of the instrument of conveyance for, any interests that it has conveyed under this article.

If a permitted use and occupancy violates any condition of this article or any other condition imposed by the licensee for protection and enhancement of the project's scenic, recreational, or other environmental values, or if a covenant of a conveyance made under the authority of this article is violated, the licensee shall take any lawful action necessary to correct the violation. For a permitted use or occupancy, that action includes, if necessary, canceling the permission to use and occupy the project lands and waters and requiring the removal of any non-complying structures and facilities.

(b) The types of use and occupancy of project lands and waters for which the licensee may grant permission without prior Commission approval are: (1) landscape plantings; (2) non-commercial piers, landings, boat docks, or similar structures and facilities that can accommodate no more than 10 watercraft at a time and where said facility is intended to serve single-family type dwellings; (3) embankments, bulkheads, retaining walls, or similar structures for erosion control to protect the existing shoreline; and (4) food plots and other wildlife enhancements.

To the extent feasible and desirable to protect and enhance the project's scenic, recreational, and other environmental values, the licensee shall require multiple use and occupancy of facilities for access to project lands or waters. The licensee shall also ensure, to the satisfaction of the Commission's authorized representative, that the use and occupancies for which it grants permission are maintained in good repair and comply with applicable state and local health and safety requirements. Before granting permission for construction of bulkheads or retaining walls, the licensee shall: (1) inspect the site of the proposed construction, (2) consider whether the planting of vegetation or the use of riprap would be adequate to control erosion at the site, and (3) determine that the proposed construction is needed and would not change the basic contour of the reservoir shoreline. To implement this paragraph (b), the licensee may, among other things, establish a program for issuing permits for the specified types of use and occupancy of project lands and waters, which may be subject to the payment of a reasonable fee to cover the licensee's costs of administering the permit program. The Commission reserves the right to require the licensee to file a description of its standards, guidelines, and procedures for implementing this paragraph (b) and to require modification of those standards, guidelines, or procedures.

(c) The licensee may convey easements or rights-of-way across, or leases of, project lands for: (1) replacement, expansion, realignment, or maintenance of bridges or roads where all necessary state and federal approvals have been obtained; (2) storm drains and water mains; (3) sewers that do not discharge into project waters; (4) minor access roads; (5) telephone, gas, and electric utility distribution lines; (6) non-project overhead electric transmission lines that do not require erection of support structures within the project boundary; (7) submarine, overhead, or underground major telephone distribution cables or major electric distribution lines (69-kV or less); and (8) water intake or pumping facilities that do not extract more than one million gallons per day from a project reservoir. No later than January 31 of each year, the licensee shall file three copies of a report briefly describing for each conveyance made under this paragraph (c) during the prior calendar year, the type of interest conveyed, the location of the lands subject to the conveyance, and the nature of the use for which the interest was conveyed.

(d) The licensee may convey fee title to, easements or rights-of-way across, or leases of project lands for: (1) construction of new bridges or roads for which all necessary state and federal approvals have been obtained; (2) sewer or effluent lines that discharge into project waters, for which all necessary federal and state water quality certification or permits have been obtained; (3) other pipelines that cross project lands or waters but do not discharge into project waters; (4) non-project overhead electric transmission lines that require erection of support structures within the project boundary, for which all necessary federal and state approvals have been obtained; (5) private or public marinas that can accommodate no more than 10 watercraft at a time and are located at least one-half mile (measured over project waters) from any other private or public marina; (6) recreational development consistent with an approved Exhibit R or approved report on recreational resources of an Exhibit E; and (7) other uses, if: (i) the amount of land conveyed for a particular use is five acres or less; (ii) all of the land conveyed is located at least 75 feet, measured horizontally, from project waters at normal surface elevation; and (iii) no more than 50 total acres of project lands for each project development are conveyed under this clause (d)(7) in any calendar year.

At least 60 days before conveying any interest in project lands under this paragraph (d), the licensee must submit a letter to the Director, Office of Energy Projects, stating its intent to convey the interest and briefly describing the type of interest and location of the lands to be conveyed (a marked exhibit G or K map may be used), the nature of the proposed use, the identity of any Federal or state agency official consulted, and any Federal or state approvals required for the proposed use. Unless the Director, within 45 days from the filing date, requires the licensee to file an application for prior approval, the licensee may convey the intended interest at the end of that period.

(e) The following additional conditions apply to any intended conveyance under paragraph (c) or (d) of this article:

(1) Before conveying the interest, the licensee shall consult with Federal and state fish and wildlife or recreation agencies, as appropriate, and the State Historic Preservation Officer.

(2) Before conveying the interest, the licensee shall determine that the proposed use of the lands to be conveyed is not inconsistent with any approved exhibit R or approved report on recreational resources of an exhibit E; or, if the project does not have an approved exhibit R or approved report on recreational resources, that the lands to be conveyed do not have recreational value.

(3) The instrument of conveyance must include the following covenants running with the land: (i) the use of the lands conveyed shall not endanger health, create a nuisance, or otherwise be incompatible with overall project recreational use; (ii) the grantee shall take all reasonable precautions to insure that the construction, operation, and maintenance of structures or facilities on the conveyed lands will occur in a manner that will protect the scenic, recreational, and environmental values of the project; and (iii) the grantee shall not unduly restrict public access to project waters.

(4) The Commission reserves the right to require the licensee to take reasonable remedial action to correct any violation of the terms and conditions of this article, for the

protection and enhancement of the project's scenic, recreational, and other environmental values.

(f) The conveyance of an interest in project lands under this article does not in itself change the project boundaries. The project boundaries may be changed to exclude land conveyed under this article only upon approval of revised exhibit G or K drawings (project boundary maps) reflecting exclusion of that land. Lands conveyed under this article will be excluded from the project only upon a determination that the lands are not necessary for project purposes, such as operation and maintenance, flowage, recreation, public access, protection of environmental resources, and shoreline control, including shoreline aesthetic values. Absent extraordinary circumstances, proposals to exclude lands conveyed under this article from the project shall be consolidated for consideration when revised exhibit G or K drawings would be filed for approval for other purposes.

(g) The authority granted to the licensee under this article shall not apply to any part of the public lands and reservations of the United States included within the project boundary.

(F) The licensee shall serve copies of any Commission filing required by this order on any entity specified in this order to be consulted on matters related to that filing. Proof of service on these entities must accompany the filing with the Commission.

(G) This order is issued under authority delegated to the Director and is final unless a request for a rehearing is filed within 30 days from the date of its issuance, pursuant to 18 CFR § 385.713. The filing of a request for a rehearing does not operate as a stay of the effective date of this license or of any other date specified in this order, except as specifically ordered by the Commission. The licensee's failure to file a request for rehearing of this order shall constitute acceptance of the license.

J. Mark Robinson
Director
Office of Energy Projects

Appendix A.3

Federal Energy Regulatory Commission exemptions and requirements of the Beaverton hydro-electric dam, Tributaries – Tobacco River. This Commission grant was issued December 31, 1981.

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17 FERC ¶62,522

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

City of Beaverton, Michigan) Project No. 5308-000

ORDER GRANTING EXEMPTION FROM LICENSING OF A SMALL HYDROELECTRIC PROJECT OF 5 MEGAWATTS OR LESS

(Issued December 31, 1981)

The Applicant 1/ filed an application for exemption from all or part of Part I of the Federal Power Act pursuant to 18 C.F.R. Part 4 SUBPART K (1980) implementing in part Section 408 of the Energy Security Act (Act) of 1980 for a project as described in the attached public notice. 2/ 3/

Notice of the application was published in accordance with Section 408 of the Act and the Commission's regulations and comments were requested from interested Federal and State agencies including the U. S. Fish and Wildlife Service and the State Fish and Wildlife Agency. All comments, protests and petitions to intervene that were filed have been considered. No agency has any objection relevant to issuance of this exemption.

Standard Article 2 included in this exemption, requires compliance with any terms and conditions that Federal or State fish and wildlife agencies have determined appropriate to prevent loss of, or damage to, fish and wildlife resources. The terms and conditions referred to in Article 2 are contained in any letters of comment by these agencies which have been forwarded to the Applicant in conjunction with this exemption.

1/ City of Beaverton, Michigan, Project No. 5308, filed on August 28, 1981.

2/ Pub. Law 96-294, 94 Stat. 611. Section 408 of the ESA amends inter alia, Sections 405 and 408 of the Public Utility Regulatory Policies Act of 1978 (16 U.S.C. §§2705 and 2708).

3/ Authority to act on this matter is delegated to the Deputy Director, Office of Electric Power Regulation under §375.308 of the Commission's regulations 45 Fed. Reg. 21216 (1980), as amended by Order No. 112 in Docket No. RM81-5, issued November 21, 1980, (45 Fed. Reg. 79024).

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Should the Applicant contest any terms or conditions that were proposed by Federal or State agencies in their letters of comment as being outside the scope of Article 2, the Commission shall determine whether the disputed terms or conditions are outside the scope of Article 2.

The Beaverton Hydroelectric Project is classified as a high hazard dam. Therefore, pursuant to the Commission's regulations, Article 6 included in this exemption requires that an Emergency Action Plan for the project be filed, and that inspection of the project be performed by an independent Engineering Consultant. In addition, Article 6 reserves to the Commission the right to make periodic project inspections.

<u>It is ordered that:</u>

(A) The Beaverton Hydroelectric Project No. 5308 as described and designated in the City of Beaverton, Michigan's application filed on August 21, 1981, is exempted from all of the requirements of Part I of the Federal Power Act, including licensing, subject to the standard articles in §4.106 of the Commission's regulations attached hereto as Form E-2, 18 C.F.R. §4.106 45 Fed. Reg. 76115 (November 18, 1980), and the following Special Article.

<u>Article 6.</u> This exemption is subject to the following provisions of 18 C.F.R., Part 12: (1) Section 12.4(b)(2)(i), (ii), (iii)(B), (iv), and (v); (2) Section 12.4(c); and (3) Subparts C and D.

(B) This order is final unless a petition appealing it to the Commission is filed within 30 days from the date of its issuance, as provided in Section 1.7(d) of the Commission's regulations, 18 C.F.R. 1.7(d)(1981), <u>as amended</u>, 44 Fed. Reg. 46449 (1981). The filing of a petition appealing this order to the Commission or an application for rehearing as provided in Section 313(a) of the Act does not operate as a stay of the effective date of this order, except as specifically ordered by the Commission.

Robert E. Cackowski
Robert E. Cackowski
Deputy Director, Office of
Electric Power Regulation

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

City of Beaverton, Michigan) Project No. 5308-000

NOTICE OF APPLICATION FOR EXEMPTION FOR SMALL HYDROELECTRIC POWER PROJECT UNDER 5 MW CAPACITY

(October 23, 1981)

Take notice that on August 21, 1981, City of Beaverton, Michigan, (Applicant) filed an application under Section 408 of the Energy Security Act of 1980 (Act) (16 U.S.C. §§2705 and 2708 as amended), for exemption of a proposed hydroelectric project from licensing under Part I of the Federal Power Act. The proposed small hydroelectric project (Project No. 5308) would be located on the Tobacco River in Gladwin County, Beaverton, Michigan. Correspondence with the Applicant should be directed to: Mr. H. James Wesley, City Manager, City of Beaverton, 124 West Brown Street, P.O. Box 477, Beaverton, Michigan 48612.

Project Description - The proposed Beaverton Hydroelectric Project would consist of: (1) an existing concrete dam approximately 40 feet long and 25 feet high, an adjacent concrete spillway approximately 113 feet long and 25 feet high with seven bays; (2) an existing reservoir with a maximum storage capacity of 2399 acre-feet at elevation 712.7 feet m.s.l.; (3) two separate existing powerhouses located adjacent to the spillway in which the east powerhouse would have a capacity of 650 kW and the west powerhouse would have a capacity of 308 kW for a combined proposed total capacity of 958 kW; and (4) appurtenant facilities. The project would be operated on a run-of-river basis. The average annual energy generation is estimated to be 3,300,000 kWh

Purpose of Project - Energy produced at the proposed project would be either sold to the Michigan Public Power Association and Consumers Power Company.

Agency Comments - The U.S. Fish and Wildlife Service, The National Marine Fisheries Service, and the Michigan Department of Natural Resources are requested, for the purposes set forth in Section 408 of the Act, to submit within 60 days from the date of issuance of this notice appropriate terms and conditions to protect any fish and wildlife resources or to otherwise carry out the provisions of the Fish and Wildlife Coordination Act. General comments concerning the project and its resources are requested; however, specific terms and conditions to be included as a condition of exemption must be clearly identified in the agency letter. If an agency does not file terms and conditions within this time period, that agency will be presumed to have none. Other Federal, State, and local agencies are requested to provide any comments they may have in accordance with their duties and responsibilities. No other formal requests for comments will be made. Comments should be confined to substantive

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issues relevant to the granting of an exemption. If an agency does not file comments within 60 days from the date of issuance of this notice, it will be presumed to have no comments. One copy of an agency's comments must also be sent to the Applicant's representatives.

Competing Application - Any qualified license applicant desiring to file a competing application must submit to the Commission, on or before DEC 3 [illegible] either the competing license application that proposes to develop at least 7.5 megawatts in that project, or notice of intent to file such a license application. Submission of a timely notice of intent allows an interested person to file the competing license application no later than 120 days from the date that comments, protests, etc. are due. Applications for preliminary permit will not be accepted.

A notice of intent must conform with the requirements of 18 C.F.R. §4.33(b) and (c) (1980). A competing license application must conform with the requirements of 18 C.F.R. §4.33(a) and (d) (1980).

Comments, Protests, or Petitions to Intervene - Anyone may submit comments, a protest, or a petition to intervene in accordance with the requirements of its Rules of Practice and Procedure, 18 C.F.R. §1.8 or §1.10 (1980). In determining the appropriate action to take, the Commission will consider all protests or other comments filed, but only those who file a petition to intervene in accordance with the Commission's Rules may become a party to the proceeding. Any comments, protests, or petitions to intervene must be received on or before DEC 3 [illegible].

Filing and Service of Responsive Documents - Any filings, must bear in all capital letters the title "COMMENTS", "NOTICE OF INTENT TO FILE COMPETING APPLICATION", "COMPETING APPLICATION", "PROTEST", or "PETITION TO INTERVENE", as applicable, and the Project Number of this notice. Any of the above named documents must be filed by providing the original and those copies required by the Commission's regulations to: Kenneth F. Plumb, Secretary, Federal Energy Regulatory Commission, 825 North Capitol Street, N.E., Washington, D.C. 20426. An additional copy must be sent to: Fred E. Springer, Chief, Applications Branch, Division of Hydropower Licensing, Federal Energy Regulatory Commission, Room 208 RB, 825 North Capitol Street, N.E., Washington, D.C. 20426. A copy of any notice of intent, competing application, or petition to intervene must also be served upon each representative of the Applicant specified in the first paragraph of this notice.

Kenneth F. Plumb
Secretary

-1- Attachment
E-2 Form

§ 4.106 Standard terms and conditions of exemption from licensing.

Any exemption from licensing granted under this subpart for a small hydroelectric power project is subject to the following standard terms and conditions:

(a) Article 1. The Commission reserves the right to conduct investigations under sections 4(g), 306, 307, and 311 of the Federal Power Act with respect to any acts, complaints, facts, conditions, practices, or other matters related to the construction, operation, or maintenance of the exempt project. If any term or condition of the exemption is violated, the Commission may revoke the exemption, issue a suitable order under section 4(g) of the Federal Power Act, or take appropriate action for enforcement, forfeiture, or penalties under Part III of the Federal Power Act.

(b) Article 2. The construction, operation, and maintenance of the exempt project must comply with any terms and conditions that any Federal or state fish and wildlife agencies have determined are appropriate to prevent loss of, or damage to, fish or wildlife resources or otherwise to carry out the purposes of the Fish and Wildlife Coordination Act, as specified in Exhibit E of the application for exemption from licensing or in the comments submitted in response to the notice of the exemption application.

(c) Article 3. The Commission may accept a license application by any qualified license applicant and revoke this exemption if actual construction or development of any proposed generating facilities has not begun within 18 months, or been completed within four years, from the date on which this exemption was granted. If an exemption is revoked, the Commission will not accept a subsequent application for exemption within two years of the revocation.

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Attachment
E-2 Form

(d) Article 4. This exemption is subject to the navigation servitude of the United States if the project is located on navigable waters of the United States.

(e) Article 5. This exemption does not confer any right to use or occupy any Federal lands that may be necessary for the development or operation of the project. Any right to use or or occupy any Federal lands for those purposes must be obtained from the administering Federal land agencies. The Commission may accept a license application by any qualified license applicant and revoke this exemption, if any necessary right to use or occupy Federal lands for those purposes has not been obtained within one year from the date on which this exemption was granted.

Appendix A.4

Federal Energy Regulatory Commission order approving minimum flow release structure at the Edenville hydro-electric dam. This Commission grant was issued November 15, 2000.

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93 FERC ¶ 62,119

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Wolverine Power Corporation — Project No. 10808-012

ORDER APPROVING MINIMUM FLOW RELEASE STRUCTURE[1]

(Issued November 15, 2000)

On June 6, 2000, Wolverine Power Corporation (licensee) filed a plan for a minimum flow release structure at the Tobacco spillway of the Edenville Project. The filing was made pursuant to paragraph (B) of the Order Modifying and Approving Reservoir Level Gaging Plan and Extension of Time to Design Minimum Flow Release Structure and Gaging System, issued June 22, 1999[2]. The project is located on the Tittabawassee River in Midland and Gladwin Counties, Michigan.

Paragraph (B) requires the licensee to file a minimum flow release design and gaging plan to provide the minimum flow releases required by article 403 of the project license. The plan shall be prepared in consultation with the U.S. Fish and Wildlife Service, U.S. Geological Survey, and the Michigan Department of Natural Resources.

In the filed plan the licensee states that the spillway gate will be opened 2.5 inches to provide 66 cfs during the summer, and 1.75 inches to provide 40 cfs during the winter. Two metal blocks were fabricated to hold the gate in the appropriate positions so that the lifting/lowering mechanism could not accidentally change the opening. The filed plan included the calculations for providing the required releases. The gate opening is small enough so that ice buildup on the gates is not expected to be a problem. The consulted agencies made no comments on the minimum flow release structure.

The filed minimum flow release design plan should ensure the required minimum flow releases are achieved. The filed plan satisfies the requirements of paragraph (B); this plan should be approved.

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[1]Paragraph (B) of the Order Modifying and Approving Reservoir Level Gaging Plan, issued June 22, 1999; Article 403.

[2]87 FERC ¶ 62,333.

The Director orders:

(A) The minimum flow release structure design plan filed on June 6, 2000, for providing minimum flows at the Edenville Project, as required by the Order Modifying and Approving Reservoir Level Gaging Plan and Extension of Time to Design Minimum Flow Release Structure and Gaging System, is approved.

(B) This order constitutes final agency action. Requests for rehearing by the Commission may be filed within 30 days of the date of issuance of this order, pursuant to 18 CFR § 385.713.

Rebecca M. Martin
Team Leader
Division of Hydropower Administration
and Compliance

Appendix B

Water quality reports available from the Michigan Department of Environmental Quality.

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Appendix C

Distribution Maps of Fish Species

Known past and present fish distributions in the Tittabawassee River system. Distribution of fishes were compiled from records located at the University of Michigan's Museums Fisheries Library, Michigan Department of Natural Resources' Institute for Fisheries Research, and Michigan Department of Natural Resources' Bay City Operations Service Center. For species that are listed under Michigan's Endangered Species Act (Part 365, Endangered Species Protection, of the Natural Resource and Environmental Protection Act, Act 451 of the Public Acts of 1994), their status follows their scientific name. Categories are declining, rare, threatened, endangered, extinct, and locally extinct.

Habitat descriptions were compiled from the Fishes of Ohio (Trautman 1981), Freshwater Fishes of Canada (Scott and Crossman 1973), Fishes of Wisconsin (Becker 1983), Fishes of Missouri (Pflieger 1975), and Fishes of the Great Lakes Region (Hubbs and Lagler 1947).

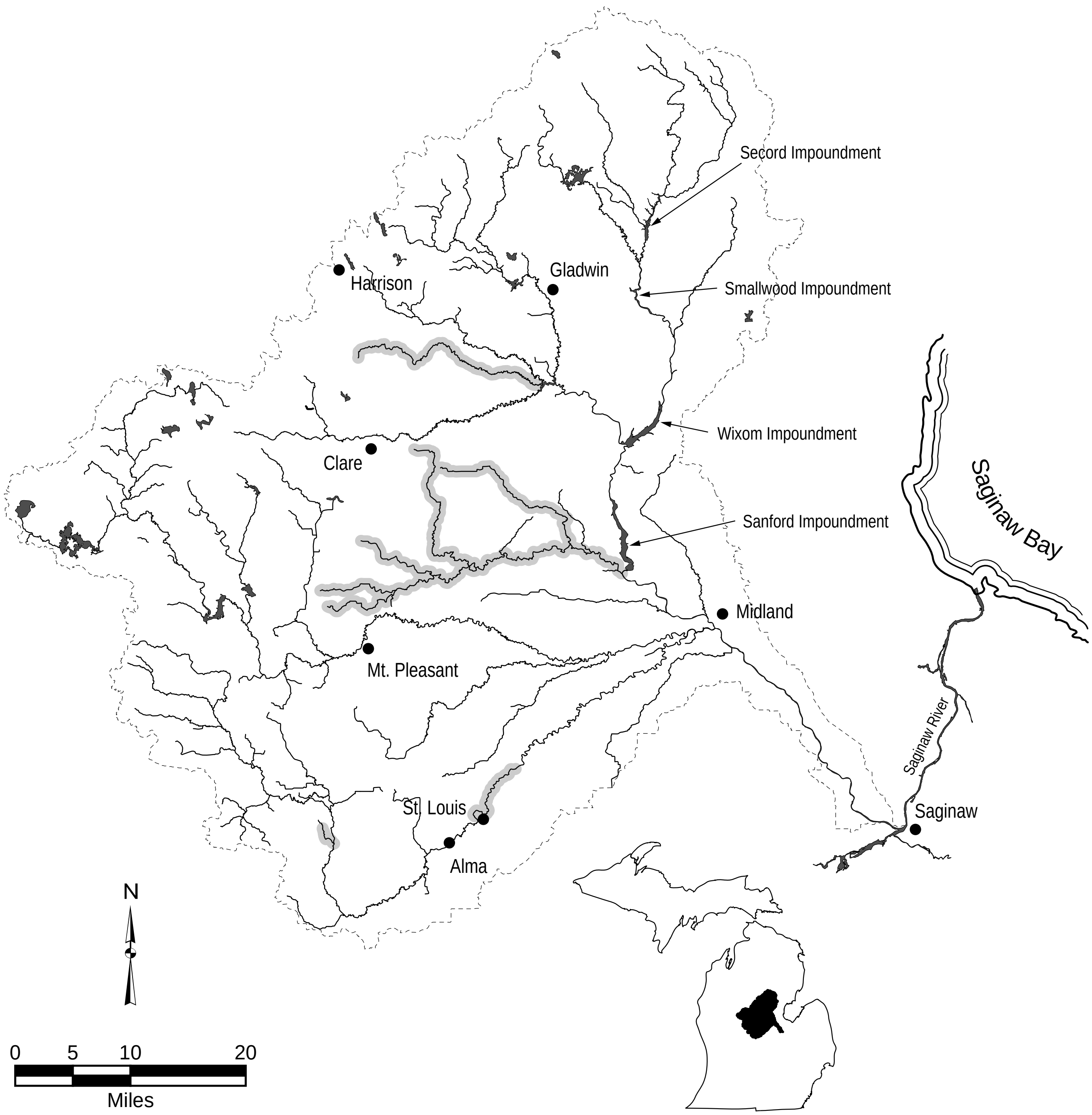
APPENDIX C INDEX

Northern brook lamprey *Ichthyomyzon fossor*

Habitat**:**

feeding - young: low gradient, substrate with bars and beds of mixed sand and organic debris
- moderately warm water

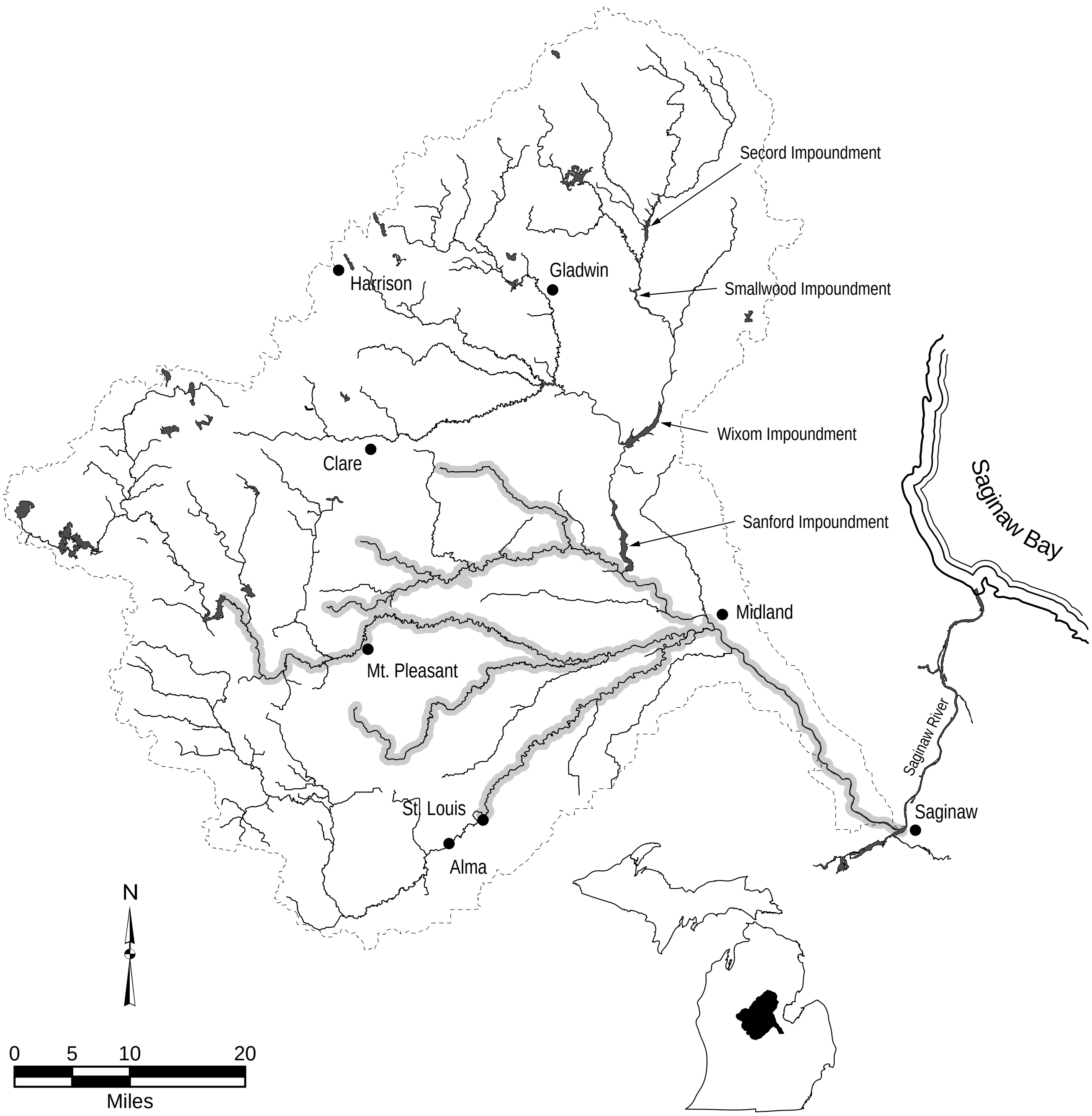
spawning - clear, high gradient streams (<15 feet wide)
- riffles with sand or gravel substrate



Silver lamprey *Ichthyomyzon unicuspis*

Habitat**:**

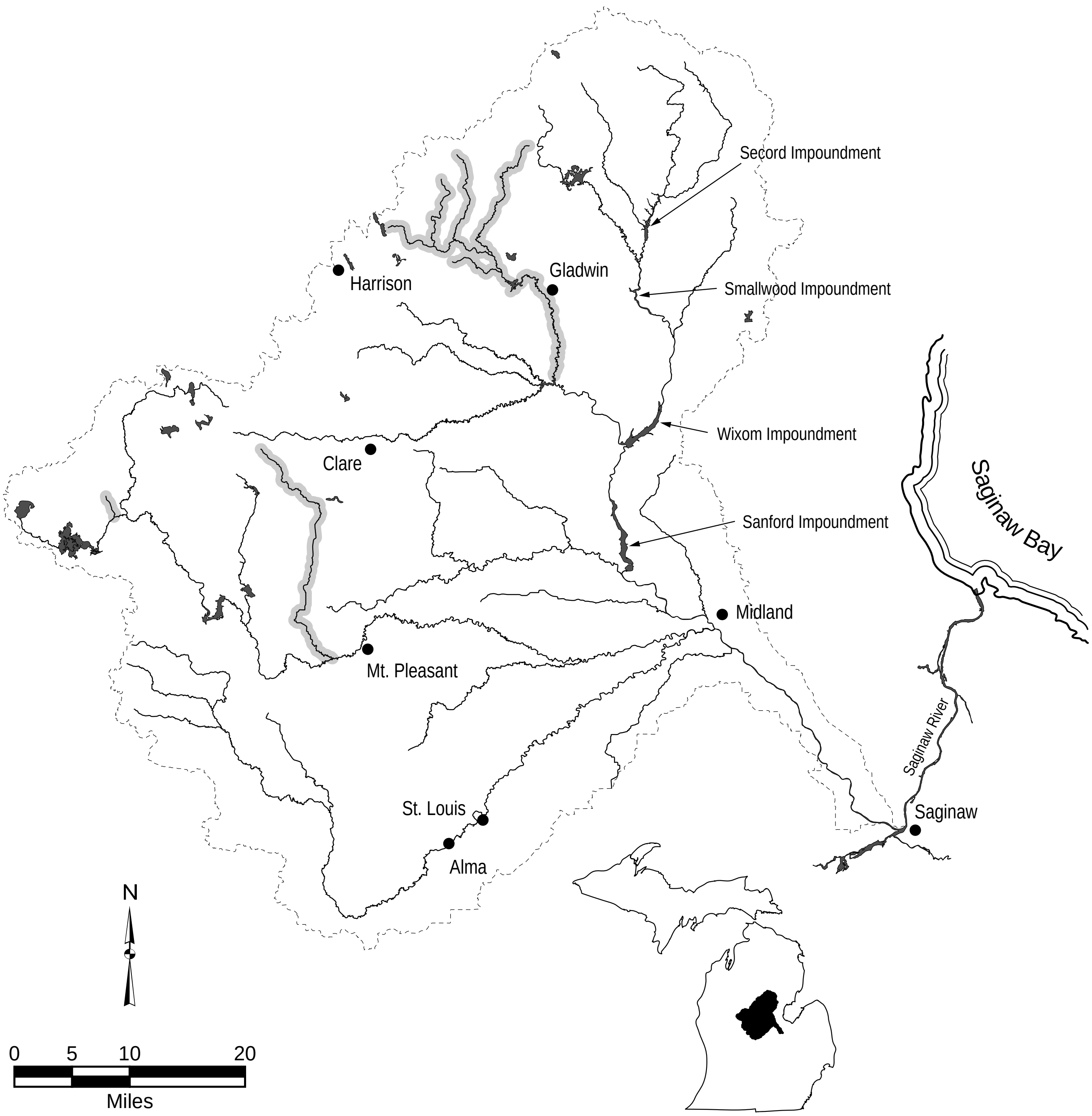
feeding	-	young: sand, muck, or organic debris substrate
	-	adults: clear river water with prey species
spawning	-	gravel and sand substrate
	-	moderate gradient
	-	moderate size stream
	-	cannot tolerate silt
	-	no dams
winter refuge	-	ammocetes burrow for 4 to 7 years in mud and silt at river margins



American brook lamprey *Lampetra appendix*

Habitat**:**

feeding	-	young: low gradient, substrate with bars and beds of mixed sand and organic debris
	-	clear cool stream water, sensitive to turbidity
spawning	-	clear, high gradient streams (>15 feet wide)
	-	cold water
	-	gravel substrate
winter refuge	-	sand or silt substrate for amnocetes

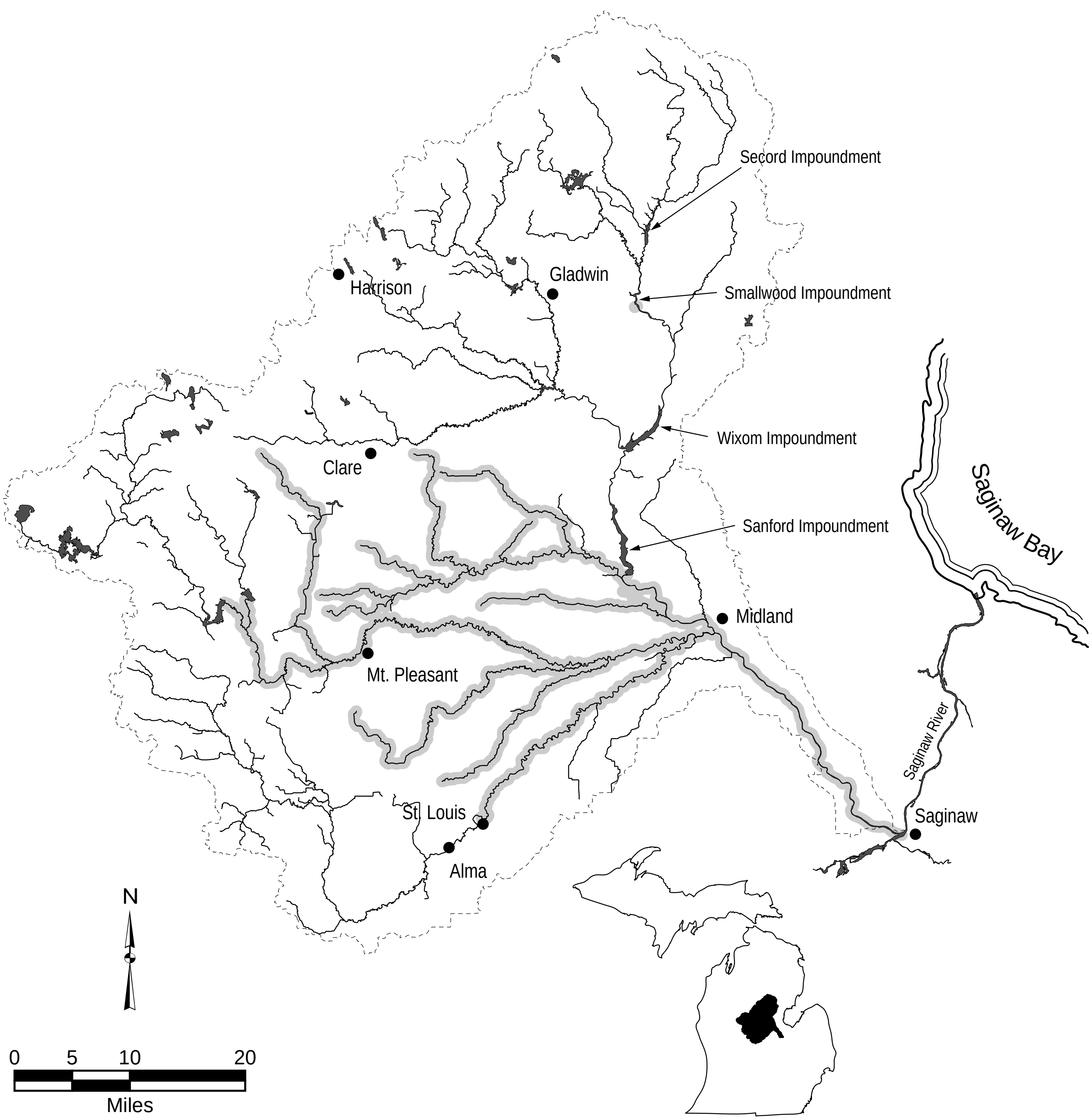


Sea lamprey *Petromyzon marinus*

Habitat**:**

feeding - young: substrate with beds of sand mixed with organic debris
- cannot tolerate silt
- adults: clear cool water of Lake Huron

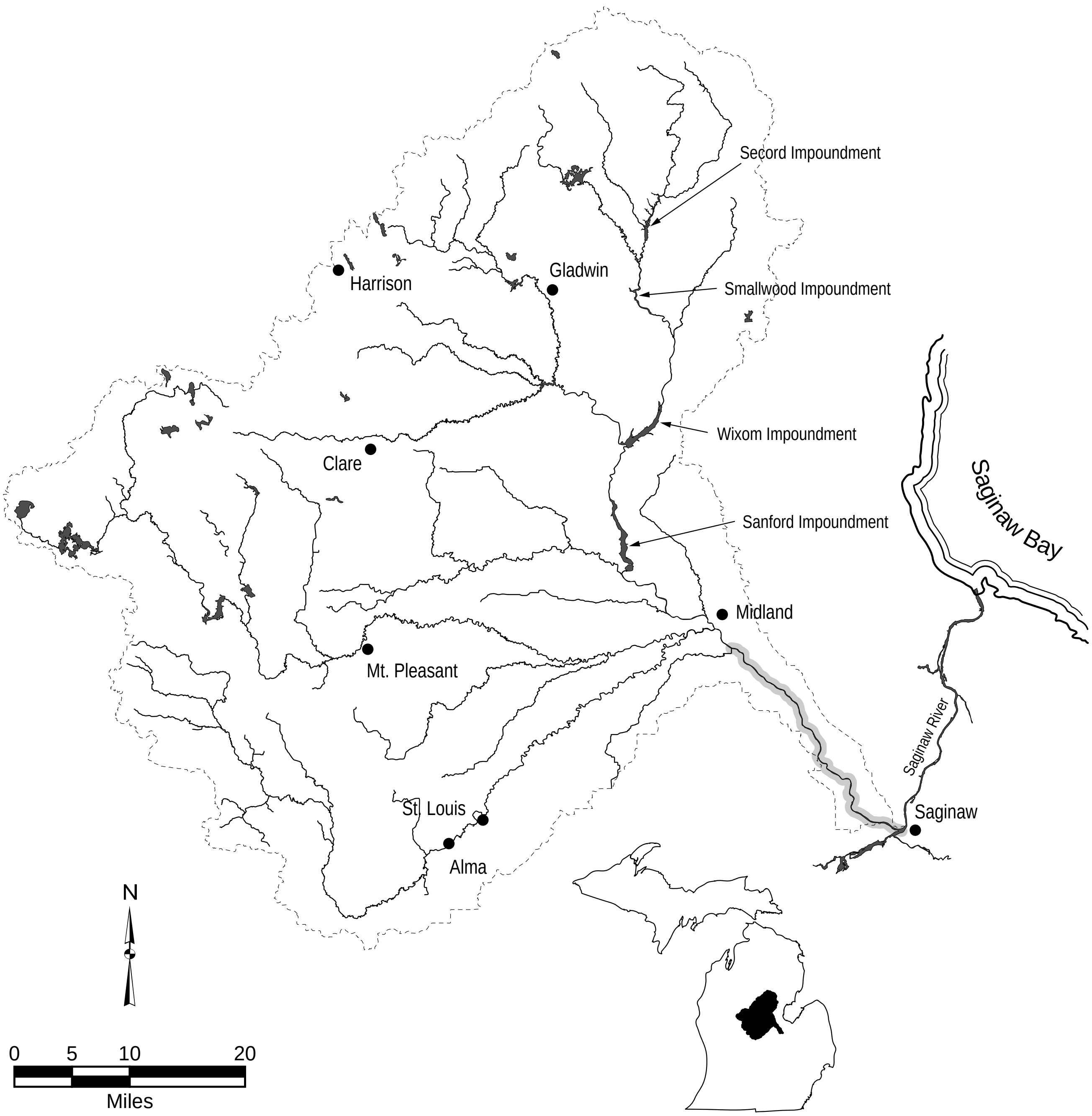
spawning - no dams
- riffles with sand and gravel substrates



Lake sturgeon *Acipenser fulvescens* - threatened

Habitat:

feeding	- shoal areas of large rivers, lakes, and impoundments
	- gravel, sand, rock substrates
spawning	- in or before rapids, at the base of dams in rivers
	- in 2-15 feet of water
	- swift current
	- rocky ledges or around rocky islands in Great Lakes

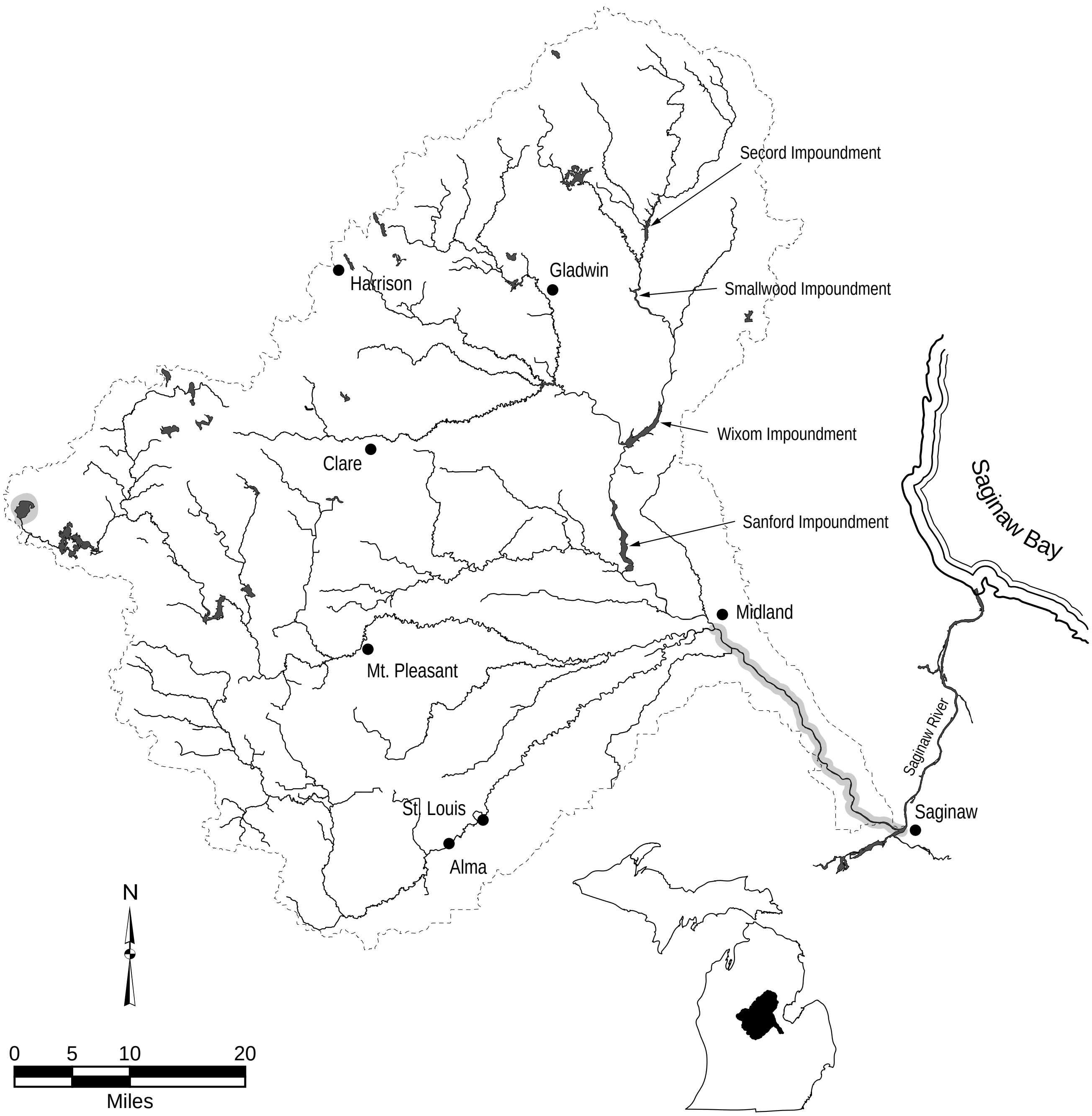


Longnose gar *Lepisosteus osseus*

Habitat**:**

feeding - adults: in deeper water
- young: in shallows
- clear water, low-gradient streams, lakes, and impoundments
- will feed in moderate current
- aquatic vegetation preferred, but not necessary
- open water fish

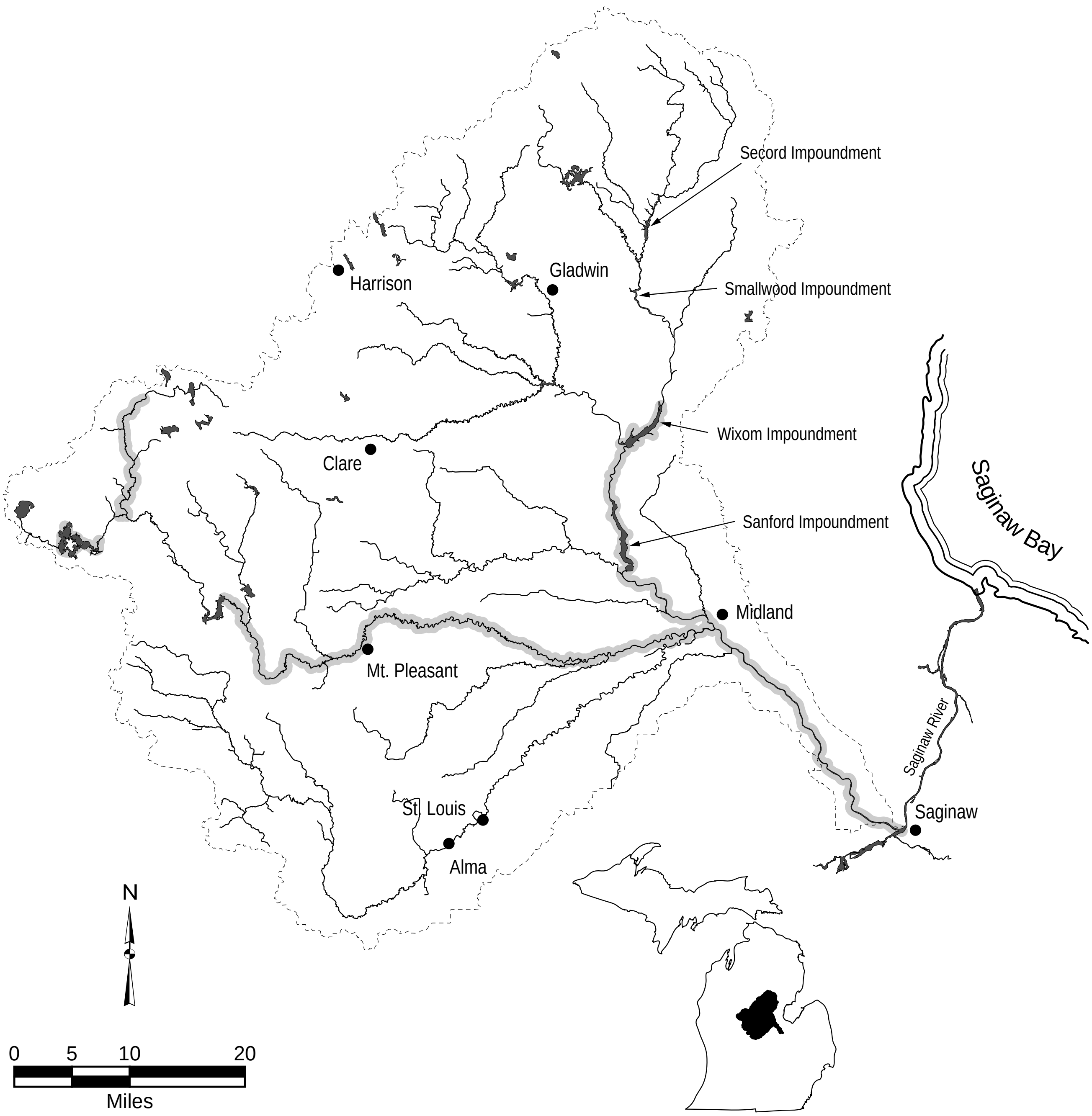
spawning - warm shallow water of lakes or streams over vegetation



Bowfin *Amia calva*

Habitat**:**

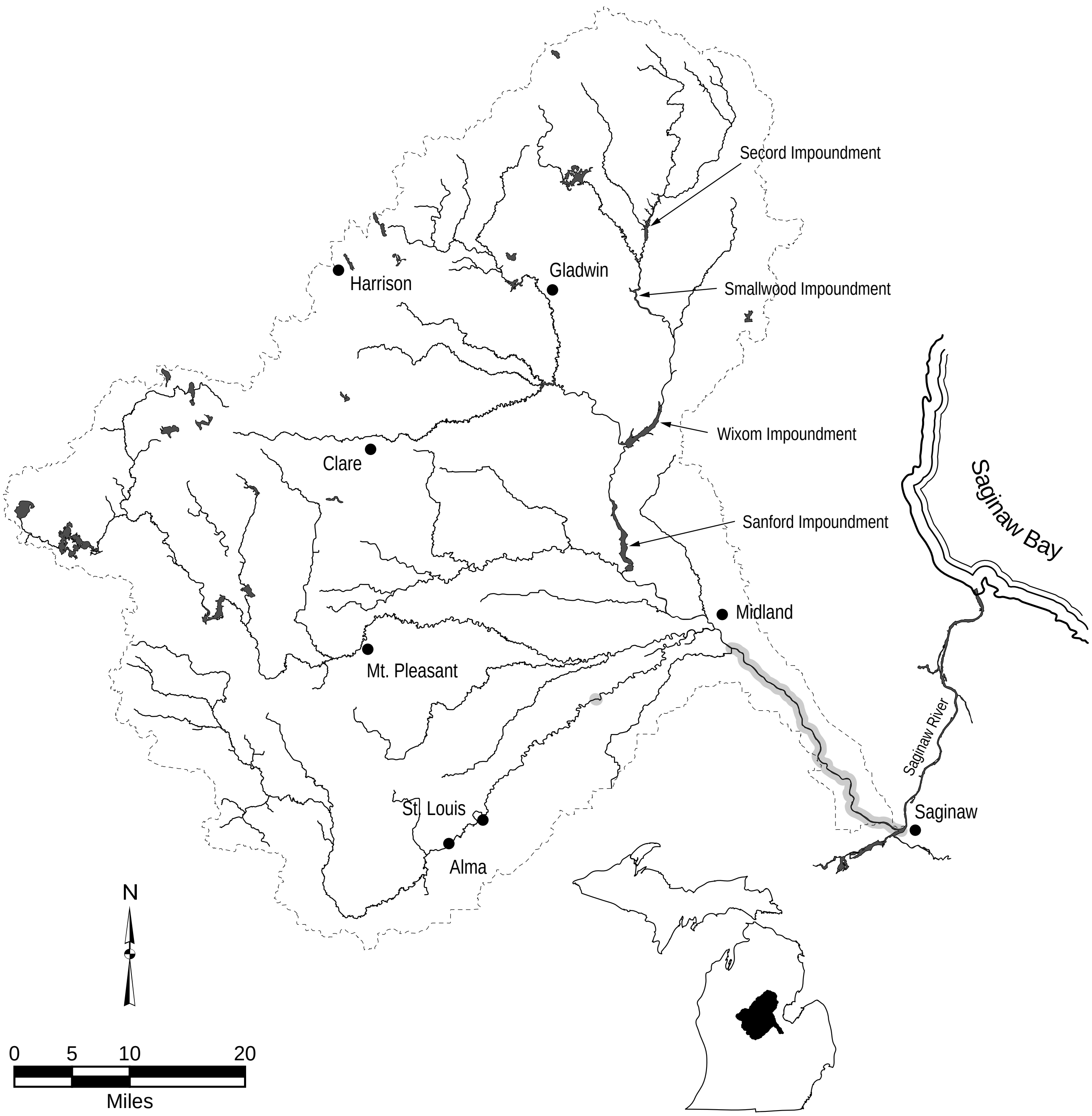
feeding	-	clear water
	-	abundant rooted aquatic vegetation
	-	low gradient streams, lakes, and impoundments
	-	tolerate only small amount of silt
spawning	-	need vegetated water, 1 to 2 feet deep
	-	can spawn under logs, stumps, or bushes
winter refuge	-	gravelly pockets among aquatic vegetation



Alewife *Alosa pseudoharengus*

Habitat**:**

feeding	-	adults: deep water of Lake Huron
	-	young: shallow water of Lake Huron
	-	prefers warmer waters
spawning	-	streams or shallow beaches of lake
	-	sand or gravelly substrate
winter refuge	-	deep water

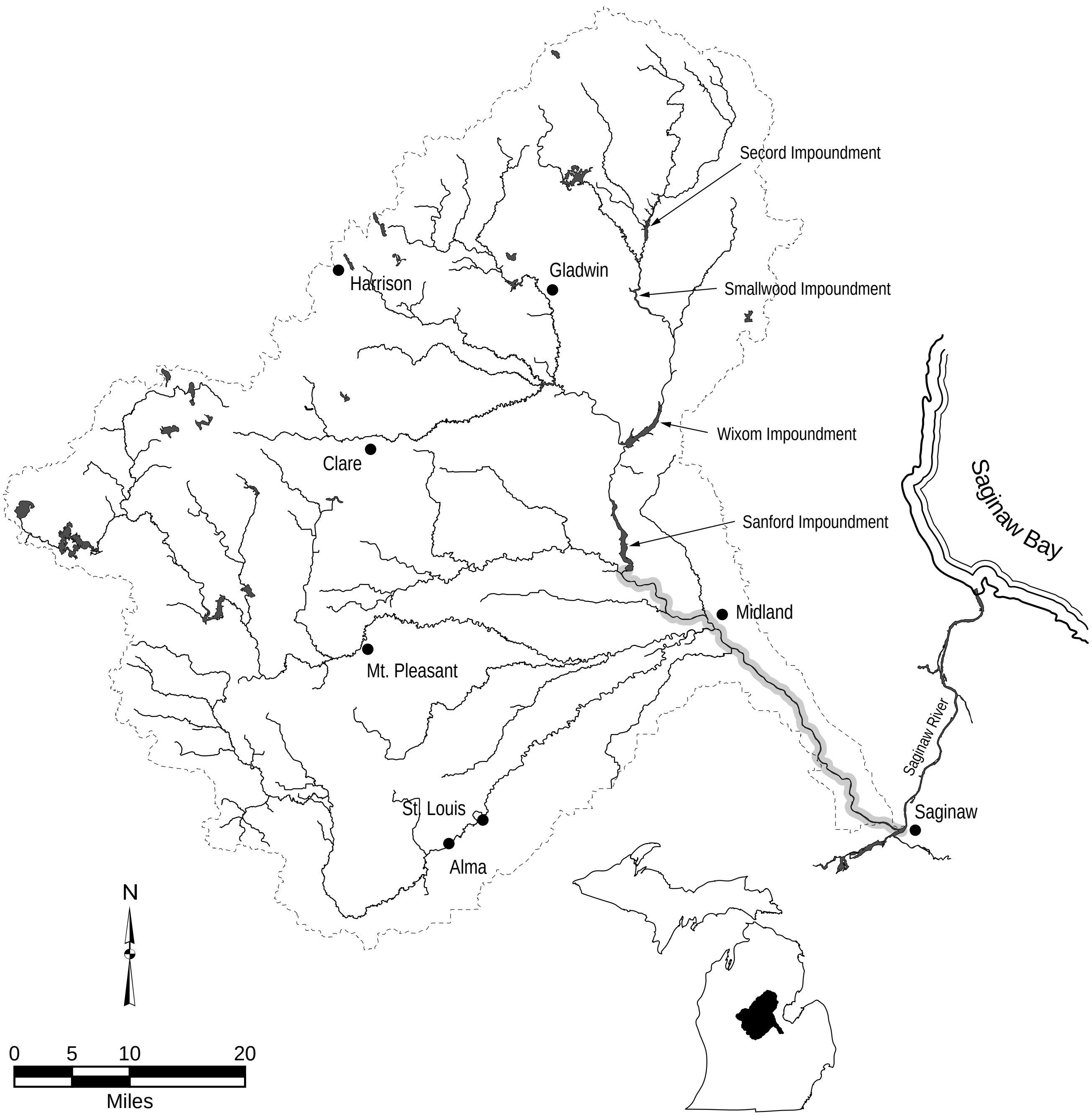


Gizzard shad *Dorosoma cepedianum*

Habitat**:**

feeding - large streams with low gradient, impoundments, and Lake Huron
- tolerant of clear and turbid water

spawning - shallow areas of ponds, lakes, and large rivers
- low gradient

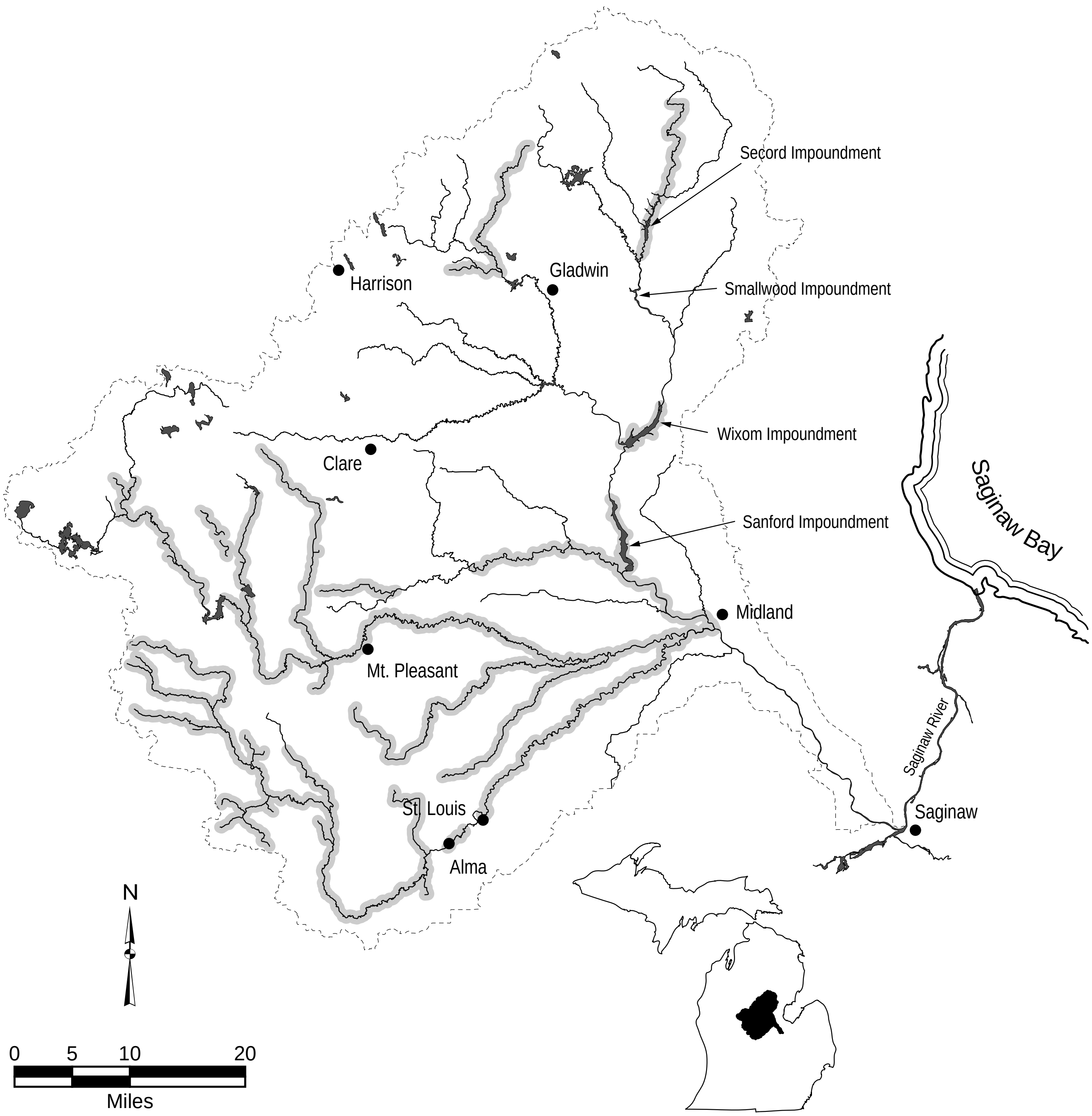


Central stoneroller *Campostoma anomalum pullam*

Habitat**:**

feeding - moderate to high gradients
- rocky riffles
- somewhat tolerant of turbidity
- riffles and adjacent pools of warm, clear, shallow streams
- gravel or cobble substrate

spawning - riffles

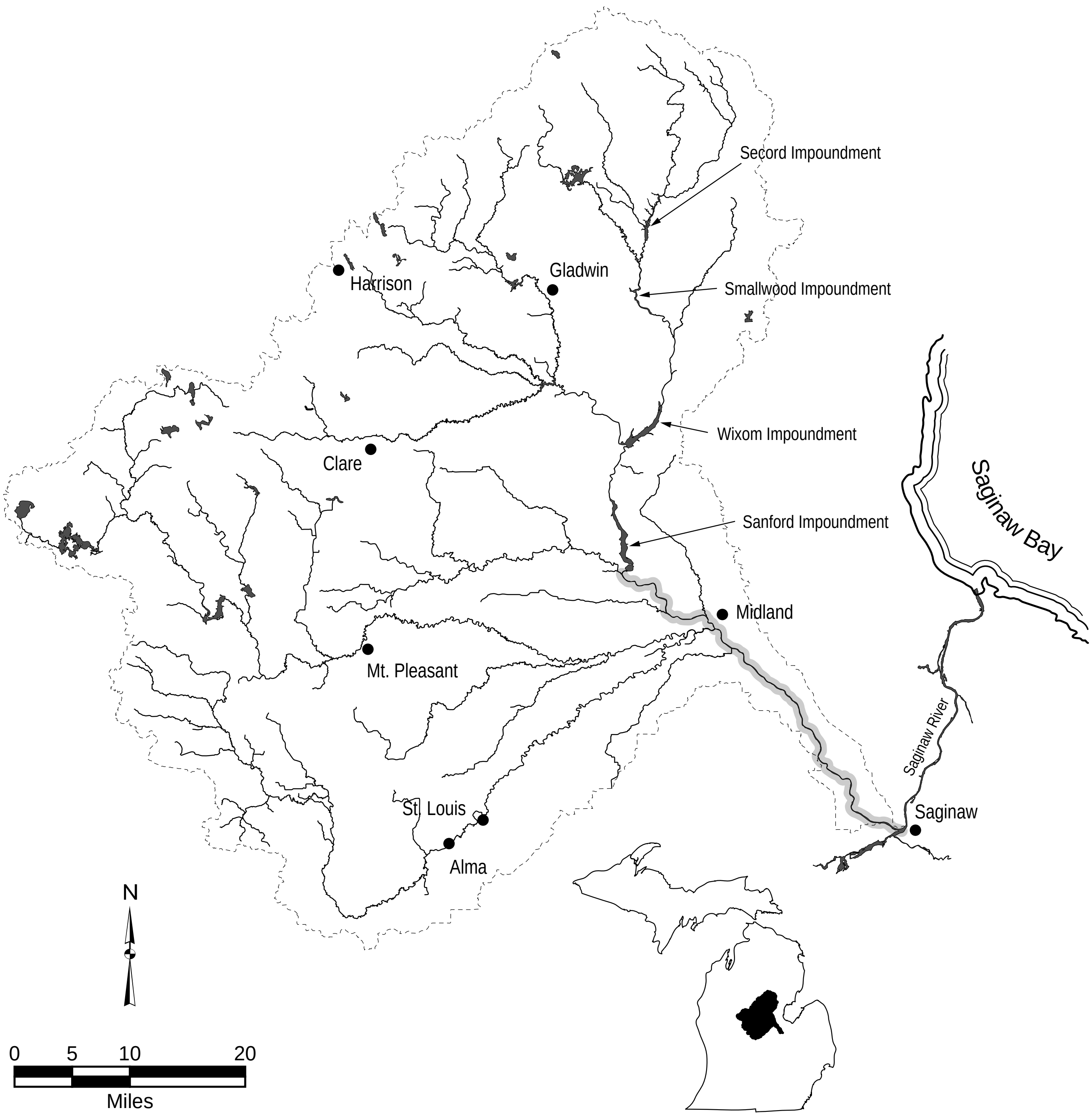


Goldfish *Carassius auratus*

Habitat**:**

feeding - vegetation
- low gradient, shallow, warm water streams, rivers, lakes, and impoundments
- tolerates some turbidity and siltation

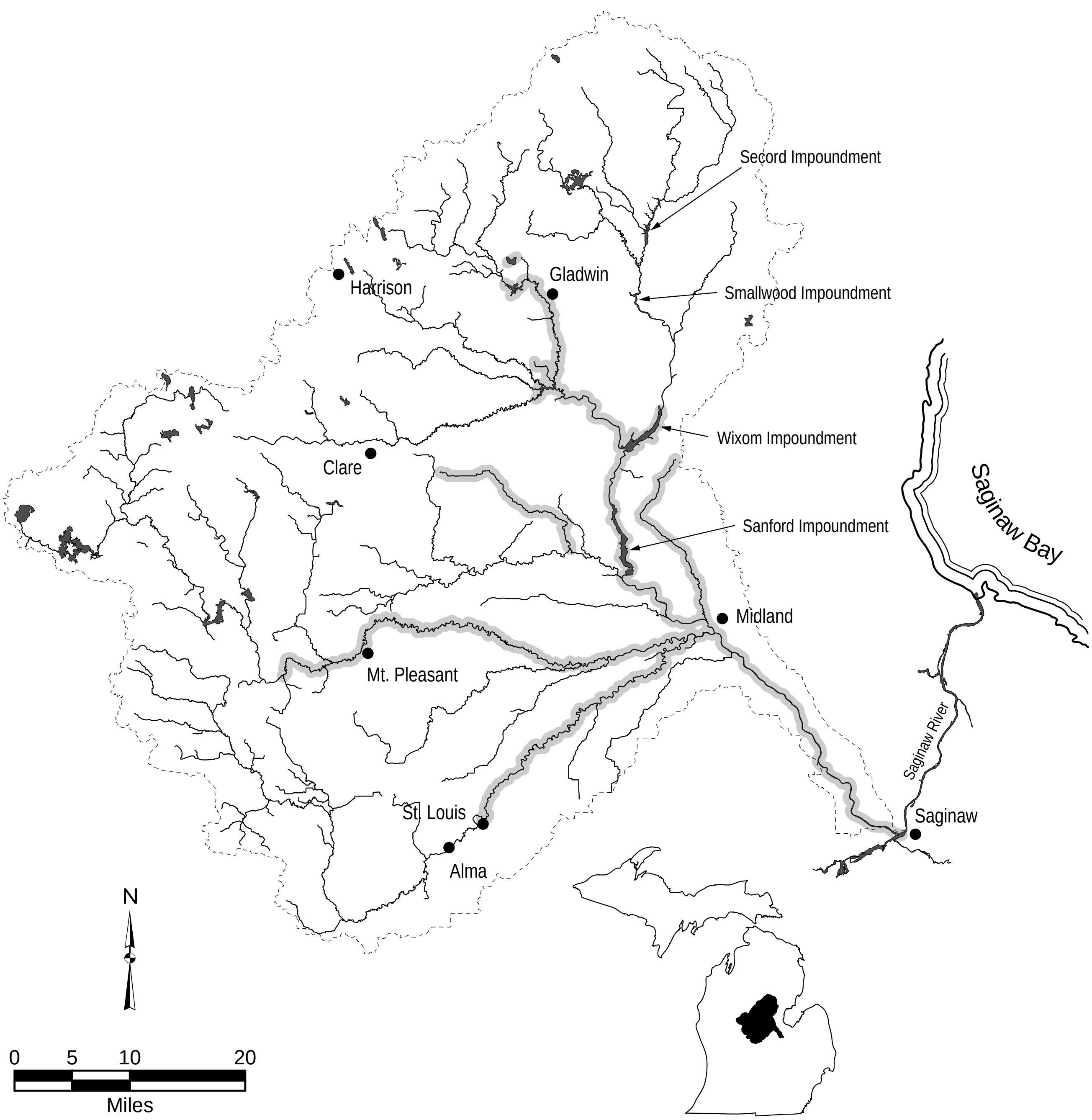
spawning - warm, weedy shallows



Spotfin shiner *Cyprinella spiloptera*

Habitat**:**

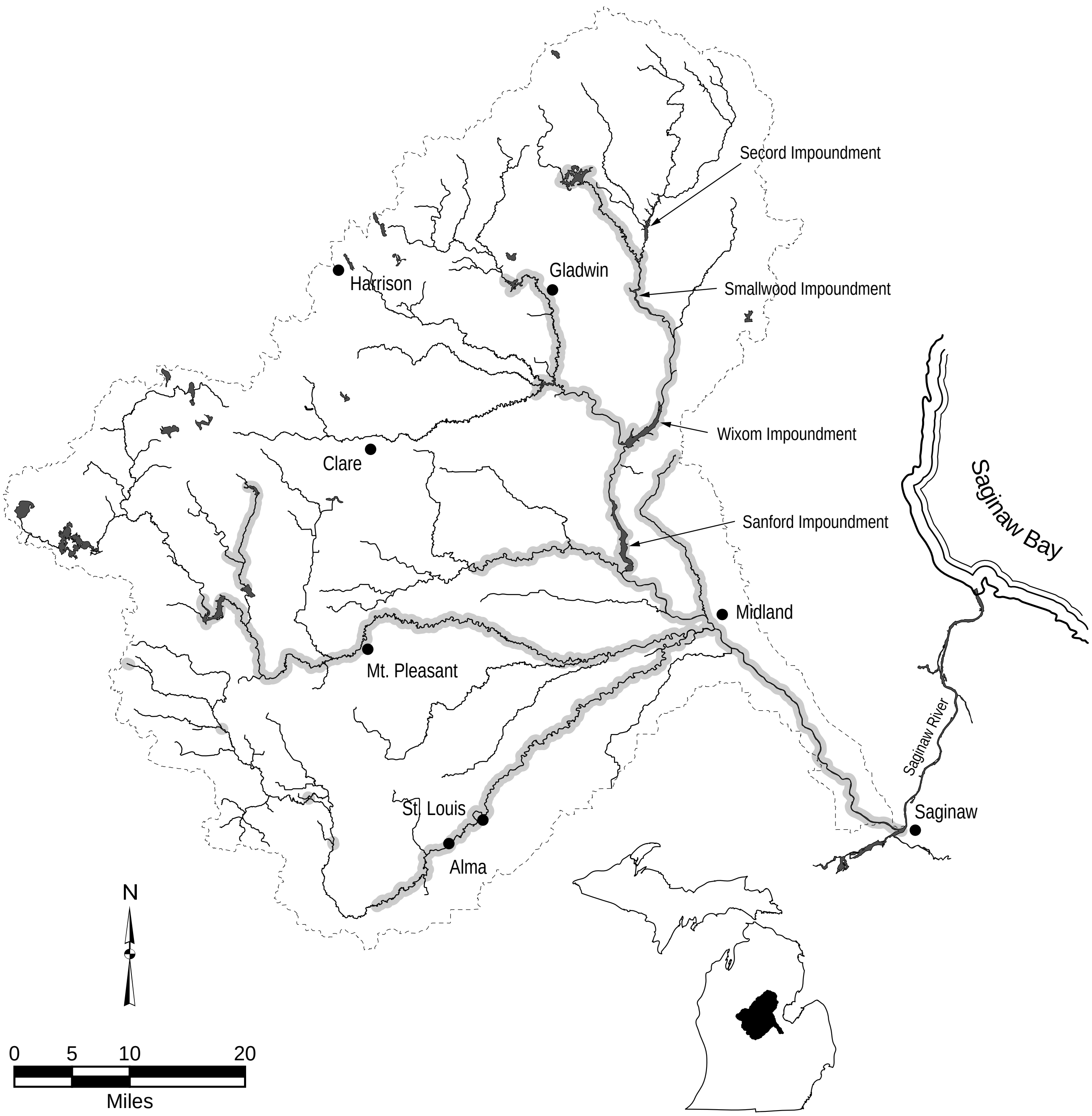
feeding	- clear water tolerant of turbidity and siltation
	- some current
	- shallow depths
	- medium sized streams, lakes, and impoundments
	- clear sand or gravel substrate
spawning	- swift current
	- crevice spawner or on underside of submerged logs and roots



