USACE photos

UPPER WABASH RIVER, INDIANA STATE OF THE SCIENCE REPORT

Sustainable Rivers Program

Abstract

This report details the current riverine conditions, available data, and literature for the Upper Wabash River to identify flow-dependent fish, mussels, and other species in the River, examine changes in these species over time, and look at alterations in the flow regime that potentially could have caused these changes.

Prepared by the U.S. Army Corps of Engineers – Chicago District and The Nature Conservancy

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1. Introduction

1.1 SRP Program Description & Partnership

It is well documented in numerous scientific publications that dams change the natural flow regime, amongst imparting many other adverse effects to river systems. This disrupts native species life cycles, decreases species diversity and abundance, separates the river from its floodplain, and promotes exotic and/or invasive species (Pyron and Neumann, 2008; Risley et al., 2010; Chen and Olden, 2017; Warner et al., 2014; Richter and Thomas, 2007). Dams, coupled with other anthropogenic activities (altered land use, water withdrawals, etc.,) can cause hydrologic alterations that reduce peaks, prolong baseflows, smooth the hydrograph, produce unseasonably high flows, and impact water quality, in particular, water temperature and dissolved oxygen (DO).

The Nature Conservancy (TNC) and U.S. Army Corps of Engineers (USACE) have partnered under the Sustainable Rivers Program (SRP) to examine opportunities to optimize reservoir releases and river flows to benefit river ecology while maintaining the effectiveness of the federal flood risk management (FRM) project. Establishing environmental flows (e-flows), or flows that benefit native species and ecological systems, would provide year-round river hydrology and hydraulics suitable for the behavioral, reproductive, and habitat needs of river and floodplain flora and fauna. The flow regime of the river also affects nutrient cycles, sediment transport, and bank erosion. Deriving more favorable e-flows requires an understanding of the conditions before the FRM project was implemented, as well as compiling available data and literature of the river system. Pyron, et al. (2020) found that the ecological integrity of the Wabash River is still relatively intact and is a viable candidate for restoration of historical hydrologic patterns.

USACE and TNC hosted a subject matter expert (SME) orientation during the fall of 2022 to engage stakeholders and resource agencies to better understand the concerns and ideas related to flows and habitat in the study area. The summary report from this orientation can be found in Appendix E.

1.2 Study Area Description

The geographic scope of the Upper Wabash River SRP includes Mississinewa, Salamonie, and J. Edward Roush Reservoirs, their corresponding tailwater reaches extending to their respective confluence with the Upper Wabash River, and the Upper Wabash River extending downstream from Roush Lake to Logansport, Indiana (Figure 1). The Wabash River, located almost entirely within the state of Indiana, is a major tributary to the Ohio River, which then flows into the Mississippi River and eventually the Gulf of Mexico. The upper reach of the Wabash River and two of its tributaries, the Salamonie and Mississinewa Rivers, are impounded by J.E. Roush Dam, Salamonie Dam, and Mississinewa Dam to form J.E. Roush Lake, Salamonie Lake, and Mississinewa Lake, respectively. The Wabash River runs approximately 53 miles from Huntington, Indiana to Logansport, Indiana. The distance between Huntington, Indiana, and the confluence of the Mississinewa retreat channel is 20.4 miles, between the confluences of the Mississinewa and Salamonie retreat channels is 19.2 miles, and between the confluence of the Salamonie retreat channel and Huntington, Indiana is 13.4 miles. The Salamonie and Mississinewa retreat channels are 2.8 and 7.1 miles long, respectively. Each of the three reservoirs are owned and operated by the USACE.

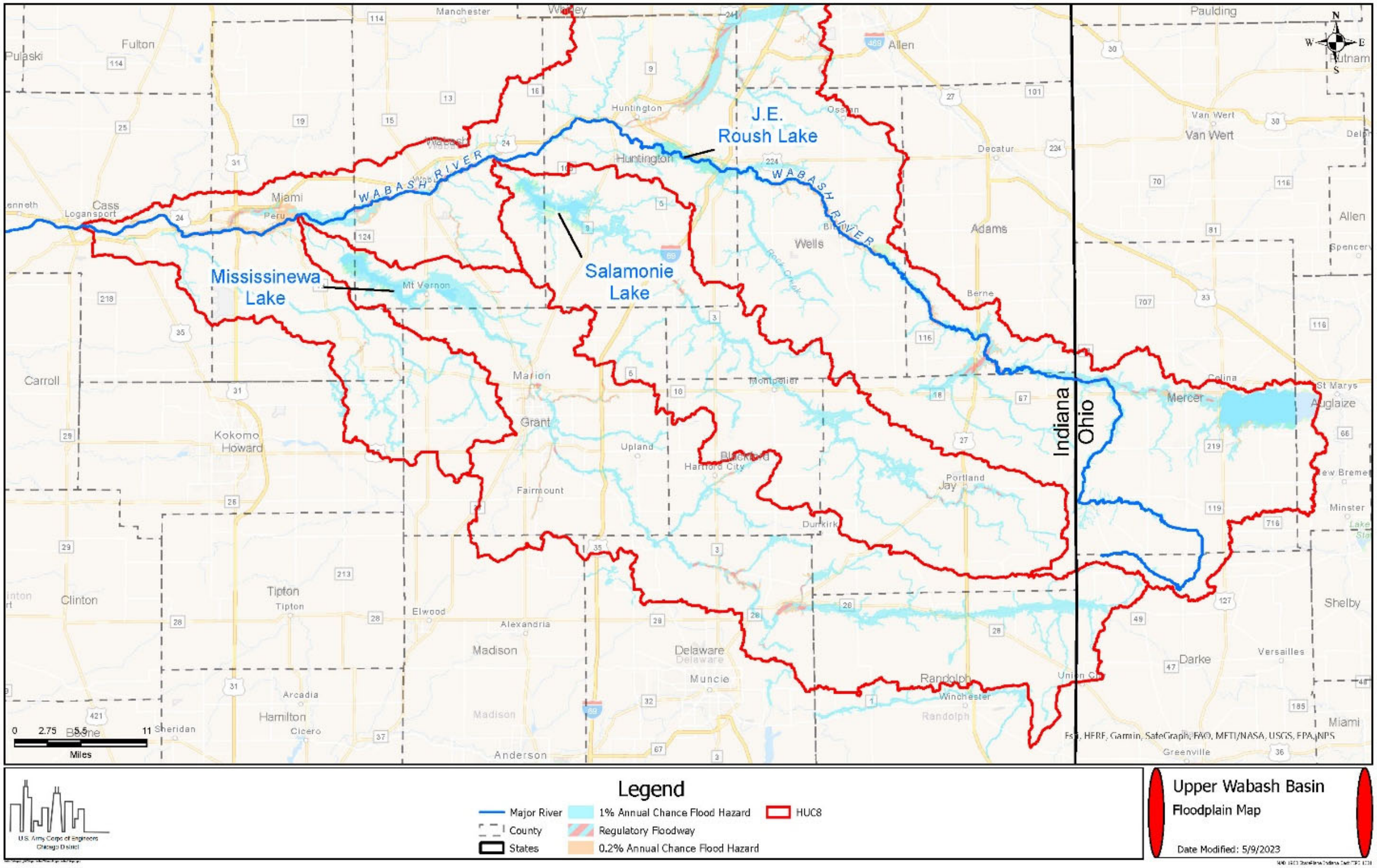
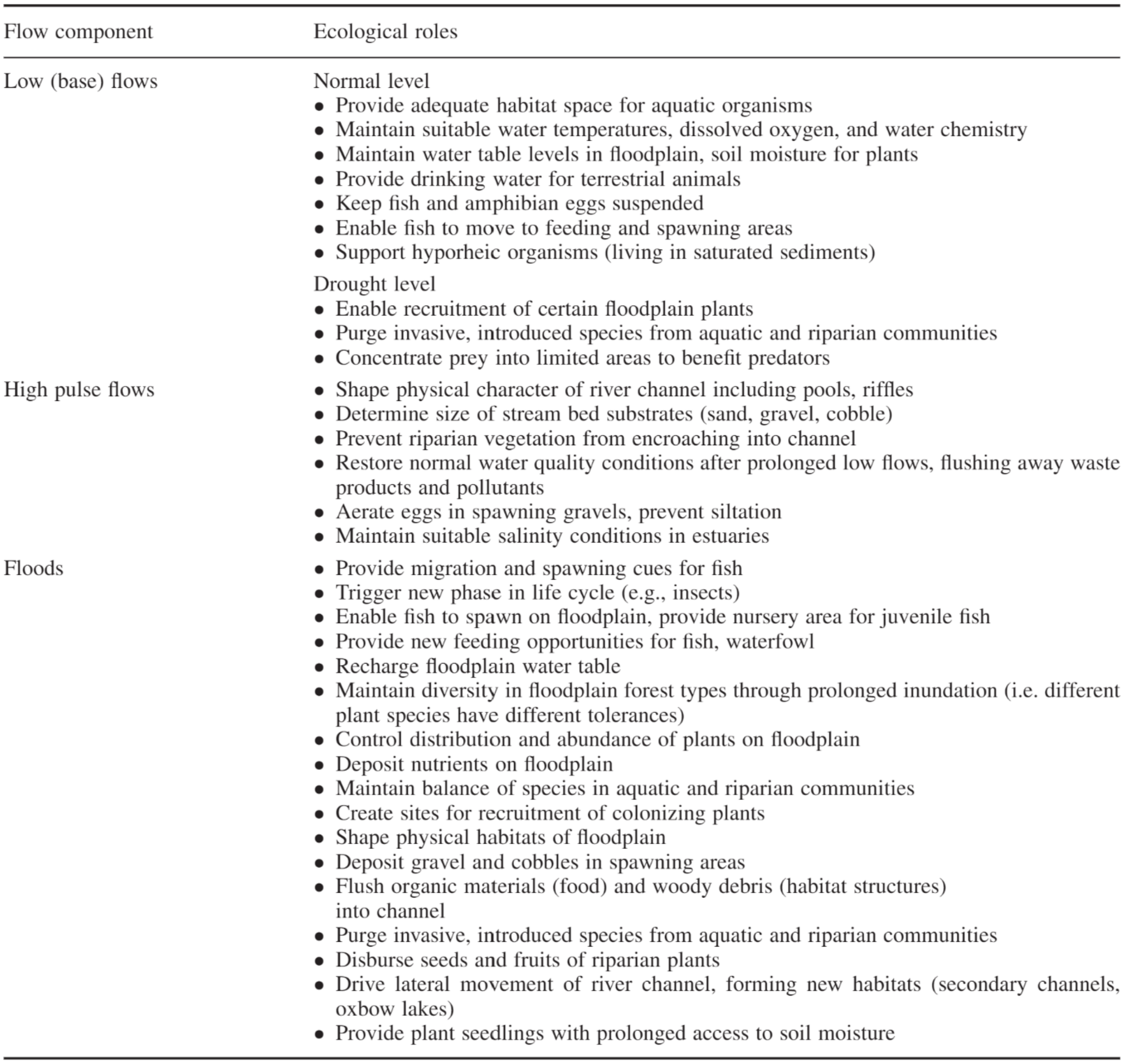


Figure 1. Depiction of study area.

1.3 Goals and Objectives of the Report

This report identifies key aspects of flow regimes that are important in sustaining the ecological health of the river-floodplain system on the Upper Wabash River (Figure 2). The information presented in this report is the basis for exploring possible improved future flow alternatives. The first step of this program was to pull together a workgroup of subject matter experts (SMEs) who study and manage the ecological and hydrological systems of the river to guide the process of determining e-flows. The next step was to assemble literature and data to identify flow-dependent fish, mussels, and other species in the Upper Wabash River (see Appendix A for important studies and reports), examine changes in these species over time, and propose a hypothesis about likely causes of these changes. In turn, USACE will take into consideration impacts caused by reservoir operations and examine possibilities for reservoir management modifications within the range of authorized reservoir releases that would create flows beneficial to the Upper Wabash River ecosystem and its biota. Ultimately, the goal of the Upper Wabash SRP effort is to identify and integrate understanding of flow needs into real-time decisions about how much and when water is released from the reservoirs to achieve more natural flow regimes, and to adjust operations as needed in response to monitoring and modeled responses.



Flow component	Ecological roles
Low (base) flows	Normal level • Provide adequate habitat space for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in floodplain, soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (living in saturated sediments)
	Drought level • Enable recruitment of certain floodplain plants • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
High pulse flows	• Shape physical character of river channel including pools, riffles • Determine size of stream bed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevent siltation • Maintain suitable salinity conditions in estuaries
Floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (e.g., insects) • Enable fish to spawn on floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (i.e. different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive, introduced species from aquatic and riparian communities • Disburse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

Figure 2. Biophysical roles performed by different flows (Richter et at., 2006).

The science report has the following objectives for the Upper Wabash, Mississinewa and the Salamonie Rivers:

- Describe the existing conditions pertinent to riverine flows within the study area;
- Compile existing data and literature on the flow requirement needs of native species;
- Identify significant data/information gaps necessary to make e-flow decisions; and
- Identify key e-flow components and compare the pre-project and current flow regime including periods of low and high flows, the duration and frequency of such discharges, and the rate of change from one condition to another.

Issues to be Explored

1) How have dam operations changed river hydrology and morphology?
    - Fluviogeomorphic processes – including channel formation, sediment dynamics, and gravel movement
    - Current and pre-project channel morphology – in the Upper Wabash River and the Salamonie and Mississinewa tributaries from the upper limits of the three reservoirs downstream to Logansport
    - Key indicator species – including a range of species with different life histories, with flow requirements identified for specific life-history stages
    - Floodplain processes and functions – including functions such as vegetation establishment, seed dispersal, riparian community structure and function, seasonal access for fish, habitat for species such as amphibians and birds, etc.
    - Water quality – including temperature, dissolved oxygen (DO), and nutrients
    - Implications for population dynamics of non-native species and their interactions with native species and communities
2) Compare the current and historical hydrographs including:
    - Low flows (seasonal, annual, and extreme low flows)
    - High flow pulses (up to bank full discharge)
    - Small floods (overbank flows, approximately 2- to 10-year return period)
    - Large floods (floodplain maintenance flows, greater than approximately 10-year return period)
3) When considering birds, amphibians and reptiles, mussels, and fish species of greatest conservation need, are there flow management strategies that would increase benefits to each group?
4) How has species usage of the river changed since the dams were initially put in service?

2. Flood Risk Management Project Overview

2.1 Authorization & History

J.E. Roush, Salamonie and Mississinewa Lakes serve as a unit of the comprehensive plan for the Ohio River Basin to affect reduction in flood stages downstream of the dam. The lakes also operate to augment natural low flow conditions downstream of the dam in the interest of water quality. In addition, the lakes provide general and fish and wildlife recreation. These projects were authorized by the Flood Control Act, approved 3 July 1958 (Public Law 85-500, 85th Congress). The appropriate part of the Act authorized the projects in accordance with recommendations of the Chief of Engineers in House Document Number 435, 84th Congress. Preparation of the general design memorandum was authorized by allotment of planning funds for Fiscal Years 1960, 1961 and 1962.

In preparation for construction of J.E. Roush Dam, relocation of Indiana State Highway 3 was begun 11 June 1963 and completed 22 October 1964. Work on the dam and outlet works started 12 May 1965 and was completed in October 1968. The reservoir was placed in operation in January 1969.

In preparation for construction of Salamonie Dam, relocation of several roads and highways begun 21 October 1965 and was completed 7 November 1967. Work on the dam and outlet works started 9 December 1961 and was completed 6 September 1966. Clearing in the lake area was begun 26 May 1965 and completed 4 December 1965. The reservoir was placed in operation in September 1966.

In preparation for construction of Mississinewa Dam several roads and highways were relocated, beginning 14 October 1965 and completed 7 November 1966. Work on the outlet works started 18 April 1962 and was completed in October 1964. Construction of the dam started 10 April 1964 and was completed 2 October 1967. Clearing in the lake area was begun 21 April 1966 and was completed 31 August 1966. Most boat ramps were completed by November 1969. The reservoir was placed in operation in October 1967.

2.2 Reservoir System & Operations

Current project operations prescribe target elevations at which the pool should be maintained during winter and summer periods and dates at which the drawdown or fill to these elevations should commence and cease. When the pools are used for flow attenuation, releases from the projects are conducted to quickly return the pools to the target elevations without adversely impacting downstream areas. While the maximum discharge capacity from the projects is defined by their physical configurations, the maximum and minimum releases from the projects during normal operations were determined to balance project objectives and impacts to downstream stakeholders. The governing water control plan is documented in water control manuals developed for each of the projects.

J. E. Roush Dam is on the Wabash River, 411.4 miles above the mouth and confluence with the Ohio River. The damsite is in Huntington County, and the reservoir extends into Wells County. The reservoir has a storage capacity of 153,100 acre-feet (at an elevation of 798 feet NAVD88) and drains approximately 717 square miles. The maximum flood pool extends from the damsite up the Wabash River approximately 29 miles. The maximum discharge capacity of the sluices with the reservoir pool at spillway crest is approximately 10,600 cubic feet per second (cfs). The maximum discharge capacity of the bypass system with the reservoir at summer pool elevation 749 feet NAVD88 is approximately 160 cfs. Maximum release for the project during normal operation is 5,500 cfs during the winter and 3,000 cfs during the crop season, or the flow which produces a nondamaging bankfull capacity downstream. Minimum release from the project during normal operation is 20 cfs.

The primary purpose of J.E. Roush Dam is to provide flood management in the Upper Wabash River Basin. It works in conjunction with Salamonie and Mississinewa Dams to reduce flooding in the Upper Wabash River Basin. The lake controls runoff from a drainage area of 707 square miles. The areas most benefited from the lake include the cities of Wabash, Peru, and Logansport, Indiana, and approximately 60,000 acres of agricultural land and related development.

J.E. Roush Dam consists of an earth fill dam 4,800 feet in length with a top elevation of 805 feet NAVD88, crown width of 46 feet, carrying Indiana State Highway 5, and a concrete gravity section located in the center containing the outlet structures. The upstream face of the earth portion is protected by riprap 18 inches thick from elevation 734 feet NAVD88 to elevation 775 feet NAVD88. The outlet works consist of three tainter gates, measuring 34 feet by 45 feet, in a concrete ogee section with a base elevation of 765 feet NAVD88, and six sluice gates 6 feet by 6 feet, under the spillway section, and an invert elevation of 718 feet NAVD88 at the inlet. A 30-inch circular low flow bypass has been provided at the request of the U.S. Fish and Wildlife Service. The inlet invert is at elevation 730 feet NAVD88 – 7 feet below Minimum Pool level of 737 feet NAVD88. The bypass will discharge into the conduit adjacent to the right abutment. The discharge area consists of a stilling basin of the roller-type bucket with radius of 45 feet and low point elevation of 717.5 feet NAVD88, the approximate level of the natural stream bed.

