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Tittabawassee River Assessment

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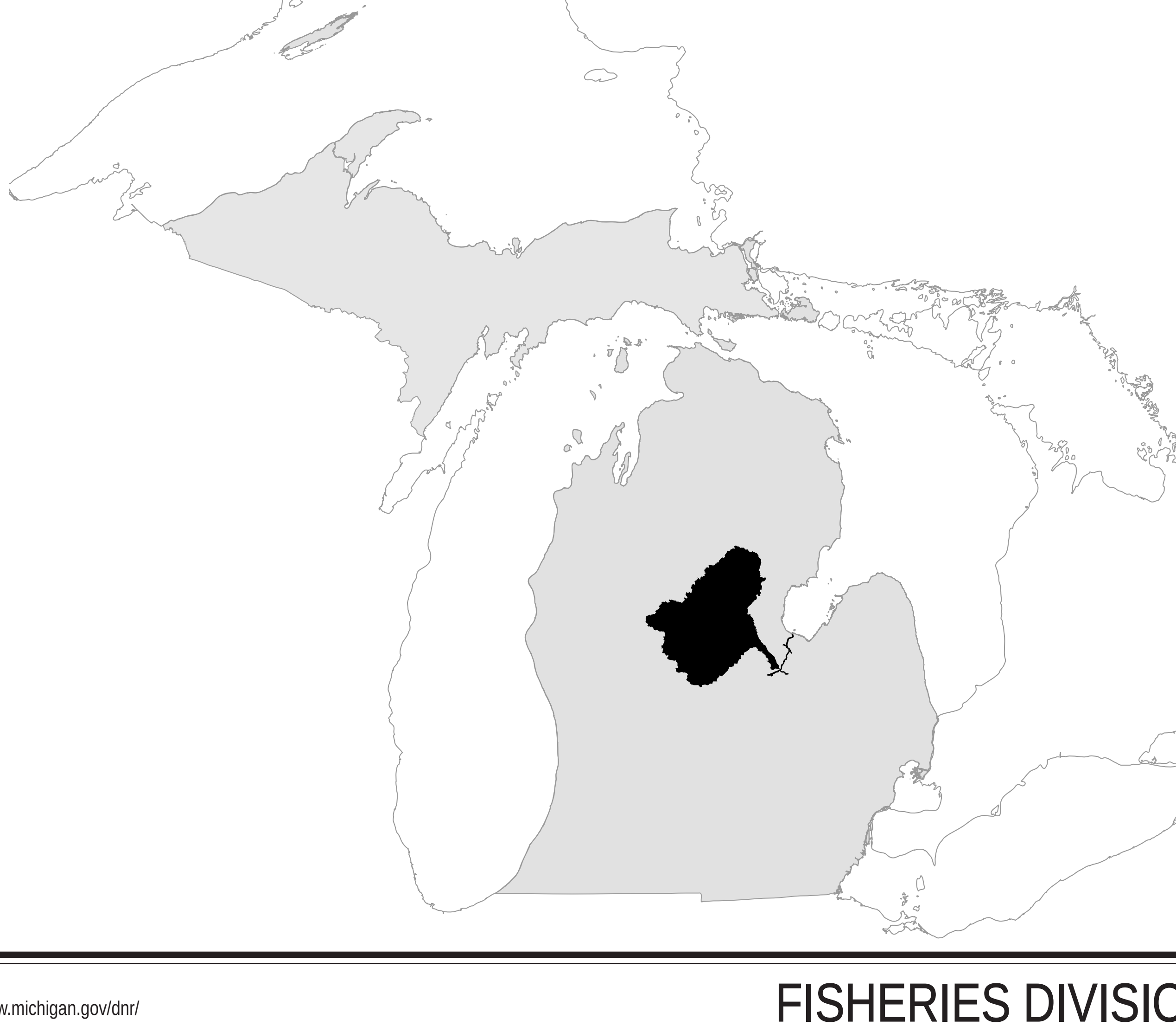

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EXECUTIVE SUMMARY

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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Michigan Department of Natural Resources
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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
Bay City Operations Service Center
3580 State Park Drive
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 10th 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