Common carp *Cyprinus carpio*

Habitat**:**

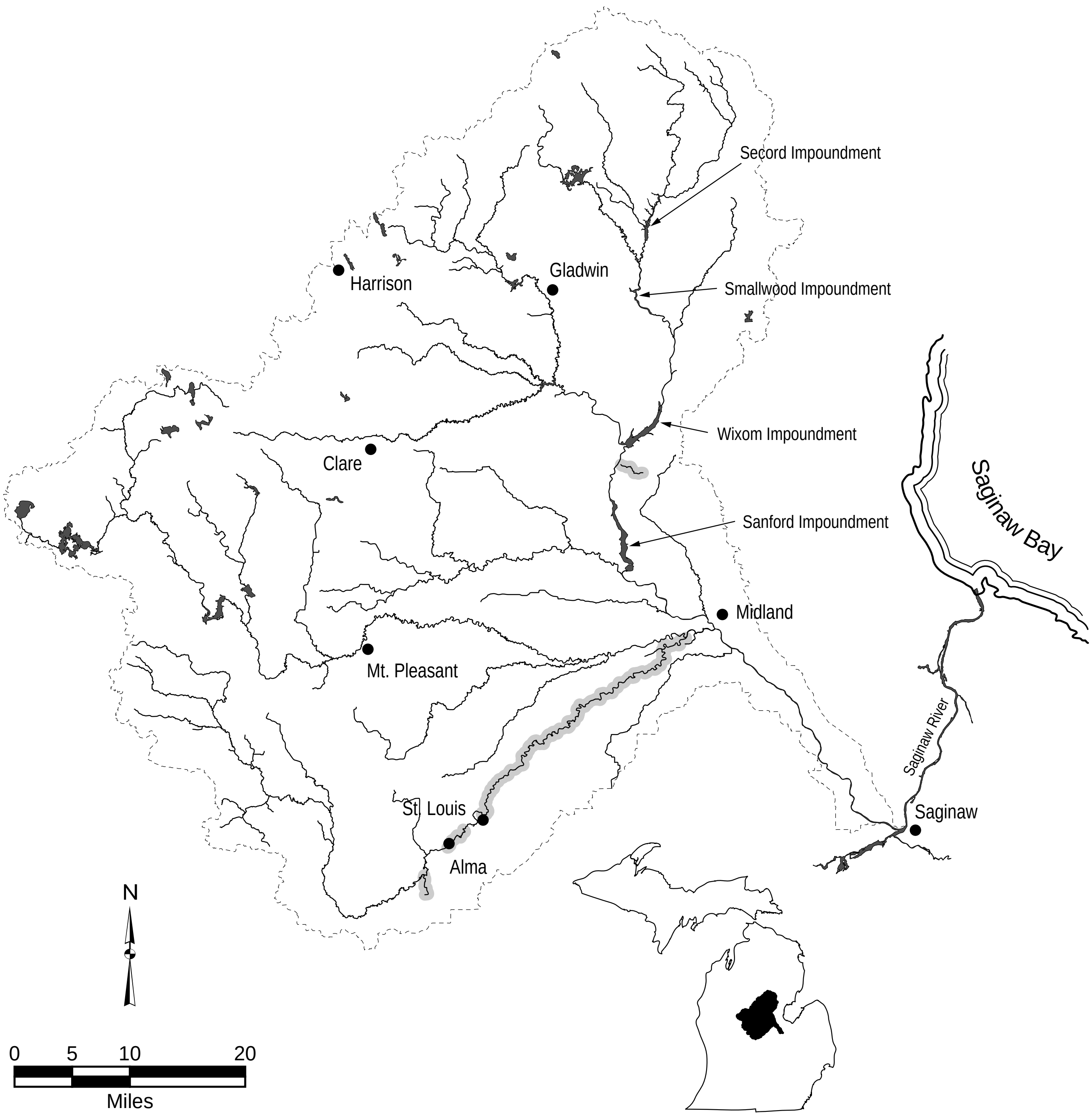
feeding	-	low gradient fertile streams, rivers, lakes, and impoundments
	-	abundance of aquatic vegetation or organic matter
	-	tolerant of all substrates and clear to turbid water
spawning	-	weedy or grassy shallows



Brassy minnow *Hybognathus hankinsoni*

Habitat**:**

feeding - cool acidic streams
- slow to moderate current
- sand or gravel substrate

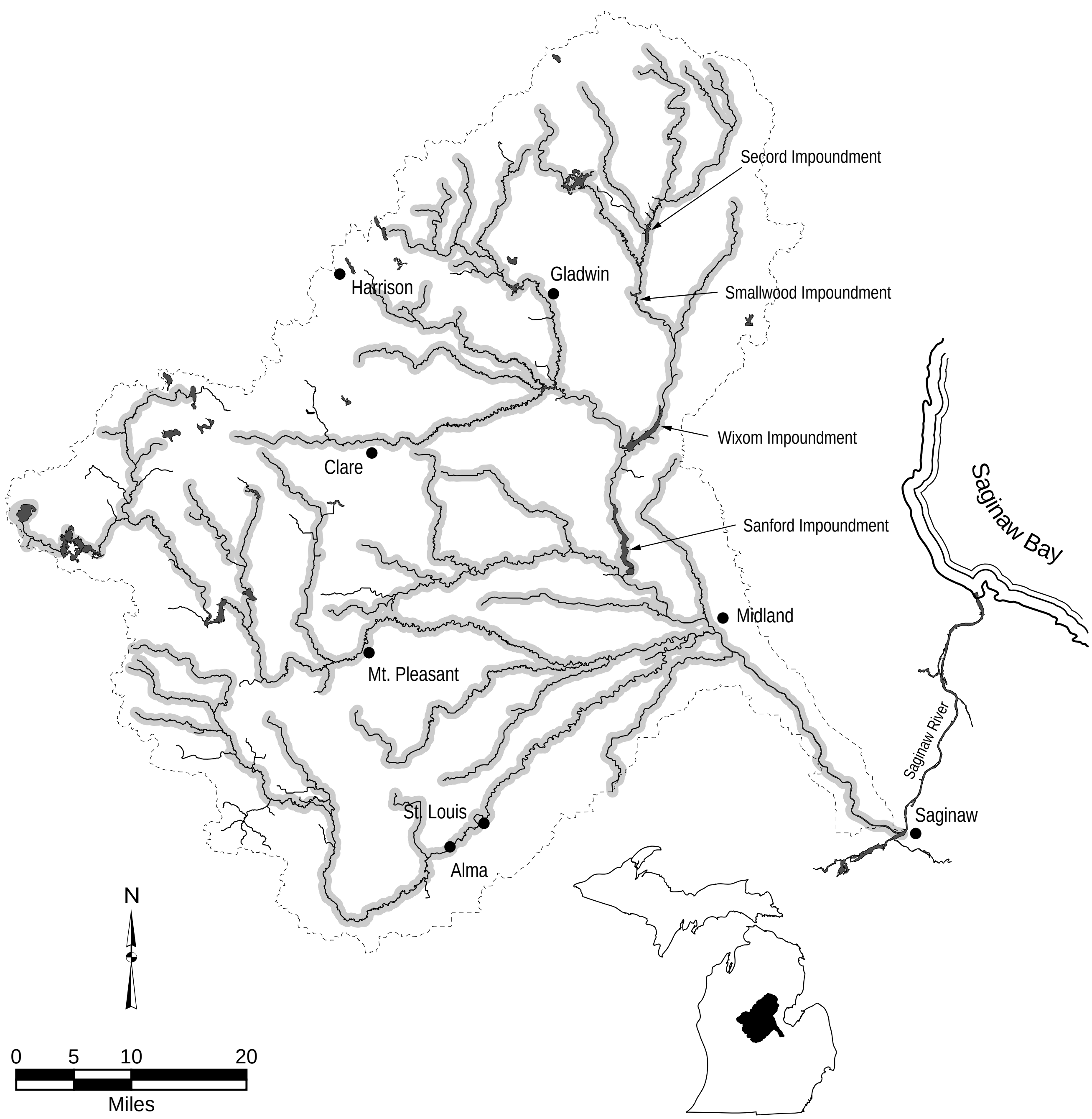


Common shiner *Luxilus cornutus*

Habitat**:**

feeding - small, clear, high-gradient streams and rivers, or shores of clear water lakes and impoundments
- gravel substrate
- can tolerate some submerged aquatic vegetation
- not very tolerant of turbidity or silted waters

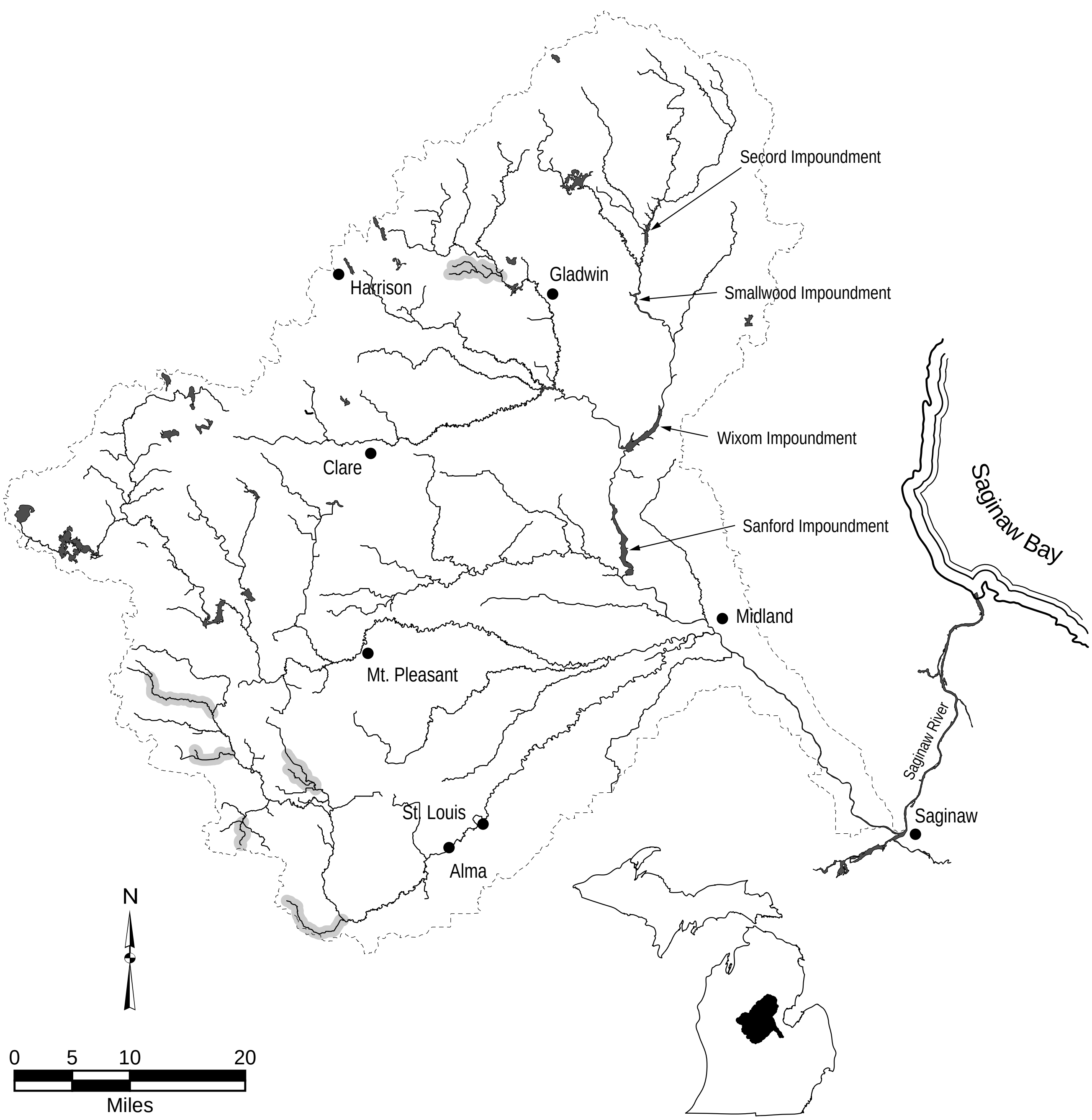
spawning - gravel nests of other fish, especially those at the head of a riffle



Northern pearl dace *Margariscus nachtriebi*

Habitat:

feeding	- cool, neutral to acidic streams and lakes
	- clear to slightly turbid water
spawning	- males are territorial
	- clear water, 18-24 inches deep
	- sand or gravel substrate
	- weak to moderate current

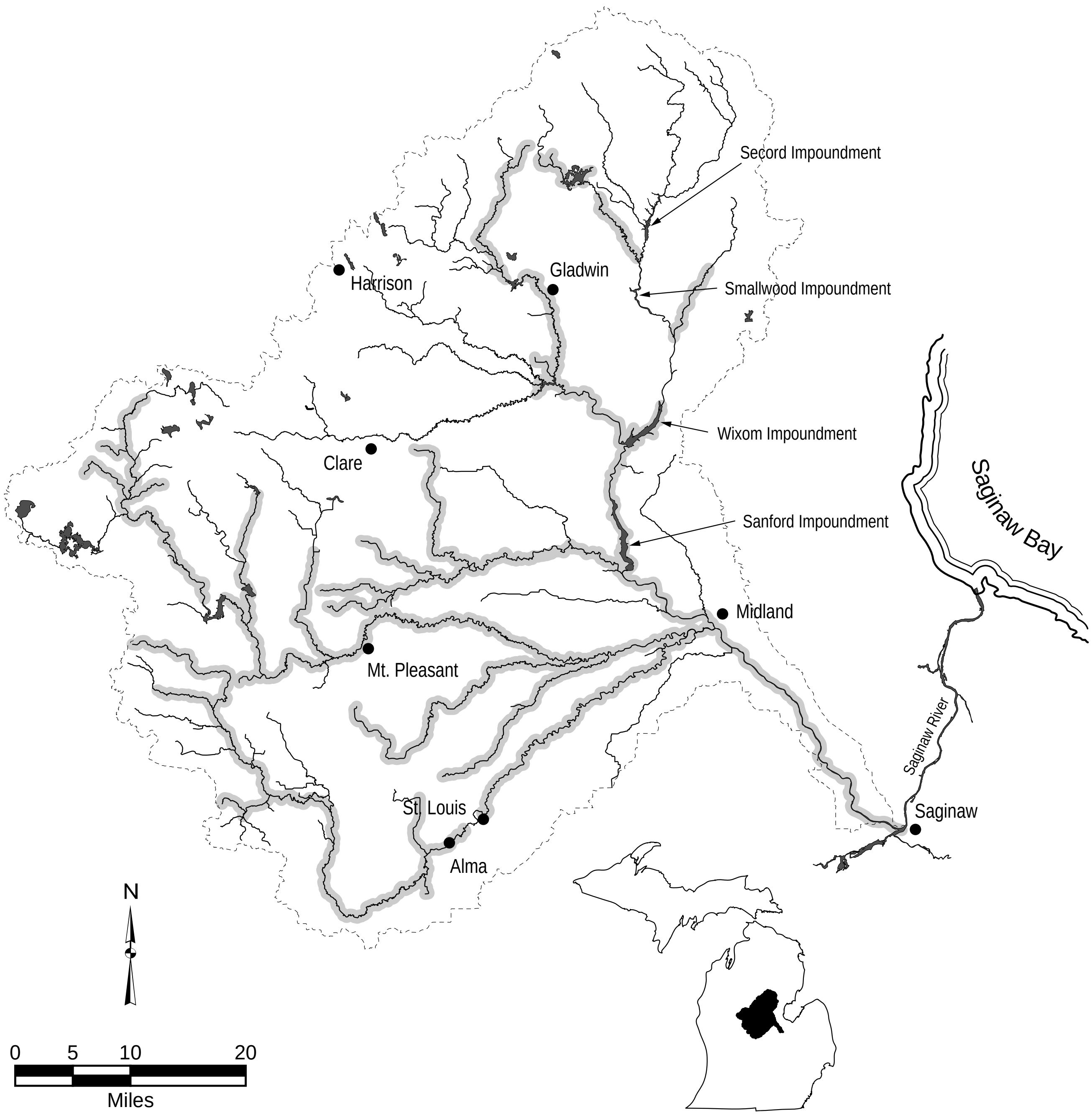


Hornyhead chub *Nocomis biguttatus*

Habitat:

feeding
- adults: near riffles
- young: near vegetation
- clear water, does not tolerate turbidity
- gravel substrate
- low gradient streams that are tributaries to large streams

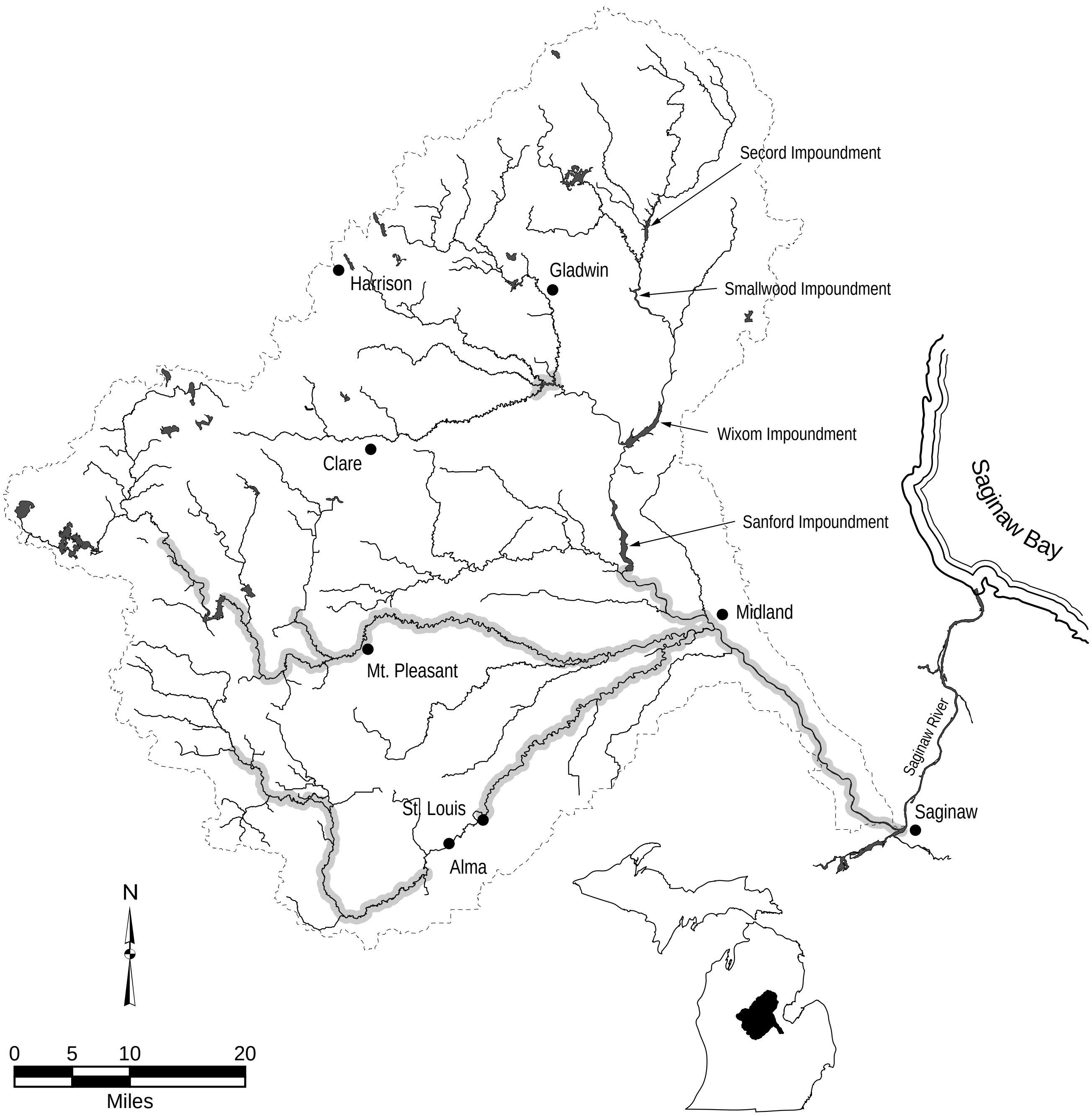
spawning
- large stones and pebbles present
- often below a riffle in shallow water
- gravel substrate



River chub *Nocomis micropogon*

Habitat:

feeding - moderate to large streams
- moderate to high gradient
- gravel, boulder, or bedrock substrate
- little to no aquatic vegetation
- cannot tolerate turbidity or siltation

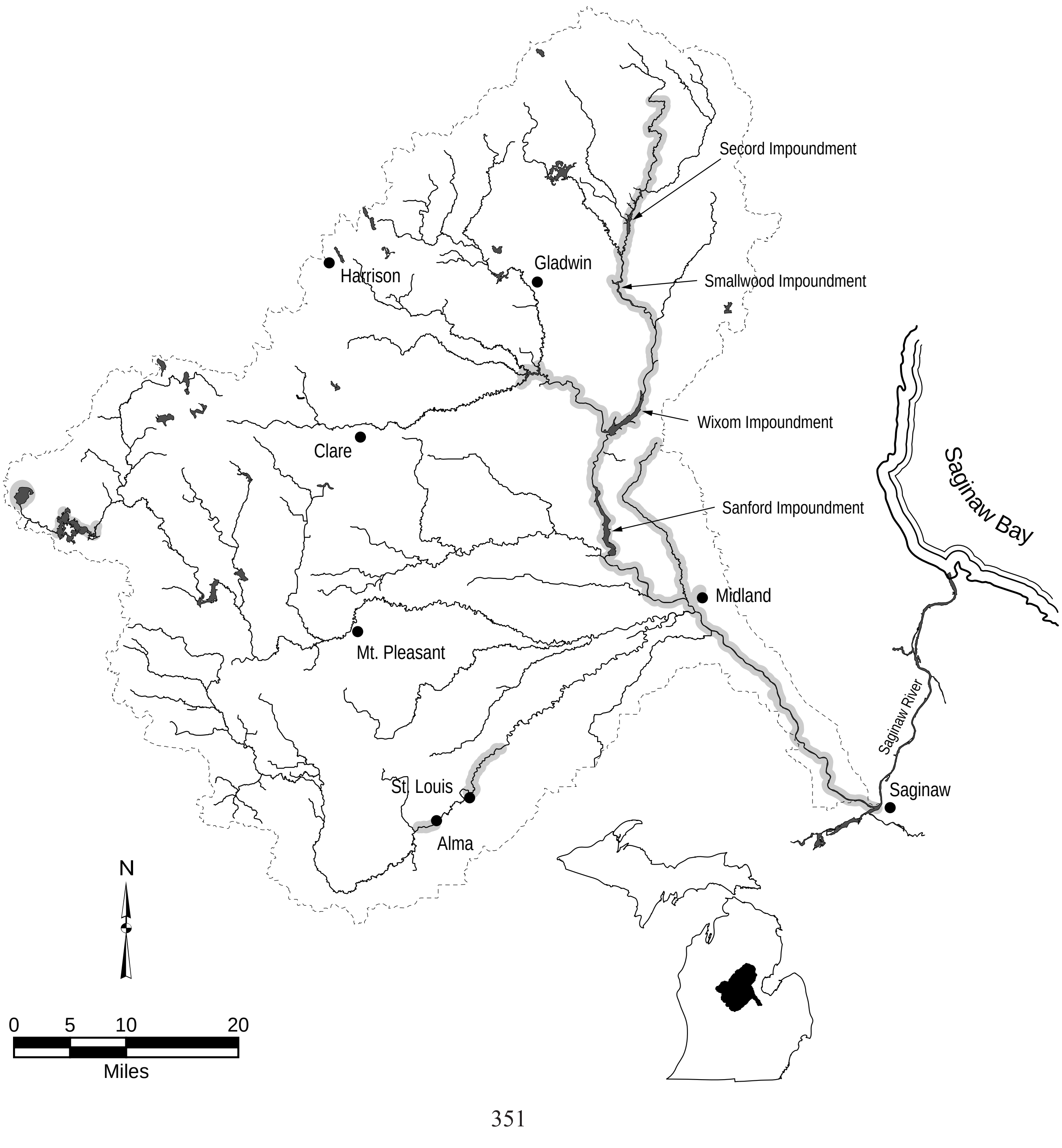


Golden shiner *Notemigonus crysoleucas*

Habitat**:**

feeding - lakes and impoundments and quiet pools of low gradient streams
- clear shallow water
- heavy vegetation

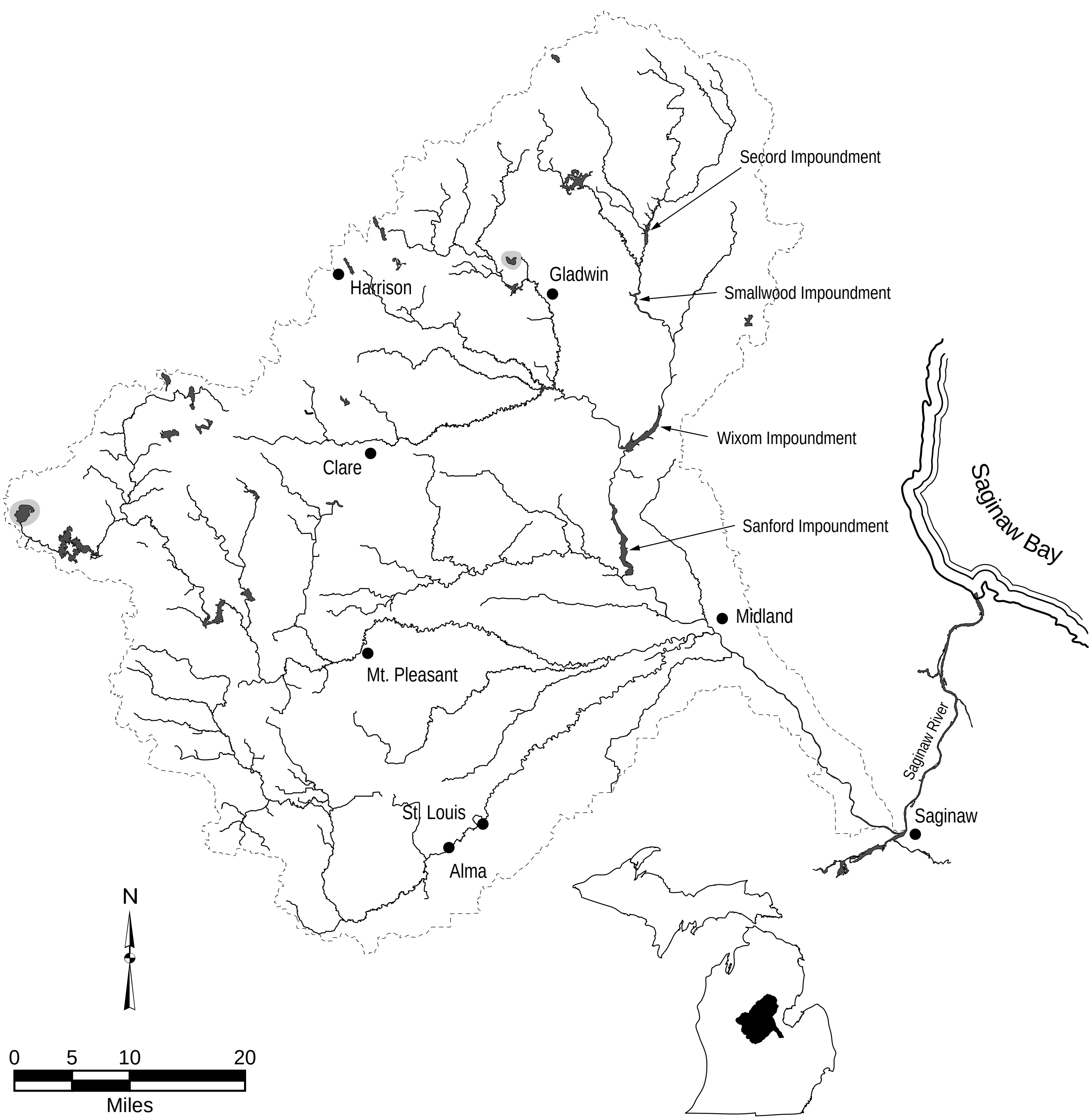
spawning - vegetation



Pugnose shiner *Notropis anogenus* **– special concern**

Habitat:

feeding - very clear water of lakes, impoundments, and low-gradient streams
- aquatic vegetation
- clean sand, marl, or organic debris substrate
- extremely intolerant of turbidity

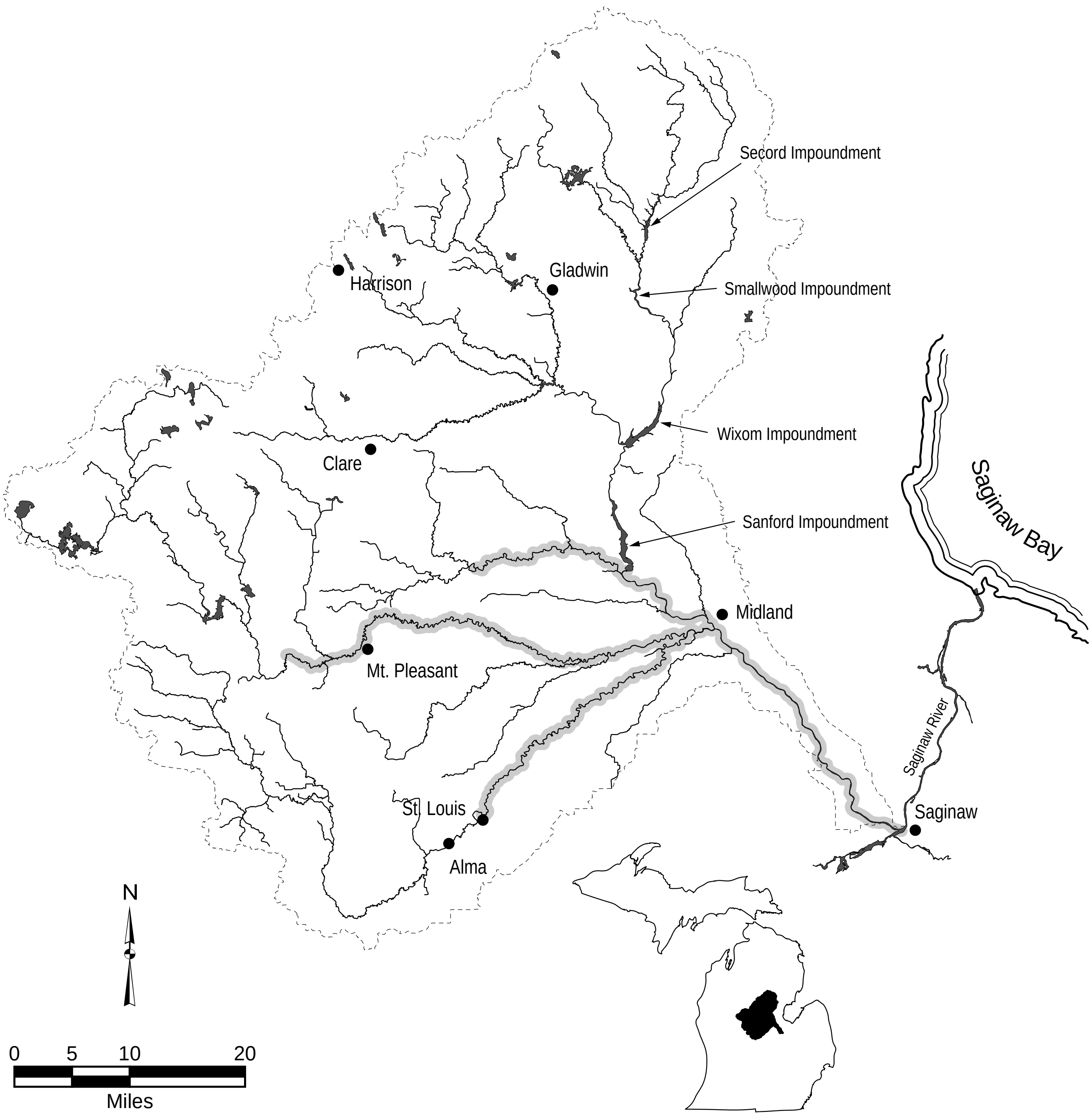


Emerald shiner *Notropis atherinoides*

Habitat**:**

feeding - open-large stream channels and lake
- low to moderate gradient
- range of turbidities and bottom types
- midwater or surface preferred, substrate of little importance
- avoids rooted vegetation

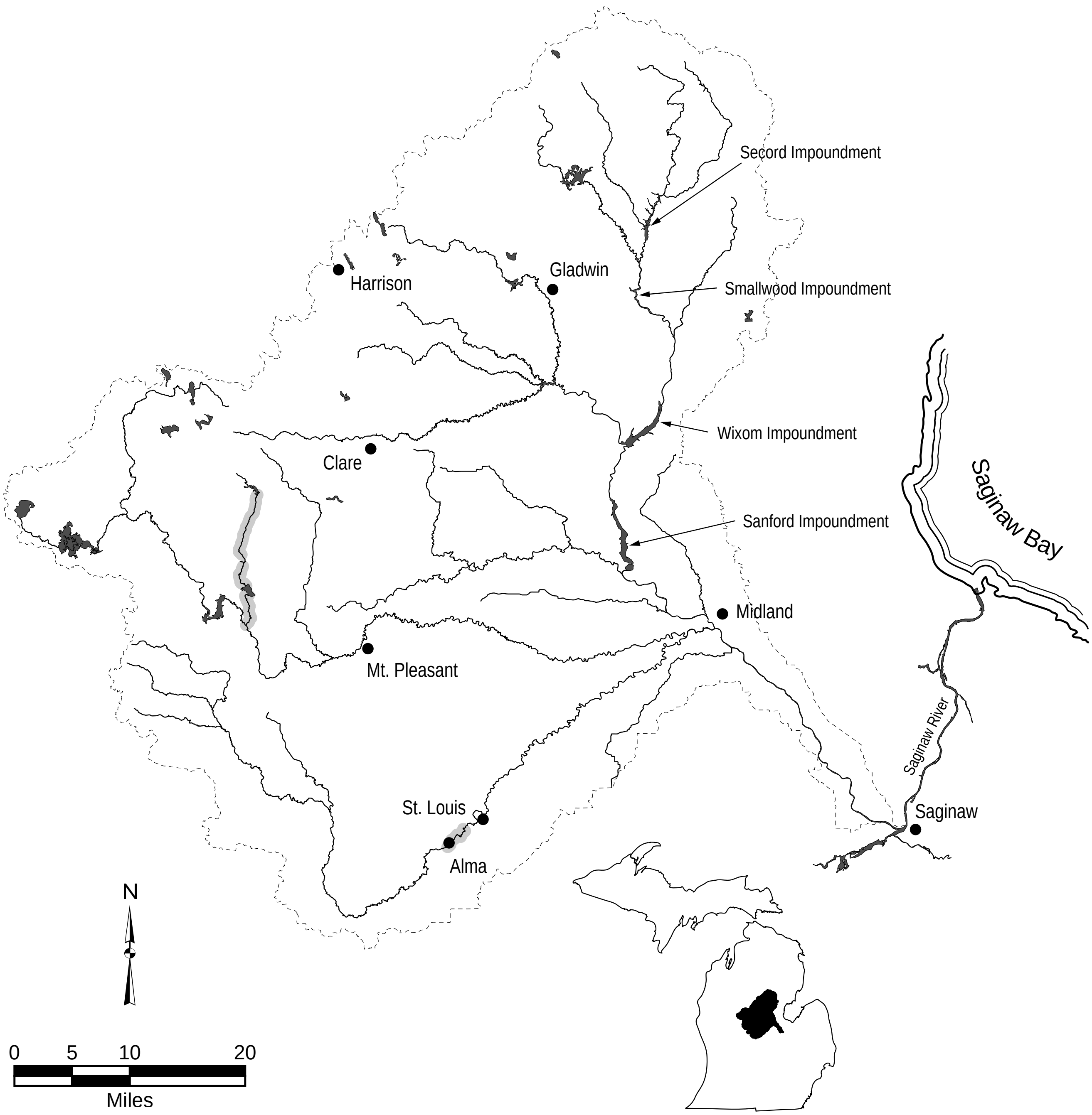
spawning - sand or firm mud substrate or gravel shoals



Blackchin shiner *Notropis heterodon*

Habitat**:**

feeding - lakes, impoundments, and quiet pools in streams and rivers
- clear water
- clean sand, gravel, or organic debris substrate
- dense beds of submerged aquatic vegetation
- cannot tolerate turbidity, silt, or loss of aquatic vegetation

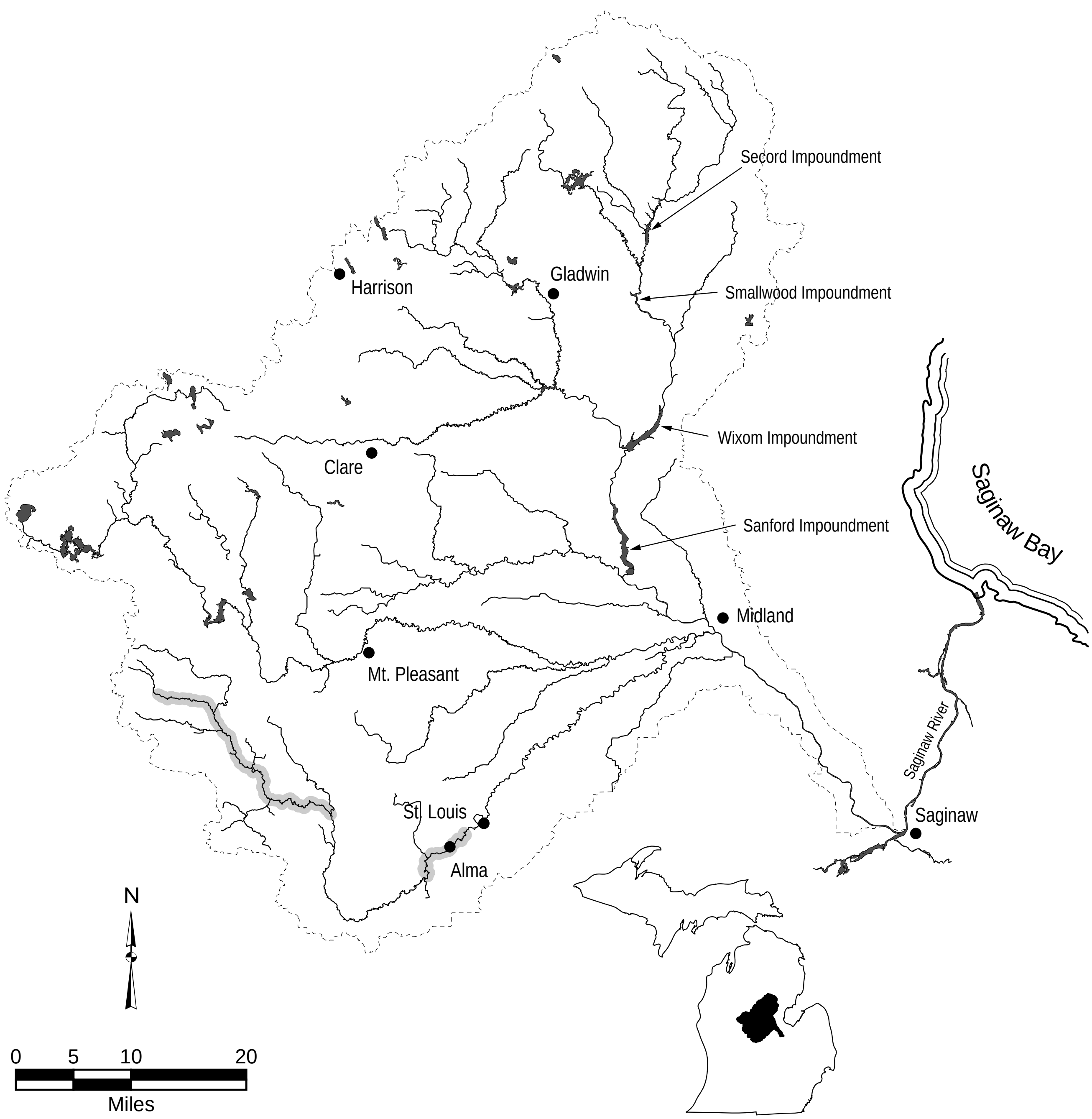


Blacknose shiner *Notropis heterolepis*

Habitat**:**

feeding - clear lakes, impoundments, and pools of small, clear, low-gradient streams
- aquatic vegetation
- clean sand, gravel, marl, muck, peat, or organic debris substrate
- cannot tolerate much turbidity, much siltation, or loss of aquatic vegetation

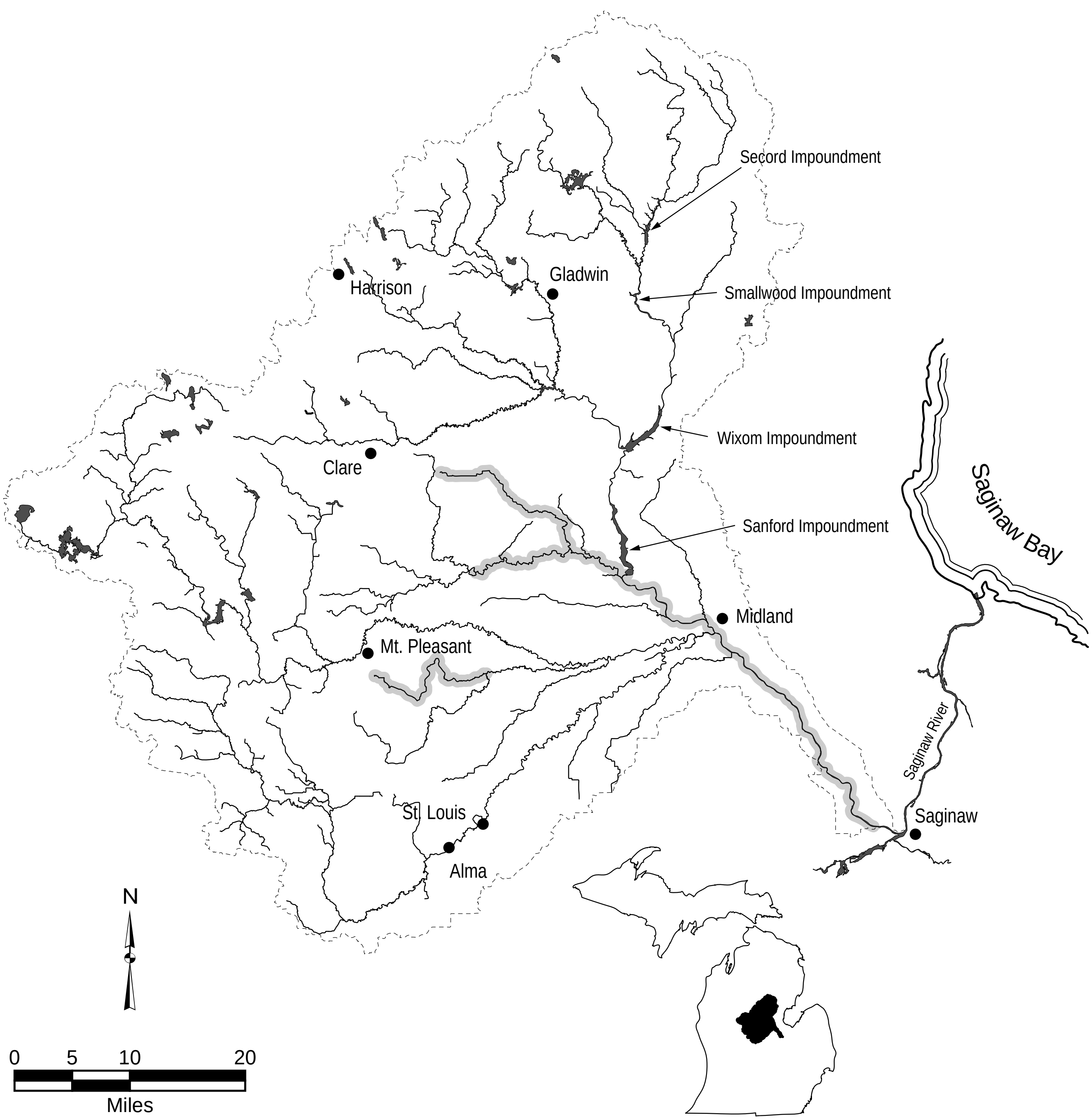
spawning - sandy substrate



Spottail shiner *Notropis hudsonius*

Habitat**:**

feeding	- large rivers, lakes, and impoundments
	- firm sand and gravel substrate
	- low current
	- sparse to moderate vegetation
	- avoids turbidity
spawning	- over sandy shoals or gravelly riffles
	- near the mouths of small streams

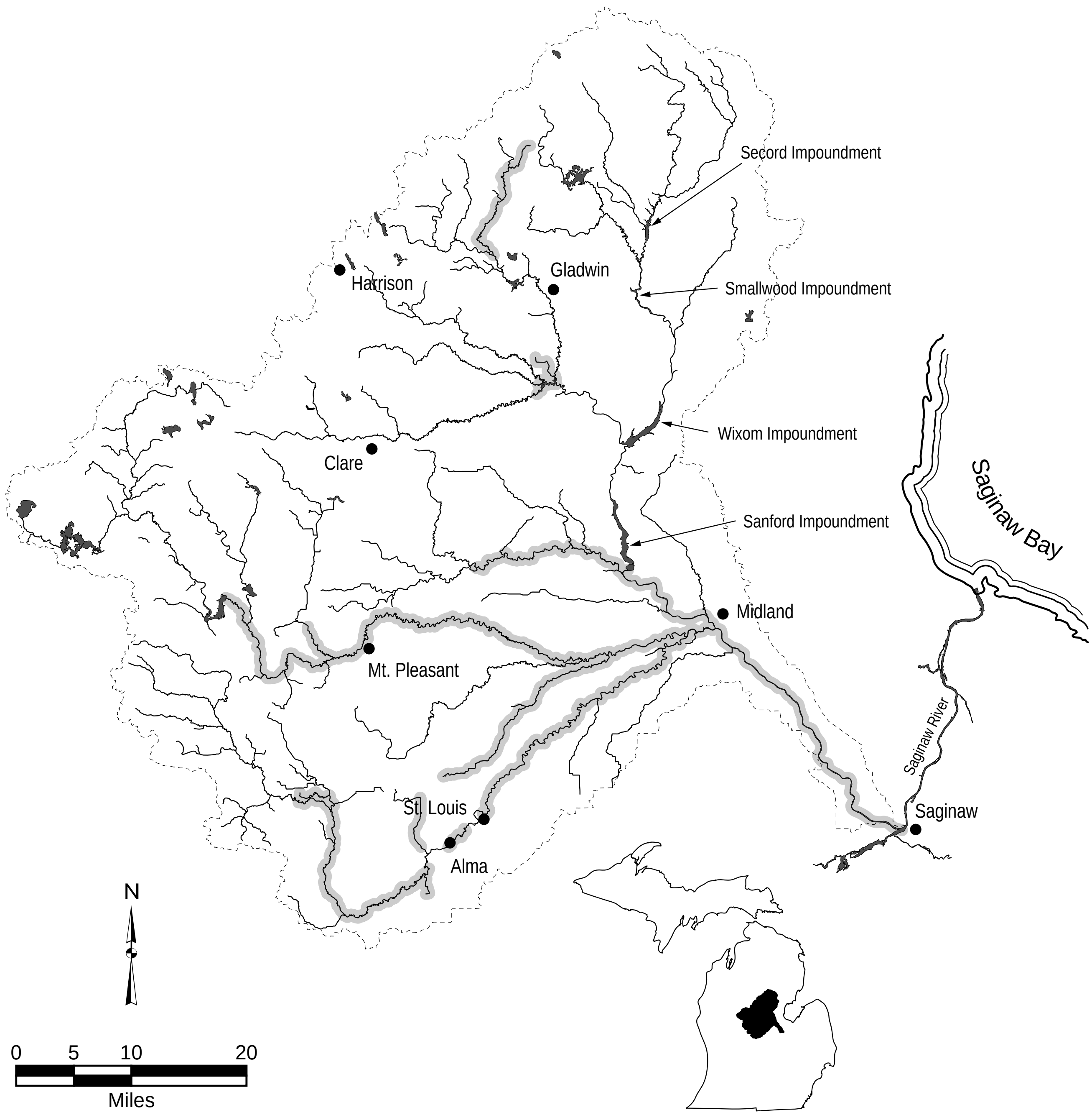


Rosyface shiner *Notropis rubellus*

Habitat**:**

feeding - moderate sized streams
- moderate to high gradient
- gravel or sand substrate; intolerant of silt substrate
- clear water; intolerant of turbidity

spawning - on nests of horneyhead chub, chesnut lamprey, and redhorses
- sandy-gravel, gravel or bedrock substrate
- shallow high gradient water

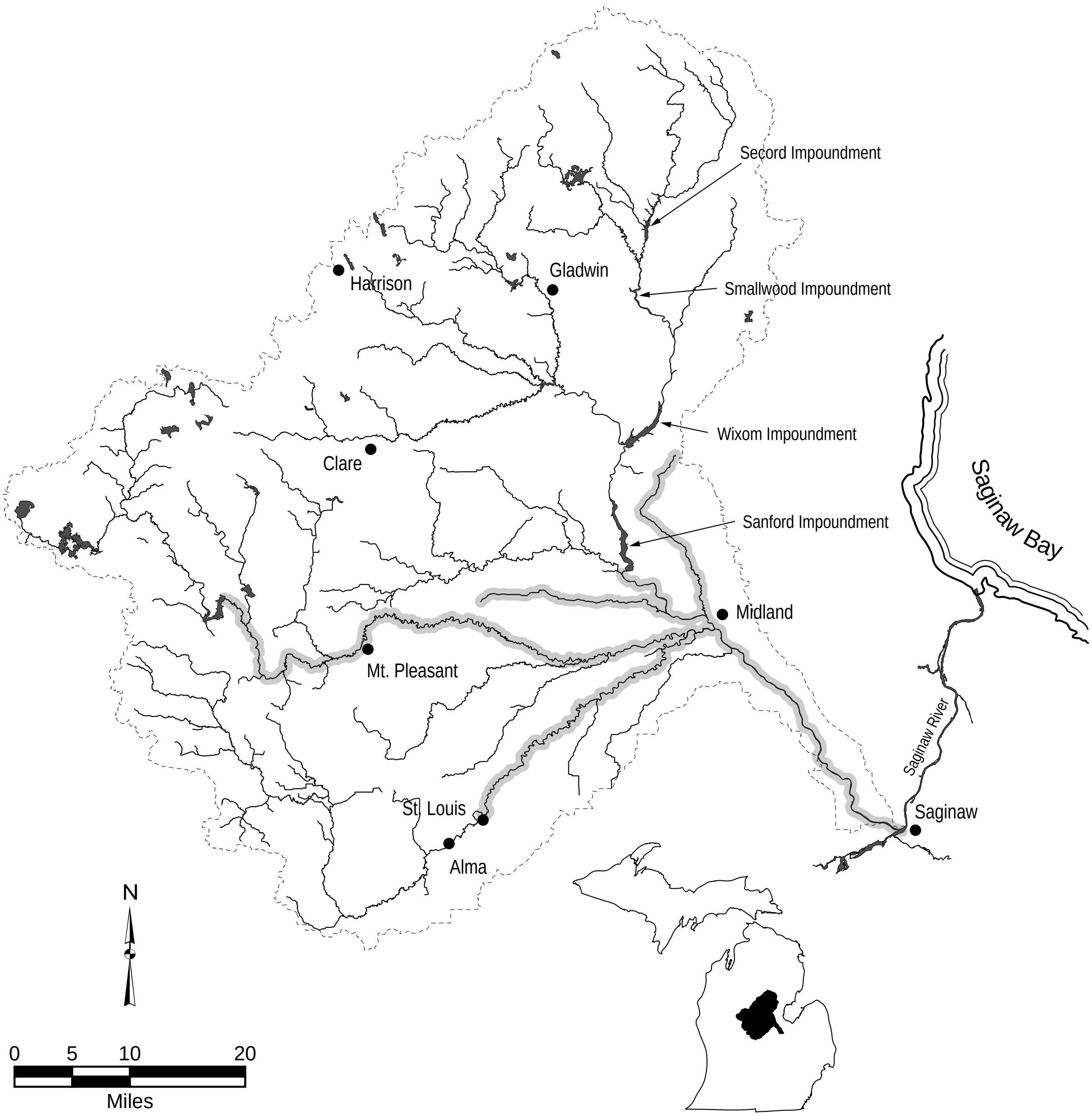


Sand shiner *Notropis stramineus*

Habitat:

feeding
- sand and gravel substrate
- shallow pools in medium size streams, lakes, and impoundments
- clear water and low gradient
- rooted aquatic vegetation preferred
- tolerant of some inorganic pollutants provided substrate is not covered

spawning
- clean gravel or sand substrate

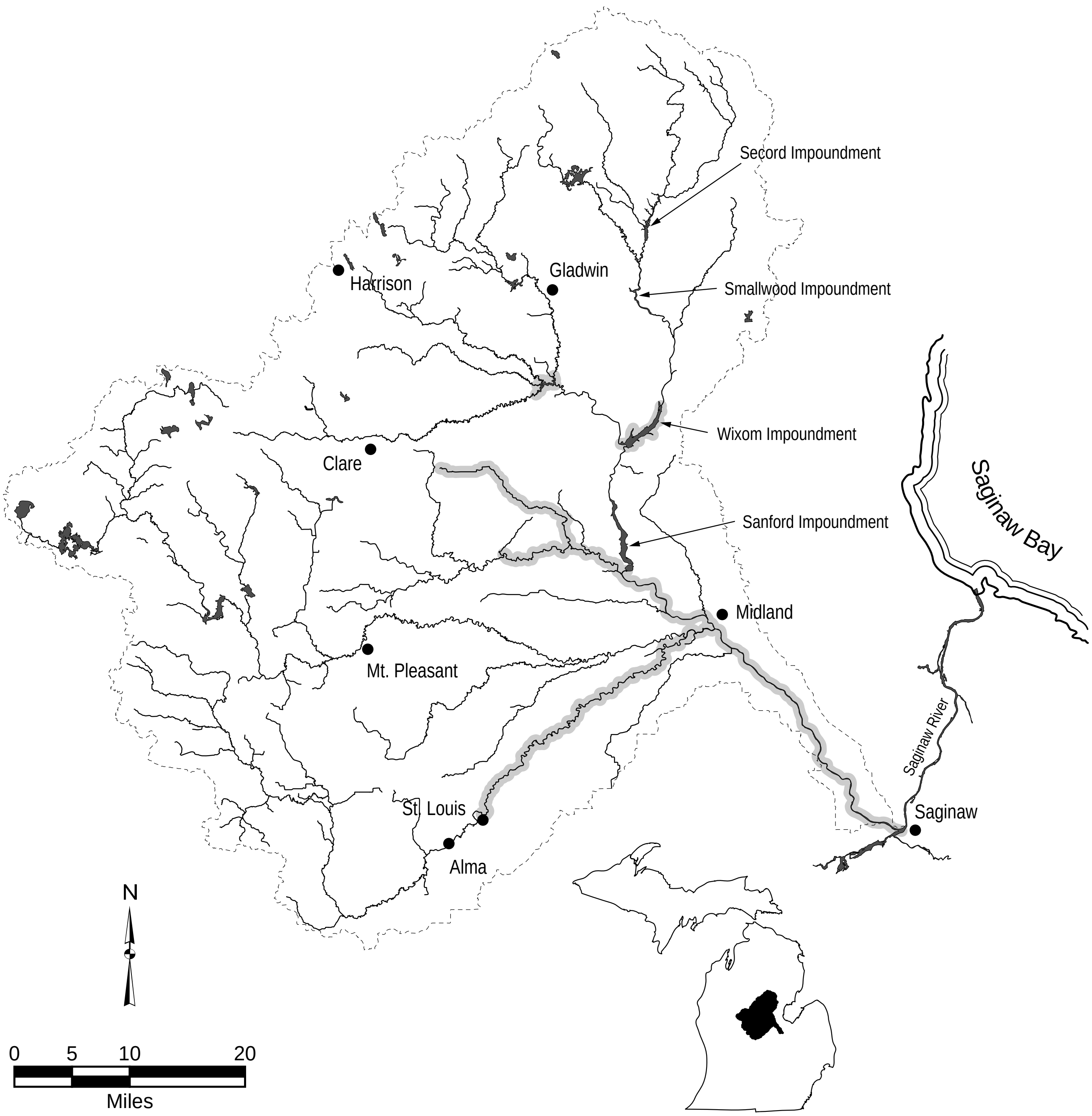


Mimic shiner *Notropis volucellus*

Habitat**:**

feeding - pools and backwater of streams, moderately weedy lakes and impoundments
- quiet or still water
- clear shallow water

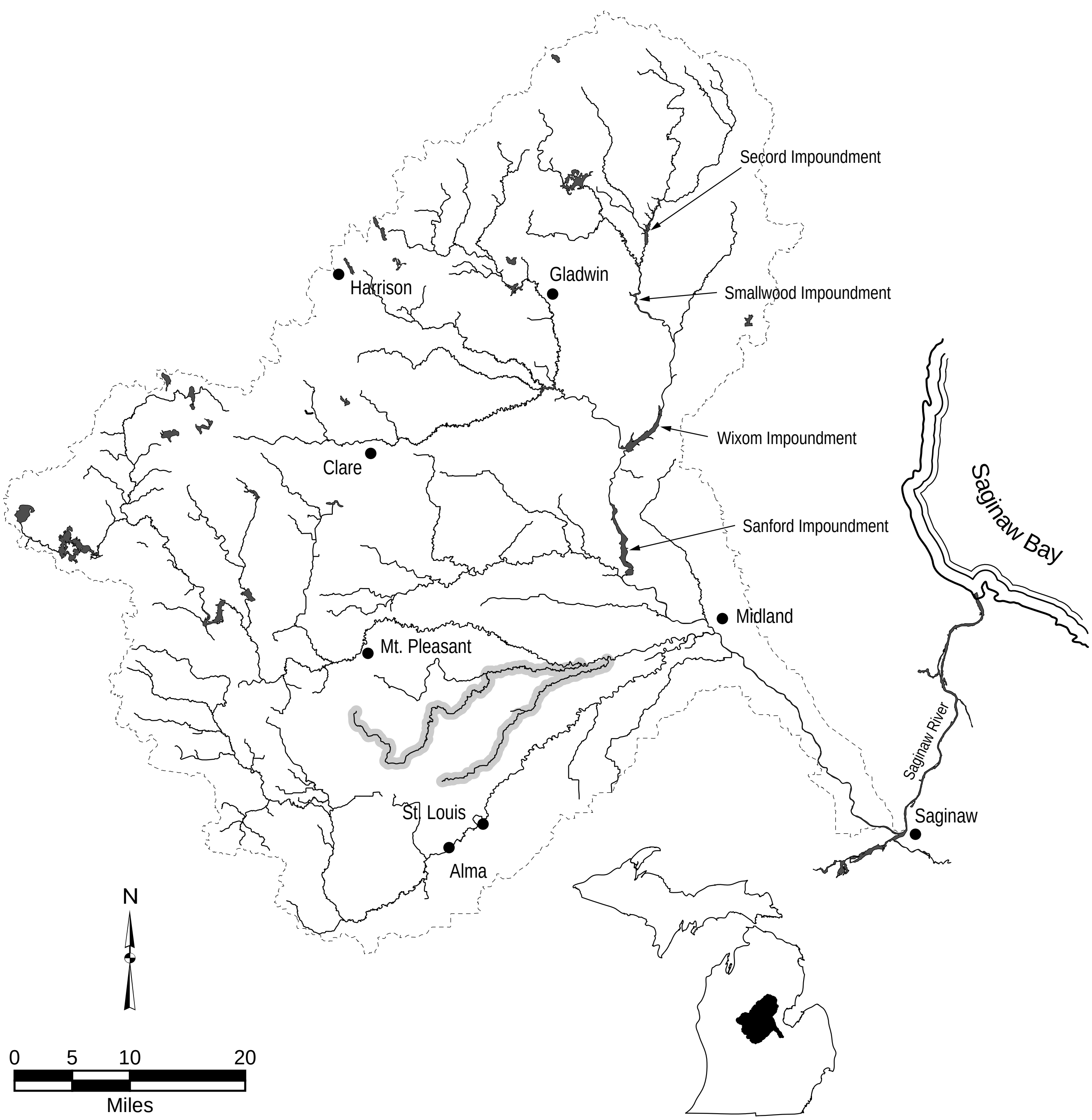
spawning - aquatic vegetation necessary



Suckermouth minnow *Phenacobius mirabilis*

Habitat:

feeding - riffles
- warm water
- low to moderate gradient, enough to keep gravel riffles free of silt
- turbid water rich in organic material
- absence of aquatic vegetation

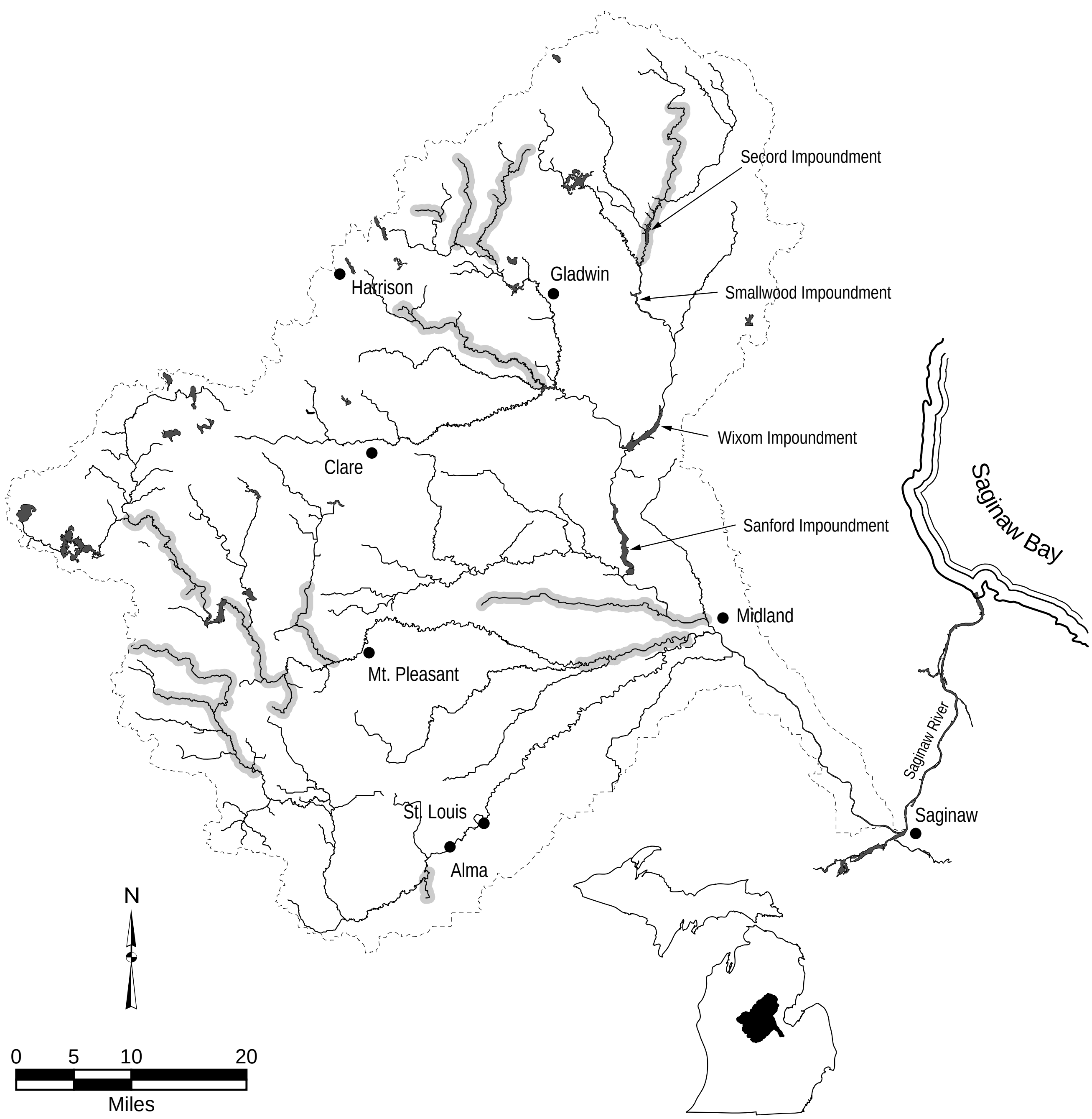


Northern redbelly dace *Phoxinus eos*

Habitat:

feeding - slow current
- in boggy lakes and streams
- detritus or silt substrate
- clear to slightly turbid water

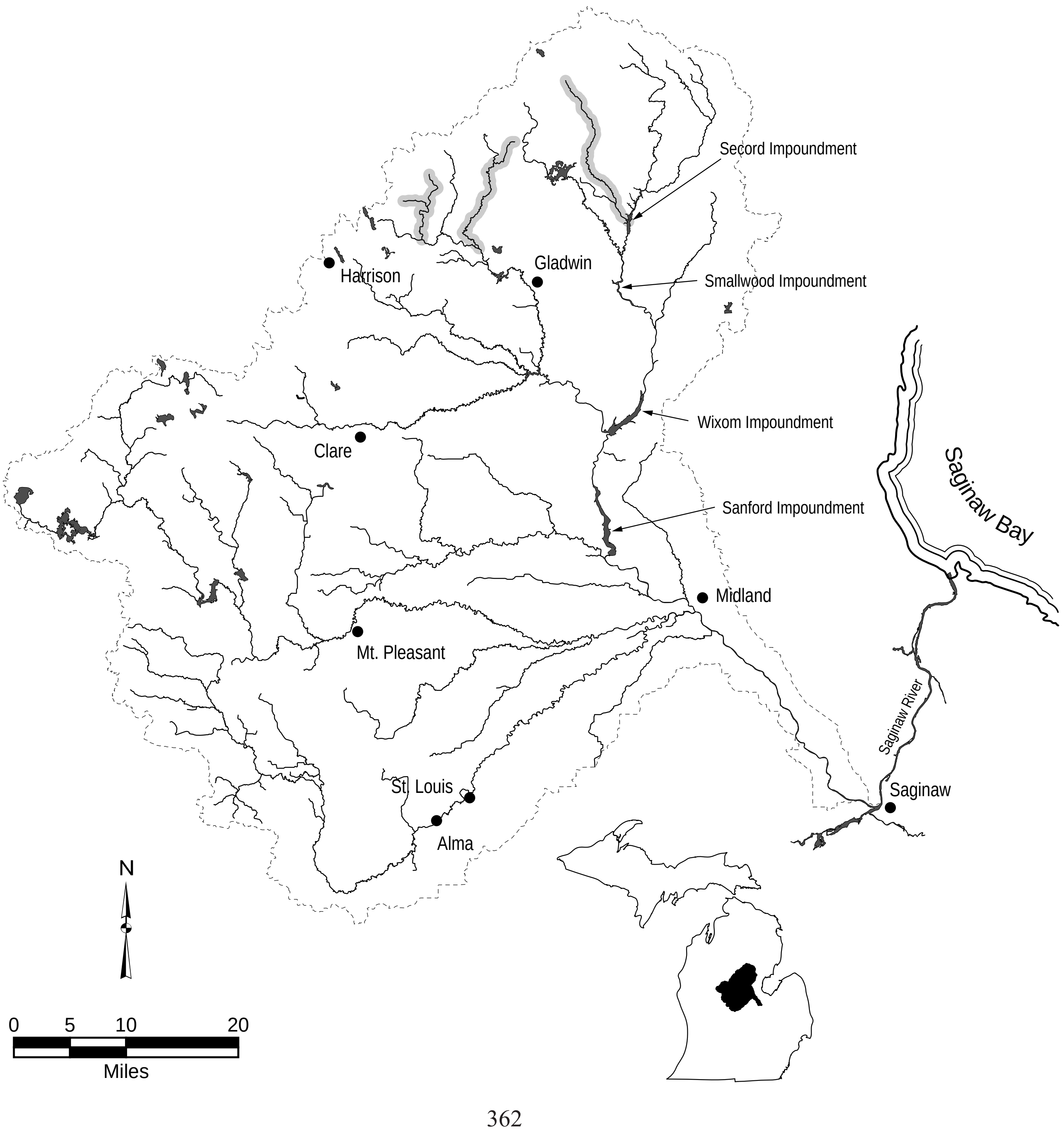
spawning - filamentous algae needed for egg deposition



Finescale dace *Phoxinus neogaeus*

Habitat:

feeding - cool bog lakes and streams
- neutral to slightly acidic waters
- various substrates

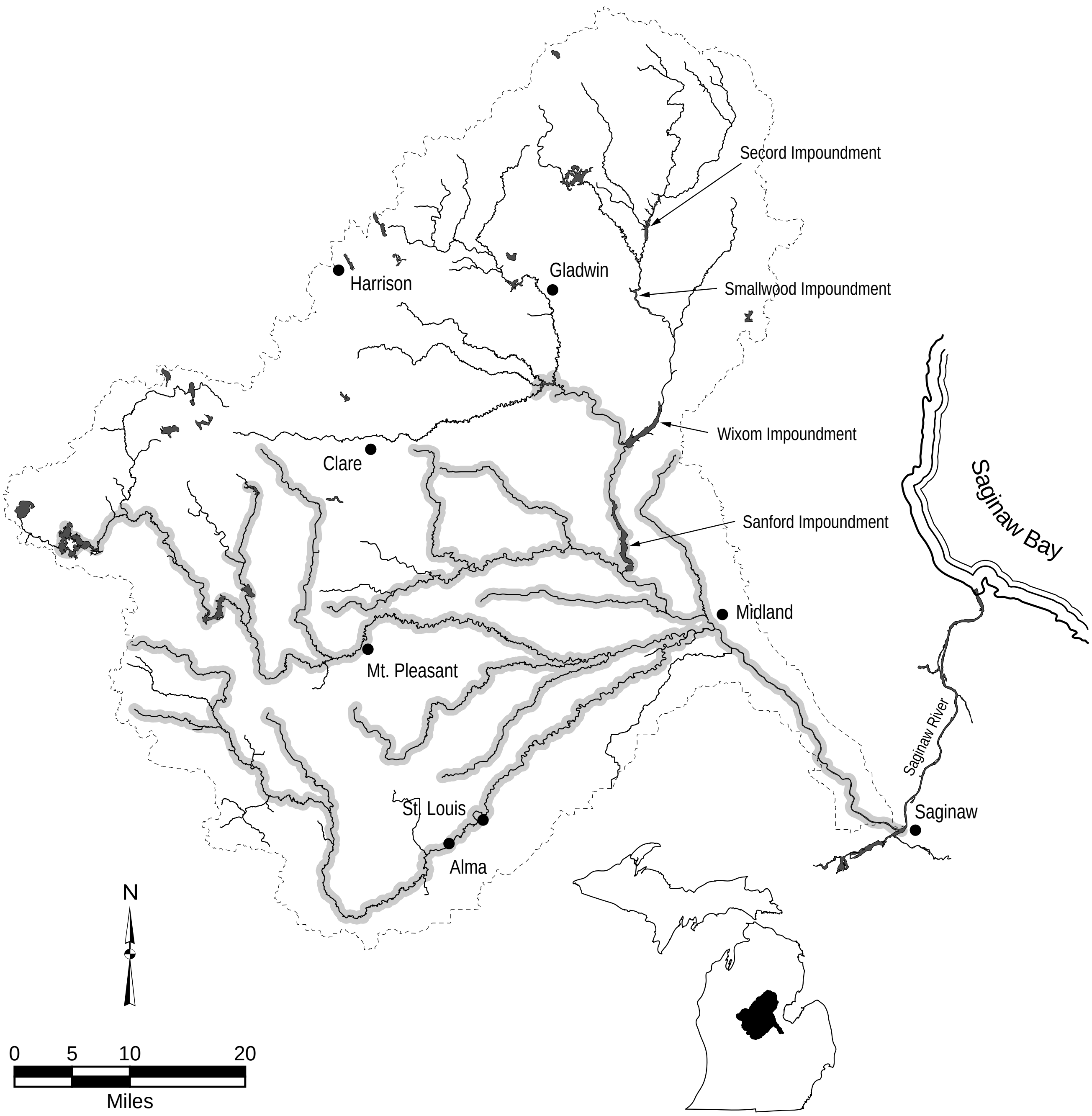


Bluntnose minnow *Pimephales notatus*

Habitat**:**

feeding - quiet pools and backwaters of medium to large streams, lakes, and impoundments
- clear warm water
- some aquatic vegetation
- firm substrates
- tolerates all gradients, turbidity, organic and inorganic pollutants