Salamonie Dam is on the Salamonie River, 2.8 miles above the mouth and confluence with the Wabash River. The damsite is in Wabash County, and the reservoir extends into Huntington County. The reservoir has a storage capacity of 256,994 acre-feet (at an elevation of 793 feet NAVD88) and drains approximately 556 square miles. The maximum flood pool extends from the dam up the Salamonie River approximately 30 miles.

Salamonie Dam operates primarily as a unit with J.E. Roush and Mississinewa Lakes to reduce flood stages in the Upper Wabash River Basin. Salamonie also operates with other lakes downstream to reduce flood stages along the lower Wabash River and the Ohio River. The areas most directly benefited include the cities of Wabash, Peru, and Logansport, Indiana, and approximately 31,500 acres of agricultural land and related developments.

Salamonie Dam consists of an earth fill dam 6,100 feet in length with top elevation of 812 feet NAVD88, and a crown width of 36 feet which carries a local access road. The upstream face of the dam is protected by riprap 36 inches thick from elevation 725 feet NAVD88 to elevation 812 feet NAVD88. The outlet works are located along the right abutment and consist of three hydraulically operated slide gates, each 4.75 feet by 16 feet, in a 16-foot circulated concrete conduit with invert at elevation 684 feet NAVD88 and exit into a drop-flip type stilling basin. Two 30-inch circular low discharge bypasses have been provided with inlets at invert elevation 715 feet NAVD88. The spillway is an uncontrolled open cut through earth in the generally flat right abutment divide between the Salamonie and Wabash Rivers, and approximately 3,600 feet upstream from the dam. The crest is at elevation 793 feet NAVD88, with a base width of 575 feet. Total length of the cut is approximately 4,760 feet along the centerline.

During the fall and winter months, when excessive rainfall is likely, Salamonie lake is kept at a relatively low level referred to as *winter pool*. Should heavy rains occur, surface water runoff is stored in the lake until the swollen streams and rivers below the dam have receded and can handle the release of the stored water without damage to lives and property. The maximum discharge capacity of the main gates with the reservoir pool at spillway crest is approximately 9,500 cfs. The maximum discharge capacity of the bypass system with the reservoir at summer pool elevation 755 feet NAVD88, is approximately 200 cfs. Maximum release for the project during normal operation is 7,000 cfs equivalent to the channel capacity in the reach of Salamonie River below the dam. Minimum release from the project during normal operation is 20 cfs.

Mississinewa Dam is on the Mississinewa River, 7.1 miles above the mouth and confluence with the Wabash River. The damsite is in Miami County, and the reservoir extends into Wabash and Grant Counties. The reservoir has a storage capacity of 737,520 acre-feet (at an elevation of 800 feet NAVD88) and drains approximately 682 square miles. The maximum flood pool extends from the dam up the Mississinewa River approximately 28 miles.

The Mississinewa Lake operates as a unit with J. E. Roush and Salamonie Lakes to reduce flood stages in the Upper Wabash River Basin. Mississinewa Lake also operates with other lakes downstream to reduce flood stages along the lower Wabash River and the Ohio River. Areas most directly benefited include the cities of Peru and Logansport, Indiana, and approximately 31,500 acres of agricultural land. Construction began in April 1962, and the lake became operational in October 1967. Since its completion, Mississinewa Lake has prevented more than $305 million in flood damages, more than 10 times its original cost of $24.4 million.

Mississinewa Dam consists of an earth fill dam, 8,000 feet in length with a top elevation of 797 feet NAVD88, and a crown width of 36 feet, which carries a local access road. The upstream face of the dam is protected by riprap 18 inches thick from elevation 707 feet NAVD88 to elevation 797 feet NAVD88. The outlet works are located along the left bank and consist of three hydraulically operated slide gates, each 4.75 feet by 16 feet, in a 16-foot circular concrete conduit with invert at elevation 665 feet NAVD88 and exit into a stilling basin with baffle blocks. Two 30-inch circular low discharge bypasses with multilevel openings have been provided with inlets at invert elevations 705 feet NAVD88, 716.25 feet NAVD88, and 727 feet NAVD88. The Mississinewa River, approximately 119 miles in length, flows northwestward to its confluence with the Wabash River at Mile 374.9, near Peru, Indiana. The Mississinewa drainage basin, has a contributing area of 819 square miles, 809 of which are controlled by the reservoir. The basin above the damsite is rectangular in shape, approximately 75 miles in length and averaging nearly 11 miles in width. The spillway is an uncontrolled open cut through earth in the flat area of the high right abutment. The crest is at elevation 779 feet NAVD88 with a base width of 1,550 feet. Total length of the cut is approximately 5,200 feet along the centerline.

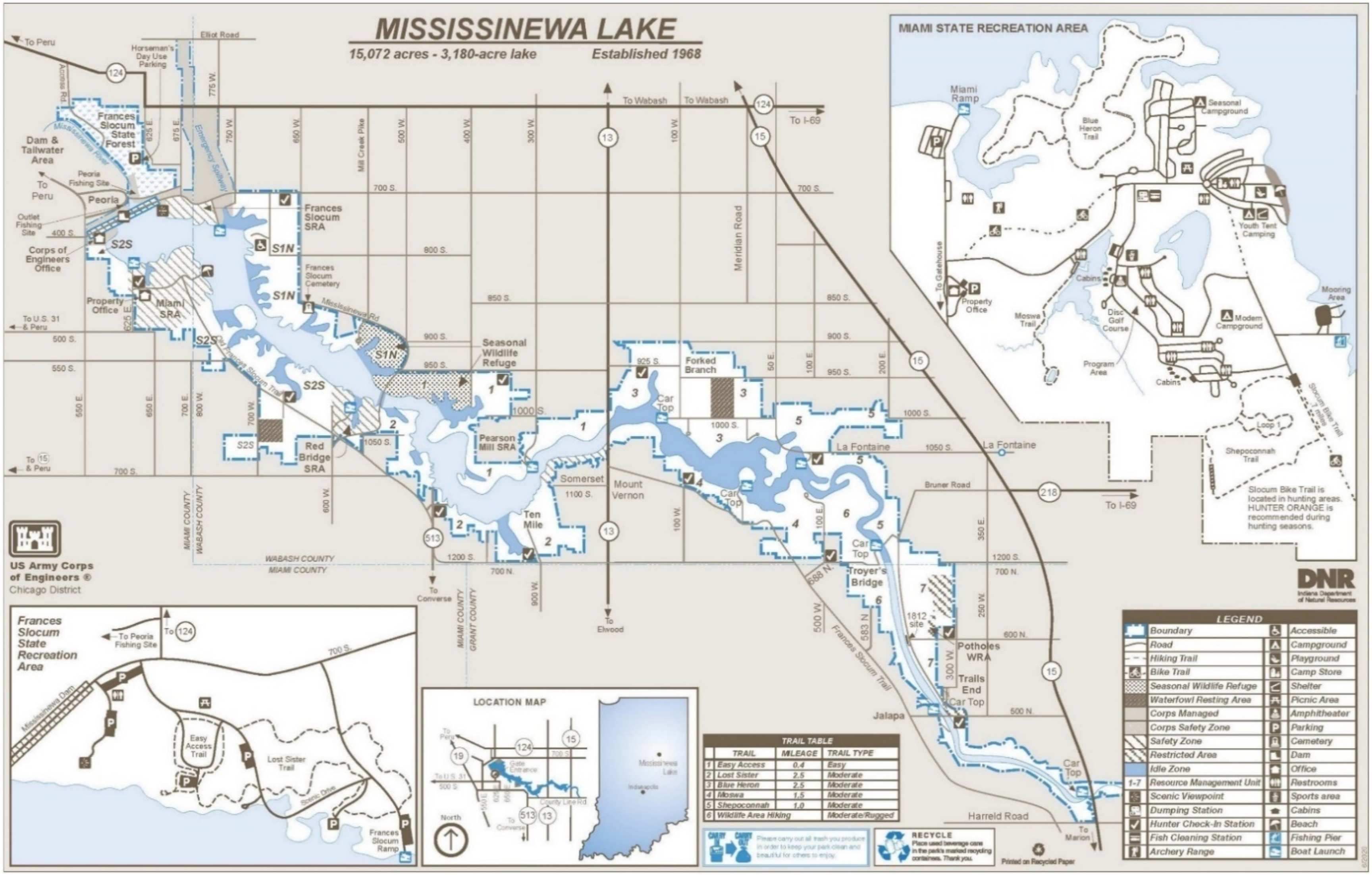
The maximum discharge capacity of the main gates with the reservoir pool at spillway crest is approximately 8,000 cfs. The maximum discharge capacity of the bypass system with the reservoir at summer pool elevation 737 NAVD88 feet is approximately 170 cfs. Maximum release for the project during normal operation is 6,000 cfs, equivalent to the channel capacity in the reach of the Mississinewa River immediately downstream of the dam. Minimum release from the project during normal operations is 35 cfs.

2.3 Recreation

Salamonie, Mississinewa, and J.E. Roush Lake projects each have many recreation areas supporting a variety of outdoor activities. Most of the land surrounding the lakes is owned by USACE but leased to the Indiana Department of Natural Resources (IDNR) for management. Peak recreation season is from May through October. Visitation is concentrated during the weekends and holidays in both peak and non-peak seasons. Popular recreational opportunities currently at the lake include hiking, boating, picnicking, camping, fishing, archery, hunting, wildlife viewing, basketball, horseshoes, disc golf, swimming, volleyball, and visiting the interpretive center.

Mississinewa Lake has a variety of recreation amenities or opportunities that are available both seasonally and year-round. Public use lands consist of seven recreational areas, six hunting and fishing areas, and other project lands designated for wildlife management purposes, general shoreline access and public hunting. Some of these areas include Frances Slocum State Recreation Area (SRA), Red Bridge SRA, and Miami SRA (Figure 3). Salamonie Lake also has a variety of recreation amenities including Mt. Hope SRA, Mt. Etna SRA, Lost Bridge West SRA, and Lost Bridge East SRA (Figure 4). J.E. Roush Lake is managed by the IDNR primarily as a fish and wildlife property dedicated to providing recreational opportunities including hunting, fishing, trapping, and wildlife viewing. Recreation areas at J.E. Roush Lake include a shooting range, Kil-So-Quah Recreation Area, and Little Turtle Pond and Fishing Pier (Figure 5).

The Upper Wabash downstream of J.E. Roush Dam has very few recreation areas along the banks. There are opportunities for recreational boating and fishing within the river, but the banks of the river mostly consist of agricultural fields closely hugging the river’s edge with a thin strip of trees right along the bank. There are several public access boat ramps in the reach of the river from J.E. Roush Dam to Logansport including ramps located in Logansport, Peru, between Peru and Wabash, and in Wabash, Indiana.



TRAIL TABLE

	TRAIL	MILEAGE	TRAIL TYPE
1	Easy Access	0.4	Easy
2	Lost Sister	2.5	Moderate
3	Blue Heron	2.5	Moderate
4	Moswa	1.5	Moderate
5	Shepoconnah	1.0	Moderate
6	Wildlife Area Hiking		Moderate/Rugged

Figure 3. Mississinewa Lake recreation areas.

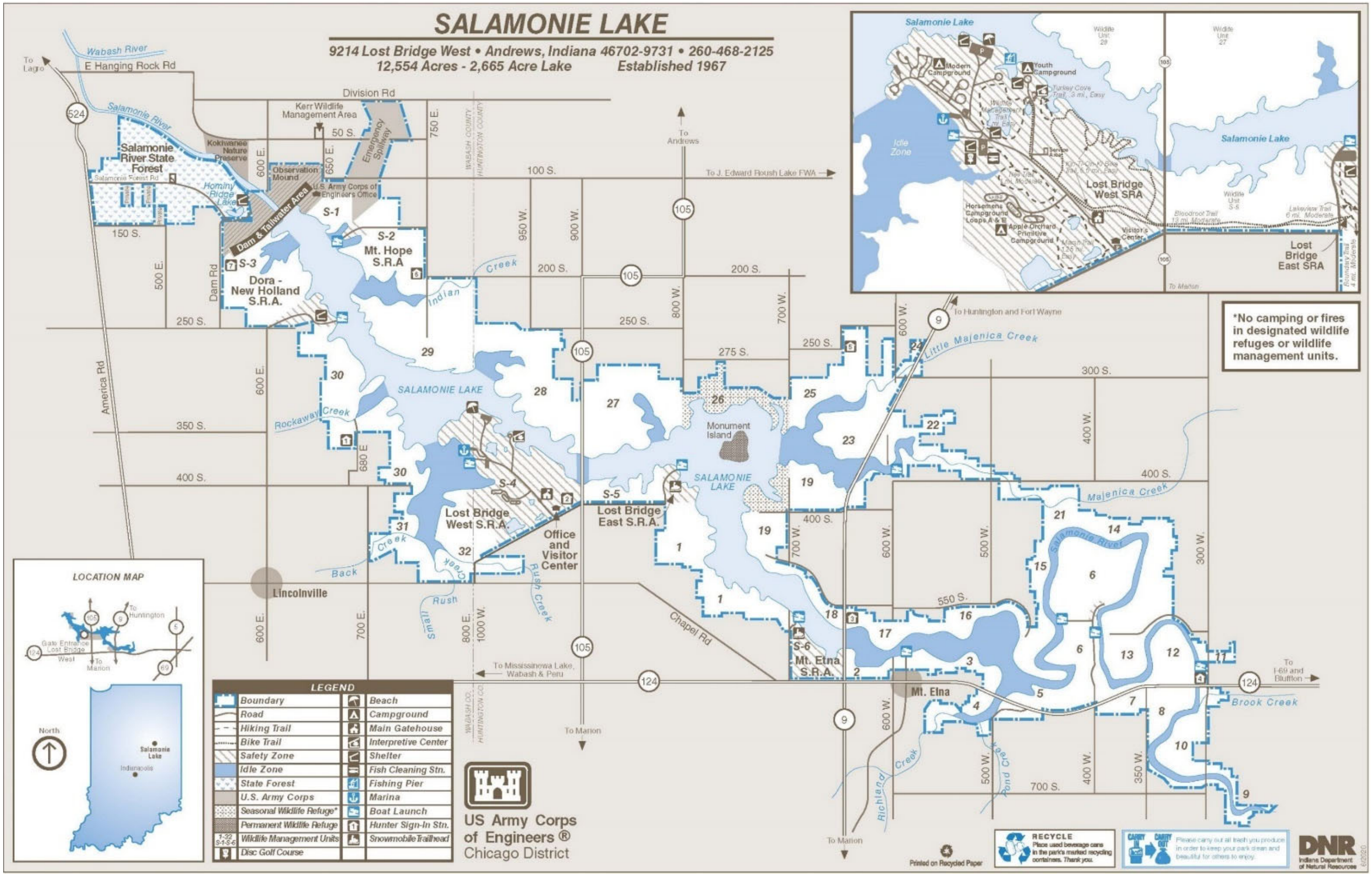


Figure 4. Salamonie Lake recreation areas.

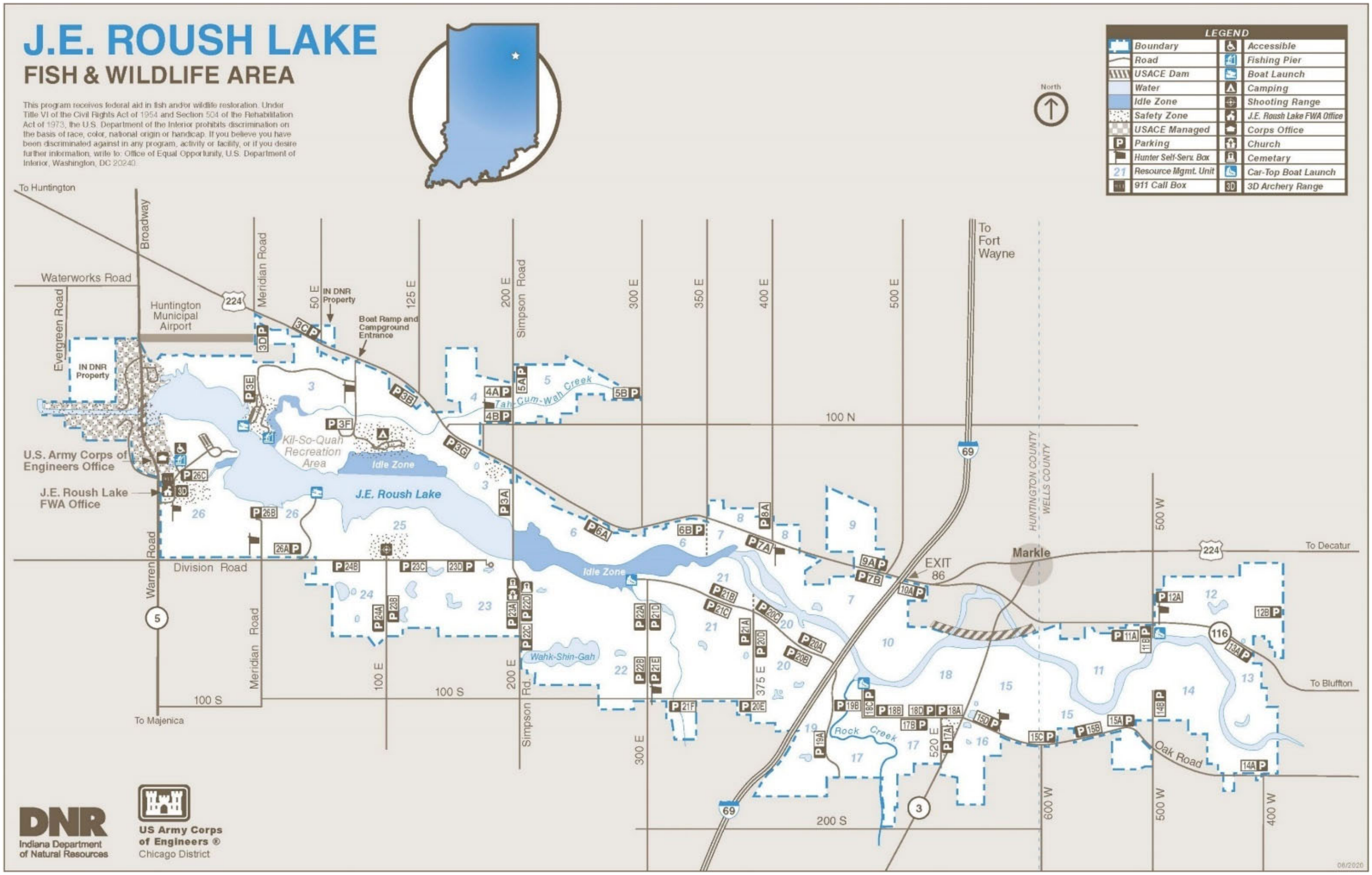


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Figure 5. J.E. Roush Lake recreation areas.

3. Existing Conditions, Literature Review, & Data Gathering

The following section provides a summary of the literature reviewed, data gathered (see Appendix B for data gathered), and existing conditions throughout the watershed.