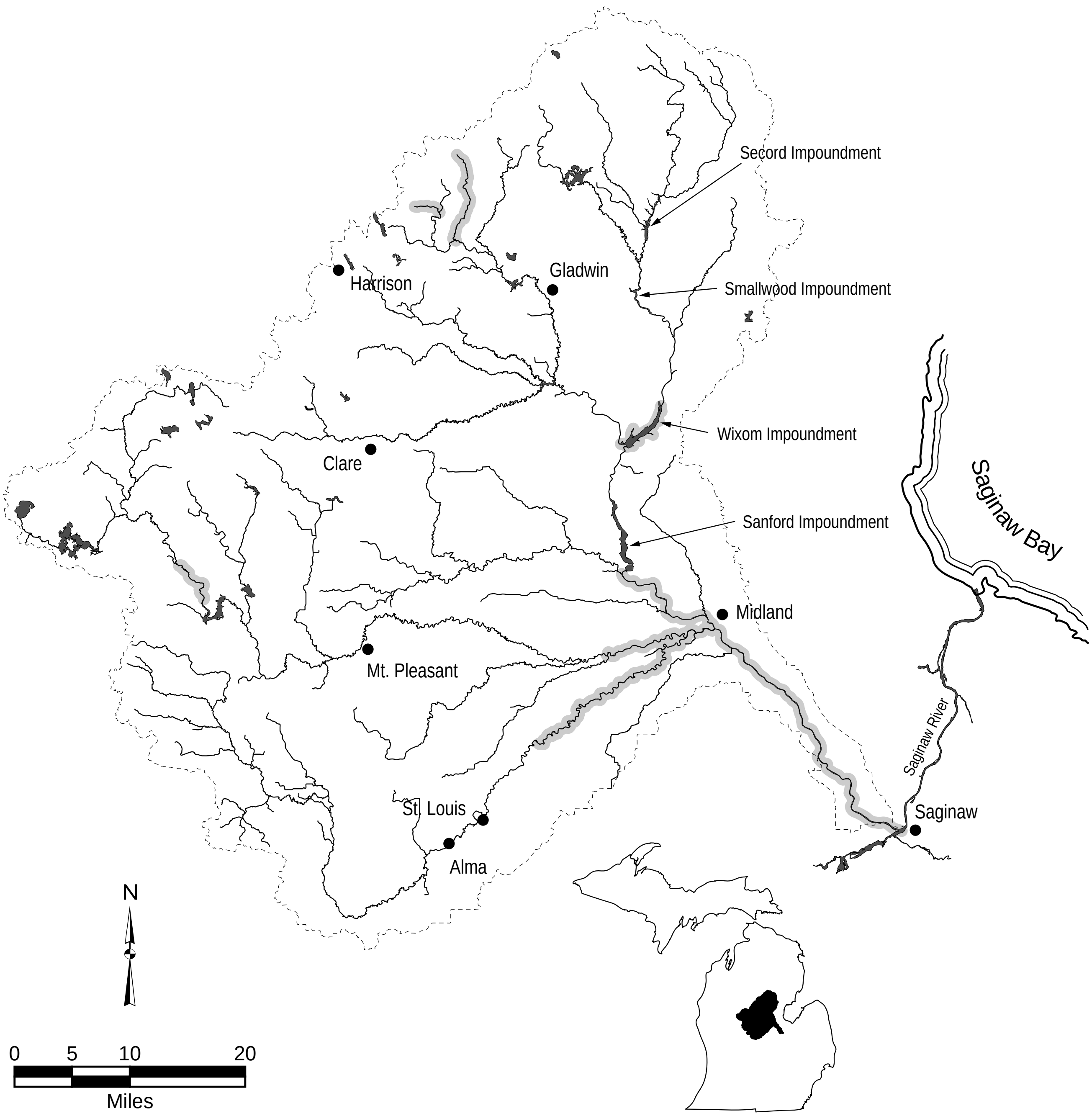
spawning - eggs deposited on the underside of flat stones or objects
- nests in sand or gravel substrate



Fathead minnow *Pimephales promelas*

Habitat**:**

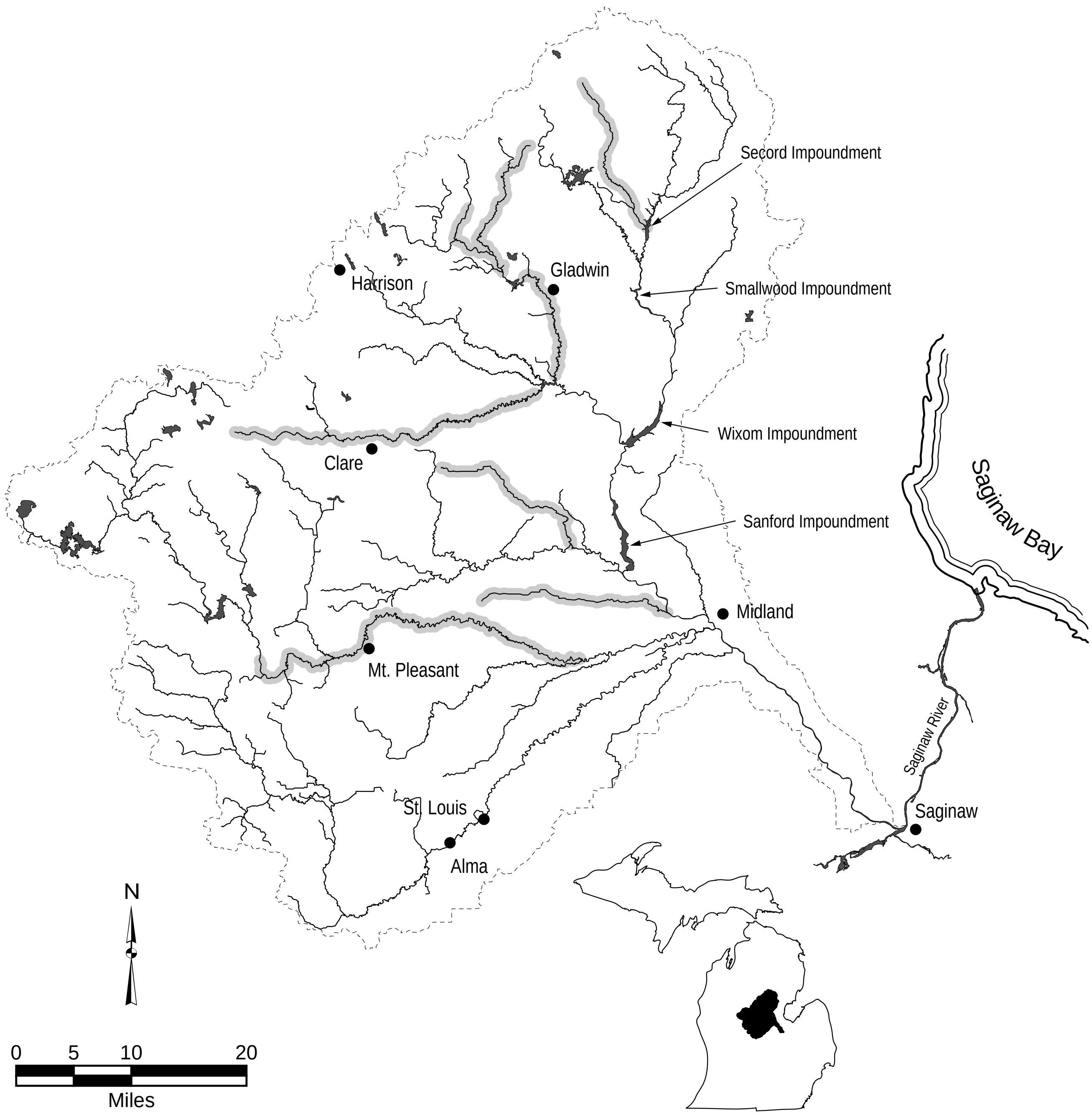
feeding	-	pools of small streams, lakes, and impoundments
	-	tolerant of turbidity, high temperatures, and low oxygen
spawning	-	on underside of objects in water 2 to 3 feet deep
	-	prefer sand, marl, or gravel substrate



Longnose dace *Rhinichthys cataractae*

Habitat**:**

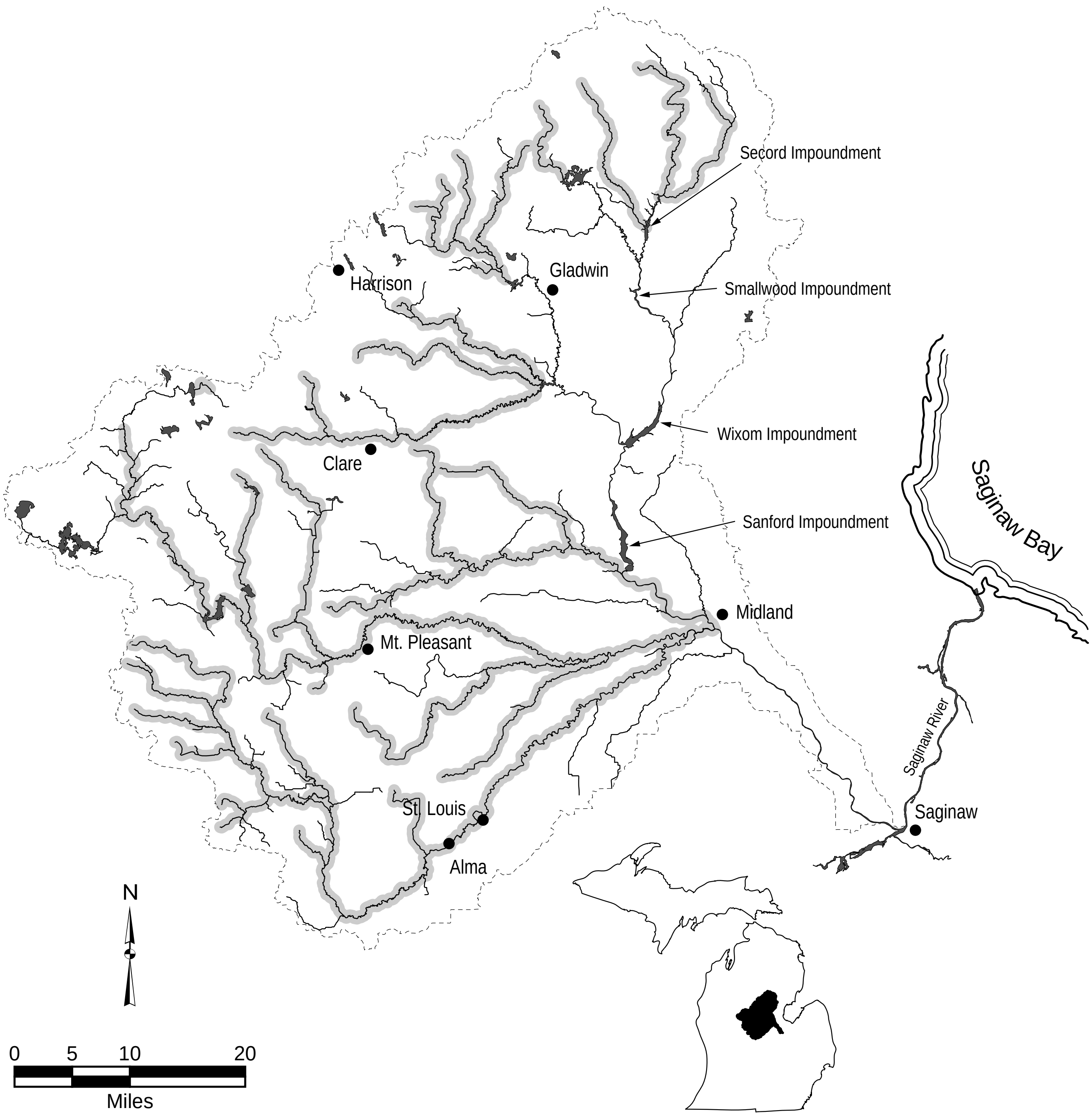
feeding - lakes and streams
- high gradient
- gravel or boulder substrate



Western blacknose dace *Rhinichthys obtusus*

Habitat**:**

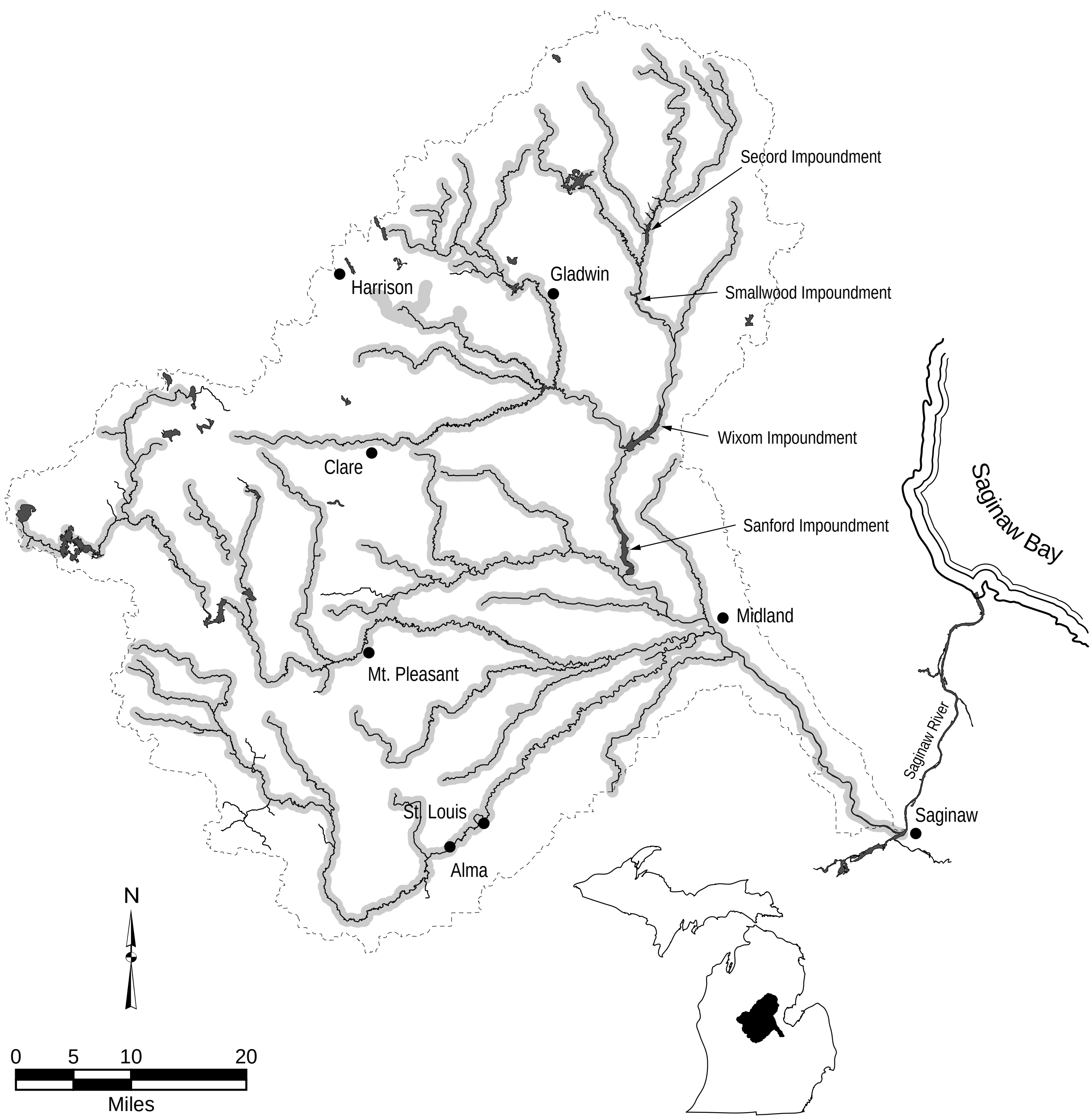
feeding	-	moderate to high gradient streams
	-	sand and gravel substrate
	-	clear cool water in pools with deep holes and undercut banks
	-	does not tolerate turbidity and silt well
spawning	-	riffles with gravel substrate and fast current
winter refuge	-	larger waters



Creek chub *Semotilus atromaculatus*

Habitat**:**

feeding	-	streams, rivers, or shore waters of lakes and impoundments
	-	can tolerate intermittent flows
	-	tolerates moderate turbidity
spawning	-	gravel nests
	-	low current
winter refuge	-	deeper pools and runs

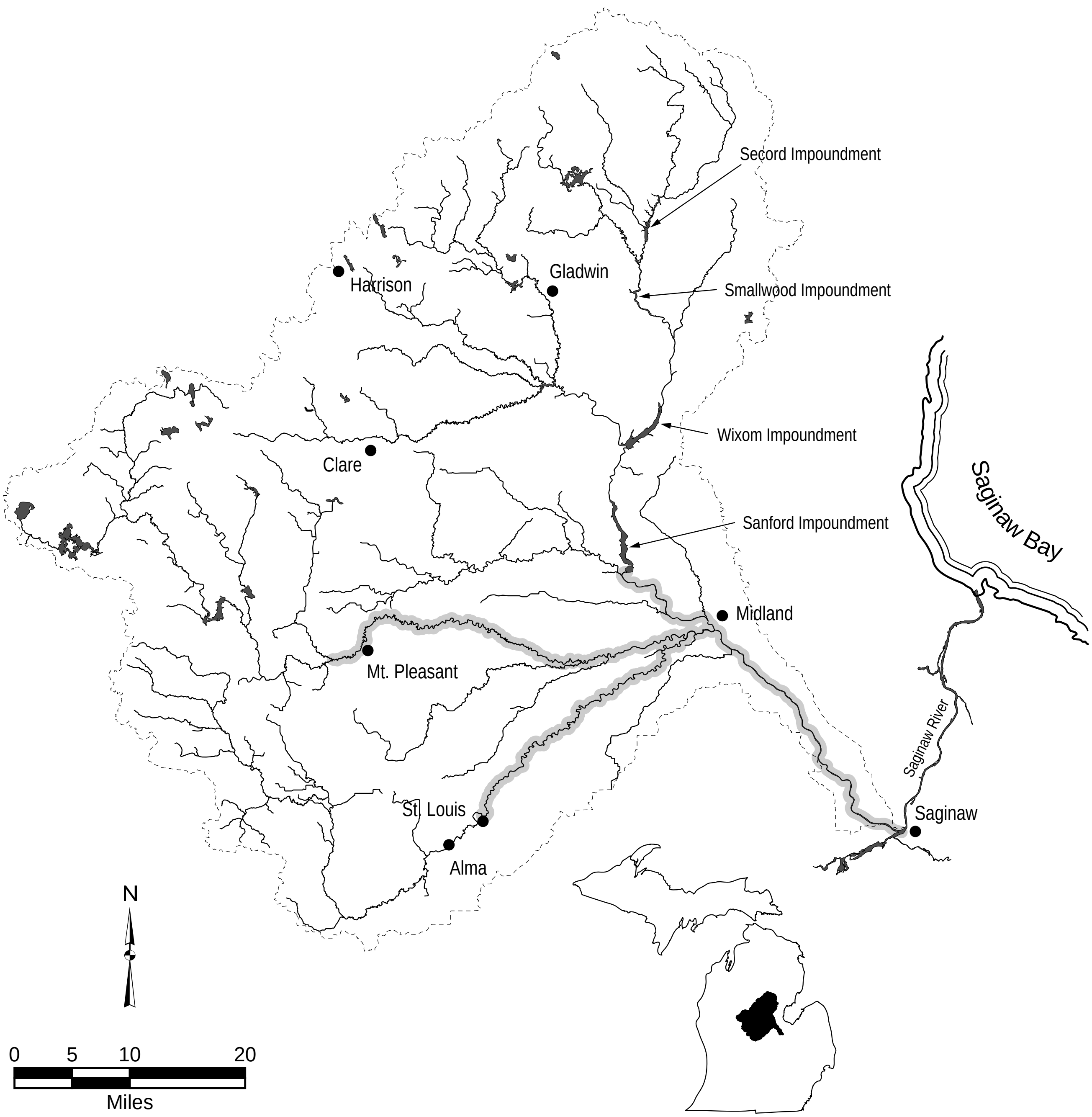


Quillback *Carpiodes cyprinus*

Habitat**:**

feeding - clear to turbid water
- Lake Huron
- sand, sandy gravel, sandy silt, or clay-silt substrate
- medium- to low-gradient rivers and streams; also lakes and sloughs

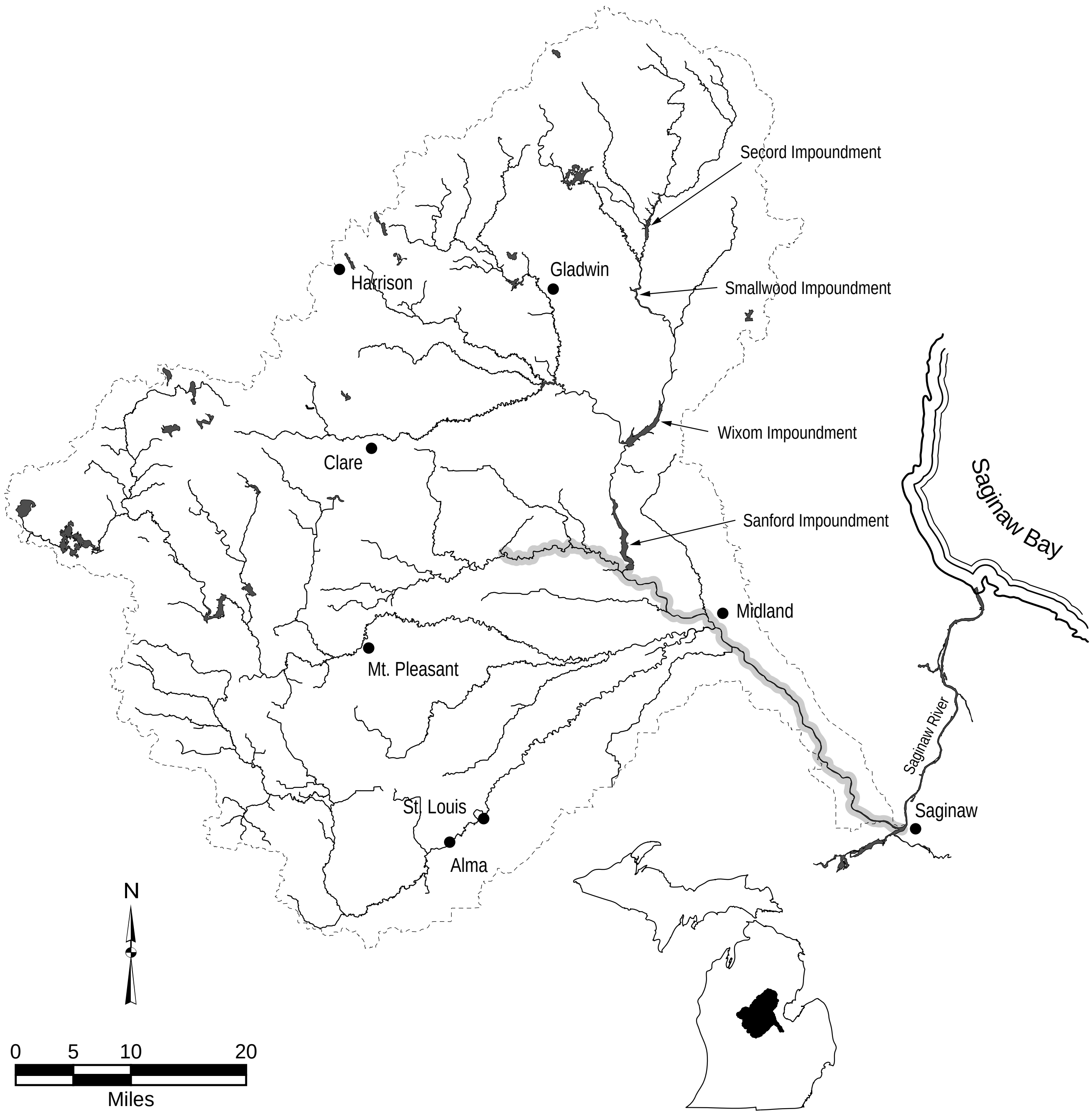
spawning - streams or overflow areas of bends of rivers or bays of lakes
- scatter eggs over sand or mud substrate



Longnose sucker *Catostomus catostomus*

Habitat**:**

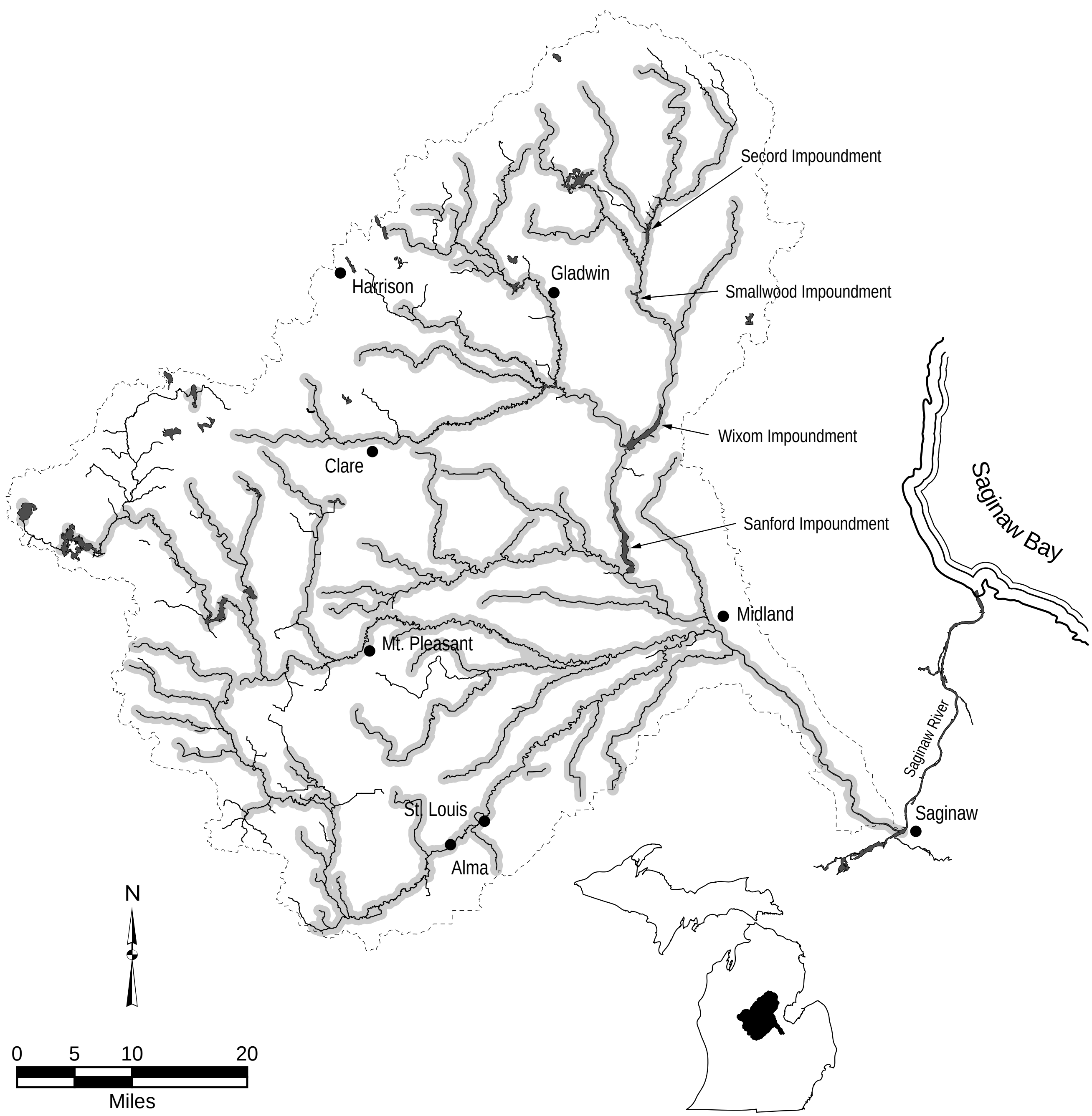
feeding	-	clear, cold rivers and lakes
spawning	-	in streams or lake shallows
	-	current
	-	gravel substrate



White sucker *Catostomus commersonii*

Habitat**:**

feeding	-	streams, rivers, lakes, and impoundments
	-	can inhabit highly turbid and polluted waters
spawning	-	quiet gravelly shallow areas of streams

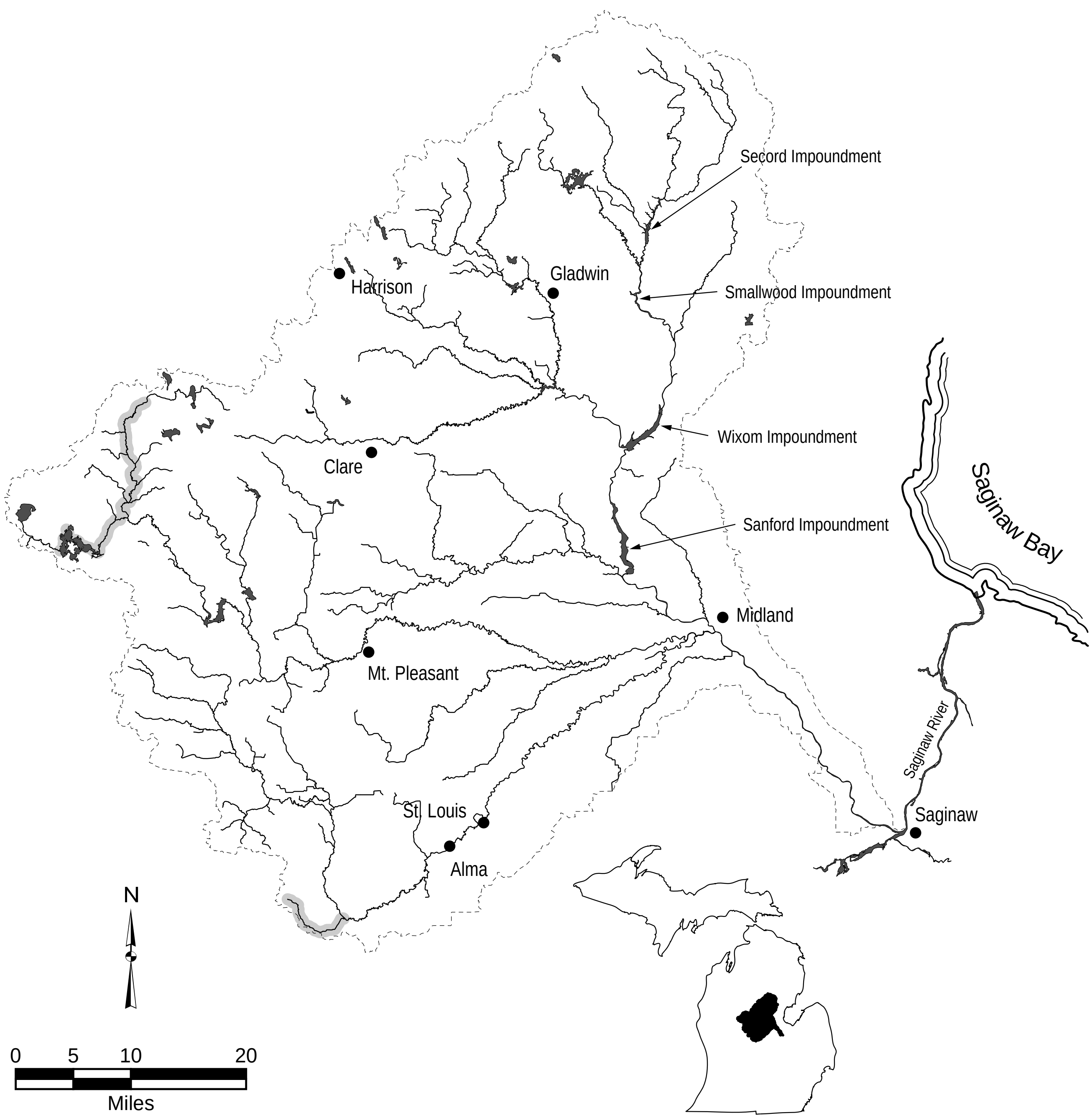


Lake chubsucker *Erimyzon sucetta*

Habitat**:**

feeding - larger clear streams, rivers, lakes, and impoundments
- cannot tolerate turbid water
- low gradient
- prefers dense vegetation over substrate of sand or silt mixed with organic debris

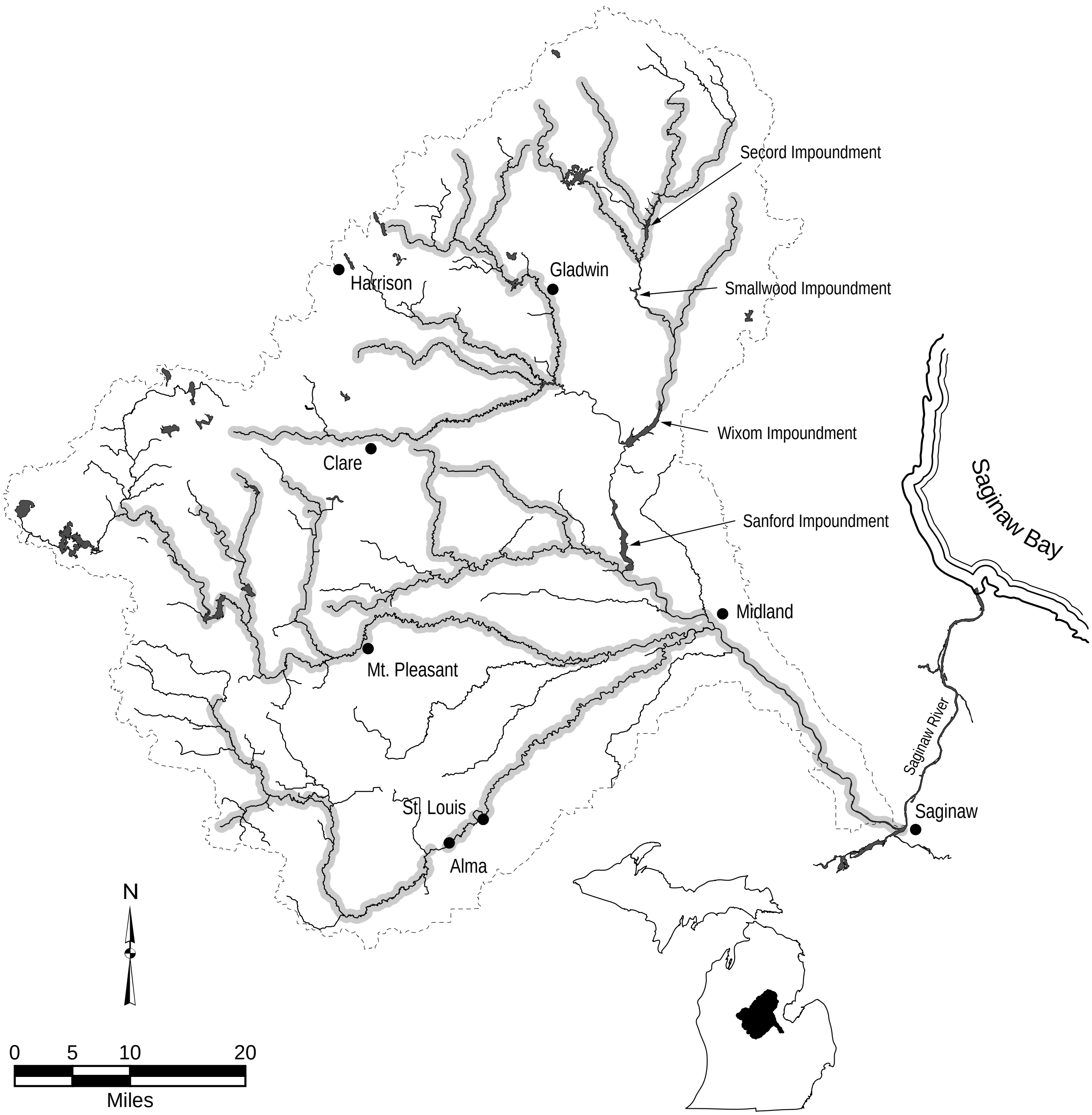
spawning - small clear streams with moderate to high gradient
- sand or gravel substrate; no clayey silt



Northern hog sucker *Hypentelium nigricans*

Habitat**:**

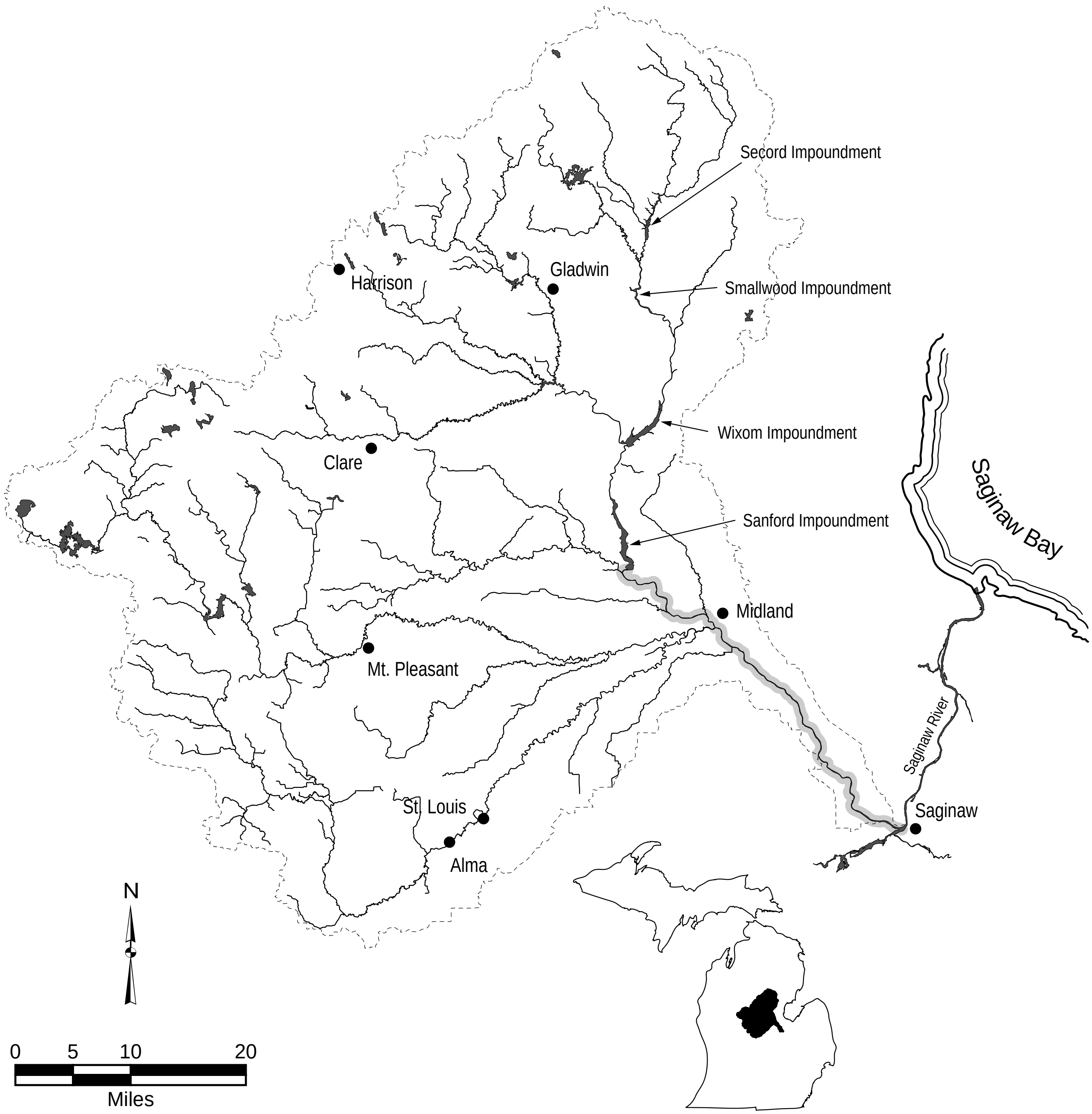
feeding	- gravel or rubble substrate
	- riffles and adjacent pools of warm shallow streams
	- clear water
	- doesn't like turbidity or siltation
	- avoids profuse amounts of aquatic vegetation
spawning	- riffles
	- shallow gravel substrate
	- high gradient
winter refuge	- deeper quieter pools



Silver redhorse *Moxostoma anisurum*

Habitat:

feeding	- streams, rivers, lakes, and impoundments
	- low current
	- pollution and turbidity intolerant
spawning	- swift current in rivers, do not spawn in tributaries
	- males territorial
	- gravel to rubble substrate

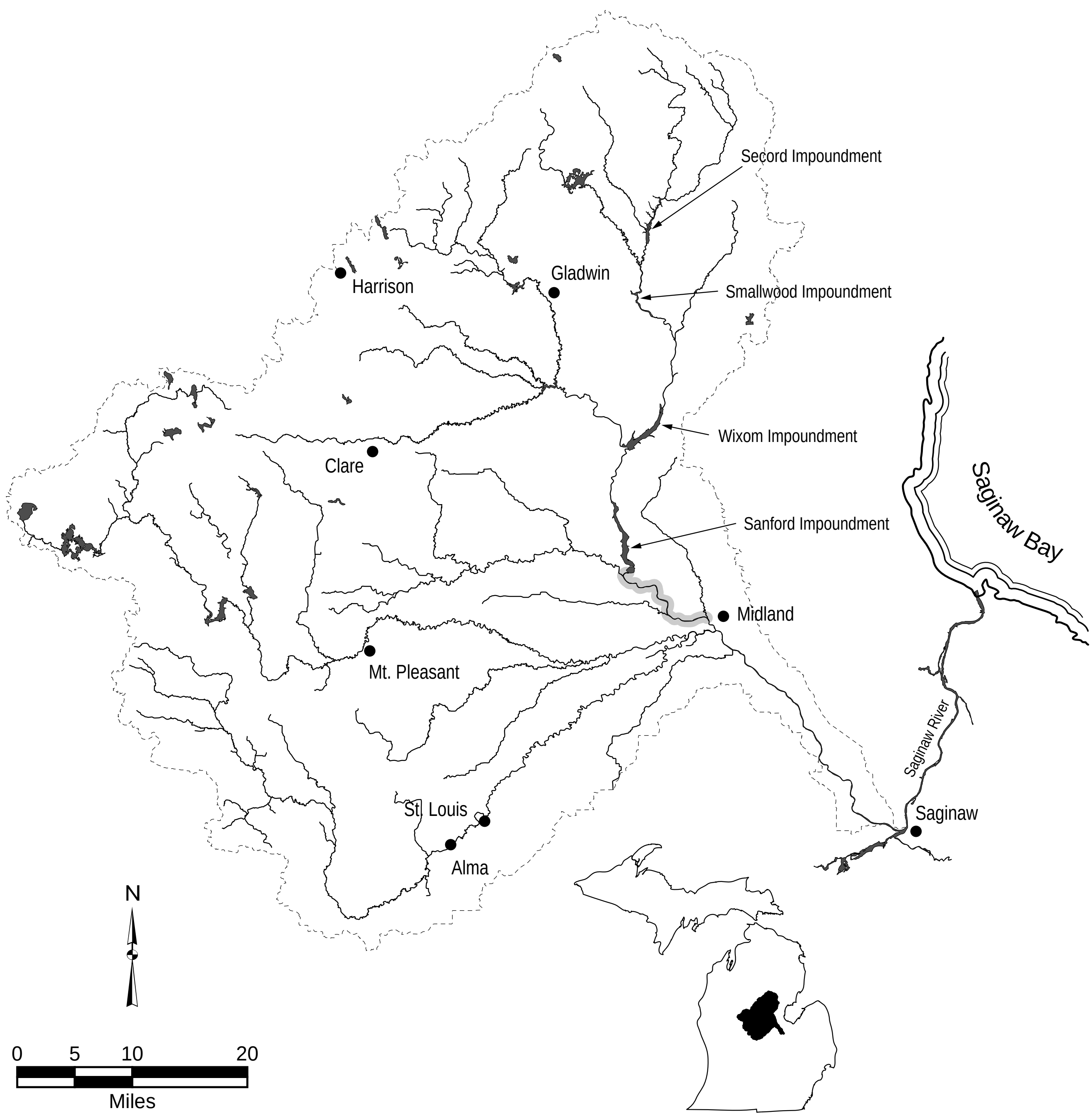


Bigmouth buffalo *Ictiobus cyprinellus*

Habitat:

feeding - deeper pools or oxbows of large streams, shallow and floodplain lakes
- slow, sluggish, or still water
- tolerates turbidity

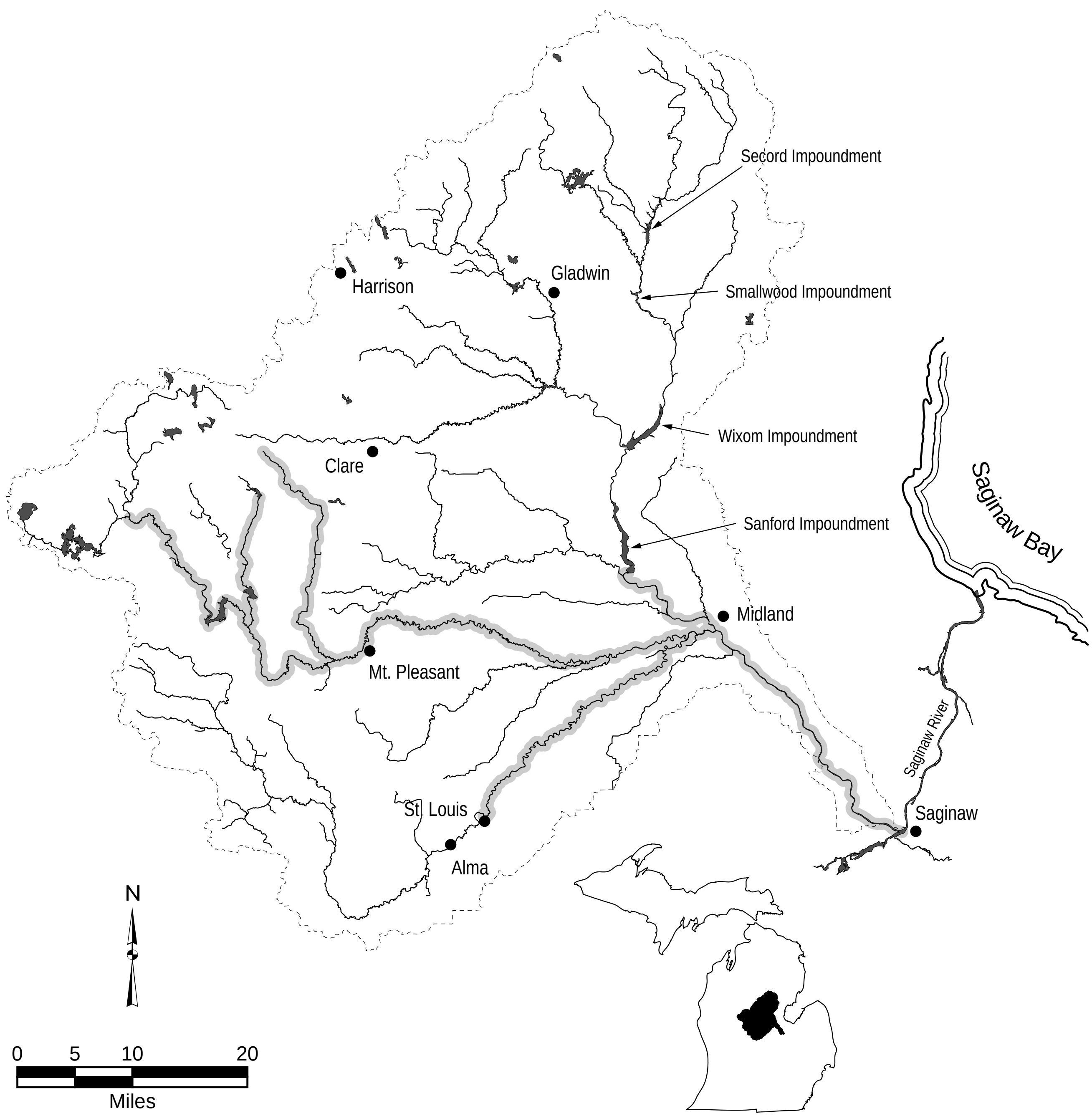
spawning - small tributaries, marshes, or shallow-flooded lake margins
- over sand or gravel with rapid flow; also in places with a lot of aquatic vegetation



Black redhorse *Moxostoma duquesnei*

Habitat:

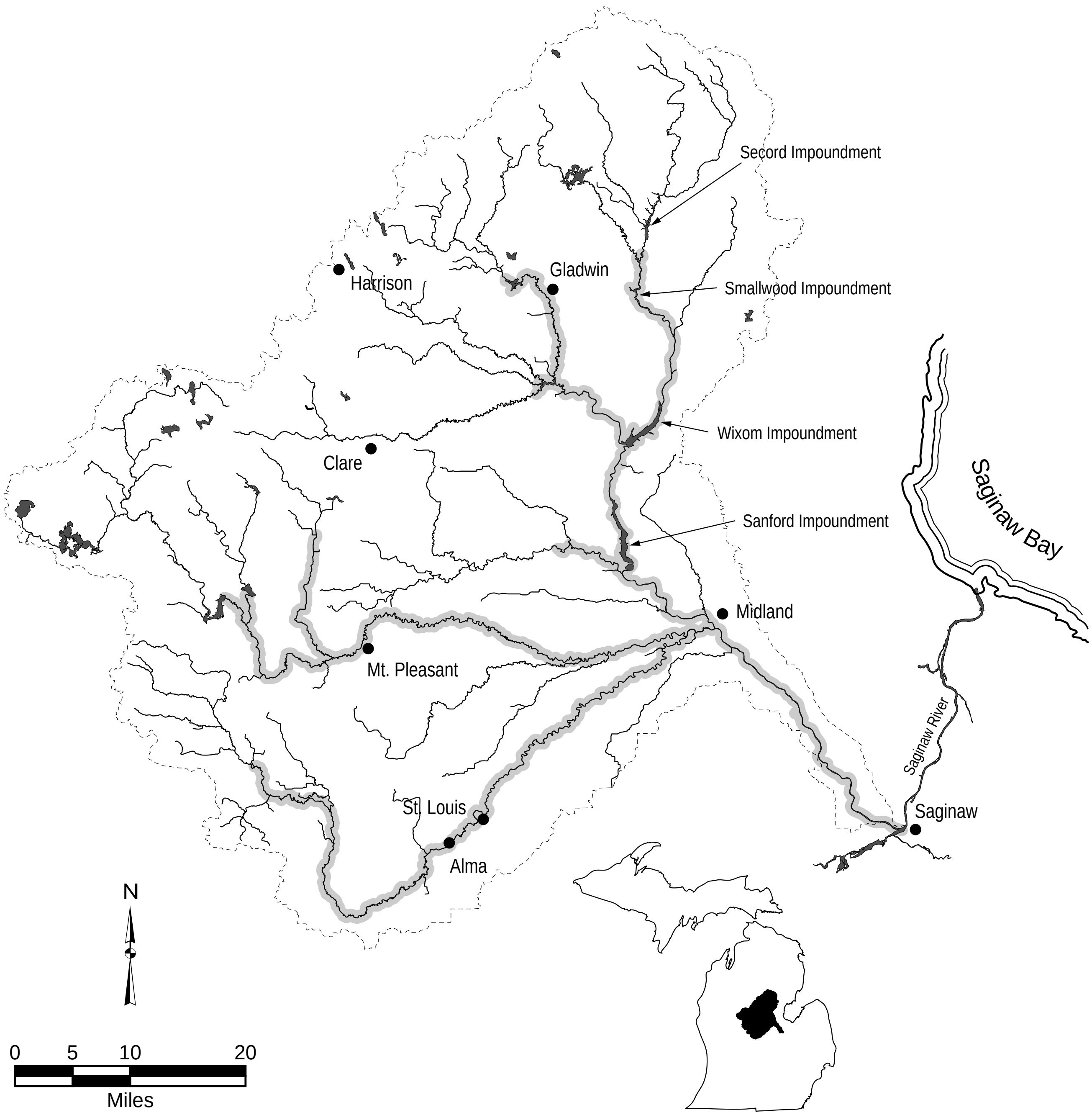
feeding	- gravel substrate
	- clear water, intolerant of siltation, turbidity, and low gradients
	- medium size streams
	- cooler swifter streams and short rocky pools with current
spawning	- gravelly riffles
winter refuge	- deeper holes



Golden redhorse *Moxostoma erythrurum*

Habitat**:**

feeding	-	warm medium gradient streams and rivers
	-	clear riffly streams
	-	medium size streams and rivers
	-	tolerates some turbidity and silt
spawning	-	shallow gravelly riffles
winter refuge	-	larger streams

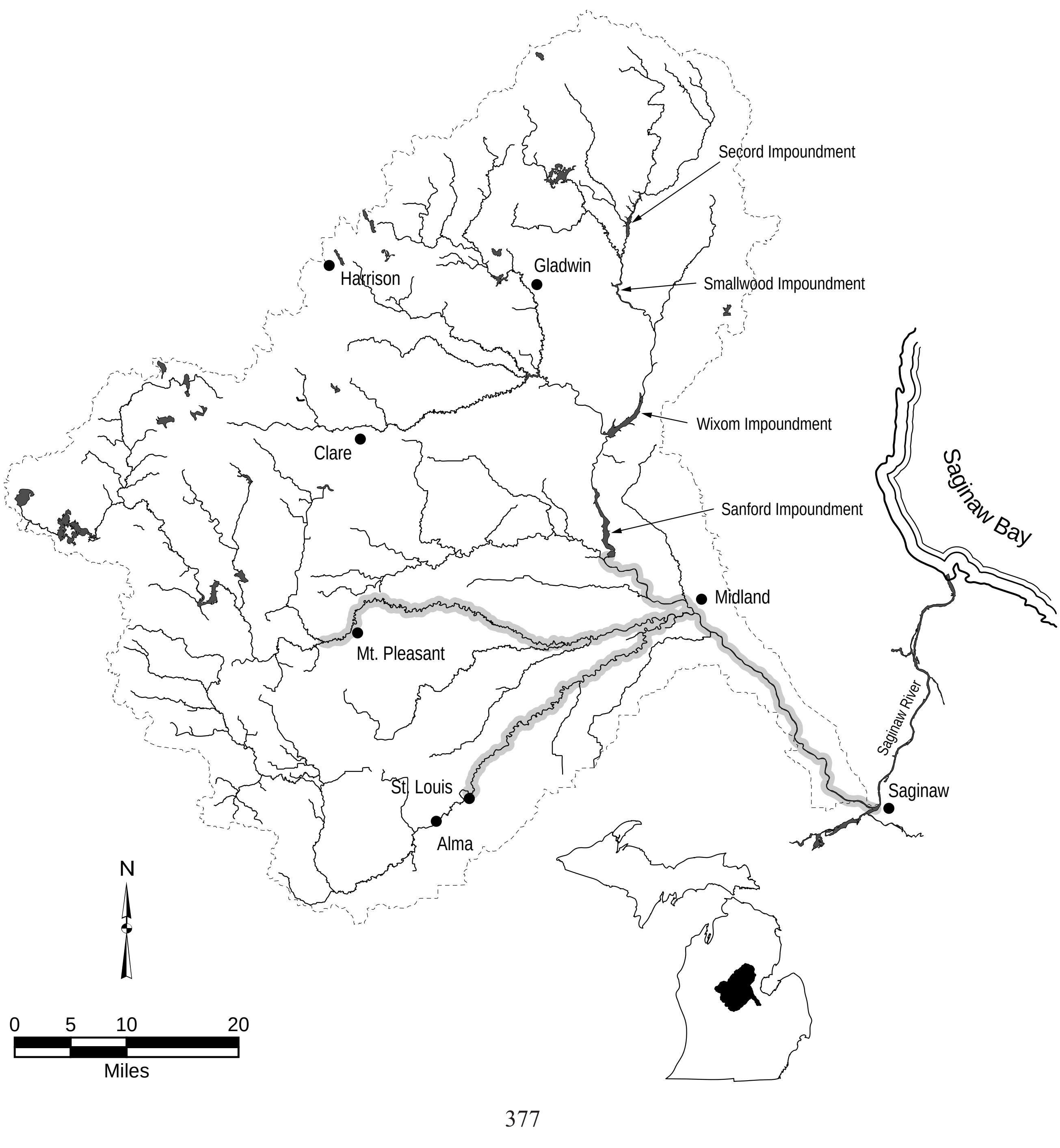


Shorthead redhorse *Moxostoma macrolepidotum*

Habitat**:**

feeding - downstream sections of large rivers, lakes, and impoundments
- rocky substrates
- swift water near riffles
- clear to slightly turbid water

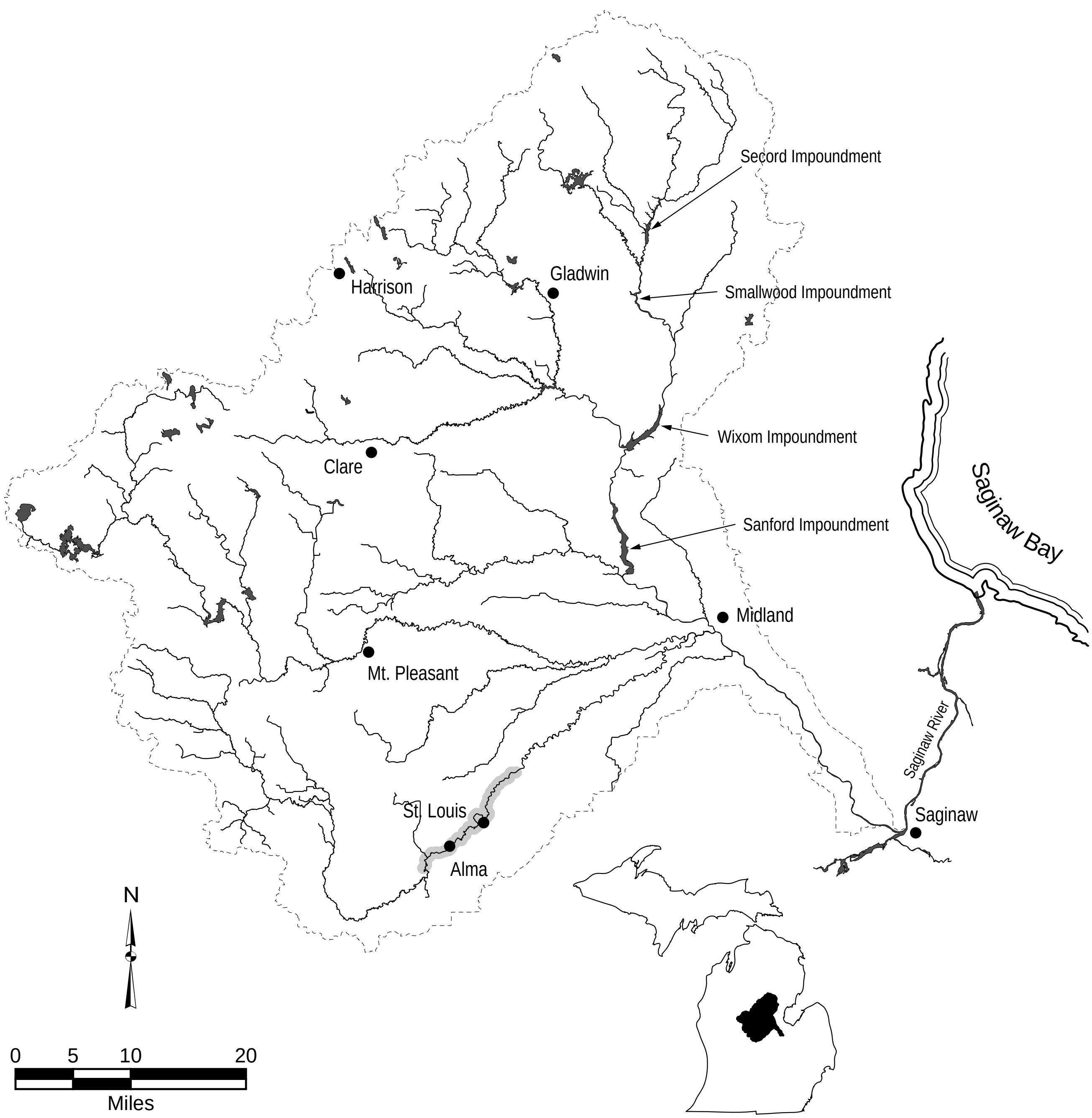
spawning - gravelly riffles in smaller feeder streams



Greater redhorse *Moxostoma valenciennesi*

Habitat**:**

feeding	- large clear streams
	- clean sand, gravel, or boulder substrate
	- intolerant of excessive turbidity and chemical pollutants
spawning	- moderately rapid current

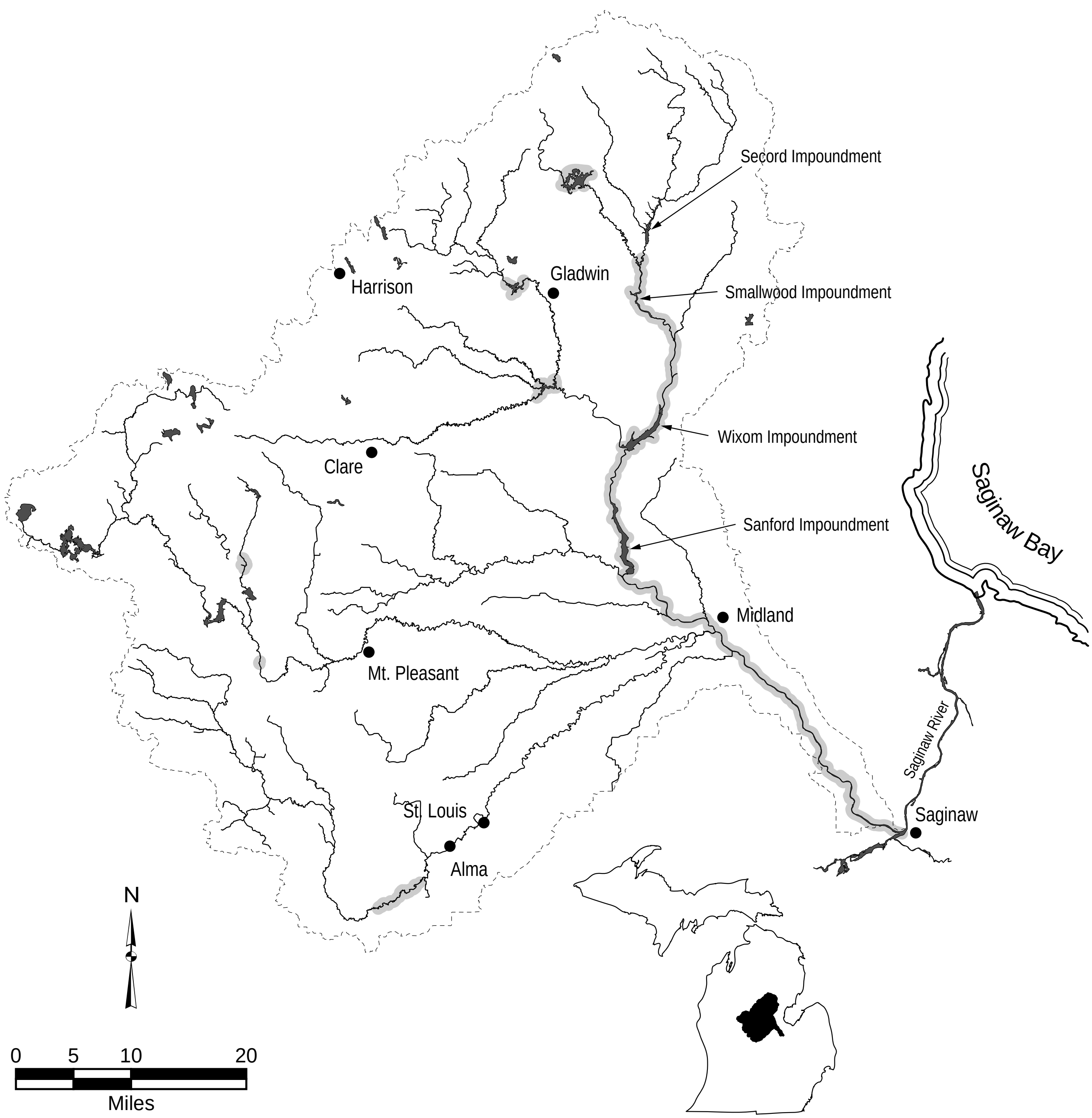


Black bullhead *Ameiurus melas*

Habitat:

feeding - turbid water
- silt bottom
- low gradient small to medium streams, pools, and headwaters of large rivers; also in lakes and impoundments
- can tolerate very warm water and very low dissolved oxygen

spawning - nest in moderate to heavy vegetation or woody debris and under overhanging banks

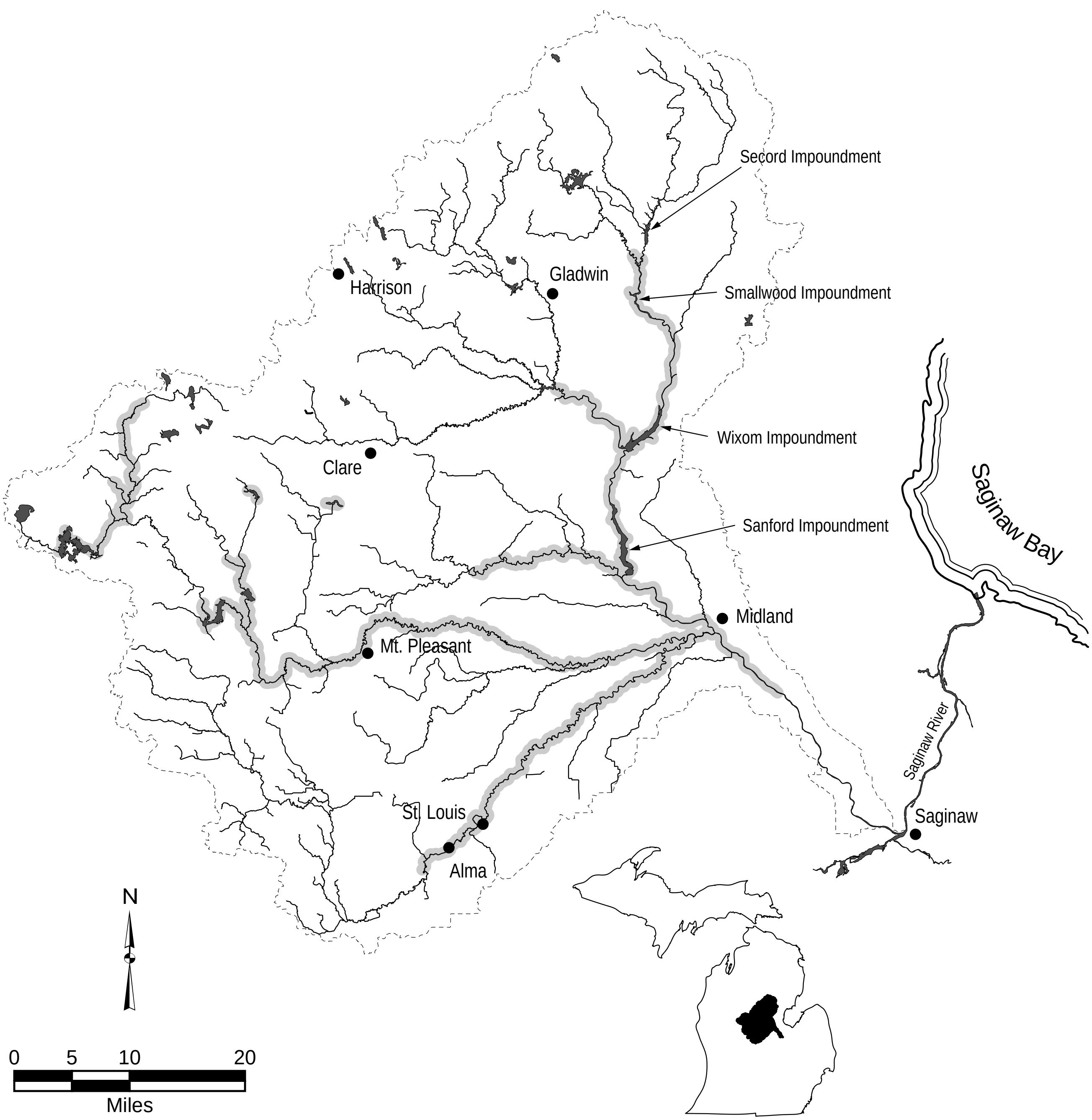


Yellow bullhead *Ameiurus natalis*

Habitat**:**

feeding - clear flowing water
- heavy vegetation
- low gradient streams, lakes, and impoundments
- tolerant of low oxygen

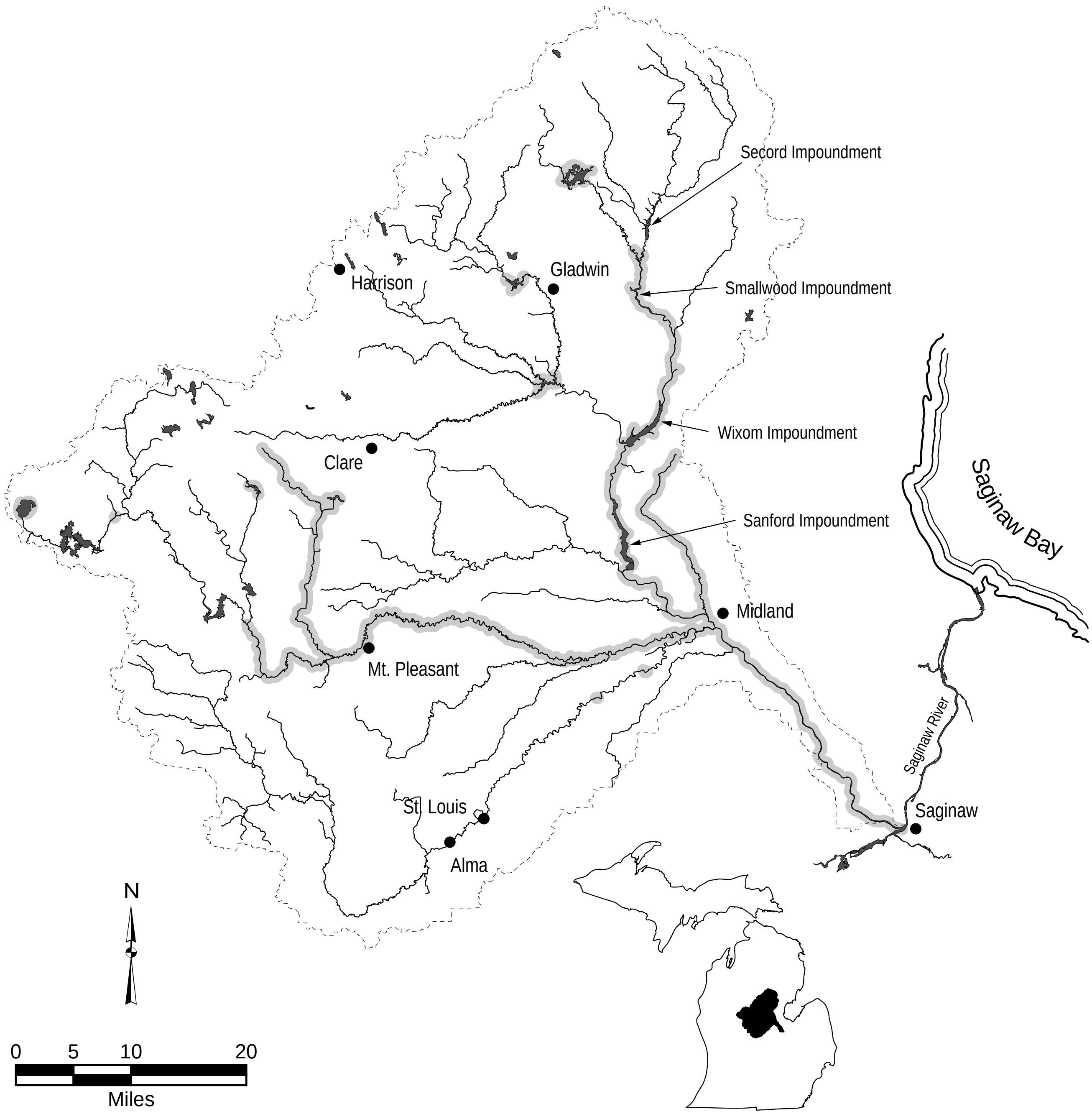
spawning - nest under a stream bank or near stones or stumps



Brown bullhead *Ameiurus nebulosus*

Habitat**:**

feeding	- larger streams and rivers, lakes and impoundments
	- clear cool water with little clayey silt
	- moderate amounts of aquatic vegetation
	- sand, gravel, or muck substrate
	- not tolerant of turbid water
	- tolerant of warm water and low oxygen
spawning	- nest in mud or sand substrate among rooted aquatic vegetation usually near a stump, tree, or rock
winter refuge	- in muddy bottoms

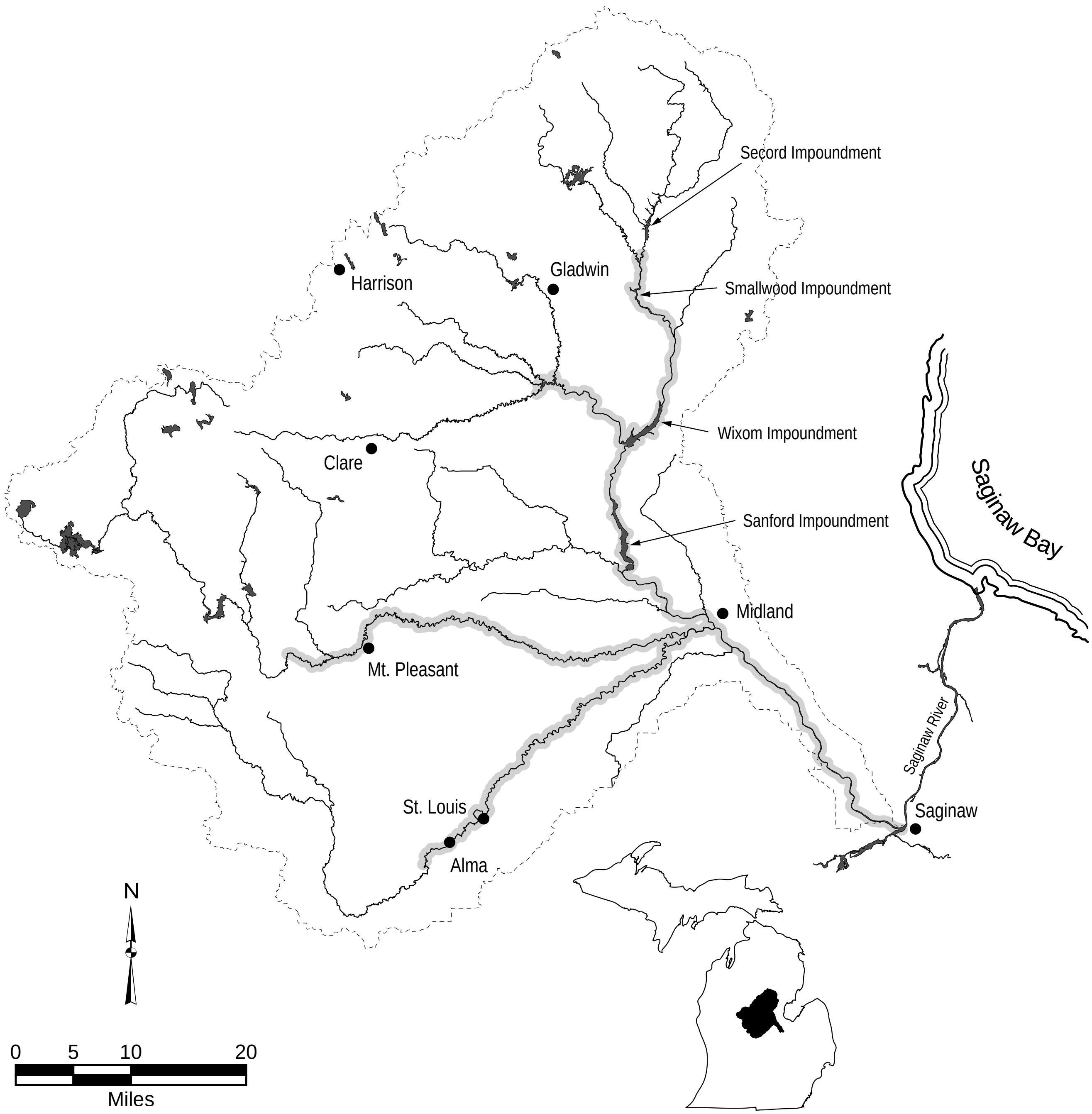


Channel catfish *Ictalurus punctatus*

Habitat**:**

feeding - moderately-clear, deeper waters of rivers, lakes, and impoundments
- sand, gravel, or rubble substrate
- low to moderate gradient

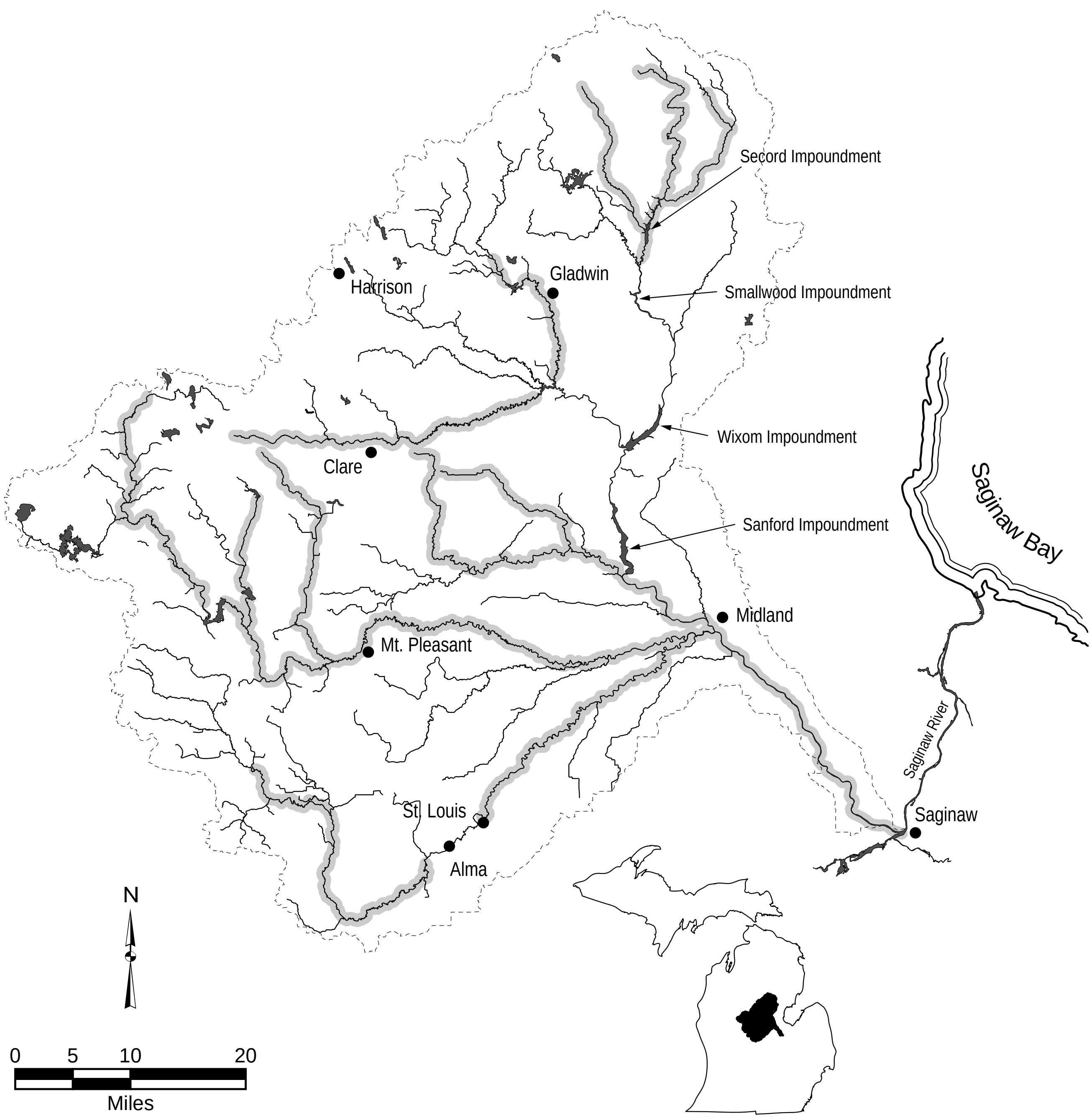
spawning - secluded semi-dark areas such as holes, under banks, log jams, or rocks



Stonecat *Noturus flavus*

Habitat**:**

feeding	-	consistent low to moderate gradient flowing water
	-	rocky riffles of larger streams and smaller rivers
	-	not tolerant of silt
	-	tolerant of low oxygen and pollution
spawning	-	eggs deposited beneath stones
	-	shallow rocky areas of streams or lakes

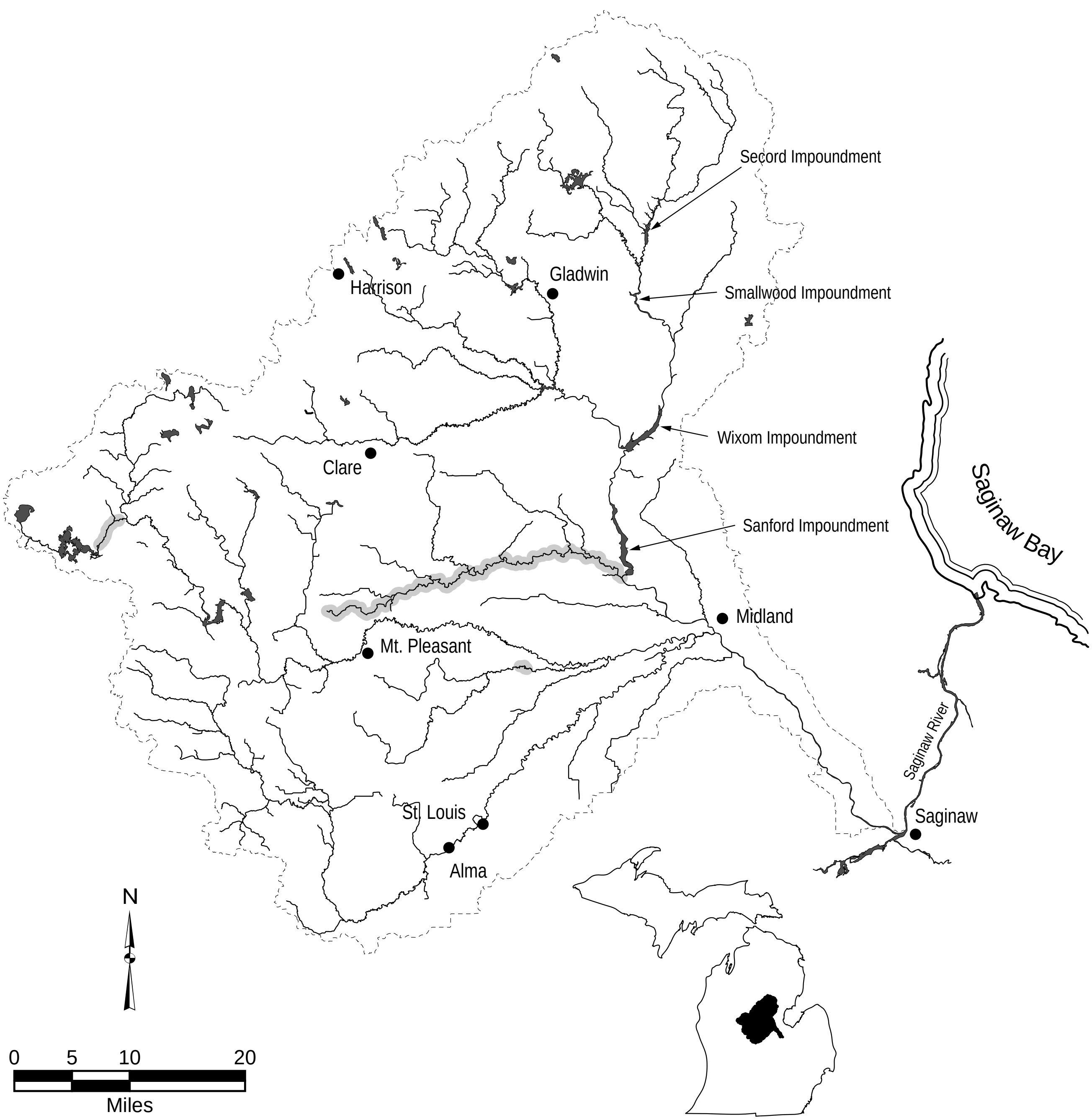


Tadpole madtom *Noturus gyrinus*

Habitat**:**

feeding - vegetative cover in low-moderate current waters
- muddy substrate with extensive vegetation
- clear waters of streams, rivers, and lakes

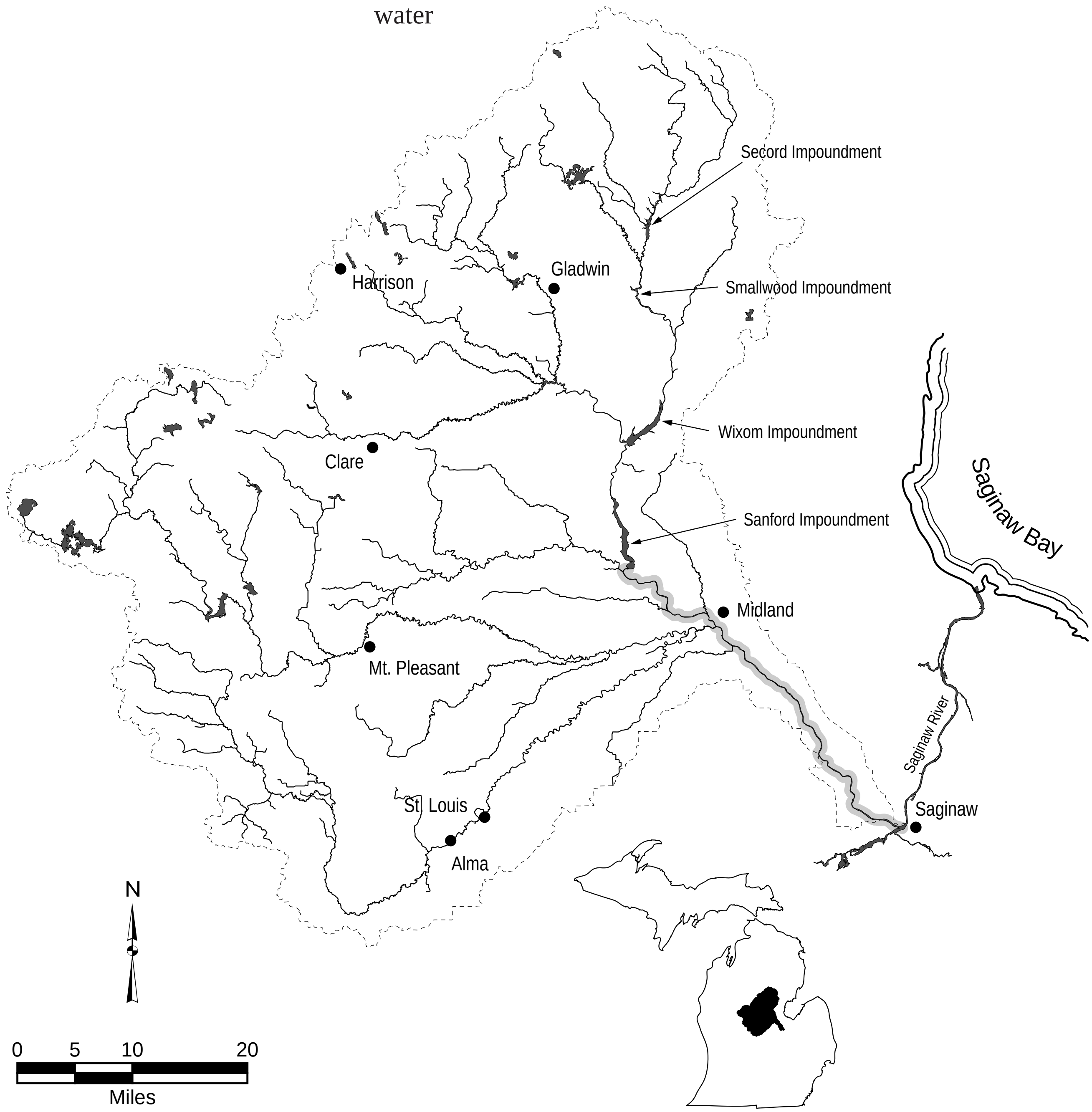
spawning - mostly in rivers, sometimes shallows of lakes
- nests in dark cavities (ex: beneath boards, logs, crayfish burrows)



Flathead catfish *Pylodictis olivaris*

Habitat:

feeding	- (young) shallow riffles in fast current
	- deep pools with a lot of woody cover
	- deep riffles
	- low gradient and current
	- prefer silt-free substrate
	- sometimes feed on shallow riffles
spawning	- secluded shelters or dark places
	- gravel or silt-free substrate
winter refuge	- muddy holes in deep water

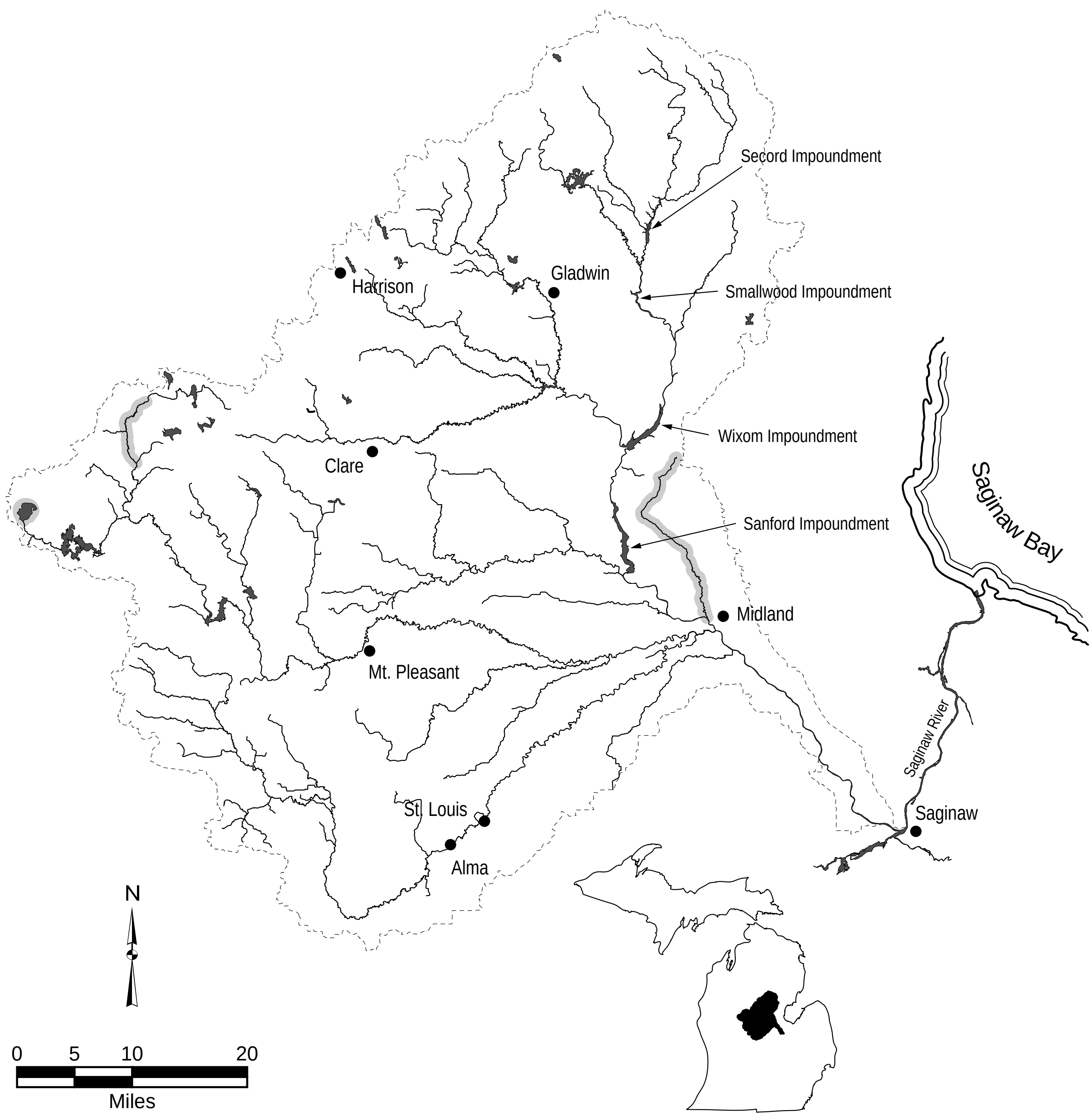


Grass pickerel *Esox americanus vermiculatus*

Habitat**:**

feeding - juveniles: along shore
- adults: in deeper portions of streams, rivers, lakes, and impoundments
- clear water, little current, dense vegetation
- tolerates low oxygen concentrations

spawning - broadcast spawner over submerged vegetation

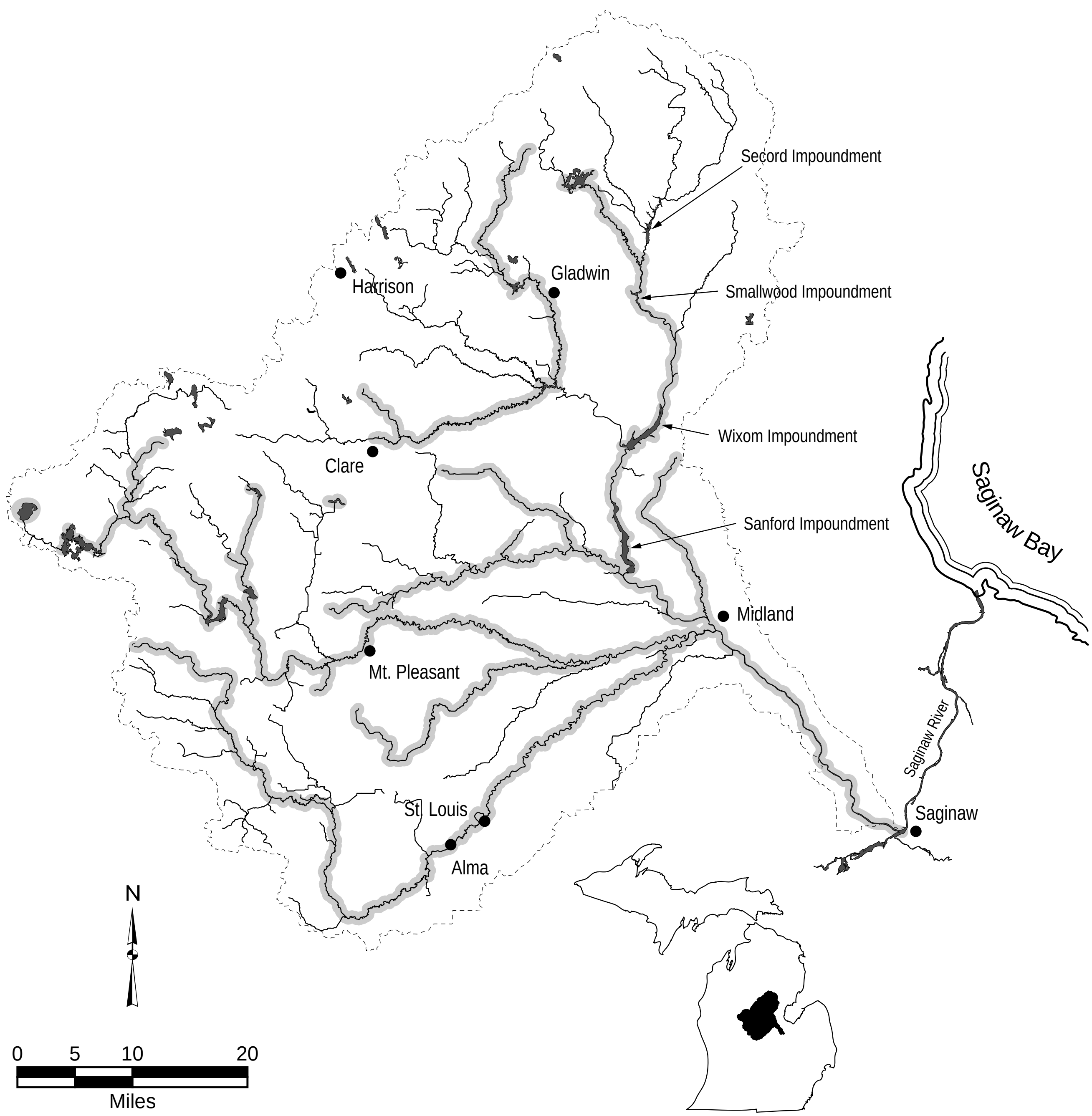


Northern pike *Esox lucius*

Habitat**:**

feeding - cool to moderately warm streams, rivers, lakes, and impoundments
- vegetation in slow to moderate current

spawning - submerged vegetation with slow current in shallow water

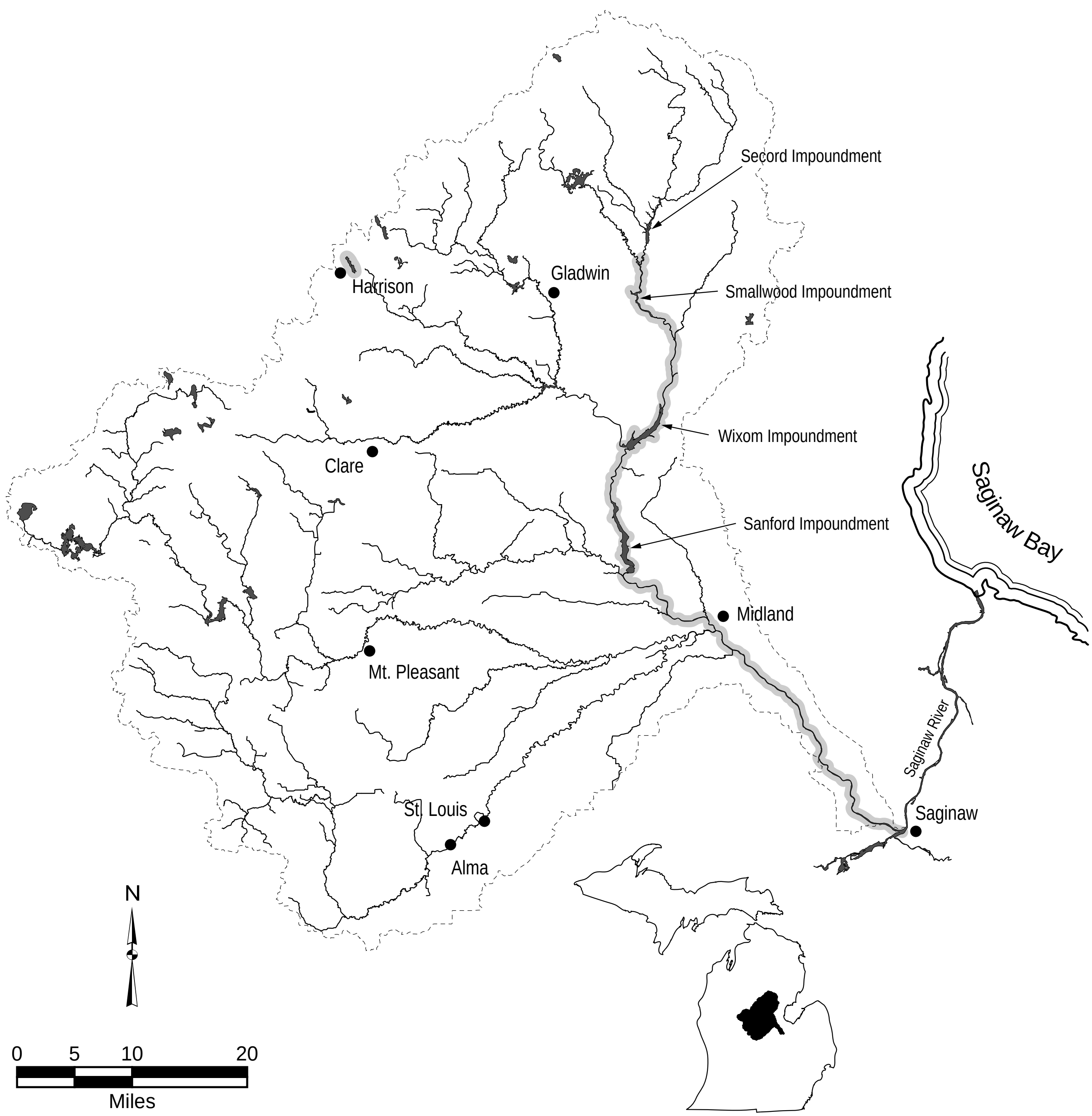


Muskellunge *Esox masquinongy*

Habitat:

feeding - warm, heavily vegetated lakes, stumpy weedy bays, and slow heavily vegetated medium to large rivers
- shallow cool water
- tolerant of low oxygen

spawning - clear shallow waters (15-20”) in heavily vegetated areas

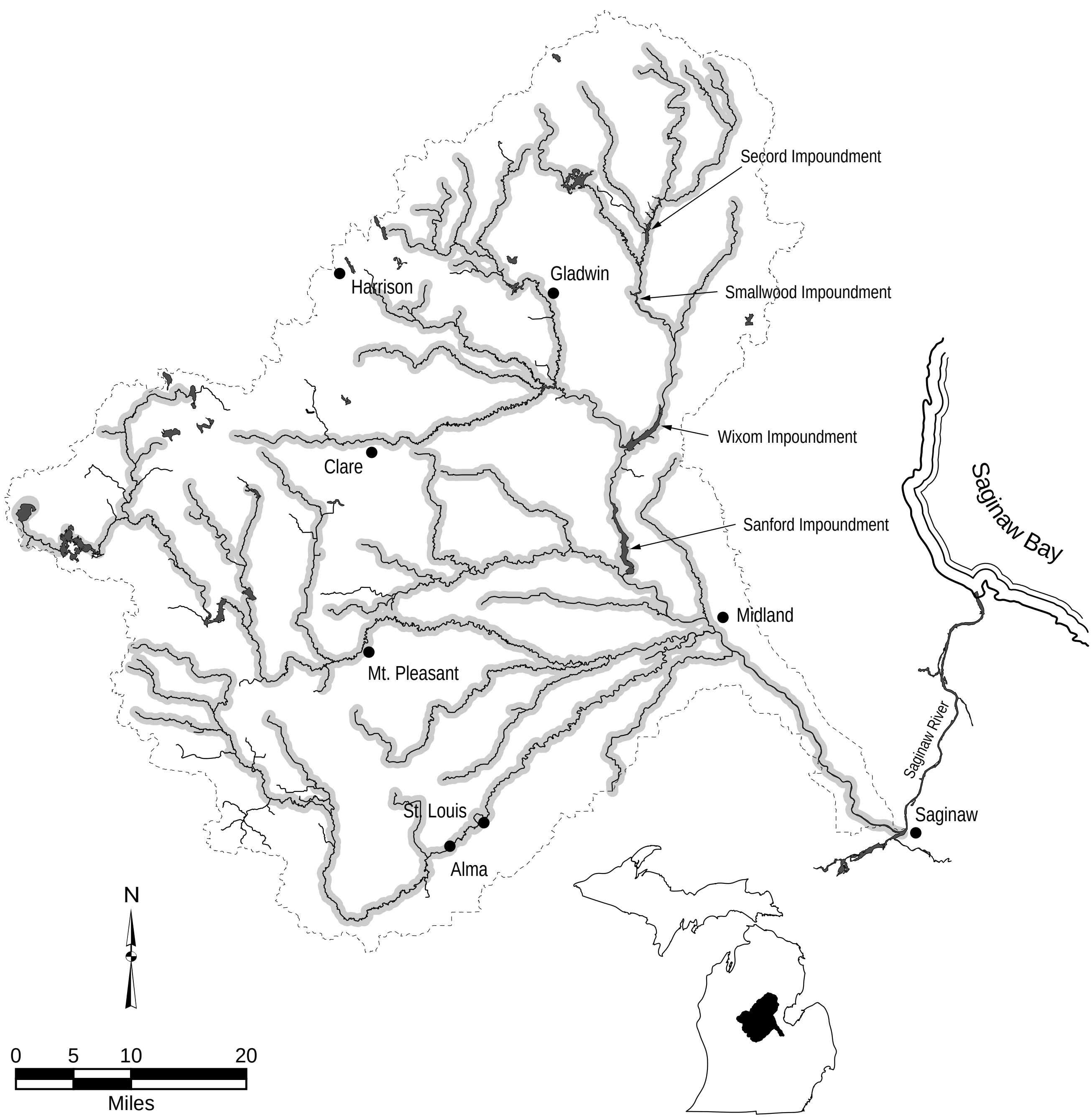


Central mudminnow *Umbra limi*

Habitat:

feeding - undisturbed clear, low-gradient streams or rivers and lakes and impoundments
- organic debris, muck, or peat substrates
- aquatic vegetation

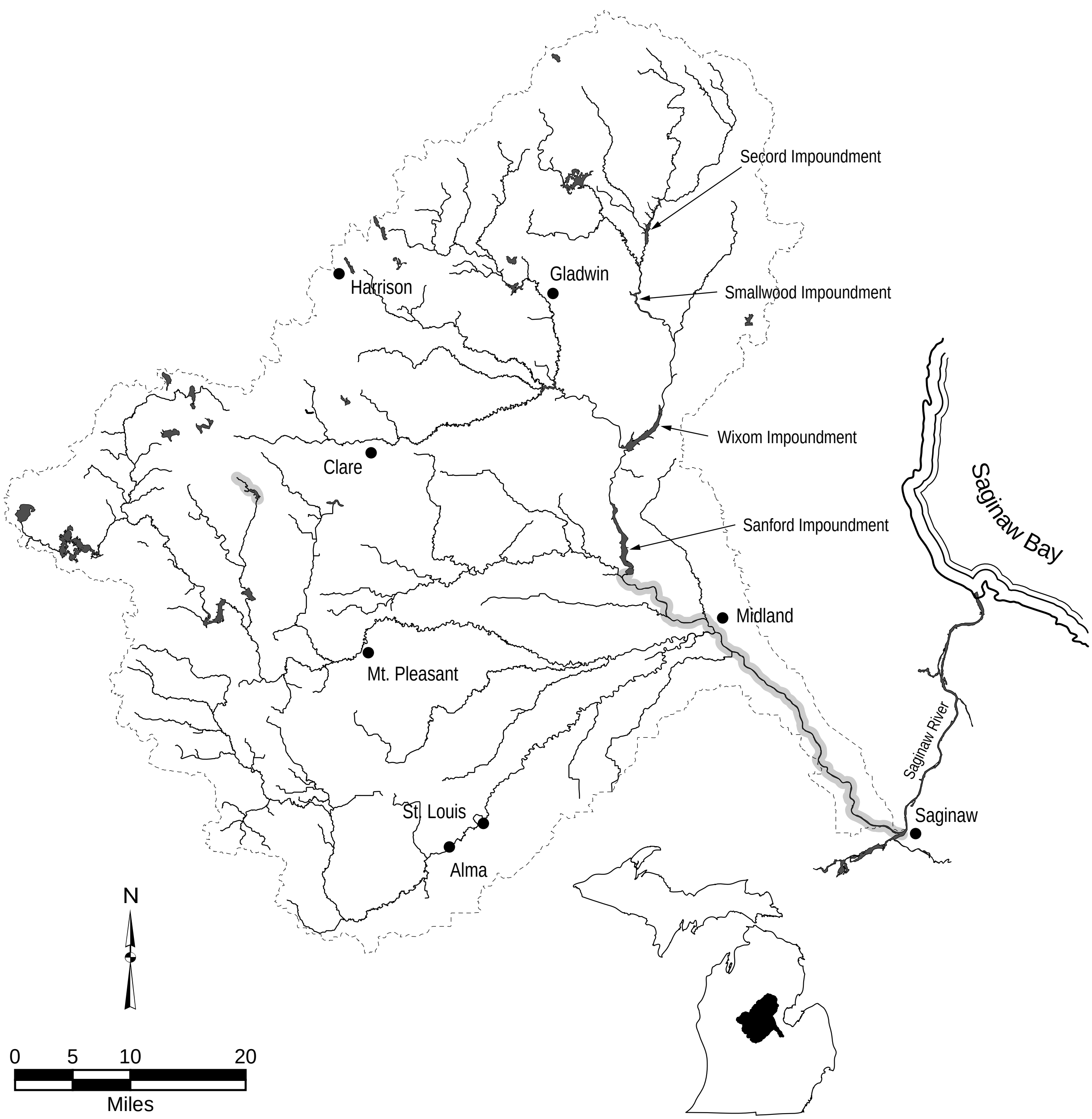
spawning - floodplain areas, on vegetation



Rainbow smelt *Osmerus mordax*

Habitat:

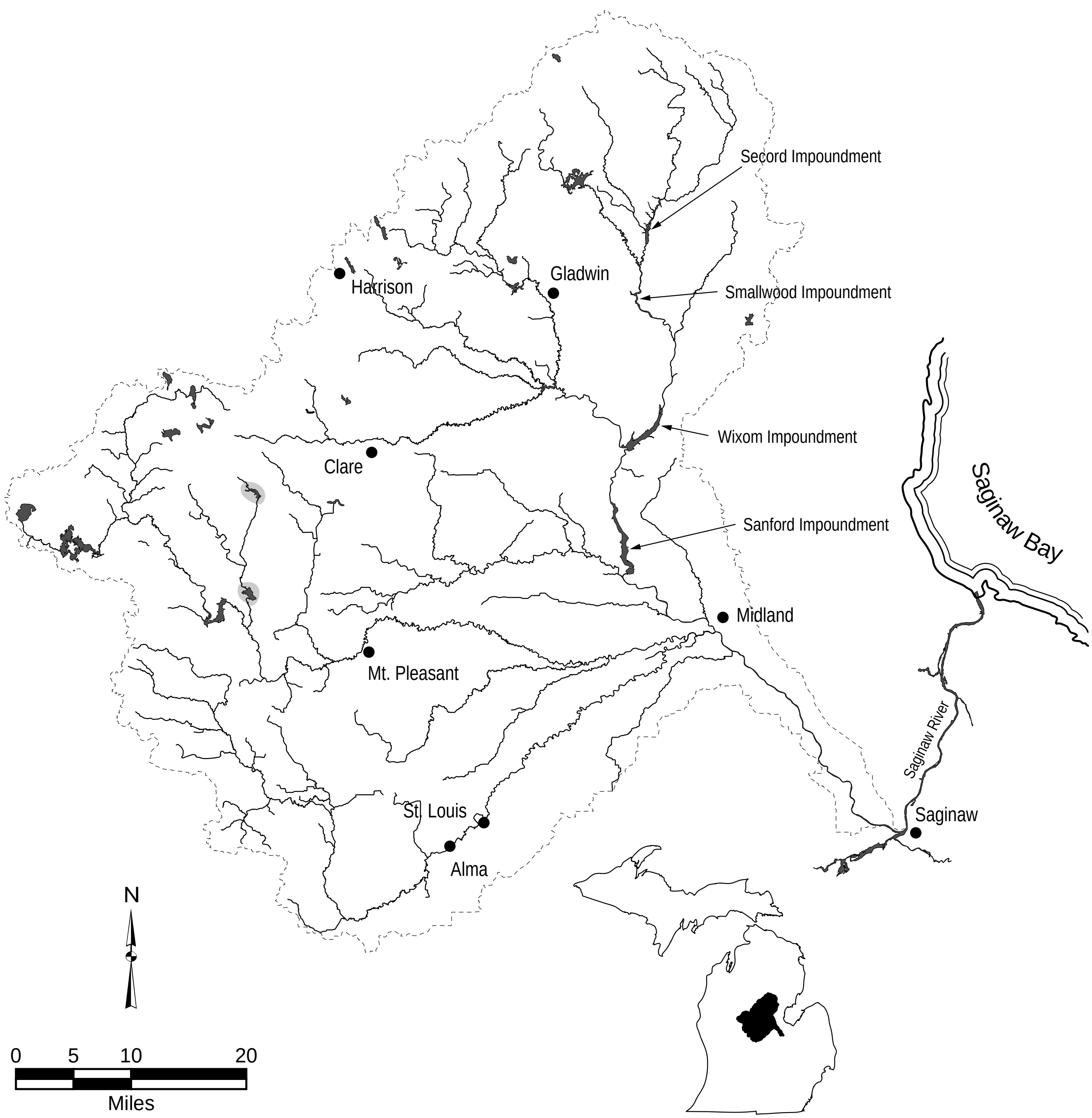
feeding	-	young: close inshore lake habitat along sand and gravel beaches
	-	cold water
spawning	-	clear high-gradient streams or wave swept shoreline
	-	riffles with coarse sand or gravel substrate
winter refuge	-	midwaters of lakes or inshore coastal waters



Cisco *Coregonus artedi* - **threatened**

Habitat:

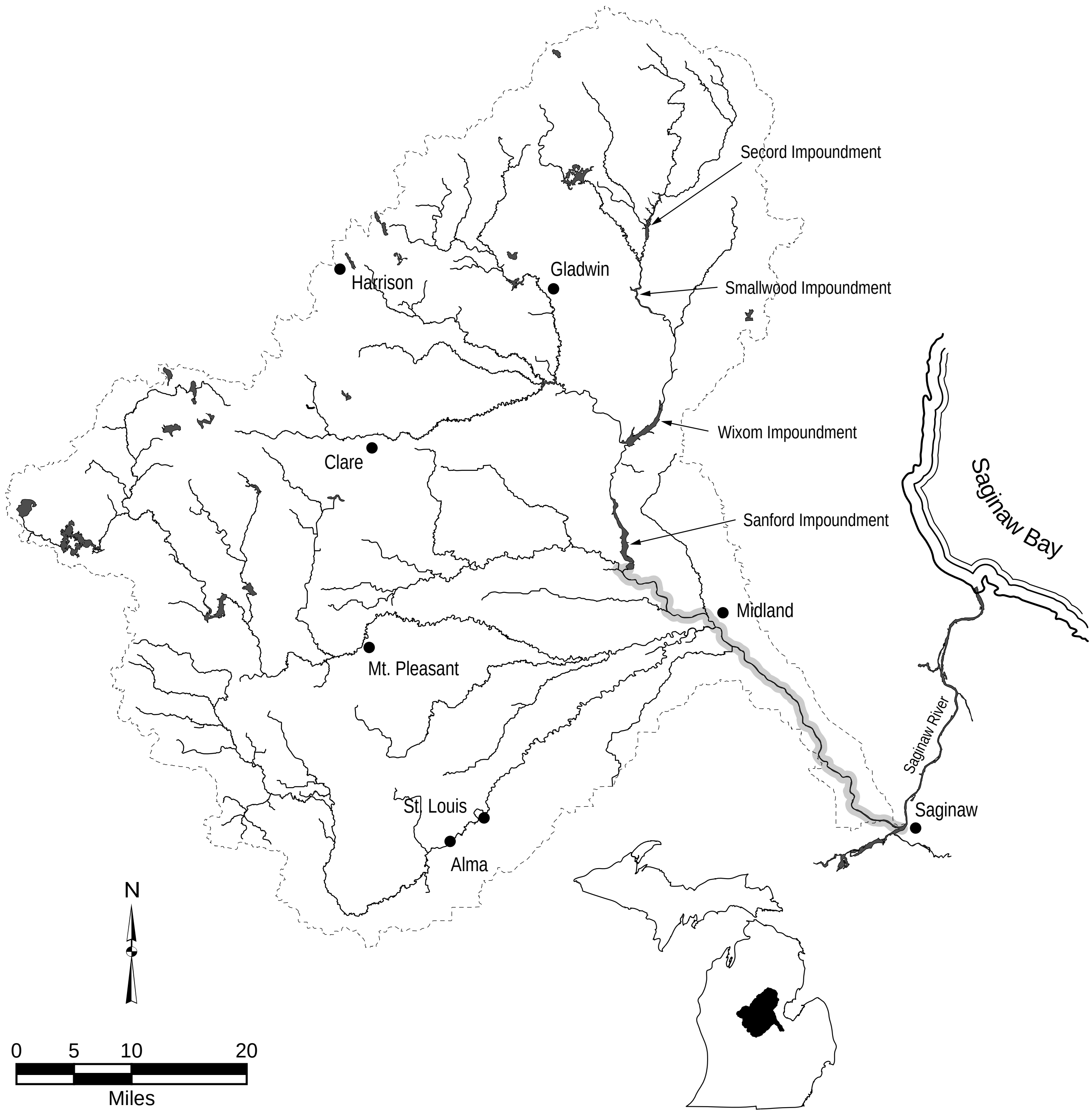
feeding - deep cool lakes, preferably oligotrophic
spawning - usually in lakes
- 3 to 6 feet of water with no vegetation
- often over gravel or stony substrate



Coho salmon *Oncorhynchus kisutch*

Habitat**:**

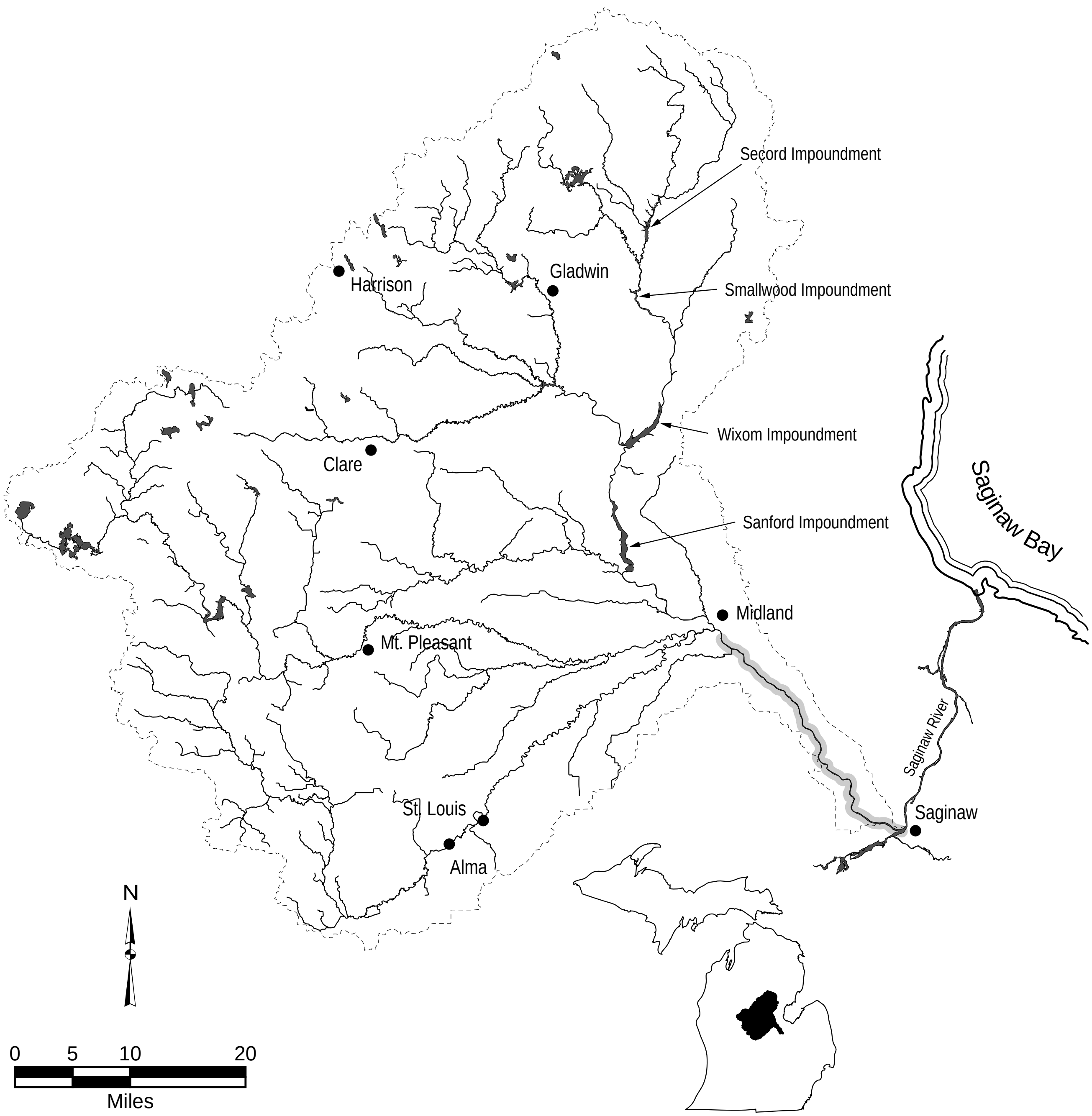
feeding	-	adults: Lake Huron
	-	young: shallow gravel substrate in cold streams, later into pools
spawning	-	cold streams and rivers
	-	swifter water of shallow gravelly substrate



Lake whitefish *Coregonus clupeaformis*

Habitat:

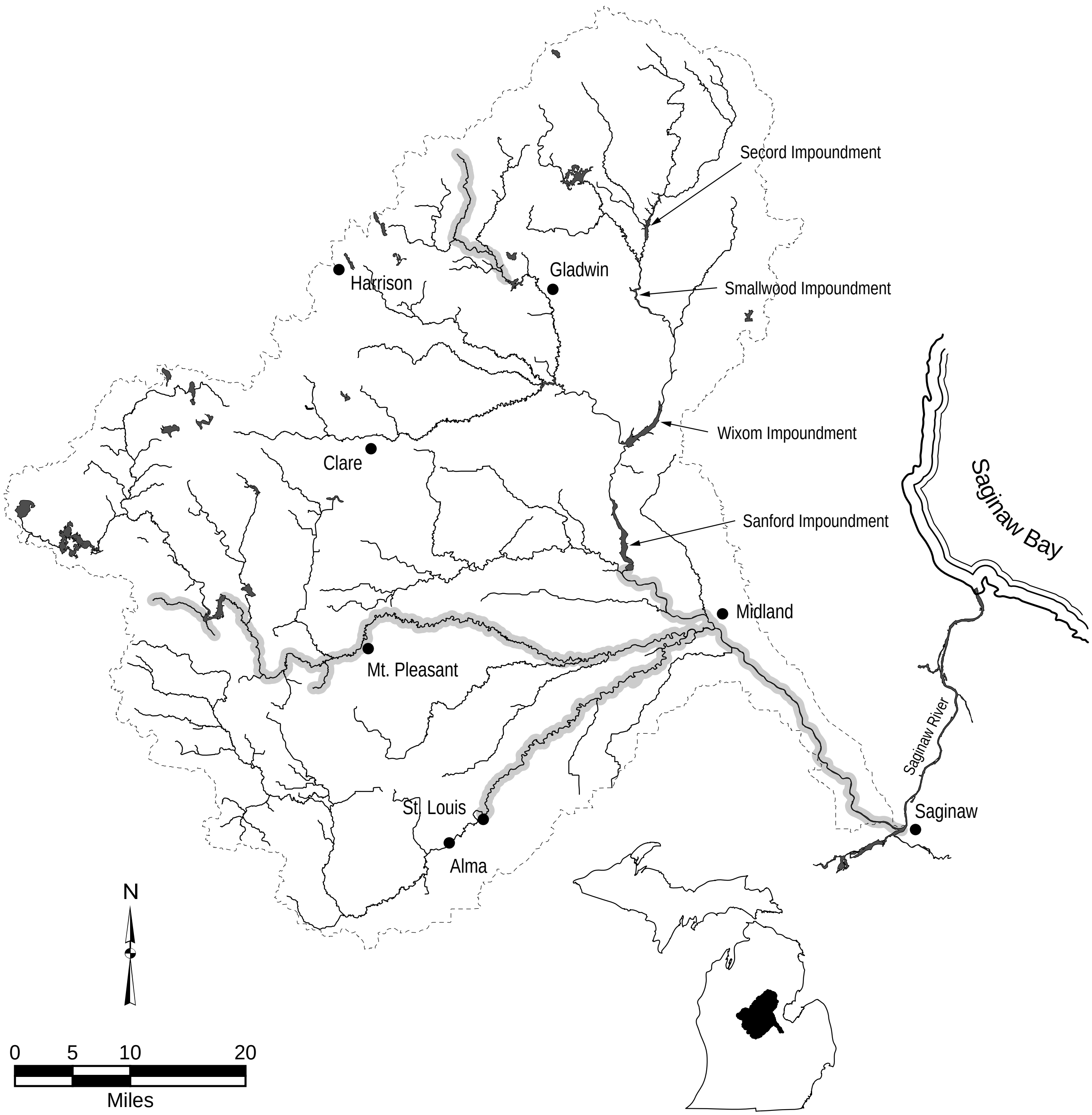
feeding	-	shallow water (for coregonids; 55-105 ft.)
spawning	-	cold shallow water (<25 ft.)
	-	hard, stony, or sand substrate



Rainbow trout *Oncorhynchus mykiss*

Habitat**:**

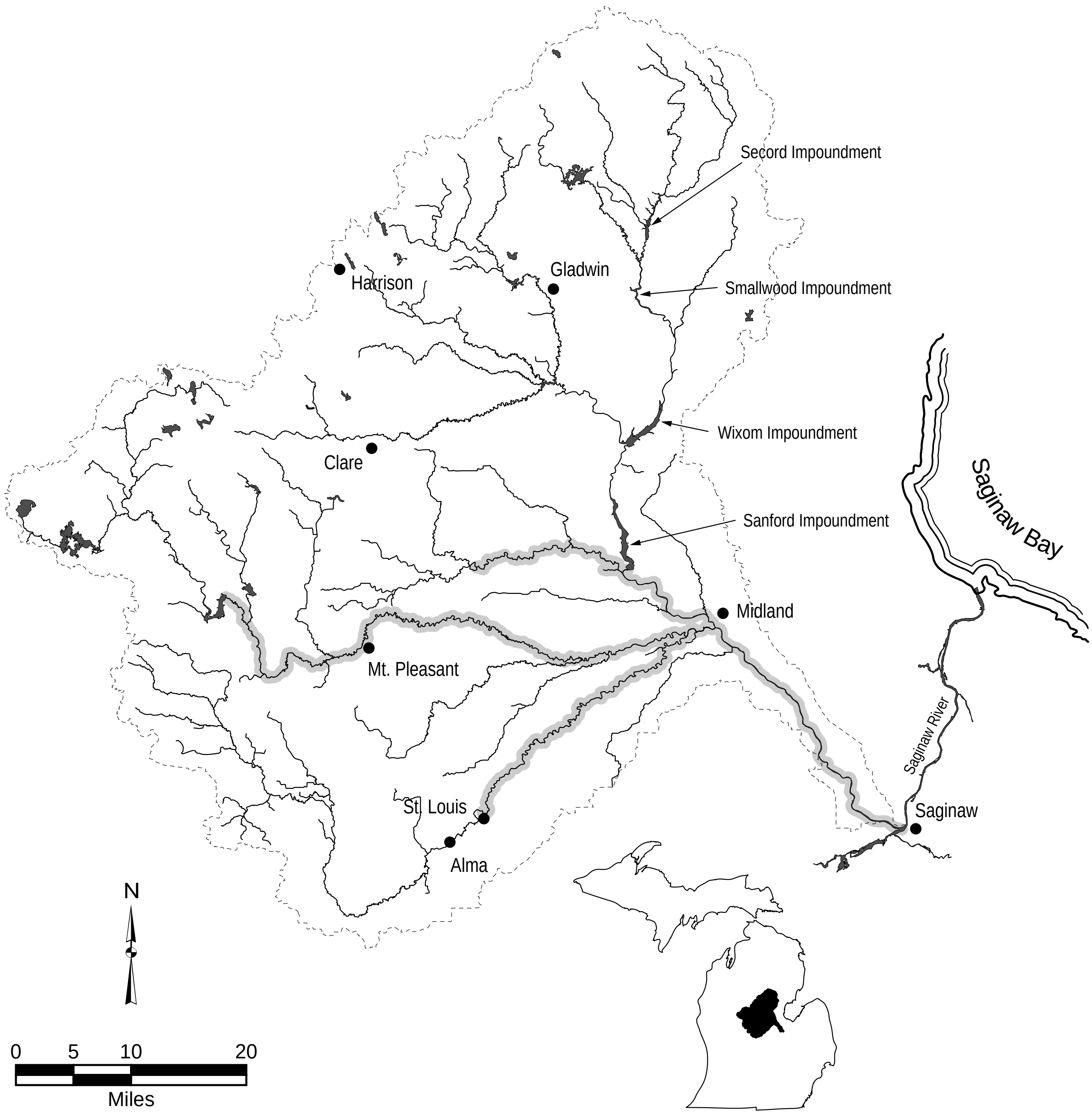
feeding	- cold clear water of rivers and Lake Huron
	- moderate current
spawning	- gravelly riffles above a pool
	- smaller tributaries



Chinook salmon *Oncorhynchus tshawytscha*

Habitat**:**

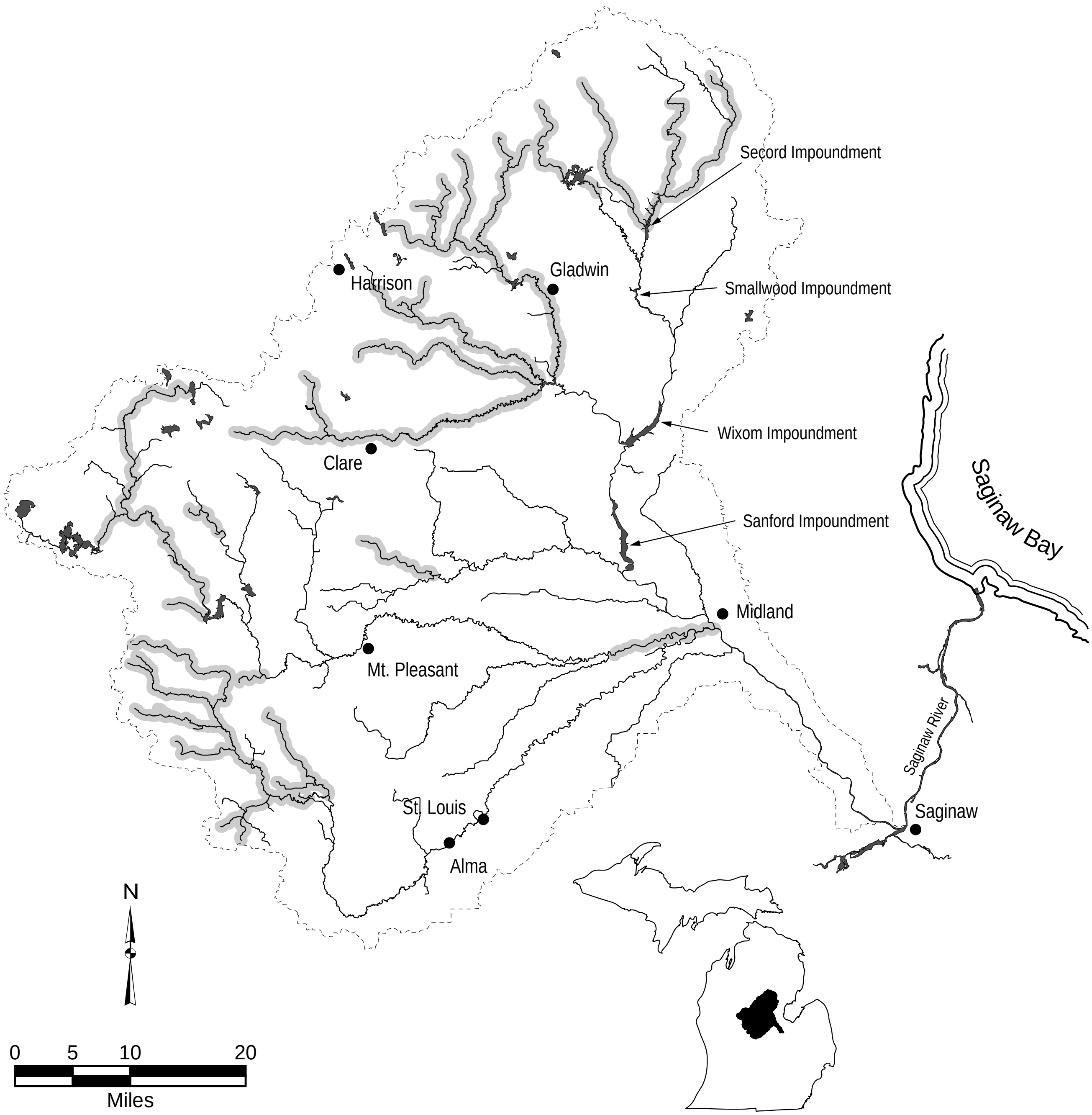
feeding	-	adults: Lake Huron
	-	young: shallow gravel substrate in cool streams, later into pools
spawning	-	gravelly substrate in cool streams



Brown trout *Salmo trutta*

Habitat**:**

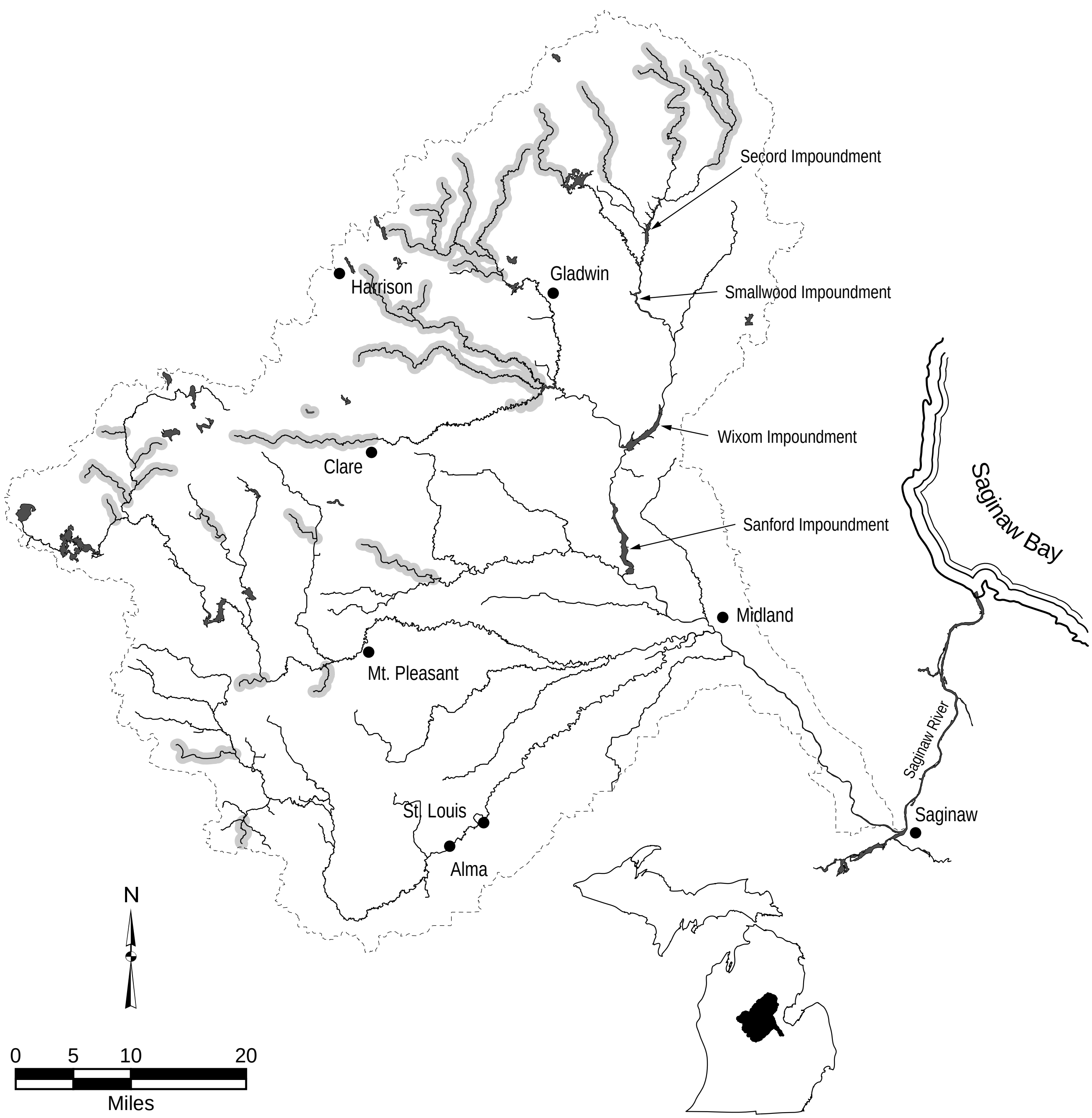
feeding	-	cold, clear streams, rivers, and lakes (not >70°F)
	-	medium to swift current in streams
	-	does not tolerate silt well
	-	prefers few individuals and species around
	-	abundance of aquatic and land insects
spawning	-	gravelly riffles; shallow headwater areas



Brook trout *Salvelinus fontinalis*

Habitat**:**

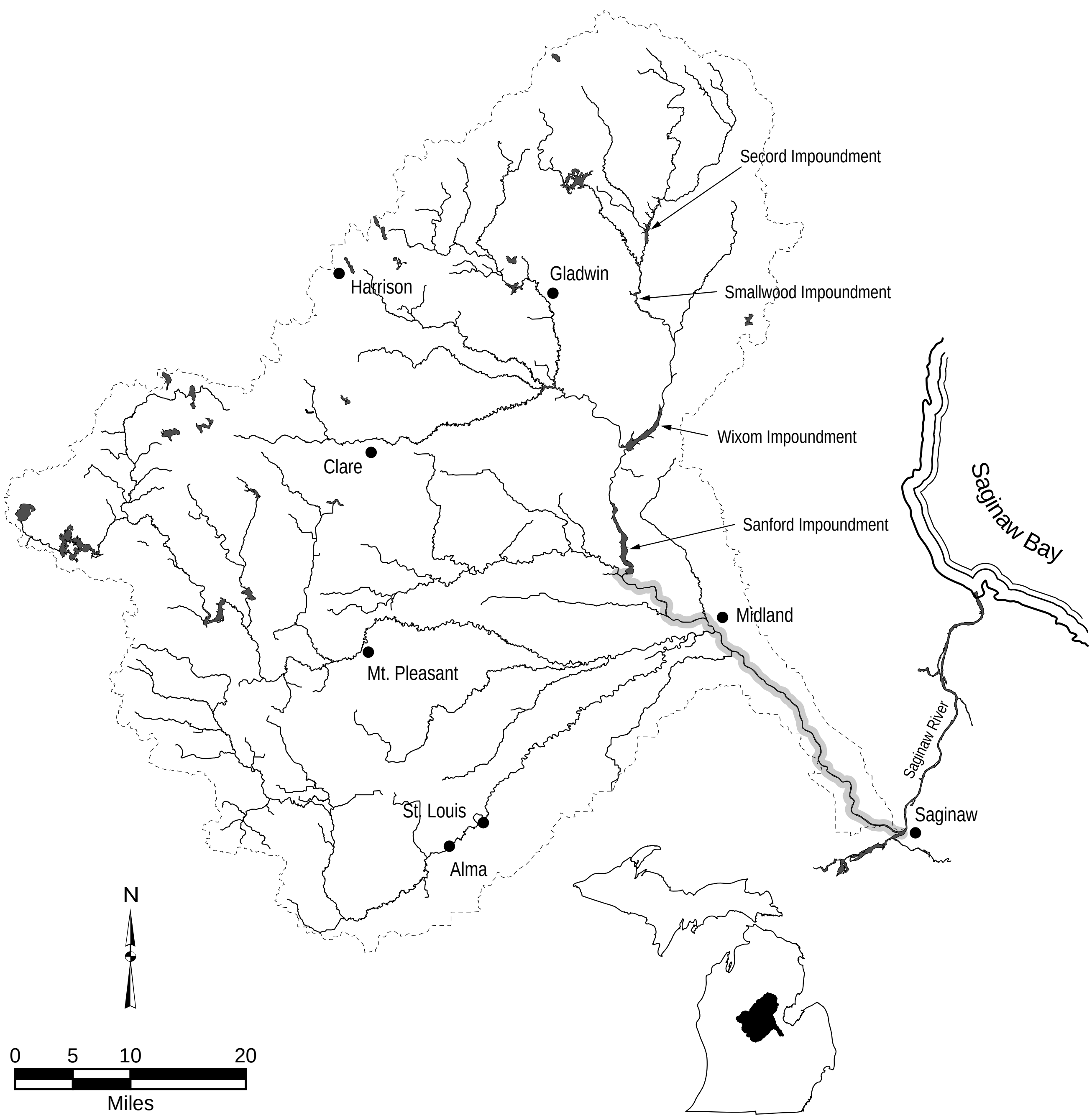
feeding	-	cold, clear streams, rivers, and lakes (not >65°F)
	-	low current
	-	well oxygenated water
spawning	-	gravelly riffles; shallow or headwater streams



Lake trout *Salvelinus namaycush*

Habitat:

feeding -	cold lakes and rivers
spawning -	large boulder or rubble substrate
-	shallow water of lakes and rivers