3.1. Basin Characteristics

Climate

Climate data for the Northeastern Indiana region was gathered from the National Weather Services (NWS) climate data website and is shown in Figure 6. Northeastern Indiana has a humid continental climate. Average annual precipitation is 38 inches and average annual snowfall is 33.5 inches. Hot summers and cold winters are typical. Mean daily temperatures for the study area range from a high of 73 degrees Fahrenheit (°F) to a low of 25 °F with July being the hottest month. The mean daily high is approximately 84.4 °F, and January is the coldest month, with a mean daily low of approximately 17 °F. The average first and last frost occur on October 17 and April 24, respectively. The area averages between 2.3 and 4.7 inches of precipitation monthly, receiving the majority in spring and summer and averaging 40.6 inches annually. On average, the area in the vicinity of Huntington, Indiana, receives precipitation 122 days per year in the form of rain and snow, sleet, or hail (NWS Climate (weather.gov)). Climate change is having an impact on the midwestern climate. The Midwest has become warmer over the past few decades. Climate change is also leading to warmer and wetter winters, springs with heavy precipitation, and hotter summers with longer dry periods (EPA, 2023).

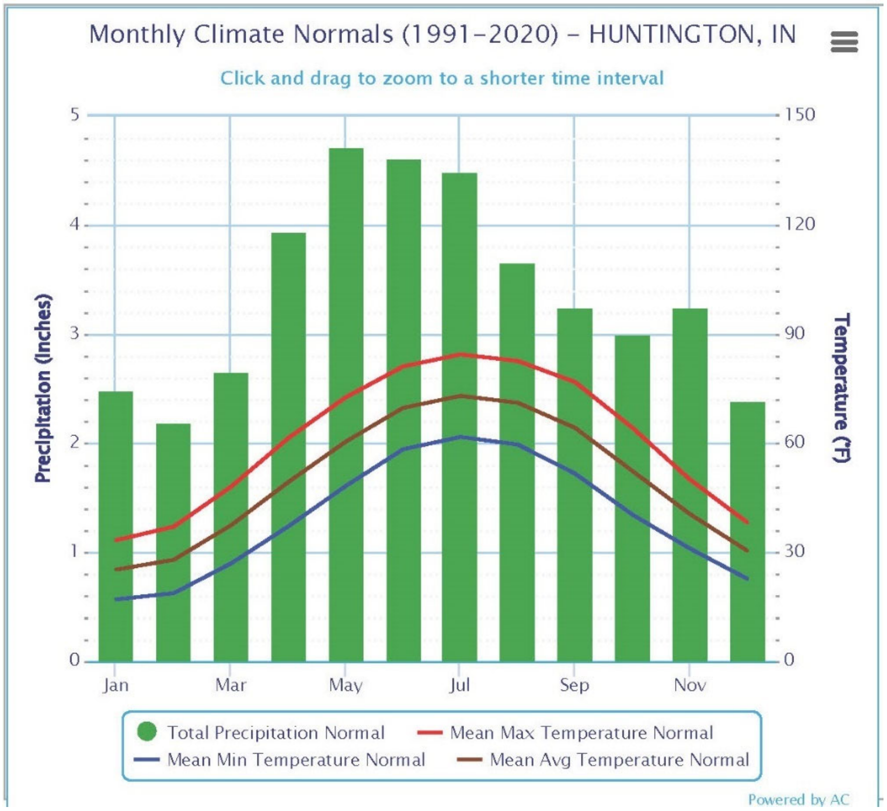


Figure 6. Normal monthly climate for Huntington, Indiana from 1991-2020 (NWS, 2023).

Physiography and Ecoregion

The Upper Wabash watershed resides almost entirely in the Bluffton Till Plain section (Figure 7) of the Central Till Plain physiographic region (Gray, 2000). The watershed is a broad, level clayey till plain with some end moraines, lake basins, and sand and gravel outwash. Most tillable ground is used for row crop production, but extensive drain tiling is required for adequate drainage. Livestock farming occurs on non-tillable ground. Scattered woodlots are dispersed throughout the watershed but are more prevalent in the riparian areas. Soils are well drained to very poorly drained, formed in Wisconsin Age glacial drift derived mostly from limestone and dolomite (NRCS, 2023).

The United States Environmental Protection Agency (USEPA) divides the US into ecoregions, which are areas where ecosystems and their associated environmental resources are similar. There are four hierarchy levels within the ecoregion. The Upper Wabash watershed is within the Clayey, High Lime Till Plains (level IV; Figure 8) ecoregion which is a subdivision of the increasingly larger Eastern Corn Belt Plains ecoregion (level III), the Central USA Plains ecoregion (level II), and the Eastern Temperate Forest ecoregion (level I) (Woods et al., 1998). The Clayey, High Lime Till Plains ecoregion is situated between the Loamy, High Lime Till Plains to the southwest, and the Maumee Lake Plains to the northeast. Most of the original beech forests and scattered elm-ash swamp forests in the eastern corn belt ecoregion were gradually replaced by agriculture, and row crop agriculture now dominates the landscape (Woods et al., 1998). The implications for surface water in a watershed dominated by row crop agriculture are further discussed in the land use and water quality sections of this report.

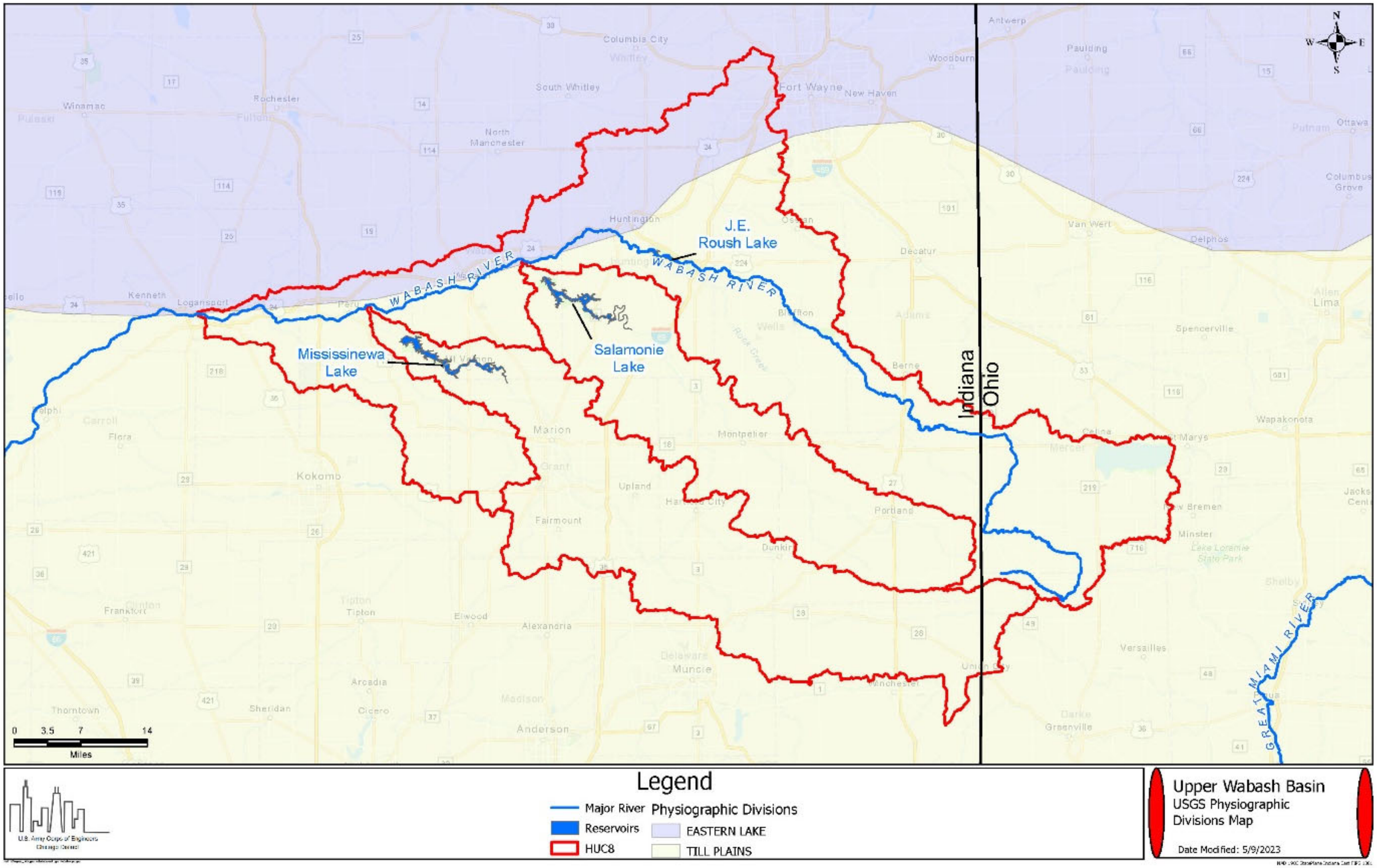


Figure 7. Till Plain Physiographic Unit (IGWS, 2000)

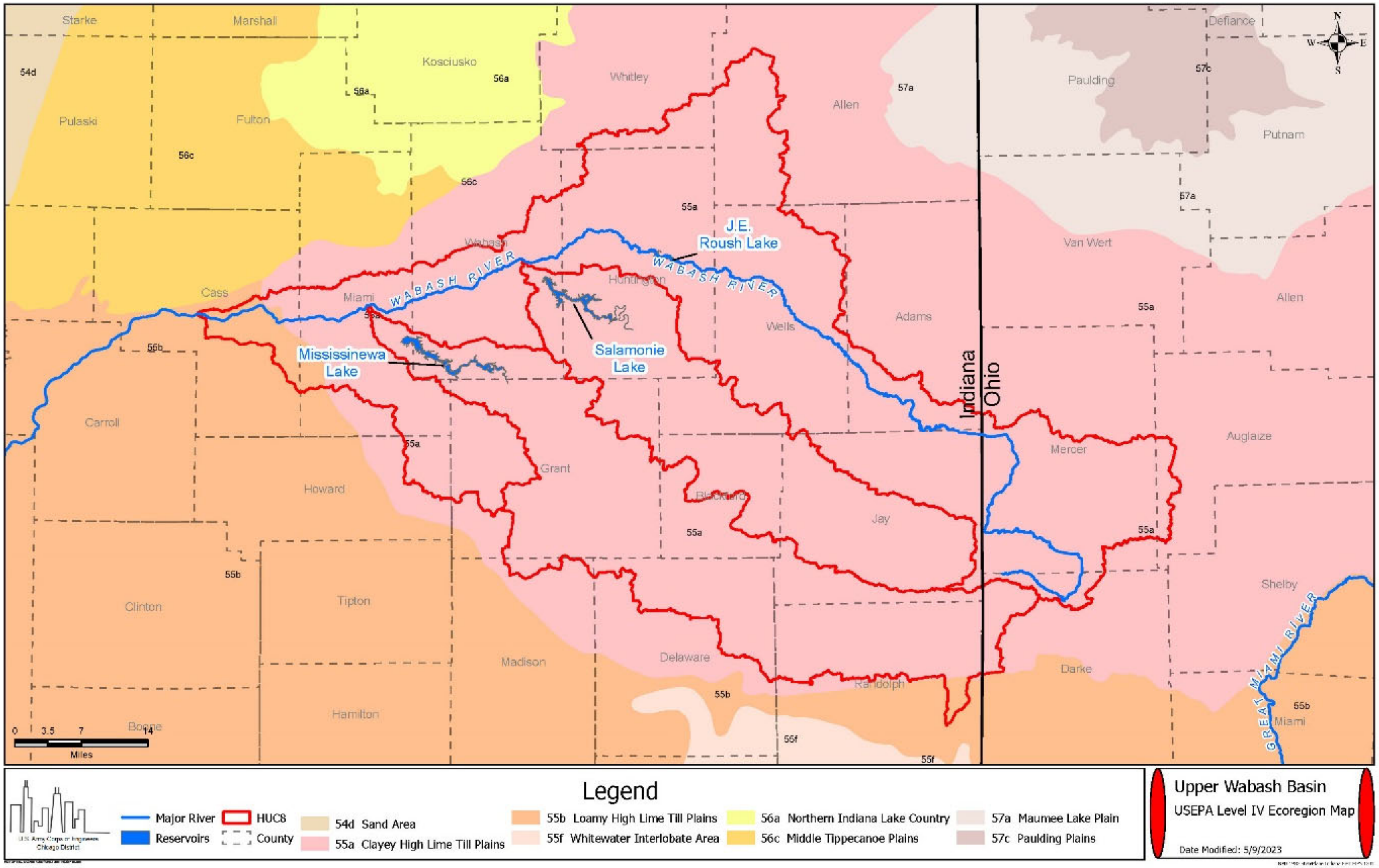


Figure 8. Environmental Protection Agency Level IV Ecoregions for the Wabash River Watershed (Woods, 1998).

Land Use

Most of the land use within the Upper Wabash watershed would have been woodlands or wetlands under natural conditions, but European settlers cleared the land and converted most of the acreage to agricultural use. As indicated in Figure 9, most of the acreage in the watershed is now held in extensive tracts for commercial agricultural production (76 percent). The dominant agricultural crops are corn and soybeans with some hay and pasture (approximately 3 percent). Woodlands and forests (approximately 10 percent) are largely confined to the Mississinewa, Salamonie, and Upper Wabash River valleys. The watershed contains only approximately 8 percent developed land, with around 5 percent of that being designated as developed open space. Just over 1 percent of the watershed consists of open water, and those areas are mostly comprised of Salamonie, Mississinewa, and J.E. Roush Lakes. The remaining land cover within the watershed is a combination of all the other land use classes, each representing less than 1 percent of the total area (Figure 9).

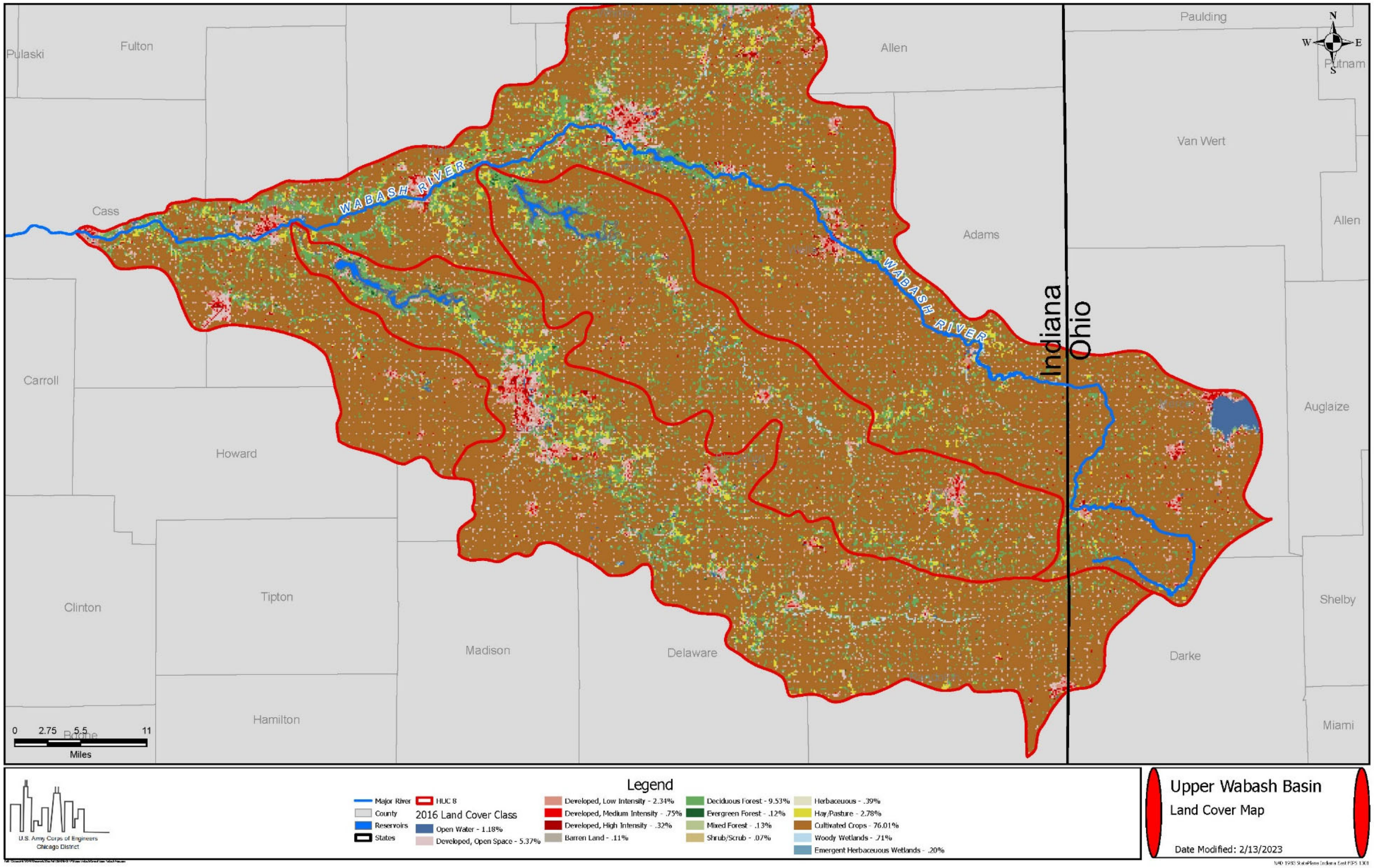


Figure 9. Land use in the Upper Wabash Watershed based on 2016 data (National Land Cover Dataset, 2016).

Soils

Soil data for the Upper Wabash watershed was collected from the United States Department of Agriculture (USDA) Natural Resources Conservation Service’s (NRCS) National Cooperative Soil Survey. There are two dominant soil series in the watershed (Figure 10). The most abundant series is the Pewamo series, which consists of very deep, very poorly drained soils formed in till on moraines. Pewamo soils are used for corn, soybean, and hay production. Pewamo soils historically supported forested wetland communities comprised of green ash, silver maple, American elm, eastern cottonwood, sedge spp., and rushes (NRCS, 2023a). The second most abundant series is the Blount Series. Blount soils consist of very deep, somewhat poorly drained soils that are moderately deep or deep to dense till. Blount soils formed in till and are on wave-worked till plains, till plains, and relict near-shore zones. As with the Pewamo series, Blount soils are mostly in corn, soybeans, and small grain agricultural production. Historic vegetation was hardwood forest (NRCS, 2023b).

According to the USDA NRCS Rapid Watershed Assessment for the Upper Wabash watershed (https://www.in.gov/isda/files/Upper_Wabash_RWA.pdf), the watershed consists of soils subject to erosion by water with high surface runoff classification. Soils are also susceptible to wind erosion. The glacial drift varies in thickness, typically averaging between 50 to 70 feet. Limited post glacial stream development occurred throughout the region with the exception of the Wabash River. The Upper Wabash watershed has more than 29,000 acres of soils with high leaching indices, which allows contaminants on the land surface to be carried into the ground water from infiltrating water. Approximately 3 percent of the watershed is within an identified wellhead protection area. The Salamonie watershed has more than 7,150 acres of soil with high leaching indices, which allows containments on the land surface to be carried easily into the ground water from infiltrating water. Because of this condition, non–point pollutants such as fertilizers, pesticides, and livestock waste have the potential to contaminate the groundwater aquifer.

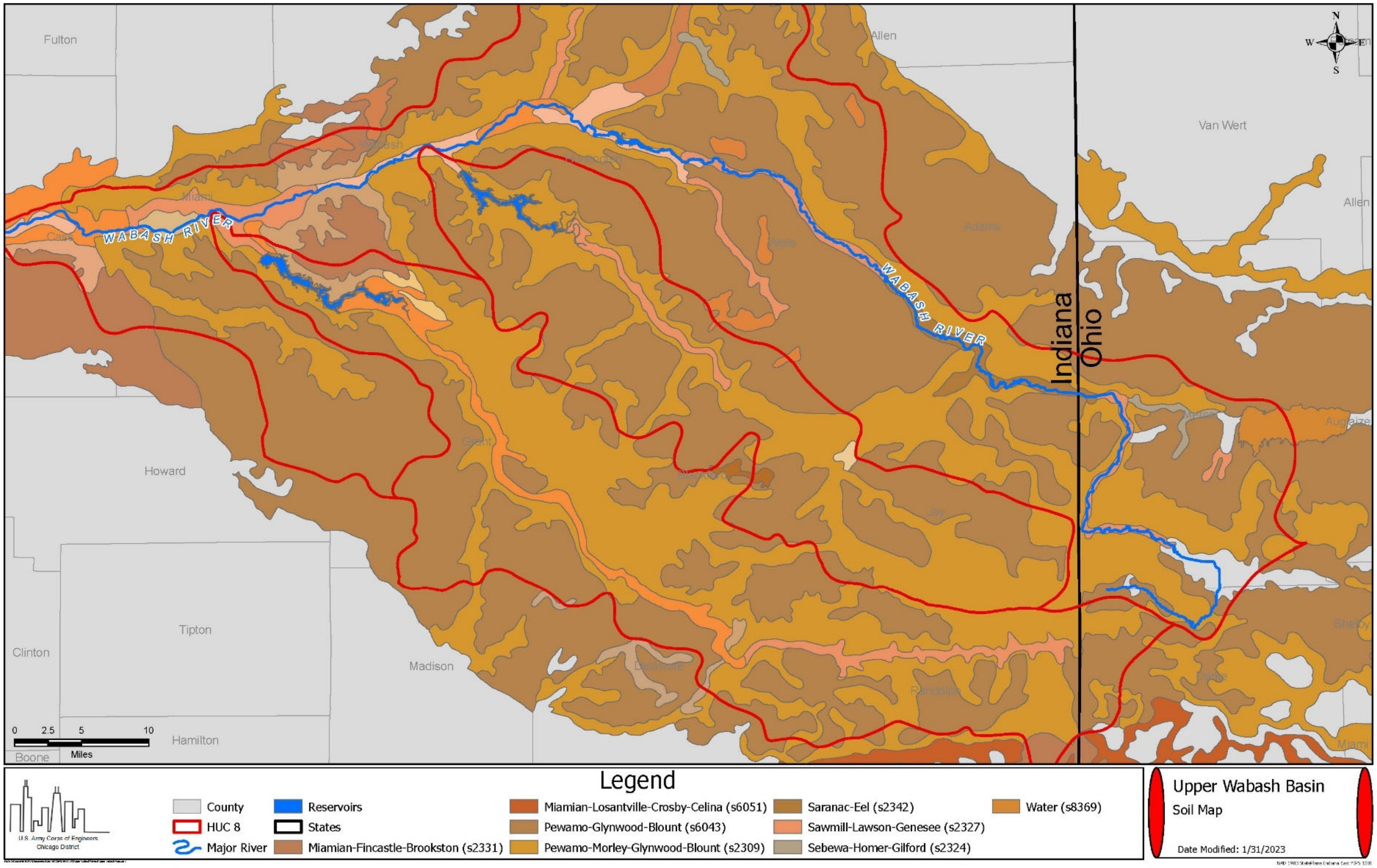


Figure 10. Soil series in the Upper Wabash Watershed (NRCS, 2023).

Geology

The bedrock of the Upper Wabash area consists of Silurian Age limestones, dolomites and shales that are collectively part of the Wabash Formation. The Wabash Formation is made up of four members but only the upper two are present at the projects discussed in this report. The typical upper, and younger member is the Liston Creek Limestone, and the typical lower and older member is the Mississinewa Shale. The Mississinewa member also contains a reef facies, commonly called the Huntington Lithofacies that ranges from impure-carbonate to pure-carbonate depending on location. The Liston Creek member, Mississinewa member, and reef facies are intimately mixed in many areas and the Wabash members can appear in any order stratigraphically (Indiana Geological and Water Survey, 2023a).

The depth to bedrock ranges from 50 to 70 feet. The Wabash Formation has a thickness of 0 to 400 feet with thickness increasing from the southeast to the northwest. The Liston Creek member is between 60 to 200 feet thick and the Mississinewa member between 60 to 200 feet thick (Droste and Shaver, 1986).

<u>Bedrock - Liston Creek Limestone Member</u>**:** The Liston Creek Limestone is named for a historical creek now underwater in the Mississinewa Reservoir. The member consists of cherty limestone and dolomitic limestone that is light gray and tan, fine to medium grained, fossil fragmental, and slabby bedded that rests with sharp, but probably conformable, contact on the Mississinewa Shale Member. Liston Creek has a reef facies that continues stratigraphically upward without break from the Mississinewa Shale into the Liston Creek (Indiana Geological and Water Survey, 2023a).

<u>Bedrock - Mississinewa Shale Member</u>: The Mississinewa Shale Member consists of argillaceous dolomitic siltstone and silty dolomite, fairly calcareous in places, that is in various shades of gray and is dense to fine grained and massive (Droste and Shaver, 1986). The Mississinewa member also has a reef facies, commonly called the Huntington Lithofacies that ranges from impure-carbonate, immature-reef rock to nearly 100-percent-pure-carbonate, mature-reef rock, depending on both stratigraphic level and distal-to-proximal position to the reef facies (Droste and Shaver, 1986).

3.2 Hydrology

Many figures, graphs, and tables were prepared to illustrate hydrology in the Upper Wabash River. Figures and graphs are referenced and can be found in Appendix C – Hydrology.

3.2.1 Gaging Stations

There are 12 U.S. Geological Survey (USGS) stream gaging sites located on the upper Wabash, Salamonie and Mississinewa Rivers: 03329000 (Wabash River at Logansport, Indiana), 03327500 (Wabash River at Peru, Indiana), 03325000 (Wabash River at Wabash, Indiana), 03323500 (Wabash River at Huntington, Indiana), 03323000 (Wabash River at Bluffton, Indiana), 03324500 (Salamonie River at Dora, Indiana), 03324300 (Salamonie River near Warren, Indiana), and 03326500 (Mississinewa River at Marion, Indiana) that measure daily mean stream discharge. Water quality stations which measure stream stage and temperature are available at 03323500 (Wabash River at Huntington, Indiana), 03324500 (Salamonie River at Dora, Indiana), and 003327000 (Mississinewa River at Peoria, Indiana). Daily lake stage measurements are available at 03323450 (J. Edward Roush Lake near Huntington, Indiana), 03324450 (Salamonie Lake at Dora, Indiana), and 03326950 (Mississinewa Lake at Peoria, Indiana). Additionally, six precipitation gages are maintained by the USGS to support project operations: Wabash River at Linn Grove, Indiana; Wabash River at Bluffton, Indiana; Salamonie River near Warren, Indiana; Salamonie River at Dora, Indiana; Wabash River at Wabash, Indiana; and Wabash River at Peru, Indiana. The location of the gages are shown in Figure 11. Peak streamflow values are not available at all of the sites.

The Logansport gage is located approximately 57.2 miles downstream of J.E. Roush Dam, 43.3 miles downstream of Salamonie Dam, and 27.8 miles downstream of Mississinewa Dam at an elevation of 572.82 feet NAVD88 and captures the drainage area of approximately 3,779 square miles. Mean daily streamflow values are available dating back to 1924 (Figure C.1); peak streamflow measurements are available from 1883 to 2021.

The Peru gage is located approximately 38.7 miles downstream of J.E. Roush Dam, 24.9 miles downstream of Salamonie Dam, and 9.5 miles downstream of Mississinewa Dam at an elevation of 617.61 feet NAVD88 and captures the drainage area of approximately 2,686 square miles. Mean daily streamflow values are available dating back to 1943 (Figure C.2).

The Wabash gage is located approximately 24.0 miles downstream of J.E. Roush Dam and 10.1 miles downstream of Salamonie Dam at an elevation of 642.15 feet NAVD88 and captures the drainage area of approximately 1,768 square miles. Mean daily stream values are available dating back to 1923 (Figure C.3).

The Huntington gage is located approximately 1.7 miles downstream of J.E. Roush Dam at an elevation of 699.57 feet NAVD88 and captures the drainage area of approximately 721 square miles. Mean daily streamflow values are available from April 1951 to mid-February 2003; peak streamflow observations are available from 1913 to 2001.

The Dora gage is located approximately 0.3 miles downstream of Salamonie Dam at an elevation of 673.33 feet NAVD88 and captures the drainage area of approximately 557 square miles. Mean daily streamflow values are available from 1924 to 2003; peak streamflow observations are available from 1924 to 2001.

The Peoria gage is located approximately 0.4 miles downstream of Mississinewa Dam at an elevation of 660.00 feet NGVD29 and captures the drainage area of approximately 808 square miles. Mean daily stage values are available back to 2001; peak streamflow observations are available from 1943 to 2001.

The Marion gage is located approximately 23.9 miles upstream of Mississinewa Dam at an elevation of 774.21 feet NAVD88 and captures the drainage area of approximately 682 square miles. Mean daily streamflow values are available dating back to 1923 (Figure C.4); peak streamflow observations are available from 1913 to 2021.

The Warren gage is located approximately 23.2 miles upstream of Salamonie Dam at an elevation of 784.42 feet NAVD88 and captures a drainage area of 425 square miles. Mean daily streamflow values are available dating back to 1957 (Figure C.5).

The Bluffton gage is located approximately 21.3 miles upstream of J.E. Roush Dam at an elevation of 792.57 feet NAVD88 and captures the drainage area of approximately 532 square miles. Mean daily streamflow values are available dating back to 1930 with a gap from 1972 to 2015 (Figure C.6); peak streamflow observations are available from 1904 to 2022.

Because of the location of the Logansport, Peru, Wabash and Huntington sites versus the Bluffton, Warren and Marion sites, downstream of the Dams and upstream of the Dams, respectively, the Logansport, Peru, Wabash and Huntington sites were the only sites used in the analysis of streamflow statistics and the comparison of historic (prior to construction of the dams) to current (after construction of the dams) streamflow characteristics. However, streamflow trends will be discussed for the Bluffton, Warren and Marion sites, as well.

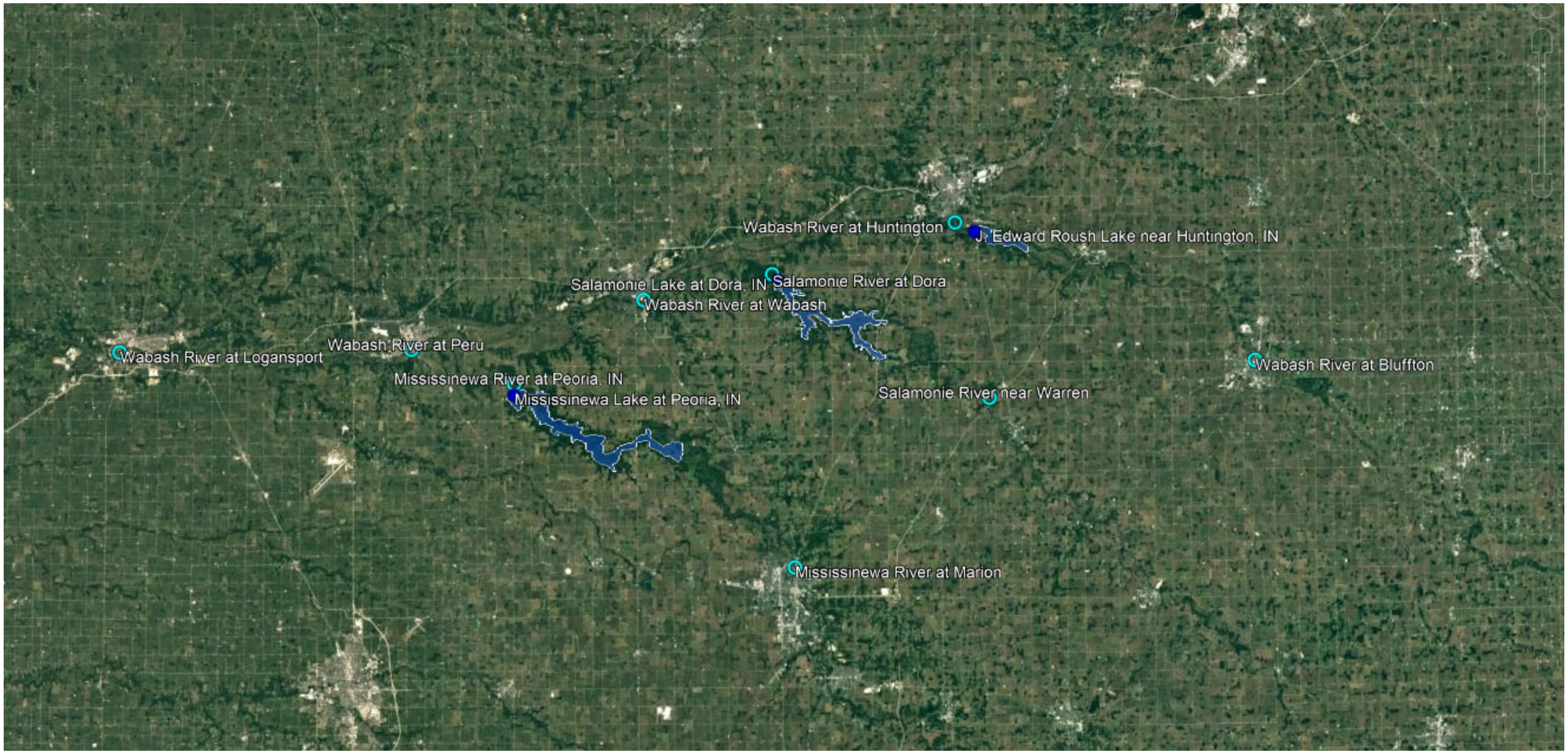


Figure 11. U.S. Geological Survey streamgage locations.

3.2.2 Historical

Streamflow statistics for the Logansport, Peru and Wabash gages were calculated for the historical streamflow data, which was obtained from the U.S. Geological Survey's National Water Information System database. The gages began collecting data 9 December 1961 when the construction of the Salamonie Dam was initiated. Streamflow statistics for Huntington was calculated for the historical streamflow data, which is considered the period from when the gages began collecting data to 12 May 1965 when the construction of the J.E. Roush dam and outlet works was initiated.

3.2.3 Current

Using the streamflow data from 'Wabash River at Linn Grove, Indiana', a gage located upstream of 'Wabash River at Bluffton, Indiana', a drainage area ratio of 1.12 was applied to fill in the missing streamflow data at the Bluffton gage, ranging from 29 September 1971 to 22 April 2015. Streamflow statistics for observed streamflow at Logansport, Peru, and Wabash were calculated using streamflow data beginning in January 1969. For the Marion, Warren and Bluffton sites, current streamflow data is considered the period after which the dams were put into operation, October 1967 (Mississinewa), September 1966 (Salamonie), and January 1969 (J.E. Roush), respectively.

3.2.4 Daily Streamflow

Extreme values in daily streamflow measurements at the stream gaging sites along the Wabash River occurred less frequently after the construction of the Upper Wabash projects. When considering the streamflow data for the Logansport, Peru and Wabash gages, peak streamflows occurred less frequently and with less severity after the early 1960's, consistent with when the Salamonie and Mississinewa Dams were constructed. The duration of low-flow periods, indicated by extended periods of red and orange shading, was reduced during the same period (Figures C.1, C.2, and C.3). The gages upstream, however, do not show a similar alteration to the frequency, duration, or intensity of extreme flows (Figures C.4., C.5 and C.6).

3.2.5 Flood Frequency and Peak Flows

The frequency of large floods has been reduced since the construction of the Upper Wabash projects. As shown at those gages located downstream of the projects (Figures C.7, C.8, and C.9), all the major floods downstream occurred before the mid-1960s. For example, the largest flood occurred in 1914, reaching a peak discharge of approximately 140,000 cfs at Logansport, Indiana (Figures C.7). Since the construction of the dams, however, there have not been similarly large events along the lower reaches of the Upper Wabash River downstream of the projects (C.10, C.11, and C.12).

3.2.5 Low Flows

In addition to high flows and peak flows, the natural frequency, duration, and magnitude of low flow variability has important ecological functions. Baseflow and extreme low flow values are unique to each stream and these hydrologic flow regimes are needed to sustain habitat and maintain suitable water quality (Yin et al., 2010). As shown in Table 1 and Figures C.13, though C.18 in Appendix C, the variability of low flows has increased since the construction of J.E. Roush, Salamonie and Mississinewa Dams. Prior to the construction of the J.E. Roush, Salamonie and Mississinewa Dams, the minimum 1-day streamflow values ranged from 4 to 135 cfs along the mainstem of the Wabash River and 4 to 6 cfs along its upper reaches and tributaries. After construction, the minimum 1-day streamflow increased to 48 to 218 cfs along the mainstem of the Wabash River while remaining similar along its upper reaches and tributaries, at 0 to 10 cfs. When considering the maximum 1-day low streamflows, however, streamflows ranged from 109 to 568 cfs along the mainstem of the Wabash River and 21 to 61 cfs along its upper reaches and tributaries. Since the construction of the dams, low flows along the Wabash River are represented by flows of greater magnitude than those which occurred prior to the dams; this is not seen at those gages upstream of the dam. A similar trend is seen in the annual minimum 7-day streamflow graphs (Figures C.19 through C.24); the magnitude and range of post-project low flow conditions are shown to increase compared to their pre-project counterparts.

Table 1. Variability of annual 1-day low flows at gages near the Upper Wabash projects.