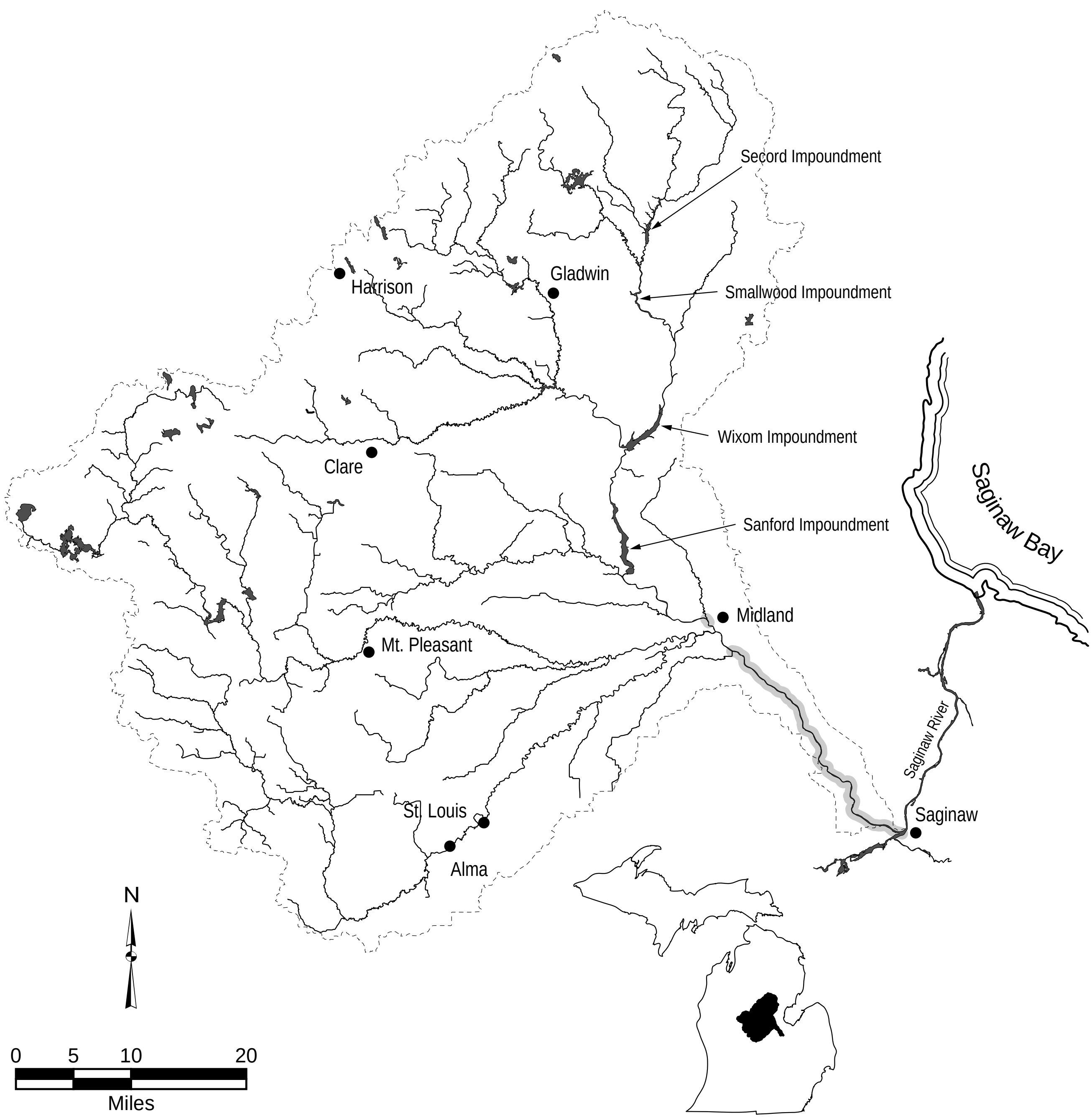


Trout-perch *Percopsis omiscomaycus*

Habitat**:**

feeding
- clean sand or fine gravel substrate
- long deep pools in low gradient streams and Lake Huron
- highly intolerant of clayey silts
- avoids rooted aquatic vegetation

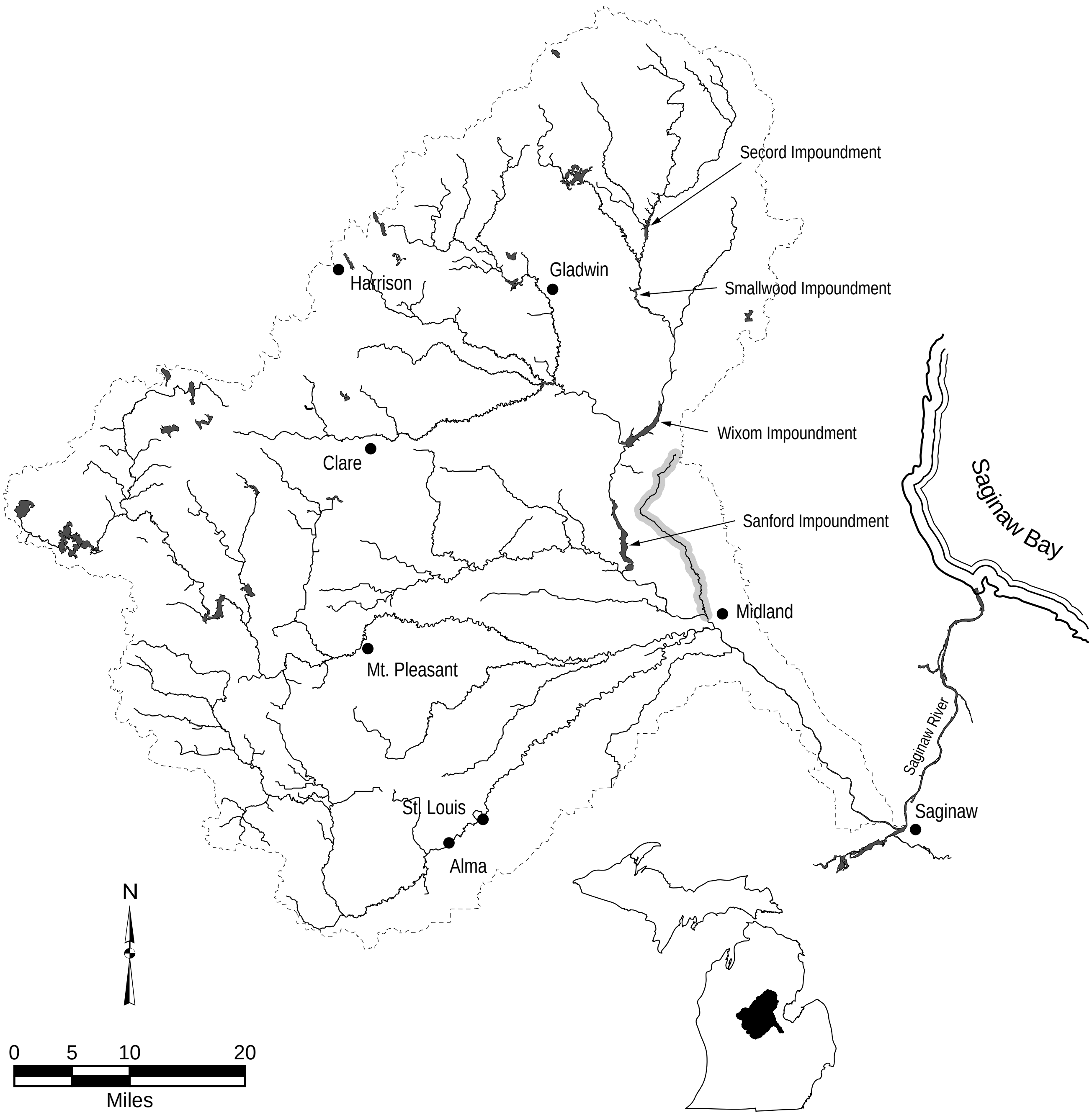
spawning
- over rocks in shallows
- over sand and gravel substrates in Lake Huron



Pirate perch *Aphredoderus sayanus*

Habitat**:**

feeding - oxbows, overflow ponds, marshes, estuaries, pools
- medium to large rivers
- low gradient, less than 3ft/mi
- sand or muck substrates covered with organic debris
- pools bordered by emergent aquatic vegetation
- clear, warm, quiet water

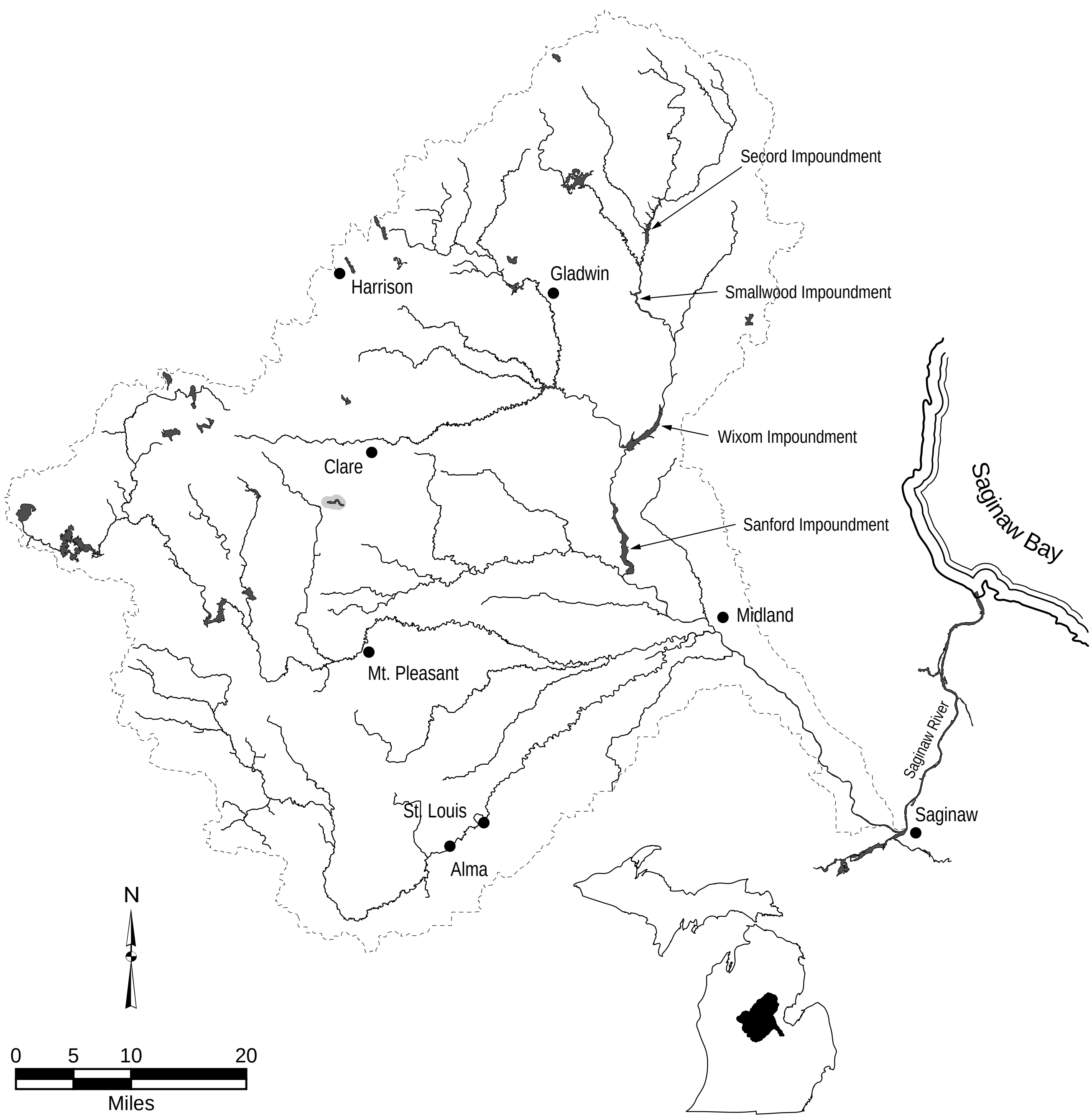


Western banded killifish *Fundulus diaphanus menona*

Habitat**:**

feeding - quiet backwaters at the mouths of streams and lakes
- substrate of sand, gravel, and a few boulders
- also found over detritus substrate where patches of submerged aquatic vegetation are present

spawning - quiet areas of weedy pools

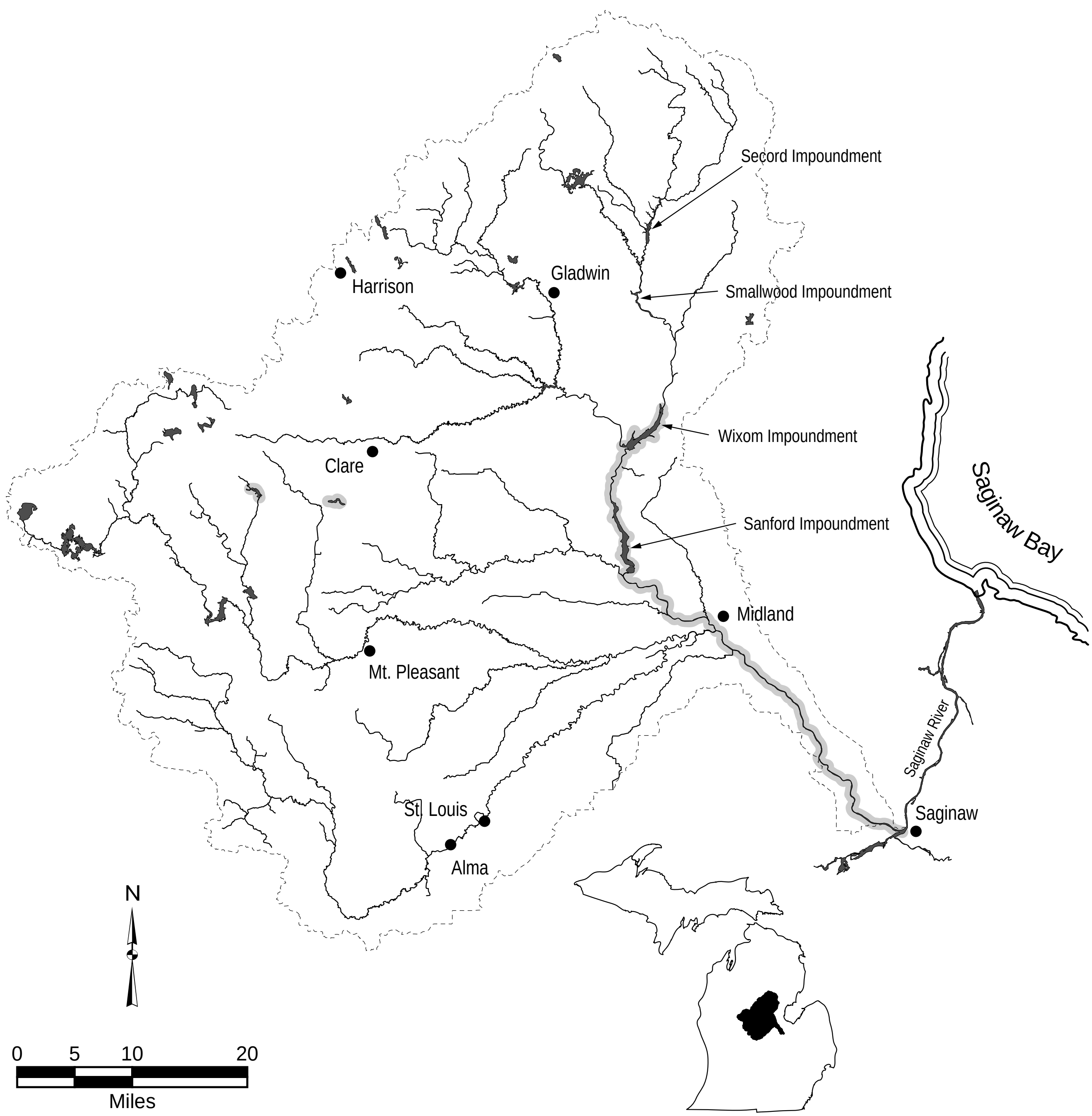


Brook silverside *Labidesthes sicculus*

Habitat:

feeding - clear, warm pools in streams and rivers; also lakes
- does not tolerate turbidity
- most frequently at surface

spawning - in and around aquatic vegetation or over gravel substrate with a moderate current

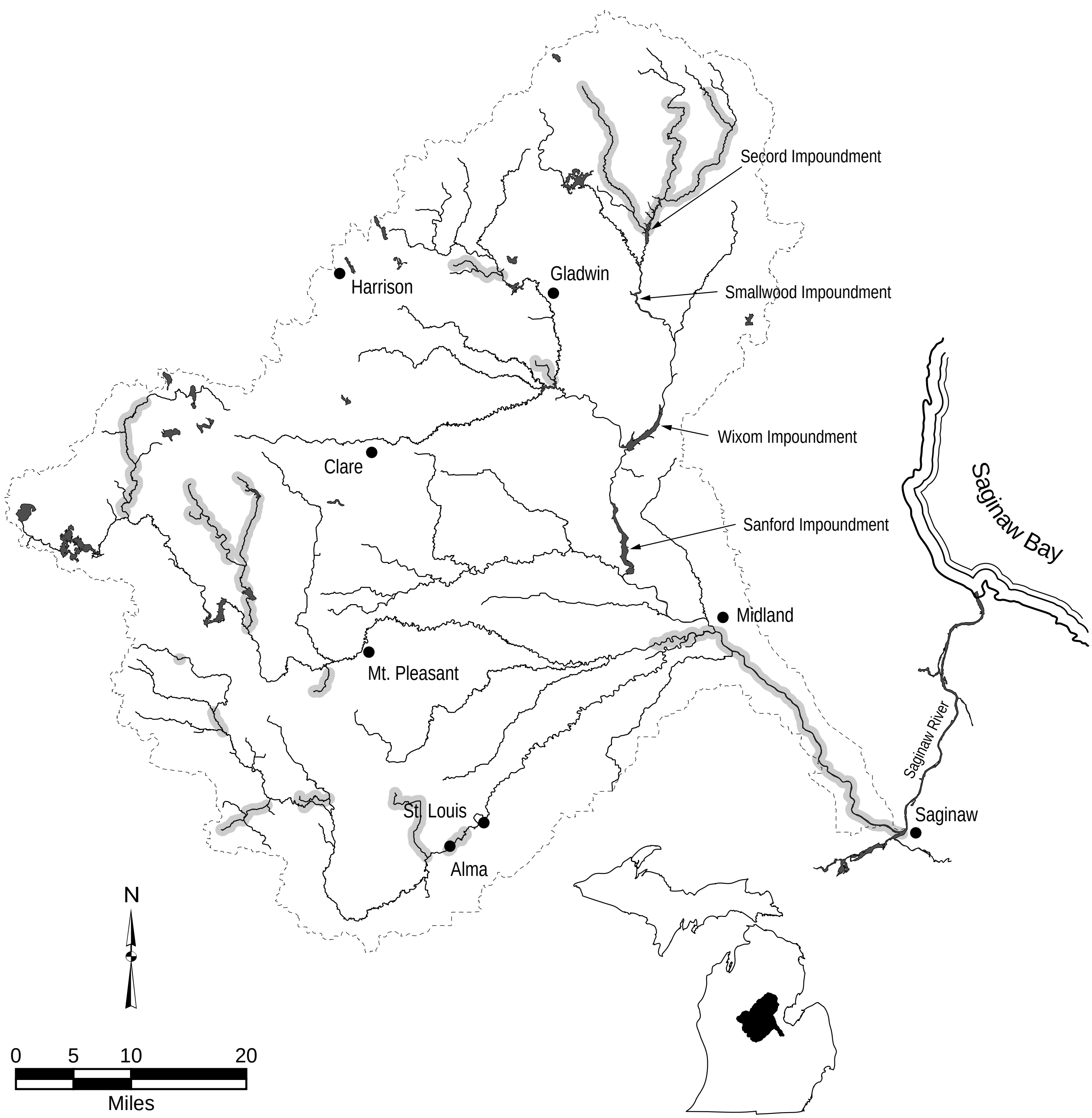


Brook stickleback *Culaea inconstans*

Habitat**:**

feeding - clear, cold, densely vegetated streams, and swampy margins of lakes
- low gradient
- muck, peat, or marl substrate
- not tolerant of turbidity

spawning - shallow cool (<66°F) water
- aquatic reeds or grasses necessary

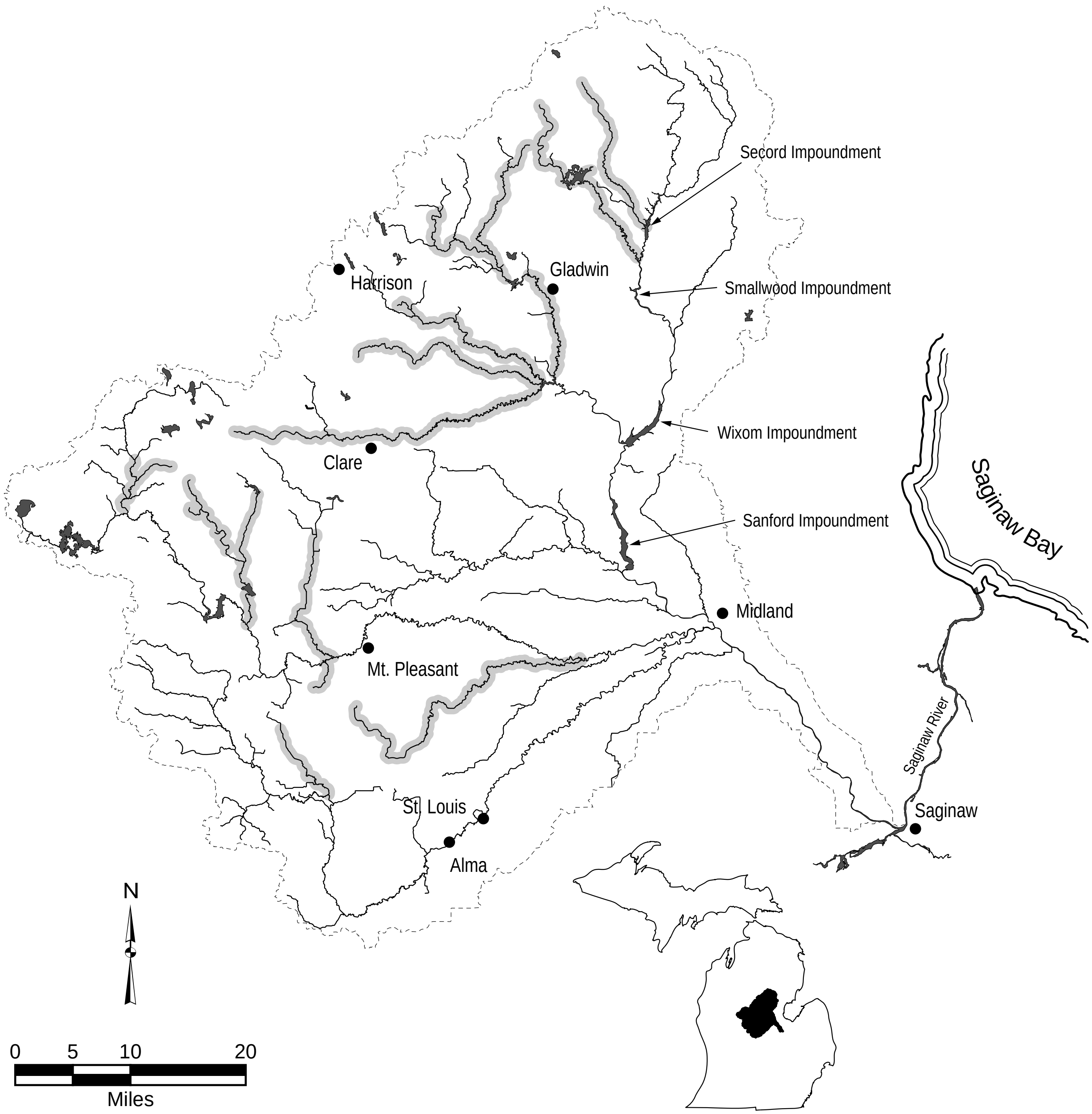


Mottled sculpin *Cottus bairdii*

Habitat**:**

feeding - cool to cold streams
- riffle and rock substrates preferred
- clear to slightly turbid shallow water

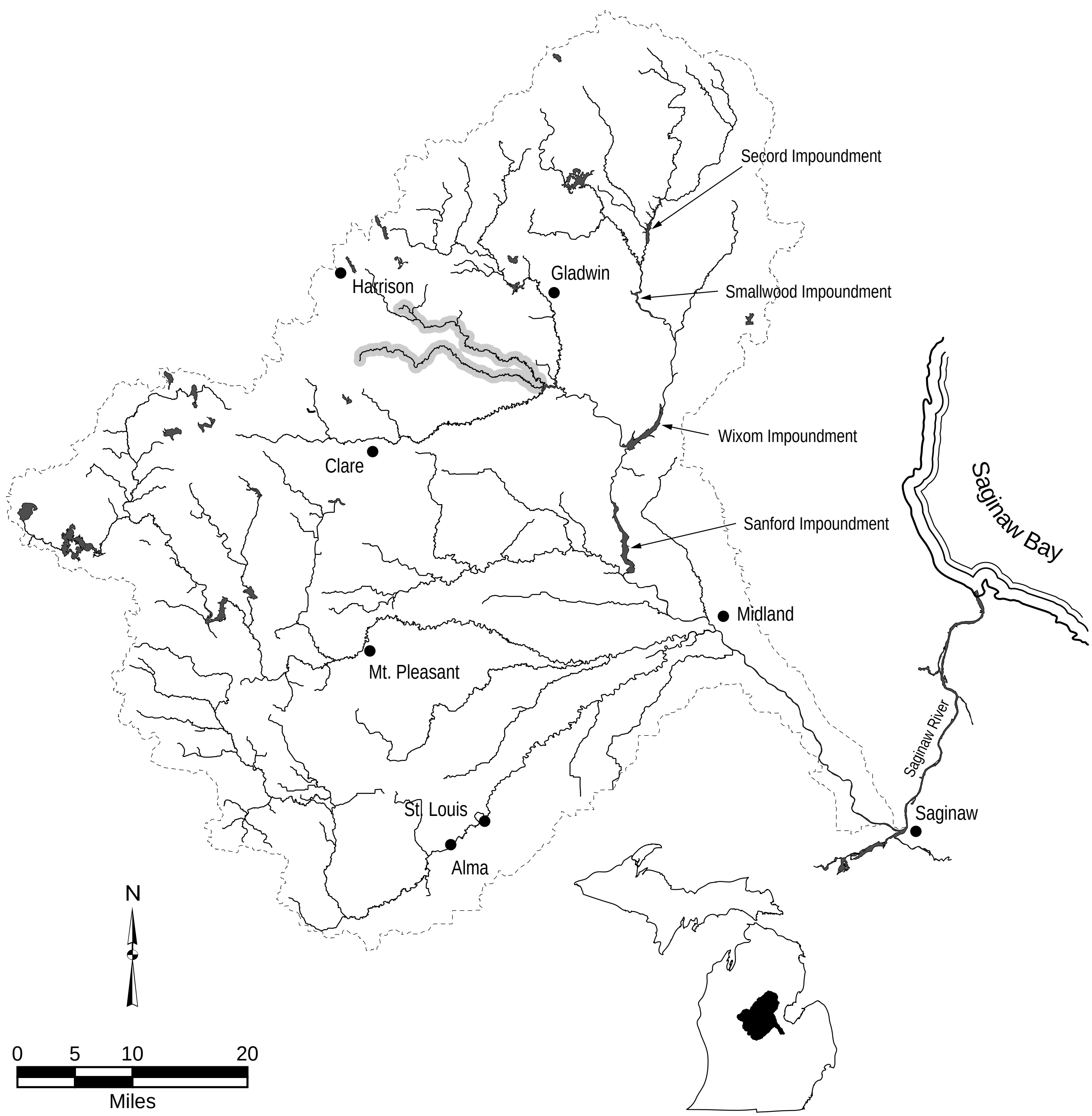
spawning - nests under logs or rock



Slimy sculpin *Cottus cognatus*

Habitat:

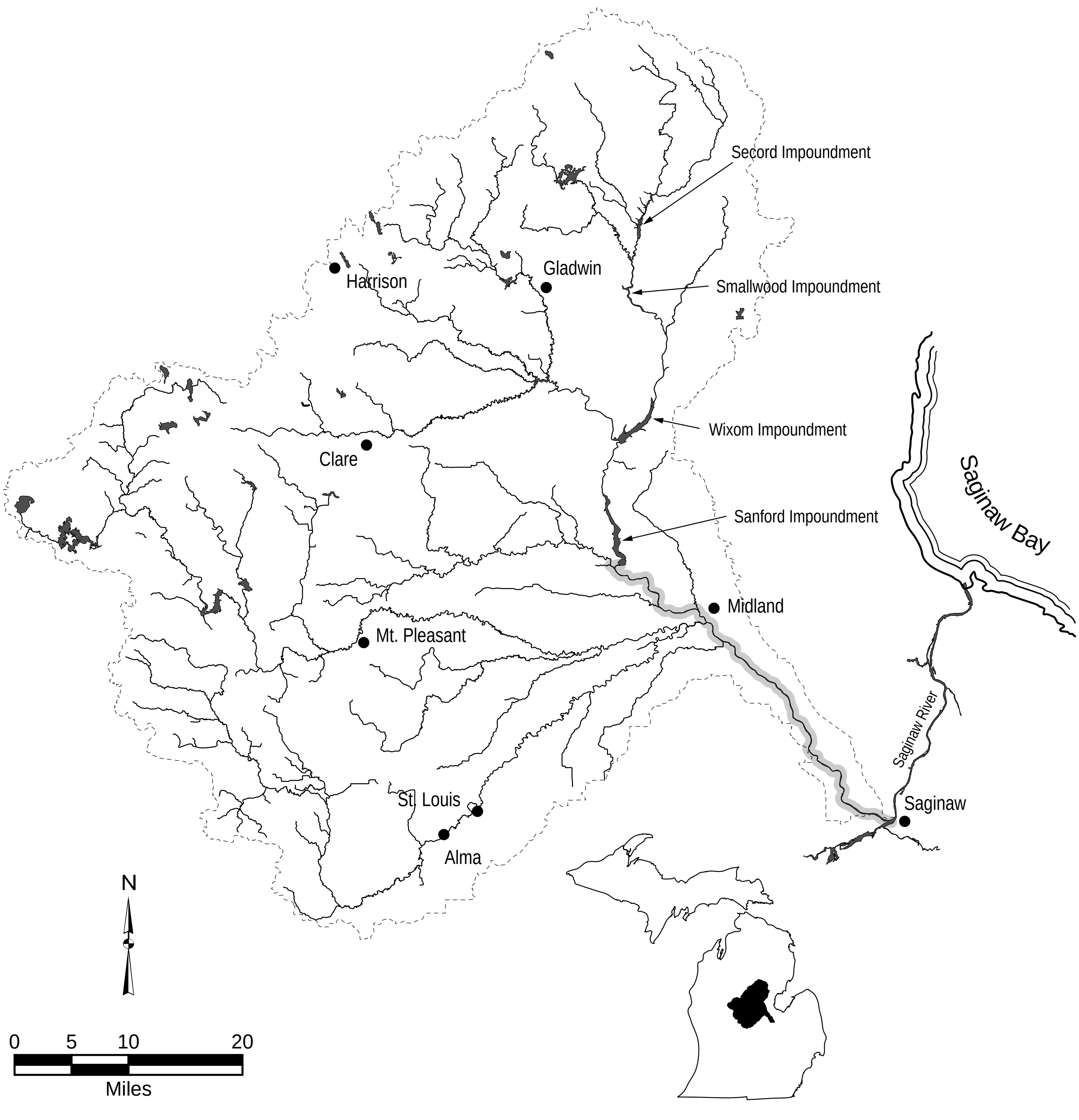
feeding	-	cool lakes, impoundments, rivers, and streams
	-	gravel or rock substrate
spawning	-	nest in shallow areas of lakes
	-	gravel substrate or rock ledge
	-	male parental care



White perch *Morone americana*

Habitat:

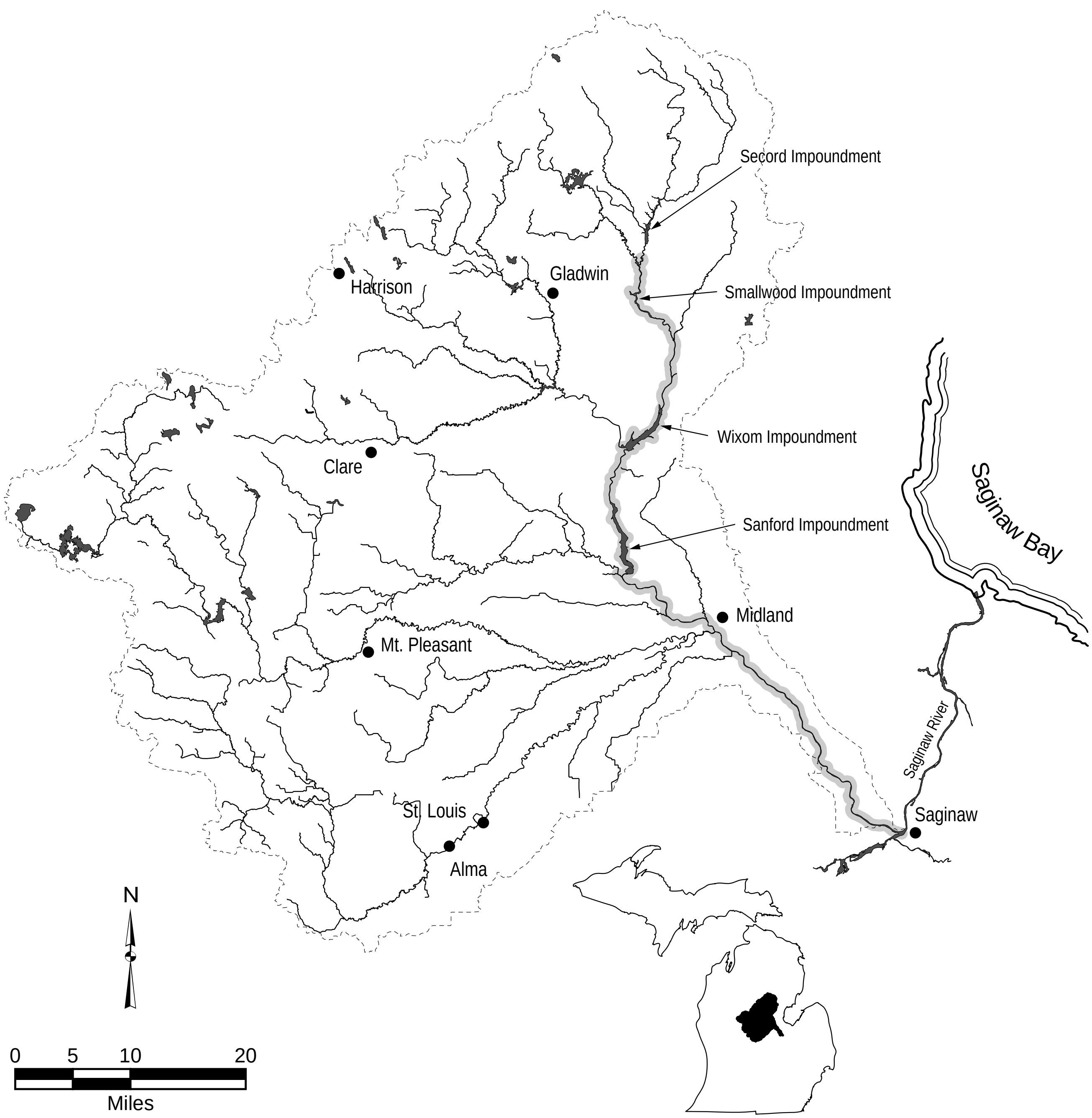
feeding - clear, warm water of low-gradient streams, lakes, impoundments, and Lake Huron
spawning - shallow water over firm substrate



White bass *Morone chrysops*

Habitat:

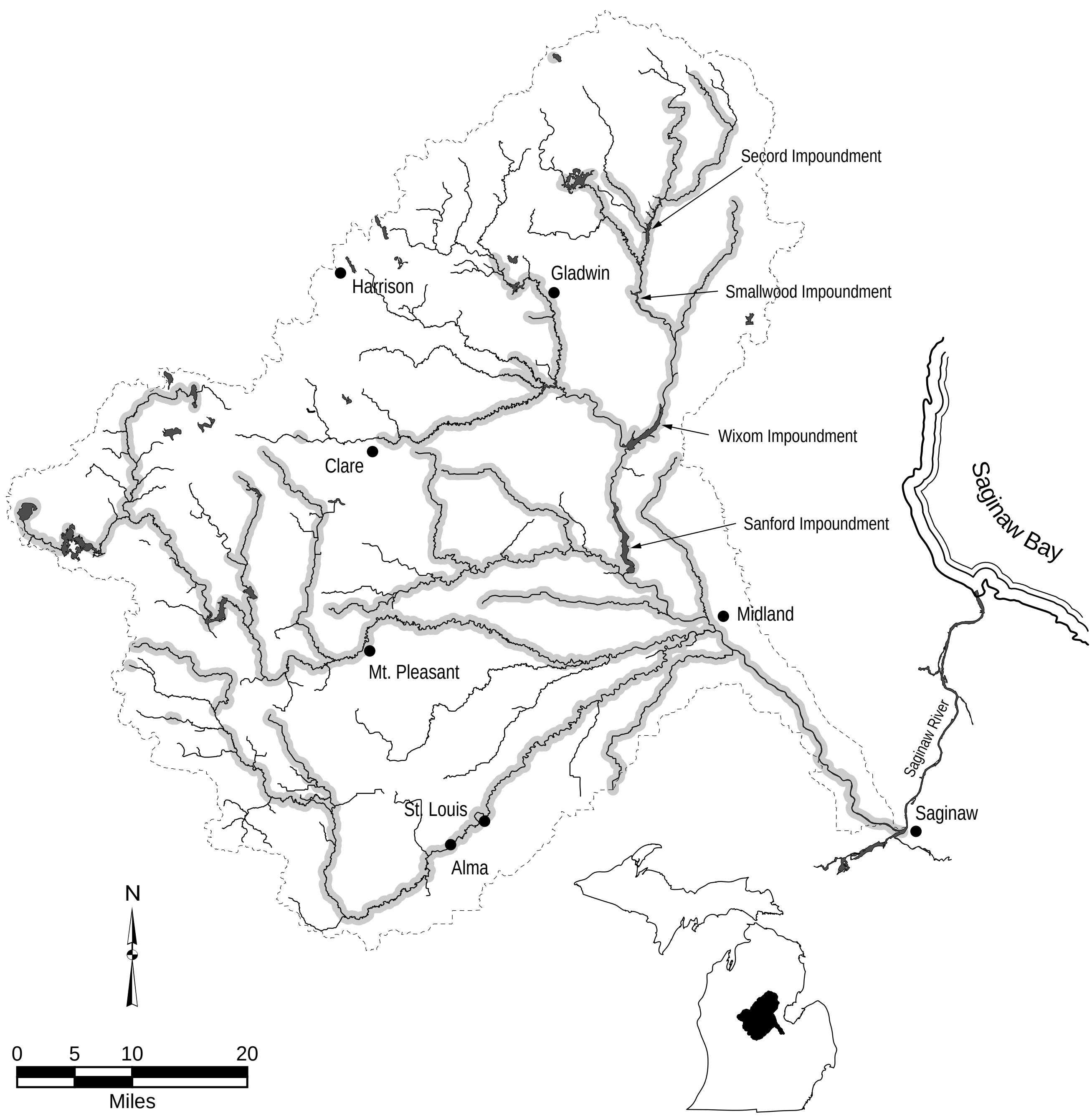
feeding	-	large lakes, impoundments, and Lake Huron
	-	clear water of 30 feet or less depth
	-	firm substrate
spawning	-	tributary streams or shallow water of lakes
	-	over firm substrate



Rock bass *Ambloplites rupestris*

Habitat**:**

feeding	-	clear, cool streams, rivers, and lakes
	-	rocky to sand substrate
	-	woody or vegetative cover
spawning	-	sand or gravel nests
	-	shallow water
winter refuge	-	deep water

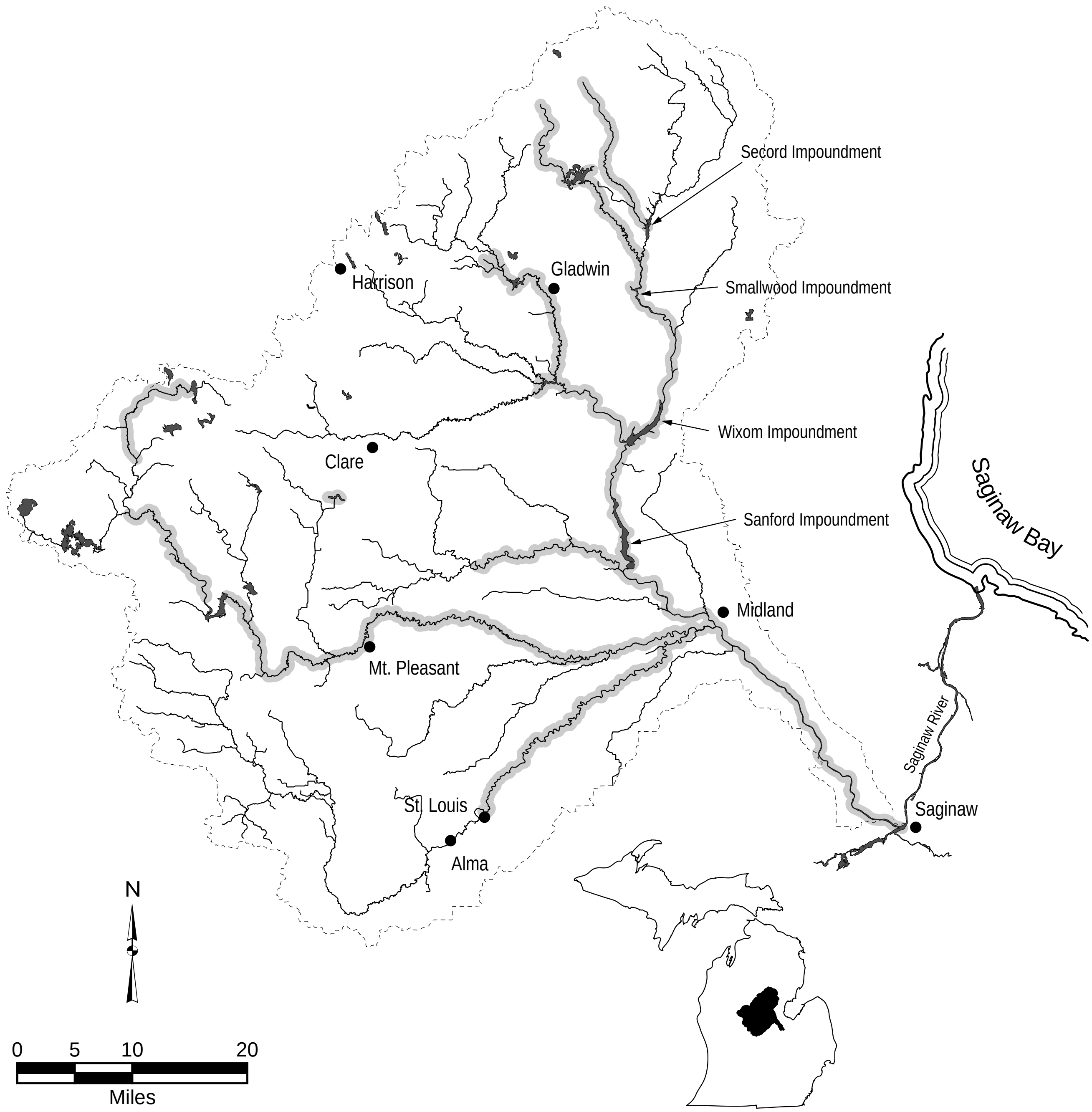


Green sunfish *Lepomis cyanellus*

Habitat**:**

feeding - impoundments and lakes, and low-current streams and rivers
- no substrate preference

spawning - nests in shallow areas sheltered by rocks, logs, or aquatic vegetation

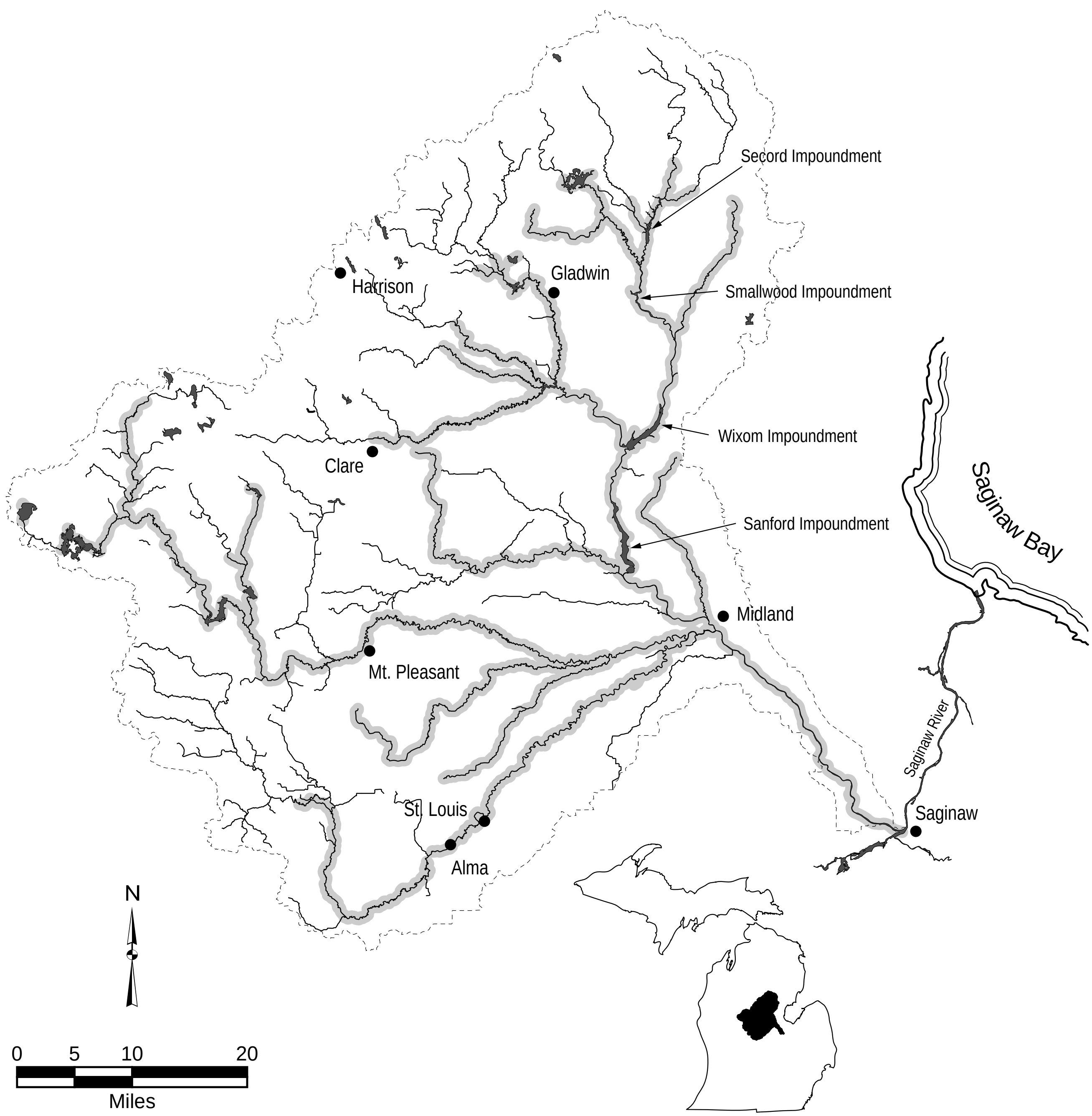


Pumpkinseed *Lepomis gibbosus*

Habitat**:**

feeding - non-flowing clear water in streams and rivers; also lakes and impoundments
- muck or sand partly covered with organic debris substrate
- dense beds of submerged aquatic vegetation

spawning - nest in sand, gravel, or rock substrate
- in shallow water near submerged vegetation

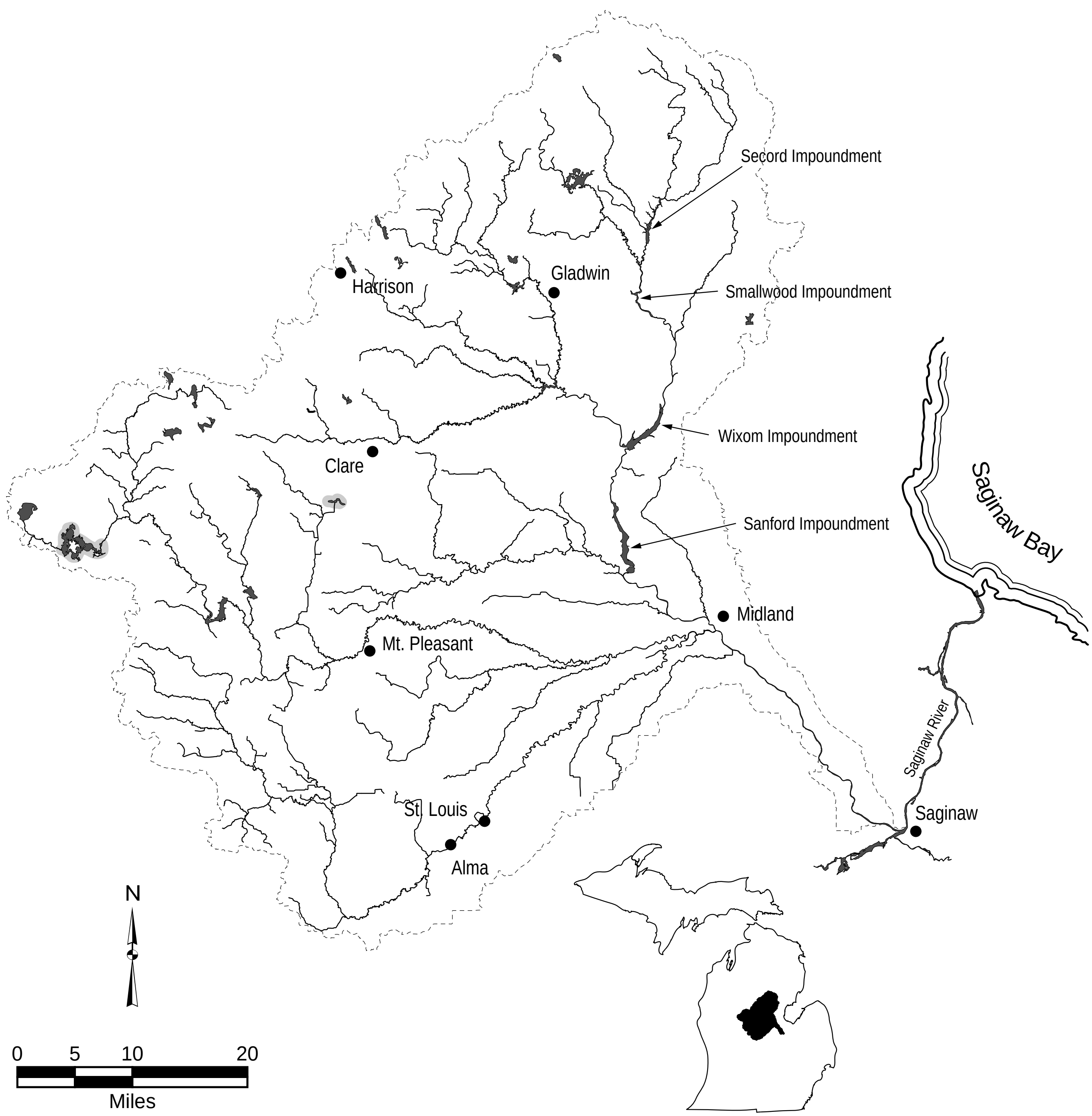


Warmouth *Lepomis gulosus*

Habitat**:**

feeding - clear lakes and impoundments and very low-gradient streams
- abundant aquatic vegetation
- silt-free water
- mucky substrate often covered with organic debris

spawning - nesting sites in loose silt, sand with silt, or rubble over silt near stumps, roots, or vegetation



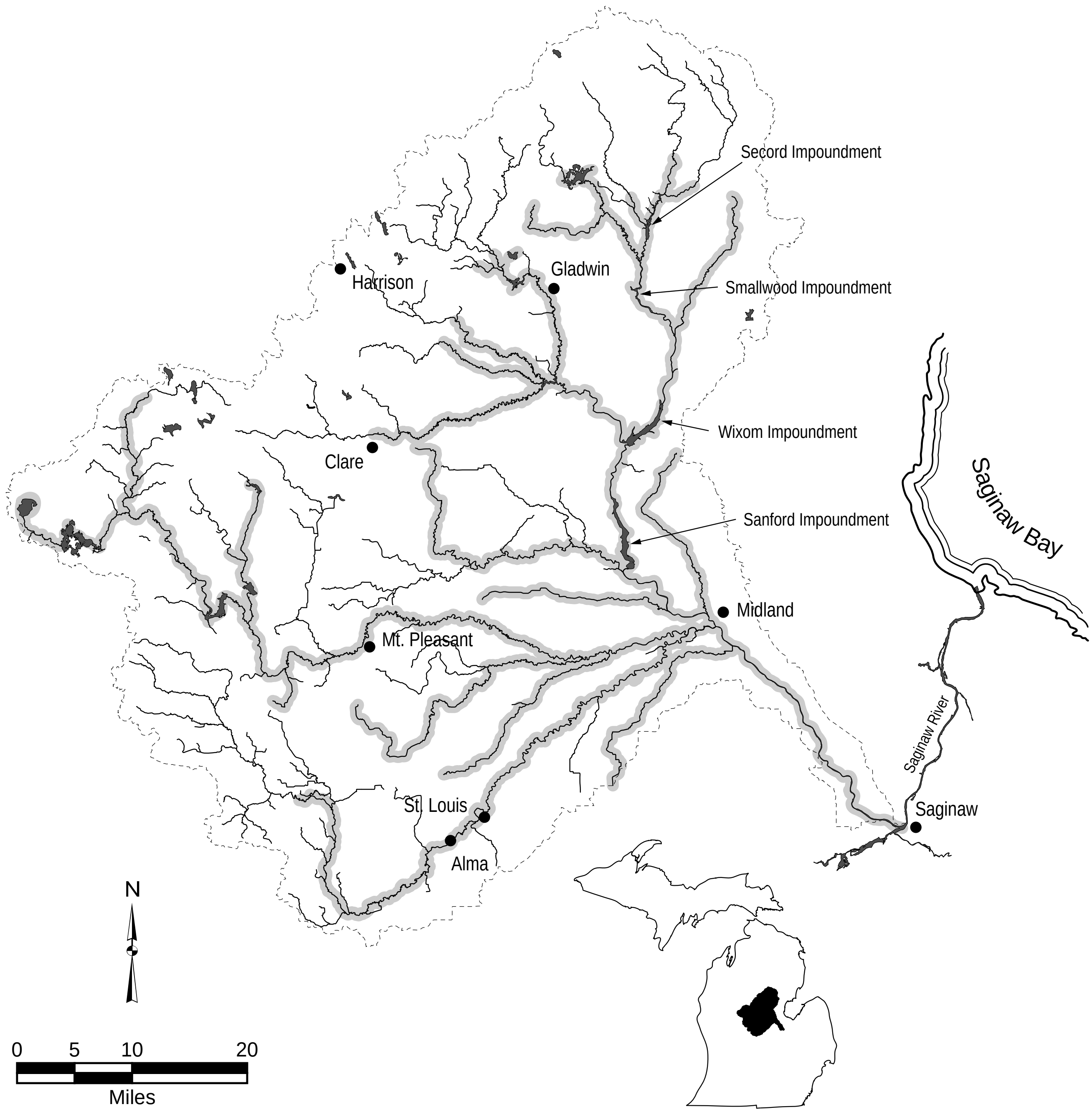
Bluegill *Lepomis macrochirus*

Habitat**:**

feeding - non-flowing clear streams and rivers; also lakes and impoundments
- sand, gravel, or muck containing organic debris substrate
- scattered beds of aquatic vegetation
- cannot tolerate low oxygen or continuous high turbidity and siltation

spawning - nests in firm substrate of gravel, sand, or mud

winter refuge - deep water

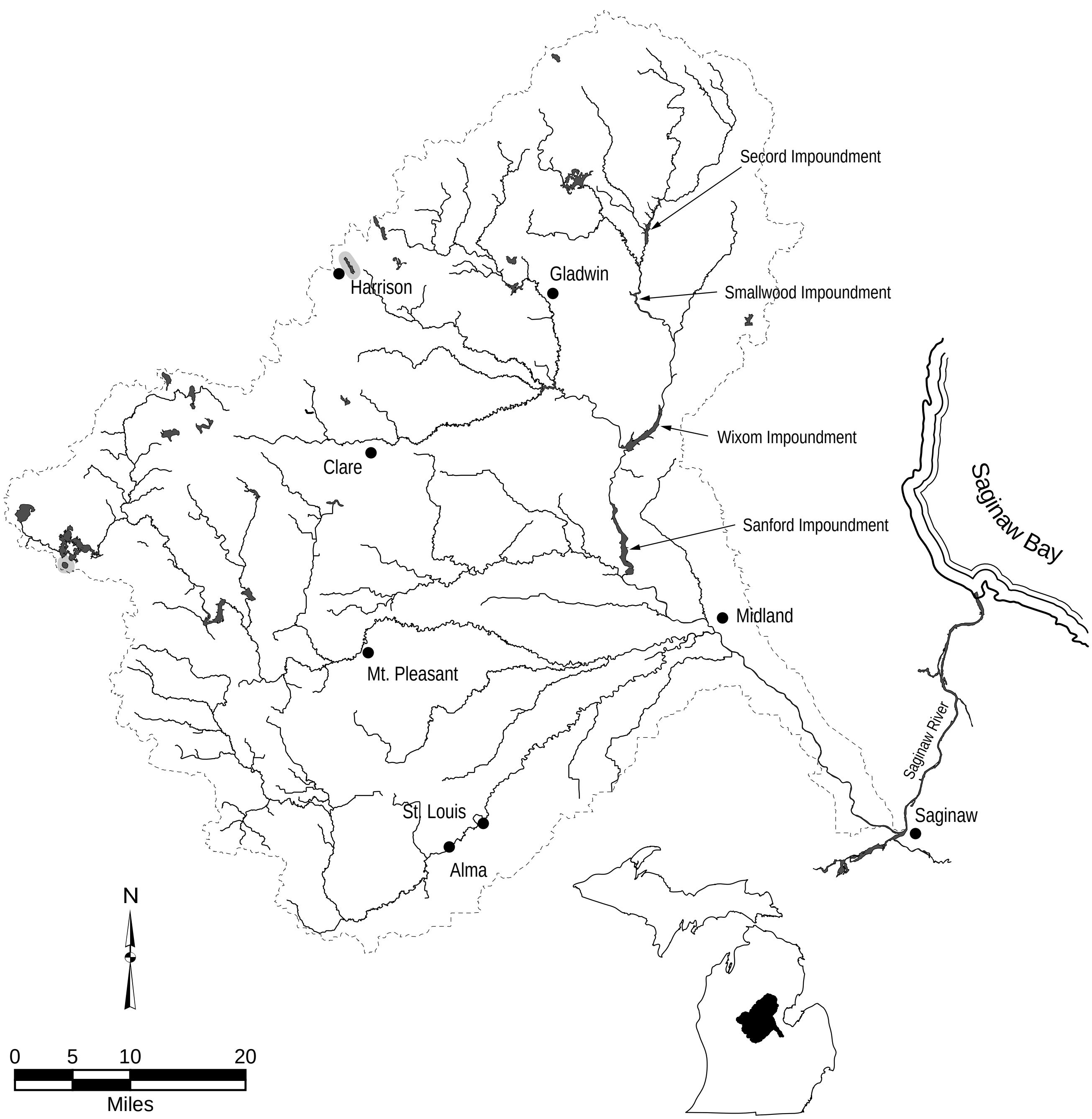


Redear sunfish *Lepomis microlophus*

Habitat**:**

feeding - non-flowing clear waters of streams and lakes
- some aquatic vegetation

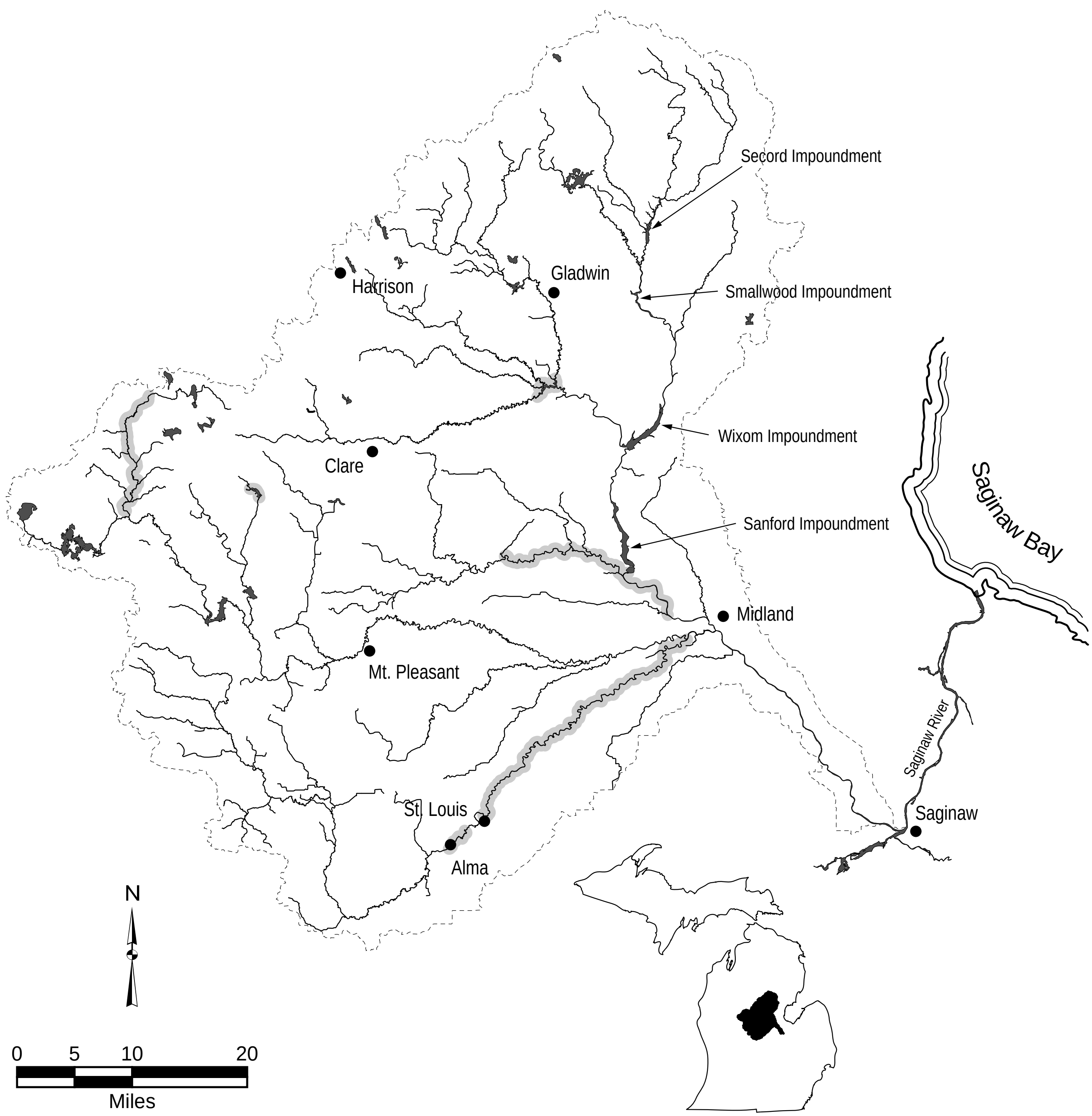
spawning - nest in silt or gravel substrate



Northern longear sunfish *Lepomis peltastes*

Habitat**:**

feeding	-	clear moderate-sized shallow streams with moderate vegetation
	-	rocky substrates
	-	little to no current
spawning	-	nests in gravel, sand, or hard rock substrate



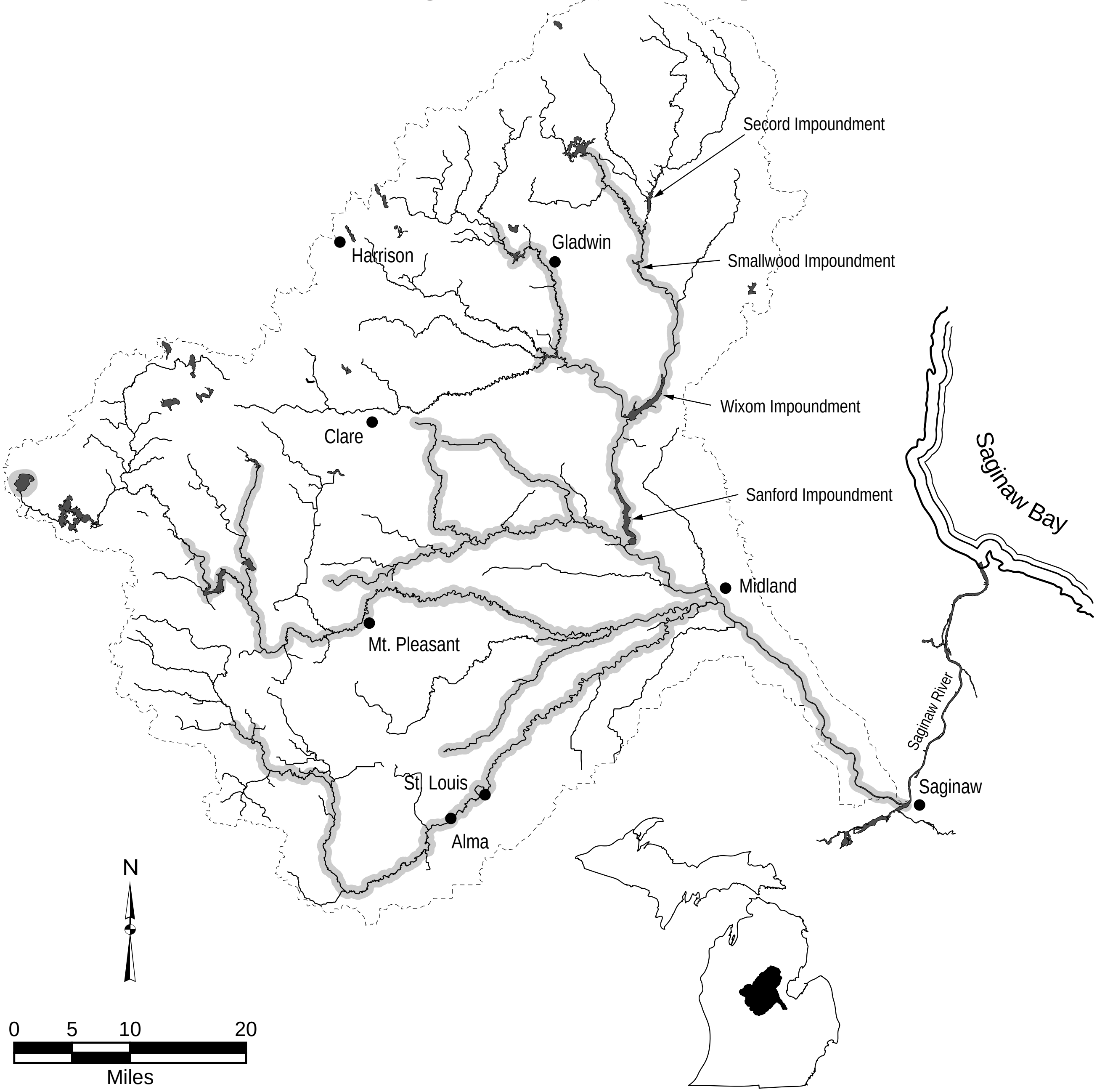
Smallmouth bass *Micropterus dolomieu*

Habitat**:**

feeding - clear, cool, deep lakes and rivers
- streams where 40% consists of riffles over clean gravel, boulder, or bedrock substrate
- in pools with a current and >4 feet of depth
- gradients between 4 and 25 feet per mile

spawning - nest in sandy, gravel, or rocky substrate
- gradients 7 to 25 feet per mile
- streams 20 to 100 feet wide

winter refuge - larger deeper waters with gradients between 3 to 7 feet per mile

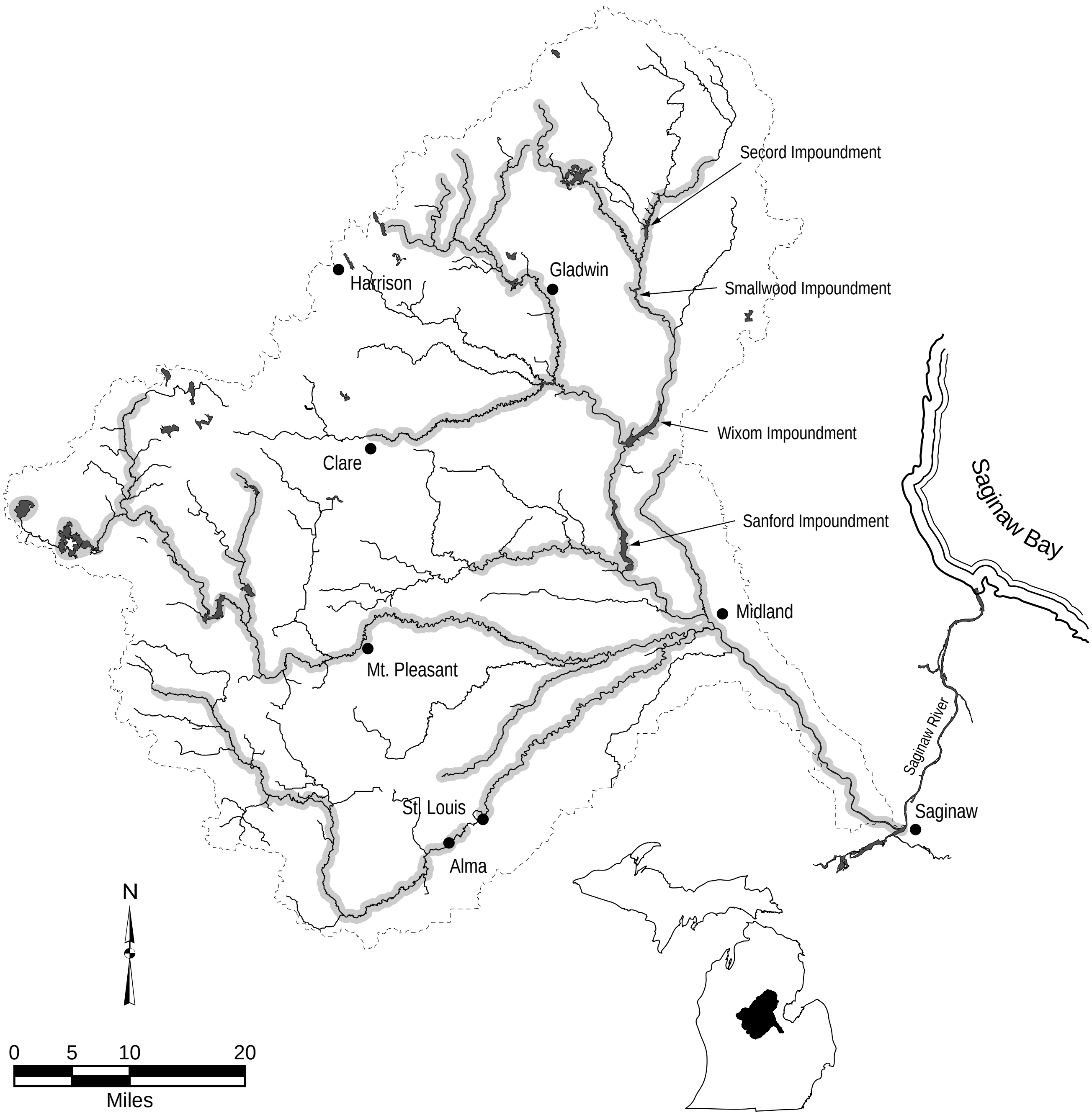


Largemouth bass *Micropterus salmoides*

Habitat**:**

feeding - non-flowing clear waters - lakes, impoundments, and pools of streams
- abundant aquatic vegetation
- soft muck, organic debris, gravel, sand, and hard non-flocculent clay substrates

spawning - nest in gravelly sand to marl and soft mud substrates
- emergent vegetation
- quiet shallow bays; no current