		Wabash River at Logansport	*Wabash River at Peru*	*Wabash River at Wabash*	*Mississinewa River at Marion*	*Salamonie River near Warren*	*Wabash River at Bluffton*
		(cfs)	*(cfs)*	*(cfs)*	*(cfs)*	*(cfs)*	*(cfs)*
Pre-Project	*Minimum*	135	17	4	4	4	6
	Maximum	568	257	109	61	21	26
	Average	295	91	44	15	11	12
	Std Dev	107	64	28	15	5	7
Post-Project	*Minimum*	218	82	48	7	0	10
	Maximum	908	501	233	130	45	46
	Average	438	223	107	39	16	26
	Std Dev	154	95	47	24	10	10

3.2.6 Upper Wabash Lake Levels

The frequency and duration of lake elevations need to be considered to maintain healthy ecological functions. Prolonged periods of drying or submergence can have adverse impacts to species not acclimated to such conditions. Figures C.25, C.26, and C.27 in Appendix C provide the percent exceedance for water surface elevations in J.E. Roush, Salamonie and Mississinewa Lakes, respectively, based on historical elevation data. Figures C.28, C.29, and C.30 in Appendix C provide the annual exceedance probability for water surface elevations in J.E. Roush, Salamonie and Mississinewa Lakes, respectively, again based on historical elevation data. These values are highly influenced by the pools which are maintained during the summer and winter months. These summer and winter pool elevations correspond to 749 and 737 at J.E. Roush, 755 and 730 at Salamonie, and 737 and 712 at Mississinewa, respectively. These target elevations are denoted on Figures C.28, C.29, and C.30, as appropriate.

3.3 Water Quality

The Indiana Department of Environmental Management (IDEM) has established water quality standards to protect the beneficial uses of waterways in the state. The standards, based on supporting the various beneficial uses in waters of the state, establish the acceptable levels or ranges for various water quality parameters, including parameters such as temperature, dissolved oxygen (DO), and pH. These parameters are important measures of water quality. Each parameter affects one or more of the beneficial uses, including full body contact (recreation), human health and wildlife uses, and warm water aquatic uses. IDEM and other state, federal, and local stakeholders monitor water quality parameters in streams and other waterbodies throughout Indiana. The National Water Quality Inventory Report to Congress (Combined 303(d)/305(b) report) is the primary means of informing Congress and the public about general water quality conditions in the United States. These reports consist of water quality assessments submitted by states, tribes, and others and summarized by the USEPA for Congress. Waterbodies that are not within the standards are listed as "water quality impaired." The list of impaired streams is called the "303(d) List of Impaired Waters," as dictated in section 303(d) of the 1972 Clean Water Act.

In 2006, a Total Maximum Daily Load (TMDL) was developed for the 475-mile Wabash River in Indiana to the confluence with the Ohio River. The Wabash River TMDL identifies the main stem of the Wabash River as impaired; *E. coli* and nutrients are the primary pollutants. Other water quality issues in the basin include impaired biotic communities, DO, rapid pH changes, and pH measurements below six and above nine units. Sources of pollution within the watershed were identified as non-point source from agriculture and farming practices, land application of manure, and urban and rural run-off, point source discharges, home sewage treatment system disposal, and combined sewer overflows (TetraTech, Inc., 2006).

The water quality in the study area has implications for both aquatic life and human beneficial uses. Multiple watershed management plans (WMPs) have been developed by state and local governments, and a variety of other stakeholders, to determine the sources of water quality problems identified in each watershed and to evaluate possible solutions. The water quality status for the Mississinewa River, Salamonie River, and Upper Wabash River basins are presented separately below.

3.3.1 Mississinewa River Watershed HUC: 05120103

Forty-nine (49) acres of freshwater lakes in the Mississinewa watershed fully support designated uses outlined in Indiana Administrative Code 14-25-7-2. Three thousand two hundred (3,200) acres of freshwater lakes are listed as overall not supporting designated uses; Mississinewa reservoir does not support human health and wildlife use due to polychlorinated biphenyls (PCBs) and mercury present in fish tissue samples. Fourteen (14) lakes have not been assessed. Approximately 600 miles of streams in the Mississinewa River watershed are listed on the 2022 Section 303(d) List of Impaired Waters; approximately 400 miles of stream have not been assessed and 80 miles are listed as fully supporting the designated uses. Impairments for stream reaches were for one or more of the following parameters: impaired biological integrity, chloride, *E. coli*, nutrients, and PCBs. The distribution of stream impairment is shown in Figure 12. Sources of impaired biological integrity, E. *coli*, and nutrients are indicated in Figure 13, Figure 14, and Figure 15, respectively. Sources of PCBs and chloride are contaminated sediments and other unknown sources, and municipal point sources, respectively (Hostetter, 2022).

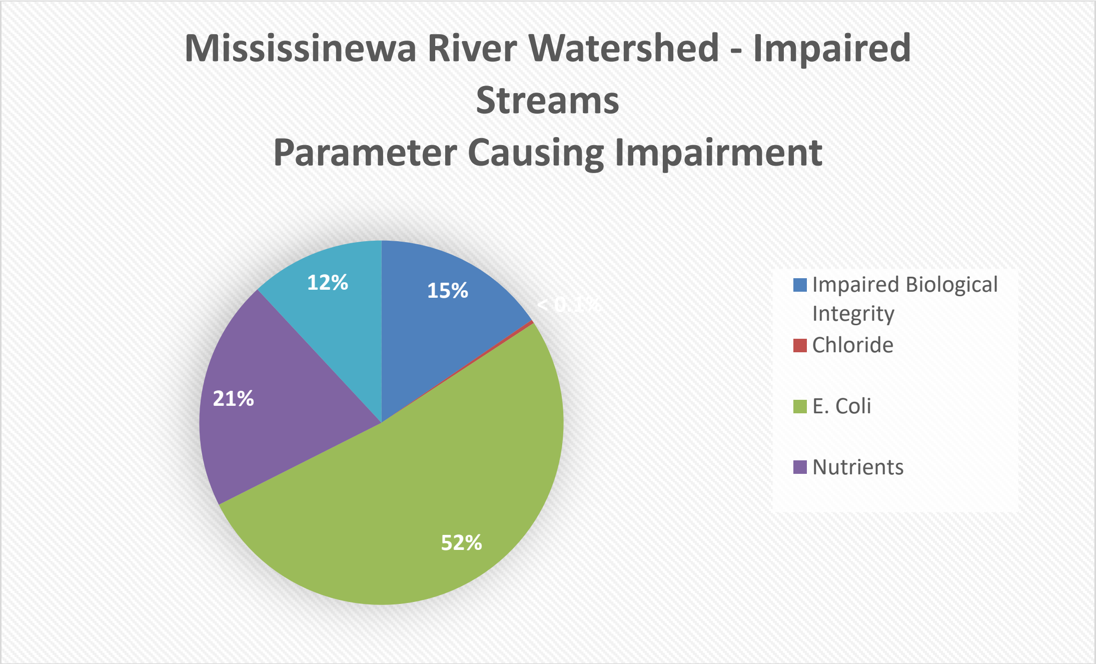


Figure 12. Mississinewa River Watershed Stream Impairment Parameters.

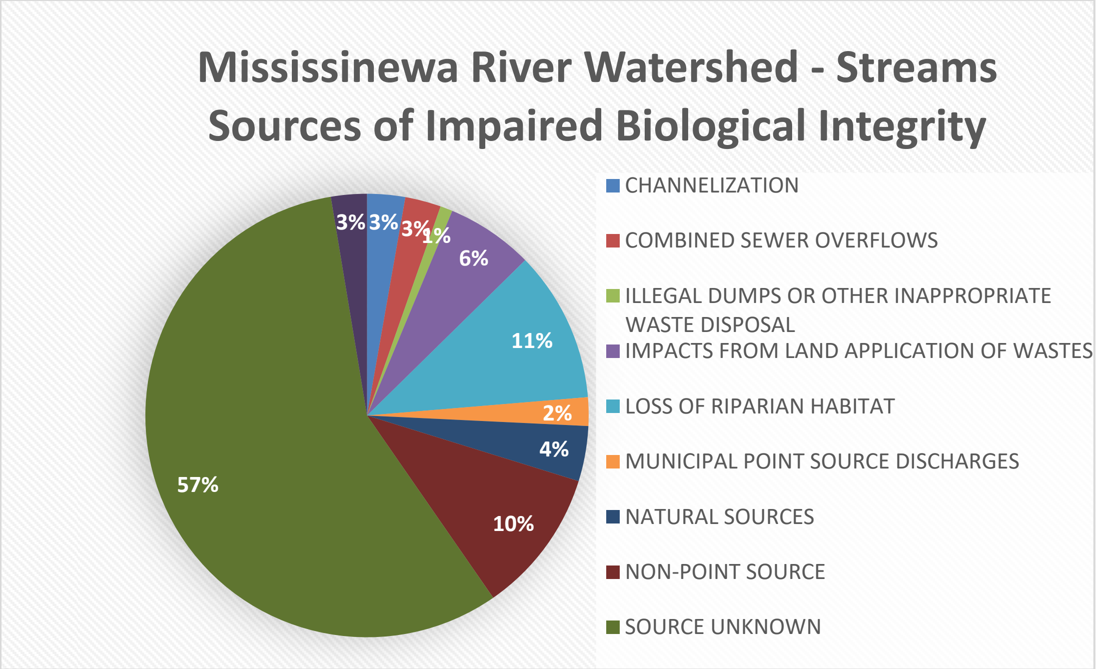


Figure 13. Mississinewa River Watershed Impaired Streams – Sources of Impaired Biological Integrity.

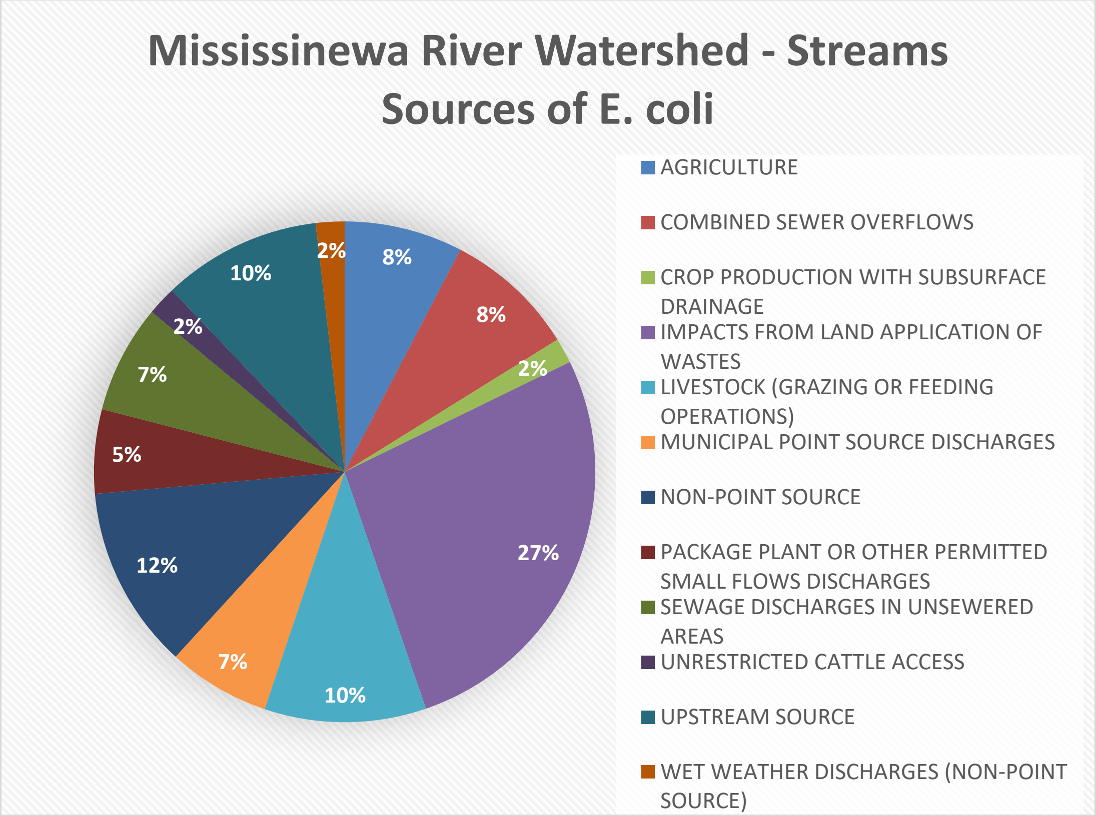


Figure 14. Mississinewa River Watershed Impaired Streams – Sources of E. coli.

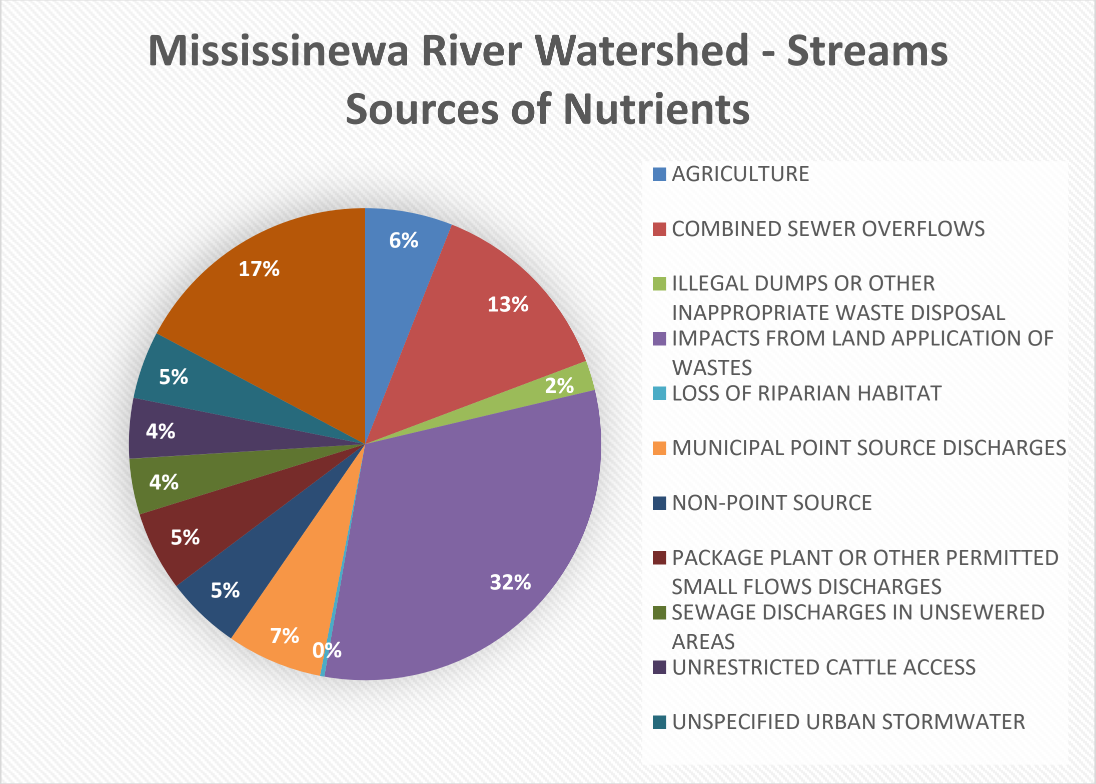
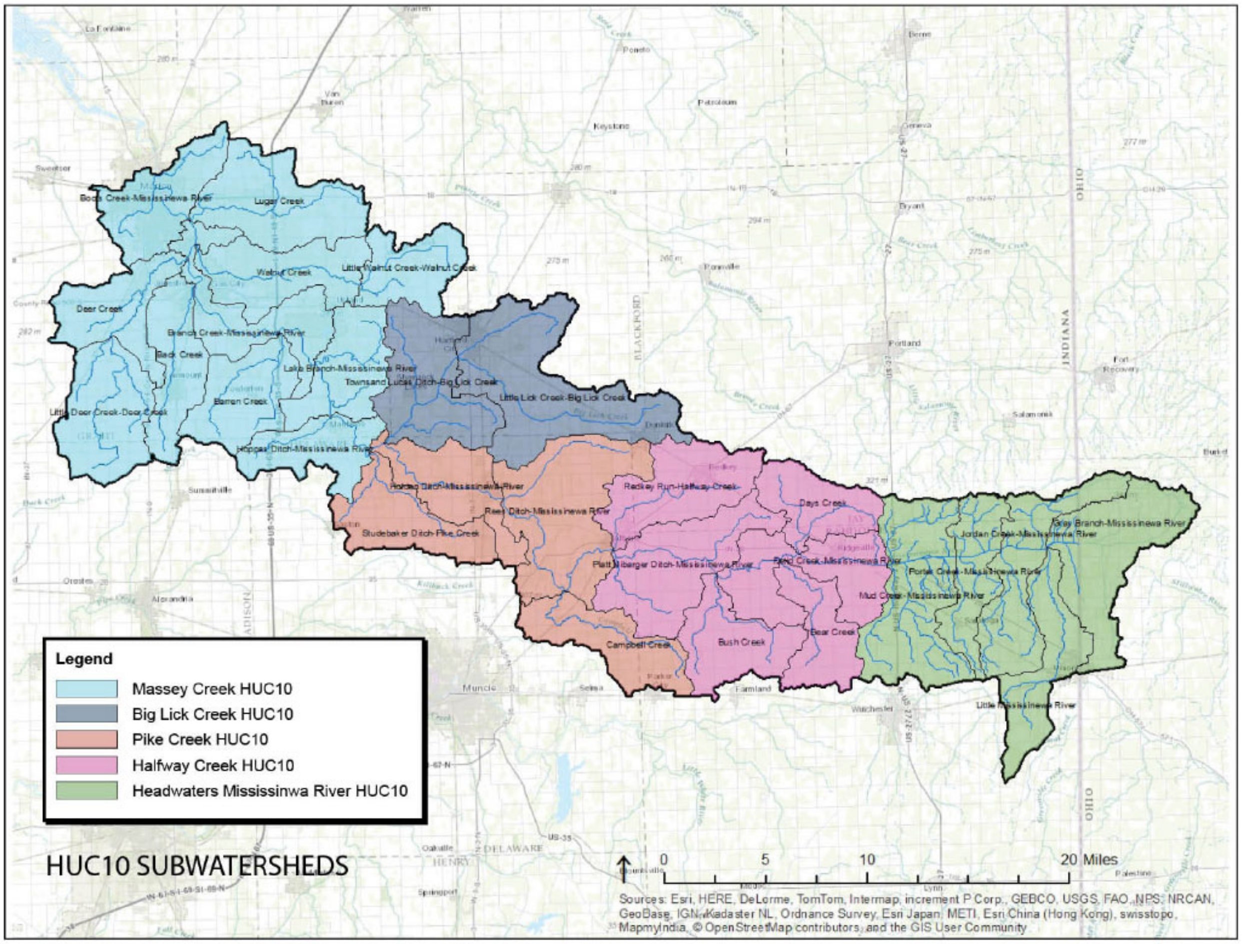


Figure 15. Mississinewa River Watershed Impaired Streams – Sources of Nutrients.

A WMP for the Upper Mississinewa River (plan boundary shown in Figure 16) was completed in January 2018 by Flatland Resources, LLC, on behalf of the Delaware County Soil and Water Conservation District (SWCD). The Upper Mississinewa River WMP is intended to provide guidance for the improvement of water quality within the upper portions of the watershed. Critical sub watersheds were identified using a combination of water quality data, watershed inventory and analysis results, and stakeholder concerns. The Upper Mississinewa River WMP defines implementation strategies to address and reduce identified non-point source pollutant loadings in each sub watershed. Excess nutrients, *E. coli* and suspended solids were identified as critical contaminants of concern and a variety of best management practices were recommended to reduce impacts, including modifications to farming practices, restoration of streambank and wetland areas, vegetation and stormwater management measures, and ditch modifications (Flatland Resources LLC, 2018).



Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 16. Upper Mississinewa River Watershed Management Plan Boundary.

3.3.1.1 Phytoplankton

Phytoplankton sampling data was collected by USACE for the 2021 annual water quality report for the Upper Wabash (USACE, 2021). Phytoplankton sampling occurred at three locations within Mississinewa Lake. Across the three locations the total phytoplankton ranged from approximately 8.26 x 10^7 individuals per Liter (ind/L) to 4.50 x 10^8 ind/L, with a lake-wide average total phytoplankton of 2.34 x 10^8 ind/L. Phytoplankton abundance can indicate nutrient levels within the lake (Zheng et al., 2007; Gao et al., 2018) (Table 2). Given the high algal abundance, Mississinewa Lake is likely eutrophic.

Table 2. Nutritional level division based on abundance presented as individuals/liter (ind/L) (Zheng et al. 2007).

	Oligotrophication	Mesotrophication	Eutrophication
Phytoplankton	< 3 x 10^5	3 – 10 x 10^5	> 10 x 10^5
Zooplankton	< 1,000	1,000 – 3,000	> 3,000

The total number of phytoplankton taxa identified lake-wide was 44, with the following percent composition of groups: Cyanophycota (92.8 percent), Cryptophycophyta (3.0 percent), Chlorophyta (2.9 percent), Bacillariophyta (1.2 percent), Euglenophycota (0.02 percent), and Pyrrhophycophyta (0.01 percent). The complete phytoplankton species list can be found in Appendix D and the percent composition of groups across the three locations within Mississinewa Lake can be found in Table 3. Cyanophycota dominates the composition of phytoplankton with 92.8 percent lake-wide, which indicates a cyanobacteria or blue-green algae bloom occurring in the lake during the sample period. Cyanobacteria blooms are caused by excess nutrients and warm water temperatures; these blooms may cause fish kills, foul-smelling water, which can affect human and ecosystem health (NOAA, 2023). The Indiana Department of Health provides a map of locations with harmful algal blooms and identified that Mississinewa Lake is at the Advisory level as of August 2022 (Indiana Department of Health, 2023). The Advisory level states the following impact: "Swimming and boating are permitted. Avoid contact with algae. Avoid swallowing water. Take a bath or shower with warm, soapy water after coming into contact with lake water. Do not use for cooking or bathing. Do not allow pets to swim or drink where present."

Phytoplankton diversity was calculated using the Shannon-Wiener Diversity Index, which is a way to measure the species diversity in a community with scores ranging from 0 to 5. Diversity ranged from 1.51 to 2.14 across the three locations, with a lake-wide diversity score of 2.14. Mississinewa had the second highest diversity score compared to Salamonie and Roush Lakes. High algae diversity is indicative of healthier lakes that are able to remove pollutants at a faster rate than low algae diverse lakes.

Pielou's evenness index describes the commonness or rarity of species with scores ranging from 0 to 1, respectively. Evenness ranged from 0.50 to 0.69 across the three locations, with a lake-wide evenness score of 0.57 (Table 4). Phytoplankton diversity was relatively low and evenness was relatively moderate in Mississinewa Lake.

Organic pollution in Mississinewa Lake was assessed by utilizing Palmer's Algal Pollution Index, which utilizes algal genera most tolerant to organic pollution. The pollution index scoring is as follows: less than 15 (very light organic pollution), 15 to 19 (probable organic pollution), and greater than 20 (high organic pollution) (Palmer, 1969). Organic pollutants in lakes typically originate from domestic sewage (raw or treated), urban run-off, and farm wastes. The pollution index scores across the three locations within Mississinewa Lake ranged from 18 to 19, indicating probable organic pollution. Lake-wide, the scoring was 19, indicating probable organic pollution (Table 4).

Table 3. Mississinewa Lake Abundance and Community Composition (values do not equal 100 due to rounding).

Mississinewa Lake Locations	Average Total Phytoplankton (ind/L)	Percent Composition of Groups					
		Bacillario-Phyta	Chloro-phyta	Crypto-phycophyta	Cyano-phycota	Eugleno-phycota	Pyrrho-phycophyta
MSR20001	2.28 x 10^8	1.5	1.7	3.2	93.5	NA	0.01
MSR21002	1.97 x 10^8	1.5	3.4	3.1	91.9	NA	0.03
MSR20003	2.92 x 10^8	0.6	3.6	2.6	93.1	0.06	NA
Lake-wide	2.34 x 10^8	1.2	2.9	3.0	92.8	0.02	0.01

Table 4. Mississinewa Lake Diversity, Evenness, and Palmer's Pollution Index scores.

Mississinewa Lake Locations	Shannon Wiener Diversity Index	Pielou's Evenness Index	Palmer's Pollution Index
MSR20001	1.51	0.50	18
MSR21002	1.93	0.60	18
MSR20003	2.14	0.69	19
Lake-wide	2.14	0.57	19

3.3.1.2 Zooplankton

Zooplankton sampling data was collected by USACE for the 2021 annual water quality report for the Upper Wabash (USACE, 2021). Zooplankton sampling occurred at three locations within Mississinewa Lake. The total number of zooplankton species identified across all three sites within Mississinewa Lake was 20, composed of copepods (7), rotifers (6), cladocerans (6), and ostracods (1). The complete zooplankton species list can be found in Appendix D. Zooplankton abundance includes a total of 644 individual organisms that were tallied with a lake-wide average density of 36.9 ind/L. Lake-wide, copepods comprised 43 percent of the total average density, followed by rotifers (38 percent) and cladocerans (19 percent) (Table 5) (USACE, 2021). Typically, high rotifer densities are associated with eutrophic lakes (Aboul Ezz et al., 1996; Brito et al., 2011). Additionally, rotifers such as *Asplanchna* spp. are known indicators of eutrophic conditions (Yu et al., 2019). Rotifers comprised 38 percent of the total average density, and *Asplanchna* spp. comprised approximately 31 percent of the total abundance. The densities and abundances of taxa indicate that Mississinewa Lake is likely eutrophic, which would be characteristic of high nutrients with high algae and/or macrophyte growth and corroborates the phytoplankton indicators for eutrophic conditions. Chlorophyll *a* values can also be used to verify trophic conditions indicated by phytoplankton and zooplankton (Table 6). Chlorophyll a values ranged from 9.6 to 83 milligram per cubic meter (mg/m3) throughout Mississinewa Lake, which falls into eutrophic and hypertrophic conditions (Table 6).

Zooplankton diversity was calculated using Shannon-Wiener Diversity Index which ranged from 1.14 to 1.71 across the three locations (Table 5). Lake-wide zooplankton Shannon-Wiener Diversity Index was 2.12. Pielou's Evenness Index for the entire lake was calculated with a value of 0.71. Zooplankton Shannon-Wiener Diversity Index is relatively low and evenness are relatively moderate in Mississinewa Lake.

Table 5. Mississinewa Lake Zooplankton Abundance, Community Composition, and Diversity (values do not equal 100 due to rounding).

Mississinewa Lake Locations	Average Total Zooplankton (ind/L)	Percent Composition of Groups				Shannon Wiener Diversity Index (0 to 5)	Pielou's Evenness Index (0 to 1)
		Copopoda	Cladocera	Rotifera	Ostracoda		
MSR20001	40.0	16.0	7.0	77.0	NA	1.14	0.44
MSR21002	26.7	77.0	13.0	9.0	< 0.5	1.70	0.63
MSR20003	44.0	47.0	33.0	20.0	1.0	1.71	0.63
Lake-wide	36.9	43.0	19.0	38.0	< 0.5	2.12	0.71

Table 6. Chlorophyll a conditions for each trophic class.

Trophic Class	Chlorophyll *a* (mg/m^3)
Oligotrophic	0 to 2.6
Mesotrophic	2.6 to 7.3
Eutrophic	7.6 to 56
Hypertrophic	56 to 155+

3.3.2 Salamonie River Watershed HUC: 05120102

Salamonie Lake (2,855 acres) fully supports designated water quality uses outlined in Indiana Administrative Code 14-25-7-2. Approximately 140 miles of streams in the Salamonie River watershed are listed on the 2022 Section 303(d) List of Impaired Waters; approximately 750 miles of stream have not been assessed and 20 miles are listed as fully supporting the designated uses. Impairments for stream assessment units were for one or more of the following parameters: impaired biotic integrity, chloride, *E. coli*, nutrients, and PCB in fish tissue. The distribution of stream impairment is shown in Figure 17. Sources of impaired biological integrity, *E. coli*, and nutrients are indicated in Figure 18, Figure 19, and Figure 20, respectively. Sources of chloride are industrial point source and/or other permitted small flow discharges. Sources of PCBs are unknown (Hostetter, 2022).

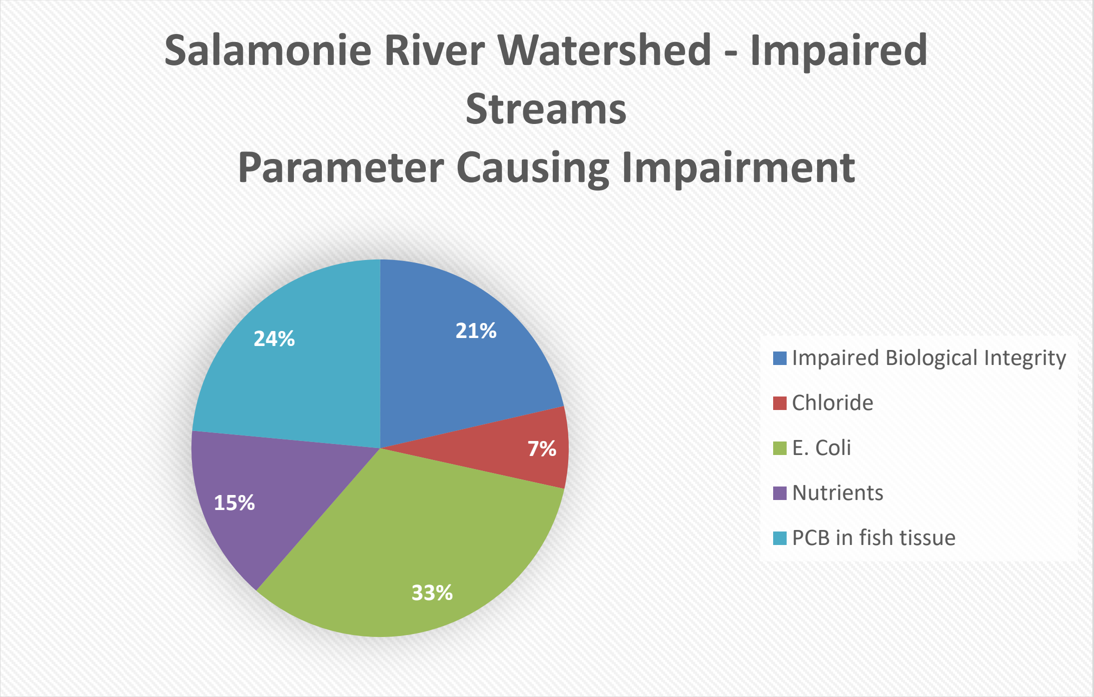


Figure 17. Salamonie River Watershed Stream Impairment Parameters.

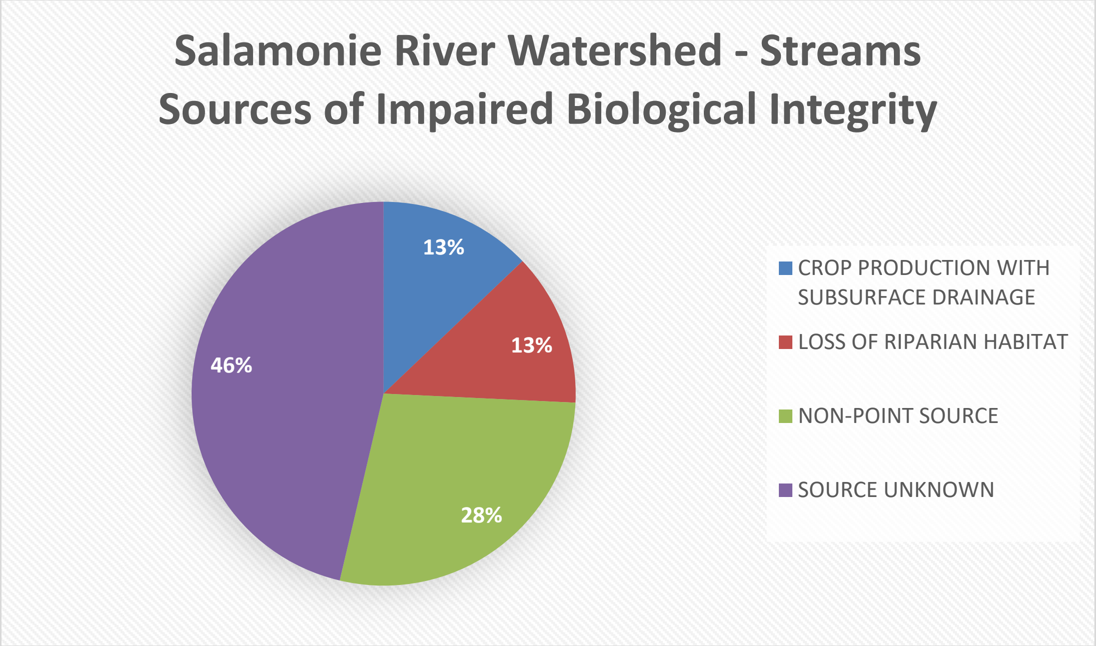


Figure 18. Salamonie River Watershed Impaired Streams – Sources of Impaired Biological Integrity.

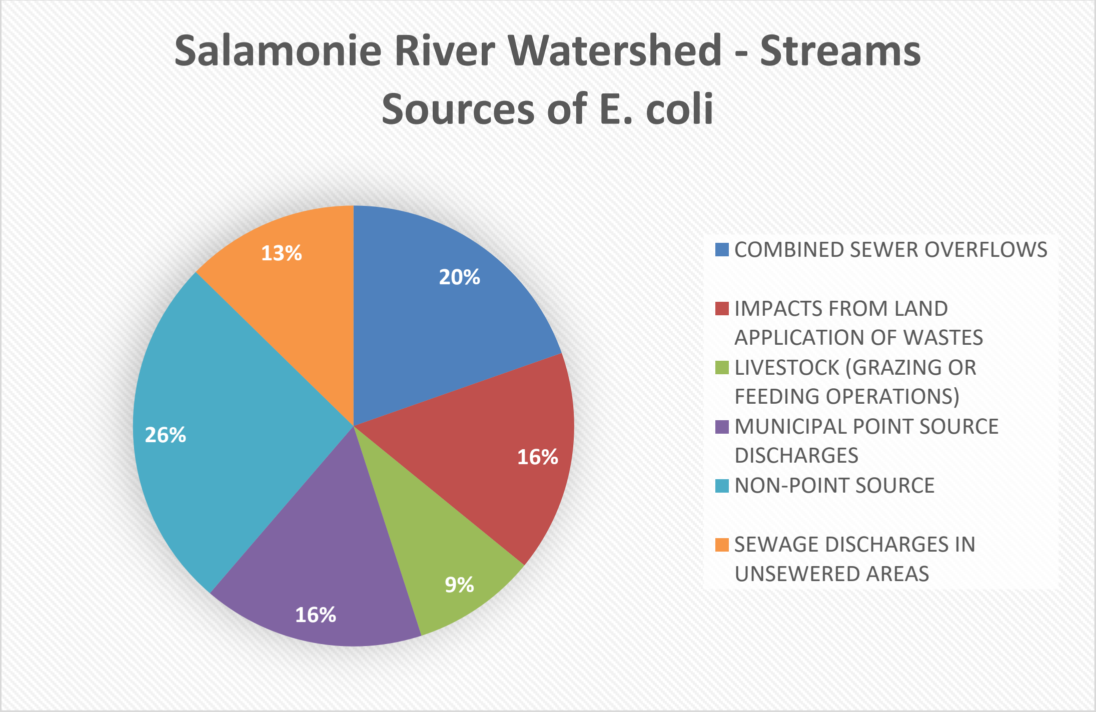


Figure 19. Salamonie River Watershed Impaired Streams – Sources of E. coli.

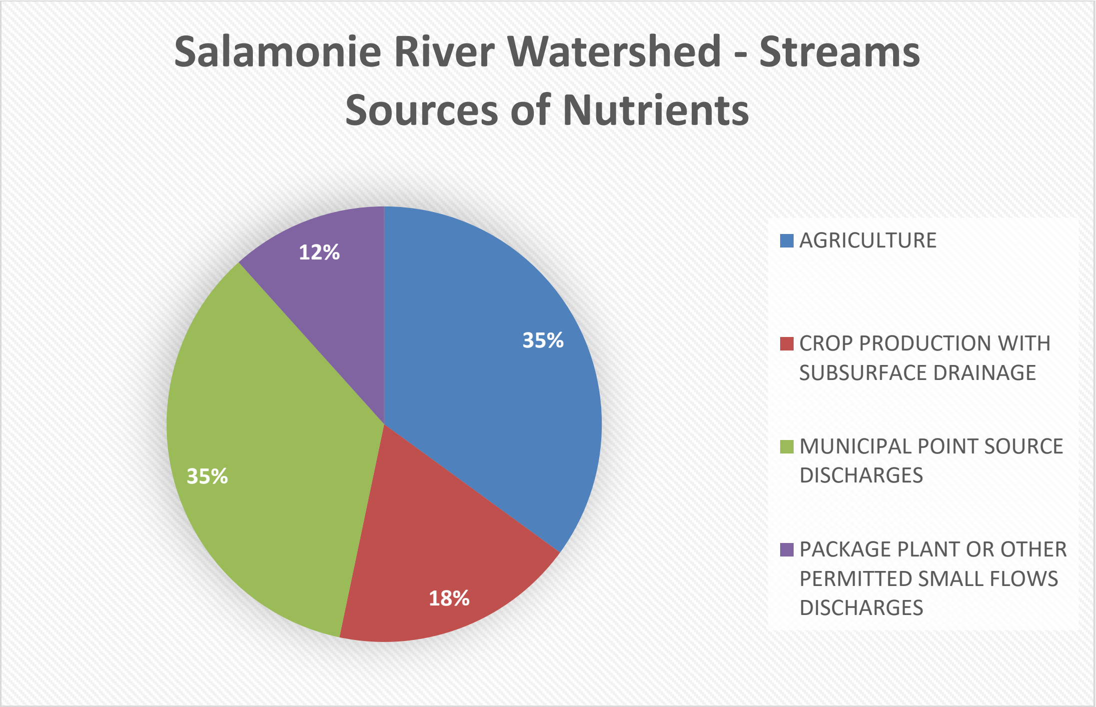


Figure 20. Salamonie River Watershed Impaired Streams – Sources of Nutrients.