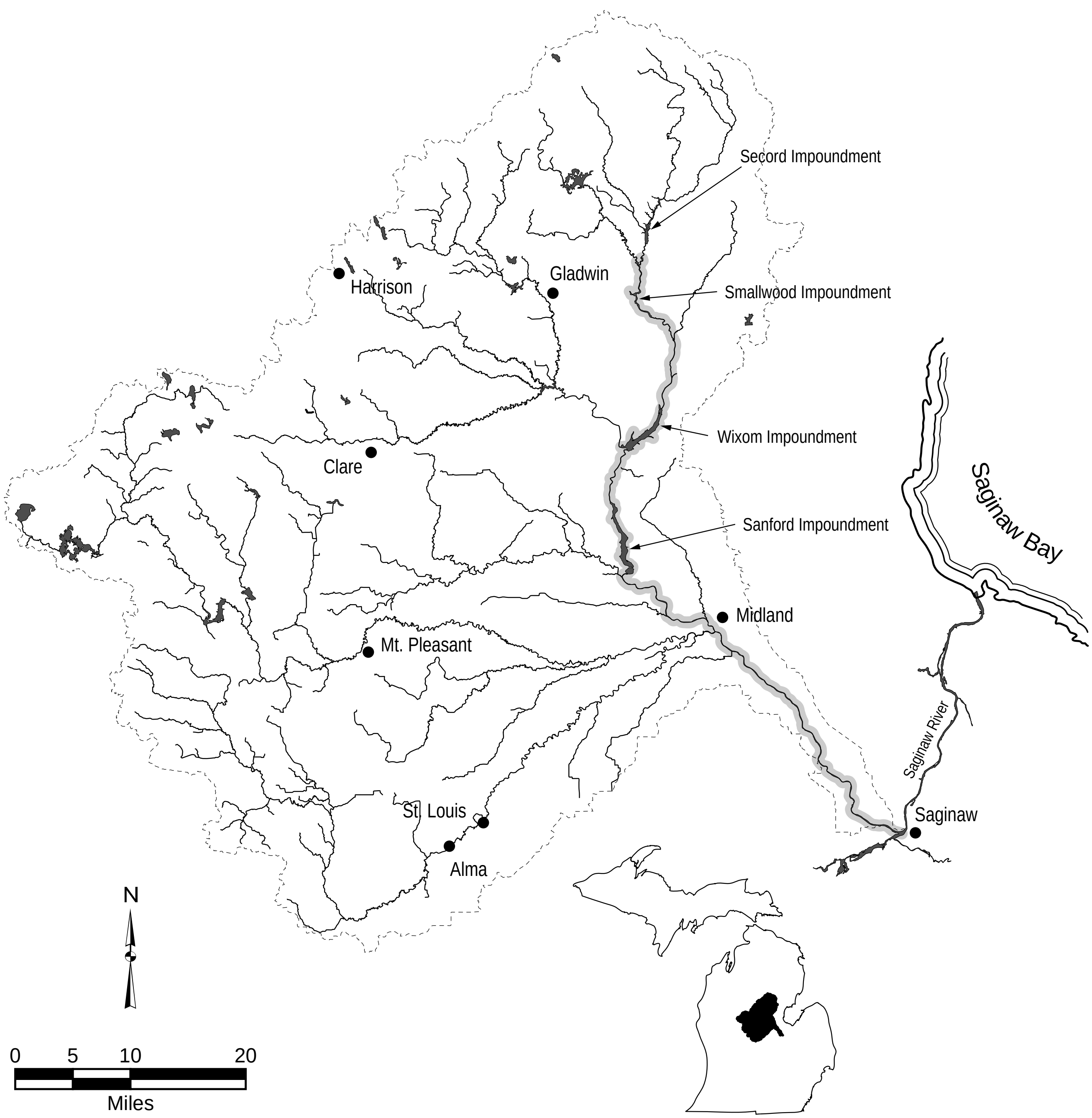


White crappie *Pomoxis annularis*

Habitat**:**

feeding - lakes and impoundments >5 acres
- sluggish pools of moderate to large low-gradient rivers
- no substrate preference
- can tolerate severe turbidity and rapid siltation

spawning - various substrates usually beside rooted aquatic vegetation
- sometimes under banks

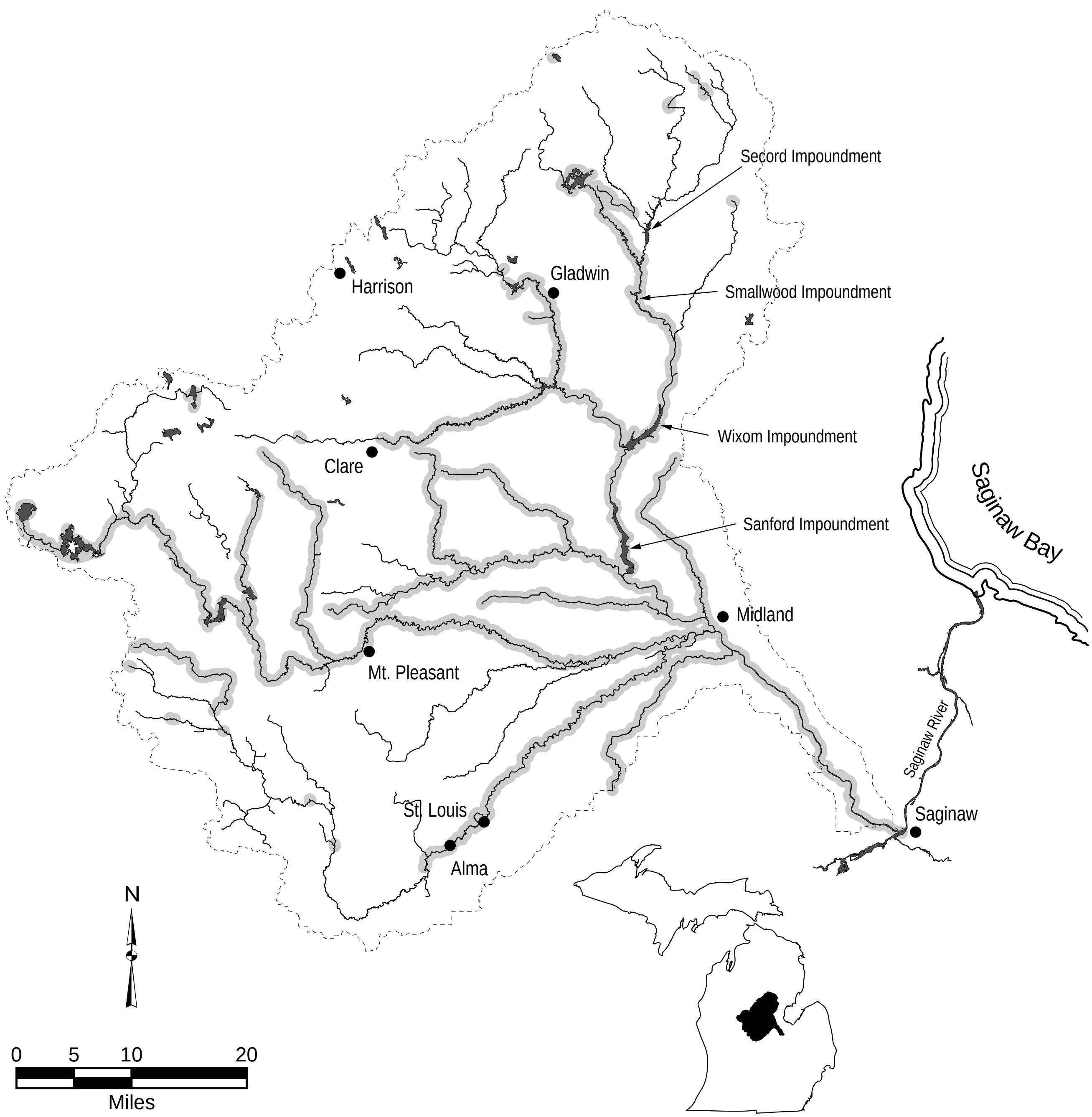


Black crappie *Pomoxis nigromaculatus*

Habitat**:**

feeding - larger clear non-silty low-gradient rivers; also in lakes and impoundments
- clean hard sand or muck substrate
- associated with submerged aquatic vegetation
- does not tolerate silt or turbidity well

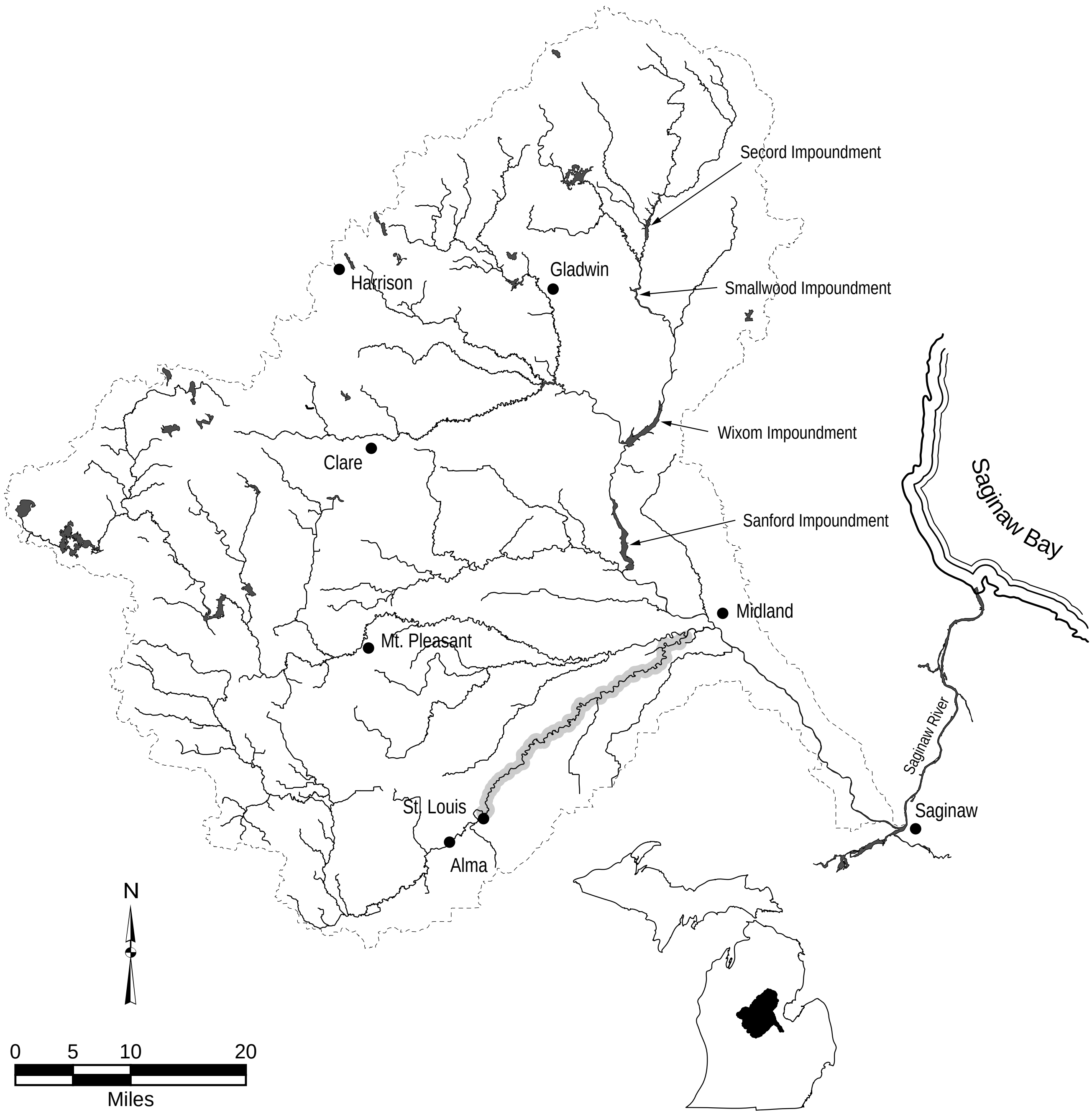
spawning - nests in gravel, sand, or mud substrate
- some vegetation must be present
- sometimes nests under banks



Greenside darter *Etheostoma blennioides*

Habitat:

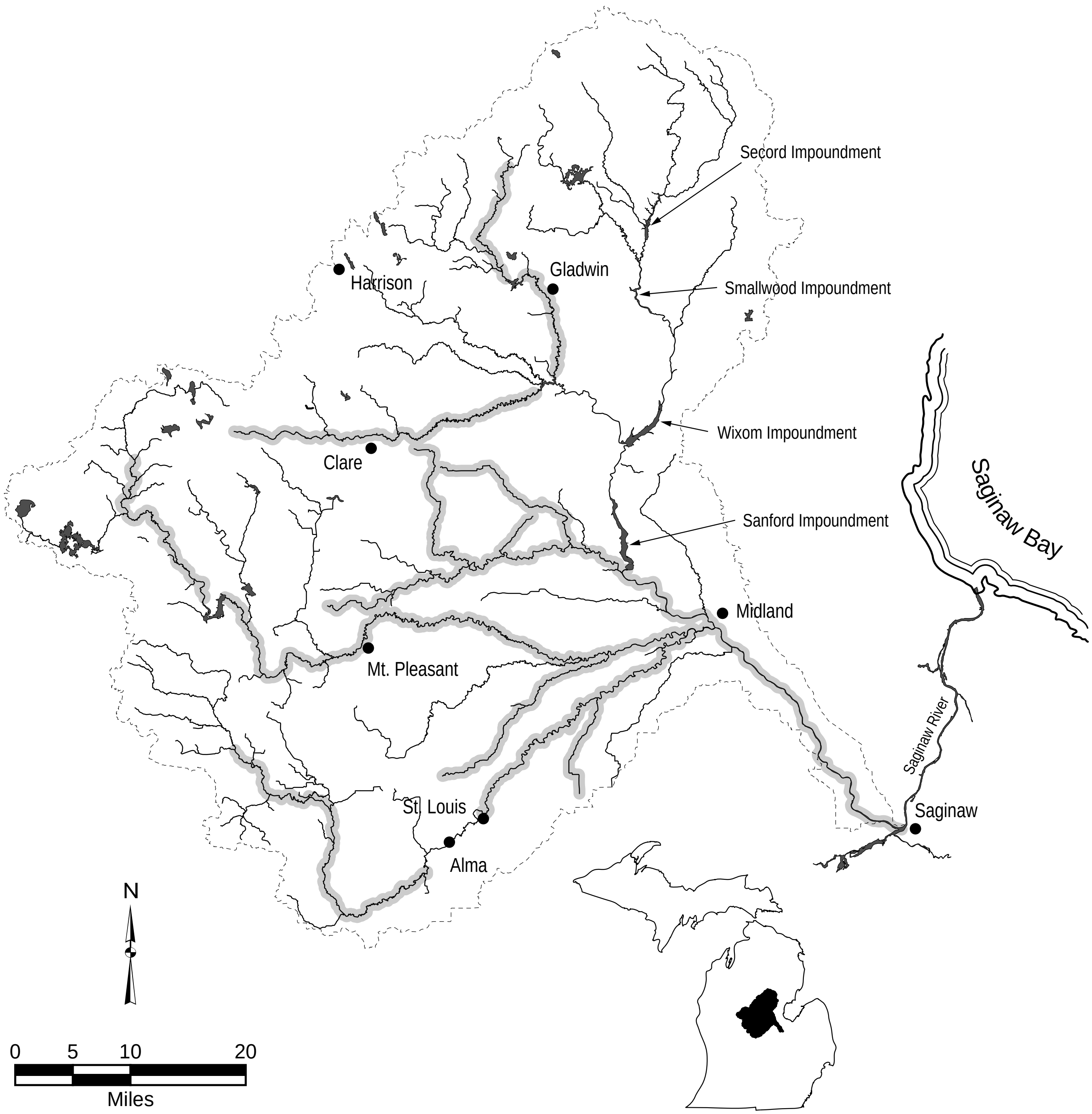
feeding	-	young: in quiet water
	-	swift gravelly riffles or pools with current of streams and rivers
spawning	-	filamentous algae necessary for egg deposition



Rainbow darter *Etheostoma caeruleum*

Habitat**:**

feeding	-	gravelly high gradient riffles
	-	clear, moderate to large streams
	-	in shallows (average 1 foot)
spawning	-	gravel or rubble riffles

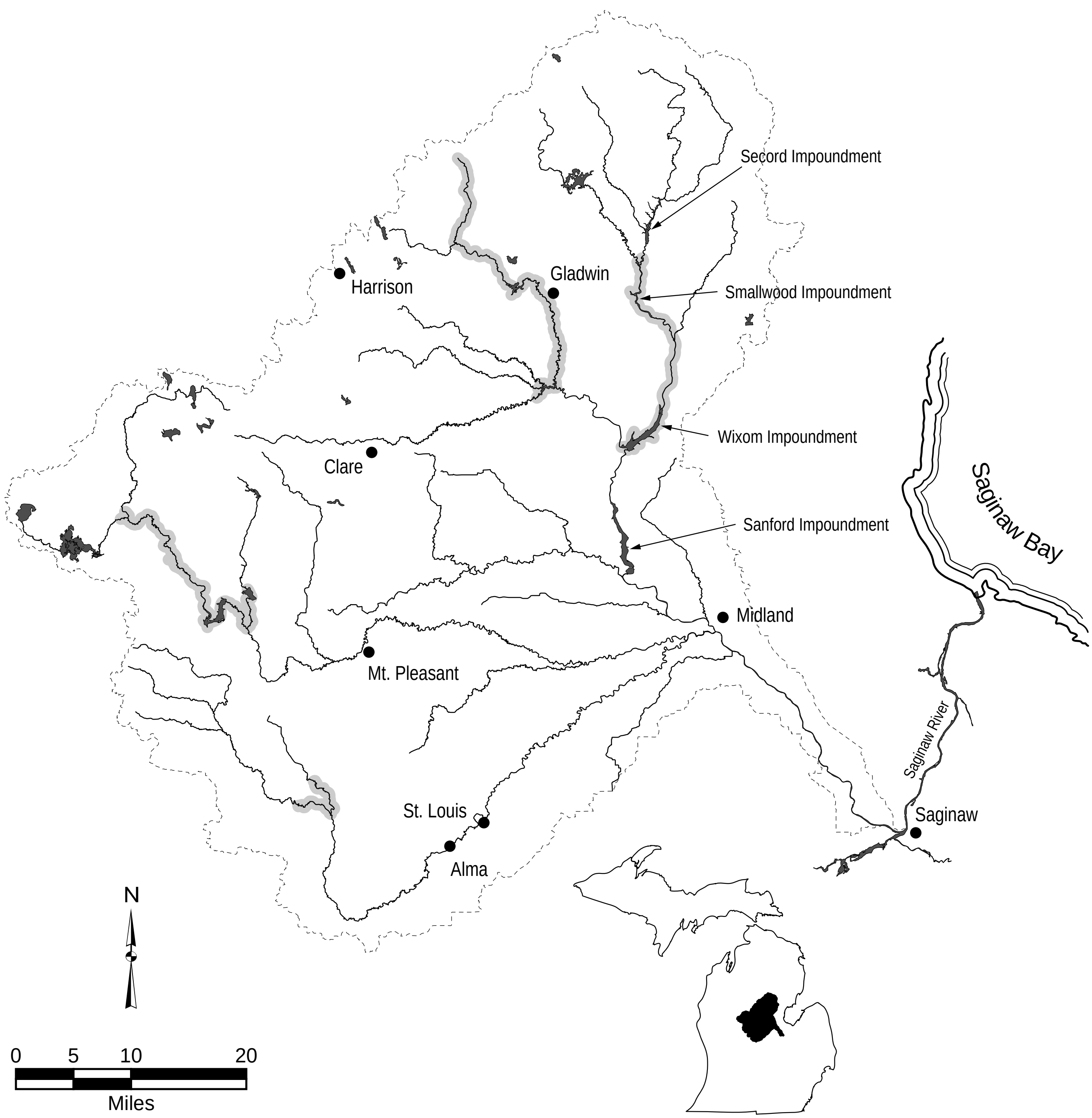


Iowa darter *Etheostoma exile*

Habitat**:**

feeding - clear, slow moving streams and lakes
- sandy to muddy substrates
- intolerant of turbid water
- lives in rooted aquatic vegetation

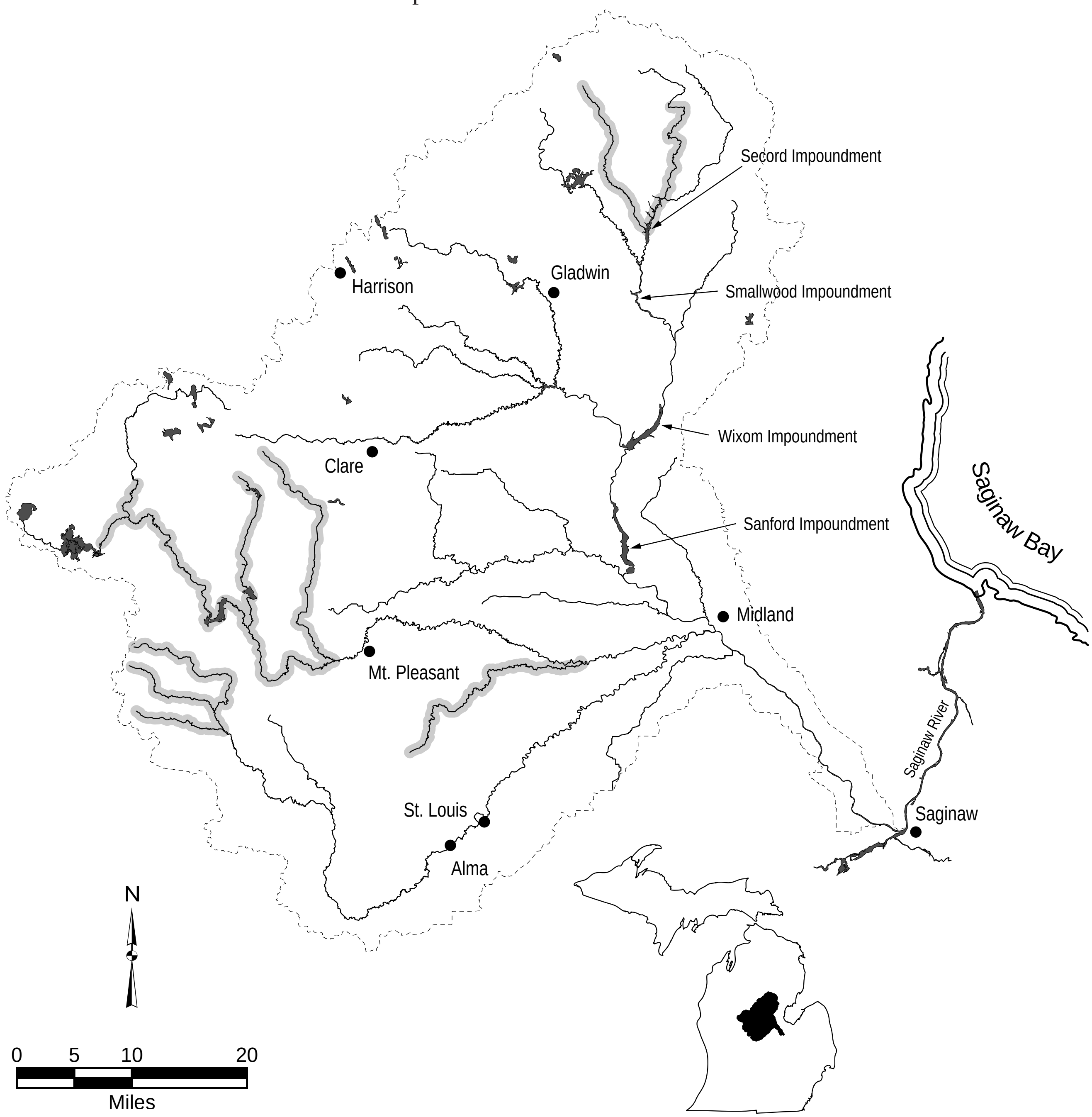
spawning - in pond-like extensions of streams on organic matter or roots
- in shallows



Fantail darter *Etheostoma flabellare*

Habitat:

feeding	-	small, shallow (<18 inches) streams
	-	some tolerance of turbidity and siltation
	-	clear warm waters
	-	slow to moderate current
	-	gravel and boulder substrate
spawning	-	gravel in slower water
	-	lays eggs on underside of rocks, male guards and fans them
winter refuge	-	moves downstream to larger and deeper waters

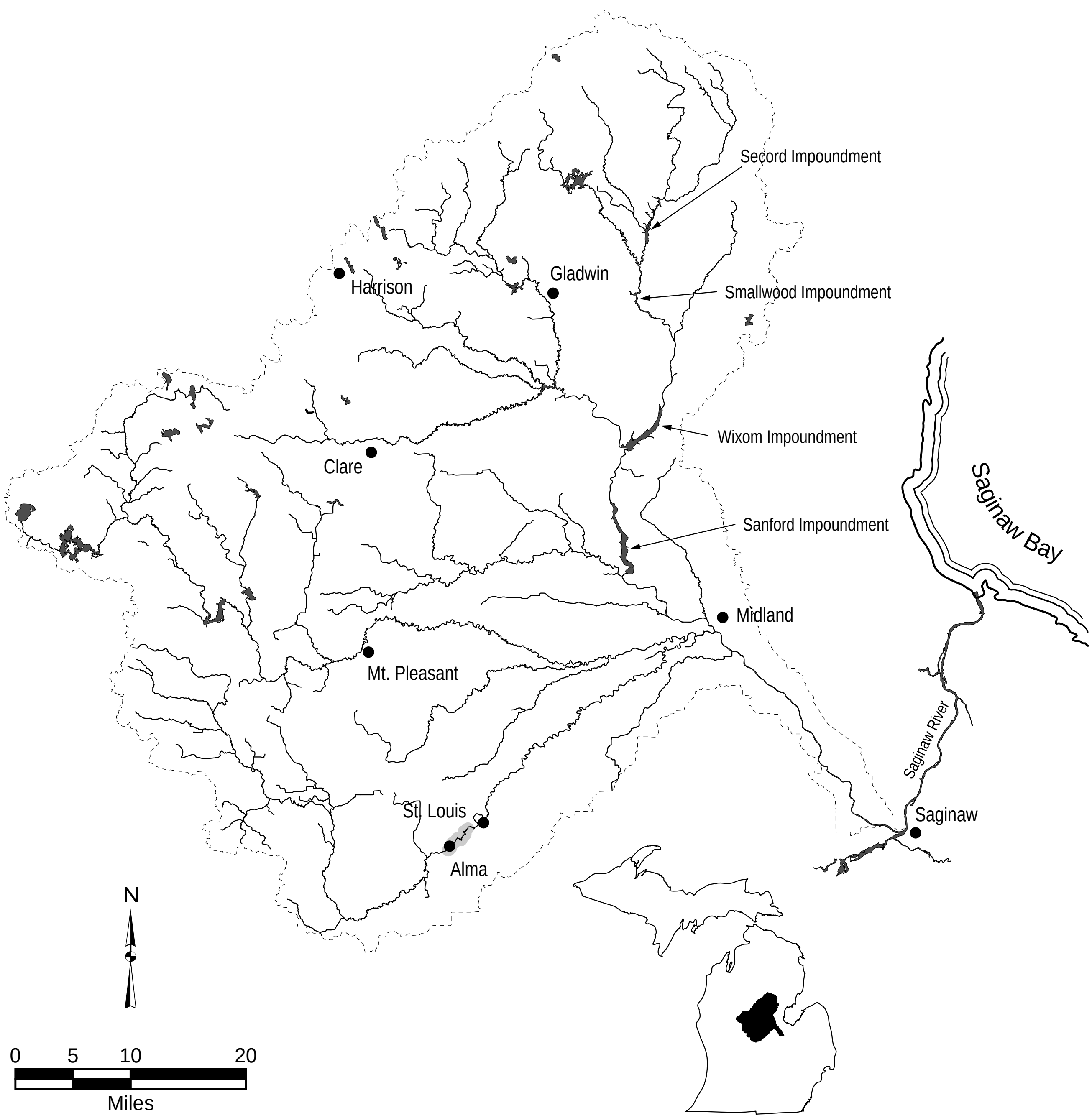


Least darter *Etheostoma microperca*

Habitat:

feeding - moderate to warm temperature
- clear quiet low-gradient vegetated streams (wetlands, floodplains)
- soft substrate

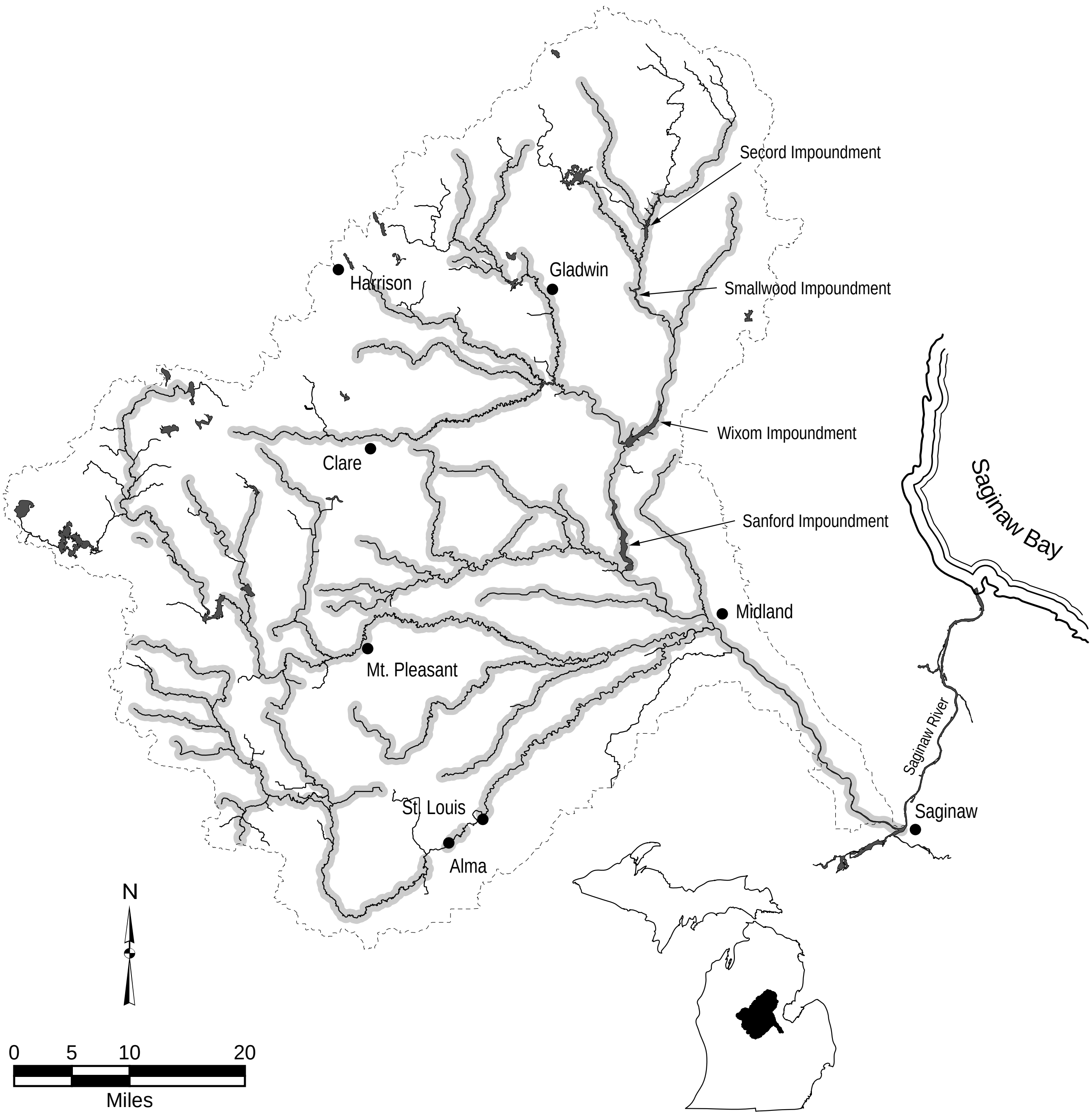
spawning - spawning occurs on stems of plants
- male guards a territory in a vegetated area



Johnny darter *Etheostoma nigrum*

Habitat**:**

feeding	-	sand and silt substrate
	-	little to moderate current
	-	shallow areas of streams, rivers, lakes, and impoundments
	-	tolerant of many organic and inorganic pollutants and turbidity
spawning	-	underneath rocks
	-	in stream pools or protected shallows of lakes

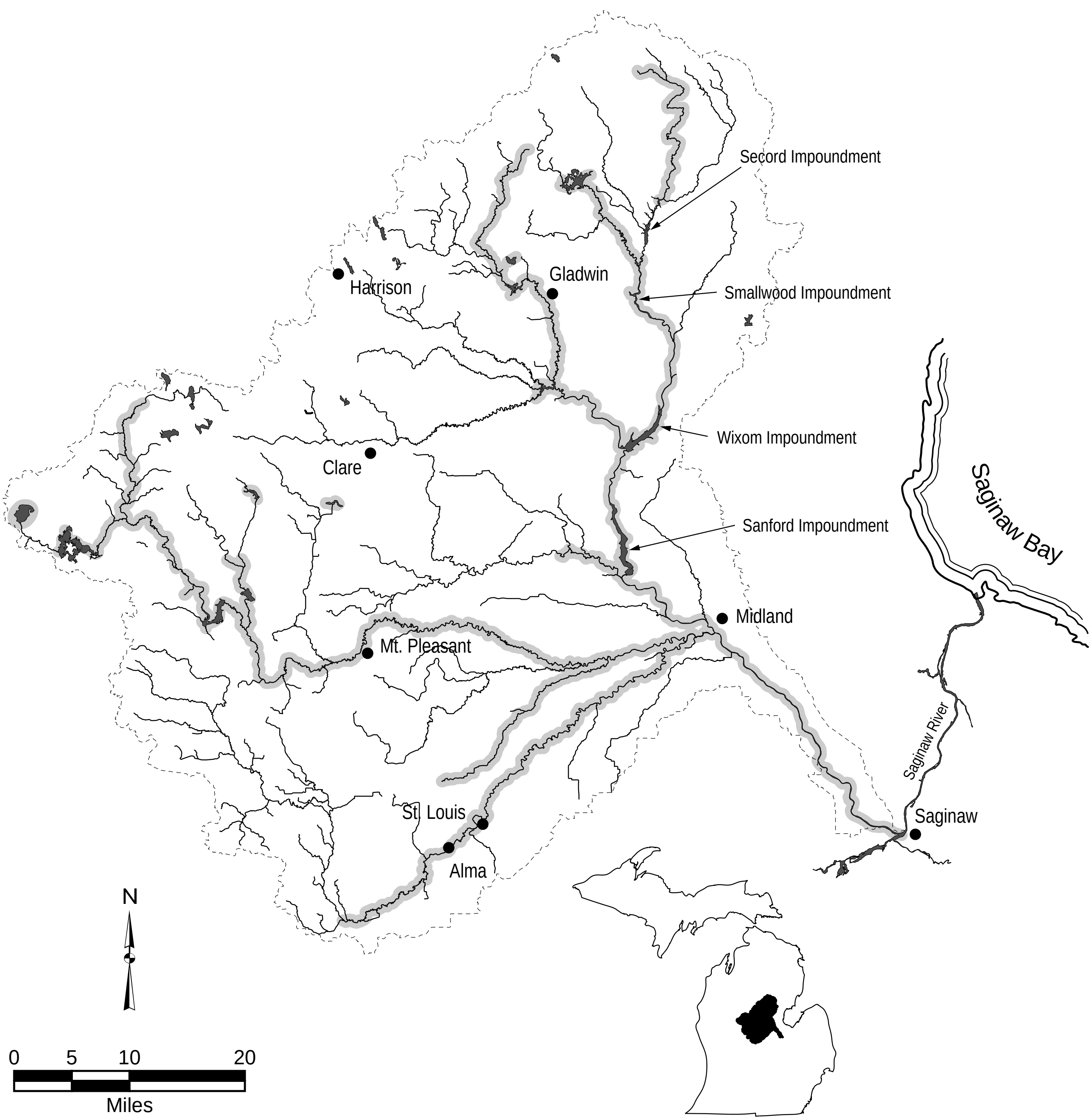


Yellow perch *Perca flavescens*

Habitat**:**

feeding
- clear lakes and impoundments; also Lake Huron
- low gradient rivers
- abundance of rooted aquatics
- muck, organic debris, sand, or gravel substrate
- does not tolerate turbidity and siltation

spawning
- shallows of lakes, tributaries of streams
- occurs over rooted vegetation, submerged brush, fallen trees
- may occur over sand or gravel

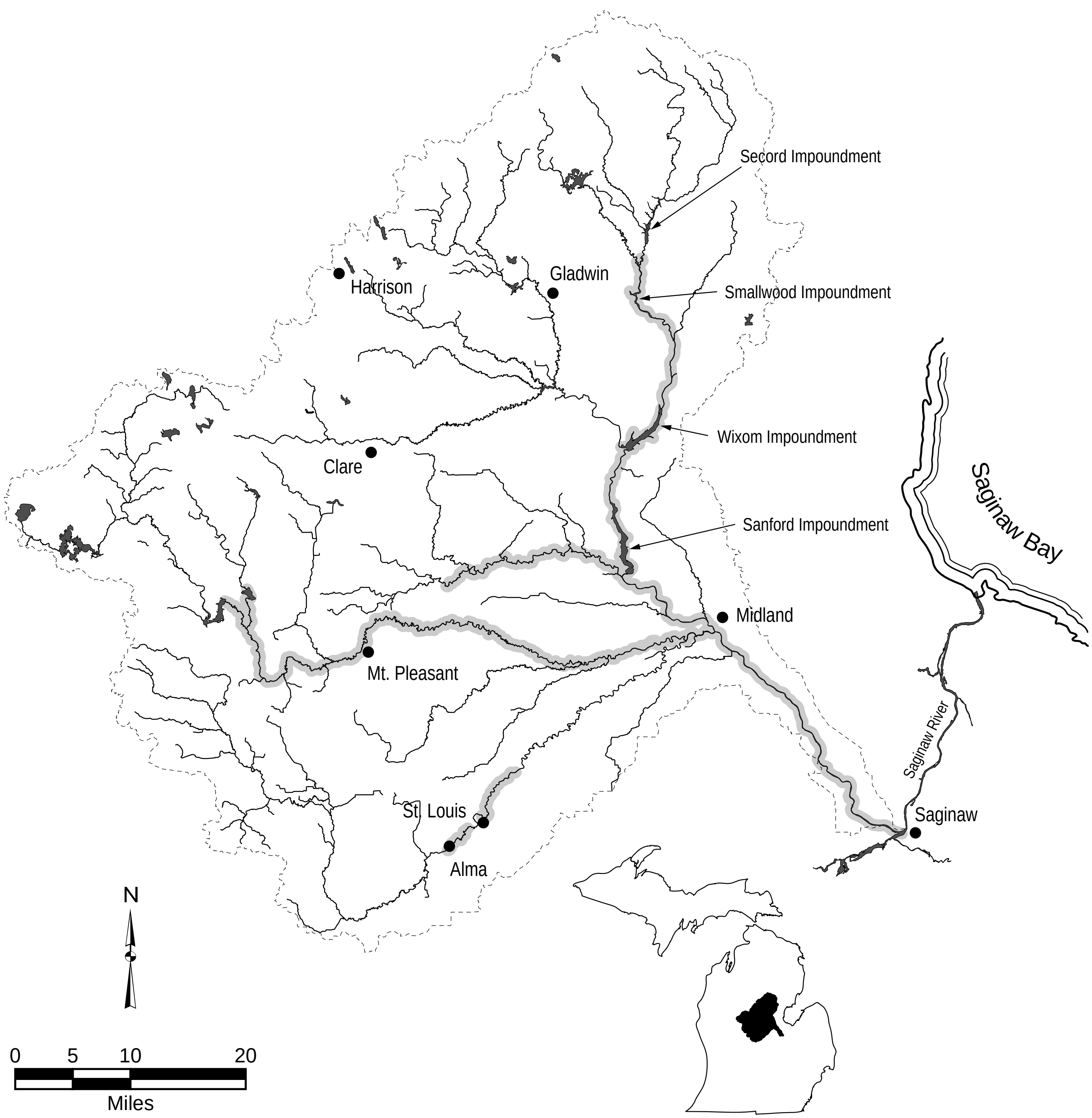


Northern logperch *Percina caprodes semifasciata*

Habitat**:**

feeding - gravel riffles, deeper slower sections of rivers
- medium size streams; also lakes, impoundments, and Lake Huron
- sand, gravel, or rock substrate
- avoids turbidity and silt

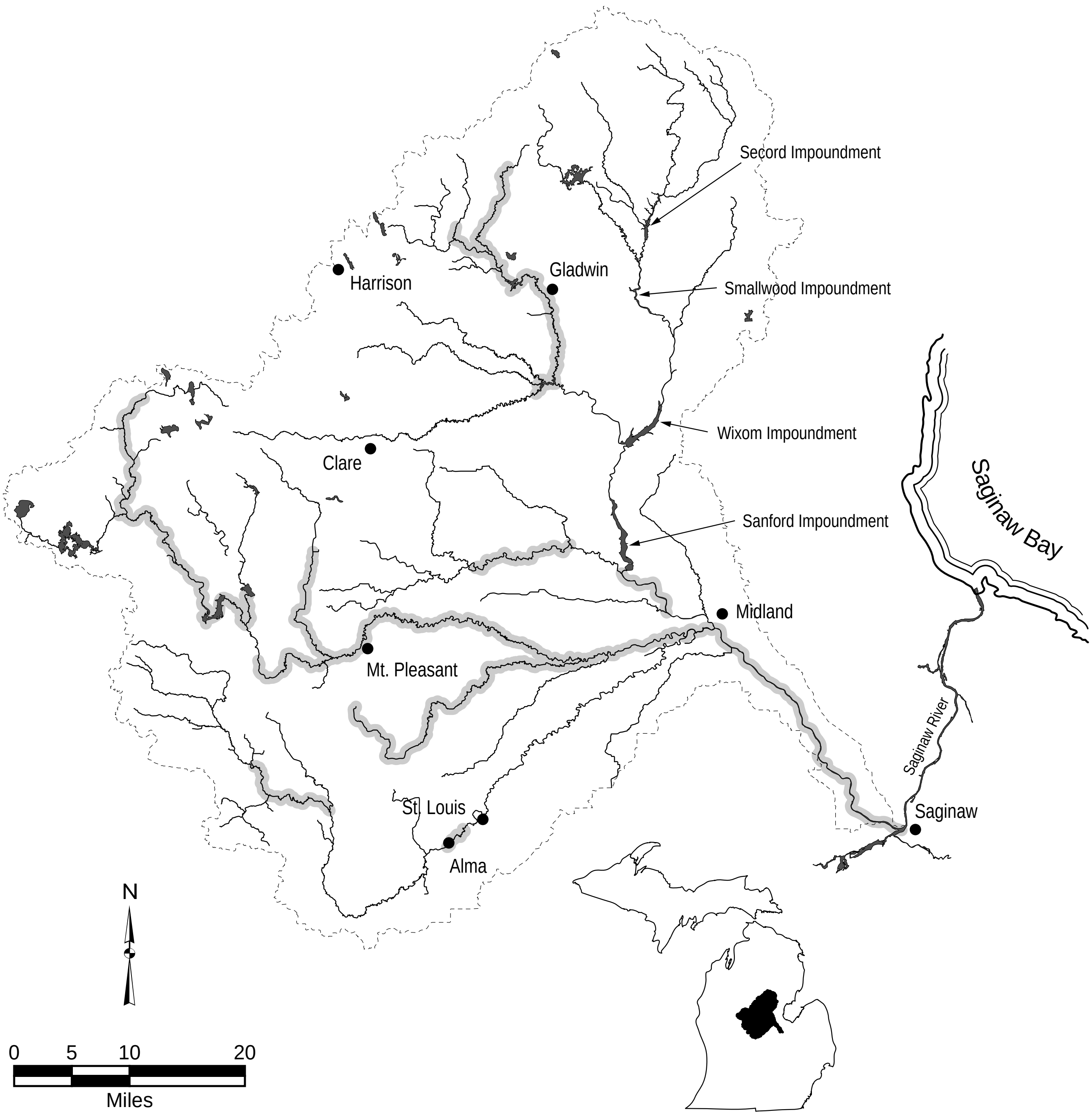
spawning - riffles or sandy in-shore shallows



Blackside darter *Percina maculata*

Habitat**:**

feeding	-	small to medium streams
	-	low to medium gradient
	-	gravel and sand substrate
	-	tolerate some turbidity
spawning	-	gravel and sand substrate



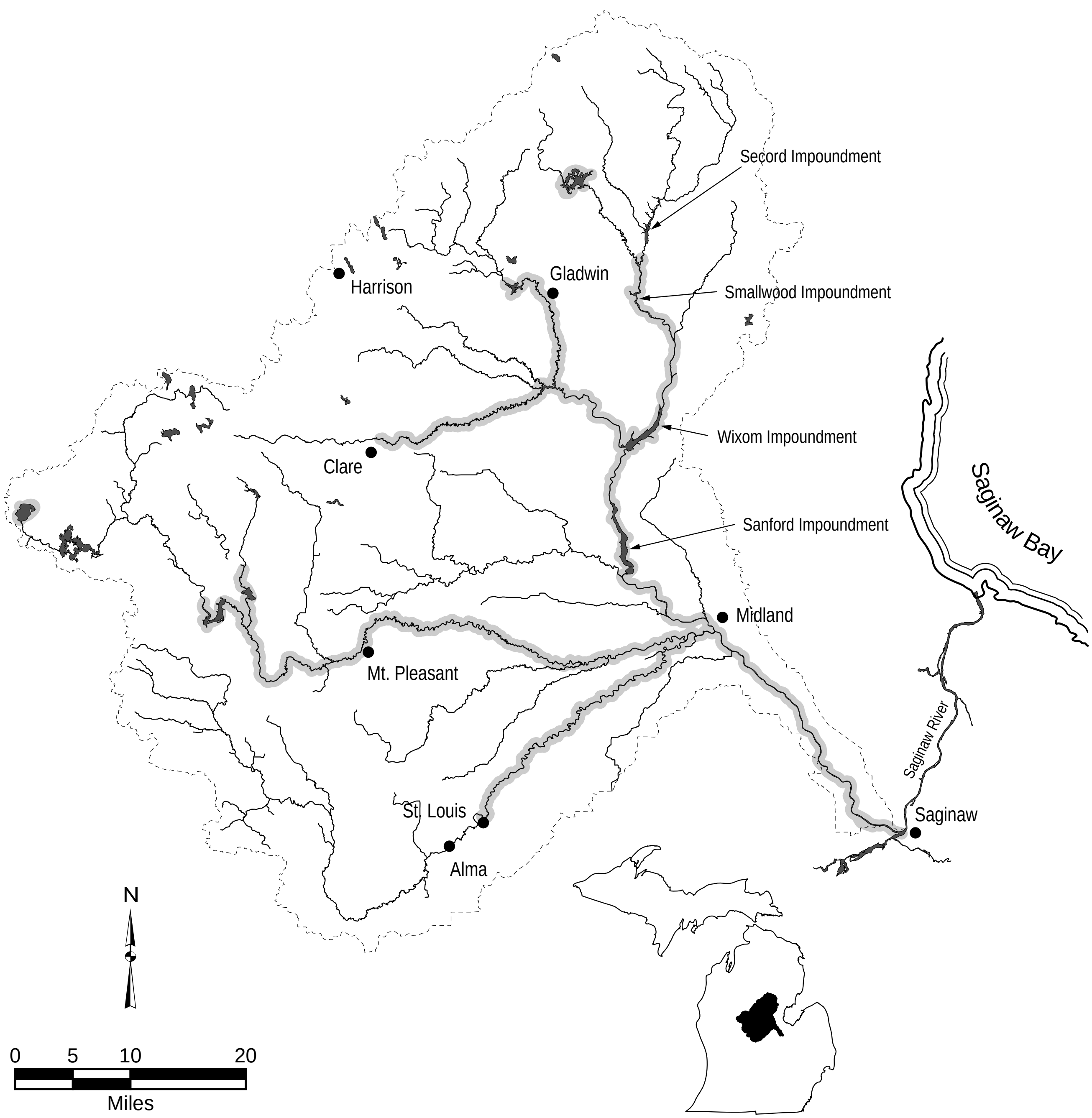
Walleye *Sander vitreus*

Habitat**:**

feeding - larger, deeper streams and in large, shallow, turbid lakes and impoundments; also Lake Huron
- gravel, bedrock, and firm substrates preferred
- does not tolerate a lot of turbidity or low oxygen

spawning - rocky substrates in high gradient water in rivers
- boulder to coarse gravel shoals in lakes

winter refuge - avoids strong currents

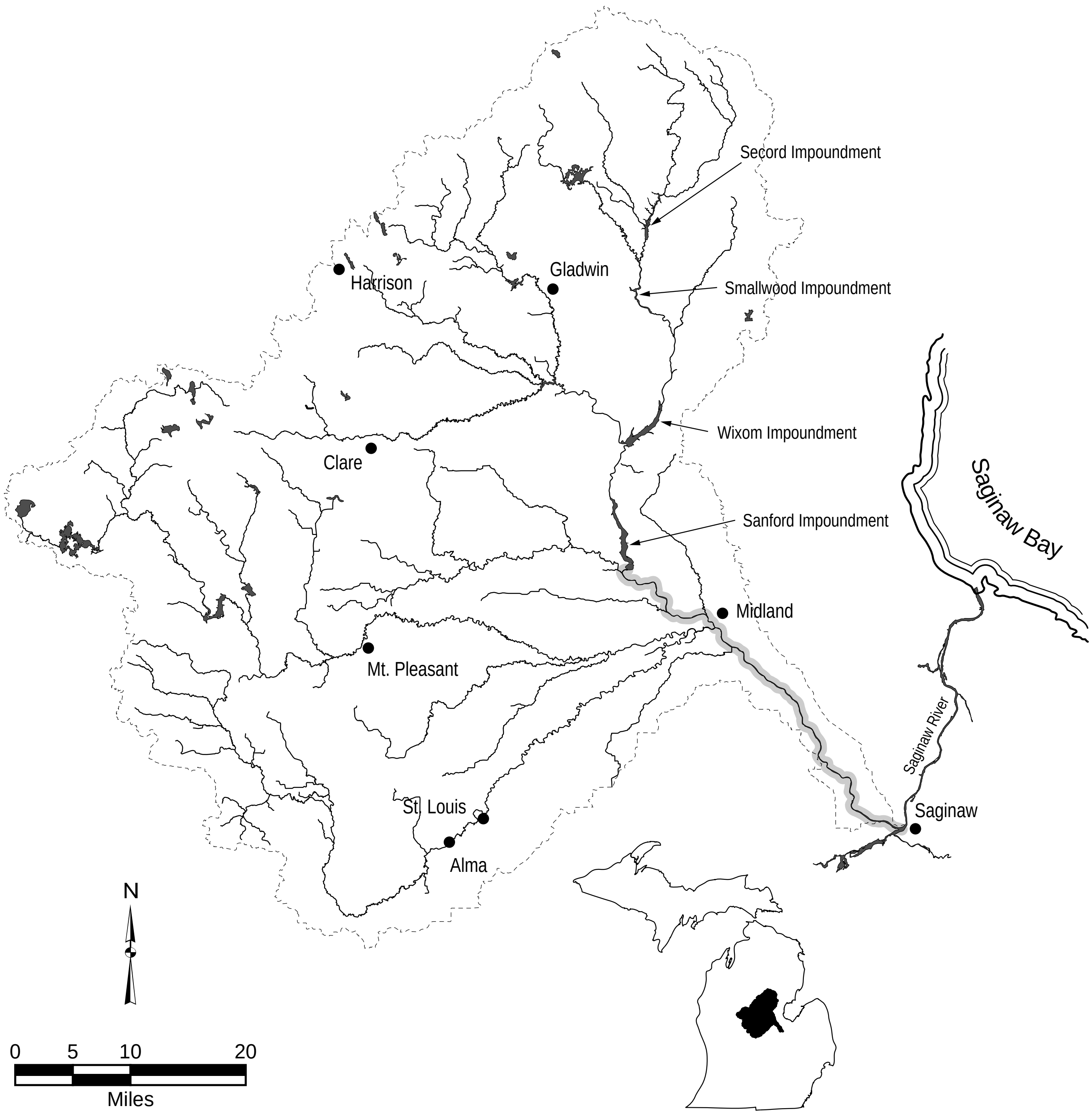


Freshwater drum *Aplodinotus grunniens*

Habitat**:**

feeding - deeper pools of rivers and Lake Huron
- in shallows
- prefers clear waters and clean substrates
- can adapt to high turbidity levels

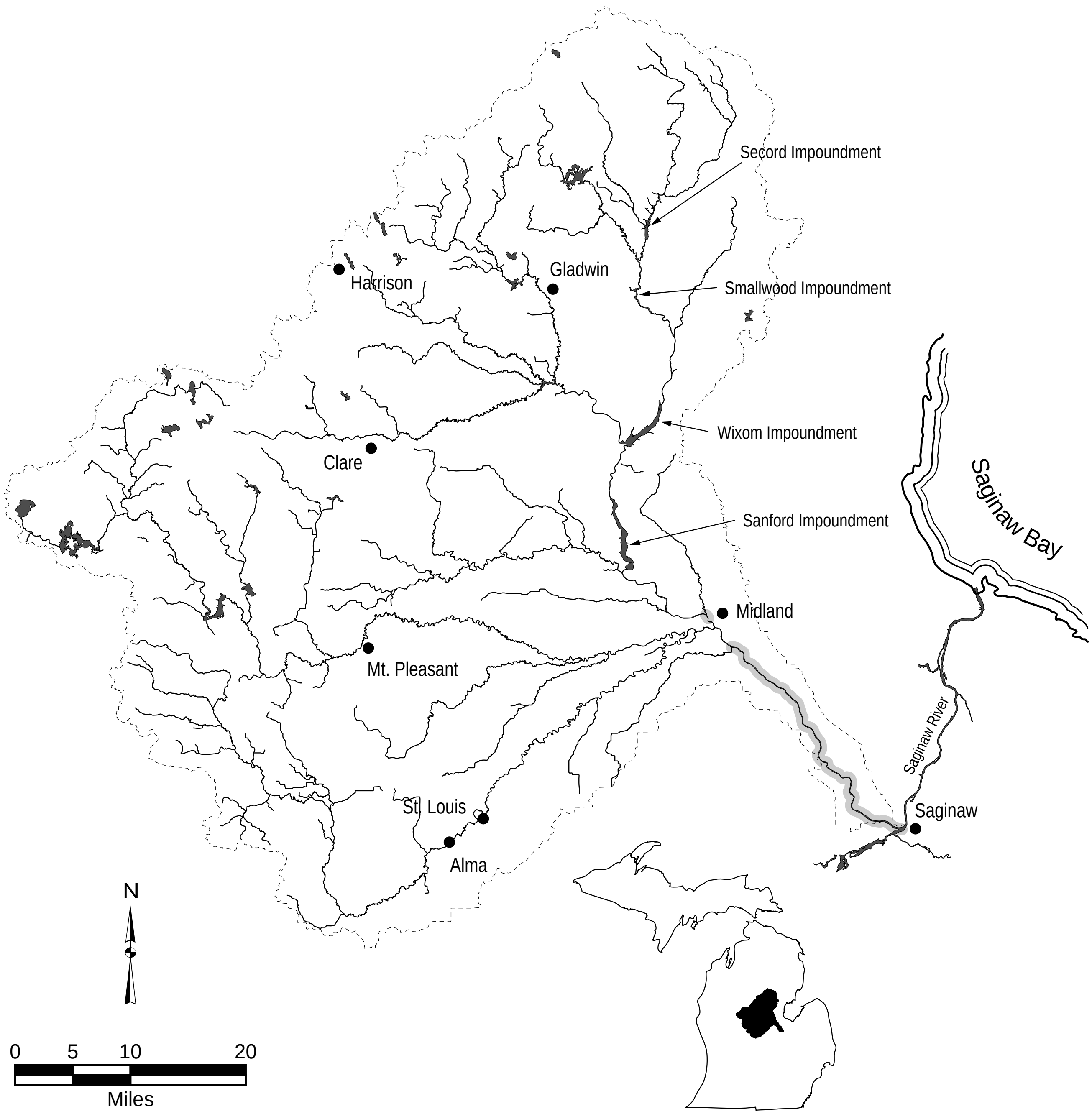
spawning - pelagically, in open water, over sand or mud substrate
- occurs in bays or lower portions of marshes



Round goby *Neogobius melanostomus* - **non-native species**

Habitat**:**

feeding	-	rock, cobble, riprap, and vegetate areas of rivers and lakes
	-	young found over sand substrate
spawning	-	rocky substrate with large interstitial spaces
winter refuge	-	rocky substrate with large interstitial spaces
	-	deep water



Appendix D

Miscellaneous angler survey data collected from 1928 to 1967 for the Tittabawassee River, its tributaries, and watershed lakes.

Miscellaneous angler survey results are presented in tables D.1 through D.7. These results include angler diary data (Table D.1), complemented surveys using counts and angler interviews (Table D.2), and counts of ice fishing shanties at various locations (tables D.3 through D.7).

Estimated catch rate and mean length of harvested fish are presented in tables D.8, D.10 through D.32 for rivers; and D.33, D.35 through D.50 for lakes. Multiple tables were necessary to accommodate the diverse fisheries found within the watershed. Table D.9 notes creel data by subwatershed, river, and time period, which are found in tables D.10 through D.32. Similarly, Table D.34 notes creel data by subwatershed, lake, and time period, which are found in tables D.35 through D.50.

Data presented in tables D.8 through D.50 are from the General Creel Census and were collected by MDNR conservation officers as they performed their normal duties (Ryckman 1981, Lockwood 2000). Limitations of these data must be clearly understood. While this data collection program was referred to as the General Creel Census, these angler survey data do not represent a true census (i.e., not every member of the population is sampled (Everitt 1998)), rather they are a subsample of the angling population at a given site at a given time. While these data provide historical evidence of species presence, they were not collected following traditional random sampling designs and are correctly referred to as convenience samples (Pollock et al. 1994). Originally, interview records were recorded by angler or angling party. Daily summaries were then prepared for each lake or river site. These daily summaries then contain the catch and effort information for one or multiple anglers. The original interview records have been discarded. As a result, variation between angler and angler party cannot be estimated. Variation (1 Standard Error) reported here is between days. Summaries of these interviews are archived at the Institute for Fisheries Research, Ann Arbor, MI.

Estimated catch rates presented in tables D.8, D.10 through D.32, D.33, and D.35 through D.50 were calculated using the ratio-of-means estimator. Specific formulae for estimating catch rate and catch rate Standard Error (SE) are given in Lockwood et al. (1999). Weighted mean length $\overline{L}$ for species *s* was estimated as:

$$\overline{L}_s = \frac{\sum_{i=1}^{N} L_{si} C_{si}}{\sum_{i=1}^{n} C_{si}},$$

for *C* fish caught on day *i* and *N* days sampled. Standard Error *SE* of $\overline{L}$ for species *s*

was estimated as:

$$SE_s = \sqrt{\frac{\sum_{i=1}^{N} \left(L_{si} - \overline{L}_s\right)^2 C_{si}}{\left(\sum_{i=1}^{N} C_{si}\right)\left(\left[\sum_{i=1}^{N} C_{si}\right] - 1\right)}}.$$

References

Everitt, B. S. 1998. The Cambridge dictionary of statistics. Cambridge University Press, New York.

Lockwood, R. N. 2000. Conducting roving and access site angler surveys. Chapter 14 *in* Schneider, James C. (editor) 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Lockwood, R. N., D. M. Benjamin, and J. R. Bence. 1999. Estimating angling effort and catch from Michigan roving and access site angler survey data. Michigan Department of Natural Resources, Fisheries Research Report 2044, Ann Arbor.

Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society Special Publication 25.

Ryckman, J. R. 1981. Creel census methods in general. Appendix VI-A-9 *in* J. W. Merna, J. C. Schneider, G. R. Alexander, W. D. Alward and R. L. Eschenroder, editors. Manual of fisheries survey methods. Fisheries Management Report No. 9, Michigan Department of Natural Resources, Lansing.

Table D.1.–Diary angler creel data collected during spring and summer 1948. Estimates are given with 1 standard error in parentheses.

River	No. Anglers	Hours	Records	Catch per hour Brook Trout
Tittabawassee	6	30.0	3	0.30 (0.14)

Table D.2.–Rainbow trout angler survey conducted during winter 1959–60. These estimates are from an April 7, 1960 letter from Max A. Hunt to M. J. DeBoar (Fisheries Division files). Confidence limits are given in parentheses. No definition for confidence limits was given in this letter. Typically, confidence limits (error bounds) are 2 standard errors, which represent 75–95% confidence limits. Rainbow trout catch is assumed to be harvest. Missing confidence limits are given as (–).

Subwatershed	Lake	Hours per trip	Angler hours	Angler trips	Rainbow trout Harvest	Rainbow trout Catch per hour
Main stem-headwaters	George	2.39 (–)	1,437 (230)	601 (106)	391 (109)	0.27 (–)
Tobacco River	Arnold	3.33 (–)	3,016 (–)	906 (158)	14 (11)	<0.01 (–)
Chippewa River	Littlefield	3.13 (–)	4,601 (–)	1,470	85	0.02 (–)

Table D.3.–Counts of ice fishing shanties by subwatershed for year 1962. All counts were made on February 12, 1962 and only one count was made per lake. Count data were retrieved from letters in Fisheries Division files and these letters did not specify if counts were of occupied shanties or of all shanties present on a lake (occupied and unoccupied shanties).

Subwatershed	Lake	Number of shanties
Main stem-headwaters	Elk	16
	Four	7
Main stem-middle	Sanford	147
	Secord	19
	Smallwood	13
	Wixom	201
Tobacco River	Arnold	14
	Budd	34
	Cranberry	1
	Five	41
	Little Long	0 [1]
	McGilvery	1
	Pratt	28
	Ross	0 [1]
	Sutherland	0
	Thirteen	9
	Wiggins	33
Chippewa River	Coldwater	52
	Eight Point	5
	Littlefield	14
	Stevenson	6

[1] Lake closed to fishing as result of chemical treatment.
[2] Pond was drawn down during year.

Table D.4.–Counts of ice fishing shanties by subwatershed for year 1963. All counts were made on February 15, 1963 and only one count was made per lake. Count data were retrieved from letters in Fisheries Division files and these letters did not specify if counts were of occupied shanties or of all shanties present on a lake (occupied and unoccupied shanties).

Subwatershed	Lake	Number of shanties
Main stem-headwaters	Elk	9
	Four	4
	Indian	1
Main stem-middle	Sanford	168
	Secord	23
	Smallwood	12
	Wixom	272
Tobacco River	Arnold	7
	Bertha	0
	Budd	40
	Cranberry	4
	Dodge	1
	Five	32
	Little Long	0 [1]
	McGilvery	1
	Pratt	49
	Ross	3
	Sutherland	6
	Thirteen	10
	Wiggins	0 [2]
Chippewa River	Coldwater	40
	Big Mud	0
	Eight Point	7
	Littlefield	33
	Perch	1
	Stevenson	10
Pine River	Halls	0

[1] Lake closed to fishing as a result of chemical treatment.
[2] Lake chemically treated, fall, 1962.

Table D.5.–Counts of ice fishing shanties by subwatershed for year 1965. All counts were made on February 19, 1965 and only one count was made per lake. Count data were retrieved from letters in Fisheries Division files and these letters did not specify if counts were of occupied shanties or of all shanties present on a lake (occupied and unoccupied shanties).

Subwatershed	Lake	Number of shanties
Main stem-headwaters	Elk	6
	Four	6
	Indian	1
Main stem-middle	Sanford	111
	Secord	13
	Smallwood [1]	1
	Smallwood [2]	5
	Wixom	189
Tobacco River	Arnold	6
	Bertha	0
	Budd	42
	Cranberry	9
	Deer	1
	Dodge	3
	Five	15
	Little Long	0
	McGilvery	3
	Pratts	41
	Ross	1
	Sutherland	5
	Thirteen	39
	Wiggins	7
Chippewa River	Big Mud	3
	Coldwater	13
	Eight Point	13
	Littlefield	47
	Stevenson	8
	Townline	0
Pine River	Halls	6

[1] South of Highway 61.
[2] North of Highway 61.

Table D.6.–Counts of ice fishing shanties by subwatershed for year 1966. All counts were made on February 15, 1966 and only one count was made per lake. Count data were retrieved from letters in Fisheries Division files and these letters did not specify if counts were of occupied shanties or of all shanties present on a lake (occupied and unoccupied shanties).

Subwatershed	Lake	Number of shanties
Main stem-headwaters	Elk	2
	Four	7
	Indian	0
Main stem-middle	Sanford	102
	Secord	5
	Smallwood [1]	2
	Smallwood [2]	2
	Wixom	118
Tobacco River	Arnold	11
	Bertha	0
	Budd	34
	Cranberry	3
	Deer	0
	Dodge	3
	Five	23
	Little Long	0
	McGilvery	0
	Pratts	32
	Ross	1
	Sutherland	1
	Thirteen	12
	Wiggins	3
Chippewa River	Big Cranberry	1
	Chippewa	51
	Coldwater	19
	Diamond	1
	Eight Point	10
	Littlefield	23
	Perch	1
	Pretty	4
	Stevenson	16
	Townline	4
Pine River	Halls	2

[1] South of Highway 61.
[2] North of Highway 61.

Table D.7.–Counts of ice fishing shanties by subwatershed for year 1967. All counts were made on February 21, 1967 and only one count was made per lake. Count data were retrieved from letters in Fisheries Division files and these letters did not specify if counts were of occupied shanties or of all shanties present on a lake (occupied and unoccupied shanties).

Subwatershed	Lake	Number of shanties
Main stem-headwaters	Elk	7
	Four	9
	Indian	1
Main stem-middle	Sanford	123
	Secord	3
	Smallwood [1]	2
	Smallwood [2]	0
	Wixom	165
Tobacco River	Arnold	15
	Bertha	0
	Budd	35
	Cranberry	2
	Deer	1
	Dodge	4
	Five	31
	Little Long	7
	McGilvery	1
	Pratts	48
	Ross	1
	Sutherland	3
	Thirteen	14
	Wiggins	1
Chippewa River	Big Cranberry	2
	Big Mud	0
	Chippewa	35
	Coldwater	26
	Diamond	0
	Eight Point	8
	Littlefield	24
	Perch	2
	Pretty	5
	Stevenson	23
	Townline	1
Pine River	Halls	8

[1] South of Highway 61.
[2] North of Highway 61.

Table D.8.–Direct contact lake angler creel data for the Tittabawassee River headwaters. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

				Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Yellow perch		Northern pike		Bullhead sp.		Sucker sp.	
River/Creek	Year	Total hours	Days (N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Chatman	1928	26.0	7									0.27 (0.14)	11.67 (0.67)	0.08 (0.08)				0.54 (0.56)				0.38 (0.30)	21.50 (0.00)				
Elk Lake	1937	3.5	2																								
	1945	4.0	1																								
Spring	1928	5.0	1	2.20 (–)	8.00 (–)																						
	1929	38.0	10	1.84 (0.41)	7.87 (0.04)			0.05 (0.03)	8.00 (0.50)																		
	1930	24.0	9	2.21 (0.56)	7.62 (0.16)																						
	1931	10.0	6	0.90 (0.60)	7.56 (0.18)																						
	1933	34.0	7	1.09 (0.16)	8.28 (0.06)																						
	1934	3.0	2																								
	1938	7.5	2																								
	1944	3.0	1					0.33 (–)	10.00 (–)																		
	1948	17.5	4	1.20 (0.59)																							
	1949	20.3	3	0.84 (0.14)																							
Spring	1953	10.0	1	0.10 (–)																							
	1955	10.0	1	1.30 (–)																							
	1956	9.0	1	0.33 (–)																							

Table D.8.–Continued.

River/Creek	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Brown trout AL	Rainbow trout CPE	Rainbow trout AL	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Bullhead sp. AL	Sucker sp. CPE	Sucker sp. AL
	1959	4.0	1	0.75 (–)																							
	1960	41.0	1	0.66 (–)																							
	1961	6.0	1																								
Tittabawassee, East Br.	1928	8.0	2	1.88 (0.41)	8.00 (0.00)																						
	1929	45.5	7	0.76 (0.41)	8.37 (0.03)																	0.02 (–)					
	1930	63.0	22	0.03 (0.03)						0.11 (0.07)				0.03 (0.02)		0.05 (0.03)				0.90 (0.30)	7.87 (0.09)	0.11 (0.05)	19.67 (2.33)				
	1932	28.0	7									0.11 (0.11)	14.00 (0.00)	1.14 (0.66)		0.39 (0.29)		0.14 (0.09)		1.11 (0.47)		0.07 (0.07)					
	1933	43.0	10	0.05 (0.04)						0.12 (0.08)				0.35 (0.23)	7.00 (0.00)	0.09 (0.09)		0.26 (0.20)		0.23 (0.12)		0.02 (0.02)		0.30 (0.24)			
	1934	50.8	13									0.10 (0.10)		0.59 (0.33)	7.00 (0.00)	0.14 (0.10)				0.04 (0.04)		0.20 (0.08)	22.67 (0.42)	0.06 (0.06)	8.00 (0.00)	0.02 (0.02)	
	1935	1.0	1	1.00 (–)	10.00 (–)																						
	1937	23.0	1	0.78 (–)	8.50 (–)																						
Tittabawassee, East Br.	1939	5.0	1															1.00 (–)	7.00 (–)								
	1940	8.5	2											0.24 (0.06)	7.00 (0.00)												
	1941	70.5	3							0.03 (0.05)	14.00 (0.00)			0.91 (0.13)	7.40 (0.00)			0.01 (0.00)	7.00 (–)			0.03 (0.02)	21.50 (1.50)	0.13 (0.02)	12.00 (0.00)		
	1945	2.0	1	1.50 (–)	9.00 (–)			0.50 (–)	10.00 (–)																		
	1948	3.0	1	1.00 (–)																							
	1959	8.0	2					0.25 (0.06)										0.25 (0.44)		0.38 (0.66)							

Table D.8.–Continued.

River/Creek	Year	Total hours	Days (N)	Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Yellow perch		Northern pike		Bullhead sp.		Sucker sp.	
				CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Tittabawassee, Middle Br.	1928	1.0	1																								
	1929	2.0	1	2.00 (–)	10.00 (–)																						
	1930	5.0	1	0.80 (–)	9.00 (–)			0.40 (–)	9.00 (–)																		
	1933	28.5	8							0.11 (0.09)				0.67 (0.38)	7.00 (0.00)			0.07 (0.07)				0.04 (0.03)					
	1934	5.5	3	0.91 (0.55)	7.90 (0.37)	0.18 (0.20)	9.00 (–)																				
	1948	1.0	1	2.00 (–)																							
	1949	8.0	2															0.75 (0.56)	8.50 (0.00)								
	1959	1.5	1																								
Tittabawassee, West Br.	1929	37.5	9	0.64 (0.21)	8.08 (0.08)																						
	1930	40.8	13	0.49 (0.17)	7.83 (0.07)					0.07 (0.08)	13.00 (0.00)											0.05 (0.04)					
	1931	15.5	10	0.45 (0.19)	7.71 (0.18)																						
	1932	41.5	7	0.05 (0.07)	9.00 (0.00)																						
	1933	101.0	30									0.02 (0.02)		0.73 (0.25)		0.09 (0.05)		0.46 (0.11)		0.64 (0.18)		0.07 (0.04)	24.50 (0.67)	0.11 (0.07)		0.05 (0.05)	
	1934	52.5	13									0.06 (0.06)	12.50 (0.00)					0.34 (0.17)		0.17 (0.12)		0.02 (0.02)	20.00 (–)	0.08 (0.08)		0.06 (0.04)	
	1937	2.3	2																								
	1940	24.0	15															0.25 (0.25)	8.00 (0.00)			0.25 (0.12)	24.33 (1.32)				
	1942	161.5	6							0.03 (0.03)	12.00 (0.00)	0.01 (0.01)	15.00 (–)	0.01 (0.00)	6.00 (–)			0.06 (0.06)	7.00 (0.00)			0.02 (0.01)	19.50 (0.50)				

Table D.8.–Continued.

		Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Yellow perch		Northern pike		Bullhead sp.		Sucker sp.	
River/Creek	Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
	1954	2.0	1																								
	1955	43.5	3	1.20 (0.11)		0.46 (0.10)																					
	1956	55.0	3	0.09 (0.08)																							
	1957	45.0	1	0.16 (–)		0.09 (–)		1.22 (–)																			
	1958	2.0	1																								
Tittabawassee, West Br.	1959	25.0	3	0.20 (0.07)																							
	1962	6.0	1																							1.67 (–)	

Table D.9.–To accommodate all species, creel data on the additional rivers within the Tittabawassee River subwatersheds have been separated into a series of tables. Tables 3–25 contain creel data for the subwatersheds, rivers, and time periods listed below.

Sub-watershed	River/creek	Years	Table
Main stem-headwaters	Black	1941–50, 1952–64	3
	Larrabee Lake	1935, 1937	4
	Little Molasses	1935, 1958	4
	Little Tobacco	1929–30, 1934–35, 1937, 1942, 1948, 1952, 1956–59	4
	Long Lake	1937	4
	Molasses	1934–35, 1952, 1957, 1960	4
	Sugar	1929–30, 1932–35, 1937, 1939–45, 1947–62	4
Main stem-middle	Tea	1934, 1954, 1957, 1959	5
	Tittabawassee	1928–39	6
	Tittabawassee	1940–43	7
	Tittabawassee	1944–49	8
	Tittabawassee	1950–59	9
	Tittabawassee	1960–64	10
	Varity	1943, 1946–50, 1953–64	11
Main stem-mouth	Tittabawassee	1945, 1948, 1954, 1956	12
Tobacco River	Bailey	1940	13
	Beaver	1950–51	13
	Black	1960	13
	Cedar	1929–33	13
	Cedar	1934–35	14
	Cedar	1937–48	15
	Cedar	1949–63	16
	Middle Br. Cedar	1933–34, 1939, 1953, 1955–58, 1962	17
	North Br. Cedar	1929–30, 1937, 1939, 1944, 1947, 1957, 1962	17
	West Br. Cedar	1928–29, 1933–34, 1938, 1940, 1944, 1946–51, 1955–62	17
	Elm	1930, 1935, 1948, 1956, 1958	17
	Five Lakes	1938	17
	Jose	1956	17
	McCurran	1948	17
	Popple	1933, 1949	17
	Sanford	1951	17
	Spike Horn	1937, 1940	17
	Tobacco	1929–30, 1932–35, 1937–40	18
	Tobacco	1941–46	19
	Tobacco	1947–64	20
	Middle Br. Tobacco	1929, 1934–35, 1939, 1945–46, 1948, 1950–51, 1953, 1955, 1957–61, 1963	21
	North Br. Tobacco	1928–30, 1932–35, 1937–38, 1943–48, 1950–55, 1957–62	22
	South Br. Tobacco	1929–30, 1933–35, 1939, 1945, 1948	23
	South Br. Tobacco	1950–60	24
	West Br. Tobacco	1929, 1934–35	25

Table D.10.–Direct contact river angler creel data for the Tittabawassee River main stem-middle Black River. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

			Brook trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Carp	
Year	Total hours	Days (N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1941	28	2													0.21 (0.11)	7.00 (0.00)										
1942	280	6			0.01 (0.01)	13.00 (0.00)	0.01 (0.01)	13.50 (0.50)	0.54 (0.11)	6.95 (0.01)	0.04 (0.04)	7.00 (0.00)			0.29 (0.03)	7.00 (0.00)										
1943	39	1											0.03 (–)	9.00 (–)	2.79 (–)	8.00 (0.00)	0.38 (–)	8.00 (0.00)								
1944	347.5	5			0.01 (<0.01)	12.00 (0.00)			1.19 (0.14)	7.49 (0.02)	0.05 (0.04)	7.31 (0.09)			0.15 (0.05)	7.96 (0.04)	0.03 (0.01)	6.64 (0.18)			<0.01 (<0.01)	26.00 (–)				
1945	45	4	<0.01 (<0.01)		0.04 (0.03)	12.00 (0.00)			0.33 (0.14)	7.73 (0.12)					0.18 (0.10)	7.38 (0.38)										
1946	394	20			<0.01 (<0.01)	13.00 (–)			0.12 (0.06)	6.19 (0.05)			0.01 (<0.01)	7.00 (1.00)	0.17 (0.07)	7.15 (0.04)	<0.01 (<0.01)	7.00 (–)	0.01 (0.01)	28.00 (0.00)	0.01 (0.01)	20.00 (0.00)				
1947	159.5	12							0.56 (0.17)		0.01 (0.01)				0.04 (0.02)						0.01 (0.01)					
1948	276	14			0.03 (0.02)				0.11 (0.04)				0.01 (0.01)		0.47 (0.11)						0.01 (0.01)				<0.01 (<0.01)	
1949	715	23							0.01 (0.01)				0.06 (0.02)		0.37 (0.08)		0.06 (0.02)		<0.01 (<0.01)		0.01 (<0.01)					
1950	306	20							0.12 (0.05)						2.55 (0.31)		0.67 (0.11)		<0.01 (<0.01)		0.02 (0.01)					
1952	39	2							0.49 (0.62)						1.03 (0.96)		0.15 (0.01)									
1953	75	6									0.23 (0.10)				3.88 (1.43)		0.29 (0.13)				0.05 (0.04)					
1954	404	31			<0.01 (<0.01)		0.01 (0.01)		0.20 (0.05)		0.02 (0.01)		<0.01 (<0.01)		1.18 (0.19)		0.04 (0.01)				0.01 (0.01)					
1955	118	17							0.25 (0.09)		0.05 (0.05)				0.36 (0.15)		0.02 (0.01)				0.03 (0.02)					
1956	182	18			0.01 (0.01)				0.10 (0.04)		0.01 (0.01)				1.38 (0.39)		0.01 (0.01)				0.01 (0.01)		0.11 (0.10)			
1957	292	24							0.20 (0.10)		<0.01 (<0.01)				0.82 (0.19)		0.01 (0.01)				0.01 (<0.01)					
1958	299	15			0.02 (0.01)		0.03 (0.03)		0.14 (0.07)		0.01 (0.01)		0.01 (0.01)		0.91 (0.36)		0.01 (0.01)				0.01 (0.01)		<0.01 (<0.01)			
1959	167	9							0.17 (0.12)		0.01 (0.01)		0.02 (0.01)		0.44 (0.12)		0.02 (0.01)									

Table D.10.–Continued.

	Total	Days	Brook trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Carp	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1960	182	13					0.01		0.12		0.03		0.27		0.40		0.07				0.01					
							(0.01)		(0.05)		(0.02)		(0.22)		(0.19)		(0.04)				(0.01)					
1961	122	13							0.02		0.04				1.79		0.46									
									(0.02)		(0.04)				(0.48)		(0.13)									
1962	147	10							0.03				0.01		0.75		0.11									
									(0.02)				(0.01)		(0.31)		(0.06)									
1963	57	6											0.04		3.68		0.07									
													(0.04)		(0.95)		(0.06)									
1964	11	1																								

Table D.11.–Direct contact river angler creel data for the Tittabawassee River main stem-middle Larrabee Lake, Little Molasses, Little Tobacco, Long Lake, Molasses, and Sugar rivers. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

		Total	Days	Brook trout		Brown trout		Rainbow trout		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Northern pike		Bullhead sp.		Carp		Suckers sp.	
River/Creek	Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Larrabee Lake	1935	4	2											1.50 (1.50)	7.00 (0.00)	2.75 (2.75)	7.50 (0.00)										
	1937	2.25	1																								
Little Molasses	1935	1.5	1	0.67 (–)	17.25 (–)																						
	1958	1	1																	1.00 (–)						1.00 (–)	
Little Tobacco	1929	9.5	4																	0.11 (0.12)	24.00 (–)						
	1930	25.5	10															0.20 (0.18)		0.20 (0.06)	20.00 (2.00)						
	1934	13	2																	0.08 (0.07)	20.00 (–)						
	1935	3	5													1.33 (0.77)	8.00 (0.00)										
	1937	6	5											0.17 (0.18)	7.00 (–)	0.17 (0.18)	8.00 (–)			0.17 (0.16)	26.00 (–)	0.17 (0.18)	9.00 (–)			0.17 (0.18)	20.00 (–)
	1942	6	1													0.50 (–)	7.00 (–)										
	1948	1	1													1.00 (–)											
	1952	16	2													0.06 (0.09)				0.13 (0.06)							
	1956	11	3							0.73 (0.50)						0.09 (0.06)		0.36 (0.25)				0.36 (0.45)		0.09 (0.10)			
	1957	7	3							0.14 (0.15)																	
	1958	10	2							2.30 (0.32)		0.20 (0.32)				1.20 (0.48)		0.50 (0.20)									
	1959	8	2							0.13 (0.22)						2.00 (0.25)											
Long Lake	1937	11.75	2	0.34 (0.17)	7.38 (0.07)																						
Molasses	1934	4	1											3.00 (–)				1.50 (–)						0.25 (–)			
	1935	2.5	1											1.20 (–)				0.80 (–)								1.20 (–)	

Table D.11.–Continued.

		Total	Days	Brook trout		Brown trout		Rainbow trout		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Northern pike		Bullhead sp.		Carp		Suckers sp.	
River/Creek	Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Molasses	1952	1	1																								
	1957	2	1																								
	1960	1	1																								
	1929	199.5	34	0.21 (0.06)	7.40 (0.06)																						
	1930	68.25	16	0.59 (0.16)	7.41 (0.04)																						
	1932	64	13	0.58 (0.13)	7.81 (0.09)																						
	1933	108	27	0.53 (0.14)	8.24 (0.07)			0.06 (0.04)	8.25 (1.25)					0.04 (0.04)				0.05 (0.05)				0.02 (0.02)				0.07 (0.07)	
	1934	47	9	0.34 (0.16)	8.84 (0.43)	0.02 (0.02)	13.00 (–)																				
	1935	249.25	71	0.43 (0.09)	7.94 (0.04)			<0.01 (<0.01)	8.00 (–)																		
	1937	230.75	56	0.15 (0.04)	7.75 (0.13)	<0.01 (<0.01)	10.00 (–)											<0.01 (<0.01)	6.50 (–)	<0.01 (<0.01)	25.00 (–)						
	1939	8	2	1.00 (0.25)	8.00 (0.38)																						
	1940	117.25	34	1.01 (0.28)	7.58 (0.06)	0.01 (0.01)	10.00 (–)																				
	1941	143	1			0.01 (–)	14.00 (0.00)	0.01 (–)	12.00 (–)																	0.02 (–)	
	1942	5	2	1.00 (<0.01)	7.80 (0.20)			0.40 (0.16)	8.00 (0.00)																		
	1943	174.5	6	0.15 (0.07)	8.11 (0.11)																						
	1944	251	7	0.98 (0.25)	8.98 (0.01)																						
	1945	212.5	6	0.47 (0.09)	8.00 (0.00)	<0.01 (<0.01)	9.00 (–)	<0.01 (<0.01)	9.00 (–)																		
	1947	240	1	0.60 (–)		0.03 (–)																					
	1948	676.5	8	0.75 (0.13)		0.08 (0.01)																					
	1949	22	4	0.68 (0.08)		0.09 (0.10)		0.14 (0.12)																			
	1950	16	1	0.13 (–)																							

Table D.11.–Continued.

		Total	Days	Brook trout		Brown trout		Rainbow trout		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Northern pike		Bullhead sp.		Carp		Suckers sp.	
River/Creek	Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Molasses	1951	98	2	0.69	0.00																						
				(0.16)	(0.00)																						
	1952	65	4	0.54		0.03																					
				(0.08)		(0.02)																					
	1953	43	3	0.33		0.05																					
				(0.26)		(0.04)																					
	1954	87	5	0.48	0.00	0.10																					
				(0.32)	(0.00)	(0.06)																					
	1955	42	3	0.81		0.02																					
				(0.12)		(0.01)																					
	1956	63	4	0.79				0.02																			
				(0.11)				(0.02)																			
	1957	99	9	0.29	0.00	0.28	0.00																				
				(0.15)	(0.00)	(0.10)	(–)																				
	1958	160	12	0.94		0.48		0.01												0.01						0.01	
				(0.34)		(0.42)		(0.01)												(0.01)						(0.01)	
	1959	55	4	1.25																							
				(0.48)																							
	1960	29	3	0.79																							
				(0.07)																							
	1961	9	1			0.33																					
						(–)																					
	1962	12	2	<0.01																							
				(0.00)																							

Table D.12.–Direct contact river angler creel data for the Tittabawassee River main stem-middle Tea Creek. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

		Total	Days	Crappie sp.		Northern pike	
River/Creek	Year	hours	(N)	CPE	AL	CPE	AL
Tea	1934	2	1			5.50 (–)	25.00 (0.00)
	1954	2	1				
	1957	2	1	1.50 (–)			
	1959	3	1				

Table D.13.–Direct contact river angler creel data for the Tittabawassee River main stem-middle 1928–39. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brook trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Carp		Suckers sp.	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1928	63	6																			0.16	21.60						
																					(0.06)	(0.70)						
1929	629	84			<0.01	12.00							<0.01				0.02	8.45			0.07	22.31						
					(<0.01)	(–)							(<0.01)				(0.01)	(0.21)			(0.02)	(0.49)						
1930	511.75	122			0.01				0.02		<0.01		<0.01		<0.01		0.17	8.86			0.12	22.13	0.17	8.05				
					(0.01)				(0.01)		(<0.01)		(<0.01)		(<0.01)		(0.06)	(0.17)			(0.02)	(0.35)	(0.08)	(0.20)				
1931	31	8	0.81		0.71												2.48		0.13		0.29	25.00						
			(0.45)		(0.39)												(0.94)		(0.13)		(0.12)	(0.00)						
1932	117	26			0.09	14.00	0.03		0.68		0.13		0.26				0.80	7.18			0.15	21.30	0.22					
					(0.04)	(0.00)	(0.02)		(0.23)		(0.07)		(0.09)				(0.23)	(0.25)			(0.04)	(0.94)	(0.13)					
1933	144.5	27									0.05		0.33	7.00			0.28	7.00			0.22	23.04	0.03		0.01			
											(0.05)		(0.16)	(0.00)			(0.12)	(0.00)			(0.07)	(0.47)	(0.04)		(0.01)			
1934	511.25	92											0.25	7.00	0.02	8.00	0.07				0.04	27.79	0.03	7.00			0.01	18.00
													(0.06)	(0.00)	(0.01)	(0.00)	(0.02)				(0.01)	(1.51)	(0.02)	(0.00)			(0.01)	(0.00)
1935	498.75	181			0.01	10.92	0.01	11.50	0.07	6.93	0.01	6.50	0.28	7.44	0.33	7.37	0.07	7.00	<0.01	18.00	0.02	19.83	0.08	8.39	<0.01	10.00	0.03	12.13
					(0.01)	(0.27)	(0.01)	(0.50)	(0.04)	(0.05)	(0.01)	(0.00)	(0.08)	(0.05)	(0.09)	(0.07)	(0.02)	(–)	(<0.01)	(–)	(0.01)	(1.66)	(0.03)	(0.09)	(<0.01)	(–)	(0.03)	(0.13)
1936	235.5	90					<0.01		<0.01	7.00			0.06	7.14	3.16	7.70	0.06	7.33			<0.01		0.03		0.01		0.11	16.56
							(<0.01)		(<0.01)	(–)			(0.02)	(0.32)	(0.38)	(0.02)	(0.03)	(0.13)					(<0.01)		(0.01)		(0.04)	(0.13)
1937	290.5	128			<0.01		0.01						0.11		0.98	7.39	0.03	7.25	<0.01	20.00	0.01	23.00	0.04	7.95			<0.01	18.00
					(<0.01)		(<0.01)						(0.04)		(0.18)	(0.04)	(0.02)	(0.11)	(<0.01)	(–)	(0.01)	(1.00)	(0.03)	(0.05)			(<0.01)	(–)
1938	12	2	<0.01						0.42	7.00											0.17	17.50						
			(<0.01)						(0.42)	(0.00)											(0.17)	(0.00)						
1939	567	161			0.02	12.00	<0.01	15.00	0.12	6.90	0.02	7.78	0.10	7.52	0.65	7.97	0.03	7.50	<0.01	17.00	0.03	18.42	0.01	10.00	0.02	17.60		
					(0.01)	(0.00)	(<0.01)	(0.00)	(0.07)	(0.05)	(0.01)	(0.22)	(0.02)	(0.08)	(0.14)	(0.02)	(0.01)	(0.16)	(<0.01)	(–)	(0.01)	(1.01)	(0.01)	(0.00)	(0.01)	(0.72)		

Table D.14.–Direct contact river angler creel data for the Tittabawassee River main stem-middle 1940–43. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

Year	Total hours	Days (N)	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Bullhead sp. AL	Carp CPE	Carp AL	Sucker sp. CPE	Sucker sp. AL	Bowfin CPE	Bowfin AL
1940	930.5	358	<0.01	10.33			0.08	6.72	<0.01	7.00	0.12	7.50	1.67	7.23	0.02	7.80	0.02	24.57	<0.01	10.17					<0.01	19.00
			(<0.01)	(0.33)			(0.04)	(0.03)	(<0.01)	(–)	(0.02)	(0.11)	(0.16)	(0.01)	(0.01)	(0.33)	(0.01)	(0.81)	(<0.01)	(0.17)					(<0.01)	(–)
1941	1011.5	26	0.03	11.75	<0.01	15.50	0.04	6.01	<0.01	6.00	0.03	7.67	0.41	7.93	0.02	7.85	0.01	22.33	<0.01	8.00	0.01	25.00	<0.01			
			(0.01)	(0.24)	(<0.01)	(0.00)	(0.02)	(0.01)	(<0.01)	(0.00)	(0.01)	(0.11)	(0.15)	(0.02)	(0.01)	(0.28)	(<0.01)	(1.82)	(<0.01)	(–)	(0.01)	(0.00)	(<0.01)			
1942	841.75	24	0.04	11.59	0.03	12.39	0.19	6.95	<0.01	7.00	0.01	7.60	0.12	7.04	0.02	7.43	0.02	25.11	0.01	9.00						
			(0.02)	(0.09)	(0.02)	(0.12)	(0.10)	(0.02)	(<0.01)	(–)	(0.01)	(0.00)	(0.05)	(0.06)	(0.01)	(0.12)	(0.01)	(0.99)	(<0.01)	(1.00)						
1943	735.5	20	0.02	12.50	<0.01	11.00	0.40	7.12	<0.01	6.50	<0.01	7.25	0.37	7.33	0.01	7.50	0.01	19.73								
			(0.01)	(0.26)	(<0.01)	(0.00)	(0.11)	(0.02)	(<0.01)	(0.00)	(<0.01)	(0.75)	(0.14)	(0.02)	(<0.01)	(0.29)	(0.01)	(1.04)								

Table D.15.–Direct contact river angler creel data for the Tittabawassee River main stem-middle 1944–49. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

Year	Total hours	Days (N)	Brown trout CPE	Brown trout AL	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Bullhead sp. AL	Carp CPE	Carp AL	Sucker sp. CPE	Sucker sp. AL
1944	843.5	33	<0.01	15.00	0.03	11.65	0.01	13.48	0.08	6.75	0.05	6.95	0.04	7.00	0.17	7.48	0.04	7.71	0.01	18.80	0.03	19.28	<0.01	10.00				
			(<0.01)	(0.00)	(0.01)	(0.21)	(0.01)	(0.87)	(0.04)	(0.06)	(0.03)	(0.03)	(0.02)	(0.08)	(0.08)	(0.04)	(0.02)	(0.16)	(<0.01)	(0.92)	(0.01)	(0.77)	(<0.01)	(–)				
1945	1575.25	83			0.03	13.15			0.08	6.66			0.01	8.35	0.73	8.14	0.05	8.18	<0.01	22.00	0.03	18.95	<0.01	11.00	<0.01	20.00		
					(0.02)	(0.15)			(0.04)	(0.03)			(0.01)	(0.25)	(0.21)	(0.01)	(0.02)	(0.09)	(<0.01)	(–)	(0.01)	(0.28)	(<0.01)	(–)	(<0.01)	(0.00)		
1946	308	13					<0.01	18.00	0.06	7.04					0.72	7.14	0.02	6.40			<0.01	18.00						
							(<0.01)	(–)	(0.05)	(0.02)					(0.15)	(0.02)	(0.01)	(0.24)			(<0.01)	(–)						
1947	1214.5	25							0.04				0.03		1.31		0.11		<0.01		0.01		0.01		<0.01		<0.01	
									(0.03)				(0.02)		(0.30)		(0.04)		(<0.01)		(0.01)		(0.01)		(<0.01)		(<0.01)	
1948	2499	69			0.01		0.01		0.12		<0.01		0.04		0.50		0.08		<0.01		0.03		<0.01		0.01			
					(<0.01)		(<0.01)		(0.03)		(<0.01)		(0.02)		(0.06)		(0.02)		(<0.01)		(0.01)		(<0.01)		(0.01)			
1949	2151.5	59			0.03		0.01		0.19		<0.01		0.06		0.90		0.09		<0.01		0.03		<0.01					
					(0.01)		(<0.01)		(0.04)		(<0.01)		(0.02)		(0.25)		(0.02)		(<0.01)		(0.01)		(<0.01)					

Table D.16.–Direct contact river angler creel data for the Tittabawassee River main stem-middle 1950–59. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brown trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Sucker sp.	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1950	403	16											<0.01 (<0.01)		1.81 (0.20)		0.12 (0.05)				0.02 (0.01)					
1951	236.5	17							0.01 (0.01)				0.21 (0.09)		2.00 (0.55)		0.16 (0.08)				<0.01 (<0.01)		<0.01 (<0.01)			
1952	390.5	24							0.18 (0.12)		0.01 (0.01)		0.01 (<0.01)		1.63 (0.49)		0.33 (0.25)				0.01 (0.01)		<0.01 (<0.01)			
1953	573.75	29			0.01 (<0.01)		0.01 (0.01)		0.13 (0.05)		0.04 (0.02)		0.07 (0.03)		1.65 (0.40)		0.28 (0.09)		<0.01 (<0.01)		0.05 (0.02)					
1954	152	10			0.02 (0.02)		0.02 (0.02)		0.11 (0.03)		0.02 (0.01)		0.01 (0.01)		1.48 (0.52)		0.07 (0.03)				0.02 (0.01)				0.18 (0.16)	
1955	1269	75			0.02 (<0.01)		0.01 (0.01)		0.10 (0.03)		0.03 (0.01)		0.04 (0.01)		1.04 (0.13)		0.14 (0.04)				0.01 (<0.01)		0.02 (0.01)		0.02 (0.01)	
1956	566	51			0.02 (0.01)		<0.01 (<0.01)		0.12 (0.05)		0.02 (0.01)		0.01 (<0.01)		1.36 (0.49)		0.06 (0.02)				0.01 (0.01)		<0.01 (<0.01)		0.02 (0.02)	
1957	755.5	44	<0.01 (<0.01)		0.04 (0.01)		0.01 (<0.01)		0.31 (0.08)		0.14 (0.04)		0.14 (0.05)		0.47 (0.09)		0.14 (0.05)				<0.01 (<0.01)					
1958	603	35			<0.01 (<0.01)		<0.01 (<0.01)		0.09 (0.03)		0.02 (0.01)		0.02 (0.01)		0.64 (0.17)		0.15 (0.07)		<0.01 (<0.01)		0.01 (<0.01)		<0.01 (<0.01)		0.02 (0.02)	
1959	349	14			<0.01 (<0.01)				0.06 (0.03)		0.04 (0.02)		0.04 (0.02)		1.80 (0.42)		0.06 (0.02)				0.01 (0.01)		0.01 (0.01)		0.01 (0.01)	

Table D.17.–Direct contact river angler creel data for the Tittabawassee River main stem-middle 1960–64. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brook trout		Brown trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Northern pike		Bullhead sp.		Sucker sp.	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1960	108	15					0.03 (0.02)		<0.01 (<0.01)		<0.01 (<0.01)		<0.01 (<0.01)		0.05 (0.04)		0.63 (0.24)		0.54 (0.32)		0.02 (0.01)		<0.01 (<0.01)			
1961	305.25	22					0.01 (0.01)				0.01 (0.01)		0.02 (0.01)		0.12 (0.05)		0.95 (0.41)		0.19 (0.06)		0.02 (0.01)				0.01 (0.01)	
1962	140	13					0.01 (0.01)				0.28 (0.14)		0.16 (0.14)		0.06 (0.03)		0.72 (0.22)		0.09 (0.04)		0.01 (0.01)					
1963	228	9	<0.01 (<0.01)		<0.01 (<0.01)						0.03 (0.03)	0.00 (0.00)	<0.01 (<0.01)		0.12 (0.09)		1.69 (0.56)		0.15 (0.09)		0.02 (0.01)					
1964	283	10					0.04 (0.04)				0.03 (0.02)		0.01 (0.01)		0.01 (0.01)		0.92 (0.76)		0.06 (0.03)							

Table D.18.–Direct contact river angler creel data for the Tittabawassee River main stem-middle Varity Creek. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

			Brook Trout		Smallmouth Bass		Largemouth Bass		Bluegill		Pumpkinseed Sunfish		Rock Bass		Crappie sp.		Yellow Perch		Walleye		Northern Pike		Bullhead sp.		Carp	
Year	Total hours	Days (N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1943	27.25	1													3.41 (–)	7.50 (0.00)										
1946	131.5	5			0.01 (0.01)	12.00 (–)									0.10 (0.09)	6.42 (0.01)					0.04 (0.02)	22.00 (0.00)				
1947	67	5													0.03 (0.03)		0.01 (0.01)									
1948	198	12			0.03 (0.02)				0.24 (0.10)				0.02 (0.01)		0.66 (0.17)		0.10 (0.09)				0.01 (<0.01)				0.01 (0.01)	
1949	147	7	<0.01 (<0.01)										0.01 (0.01)		0.21 (0.07)		0.01 (0.01)				0.02 (0.01)					
1950	218	13							0.10 (0.06)				<0.01 (<0.01)		2.19 (0.27)		0.41 (0.10)				<0.01 (<0.01)					
1953	70	5							0.24 (0.23)		0.23 (0.10)				3.30 (0.80)		0.49 (0.12)		0.01 (0.01)		0.07 (0.05)					
1954	261	15							0.13 (0.05)						2.23 (0.31)		0.02 (0.01)				<0.01 (<0.01)					
1955	75	15					0.01 (0.01)		0.16 (0.08)						0.49 (0.22)		0.08 (0.03)						0.05 (0.06)			
1956	200	15			0.01 (0.01)				0.06 (0.02)						0.56 (0.16)		0.04 (0.02)						0.13 (0.09)			
1957	152	14					0.01 (0.01)		0.03 (0.02)		0.03 (0.02)				0.78 (0.24)		0.04 (0.01)									
1958	201	11			0.00 (0.00)		0.01 (0.01)		0.02 (0.02)		0.00 (0.01)		<0.01 (0.01)		0.47 (0.16)		0.03 (0.02)				0.02 (0.01)					
1959	30	4							0.07 (0.06)		0.13 (0.13)				0.37 (0.18)		0.10 (0.05)									
1960	173	12							0.02 (0.02)		0.01 (0.01)		0.01 (0.01)		0.83 (0.30)		0.06 (0.03)									
1961	108	8											0.05 (0.05)		1.16 (0.35)		0.02 (0.02)									
1962	71	5							0.04 (0.04)		0.03 (0.03)				1.63 (1.04)		0.13 (0.06)				0.04 (0.03)					
1963	41	4													3.32 (1.11)		0.07 (0.09)									
1964	9	1													0.89 (–)											

Table D.19.–Direct contact river angler creel data for the Tittabawassee River main stem-mouth. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brown trout		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Northern pike		Bullhead sp.		Channel catfish	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1945	9	1																
1948	49	2	0.04 (<0.01)				0.27 (0.01)		0.08 (0.09)		0.04 (0.04)				0.04 (0.04)			
1954	31	2			0.06 (0.12)		0.10 (0.18)						0.03 (<0.00)				1.19 (0.15)	
1956	15	5					0.13 (0.13)											

Table D.20.–Direct contact river angler creel data for the Tobacco River subwatershed Bailey, Beaver, and Black creeks, and Cedar River 1929–33. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

River/Creek	Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass	Bluegill		Pumpkinseed sunfish		Yellow perch		Northern pike		Carp		Sucker sp.		Eastern sturgeon
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
Bailey																								
1940	2	1																				3.50 (–)	13.00 (–)	
Beaver																								
1950	7	4	0.43 (0.42)																					
1951	12	1																						
Black																								
1960	10	1																				2.00 (–)		
Cedar																								
1929	120.5	8	0.18 (0.10)	7.96 (0.05)	<0.00 (<0.00)		0.02 (0.01)	7.50 (0.00)				0.01 (0.01)	8.00 (–)	0.01 (0.01)	8.00 (–)	0.01 (0.01)	9.00 (–)	0.12 (0.07)	20.32 (0.07)	0.01 (0.01)	12.00 (–)			
1930	33.5	7	0.30 (0.12)	7.90 (0.23)			0.45 (0.28)	11.00 (0.00)	0.09 (0.10)	12.00 (0.00)	0.09 (0.08)							0.06 (0.04)	18.00 (–)					0.03 (0.03)
1931	36	6	0.44 (0.14)	7.94 (0.04)			0.75 (0.22)	7.94 (0.03)																
1932	303.5	82	0.58 (0.08)	9.02 (0.08)	0.29 (0.05)	10.51 (0.24)	1.37 (0.23)	9.42 (0.06)														0.07 (0.05)	20.91 (0.22)	
1933	45	6	0.24 (0.12)	8.50 (0.00)	0.13 (0.14)	9.00 (0.00)	0.18 (0.05)	8.00 (0.00)										0.02 (0.03)	20.00 (–)					

Table D.21.–Direct contact river angler creel data for the Tobacco River subwatershed Cedar River 1934–35. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass	Pumpkinseed sunfish	Rock bass	Crappie sp.		Yellow perch	Northern pike	Bullhead sp.		Sucker sp.		Redhorse sp.	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	CPE	CPE	AL	CPE	CPE	CPE	AL	CPE	AL	CPE	AL
1934	237.25	47	0.56 (0.11)	8.27 (0.05)	0.03 (0.03)	9.88 (0.08)	0.13 (0.06)	9.13 (0.18)	0.02 (0.01)	0.03 (0.02)	0.03 (0.03)	0.02 (0.02)		0.04 (0.02)	0.01 (0.01)	0.03 (0.02)		0.01 (0.01)		<0.00 (<0.00)	
1935	66	15	0.33 (0.19)	8.73 (0.10)			0.06 (0.04)	10.00 (0.00)				0.15 (0.08)	9.00 (0.00)			0.03 (0.02)	9.50 (0.50)	0.02 (0.01)	14.00 #DIV/0!	0.11 (0.08)	12.00 (0.00)

Table D.22.–Direct contact river angler creel data for the Tobacco River subwatershed Cedar River 1937–48. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

			Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Northern pike		Sucker sp.		Eastern sturgeon
Year	Total hours	Days (N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
1937	229	103	0.10 (0.05)	9.25 (0.17)	0.11 (0.04)	9.15 (0.26)	0.09 (0.04)	9.38 (0.22)	<0.00 (<0.00)	10.50 (–)	<0.00 (<0.00)	15.00 (–)	0.01 (0.01)	7.00 (0.00)	<0.00 (<0.00)		0.02 (0.01)	6.50 (–)	0.69 (0.22)	7.75 (0.04)	<0.00 (<0.00)	7.00 (–)	<0.00 (<0.00)	25.00 (–)	0.01 (0.01)	14.50 (0.50)	
1938	174.2	47	0.21 (0.06)	8.62 (0.14)	0.35 (0.10)	10.51 (0.20)	0.16 (0.06)	11.11 (0.74)																			
1939	184.5	38	0.15 (0.05)	8.02 (0.16)	0.64 (0.16)	10.69 (0.12)	0.33 (0.11)	9.60 (0.11)			0.03 (0.02)	11.83 (0.48)			0.01 (0.01)	8.00 (0.00)	0.02 (0.02)	6.88 (0.13)			0.02 (0.01)	9.00 (1.00)			0.12 (0.06)	15.00 (0.00)	0.01 (0.01)
1940	234.2	63	0.22 (0.05)	7.88 (0.11)	0.66 (0.12)	10.42 (0.09)	0.12 (0.04)	9.21 (0.20)																	0.08 (0.06)	14.33 (0.30)	
1941	173.5	16	0.27 (0.12)	8.43 (0.10)	0.11 (0.05)	10.26 (0.21)	0.06 (0.02)	11.27 (0.09)																			
1942	59	10	0.22 (0.22)	9.00 (0.00)	0.27 (0.15)	9.38 (0.31)	0.08 (0.06)	8.20 (0.20)	0.02 (0.02)	11.00 (–)			0.05 (0.05)	7.00 (0.00)							0.02 (0.02)	10.00 (–)					
1943	171	12	0.07 (0.03)	8.42 (0.29)	0.26 (0.12)	9.48 (0.32)	0.04 (0.02)	9.82 (0.26)																			
1944	197.5	19	0.21 (0.15)	8.78 (0.08)	0.50 (0.08)	10.06 (0.14)	0.06 (0.02)	9.67 (0.58)																			
1945	471.2	38	0.37 (0.10)	9.22 (0.08)	0.17 (0.06)	10.18 (0.15)	0.27 (0.11)	7.75 (0.09)																	0.03 (0.03)	14.67 (0.25)	
1946	297.5	28	0.24 (0.10)	9.17 (0.03)	0.29 (0.10)	9.82 (0.11)	0.50 (0.13)	9.05 (0.08)																			
1947	220	19	0.01 (0.01)		0.52 (0.09)		0.11 (0.06)																				
1948	288.5	21	0.07 (0.02)		0.40 (0.10)		0.22 (0.10)																		0.02 (0.02)		

Table D.23.–Direct contact river angler creel data for the Tobacco River subwatershed Cedar River 1949–63. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 standard errors could not be estimated and are reported as (–). No length data were collected. CPE = Catch per hour.

Year	Total Hours	Days (N)	Brook trout CPE	Brown trout CPE	Rainbow trout CPE	Rock bass CPE	Crappie sp. CPE	Yellow perch CPE	Walleye CPE	Northern pike CPE	Sucker sp. CPE
1949	875.5	17	0.09	0.10	0.05	0.23	0.40	0.19	0.01	0.01	<0.00
			(0.04)	(0.04)	(0.03)	(0.14)	(0.22)	(0.10)	(0.01)	(0.01)	(<0.00)
1950	126	6	0.03	0.06	0.02						0.01
			(0.09)	(0.18)	(0.04)						(0.02)
1951	187.5	10	0.02	0.10	0.07						
			(0.01)	(0.06)	(0.05)						
1952	191	12	0.02	0.48	0.02						
			(0.01)	(0.14)	(0.01)						
1953	162	11	0.17	0.85	0.01						
			(0.14)	(0.19)	(0.01)						
1954	170	5		0.46		0.05	0.15				0.02
				(0.29)		(0.05)	(0.15)				(0.02)
1955	213	14	0.05	0.43	0.03						
			(0.04)	(0.09)	(0.02)						
1956	111	13	0.06	0.32	0.09						
			(0.04)	(0.15)	(0.08)						
1957	422	27	0.06	0.15	0.35	0.01	0.02	<0.00			0.01
			(0.04)	(0.06)	(0.13)	(0.01)	(0.02)	(<0.00)			(0.01)
1958	297	24	0.22	0.11	0.22						0.02
			(0.15)	(0.03)	(0.06)						(0.02)
1959	203	10	<0.00	0.30	0.22						
			(<0.00)	(0.10)	(0.06)						
1960	176	12	0.12	0.27	0.13						
			(0.08)	(0.04)	(0.06)						
1961	141	7	0.04	0.04	0.11						
			(0.03)	(0.02)	(0.06)						
1962	155	12	0.08	0.11	0.30						0.03
			(0.07)	(0.06)	(0.22)						(0.02)
1963	131	8		0.24	0.31			0.19			
				(0.08)	(0.19)			(0.17)			

Table D.24.–Direct contact river angler creel data for the Tobacco River subwatershed Middle Branch Cedar, North Branch Cedar, West Branch Cedar rivers, Elm, Five Lakes, Jose, McCurran, Popple, Sanford, and Spike Horn creeks. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

River/Creek	Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Suckers sp.	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Cedar , Middle Branch												
1933	48.5	16	2.82	7.56	0.06	8.00	0.12	8.00				
			(0.84)	(0.06)	(0.05)	(0.00)	(0.11)	(0.00)				
1934	2.0	1										
1939	21.5	5			0.60	10.35	0.65	8.96	0.05	11.00		
					(0.27)	(0.42)	(0.17)	(0.22)	(0.04)	(–)		
1953	9.0	1			2.78							
					(–)							
1955	12.0	1			1.67							
					(–)							
1956	10.0	1			0.10							
					(–)							
1957	4.0	1					0.25					
							(–)					
1958	34.0	3			1.29		0.06					
					(0.52)		(0.08)					
1962	2.0	1					0.50					
							(–)					
Cedar , North Branch												
1929	19.0	4	0.84	8.72								
			(0.16)	(0.15)								
1930	34.5	9	0.61	7.93			0.09	9.00				
			(0.15)	(0.11)			(0.09)	(0.00)				
1937	19.0	6	0.05	7.00	0.21	12.63	0.16	9.00				
			(0.05)	(–)	(0.15)	(0.38)	(0.10)	(0.00)				
1939	6.3	1			0.32	8.00						
					(–)	(–)						
1944	13.3	1	0.98	7.40								
			(–)	(–)								
1947	2.0	1			3.50							
					(–)							
1957	67.0	3			0.33							
					(0.24)							
1962	11.0	1	0.09		0.09		0.73					
			(–)		(–)		(–)					
Cedar , West Branch												
1928	4.0	1	0.50	8.50			0.25	8.50				
			(–)	(–)			(–)	(–)				
1929	259.5	22	0.43	7.93			0.07	8.47				
			(0.12)	(0.07)			(0.05)	(0.19)				
1933	5.0	1	0.60	7.00	0.80	7.00						
			(–)	(–)	(–)	(–)						
Cedar , West Branch												
1934	1.3	1										
1938	5.0	2			2.80	10.36	1.20	8.63				
					(1.20)	(0.06)	(0.00)	(0.17)				

Table D.24.–Continued.

River/Creek	Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Suckers sp.	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1940	6.0	3	0.33	10.00	0.83	9.80	0.50	10.83				
			(0.21)	(0.00)	(0.09)	(0.96)	(0.07)	(1.59)				
1944	33.0	6	0.03	8.50	0.73	9.40	0.03	14.00			0.21	12.00
			(0.03)	(–)	(0.44)	(0.13)	(0.02)	(–)			(0.15)	(0.00)
1946	5.0	1			0.20	9.00	0.80	9.00				
					(–)	(–)	(–)	(–)				
1947	102.0	16	0.50		0.19		0.09					
			(0.20)		(0.06)		(0.02)					
1948	14.0	6			0.29							
					(0.08)							
1949	6.0	1			2.33							
					(–)							
1950	10.0	1					0.20					
							(–)					
1951	4.0	1			0.25							
					(–)							
1955	52.0	4	0.02		0.10		0.06					
			(0.01)		(0.01)		(0.02)					
1956	101.0	7			0.36							
					(0.10)							
1957	16.0	5					0.06					
							(0.05)					
1958	35.0	2			0.09		0.23				0.03	
					(0.00)		(0.01)				(0.06)	
1959	24.0	1			0.17		0.08					
					(–)		(–)					
1960	22.0	2			0.32		0.36					
					(0.17)		(0.20)					
1961	30.0	2			0.13		0.03					
					(0.02)		(0.03)					
1962	34.0	4			0.09							
					(0.07)							
Elm												
1930	2.0	1			0.50	8.00						
					(–)	(–)						
1935	2.0	1	0.50	7.50								
			(–)	(–)								
1948	40.0	4	0.13		0.03		0.05					
			(0.08)		(0.02)		(0.03)					
1956	7.0	1										
1958	4.0	1	1.50									
			(–)									
Five Lakes												
1938	4.0	1	0.50	7.50								
			(–)	(–)								
Jose												
1956	10.0	1	2.30									
			(–)									
McCurran												
1948	27.0	2									0.63	
											(0.31)	

Table D.24.–Continued.

River/Creek Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Brown trout AL	Rainbow trout CPE	Rainbow trout AL	Smallmouth bass CPE	Smallmouth bass AL	Suckers sp. CPE	Suckers sp. AL
Popple												
1933	4.0	1	1.75 (–)	8.00 (–)								
1949	1.0	1	1.00 (–)									
Sanford												
1951	1.5	1			2.00 (–)							
Spike Horn												
1937	15.0	3										
1940	17.0	5	0.35 (0.15)	7.25 (0.11)								

Table D.25.–Direct contact river angler creel data for the Tobacco River 1929–40. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass		Bluegill	Pumpkinseed sunfish	Rock bass		Crappie sp.		Yellow perch		Northern pike		Bullhead sp.		Carp		Suckers		Redhorse sp.	Cisco sp.
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE
1929	323.3	49	0.29 (0.11)	7.96 (0.10)					<0.01 (<0.01)	13.00 (–)							<0.01 (<0.01)	8.00 (–)	0.01 (<0.01)		0.03 (0.02)	25.33 (1.15)	0.06 (0.03)	8.00 (1.08)	0.01 (0.01)	21.00 (0.00)	0.04 (0.04)	12.77 (0.23)		
1930	191.8	60	0.21 (0.10)	8.59 (0.07)	0.02 (0.01)	11.33 (1.33)	0.02 (0.01)	9.00 (0.71)			0.02 (0.02)				0.04 (0.03)				0.10 (0.06)	7.00 (–)	0.10 (0.02)	21.50 (1.01)	0.10 (0.06)	11.00 (0.00)			0.03 (0.02)		0.01 (0.01)	0.12 (0.08)
1932	157.0	35	0.07 (0.05)				0.01 (0.01)		0.17 (0.05)	10.40 (0.24)	0.06 (0.05)	14.00 (0.00)	0.08 (0.04)	0.20 (0.09)	0.42 (0.09)		0.53 (0.14)		0.43 (0.09)		0.04 (0.03)	23.67 (1.67)	0.31 (0.16)	22.00 (0.00)	0.03 (0.02)		0.08 (0.05)		0.10 (0.06)	
1933	345.0	77							0.01 (0.01)		0.02 (0.01)		0.01 (0.01)	0.14 (0.04)	0.12 (0.03)	8.00 (–)	0.43 (0.16)	8.63 (0.11)	0.36 (0.08)	7.00 (0.00)	0.02 (0.01)	27.00 (3.00)	0.42 (0.10)	6.71 (0.08)	0.01 (0.01)	20.00 (0.00)	0.03 (0.02)			
1934	530.0	138	0.01 (0.01)	9.00 (–)	0.03 (0.02)	7.18 (0.25)	<0.01 (<0.01)		0.01 (0.01)	12.50 (0.00)	0.01 (<0.01)	11.00 (–)	0.03 (0.01)	0.07 (0.03)	0.07 (0.02)	7.00 (0.00)	0.56 (0.10)	7.22 (0.04)	0.15 (0.04)	7.00 (0.00)	0.02 (0.01)	23.67 (1.67)	0.15 (0.05)	6.24 (0.07)	<0.01 (<0.01)		0.04 (0.02)	18.00 (0.00)	0.02 (0.01)	
1935	63.5	24							0.02 (0.02)	11.00 (–)	0.36 (0.17)	14.00 (0.00)	1.80 (0.67)		0.02 (0.02)	7.00 (–)	0.11 (0.09)	6.50 (0.00)	0.13 (0.10)		0.17 (0.06)		0.02 (0.02)							
1937	165.8	65													0.05 (0.03)	7.94 (0.15)	0.54 (0.18)	7.42 (0.04)	0.06 (0.04)	7.30 (0.21)	0.02 (0.01)	20.67 (3.71)					0.02 (0.01)	14.33 (0.33)		
1938	31.0	10	0.10 (0.07)	8.17 (0.33)	0.06 (0.06)	12.00 (0.00)	0.03 (0.03)	8.00 (–)																						
1939	80.0	24	0.40 (0.20)	8.16 (0.12)	0.18 (0.13)	8.21 (0.11)									0.01 (0.01)	7.00 (–)	1.20 (0.59)	7.43 (0.07)	0.06 (0.04)	7.50 (0.00)	0.01 (0.01)	18.00 (–)								
1940	221.8	68	0.08 (0.03)	7.57 (0.13)					<0.01 (<0.01)	18.00 (–)					0.15 (0.14)	7.00 (0.06)	0.79 (0.25)	7.93 (0.04)	0.08 (0.04)	7.89 (0.16)							0.04 (0.03)	10.50 (0.33)		

Table D.26.–Direct contact river angler creel data for the Tobacco River 1941–46. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brook trout		Brown trout		Rainbow trout		Largemouth bass		Bluegill		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Suckers sp.		Redhorse sp.	
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1941	132.0	17	0.08	8.00	0.06	10.50	0.02	8.00					0.01	8.00	0.80	7.46			0.01	18.00	0.01	18.00						
			(0.07)	(–)	(0.05)	(0.50)	(0.02)	(0.00)					(0.01)	(–)	(0.41)	(0.01)			(<0.01)	(–)	(0.01)	(–)						
1942	142.8	32	0.03	9.00	0.22	9.92	0.11	9.00			0.01	7.00	0.01	7.00	0.43	7.54	0.01	10.00					0.01	10.00				
			(0.02)	(0.00)	(0.07)	(0.17)	(0.05)	(0.11)			(0.01)	(–)	(0.01)	(0.00)	(0.15)	(0.06)	(0.01)	(0.00)					(0.01)	(–)				
1943	81.0	22	0.10	7.69	0.14	8.64	0.16	10.08																				
			(0.05)	(0.16)	(0.08)	(0.54)	(0.05)	(0.87)																				
1944	174.0	23	0.03	7.50	0.14	9.00	0.10	10.18	0.01	11.00	0.01	7.00	0.02	7.75	0.44	7.43	0.01	9.00							0.01	12.00		
			(0.02)	(0.22)	(0.05)	(0.16)	(0.05)	(0.35)	(0.01)	(0.00)	(0.01)	(–)	(0.02)	(0.25)	(0.19)	(0.06)	(0.01)	(0.00)							(0.01)	(0.00)		
1945	484.5	40	0.08	8.97	0.09	9.78	0.03	8.25					0.01	7.33	1.53	7.68	0.03	8.18	0.00	16.00	<0.01	23.00			0.08	15.88	<0.01	7.50
			(0.06)	(0.10)	(0.03)	(0.12)	(0.01)	(0.17)					(0.01)	(0.21)	(0.50)	(0.02)	(0.01)	(0.26)	(<0.01)	(–)	(<0.01)	(–)			(0.06)	(0.37)	(<0.01)	(–)
1946	107.0	20	0.05	9.20	0.23	9.48	0.24	8.54	0.01	14.00	0.10	6.80			0.15	8.00	0.04	7.20										
			(0.04)	(0.49)	(0.16)	(0.19)	(0.17)	(0.19)	<(0.01)	(–)	(0.04)	(0.00)			(0.06)	(0.00)	(0.02)	(0.00)										

Table D.27.–Direct contact river angler creel data for the Tobacco River 1947–64. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 standard errors could not be estimated and are reported as (–). No length data were collected. CPE = Catch per hour.

Year	Total hours	Days (N)	Brook trout CPE	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Largemouth bass CPE	Bluegill CPE	Pumpkinseed sunfish CPE	Rock bass CPE	Crappie sp. CPE	Yellow perch CPE	Northern pike CPE	Bullhead sp. CPE	Carp CPE	Suckers sp. CPE
1947	543.3	45	0.05 (0.03)	0.12 (0.05)	0.01 (0.01)	0.00 (0.00)		0.08 (0.07)	0.03 (0.03)	0.03 (0.02)	1.31 (0.36)	0.12 (0.05)	0.01 (0.01)		0.00 (0.00)	
1948	1635.0	31		0.00 (0.00)		0.01 (0.01)	0.00 (0.00)	0.07 (0.05)	0.00 (0.00)	0.04 (0.01)	1.00 (0.15)	0.11 (0.03)	0.01 (0.01)			0.02 (0.02)
1949	811.0	20	0.00 (0.00)					0.05 (0.03)		0.06 (0.03)	1.52 (0.23)	0.17 (0.04)	0.03 (0.01)			
1950	144.0	8	0.00 (0.00)								1.35 (0.37)	0.02 (0.01)	0.01 (0.01)	0.01 (0.01)		0.01 (0.01)
1951	356.5	14		0.01 (0.01)						0.00 (0.00)	1.53 (0.20)	0.28 (0.09)				
1952	154.0	12					0.01 (0.00)	0.19 (0.11)	0.08 (0.05)	0.03 (0.04)	0.95 (0.62)	0.38 (0.22)				
1953	223.0	9		0.03 (0.03)		0.00 (0.00)		0.06 (0.05)		0.07 (0.04)	1.65 (0.50)	0.14 (0.07)				
1954	82.0	2		0.00 (0.00)						0.45 (0.34)	0.65 (0.49)	0.62 (0.28)				
1955	401.5	35				0.00 (0.01)		0.16 (0.07)	0.02 (0.02)	0.01 (0.01)	1.87 (0.28)	0.21 (0.08)				0.01 (0.01)
1956	247.0	21	0.17 (0.11)	0.06 (0.04)	0.01 (0.01)	0.01 (0.01)		0.09 (0.05)	0.01 (0.01)		0.86 (0.23)	0.03 (0.02)	0.01 (0.01)			0.04 (0.04)
1957	382.5	25	0.06 (0.04)	0.00 (0.00)		0.03 (0.02)	0.00 (0.00)	0.07 (0.03)	0.05 (0.03)	0.19 (0.05)	0.38 (0.19)	0.15 (0.05)	0.01 (0.01)			0.19 (0.11)
1958	477.5	28	0.00 (0.00)	0.05 (0.05)	0.01 (0.01)					0.01 (0.00)	0.58 (0.24)	0.01 (0.01)	0.01 (0.00)			0.38 (0.11)
1959	11.0	1	1.18 (–)													
1960	92.0	5		0.01 (0.01)		0.02 (0.02)				0.03 (0.03)	2.05 (1.31)		0.01 (0.01)			0.04 (0.03)

Table D.27.–Continued.

Year	Total hours	Days (N)	Brook trout CPE	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Largemouth bass CPE	Bluegill CPE	Pumpkinseed sunfish CPE	Rock bass CPE	Crappie sp. CPE	Yellow perch CPE	Northern pike CPE	Bullhead sp. CPE	Carp CPE	Suckers sp. CPE
1961	32.0	1								0.28	3.44	1.66	0.03			0.03
										(–)	(–)	(–)	(–)			(–)
1962	206.0	3						0.03	0.05		2.18	0.03	0.00	0.06		0.07
								(0.02)	(0.04)		(0.67)	(0.01)	(0.01)	(0.05)		(0.07)
1963	11.0	1														0.09
																(–)
1964	28.0	2		0.32	0.11											
				(0.13)	(0.11)											

Table D.28.–Direct contact river angler creel data for the Middle Branch Tobacco River 1929–63. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brook trout		Brown trout		Rainbow trout		Rock bass	Crappie sp.	Yellow perch	Bullhead sp.	Suckers sp.		Redhorse sp.
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	CPE	CPE	CPE	AL	CPE
1929	9.0	3	1.78	8.00											
			(0.36)	(0.00)											
1934	30.5	9	0.03	10.00			0.03	10.00	0.16	0.26	0.20	0.43	0.23	20.00	0.03
			(0.04)	(–)			(0.04)	(–)	(0.08)	(0.26)	(0.10)	(0.19)	(0.14)	(0.00)	(0.03)
1935	19.0	2	0.11	8.50	0.37	9.71									
			(0.19)	(0.00)	(0.03)	(0.29)									
1939	3.5	1			0.57	9.00	0.57	8.00							
					(–)	(–)	(–)	(–)							
1945	17.0	4	1.65	8.00	1.35	8.00									
			(0.89)	(0.00)	(1.00)	(0.00)									
1946	6.0	1	0.33	8.00	0.17	17.00									
			(–)	(–)	(–)	(–)									
1948	40.5	5	0.20										0.02		
			(0.18)										(0.01)		
1950	16.0	2	0.06		0.19										
			(0.03)		(0.21)										
1951	35.0	1			0.11										
					(–)										
1953	7.0	1			0.29										
					(–)										
1955	62.0	4			0.58		0.02								
					(0.53)		(0.01)								
1957	62.0	2	0.02		0.15										
			(0.02)		(0.15)										
1958	133.0	7	0.04		0.09		0.14								
			(0.03)		(0.04)		(0.07)								
1959	76.0	2	0.09		0.01										
			(0.02)		(0.02)										

Table D.28.–Continued.

	Total	Days	Brook trout		Brown trout		Rainbow trout		Rock bass	Crappie sp.	Yellow perch	Bullhead sp.	Suckers sp.		Redhorse sp.
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	CPE	CPE	CPE	AL	CPE
1960	116.0	5	0.03 (0.02)		0.05 (0.03)		0.13 (0.08)								
1961	71.0	3	<0.01 (<0.01)		0.27 (0.10)								0.04 (0.02)		
1963	43.0	1	0.09 (–)		0.02 (–)										

Table D.29.–Direct contact river angler creel data for the North Branch Tobacco River 1928–62. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass	Rock bass	Yellow perch	Bullhead sp.	Suckers sp.		Redhorse sp.		Chubs
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	CPE	CPE	CPE	AL	CPE	AL	CPE
1928	12.0	4	0.67	7.64			0.08	7.50									
			(0.11)	(0.09)			(0.06)	(–)									
1929	33.0	5	0.39	7.81			0.03	7.50									
			(0.33)	(0.16)			(0.03)	(–)									
1930	64.5	22	0.96	8.90			0.14	8.89					0.03	12.00	0.09	14.00	0.03
			(0.26)	(0.09)			(0.10)	(0.35)					(0.03)	(0.00)	(0.09)	(0.00)	(0.03)
1932	7.0	2	0.57	10.00			1.86	9.00									
			(0.65)	(0.00)			(1.59)	(0.00)									
1933	2.5	2	1.60	8.00					0.40								
			(0.64)	(0.00)					(0.16)								
1934	16.8	7								0.42	0.30	0.60	0.48				
										(0.22)	(0.16)	(0.25)	(0.35)				
1935	121.5	24	0.29	8.79	0.06	9.14	0.05	9.17									
			(0.09)	(0.14)	(0.03)	(0.34)	(0.03)	(0.40)									
1937	3.5	1															
1938	6.0	1					0.67	8.00									
							(–)	(–)									
1943	4.0	1					0.25	10.00									
							(–)	(–)									
1944	12.5	2	0.32	8.00	0.08	10.00	0.24	8.00									
			(0.26)	(0.00)	(0.10)	(–)	(0.29)	(0.00)									
1945	56.3	12	0.21	8.00	0.52	8.38	0.16	8.67					0.02	15.00			
			(0.14)	(0.00)	(0.15)	(0.11)	(0.09)	(0.20)					(0.02)	(–)			
1946	45.5	8	0.09	8.00	0.13	9.67	0.31	8.43									
			(0.09)	(0.00)	(0.06)	(0.21)	(0.12)	(0.10)									

Table D.29.–Continued.

Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Brown trout AL	Rainbow trout CPE	Rainbow trout AL	Smallmouth bass CPE	Rock bass CPE	Yellow perch CPE	Bullhead sp. CPE	Suckers sp. CPE	Suckers sp. AL	Redhorse sp. CPE	Redhorse sp. AL	Chubs CPE
1947	44.0	10	0.25 (0.12)		0.18 (0.08)		0.34 (0.14)										
1948	49.0	6	0.06 (0.06)		0.04 (0.02)		0.08 (0.05)										
1950	141.0	2	0.03 (<0.01)		0.09 (0.13)												
1951	52.5	3	0.34 (0.20)		0.19 (0.16)		0.02 (0.02)										
1952	37.0	1			0.11 (–)												
1953	8.0	1			0.13 (–)												
1954	4.0	1			0.75 (–)												
1955	97.0	3			0.61 (0.19)						0.01 (0.01)		0.02 (0.01)				
1957	16.0	2			0.19 (0.16)		0.06 (0.07)										
1958	111.0	8	0.03 (0.02)		0.11 (0.03)		0.46 (0.22)										
1959	69.0	4			0.04 (0.03)		0.04 (0.02)										
1960	12.0	1					0.75 (–)										
1961	35.0	1			0.23 (–)												
1962	35.5	2			0.70 (0.06)												

Table D.30.–Direct contact river angler creel data for the South Branch Tobacco River 1929–48. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length. Carp were also caught in small numbers (CPE=<0.01 ±<0.01).

	Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass	Bluegill	Pumpkinseed sunfish		Rock bass	Crappie sp.		Yellow perch	Northern pike		Bullhead sp.		Suckers sp.		Redhorse sp.
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	CPE	AL	CPE	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE
1929	12.0	2	1.25 (0.42)		<0.01 (<0.01)																				
1930	18.8	6	0.21 (0.21)	8.00 (0.00)							0.05 (0.05)					0.11 (0.10)			0.05 (0.05)						
1933	7.0	2									0.14 (0.16)					0.57 (0.65)		0.29 (0.33)							
1934	257.8	72	0.01 (0.01)	8.00 (0.00)			<0.01 (<0.01)	7.00 (–)	0.03 (0.01)			0.03 (0.02)	0.06 (0.03)	8.00 (0.00)	0.05 (0.02)	0.24 (0.07)	7.59 (0.14)	0.02 (0.01)	0.02 (0.01)	37.00 (1.00)	0.05 (0.03)	7.00 (0.00)	0.07 (0.02)		0.05 (0.02)
1935	33.0	18	0.15 (0.14)	8.00 (0.00)															0.03 (0.03)	32.00 (–)			0.55 (0.23)	16.00 (0.00)	0.85 (0.33)
1939	36.0	10	0.06 (0.05)	8.00 (0.00)	0.36 (0.20)	8.38 (0.14)			0.06 (0.06)	13.50 (0.00)															
1945	58.0	2	1.66 (0.11)	8.30 (0.00)	0.14 (0.01)	8.30 (0.00)	0.16 (0.01)	8.80 (0.00)																	
1948	462.5	44	0.10 (0.02)		0.12 (0.05)		0.06 (0.01)									<0.01 (<0.01)							<0.01 (<0.01)		

Table D.31.–Direct contact river angler creel data for the South Branch Tobacco River 1950–60. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1, standard errors could not be estimated and are reported as (–). No length data were collected. CPE = Catch per hour.

Year	Total hours	Days (N)	Brook trout CPE	Brown trout CPE	Rainbow trout CPE	Bluegill CPE	Rock bass CPE	Crappie sp. CPE	Yellow perch CPE	Northern pike CPE	Bullhead sp. CPE	Channel catfish CPE	Suckers sp. CPE
1950	317.0	25	0.01 (0.01)	0.04 (0.02)	<0.01 (<0.01)					0.03 (0.02)			
1951	205.0	7	0.11 (0.08)	0.18 (0.10)	<0.01 (<0.01)		0.02 (0.02)	0.22 (0.23)	0.05 (0.05)	0.01 (0.01)			0.05 (0.04)
1952	166.0	19	0.02 (0.02)	0.12 (0.03)				0.18 (0.16)	0.02 (0.03)		0.01 (0.01)		0.01 (0.01)
1953	110.0	7		0.15 (0.04)					0.02 (0.02)				0.24 (0.20)
1954	129.0	12	<0.01 (<0.01)	0.03 (0.02)		0.01 (0.01)	0.20 (0.12)	1.06 (0.36)	0.09 (0.07)	0.01 (0.01)			
1955	207.0	15	0.01 (0.01)	0.14 (0.06)	0.01 (0.01)	<0.01 (0.01)	0.01 (0.01)	0.03 (0.03)	0.10 (0.07)	0.02 (0.01)	<0.01 (0.01)		0.03 (0.02)
1956	48.0	5		0.08 (0.03)	0.10 (0.07)								
1957	273.0	13	0.01 (<0.01)	0.09 (0.03)	0.15 (0.04)		0.01 (0.01)		<0.01 (<0.01)	<0.01 (<0.01)			0.08 (0.06)
1958	302.0	16	0.01 (0.01)	<0.01 (<0.01)	0.22 (0.12)		0.02 (0.02)	0.09 (0.06)	0.01 (0.01)	0.01 (0.01)		0.01 (0.01)	0.06 (0.03)
1959	116.0	5	0.03 (0.02)	0.03 (0.02)	0.15 (0.12)								
1960	76.0	3		0.39 (0.24)	0.39 (0.10)				0.01 (0.02)				

Table D.32.–Direct contact river angler creel data for the West Branch Tobacco River 1929, 1934–35. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

		Total	Days	Brook trout		Rainbow trout		Crappie sp.	
River/Creek	Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL
Tobacco, West Branch	1929	21.5	5	0.37	7.81	0.09	8.00		
				(0.20)	(0.31)	(0.11)	(0.00)		
	1934	30.5	8					0.69	7.57
								(0.22)	(0.11)
	1935	4.0	1	2.75	10.00				
				(–)	(–)				

Table D.33.–Direct contact lake angler creel data for the Tittabawassee River main stem-headwaters. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Warmouth CPE
Gladwin																										
Cedar	1932	14	4																5.64 (0.69)	7.11 (0.02)						
	1937	1	2																							
	1942	6	1									0.50 (–)	7.00 (–)				0.33 (–)	7.00 (–)								
Elk	1928	8	1									1.25 (–)	8.00 (–)													
	1930	5	2																				0.40 (0.48)	22.00 (0.00)		
	1932	6	2					0.33 (0.33)	10.50 (0.00)			0.67 (0.67)		0.83 (0.83)					0.50 (0.50)							
	1933	11	3																0.55 (0.45)	8.00 (0.00)			0.18 (0.20)	22.00 (0.00)		
	1935	9	3							0.22 (0.22)	11.00 (0.00)	0.33 (0.33)	7.00 (0.00)			0.22 (0.22)			0.33 (0.33)							
	1942	4	1									1.25 (–)	8.00 (–)													
	1944	6	1																							
	1945	6	1									1.17 (–)	7.00 (–)													
	1948	5	3													1.00 (0.35)			0.40 (0.12)							
	1949	20	2																0.30 (0.48)							
	1950	48	1									1.29 (–)							0.27 (–)							
	1951	10	1									0.30 (–)							0.90 (–)							
	1953	22	1																3.00 (–)							
	1954	20	2									0.65 (0.26)				0.05 (0.02)			0.35 (0.56)				0.05 (0.02)			
	1957	5	1																							

Table D.33.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Warmouth CPE
Gladwin																										
Elk	1958	47	5									0.70 (0.42)							0.09 (0.05)				0.02 (0.01)			
	1961	91	2				0.46 (0.60)																			
	1962	25	1				0.08 (–)																			
	1963	54	3				0.22 (0.19)					0.61 (0.51)							0.11 (0.09)							
	1964	22	1				0.18 (–)					0.09 (–)							0.23 (–)							
Indian	1932	14	4									0.29 (0.17)		0.21 (0.22)					3.21 (0.43)	6.46 (0.10)						
	1933	6	2																				0.17 (0.11)			
	1934	16	4																				0.31 (0.09)		0.13 (0.11)	
	1940	4	1																1.75 (–)	9.00 (–)						
	1941	13.5	3																0.96 (0.81)	10.00 (0.00)						
	1942	6	1					0.67 (–)	11.00 (–)																	
	1944	23	2							0.22 (0.28)	15.60 (0.00)												0.17 (0.23)	20.00 (0.00)		
	1949	8	1									2.13 (–)											0.13 (–)			
	1950	4	1																							
	1953	27	1									0.07 (–)							0.15 (–)							
	1954	6	1																2.17 (–)							
	1956	9	1									0.11 (–)							1.33 (–)							
	1932	2	1									1.00 (–)	7.00 (–)													
	1941	20	1									1.85 (–)	9.00 (–)													

Table D.33.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Warmouth CPE
Gladwin																										
Lake Four	1932	13.5	3									1.11 (0.59)		0.52 (0.26)					1.41 (0.50)							
	1942	2	1																							
	1948	66	1									1.18 (–)		0.15 (–)					0.21 (–)				0.02 (–)			
	1949	72	2									1.11 (0.21)							0.07 (0.06)				0.14 (0.09)			
	1957	80	4					0.04 (0.03)				1.09 (0.39)											0.11 (0.10)			
	1958	13	2									0.23 (0.28)														
	1959	10	1									0.40 (–)											0.10 (–)			
	1961	35	4									0.83 (0.22)					1.34 (1.03)									
	1964	35	1									1.66 (–)							0.37 (–)				0.06 (–)			
Mud	1930	3	1																				1.67 (–)	16.00 (–)		
	1931	3	1														6.67 (–)		1.00 (–)							
	1940	1	1																							
	1941	3	1																							
	1944	20	2																		0.10 (0.12)	16.00 (0.00)				
	1945	19	2																							
	1948	2	1																							
	1951	2	1																2.50 (–)							
	1964	16	1																				0.06 (–)			

Table D.33.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Warmouth CPE
Ogemaw																										
Chatman (Chatlan)	1930	21	4									0.24 (0.29)	7.00 (0.00)										0.05 (0.04)	26.00 (–)		
Frost	1928	2	1																2.50 (–)	9.00 (–)						
	1930	4	1									1.50 (–)							1.00 (–)							
	1936	5.25	2																		0.19 (0.22)	17.00 (–)				
	1949	5.5	2																							
	1951	1.5	1																							
	1954	9	2							0.11 (0.12)																
Lake George	1948	31	5									0.13 (0.06)							0.32 (0.08)							
	1949	7.75	1																3.35 (–)							
	1950	1	1																<0.01 (–)							
	1951	8.5	2											0.12 (0.03)					1.65 (0.39)							
	1953	14.5	1				0.28 (–)												0.14 (–)							
	1954	34.5	2				0.06 (<0.01)												0.06 (0.06)							
	1955	93	3			0.01 (0.01)	0.19 (0.11)									0.01 (0.01)			0.01 (0.01)							
	1956	95.5	5				0.08 (0.05)														0.01 (0.01)					
	1957	61.5	5				0.03 (0.02)												0.10 (0.09)							
	1958	115.5	5				0.12 (0.03)																			
	1959	91	6														0.02 (0.03)						0.01 (0.01)			
	1960	40	4				0.20 (0.15)												0.03 (0.03)							

Table D.33.–Continued.

County		Total	Days	Brook trout		Brown trout	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass	Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.	Warmouth
Lake	Year	hours	(N)	CPE	AL	CPE	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE
Ogemaw																										
Lake George	1961	27	3				0.07 (0.04)																			
	1962	15	1				0.07 (–)												0.07 (–)							
	1964	18	1																<0.01 (–)							
	1965	15	1				0.07 (–)												0.13 (–)							
Mud	1928	3	1									2.67 (–)							1.00 (–)							
	1929	3	1	2.67 (–)	9.00 (–)																					
	1931	3	1														6.67 (–)		1.00 (–)							
Tee	1928	2	1																				0.50 (–)	19.00 (–)		
	1930	3	1											2.00 (–)	6.50 (–)											
	1934	4	1							0.75 (–)		1.25 (–)							0.75 (–)							
	1936	5	2									0.20 (0.16)	6.00 (–)						0.20 (0.16)	7.00 (–)			0.20 (0.16)	14.00 (–)		
	1945	27	1					0.04 (–)	14.00 (–)			1.67 (–)	7.00 (–)	1.67 (–)	7.00 (–)											
	1948	13	3									0.23 (0.24)														
	1949	19	2							0.11 (0.01)		0.95 (0.10)		0.11 (0.01)												
	1951	15	1									1.60 (–)		0.20 (–)												
Roscommon																										
Clear	1929	4	1							1.50 (–)											0.75 (–)					
	1930	19	7					0.58 (0.13)	12.50 (5.59)			0.32 (0.30)		0.42 (0.39)					0.58 (0.26)							
	1931	24	5									0.83 (0.52)		0.83 (0.52)		0.46 (0.29)										

Table D.33.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Warmouth CPE
Roscommon																										
Clear	1932	4	1																							
	1933	35	8					0.06 (0.05)	12.00 (0.00)	0.54 (0.25)	11.82 (0.10)	0.31 (0.31)		0.57 (0.57)					0.57 (0.57)							
	1935	4	2					0.75 (1.13)	12.00 (0.00)	0.25 (0.13)	12.00 (–)															
West Twin	1932	2	1																							2.50 (–)

Table D.34.–To accommodate all species, creel data on the additional lakes within the Tittabawassee River subwatersheds have been separated into a series of tables. Tables 28–43 contain creel data for the subwatersheds, lakes, and time periods listed below.

Sub-watershed	Lake	Years	Table
Main stem-middle	Molasses	1939	28
	Round	1929–30, 1932, 1950–52, 1954	28
	Sanford	1932–35, 1937, 1940–43, 1945, 1950, 1952–63	29
	Secord	1929–30, 1932–35, 1939–41, 1945–46, 1954, 1957–61, 1963	30
	Smallwood	1932, 1934–35, 1937, 1946, 1954, 1957–61, 1963–64	31
	Wixom	1932–35, 1939–40, 1942–43, 1945–47, 1950, 1952–65	32
Tobacco River	Arnold	1929, 1934, 1938–39, 1942, 1944, 1947–62	33
	Bailey	1940–41	33
	Beebe	1941, 1954–55	33
	Blue	1932–34, 1937, 1939, 1942, 1958	33
	Boathouse	1935, 1940, 1947, 1957	33
	Lower Brennan	1951–52, 1957–58	33
	Upper Brennan	1950	33
	Budd	1929–30, 1932–35, 1937, 1939–45, 1947–51, 1953, 1955–64	34
	Cranberry (Clare & Missaukee Co.)	1939, 1944, 1948–56, 1958–59, 1961–62, 1964	35
	Cranberry (Clare Co.)	1928–30, 1932, 1934, 1937–38, 1942–43, 1946–64	35
	Deadman	1935, 1956	36
	Decker	1938	36
	Deer	1942	36
	Dodge	1929–30, 1935, 1937–41, 1947, 1952, 1955–57	36
	Dunham	1959–60	36
	Elbow	1930	36
	Five	1928–30, 1933, 1935, 1948–51, 1953, 1955, 1957–61, 1964	36
	Gut	1947, 1950	36
	Hoister	1934, 1948–49, 1953, 1956–64	37
	House	1956–58, 1961–64	37
	Howland	1949, 1958	37
	Lily	1950–62	37
	Little Long	1930, 1934–35, 1939–64	37
	Big Loon	1932–33, 1940	38
	Little Loon	1929–30, 1935, 1943, 1951–53, 1955, 1957–58	38
	McGilvery	1930, 1933, 1940–45, 1953, 1955, 1957–60	38
	McWatty	1949	38
	Mill Pond	1929, 1938–39	38

Table D.34.–To accommodate all species, creel data on the additional lakes within the Tittabawassee River subwatersheds have been separated into a series of tables. Tables 28–43 contain creel data for the subwatersheds, lakes, and time periods listed below.