A WMP for the Upper Salamonie River, upstream of the Salamonie Lake, was completed in January 2015 for the Jay County Commissioners and Jay County SWCD. Of the 358,375-acre Salamonie River watershed, nearly half is considered the Upper Salamonie River watershed (shown on Figure 21). The upper watershed is located in east central Indiana; 456 miles of rivers, streams and ditches drain 161,949 acres of mixed land use consisting mainly of row crop agriculture and pasture. The watershed drains major sections of Jay and Blackford counties, and a small portion of Wells County. According to the WMP, sampling data collected by USACE and IDEM in 2009 found elevated levels of nutrients causing harmful algal blooms in the Salamonie Lake, as well as other pollutants in the watershed. In 2012, toxic algal blooms attracted media attention when two dogs were reported to have died after swimming in the Salamonie Lake. In addition, several reaches of the river were on the IDEM 303(d) List of Impaired Waterbodies for *E. coli*, chlorides, and impaired biotic communities. The Upper Salamonie River WMP defines implementation strategies to address and reduce identified non-point source pollutant loadings in each sub watershed. Excess nutrients suspended solids, bacterial and pathogen loading, and impaired habitat were identified as critical concerns and a variety of best management practices were recommended to reduce impacts, including modifications to farming practices, restoration of streambank areas, vegetation and stormwater management measures, and septic system maintenance (Kroeker, 2015).

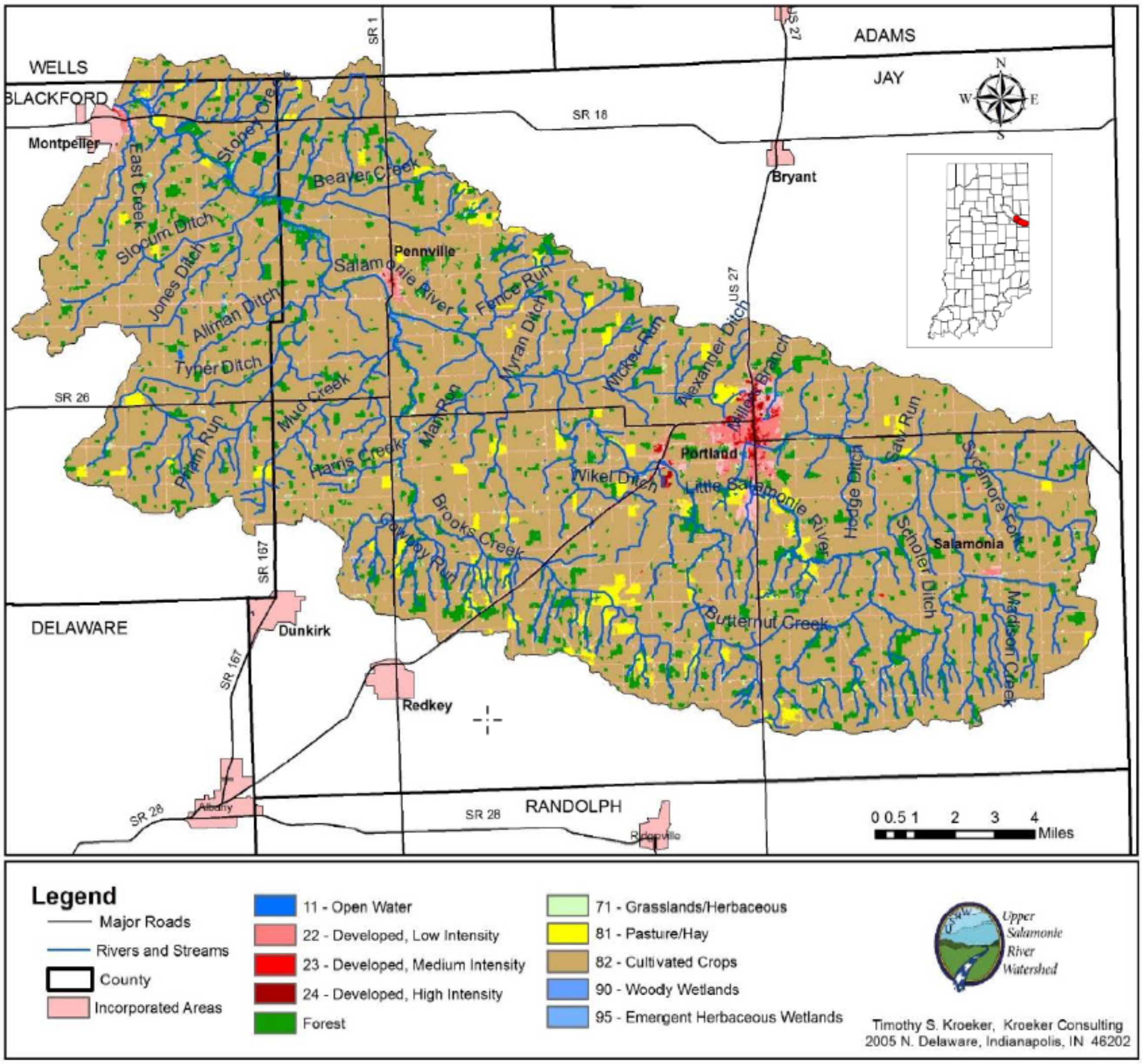


Figure 21. Upper Salamonie River Watershed Management Plan Boundary.

3.3.2.1 Phytoplankton

Phytoplankton sampling data was collected by USACE for the 2021 annual water quality report for the Upper Wabash (USACE, 2021). Phytoplankton sampling occurred at four locations within Salamonie Lake. Across the four locations the total phytoplankton ranged from approximately 1.24 x 10^8 algae cells/L to 1.74 x 10^9 ind/L, with a lake-wide average total phytoplankton of 7.69 x 10^8 ind/L. Phytoplankton abundance can indicate nutrient levels within the lake (Zheng et al., 2007; Gao et al., 2018) (Table 2). Given the high algal abundance, Salamonie Lake is likely eutrophic.

The total number of phytoplankton taxa identified lake-wide was 95, with the following percent composition of groups: Cyanophycota (97.4 percent), Chlorophyta (0.8 percent), Bacillariophyta (0.7 percent), Haptophyta (0.6 perecent), Cryptophycophyta (0.5 percent), Pyrrhophycophyta (0.04 percent), Chrysophyta (0.02 percent), and Euglenophycota (0.02 percent) (Table 7). The complete phytoplankton species list can be found in Appendix D and the percent composition of groups across the four locations within Salamonie Lake can be found in Table 7. Cyanophycota dominates the composition of phytoplankton with 97.4 percent lake-wide, which indicates a cyanobacteria or blue-green algae bloom occurring in the lake during the sample period. The Indiana Department of Health provides map locations with harmful algal blooms and identified that Salamonie Lake is at the Advisory level as of August 2022 (Indiana Department of Health, 2023).

Phytoplankton diversity was calculated using Shannon-Wiener Index (defined above), and diversity ranged from 1.92 to 2.12 across the four locations, with a lake-wide diversity score of 2.79. Salamonie had the highest diversity score compared to Mississinewa and Roush Lakes. High algae diversity is indicative of healthier lakes that can remove pollutants at a faster rate than low algae diverse lakes. Pielou's evenness index ranged from 0.59 to 0.68 across the four locations, with a lake-wide evenness score of 0.61 (
Table *8*). Phytoplankton diversity and evenness was relatively moderate in Salamonie Lake.

Organic pollution in Salamonie Lake was assessed by utilizing Palmer's Algal Pollution Index. The pollution index scores across the four locations within Salamonie Lake ranged from 19 to 27, indicating probable organic pollution to high organic pollution. Lake-wide, the scoring was 31, indicating high organic pollution (
Table *8*).

Table 7. Salamonie Lake Abundance and Community Composition (values do not equal 100 due to rounding).

Salamonie Lake Locations	Average Total Phytoplankton (ind/L)	Percent Composition of Groups							
		Bacillario-phyta	Chloro-phyta	Chryso-phyta	Cryptophyco-phyta	Cyano-phycota	Eugleno-phycota	Hapto-phyta	Pyrrhoph-ycophyta
SRR20001	6.59 x 10^8	0.7	0.6	NA	0.1	97.9	0.020	0.60	0.03
SRR20029	7.36 x 10^8	0.9	0.6	NA	0.7	97.3	NA	0.50	0.05
SRR20002	9.15 x 10^8	0.7	1.0	0.004	0.3	97.4	0.020	0.50	0.05
SRR2025	7.92 x 10^8	0.6	1.1	0.035	0.8	96.8	0.037	0.60	0.03
Lakewide	7.69 x 10^8	0.7	0.8	0.020	0.5	97.4	0.020	0.60	0.04

Table 8. Salamonie Lake Diversity, Evenness, and Palmer's Pollution Index scores

Salamonie Lake Locations	Shannon Wiener Diversity Index (H')	Pielou's Evenness Index (J)	Palmer's Pollution Index
SRR20001	1.92	0.59	27
SRR20029	2.12	0.68	20
SRR20002	1.96	0.60	26
SRR2025	2.10	0.65	19
Lake-wide	2.79	0.61	31

3.3.2.2 Zooplankton

Zooplankton sampling data was collected by USACE for the 2021 annual water quality report for the Upper Wabash (USACE, 2021). Zooplankton sampling occurred at four locations within Salamonie Lake. The total number of zooplankton species identified across all four sites within Salamonie Lake was 19, composed of copepods (10), followed by cladocerans (6), and rotifers (3). The complete zooplankton species list can be found in Appendix D. Zooplankton abundance includes the total of 884 individual organisms that were tallied with a lake-wide average density of 625.4 ind/L. Copepods comprised of 75 percent of the total average density, followed by cladocerans (25 percent) and rotifers (0.45 percent), respectively (Table 9). Typically, cladocerans and high rotifer densities are associated with eutrophic lakes (Aboul Ezz et al., 1996; Brito et al., 2011). However, rotifers only comprised 0.45 percent of the total average density, which is a poor indicator to use. The small bodied cladoceran, *Diaphanosoma brachyurum*, prefers high-trophy waters (Ochocka, 2016), and comprised approximately 28 percent of the total abundance, indicating eutrophic conditions at Salamonie Lake. Calanoid and cyclopoid copepods were the next abundant taxa with approximately 26 percent and 15.5 percent, respectively. Calanoid copepods are known to dominate oligotrophic and mesotrophic lakes (Burkholder and Glibert, 2013), whereas cyclopoid copecopods occur at higher abundances in meso-eutrophic environments (Suliman et al., 2017). The densities and abundances of these taxa indicate that Salamonie Lake likely has mesotrophic and eutrophic conditions within the lake based on location. Eutrophic conditions, which would be characteristic of high nutrients with high algae and/or macrophyte growth, corroborates the phytoplankton indicators for eutrophic conditions. Chlorophyll *a* values can also be used to verify trophic conditions indicated by phytoplankton and zooplankton (Table 9). Chlorophyll a values ranged from 2.8 to 12 mg/m3 throughout Salamonie Lake, which falls into mesotrophic and eutrophic conditions.

Zooplankton diversity was calculated using Shannon-Wiener index which ranged from 1.01 to 2.12 across the four locations (Table 9). Lake-wide zooplankton diversity was 2.04. Pielou's evenness index for the lake was calculated with a value of 0.71. Zooplankton diversity and evenness in Salamonie Lake are relatively low to moderate.

Table 9. Salamonie Lake Zooplankton Abundance, Community Composition, and Diversity (values do not equal 100 due to rounding).

Salamonie Lake Locations	Average Total Zooplankton (ind/L)	Percent Composition of Groups			Shannon Wiener Diversity Index	Pielou's Evenness Index
		Copopoda	Cladocera	Rotifera		
SRR20001	354.90	70.0	27.0	3.20	2.12	0.73
SRR20029	549.08	56.0	44.0	0.00	1.76	0.66
SRR20002	731.33	63.0	37.0	0.00	1.96	0.74
SRR2025	866.14	99.0	1.0	0.00	1.01	0.41
Lake-wide	625.37	75.0	25.0	0.45	2.04	0.71

3.3.3 Upper Wabash Watershed HUC: 05120101

The 1,020-acres of freshwater lakes in the Upper Wabash watershed are listed as overall not supporting designated uses; J.E. Roush Lake and Center Lake do not support human health and wildlife and/or warm water aquatic wildlife use due to the presence of iron and/or phosphorous in the waterbody and/or PCB present in fish tissue. One forty-five-acre freshwater lake in the Upper Wabash River watershed (Kunkel Lake) fully supports designated uses outlined in Indiana Administrative Code 14-25-7-2. Seventeen lakes have not been assessed. Approximately 730 miles of streams in the Upper Wabash River watershed are listed on the 2022 Section 303(d) List of Impaired Waters; approximately 1,170 miles of stream have not been assessed and 110 miles are listed as fully supporting the designated uses. Impairments for stream assessment units were for one or more of the following parameters: impaired biotic integrity, dissolved oxygen, *E. coli*, chloride, and PCB in fish tissue. The distribution of stream impairment is shown in Figure 22. Sources of impaired biological integrity, *E. coli*, and nutrients are summarized in Figure 23,Figure 24, andFigure 25, respectively. Sources of dissolved oxygen are due to impacts from land application of wastes, natural sources, and non-point sources. Sources of PCBs are unknown (Hostetter, 2022).

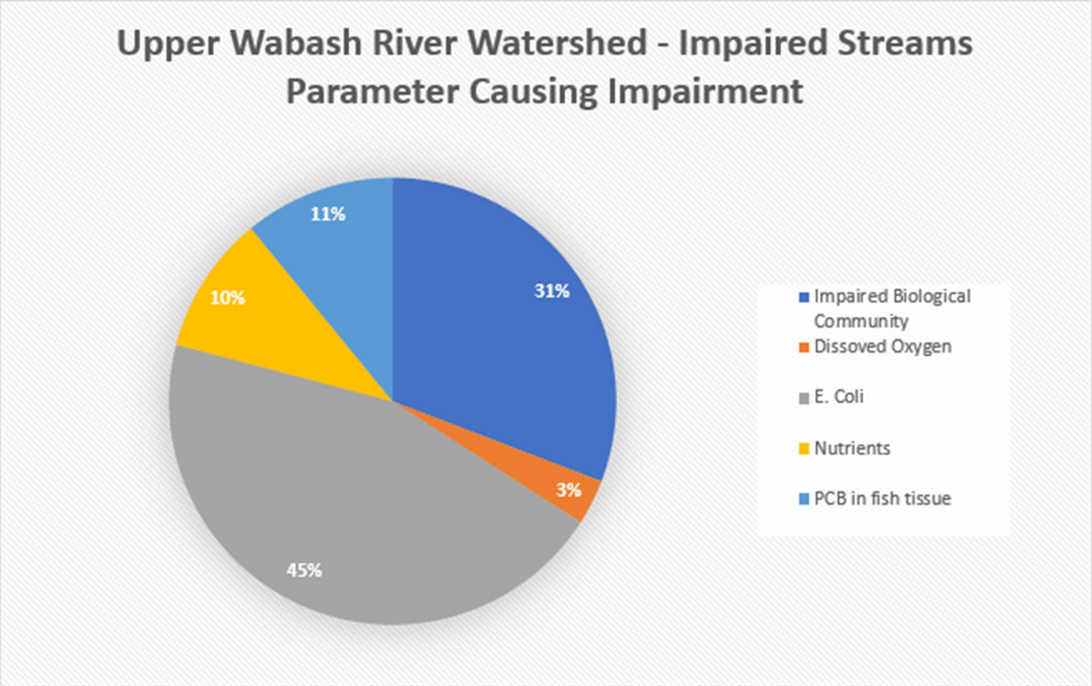


Figure 22. Upper Wabash River Watershed Stream Impairment Parameters.

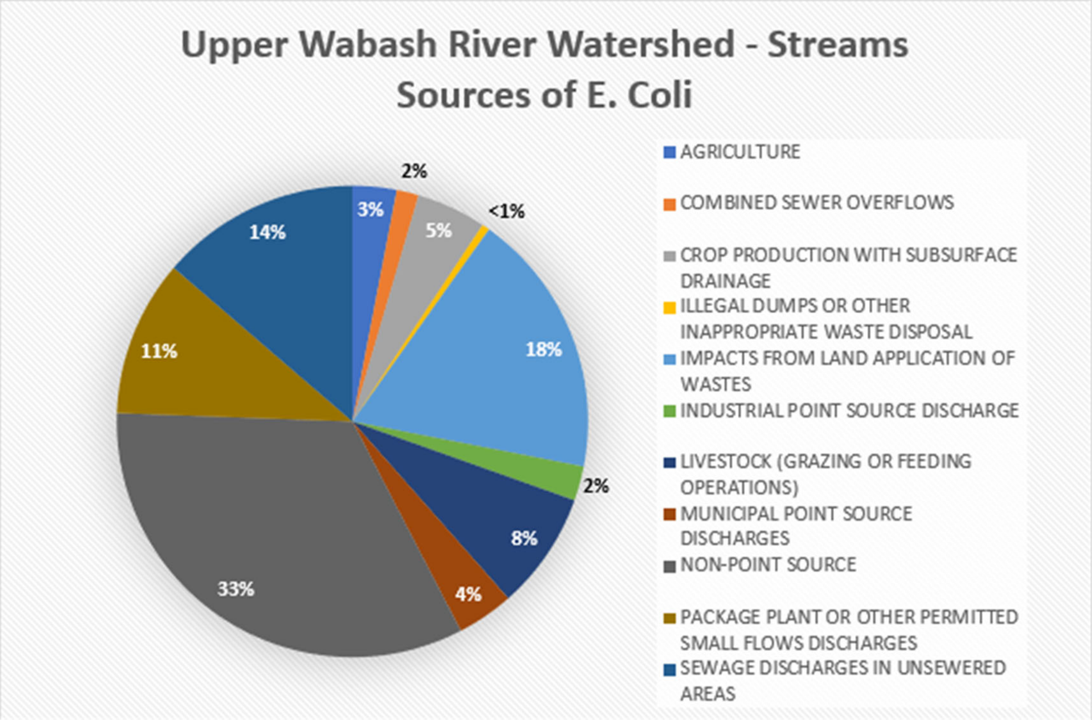


Figure 23. Upper Wabash River Watershed Impaired Streams – Sources of E. coli.