Sub-watershed	Lake	Years	Table
Tobacco River	Mud	1935	38
	Nestor	1951, 1956–59	38
	Otter	1949–55, 1957–58	38
	Pratt	1930, 1932–35, 1939–44, 1948–64	38
	Puro	1941–44, 1948, 1950, 1953–54, 1956–59, 1961, 1963	39
	Ross	1929–30, 1932–35, 1939–47, 1953–54, 1956–65	39
	Round	1928, 1930, 1934, 1937, 1939	39
	Schoolhouse	1939–40, 1942	39
	South	1938, 1952, 1958	39
	Streaked	1932–35, 1937, 1939–40, 1961, 1964	40
	Sutherland	1934, 1939–40, 1945–48, 1950, 1952–62	40
	Thurston	1943, 1950–55, 1957	40
	Townline	1937–41, 1948, 1952, 1954–55, 1957	40
	Trout (Clare Co.)	1933, 1938–39	41
	Trout (Gladwin Co.)	1934, 1962–64	41
	Wiggins	1929–30, 1932–35, 1939–49	42
	Wiggins	1950–64	43

Table D.35.–Direct contact lake angler creel data for the Tittabawassee River main stem-middle Molasses and Round lakes, Gladwin County. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

				Smallmouth bass		Bluegill		Rock bass		Crappie sp.	Yellow perch		Northern pike	
Lake	Year	Total hours	Days (N)	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL
Molasses	1939	2.3	1					1.33 (–)	7.00 (–)					
Round	1929	30.5	3			0.33 (0.44)	9.00 (0.00)						0.10 (0.05)	30.00 (0.00)
	1930	2.5	2	1.60 (0.64)	14.00 (0.00)									
	1932	7.0	3								1.00 (0.65)	5.00 (0.00)	0.29 (0.24)	
	1950	5.0	1							1.20 (–)				
	1951	14.0	1							1.07 (–)	0.14 (–)			
	1952	6.0	1							0.83 (–)				
	1954	4.0	1											

Table D.36.–Direct contact lake angler creel data for the Tittabawassee River main stem-middle Sanford Lake, Midland County. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

Year	Total hours	Days (N)	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Carp		Suckers sp.	White bass
			CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE
1932	19.0	5											2.26 (1.08)	7.00 (0.00)	1.16 (0.51)	6.00 (0.00)					0.05 (0.05)					
1933	53.0	12									0.06 (0.02)		0.43 (0.14)													
1934	99.5	33	0.01 (0.01)						0.02 (0.02)		0.01 (0.01)		0.40 (0.25)	6.50 (0.00)	0.24 (0.14)		0.01 (0.01)				0.02 (0.01)					
1935	96.0	31	0.15 (0.11)	17.36 (0.88)	0.21 (0.20)	11.05 (0.05)			0.01 (0.01)	6.50 (–)	0.01 (0.01)	7.00 (–)	0.95 (0.28)	7.05 (0.04)	0.11 (0.07)	6.64 (0.12)					0.20 (0.14)	8.00 (0.00)				
1937	491.8	161	<0.01 (<0.01)	11.25 (0.75)	<0.01 (<0.01)	15.00 (5.00)	0.01 (0.01)	6.67 (0.11)	<0.01 (<0.01)	7.00 (–)	0.02 (0.01)	6.61 (0.29)	1.70 (0.29)	7.43 (0.01)	0.06 (0.01)	7.11 (0.10)					0.01 (<0.01)	11.90 (3.28)	<0.01 (<0.01)	24.00 (–)		
1940	83.8	21	0.01 (0.01)	16.00 (–)			0.10 (0.07)	6.50 (0.50)					0.08 (0.06)	6.79 (0.21)	0.07 (0.06)	8.00 (–)			0.01 (0.01)	22.00 (–)	0.01 (0.01)	7.00 (–)				
1941	497.8	20					0.01 (<0.01)	6.67 (0.17)			0.01 (<0.01)	6.60 (0.00)	0.67 (0.11)	7.26 (0.02)	0.01 (<0.01)	6.75 (0.25)			0.01 (0.01)	23.50 (1.19)						
1942	576.0	12	<0.01 (<0.01)	11.50 (–)			1.39 (0.41)	7.00 (0.00)	<0.01 (<0.01)	7.00 (–)	0.01 (<0.01)	7.00 (0.00)	0.28 (0.16)	6.84 (0.01)	0.01 (<0.01)	6.70 (0.10)										
1943	61.5	1	0.02 (–)	12.00 (–)	0.07 (–)	11.00 (–)	0.13 (–)	6.00 (–)					0.50 (–)	7.00 (–)			0.05 (–)	15.30 (–)	0.02 (–)	18.00 (–)						
1945	125.0	16	0.09 (0.06)	11.31 (0.08)			0.02 (0.01)	6.50 (0.00)			0.02 (0.03)	7.00 (0.00)	0.25 (0.09)	8.03 (0.16)	0.01 (0.01)	8.00 (–)			0.06 (0.04)	21.86 (0.55)						
1950	205.0	13					0.20 (0.09)						3.04 (0.46)		0.56 (0.17)				0.03 (0.01)							
1952	771.0	26	0.05 (0.02)				0.16 (0.06)		<0.01 (<0.01)		<0.01 (<0.01)		1.18 (0.16)		0.08 (0.01)		<0.01 (<0.01)		0.01 (<0.01)		<0.01 (<0.01)					
1953	88.0	5							0.31 (0.08)				3.82 (0.62)		0.56 (0.31)				0.05 (0.04)							
1954	427.0	39	0.02 (0.01)		0.03 (0.01)		0.26 (0.05)		0.03 (0.01)		0.03 (0.01)		0.99 (0.14)		0.15 (0.03)				0.03 (0.01)						0.06 (0.06)	
1955	36.0	4	0.14 (0.16)				0.17 (0.21)		0.06 (0.07)				1.06 (0.49)		0.08 (0.10)											
1956	139.0	15					0.12 (0.06)		0.01 (0.01)		0.01 (0.01)		1.31 (0.42)		0.06 (0.04)				0.01 (0.01)							
1957	461.0	24	0.02 (0.02)				0.01 (<0.01)		0.02 (0.01)		0.03 (0.02)		1.63 (0.50)		0.10 (0.03)				<0.01 (<0.01)							
1958	307.0	10			<0.01 (<0.01)		0.08 (0.04)		0.01 (0.01)		0.02 (0.01)		1.39 (0.47)		0.01 (0.01)				0.01 (0.01)							

Table D.36.–Continued.

Year	Total hours	Days (N)	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Bullhead sp. AL	Carp CPE	Carp AL	Suckers sp. CPE	White bass CPE
1959	336.0	11					0.03 (0.03)		0.02 (0.01)		<0.01 (<0.01)		1.84 (0.46)		0.19 (0.09)											
1960	508.0	17	<0.01 (<0.01)				0.02 (0.01)		<0.01 (<0.01)		0.01 (0.01)		0.91 (0.18)		0.27 (0.10)		<0.01 (<0.01)		<0.01 (<0.01)							
1961	162.0	8											1.19 (0.28)		0.53 (0.27)											
1962	519.0	18	0.01 (<0.01)				0.01 (0.01)		0.01 (0.01)		<0.01 (<0.01)		1.84 (0.29)		0.21 (0.08)								0.01 (0.01)			0.01 (0.01)
1963	57.0	5											2.61 (0.47)		0.26 (0.11)											

Table D.37.–Direct contact lake angler creel data for the Tittabawassee River main stem-middle Secord Lake, Gladwin County. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

			Brook trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Northern pike		Bullhead sp.	
Year	Total hours	Days (N)	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
1929	28	3																0.39 (0.17)	21.35 (0.30)		
1930	4.5	2																			
1932	39	7		0.13 (0.10)		0.05 (0.06)		1.36 (0.31)		0.21 (0.11)		0.26 (0.20)				2.15 (1.06)		0.08 (0.05)	22.00 (0.00)		
1933	140	28				0.01 (0.01)		0.09 (0.05)		0.05 (0.05)		0.51 (0.30)		0.03 (0.03)		0.50 (0.20)	8.50 (0.00)	0.06 (0.03)	20.00 (1.15)	0.11 (0.11)	8.00 (0.00)
1934	4.5	3																			
1935	147.5	74				0.08 (0.03)	10.75 (0.41)	1.26 (0.30)	6.82 (0.03)	0.02 (0.02)		0.05 (0.03)	7.00 (0.00)			0.07 (0.04)	7.00 (0.00)				
1939	41	12		0.15 (0.08)	15.50 (0.50)			0.98 (0.51)	7.00 (0.00)			0.07 (0.05)	8.00 (–)					0.05 (0.03)	16.25 (1.75)		
1940	20	3		0.50 (0.47)	14.00 (0.00)	0.05 (0.04)	12.00 (–)					0.15 (0.06)	8.00 (1.00)					0.05 (0.05)	21.00 (–)		
1941	50	3		0.14 (0.15)	14.00 (0.00)	0.02 (0.02)	17.00 (–)					0.02 (0.02)	7.00 (–)								
1945	9	1						2.22 (–)	7.00 (–)					0.22 (–)	7.00 (–)						
1946	264	4				<0.01 (<0.01)	12.00 (–)	0.03 (0.03)	7.00 (0.00)	<0.01 (<0.01)	6.00 (–)	0.04 (0.02)	7.00 (0.00)	0.06 (0.05)	7.00 (0.00)	0.03 (0.02)	7.03 (0.21)	0.01 (0.01)	31.00 (1.00)		
1954	100	2						0.78 (0.84)						0.79 (0.05)				0.03 (<0.01)			
1957	86	6						0.20 (0.11)		0.01 (0.01)				0.67 (0.20)		0.13 (0.05)					
1958	213	6						0.11 (0.05)						0.38 (0.33)		0.04 (0.03)		0.01 (0.01)			
1959	6	1						2.83 (–)						2.50 (–)							
1960	1	1																			
1961	38	1						0.82 (–)								0.08 (–)		0.03 (–)			
1963	48	2				0.06 (0.03)		0.29 (0.12)		0.02 (0.01)				0.13 (0.18)				0.02 (0.03)			

Table D.38.–Direct contact lake angler creel data for the Tittabawassee River main stem-middle Smallwood Lake, Gladwin County. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

			Smallmouth bass	Largemouth bass		Bluegill		Pumpkinseed sunfish	Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.	Suckers sp.
Year	Total hours	Days (N)	CPE	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE
1932	5	1						1.60 (–)	1.20 (–)				0.60 (–)						1.40 (–)	
1934	8	2											0.38 (0.42)							
1935	114	56	0.01 (0.01)	0.05 (0.02)	11.67 (1.20)	0.44 (0.14)	6.82 (0.07)	0.03 (0.03)	0.01 (0.01)	7.00 (–)	0.07 (0.03)	7.43 (0.30)	0.04 (0.02)	8.00 (–)			0.06 (0.03)	23.00 (1.00)		
1937	84	55											0.57 (0.24)	6.92 (0.04)	0.01 (0.01)	20.00 (–)	0.01 (0.01)	24.00 (–)		
1946	38	3									0.21 (0.11)	7.50 (0.09)	0.05 (0.05)	7.00 (0.00)			0.08 (0.07)	32.00 (0.00)		
1954	40	2									1.18 (1.18)									
1957	163	13				0.15 (0.08)		0.02 (0.02)	0.15 (0.08)		0.76 (0.27)		0.25 (0.17)						0.02 (0.02)	0.01 (0.01)
1958	113	8	0.01 (0.01)			0.15 (0.11)			0.02 (0.02)		0.71 (0.21)		0.04 (0.03)				0.02 (0.01)		0.02 (0.02)	
1959	72	3	0.01 (0.01)			0.96 (0.51)		0.11 (0.07)	0.03 (0.03)		0.86 (0.15)		0.06 (0.05)							
1960	73	5									0.53 (0.38)		0.04 (0.02)							
1961	39	4									0.82 (0.41)						0.10 (0.04)			
1963	41	2							0.02 (0.03)		0.46 (0.52)						0.05 (0.05)			
1964	13	2									0.62 (0.62)		0.08 (0.08)							

Table D.39.–Direct contact lake angler creel data for the Tittabawassee River main stem-middle Wixom Lake, Gladwin County. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Carp		Suckers sp.
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
1932	109.0	26	0.13 (0.05)				0.20 (0.08)		0.05 (0.04)		0.34 (0.13)	8.00 (0.00)	0.28 (0.16)		0.50 (0.15)				0.01 (0.01)	28.00 (–)	1.56 (0.38)	6.26 (0.07)			
1933	315.5	79	0.01 (0.01)		0.01 (0.01)				0.02 (0.02)		0.07 (0.03)		0.17 (0.08)	7.06 (0.07)	0.18 (0.08)		0.01 (0.01)	22.67 (1.33)	0.08 (0.02)	22.57 (0.70)	0.81 (0.23)	7.48 (0.08)	0.01 (0.01)	25.00 (0.00)	0.01 (0.01)
1934	291.0	65	0.02 (0.01)	13.50 (0.29)	<0.01 (<0.01)		0.03 (0.02)		0.06 (0.03)		0.01 (0.01)		0.17 (0.06)	7.88 (0.04)	0.17 (0.06)	7.50 (0.00)			0.07 (0.02)	23.74 (0.70)	0.20 (0.08)	8.00 (0.00)			
1935	172.0	88			0.08 (0.04)	12.08 (0.29)	0.07 (0.04)	6.67 (0.11)	0.05 (0.03)	7.00 (0.00)	0.06 (0.03)	6.56 (0.24)	1.72 (0.33)	7.15 (0.03)	0.09 (0.04)	8.00 (–)									
1939	52.0	18	0.13 (0.07)	14.00 (0.31)			0.23 (0.19)	6.92 (0.08)			0.04 (0.04)	6.00 (0.00)	0.35 (0.24)	7.00 (0.00)	0.12 (0.09)	7.83 (0.17)	0.02 (0.02)	30.00 (–)	0.04 (0.02)	17.00 (3.00)					
1940	16.0	3									0.50 (0.47)	8.00 (0.00)													
1942	2.0	1	0.50 (–)	11.00 (–)																					
1943	2.0	1					0.50 (–)	6.00 (–)																	
1945	8.0	1																							
1946	345.0	4	<0.01 (<0.01)	8.00 (–)			0.02 (<0.01)	6.79 (0.06)					1.01 (0.15)	7.75 (0.00)	0.01 (0.01)	7.00 (0.00)			0.01 (0.01)	28.00 (1.10)					
1947	131.5	4					0.04 (0.03)				0.02 (0.01)		1.96 (0.77)		0.05 (0.05)		0.01 (0.01)		0.01 (0.01)						
1950	75.0	2											3.13 (0.02)		0.71 (0.19)										
1952	282.0	7	0.07 (0.07)				0.38 (0.20)				<0.01 (<0.01)		1.88 (0.76)		0.17 (0.08)				<0.01 (<0.01)		<0.01 (<0.01)				
1953	69.0	5											0.71 (0.24)		0.41 (0.27)										0.09 (0.11)
1954	321.0	9	0.01 (0.01)				0.15 (0.08)		0.02 (0.02)		0.05 (0.03)		1.49 (0.40)		0.22 (0.08)				0.01 (0.01)						
1955	136.0	6	0.05 (0.02)				0.29 (0.16)		0.03 (0.02)				0.74 (0.33)		0.08 (0.04)										
1956	275.5	12	0.02 (0.02)				0.36 (0.06)		<0.01 (<0.01)		0.03 (0.02)		0.29 (0.11)		0.44 (0.28)										
1957	967.0	45	0.01 (<0.01)		<0.01 (<0.01)		0.14 (0.04)		0.03 (0.01)		0.04 (0.01)		0.94 (0.14)		0.25 (0.05)		<0.01 (<0.01)		0.02 (0.01)				<0.01 (<0.01)		<0.01 (<0.01)

Table D.39.–Continued.

Year	Total hours	Days (N)	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Carp		Suckers sp.
			CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
1958	1975.2	39	0.02 (0.01)				0.05 (0.02)		0.02 (0.01)		0.02 (0.01)		0.81 (0.13)		0.17 (0.03)				0.02 (0.01)				<0.01 (<0.01)		
1959	2561.5	36	<0.01 (<0.01)				0.07 (0.02)		0.05 (0.01)		0.08 (0.02)		1.17 (0.11)		0.12 (0.01)		<0.01 (<0.01)		0.01 (<0.01)				<0.01 (<0.01)		<0.01 (<0.01)
1960	1780.5	31	0.01 (<0.01)		0.01 (<0.01)		0.12 (0.04)		0.05 (0.01)		0.11 (0.04)		1.15 (0.19)		0.14 (0.04)				0.01 (<0.01)						0.02 (0.01)
1961	1456.0	27	0.03 (0.01)				0.02 (0.01)		0.01 (<0.01)		0.04 (0.02)		1.31 (0.32)		0.21 (0.07)				0.02 (0.01)		<0.01 (<0.01)				<0.01 (<0.01)
1962	1248.2	32	0.01 (<0.01)				0.02 (0.01)		0.02 (0.01)		0.10 (0.02)		1.34 (0.15)		0.23 (0.10)				0.04 (0.01)		0.01 (0.01)				0.05 (0.04)
1963	381.5	10					<0.01 (<0.01)		0.03 (0.02)		0.04 (0.03)		1.69 (0.33)		0.08 (0.06)				0.06 (0.04)		0.01 (0.01)				0.03 (0.03)
1964	692.0	14	0.01 (<0.01)				0.01 (0.01)		0.03 (0.01)		0.14 (0.04)		1.56 (0.46)		0.14 (0.04)				0.01 (<0.01)		<0.01 (<0.01)				
1965	231.0	5							0.10 (0.05)		0.14 (0.03)		1.45 (0.51)		0.26 (0.08)				0.01 (0.01)						

Table D.40.–Direct contact lake angler creel data for Arnold, Bailey, Beebe, Blue, Boathouse, Lower Brennan, and Upper Brennan lakes. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

County		Total	Days	Brook trout		Brown trout	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Northern pike		Sucker sp.
Lake	Year	hours	(N)	CPE	AL	CPE	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
Clare																								
Arnold	1929	91.0	9					0.04 (0.02)	12.00 (–)	0.02 (0.02)		0.03 (0.03)		0.01 (0.01)								0.09 (0.03)	20.50 (1.50)	
	1934	12.0	4					0.33 (0.41)		0.92 (0.10)	12.05 (0.63)													
	1938	24.0	6					0.04 (0.04)	11.00 (–)			0.38 (0.35)	6.00 (–)							0.17 (0.18)		0.04 (0.04)	28.00 (–)	
	1939	4.5	1																					
	1942	31.0	3							0.19 (0.15)	14.33 (0.33)	0.97 (0.70)	8.00 (0.00)											
	1944	41.5	2							0.12 (0.15)	12.00 (0.00)	0.10 (0.03)	7.25 (0.25)							0.02 (0.02)	7.00 (–)			
	1947	7.0	1									0.43 (–)												
	1948	12.0	1									2.08 (–)		0.67 (–)		0.17 (–)								
	1949	23.0	3																			0.09 (0.04)		
	1950	51.0	3									1.45 (0.42)		0.12 (0.13)						0.22 (0.13)				
	1951	180.0	13							0.05 (0.04)		1.20 (0.42)								0.04 (0.03)		0.03 (0.03)		
	1952	50.0	5									1.32 (0.18)								0.02 (0.02)		0.04 (0.05)		
	1953	36.0	6				0.03 (0.03)					0.47 (0.37)								0.06 (0.05)		0.14 (0.07)		
	1954	52.0	3	0.04 (0.05)		0.25 (0.06)	0.06 (0.02)					0.35 (0.48)												
	1955	141.0	13				0.02 (0.02)					0.25 (0.16)						0.01 (0.01)		0.01 (0.01)		0.06 (0.03)		
	1956	117.0	11			0.06 (0.04)	0.05 (0.03)			0.03 (0.03)		0.62 (0.27)								0.07 (0.07)		0.01 (0.01)		
	1957	192.5	15			0.01 (0.01)	0.02 (0.02)					0.98 (0.30)						0.02 (0.02)		0.03 (0.02)		0.04 (0.03)		

Table D.40.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Northern pike AL	Sucker sp. CPE
Clare																								
Arnold	1958	127.0	12			0.02 (0.03)						1.10 (0.33)								0.02 (0.02)				
	1959	22.0	3				0.05 (0.05)							0.32 (0.22)						0.09 (0.06)		0.05 (0.03)		
	1960	78.5	2				0.01 (<0.01)					0.61 (0.06)						0.24 (0.09)		0.01 (<0.01)		0.03 (0.02)		
	1961	35.0	3																	0.06 (0.04)		0.11 (0.08)		
	1962	27.0	2				0.04 (0.03)					0.30 (0.33)								0.07 (0.08)		0.07 (0.08)		
Bailey	1940	61.5	16									5.50 (1.18)	7.69 (0.02)	0.88 (0.63)	7.00 (0.00)			0.54 (0.18)	8.33 (0.12)	0.07 (0.07)				
	1941	96.5	13									0.07 (0.04)	7.14 (0.14)					0.03 (0.01)	8.00 (1.15)					
Beebe	1941	31.0	5									0.16 (0.15)	7.00 (0.00)	0.03 (0.03)	6.00 (–)							0.03 (0.03)	20.00 (–)	
	1954	1.0	1									1.00 (–)		2.00 (–)										
	1955	4.0	1																					
Gladwin																								
Blue	1932	9.0	2	0.22 (0.25)	10.00 (0.00)																			
	1933	9.0	3	1.78 (0.90)	8.22 (0.06)																			
	1934	4.5	1	0.44 (–)	8.50 (–)																			
	1937	4.3	2																					
	1939	1.5	1																					
	1942	20.0	1							0.40 (–)	12.00 (–)	0.05 (–)	6.00 (–)			0.25 (–)	6.50 (–)			0.30 (–)	7.00 (–)			
	1958	2.0	1																					

Table D.40.–Continued.

County		Total	Days	Brook trout		Brown trout	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Northern pike		Sucker sp.
Lake	Year	hours	(N)	CPE	AL	CPE	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
Clare																								
Boathouse	1935	6.0	1							0.67 (–)	12.00 (–)													
	1940	2.0	1																	4.50 (–)	9.00 (–)			
	1947	18.0	1							0.28 (–)		2.22 (–)												
	1957	11.0	1																	0.09 (–)				0.09 (–)
Brennan, Lower	1951	25.0	3									0.08 (0.04)								0.28 (0.35)		0.04 (0.05)		
	1952	2.0	1																	2.00 (–)				
	1957	5.0	2																					
	1958	24.0	2									0.42 (0.31)								0.38 (0.28)				0.29 (0.51)
Brennan, Upper	1950	3.0	1									1.33 (–)												

Table D.41.–Direct contact lake angler creel data for Budd Lake, Clare County. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

	Total	Days	Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.	Muskellunge
Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE
1929	233.0	54					0.05 (0.02)	11.80 (0.20)	0.04 (0.01)	11.67 (0.67)	0.27 (0.07)	6.86 (0.08)	0.08 (0.03)	8.00 (0.00)					0.09 (0.03)	7.50 (0.00)					0.02 (0.02)	
1930	211.0	37					0.18 (0.08)	13.45 (0.16)	0.16 (0.06)	15.00 (0.50)	0.89 (0.40)	8.08 (0.03)	0.01 (0.01)		0.01 (0.01)				0.02 (0.01)						0.05 (0.06)	
1932	4.0	2					0.25 (0.38)	18.00 (–)					6.25 (3.13)													
1933	441.0	4					0.05 (0.01)		0.04 (<0.01)		2.57 (0.24)		0.40 (0.05)						0.04 (0.01)							
1934	402.6	77					0.11 (0.03)	12.43 (0.37)	0.04 (0.02)	14.00 (0.00)	3.89 (0.33)	7.59 (0.04)	0.61 (0.14)	7.00 (0.00)	0.06 (0.03)	6.00 (0.00)			0.41 (0.17)				<0.01 (<0.01)	36.00 (–)		
1935	19.0	7									3.16 (0.85)	7.60 (0.05)														
1937	95.8	56					0.16 (0.09)	11.04 (0.04)			1.01 (0.18)	7.32 (0.06)	0.24 (0.11)	7.43 (0.12)	0.01 (0.01)	7.00 (–)			0.11 (0.06)	8.80 (0.39)						
1939	20.5	11					0.10 (0.06)	12.50 (2.50)	0.68 (0.35)	12.18 (0.41)	0.83 (0.66)		0.10 (0.08)		0.15 (0.13)	7.00 (0.00)										
1940	93.5	25					0.15 (0.06)	11.79 (0.31)	0.29 (0.08)	11.59 (0.25)	0.61 (0.18)	7.12 (0.06)	0.41 (0.14)	7.93 (0.03)	0.17 (0.09)				0.11 (0.10)	11.00 (0.00)						
1941	95.0	15					0.12 (0.07)	11.64 (0.15)			1.61 (0.80)	8.85 (0.04)	0.16 (0.12)	7.17 (0.17)			0.08 (0.09)	10.00 (0.00)								
1942	733.5	40					0.08 (0.02)	11.72 (0.14)	0.05 (0.01)	11.53 (0.08)	2.06 (0.18)	7.99 (0.01)	0.06 (0.05)	8.33 (0.07)	<0.01 (<0.01)	8.00 (–)	0.03 (0.03)	9.54 (0.03)			<0.01 (<0.01)	12.00 (–)				
1943	238.0	18					0.07 (0.02)	11.13 (0.17)	0.06 (0.03)	12.00 (0.48)	1.13 (0.18)	7.94 (0.01)	0.17 (0.04)	7.98 (0.02)	0.13 (0.05)	6.73 (0.08)	0.02 (0.01)	10.00 (0.00)	<0.01 (<0.01)	8.00 (–)						
1944	608.5	29	<0.01 (<0.01)	19.00 (–)	<0.01 (<0.01)	12.00 (–)	0.07 (0.02)	11.95 (0.03)	0.09 (0.02)	11.96 (0.09)	1.50 (0.18)	7.92 (0.01)	0.14 (0.02)	7.79 (0.06)	0.03 (0.01)	6.88 (0.08)	0.02 (0.01)	10.00 (0.00)	0.01 (<0.01)	8.50 (1.19)						
1945	225.0	15					0.04 (0.01)	11.11 (0.31)	0.05 (0.02)	12.27 (0.18)	1.75 (0.11)	7.57 (0.03)	0.06 (0.02)	7.00 (0.00)	0.02 (0.01)	7.00 (0.00)	0.06 (0.02)	10.14 (0.10)	0.03 (0.01)	7.86 (0.55)						
1947	107.0	1					0.02 (–)		0.02 (–)		1.02 (–)		0.13 (–)		0.17 (–)		0.08 (–)		0.25 (–)							
1948	274.0	13					0.04 (0.02)		0.01 (0.01)		1.11 (0.25)		0.16 (0.05)		0.03 (0.01)		<0.01 (<0.01)		0.05 (0.02)							
1949	107.8	3					0.04 (0.01)		0.02 (0.01)		1.74 (0.54)		0.14 (0.10)		0.02 (<0.01)				0.02 (0.01)							
1950	4.0	1									7.50 (–)															

Table D.41.–Continued.

Year	Total hours	Days (N)	Brown trout CPE	Brown trout AL	Rainbow trout CPE	Rainbow trout AL	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Muskellunge CPE
1951	86.0	6									2.84 (0.99)		0.21 (0.18)				0.28 (0.21)									
1953	57.0	2									1.26 (1.31)		0.28 (0.29)						0.04 (0.04)							
1955	138.0	4					0.05 (0.03)		0.02 (0.02)		0.88 (0.25)		0.01 (0.01)						0.04 (0.03)							
1956	151.0	7							0.01 (<0.01)		2.30 (1.02)		0.05 (0.04)		0.01 (<0.01)				0.15 (0.09)							
1957	161.0	9							0.03 (0.01)		1.19 (0.43)				0.01 (0.02)		0.02 (0.03)		0.07 (0.05)							
1958	147.0	5									0.35 (0.14)		0.11 (0.14)						0.21 (0.04)							
1959	129.0	7							0.05 (0.03)		0.45 (0.23)		0.04 (0.02)		0.01 (<0.01)				0.16 (0.12)							0.05 (0.04)
1960	81.0	4									1.07 (0.25)						0.02 (0.02)		0.25 (0.12)							
1961	149.5	7							0.01 (0.01)		1.18 (0.23)						0.01 (0.01)		0.18 (0.16)							
1962	240.0	4							0.03 (0.03)		1.45 (0.32)		0.01 (0.01)		0.01 (0.01)				0.02 (0.02)							
1963	118.0	2							0.01 (0.01)		1.47 (0.58)		0.03 (0.03)						0.16 (0.08)							
1964	51.0	1							0.06 (–)		0.84 (–)								0.27 (–)							

Table D.42.–Direct contact lake angler creel data for Cranberry Lake (Clare and Missaukee counties) and Cranberry Lake (Clare County. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

County		Total	Days	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.	Yellow perch	Walleye		Northern pike		Bullhead sp.	Sucker sp.
Lake	Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	CPE	AL	CPE	AL	CPE	CPE
Clare & Missaukee																					
Cranberry	1939	33.3	10	0.18 (0.18)	12.00 (0.00)	0.21 (0.09)	11.29 (0.18)			0.09 (0.09)	7.00 (0.00)	0.03 (0.03)	7.00 (–)					0.15 (0.08)	16.20 (0.20)		
	1944	17.0	2			0.59 (0.35)	12.00 (0.00)											0.18 (0.25)	22.00 (0.00)		
	1948	1.0	1																		
	1949	59.0	5															0.27 (0.07)			
	1950	90.0	3															0.12 (0.06)			
	1951	57.0	4															0.05 (0.04)			
	1952	87.5	7															0.33 (0.11)			
	1953	68.0	4												0.68 (0.19)			0.38 (0.07)			0.03 (0.04)
	1954	29.0	2															0.55 (0.17)			
	1955	14.0	1															0.14 (–)			
	1956	28.0	3															0.29 (<0.01)			
	1958	38.0	3												0.32 (0.36)			0.03 (0.03)			
	1959	12.0	1															0.33 (–)			
	1961	27.0	2												0.04 (0.01)			0.15 (0.03)			
	1962	18.0	1															0.11 (–)			
	1964	8.0	1																		

Table D.42.–Continued.

County Lake	Year	Total hours	Days (N)	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Yellow perch CPE	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Sucker sp. CPE
Clare																					
Cranberry	1928	48.0	3			0.02 (0.03)		0.73 (0.37)										0.38 (0.24)			
	1929	228.0	20			0.01 (0.01)				0.03 (0.03)								0.25 (0.05)	19.40 (0.27)		
	1930	27.5	7	0.04 (0.03)		0.07 (0.07)		0.47 (0.41)								0.18 (0.18)	19.00 (0.00)	1.02 (0.44)	16.33 (0.14)	0.04 (0.04)	
	1932	8.5	2	0.35 (0.33)	15.00 (0.00)	0.24 (0.25)	17.00 (0.00)														
	1934	93.0	14	0.02 (0.02)		0.35 (0.15)	12.60 (0.15)	0.53 (0.16)	6.44 (0.12)	0.19 (0.12)					0.14 (0.08)			0.01 (0.01)			
	1937	2.0	1			1.50 (–)	12.00 (–)														
	1938	13.0	2																		
	1942	37.0	4			0.41 (0.17)	12.33 (0.41)	1.11 (1.03)	8.00 (0.00)						0.05 (0.04)			0.03 (0.03)	15.00 (–)		
	1943	39.0	3			0.31 (0.25)	12.00 (0.00)	0.87 (0.61)	8.00 (0.00)									0.08 (0.10)	18.00 (0.00)		
	1946	10.0	1			0.10 (–)	14.00 (–)														
	1947	60.0	1					0.17 (–)		0.02 (–)					0.08 (–)			0.05 (–)			
	1948	212.5	11	<0.01 (<0.01)		0.03 (0.03)		0.18 (0.06)		0.05 (0.02)					<0.01 (<0.01)			0.16 (0.10)		0.06 (0.05)	
	1949	394.5	12	0.03 (0.01)				0.24 (0.17)		0.06 (0.03)					<0.01 (<0.01)			0.18 (0.06)			
	1950	89.0	5	0.15 (0.13)						0.02 (0.02)						0.01 (0.01)		0.04 (0.02)			
	1951	166.0	6			0.02 (0.01)		0.45 (0.36)							0.04 (0.01)			0.08 (0.01)			
	1952	175.0	13			0.02 (0.01)		0.06 (0.05)		0.01 (0.01)								0.20 (0.03)			
	1953	266.0	17			<0.01 (<0.01)		0.71 (0.30)		0.02 (0.02)					0.26 (0.23)			0.24 (0.07)			
	1954	134.0	6					0.36 (0.19)		0.01 (0.02)								0.33 (0.05)			

Table D.42.–Continued.

County Lake	Year	Total hours	Days (N)	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Yellow perch CPE	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Sucker sp. CPE
Clare																					
Cranberry	1955	191.0	11			0.01 (0.01)		0.57 (0.30)		0.04 (0.03)					0.03 (0.02)			0.11 (0.04)			
	1956	119.0	9			0.01 (0.01)		0.03 (0.02)							0.01 (0.01)			0.15 (0.02)			
	1957	148.0	6					0.07 (0.07)							0.01 (0.01)			0.14 (0.05)			
	1958	52.0	5					0.17 (0.19)							0.10 (0.10)			0.04 (0.02)			
	1959	43.0	2					0.30 (0.17)		0.09 (0.05)				0.09 (0.05)	0.12 (0.06)			0.14 (0.15)			
	1960	31.0	1					0.03 (–)							0.03 (–)			0.03 (–)			
	1961	27.0	2												0.30 (0.36)			0.07 (0.09)			
	1962	19.0	2					0.16 (0.03)						0.05 (0.01)							
	1963	91.0	3					0.36 (0.30)													
	1964	10.0	1																		

Table D.43.–Direct contact lake angler creel data for Deadman, Decker, Deer, Dodge, Dunham, Elbow, Five, and Gut lakes. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Rainbow trout CPE	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Bullhead sp. CPE
Clare																			
Deadman	1935	3.0	1	2.00	13.00														
				(–)	(–)														
	1956	12.0	1						1.67										
									(–)										
Decker	1938	1.0	1						12.00	7.00									
									(–)	(–)									
Deer	1942	16.0	2				0.31	15.00											
							(0.02)	(0.00)											
Dodge	1929	2.0	1													3.00	8.00		
																(–)	(–)		
	1930	5.0	1						8.20	4.75									
									(–)	(–)									
	1935	23.5	14				0.72	12.50								0.26	8.67		
							(0.22)	(0.49)								(0.15)	(0.21)		
	1937	14.3	5				0.42	15.50											
							(0.34)	(0.50)											
	1938	24.0	8				0.25	11.50	0.29	6.43			0.25	6.00		0.46	7.09		
							(0.11)	(0.18)	(0.14)	(0.20)			(0.24)	(0.00)		(0.42)	(0.09)		
	1939	9.5	3								0.53	7.00				0.74	7.71		
											(0.21)	(0.00)				(0.22)	(0.18)		
	1940	19.0	5													1.11	8.29		
																(0.48)	(0.12)		
	1941	6.0	1								0.17	7.00				0.33	11.00		
											(–)	(–)				(–)	(–)		
	1947	15.0	1													1.53			
																(–)			
	1952	7.0	1													0.29		0.14	
																(–)		(–)	
	1955	24.0	1						0.29						0.04				
									(–)						(–)				
	1956	8.0	3						0.38										
									(0.35)										
	1957	6.0	1																

Table D.43.–Continued.

County		Total	Days	Brook trout		Rainbow trout	Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.	Yellow perch		Northern pike	Bullhead sp.
Lake	Year	hours	(N)	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	CPE
Roscommon																			
Dunham	1959	146.0	4			0.10													
						(0.09)													
	1960	34.0	1			0.74													
						(–)													
Clare																			
Elbow	1930	0.8	1													14.67	7.50		
																(–)	(–)		
Five	1928	38.0	2						0.03							2.45	8.00		
									(0.03)							(0.84)	(0.00)		
	1929	24.0	2																
	1930	4.0	1						1.50							1.50			
									(–)							(–)			
	1933	4.0	1																
	1935	16.0	6						4.38	7.70									
									(1.20)	(0.04)									
	1948	290.5	10				0.04		0.92		0.02					0.13		<0.01	<0.01
							(0.01)		(0.12)		(0.02)					(0.03)		(<0.01)	(<0.01)
	1949	21.0	2										0.14			0.10			
													(0.20)			(0.05)			
	1950	233.0	6				0.01		0.52							0.01		<0.01	
							(0.01)		(0.18)							(0.01)		(<0.01)	
	1951	12.0	1				0.58		0.58										
							(–)		(–)										
	1953	41.0	4						0.17							0.44			
									(0.16)							(0.25)			
	1955	1.0	1																
	1957	27.0	1						2.74							0.15			
									(–)							(–)			
	1958	50.0	3				0.02		0.66									0.02	
							(0.01)		(0.08)									(0.03)	
	1959	209.0	5				0.12		0.90		0.07					0.01		0.07	
							(0.07)		(0.27)		(0.02)					(0.01)		(0.05)	
	1960	472.0	11						0.94		0.09					0.03		0.02	
									(0.10)		(0.04)					(0.02)		(0.02)	

Table D.43.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Rainbow trout CPE	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Bullhead sp. CPE
Clare																			
Five	1961	47.0	2																
	1964	90.5	4				0.06		0.34		0.01							0.03	
							(0.04)		(0.25)		(0.01)							(0.02)	
Gut	1947	15.0	1						1.73										
									(–)										
	1950	4.0	1				0.50		0.75										
							(–)		(–)										

Table D.44.–Direct contact lake angler creel data for Hoister, House, Howland, Lily, and Little Long lakes. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

County		Total	Days	Brook trout		Brown trout		Rainbow trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass	Crappie sp.	Yellow perch		Northern pike	Bullhead sp.
Lake	Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	CPE	AL	CPE	CPE
Gladwin																							
Hoister	1934	24.0	5	0.08 (0.08)														0.25 (0.27)		2.21 (0.31)	8.34 (0.04)		
	1948	6.0	1																				
	1949	13.0	1	0.08 (–)																			
	1953	6.0	1	0.67 (–)																			
	1956	13.0	2	0.38 (0.24)																			
	1957	110.5	5	0.49 (0.04)																			
	1958	134.0	4	0.50 (0.07)																			
	1959	95.0	5	0.42 (0.06)																			
	1960	93.0	3	0.58 (0.11)																			
	1961	95.0	9	0.05 (0.04)				0.37 (0.17)															
	1962	97.0	7	0.88 (0.19)																			
	1963	52.0	1	0.52 (–)																			
	1964	2.0	1																				
House	1956	7.0	1											0.43 (–)									
	1957	9.5	3																				
	1958	10.0	2											0.20 (0.04)									
	1961	42.0	5	0.38 (0.21)				0.07 (0.06)															
	1962	112.0	6			0.04 (0.04)		0.45 (0.15)															

Table D.44.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Brown trout AL	Rainbow trout CPE	Rainbow trout AL	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Crappie sp. CPE	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Bullhead sp. CPE
Gladwin																							
House	1963	22.0	1					0.45 (–)															
	1964	62.0	6					0.56 (0.15)															
Clare																							
Howland	1949	13.0	1											0.15 (–)								0.08 (–)	
	1958	18.0	1											0.06 (–)									
Lily	1950	109.0	8							0.02 (0.02)		0.05 (0.04)		1.38 (0.70)		0.17 (0.11)				0.03 (0.03)			
	1951	35.0	5									0.03 (0.04)		0.31 (0.25)		0.06 (0.03)							
	1952	248.0	8									0.05 (0.05)		0.88 (0.26)		0.01 (0.01)			<0.01 (<0.01)			0.02 (0.01)	
	1953	396.0	13							<0.01 (<0.01)		0.02 (0.02)		1.16 (0.16)		0.09 (0.05)				0.07 (0.03)			
	1954	300.0	11							0.01 (0.01)		0.01 (0.01)		0.76 (0.22)		0.03 (0.02)				0.07 (0.04)			
	1955	264.0	15									0.01 (0.01)		1.06 (0.30)						0.14 (0.06)			
	1956	252.0	13							0.01 (0.01)		0.03 (0.02)		1.05 (0.22)						0.07 (0.03)			
	1957	230.0	8									0.02 (0.01)		1.13 (0.30)						0.03 (0.01)			
	1958	362.5	13									0.01 (0.01)		1.20 (0.16)		0.01 (0.01)				0.01 (0.01)			
	1959	19.0	1											2.05 (–)									
	1961	179.0	5											0.09 (0.07)		0.01 (0.01)						0.05 (0.02)	0.03 (0.04)
	1962	36.0	2																			0.06 (0.01)	
Long, Little	1930	3.0	1			0.33 (–)	24.00 (–)																
	1934	7.0	2							0.29 (0.24)		0.43 (0.08)	19.50 (–)										
	1935	3.0	1									0.33 (–)	0.00 (–)	1.33 (–)									
	1939	17.0	5							1.06 (0.96)	9.56 (0.32)	0.59 (0.15)	12.25 (0.07)	2.82 (0.89)	9.23 (0.09)	0.06 (0.05)	9.00 (–)						

Table D.44.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Brown trout AL	Rainbow trout CPE	Rainbow trout AL	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Crappie sp. CPE	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Bullhead sp. CPE
Clare																							
Long, Little	1940	65.8	24							0.09	10.50	0.24	11.63	3.42	7.81	0.02	7.00			0.06	7.50		
										(0.03)	(0.34)	(0.06)	(0.39)	(0.50)	(0.05)	(0.02)	(–)			(0.05)	(0.50)		
	1941	51.5	9			0.16	17.75			0.02	12.00			0.76	9.56					0.02	13.00		
						(0.08)	(0.49)			(0.02)	(–)			(0.45)	(0.08)					(0.02)	(–)		
	1942	352.0	21			0.07	17.53			0.01	10.75			1.17	8.01								
						(0.03)	(0.25)			(0.01)	(0.25)			(0.19)	(0.01)								
	1943	108.0	8			0.05	16.40			0.03	11.33	0.02	12.00	1.78	8.06								
						(0.04)	(0.60)			(0.02)	(0.67)	(0.02)	(0.00)	(0.21)	(0.01)								
	1944	159.5	10			0.04	17.43			0.02	11.33	0.03	12.00	1.89	8.47								
						(0.02)	(0.95)			(0.01)	(0.67)	(0.02)	(0.55)	(0.63)	(0.03)								
	1945	487.0	22	<0.01	15.00	0.15	16.26	0.03	21.19	<0.01	12.00	0.01	10.98	0.47	7.96								
				(<0.01)	(0.00)	(0.03)	(0.10)	(0.01)	(0.15)	(<0.01)	(–)	(0.01)	(0.68)	(0.15)	(0.02)								
	1946	527.0	17			0.28	13.39	<0.01	24.50					0.16	8.54					<0.01	12.00		
						(0.03)	(0.09)	(<0.01)	(0.00)					(0.12)	(0.07)					(<0.01)	(–)		
	1947	84.0	6			0.23								0.39						0.01			
						(0.07)								(0.31)						(0.01)			
	1948	257.0	6			0.51								0.05						<0.01			
						(0.16)								(0.05)						(<0.01)			
	1949	472.0	10			0.20				0.01				0.06		<0.01							0.03
						(0.04)				(0.01)				(0.05)		(<0.01)							(0.02)
	1950	151.0	7			0.16				0.01		0.02		0.48		0.01							0.01
						(0.09)				(0.01)		(0.01)		(0.20)		(<0.01)							(<0.01)
	1951	221.0	12			0.24								0.04									
						(0.07)								(0.04)									
	1952	137.5	5			0.24								0.40									
						(0.12)								(0.25)									
	1953	133.0	6			0.15								0.09									0.14
						(0.05)								(0.07)									(0.12)
	1954	69.0	4			0.17		0.03				0.01										0.01	
						(0.14)		(0.03)				(0.01)										(0.01)	
	1955	134.0	7			0.10						0.12		0.77									
						(0.05)						(0.10)		(0.21)									
	1956	247.0	10			0.06				0.04		<0.01		0.52		0.03		<0.01		0.01		0.01	
						(0.05)				(0.02)		(<0.01)		(0.15)		(0.02)		(<0.01)		(<0.01)		(0.01)	
	1957	65.0	4			0.29								1.31						0.06			
						(0.19)								(0.72)						(0.04)			
	1958	62.5	5											0.62						0.02		0.03	
														(0.36)						(0.01)		(0.02)	
	1959	28.0	2											0.71									
														(0.31)									

Table D.44.–Continued.

County Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Brown trout AL	Rainbow trout CPE	Rainbow trout AL	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Crappie sp. CPE	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Bullhead sp. CPE
Clare																							
Long, Little	1960	200.0	7			0.01 (0.01)		0.04 (0.02)				0.06 (0.04)		0.24 (0.08)		0.05 (0.04)			0.01 (<0.01)	0.01 (0.01)			
	1961	54.0	5					0.17 (0.10)															
	1962	14.0	1																				
	1963	82.0	2			0.33 (0.01)																	
	1964	24.0	1			0.17 (–)																	

Table D.45.–Direct contact lake angler creel data for Hoister, House, Howland, Lily, and Little Long lakes. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

County		Total	Days	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass	crap sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.
Lake	Year	hours	(N)	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
Clare																						
Loon, Big	1932	6.0	2				1.67	15.00								0.17						
							(<0.01)	(0.00)								(0.17)						
	1933	12.0	4		0.42		0.17		2.08		1.92					1.75						
					(0.32)		(0.16)		(1.18)		(0.55)					(0.55)						
	1940	10.5	3													1.33	9.21					
																(0.49)	(0.11)					
Loon, Little	1929	8.0	1						0.25							3.13						
									(–)							(–)						
	1930	5.0	1				0.40															
							(–)															
	1935	2.0	1		1.50						1.50											
					(–)						(–)											
	1943	8.0	1				0.13	14.00	1.25	9.00												
							(–)	(–)	(–)	(–)												
	1951	10.0	1						0.10							0.10						
									(–)							(–)						
	1952	32.0	2						0.50		0.16					0.03						
									(0.06)		(0.06)					(0.01)						
	1953	16.0	2						0.25													
									(0.06)													
	1955	18.0	2						1.78							0.22						
									(1.47)							(0.02)						
	1957	3.0	1						2.33							0.33						
									(–)							(–)						
	1958	2.0	1																			
Gladwin																						
McGilvery	1930	13.0	5		0.08		0.08		1.69	8.00	1.46		1.85			4.08						
					(0.08)		(0.08)		(1.24)	(–)	(1.02)		(1.41)			(2.66)						
	1933	4.0	1						2.25	8.00												
									(–)	(–)												
	1940	50.3	17						1.89	8.20			0.02			0.12	7.33			0.08	23.75	
									(1.13)	(0.03)			(0.02)			(0.07)	(0.33)			(0.05)	(1.44)	
	1941	41.0	2						0.37	8.00						0.15	8.30					
									(0.14)	(0.00)						(0.09)	(0.13)					
	1942	171.0	6		0.01	12.00	0.08	13.08	0.88	7.79	0.05	8.00								0.04	21.67	
					(0.01)	(–)	(0.04)	(0.35)	(0.22)	(0.03)	(0.05)	(0.00)								(0.02)	(2.01)	

Table D.45.–Continued.

County Lake	Year	Total hours	Days (N)	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	crap sp. CPE	crap sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE
Gladwin																						
McGilvery	1943	120.0	5						2.22 (0.17)	8.00 (0.01)												
	1944	5.0	2																			
	1945	20.0	2													0.25 (0.30)	11.00 (0.00)			0.05 (0.06)	19.00 (–)	
	1953	18.0	2		0.33 (0.04)				0.83 (0.09)		0.06 (0.01)					0.22 (0.02)						
	1955	20.0	1						3.35 (–)											0.10 (–)		
	1957	11.0	1						0.45 (–)							0.09 (–)				0.09 (–)		
	1958	3.0	1																			
	1959	5.0	1																			
	1960	3.0	1																			
Clare																						
McWatty	1949	1.0	1																			
Mill Pond	1929	1.5	1	0.67 (–)																		
	1938	4.0	3																			
	1939	13.5	5		0.07 (0.09)	12.00 (–)								0.07 (0.05)	9.00 (–)							
Mud	1935	0.5	1																	2.00 (–)	22.00 (–)	
Nestor	1951	7.0	3																			
	1956	2.0	1																			
	1957	35.0	2																	0.03 (<0.01)		
	1958	42.0	3						1.40 (0.51)							0.17 (0.11)				0.02 (0.03)		0.02 (0.02)
	1959	4.0	1						2.50 (–)													

Table D.45.–Continued.

County		Total	Days	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass	crap sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.
Lake	Year	hours	(N)	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
Clare																						
Otter	1949	60.0	4													1.27 (0.31)						
	1950	28.0	3								0.04 (0.04)					1.54 (1.20)						
	1951	27.0	4													1.37 (0.57)						
	1952	14.0	2								0.07 (0.04)					1.50 (0.71)						
	1953	14.0	4													0.43 (0.42)						
	1954	6.0	1						0.17 (–)													
	1955	9.0	1								0.67 (–)					1.33 (–)						
	1957	6.0	2													0.50 (0.50)						
	1958	2.0	1																			
Gladwin																						
Pratt	1930	37.5	7		0.11 (0.10)	15.25 (0.25)	0.05 (0.06)		0.03 (0.03)							0.08 (0.09)						
	1932	11.0	3		0.09 (0.11)				0.91 (0.06)		0.36 (0.41)							0.45 (0.13)				
	1933	67.0	14		0.03 (0.02)		0.15 (0.05)	16.00 (–)	2.87 (0.31)		0.03 (0.03)		0.04 (0.05)			0.01 (0.02)		0.01 (0.02)				0.01 (0.01)
	1934	74.3	27		0.13 (0.07)	13.50 (0.00)	0.19 (0.07)	13.60 (0.40)	1.47 (0.46)	6.75 (0.03)	0.05 (0.04)											
	1935	73.5	53				0.18 (0.07)	11.67 (0.33)	1.88 (0.35)	7.01 (0.02)	0.29 (0.16)	8.00 (–)	0.10 (0.10)	0.03 (0.03)		0.11 (0.07)	7.50 (–)	0.01 (0.01)				
	1939	31.5	10		0.16 (0.09)	12.00 (0.00)	0.25 (0.17)	15.75 (0.65)	1.40 (0.56)	6.00 (0.00)	0.13 (0.07)	6.00 (–)				0.29 (0.16)	8.00 (–)	0.03 (0.03)	14.00 (–)			
	1940	5.5	1																			
	1941	7.5	1						3.87 (–)	7.00 (–)												
	1942	114.0	5		0.02 (0.02)	14.00 (0.00)	0.07 (0.06)	11.80 (0.00)	0.20 (0.05)	7.77 (0.08)				0.01 (0.01)	7.00 (–)	0.02 (0.01)	7.00 (0.00)					
	1943	136.8	3		0.14 (0.07)	11.61 (0.09)	0.01 (0.01)	12.00 (0.00)	0.64 (0.20)	8.11 (0.06)						0.06 (0.01)	8.49 (0.39)					
	1944	16.0	1		0.44 (–)	12.00 (–)																

Table D.45.–Continued.

County		Total	Days	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass	crap sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.
Lake	Year	hours	(N)	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE
Gladwin																						
Pratt	1948	52.0	3		0.02		0.02		0.60							0.44						
					(<0.01)		(<0.01)		(0.03)							(0.03)						
	1949	180.0	6		0.01		0.02		0.66		0.03					0.40				0.01		
					(0.01)		(0.02)		(0.27)		(0.02)					(0.19)				(0.01)		
	1950	387.0	13		0.01				0.99		0.03		0.01	0.02		0.24				0.01		
					(0.01)				(0.19)		(0.02)		(0.01)	(0.01)		(0.06)				(0.01)		
	1951	40.0	2						0.30							0.08						
									(0.18)							(0.12)						
	1952	138.0	10						0.96				0.01			0.12				0.01		
									(0.30)				(0.01)			(0.07)				(0.01)		
	1953	179.0	8		0.01				0.64		0.01			0.03		0.08				0.14		
					(0.01)				(0.19)		(0.01)			(0.04)		(0.05)				(0.06)		
	1954	182.0	10						0.63		0.05					0.15				0.05		
									(0.33)		(0.05)					(0.09)				(0.03)		
	1955	119.0	8						1.50					0.04		0.02				0.04		
									(0.34)					(0.03)		(0.02)				(0.02)		
	1956	88.0	7		0.03				1.77					0.10		0.34				0.01		
					(0.02)				(0.16)					(0.10)		(0.14)				(0.01)		
	1957	312.3	15		0.02		0.01		0.94					0.03		0.08				<0.01		
					(0.02)		(0.01)		(0.26)					(0.02)		(0.06)				(<0.01)		
	1958	675.0	23		<0.01				1.38		<0.01		<0.01	0.01		0.03				0.01		
					(<0.01)				(0.15)		(<0.01)		(<0.01)	(<0.01)		(0.01)				(0.01)		
	1959	200.0	20				0.02		2.31					0.01		0.04				0.03		
							(0.01)		(0.23)					(0.01)		(0.02)				(0.01)		
	1960	188.0	15						1.81		0.02			0.03		0.03				0.03		
									(0.36)		(0.02)			(0.02)		(0.02)				(0.01)		
	1961	179.0	15				0.02		1.73					0.03		0.01		0.01		0.01		
							(0.02)		(0.38)					(0.03)		(0.01)		(0.01)		(0.01)		
	1962	151.0	11				0.06		1.93							0.02				0.02		
							(0.05)		(0.56)							(0.02)				(0.01)		
	1963	142.0	5				0.02		0.99		0.01		0.01	0.01		0.08		0.04		0.06		
							(0.02)		(0.42)		(0.01)		(0.01)	(0.01)		(0.04)		(0.04)		(0.05)		
	1964	71.0	2						0.63							0.06				0.25		
									(0.41)							(0.04)				(0.16)		

Table D.46.–Direct contact lake angler creel data for Puro, Ross, Round, Schoolhouse, and South lakes. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

County Lake Year	Total hours	Days (N)	Brown trout	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish	Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Sucker sp.	
			CPE	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Gladwin																									
Puro																									
1941	5.5	1										<0.01 (–)													
1942	26.0	1												0.50 (–)	8.00 (–)										
1943	6.0	1												3.67 (–)	9.00 (–)										
1944	1.5	1																							
1948	2.0	1																							
1950	34.0	4												0.24 (0.08)											
1953	4.0	1							4.50 (–)		0.75 (–)									0.25 (–)					
1954	7.0	2														0.86 (0.93)									
1956	2.0	1																							
1957	4.0	1							3.00 (–)																
1958	10.0	1							0.30 (–)					0.10 (–)											
1959	3.0	1																							
1961	2.0	1							2.50 (–)																
1963	20.0	2							0.90 (0.53)											0.15 (0.11)					
1929	17.5	8																		0.11 (0.06)	21.00 (1.00)				

Table D.46.–Continued.

County Lake Year	Total hours	Days (N)	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Bullhead sp. AL	Sucker sp. CPE	Sucker sp. AL
Ross																									
1930	18.5	11			0.05 (0.05)	16.00 (–)								0.54 (0.27)	8.60 (0.40)							0.16 (0.16)		0.11 (0.11)	
1932	2.0	1																							
1933	2.0	1										1.00 (–)		3.00 (–)		1.50 (–)									
1934	24.0	7							0.08 (0.09)	7.00 (0.00)										0.13 (0.08)	23.33 (1.33)				
1935	77.8	27										0.08 (0.06)	7.00 (0.00)	0.57 (0.31)	8.25 (0.08)	0.06 (0.04)	9.60 (0.40)							0.04 (0.03)	13.67 (0.33)
1939	33.5	10			0.03 (0.03)	12.00 (–)	0.03 (0.03)	16.00 (–)	0.54 (0.51)			0.45 (0.43)	6.00 (0.00)	0.24 (0.24)		0.24 (0.17)				0.15 (0.10)	20.20 (1.74)				
1940	57.8	21										0.62 (0.27)	7.25 (0.41)	0.62 (0.25)	8.00 (0.00)	0.29 (0.13)	8.85 (0.10)	0.02 (0.02)	26.00 (–)	0.12 (0.08)	23.14 (1.37)			0.24 (0.25)	14.00 (0.00)
1941	120.0	7							0.02 (0.02)	7.50 (0.00)		0.05 (0.04)	7.17 (0.17)	0.06 (0.03)	7.64 (0.09)	0.05 (0.02)	8.00 (0.63)			0.08 (0.05)	24.67 (1.01)			0.08 (0.08)	14.00 (0.00)
1942	79.5	7					0.01 (0.01)	11.00 (–)	0.03 (0.03)	8.00 (0.00)	0.13 (0.07)	0.09 (0.04)	6.14 (0.14)	0.83 (0.27)	7.09 (0.04)	0.08 (0.04)	7.00 (0.00)					0.04 (0.02)	10.00 (0.00)		
1943	120.0	6									0.08 (0.07)	0.01 (0.01)	7.00 (–)	0.87 (0.78)	8.46 (0.04)					0.02 (0.01)	25.00 (5.00)	0.01 (0.01)	10.00 (–)		
1944	178.0	4										0.03 (0.03)	7.00 (0.00)	0.53 (0.05)	7.04 (0.02)	0.06 (0.03)	8.83 (0.13)			0.01 (0.01)	24.00 (–)				
1945	200.5	9												0.19 (0.07)	9.41 (0.17)	0.30 (0.11)	9.87 (0.04)			0.01 (0.01)	18.00 (0.00)			0.03 (0.04)	12.00 (0.00)
1946	241.5	4										0.13 (0.13)	7.50 (0.00)	0.39 (0.25)	8.63 (0.10)	0.10 (0.03)	9.33 (0.07)			0.01 (0.01)	21.00 (0.00)				
1947	76.0	3										0.17 (0.12)		0.25 (0.03)		0.05 (0.03)								0.07 (0.04)	
1953	53.0	6										0.02 (0.02)				0.09 (0.09)						0.13 (0.15)		0.06 (0.06)	
1954	57.0	5										0.07 (0.07)		0.25 (0.13)		0.65 (0.27)				0.02 (0.02)					

Table D.46.–Continued.

County Lake Year	Total hours	Days (N)	Brown trout CPE	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Bullhead sp. AL	Sucker sp. CPE	Sucker sp. AL
1956	265.0	20							0.01 (0.01)		<0.01 (<0.01)	0.06 (0.05)		0.24 (0.08)		0.18 (0.08)				0.02 (0.01)		0.01 (0.01)		0.25 (0.09)	
1957	961.0	46			<0.01 (<0.01)		0.01 (<0.01)		0.04 (0.03)		0.02 (0.01)	0.16 (0.06)		0.61 (0.18)		0.12 (0.03)				0.01 (<0.01)				0.16 (0.05)	
1958	352.0	25		<0.01 (<0.01)	0.01 (0.01)				0.04 (0.04)		0.05 (0.04)	0.04 (0.02)		0.68 (0.13)		0.06 (0.03)				0.03 (0.01)				0.13 (0.07)	
1959	185.0	8							0.01 (0.01)		0.04 (0.04)	0.06 (0.03)		0.42 (0.17)		0.12 (0.05)				0.02 (0.01)				0.15 (0.09)	
1960	264.0	15	<0.01 (<0.01)				0.01 (0.01)				0.01 (0.01)	0.27 (0.12)		1.20 (0.32)		0.07 (0.03)				0.03 (0.01)				0.03 (0.03)	
1961	179.0	9							0.05 (0.05)		0.04 (0.02)	0.03 (0.01)		1.31 (0.39)		0.25 (0.08)				0.05 (0.02)		0.16 (0.15)			
1962	131.0	4										0.04 (0.02)		1.31 (0.96)						0.01 (0.01)				0.45 (0.18)	
1963	119.0	5												0.32 (0.09)		0.03 (0.02)						0.17 (0.21)		0.15 (0.14)	
1964	110.0	3										0.06 (0.04)		0.55 (0.11)		0.05 (0.03)									
1965	26.0	1												0.15 (–)		0.08 (–)				0.04 (–)					
Clare																									
Round																									
1928	9.0	2					0.11 (0.20)		1.44 (0.32)											0.11 (0.20)					
1930	8.0	2							2.00 (2.00)							0.13 (0.13)									
1934	0.5	1																							
1937	5.5	2																		0.18 (0.19)					
1939	8.5	2																		0.24 (0.22)	21.50 (0.00)				

Table D.46.–Continued.

County Lake Year	Total hours	Days (N)	Brown trout	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish	Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Sucker sp.	
			CPE	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Gladwin																									
Schoolhouse																									
1939	14.0	2					0.14 (0.14)	12.50 (0.00)												0.29 (0.14)	17.44 (0.81)				
1940	7.0	2														1.14 (0.98)	7.00 (0.00)								
1942	6.0	1																		1.00 (–)	25.00 (–)				
Clare																									
South																									
1938	2.5	1																							
1952	2.0	1							3.00 (–)																
1958	2.0	1																							

Table D.47.–Direct contact lake angler creel data for Streaked, Sutherland, Thurston, and Townline lakes. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

			Total	Days	Brook trout		Brown trout		Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish	Rock bass		Yellow perch		Northern pike	Bullhead sp.
County	Lake	Year	hours	(N)	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	CPE	AL	CPE	AL	CPE	CPE
Gladwin	Streaked	1932	15.0	4	1.60	8.00												1.13	6.18		
					(1.26)	(0.00)												(0.99)	(0.10)		
		1933	10.0	2	0.70	8.00															
					(0.04)	(0.00)															
		1934	4.0	1														1.25	7.00		
																		(–)	(–)		
		1935	12.5	6	0.24	7.33					0.32	13.00									
					(0.23)	(0.17)					(0.22)	(0.00)									
		1937	2.3	2																	
		1939	26.5	13							0.23	11.63	0.04	6.00		0.30	7.38	0.38	9.00		
											(0.13)	(0.28)	(0.04)	(–)		(0.18)	(0.13)	(0.21)	(0.51)		
		1940	21.5	3					0.23	14.00								0.42	6.00		
									(0.12)	(0.00)								(0.15)	(0.00)		
		1961	8.0	3	0.13													0.25		0.13	
					(0.10)													(0.25)		(0.12)	
		1964	8.0	1														2.50			
																		(–)			
Clare	Sutherland	1934	4.0	1					0.50	11.50											
									(–)	(–)											
		1939	1.0	1							1.00	17.00									
											(–)	(–)									
		1940	2.0	1					0.50	11.00			0.50	9.00							
									(–)	(–)			(–)	(–)							
		1945	100.0	12							0.25	12.30	1.25	6.98							
											(0.06)	(0.47)	(0.22)	(0.02)							
		1946	268.5	14							0.09	12.17	1.22	7.96							
											(0.03)	(0.18)	(0.16)	(0.03)							
		1947	147.0	5							0.13		1.06		0.01			0.01		0.01	
											(0.04)		(0.10)		(0.01)			(0.01)		(0.01)	

Table D.47.–Continued.

County	Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Brown trout AL	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Rock bass CPE	Rock bass AL	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Bullhead sp. CPE
Clare	Sutherland	1948	18.5	2									0.59 (0.28)		0.05 (0.02)						
		1950	12.0	1							0.08 (–)		0.08 (–)								
		1952	5.0	1							0.40 (–)										
		1953	47.0	3							0.11 (0.06)		0.40 (0.33)							0.02 (0.01)	
		1954	52.0	3					0.10 (0.07)		0.08 (0.05)		1.00 (0.47)								
		1955	96.0	7							0.06 (0.05)		0.32 (0.21)		0.07 (0.06)			0.02 (0.02)		0.15 (0.09)	
		1956	146.5	9							0.05 (0.05)		0.35 (0.14)							0.05 (0.03)	
		1957	53.0	4									1.57 (0.80)							0.02 (0.02)	
		1958	37.5	4			0.03 (0.03)						0.40 (0.32)								
		1959	46.0	2							0.02 (0.02)		1.30 (0.34)		0.48 (0.35)						
		1960	98.0	1							0.02 (–)		0.38 (–)					0.02 (–)			0.01 (–)
		1961	18.0	2									0.56 (0.74)							0.11 (0.07)	
		1962	12.0	1																	
	Thurston	1943	8.0	1									3.00 (–)	7.00 (–)							
		1950	22.0	3									1.00 (1.09)		0.18 (0.17)			0.23 (0.22)			
		1951	17.0	2							0.06 (0.01)		1.18 (0.14)								
		1952	31.0	5									0.45 (0.17)					0.03 (0.04)			

Table D.47.–Continued.

County	Lake	Year	Total hours	Days (N)	Brook trout CPE	Brook trout AL	Brown trout CPE	Brown trout AL	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Rock bass CPE	Rock bass AL	Yellow perch CPE	Yellow perch AL	Northern pike CPE	Bullhead sp. CPE
Clare	Thurston	1953	3.0	1									4.00 (–)								
		1954	21.0	2							0.14 (0.11)		1.38 (0.20)								
		1955	17.0	2									0.53 (0.12)					0.18 (0.04)			
		1957	4.0	1									2.50 (–)								
	Townline	1937	4.5	1							0.22 (–)	11.00 (–)						0.89 (–)	7.00 (–)		
		1938	5.0	3			0.20 (0.24)	30.00 (–)													
		1939	23.0	8			0.30 (0.16)	15.14 (0.26)			0.57 (0.29)	11.00 (0.00)									
		1940	36.5	7	0.05 (0.06)	8.00 (0.00)	0.16 (0.10)	17.00 (1.34)													
		1941	24.5	4									1.92 (1.79)	8.50 (0.00)							
		1948	12.0	1																	
		1952	75.0	1									1.63 (–)		0.51 (–)						
		1954	5.0	1									2.40 (–)								
	Townline	1955	10.0	1									2.10 (–)								
		1957	1.0	1									<0.01 (–)								

Table D.48.–Direct contact lake angler creel data for Trout Lake (Clare County) and Trout Lake (Gladwin County). Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

					Brook trout	Brown trout	Smallmouth bass		Largemouth bass		Yellow perch		Bullhead sp.
County	Lake	Year	Total hours	Days (N)	CPE	CPE	CPE	AL	CPE	AL	CPE	AL	CPE
Clare	Trout	1933	3.0	1							1.33 (–)		0.67 (–)
		1938	4.0	1			0.25 (–)	10.00 (–)			1.75 (–)	8.00 (–)	
		1939	1.5	1					2.67 (–)	14.00 (–)			
Gladwin	Trout	1934	2.5	1							4.00 (–)		
		1962	47.0	8	0.94 (0.17)								
		1963	15.0	1	2.13 (–)								
		1964	46.0	4		0.07 (0.03)							

Table D.49.–Direct contact lake angler creel data for Wiggins Lake 1929–49. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour; AL = Average length.

County Lake Year	Total hours	Days (N)	Rainbow trout	Smallmouth bass		Largemouth bass		Bluegill		Pumpkinseed sunfish		Rock bass		Crappie sp.		Yellow perch		Walleye		Northern pike		Bullhead sp.		Sucker sp.	
			CPE	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL	CPE	AL
Gladwin																									
Wiggins																									
1929	60.0	3								0.05 (0.04)						0.02 (0.01)	7.00 (–)			0.27 (0.04)	18.50 (1.06)				
1930	2.0	1		1.50 (–)	14.00 (–)																				
1932	8.0	2		0.13 (0.13)														0.25 (<0.01)		0.38 (0.13)					
1933	34.0	14														0.09 (0.06)				0.32 (0.11)	19.20 (0.49)				
1934	69.0	16		0.07 (0.04)								0.03 (0.03)				0.22 (0.14)	9.00 (0.00)			0.20 (0.06)	20.40 (0.98)				
1935	0.5	1		<0.01 (–)																					
1939	45.0	14		0.20 (0.08)	13.89 (0.31)	0.04 (0.03)	15.00 (2.00)	0.93 (0.59)	7.00 (0.03)					0.02 (0.02)	8.00 (–)	0.11 (0.08)	7.00 (0.00)	0.04 (0.05)	20.00 (0.00)	0.04 (0.03)	30.00 (10.00)	0.04 (0.03)	10.50 (0.50)		
1940	29.0	10		0.07 (0.07)	12.00 (0.00)			0.07 (0.07)								1.00 (0.30)	7.70 (0.09)			0.07 (0.05)	22.50 (2.50)	0.03 (0.03)	10.00 (–)		
1941	388.0	14		0.01 (<0.01)	12.67 (1.17)			0.33 (0.10)	7.61 (0.04)	<0.01 (<0.01)	6.00 (–)			0.14 (0.09)	9.34 (0.08)	0.12 (0.03)	8.57 (0.11)			0.02 (0.01)	19.71 (1.43)	<0.01 (<0.01)	12.00 (–)	<0.01 (<0.01)	12.00 (–)
1942	116.5	7				0.01 (0.01)	14.00 (–)	0.46 (0.45)	7.87 (0.05)			0.01 (0.01)	6.00 (–)	0.04 (0.05)	10.00 (0.00)	0.03 (0.01)	8.67 (0.83)			0.01 (0.01)					
1943	23.5	3														0.30 (0.12)	7.97 (0.17)								
1944	92.5	9		0.01 (0.01)	11.00 (–)					0.01 (0.01)	7.00 (–)					1.77 (0.75)	6.71 (0.09)								
1945	251.0	11												0.05 (0.03)	7.77 (0.39)	0.42 (0.15)	8.54 (0.07)			0.02 (0.01)	19.17 (1.79)				

Table D.49.–Continued.

County Lake Year	Total hours	Days (N)	Rainbow trout CPE	Smallmouth bass CPE	Smallmouth bass AL	Largemouth bass CPE	Largemouth bass AL	Bluegill CPE	Bluegill AL	Pumpkinseed sunfish CPE	Pumpkinseed sunfish AL	Rock bass CPE	Rock bass AL	Crappie sp. CPE	Crappie sp. AL	Yellow perch CPE	Yellow perch AL	Walleye CPE	Walleye AL	Northern pike CPE	Northern pike AL	Bullhead sp. CPE	Bullhead sp. AL	Sucker sp. CPE	Sucker sp. AL
1946	64.5	4												0.03 (0.04)	8.00 (0.00)	0.37 (0.12)	7.03 (0.02)								
1947	92.0	5				0.09 (0.08)		0.24 (0.15)						0.39 (0.28)		0.16 (0.14)									
1948	111.0	8						0.03 (0.03)				0.05 (0.02)		0.62 (0.33)		0.24 (0.12)		0.01 (0.01)		0.04 (0.01)		0.01 (0.01)		0.03 (0.02)	
1949	82.5	5		0.01 (0.01)				1.10 (0.50)		0.06 (0.06)				0.16 (0.12)		0.18 (0.12)				0.01 (0.01)		0.01 (0.01)			

Table D.50.–Direct contact lake angler creel data (CPE) for the Tributaries-Tobacco River Wiggins Lake 1929–64. Estimates are given with 1 standard error in parentheses. One or multiple angler interview records are included per Days (N). When Days (N) equaled 1 or when only 1 length was reported, standard errors could not be estimated and are reported as (–). CPE = Catch per hour. No length data were collected.

County Lake Year	Total hours	Days (N)	Rainbow trout	Smallmouth bass	Largemouth bass	Bluegill	Pumpkinseed sunfish	Rock bass	Crappie sp.	Yellow perch	Northern pike	Bullhead sp.	Sucker sp.
Gladwin													
Wiggins													
1950	74.0	7				0.28			0.08	0.16			
						(0.12)			(0.08)	(0.14)			
1951	24.0	2											
1952	119.0	5				0.42			0.13	0.81	0.04		
						(0.10)			(0.10)	(0.06)	(0.01)		
1953	35.0	2				0.20			0.11		0.06		
						(0.07)			(0.04)		(0.02)		
1954	62.0	2				0.79			0.18	0.23	0.02		
						(0.64)			(0.05)	(0.10)	(0.01)		
1955	41.0	3				0.29			0.10	0.07	0.02		
						(0.10)			(0.11)	(0.07)	(0.02)		
1956	52.5	3		0.02		0.42			0.15	0.13			
				(0.02)		(0.42)			(0.11)	(0.06)			
1957	64.0	8				0.22		0.03	0.16	0.05	0.02		
						(0.15)		(0.04)	(0.13)	(0.05)	(0.02)		
1958	734.0	22		0.01	<0.01	0.36	0.03	0.01	0.14	0.22	0.02		
				(<0.01)	(<0.01)	(0.06)	(0.02)	(<0.01)	(0.06)	(0.07)	(0.01)		
1959	186.0	17		0.02		0.47	0.09	0.08	0.16	0.29		0.02	
				(0.02)		(0.16)	(0.05)	(0.04)	(0.13)	(0.04)		(0.01)	
1960	92.0	10				0.53			0.40	0.26	0.02		
						(0.21)			(0.18)	(0.08)	(0.01)		
1961	52.0	8				1.90							0.06
						(0.25)							(0.07)
1962	15.0	5		0.07		1.07	0.20		0.20	0.07			
				(0.06)		(0.40)	(0.24)		(0.16)	(0.08)			
1963	28.0	1	0.46										
			(–)										
1964	26.0	1							0.12	0.42	0.04		
									(–)	(–)	(–)		