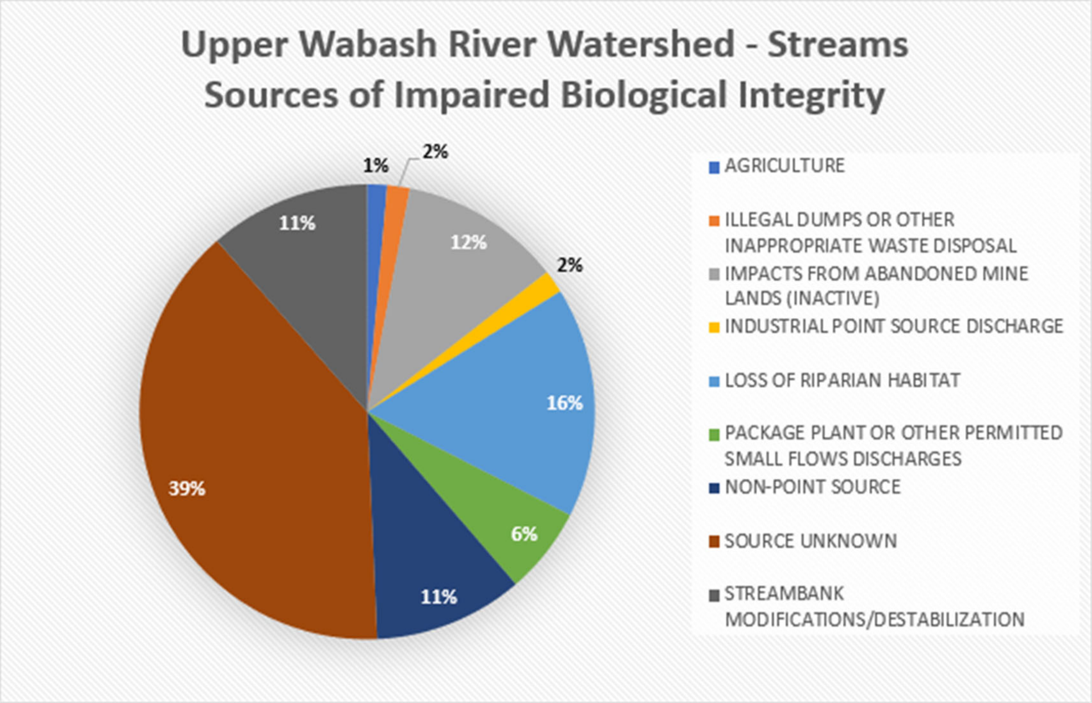


Figure 24. Upper Wabash River Watershed Impaired Streams – Sources of Impaired Biological.

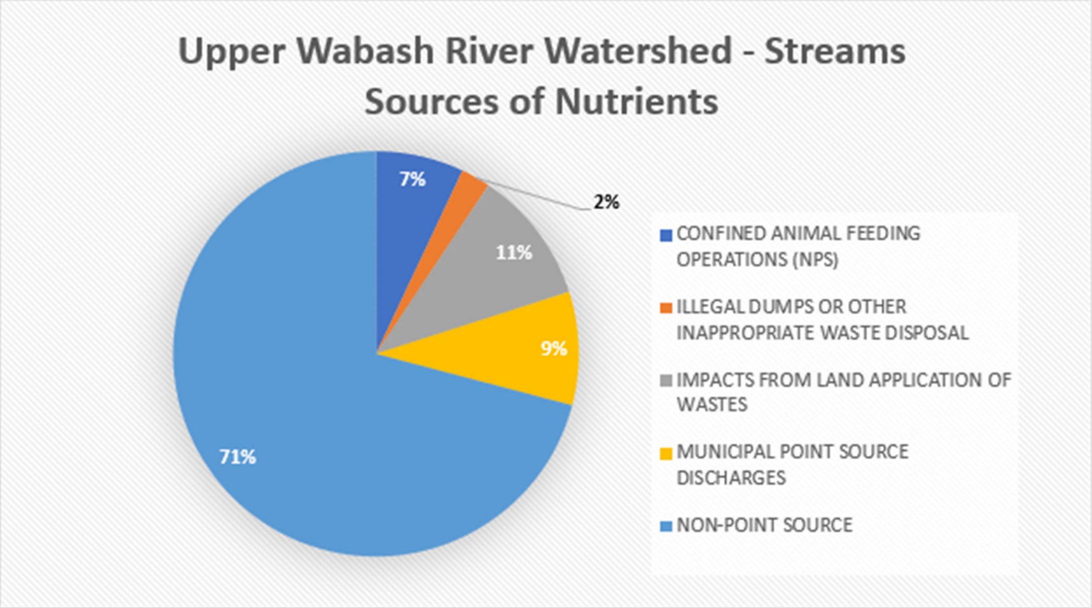


Figure 25. Upper Wabash River Watershed Impaired Streams – Sources of Nutrients.

A phased approach was used to develop the WMP for the Upper Wabash River watershed to address excess sediments, nutrients, pathogens, and *E. coli* in the watershed. Boundaries of the phased WMPs, completed between 2007 and 2021, are shown on Figure 26. The Upper Wabash River WMPs define implementation strategies to address and reduce identified non-point source pollutant loadings in each sub watershed and includes goals and recommendations for public education, flood management, agricultural management, land use/development and habitat restoration, and *E. coli* reduction.

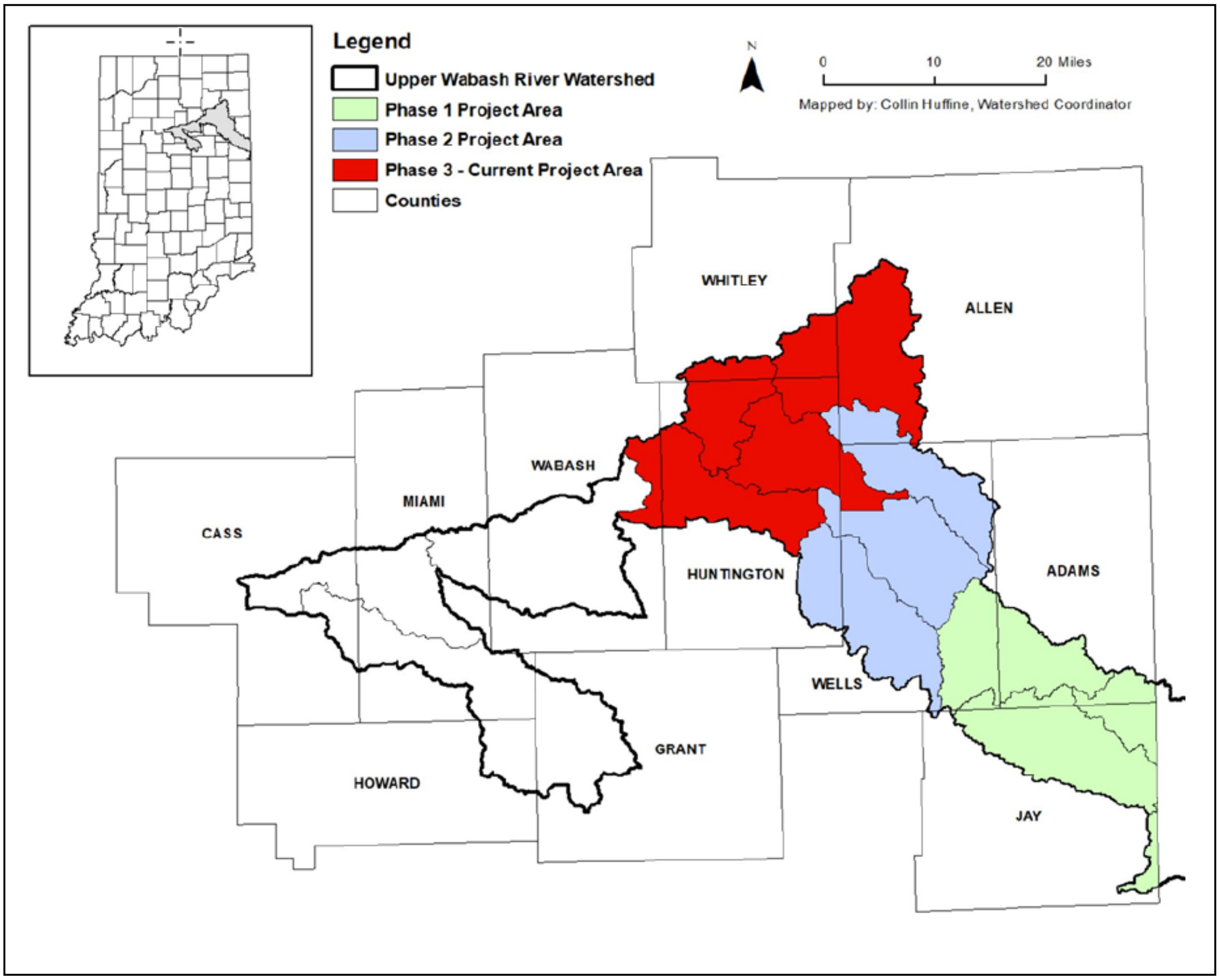


Figure 26. Upper Wabash River Phased Watershed Management Plan Boundary.

3.3.3.1 Phytoplankton

Phytoplankton sampling data was collected by USACE for the 2021 annual water quality report for the Upper Wabash (USACE, 2021). Phytoplankton sampling occurred at three locations within J.E. Roush Lake. Across the three locations the total phytoplankton ranged from approximately 1.11 x 10^8 algae cells/L to 3.95 x 10^8 ind/L, with a lake-wide average total phytoplankton of 2.41 x 10^8 ind/L. Phytoplankton abundance can indicate nutrient levels within the lake (Zheng et al., 2007; Gao et al., 2018) (Table 2). Given the high algal abundance, J.E. Roush Lake is likely eutrophic.

The total number of phytoplankton taxa identified lake-wide was 46, with the following percent composition of groups: Cyanophycota (93.2 percent), Cryptophycophyta (3.7 percent), Chlorophyta (1.8 percent), Bacillariophyta (1.3 percent), Euglenophycota (0.05 percent), and Pyrrhophycophyta (0.01

percent). The complete phytoplankton species list can be found in Appendix D, and the percent composition of groups across the three locations within Roush Lake can be found in Table 10. Cyanophycota dominates the composition of phytoplankton with 93.2 percent lake-wide, which indicates a cyanobacteria or blue-green algae bloom occurring in the lake during the sample period. Cyanobacteria blooms are caused by excess nutrients and warm water temperatures; these blooms may cause fish kills, foul-smelling water, which can affect human and ecosystem health (NOAA, 2023).

Phytoplankton diversity ranged from 1.35 to 1.86 across the three locations, with a lake-wide diversity score of 1.88. High algae diversity is indicative of healthier lakes that can remove pollutants at a faster rate than low algae diverse lakes. Roush Lake had the lowest diversity score compared to Salamonie and Mississinewa Lakes. Pielou's evenness index ranged from 0.45 to 0.60 across the three locations, with a lake-wide evenness score of 0.49 (
Table *11*). Phytoplankton diversity and evenness was relatively low in Roush Lake.

Organic pollution in Roush Lake was assessed by utilizing Palmer's Algal Pollution Index, and the pollution index scores across the three locations within Roush Lake ranged from 17 to 23, indicating probable organic pollution to high organic pollution. Lake-wide, the scoring was 27, indicating high organic pollution (
Table *11*).

Table 10. Roush Lake Abundance and Community Composition (values do not equal 100 due to rounding).

Roush Lake Locations	Average Total Phytoplankton ind/L	Percent Composition of Groups					
		Bacillario-phyta	Chloro-phyta	Crypto-phycophyta	Cyano-phycota	Eugleno-phycota	Pyrrho-phycophyta
HTR20001	1.85×10^8	1.8	1.5	2.6	94.0	0.10	0.01
HTR20417	2.58×10^8	1.3	2.4	5.7	90.6	0.02	0.01
HTR20002	3.23×10^8	0.7	1.5	2.9	95.0	0.02	0.02
Lake-wide	2.41×10^8	1.3	1.8	3.7	93.2	0.05	0.01

Table 11. Roush Lake Diversity, Evenness, and Palmer's Pollution Index scores.

Roush Lake Locations	Shannon Wiener Diversity Index	Pielou's Evenness Index	Palmer's Pollution Index
HTR20001	1.86	0.60	23
HTR20417	1.45	0.46	17
HTR20002	1.35	0.45	23
Lake-wide	1.88	0.49	27

3.3.3.2 Zooplankton

Zooplankton sampling data was collected by USACE for the 2021 annual water quality report for the Upper Wabash (USACE, 2021). Zooplankton sampling occurred at three locations within Roush Lake. The total number of zooplankton species identified across all three sites within Roush Lake was 23, composed of rotifers (11), followed by copepods (8), cladocerans (3), and ostracods (1). The complete zooplankton species list can be found in Appendix D. Zooplankton abundance includes the total of 622 individual organisms that were tallied with a lake-wide average density of 251.3 ind/L. Rotifers comprised of 48 percent of the total average density, followed by cladocerans (34 percent) and copepods (17 percent), respectively (Table 12). Typically, cladocerans and high rotifer densities are associated with eutrophic lakes (Aboul Ezz et al. 1996, Brito et al. 2011). Additionally, rotifers such as *Asplanchna* spp., and *Brachionus* spps. are known indicators of eutrophic conditions (Yu et al. 2019). Rotifers comprised 48 percent of the total average density, and *Asplanchna* spp., *Brachionis* spps., comprised approximately 24 percent and 11 percent of the total abundance, respectively. The densities and abundances of these taxa indicate that Roush Lake is likely eutrophic which would be characteristic of high nutrients with high algae and/or macrophyte growth and corroborates the phytoplankton indicators for eutrophic conditions. Chlorophyll *a* values can also be used to verify trophic conditions indicated by phytoplankton and zooplankton (**Error! Reference source not found.**). Chlorophyll *a* values ranged from 14 to 45 mg/m^3 throughout Roush Lake, which falls into eutrophic conditions.

Zooplankton diversity was calculated using Shannon-Wiener index, which ranged from 0.95 to 1.83 across the three locations (Table 12). Lake-wide zooplankton diversity was 1.84. Pielou's evenness index for the lake was calculated with a value of 0.58. Zooplankton diversity and evenness in Roush Lake are relatively low.

Table 12. Roush Lake Zooplankton Abundance, Community Composition, and Diversity (values do not equal 100 due to rounding errors).

Roush Lake Locations	Average Total Zooplankton (ind/L)	Percent Composition of Groups				Shannon Wiener Diversity Index	Pielou's Evenness Index
		Copopoda	Cladocera	Rotifera	Ostracoda		
HTR20001	305.2	36.00	9.0	54.0	< 0.5	1.83	0.74
HTR20417	69.0	0.49	87.3	12.2	NA	0.95	0.41
HTR20002	379.9	5.00	44.0	51.0	NA	1.67	0.63
Lake-wide	251.4	17.00	34.0	48.0	< 0.2	1.84	0.58

3.3.4 General Water Quality - Upper Wabash Projects

Water quality data has been collected at the Upper Wabash projects since 1971. A fixed-site sampling program has been implemented at each of the reservoirs to assist in monitoring each reservoirs' long-term water quality. These sites have been carefully chosen to be the most representative of the lake's watershed and to provide the best overall assessment. In general, regular monitoring of the Upper Wabash projects consists of the following water quality surveys:

- Project profiles are implemented to monitor the status and progression of thermal and chemical stratification in a reservoir. Project personnel collect temperature and dissolved oxygen readings at the dam and in the tailwater during reservoir stratification. Data collected from these readings are used to manage the quality of the release from the reservoir.
- Ambient surveys are used to capture the status of water quality in the reservoir and tailwater during thermal stratification. This effort is conducted through an annual sampling event. District staff sample the reservoir body, primary inflows, and tailwater. They collect field data and grab samples for various chemical and biological analyses. The data are used to evaluate reservoir operations and environmental concerns, both long- and short-term in nature.
- Intensive surveys are designed to assess water quality parameters more thoroughly within a watershed. These surveys are generally conducted on a ten-year rotation (one reservoir every three years) at each reservoir. Sample stations are sampled three times during the spring, summer, and fall, and more sample stations and parameters are assessed than during the ambient surveys. This provides a seasonal and more in-depth picture of the water quality status of a reservoir.
- Emergency and situational response surveys are conducted on an as-needed basis, typically in

response to an unusual environmental event (for example fish kills, plankton blooms, or chemical spills). Data collected during these surveys is used in future assessments, and a special report or public advisory may be issued based upon data results.

- Harmful Algal Bloom (HAB) surveys are conducted in response to a suspected HAB which could produce toxins that can be harmful to humans, wildlife, and pets/livestock. This survey type may include algae collection, toxin testing, water quality sampling, and visual inspections of the impacted areas. Coordination with state and federal agencies is crucial with HAB monitoring.
- Special studies are planned, non-routine efforts to answer questions about a reservoir and/or its watershed. Types of special studies that may be conducted include, but are not limited to, modeling, greenhouse gas, sediment, bathymetry, data collection efficiency analysis, and complex HAB analyses. These studies are conducted on an as-needed basis.

The water quality of releases in the tailwater of the USACE projects is the direct result of the water quality in the reservoir pool and the level of withdrawal. Water quality samples collected from inflow stations in the Upper Wabash reservoirs in 2021 (USACE, 2021) indicated elevated turbidity and nutrients entering the reservoirs. The mean concentrations of total nitrogen and total phosphorus measured in 2021 at inflow samples collected at J.E. Roush Lake, Mississinewa, and Salamonie Lakes are 1.9, 2, and 2.2 mg/l, and 275, 110, and 85 micrograms per liter (µg/l), respectively. Concentrations of nutrients and field measured turbidity exceed the USEPA's ecoregional nutrient criteria for rivers and streams. In addition to elevated nutrients, historic water quality sampling suggests elevated fecal coliform counts and elevated concentration of total iron have been recorded at the inflows to these projects in the past, likely associated with watershed loading during stormwater runoff events.

The most significant physical condition affecting water quality at each reservoir is thermal stratification. Thermal stratification occurs when the water in a lake forms distinct layers through heating from the sun. When the ice has melted in the spring, solar radiation warms the water at the surface of the lake much faster than in deeper waters. As the water warms, it becomes less dense and remains at the surface, floating in a layer above the cooler, denser water below. Thermal stratification results in the separation of the lake into three distinct layers. From top to bottom, these layers are called the epilimnion, metalimnion, and hypolimnion. While this process is driven by temperature, each of these layers has unique physical, chemical, and biological characteristics. The epilimnion is the layer of water that interacts with the wind and sunlight, so it becomes the warmest and contains the most dissolved oxygen. The deepest layer is the cold, dense water at the lake bottom, called the hypolimnion. The hypolimnion contains the lowest amount of dissolved oxygen and can often become anoxic (zero dissolved oxygen) while the lake is thermally stratified.

All three Upper Wabash reservoirs exhibit some degree of thermal stratification during the summer months with duration being dependent on annual and seasonal meteorological variations. During normal and warmer than normal years, these projects become thermally stratified, typical of other USACE projects located to the south. Thermal stratification at these projects normally lasts from May through September, with J.E. Roush Lake showing a tendency to destratify periodically due to cool temperatures or significant storm events during the summer. Water quality parameters of concern in the epilimnion are those which reflect existing or potential impact on fisheries, recreation, and other lake uses. Monitored parameters in the reservoirs include nutrients, which stimulate algal production; phytoplankton, zooplankton, and chlorophyll *a*, to determine the current amount of productivity in the epilimnion; temperature, dissolved oxygen, and pH to judge potential impacts to the lake fishery; and other physical and chemical parameters to describe general water quality conditions in the reservoir. In general, the DO values measured by USACE staff in the epilimnion of Mississinewa, J.E. Roush, and Salamonie Lakes in 2021 averaged around 10, 13 and 9 mg/L, respectively. Phytoplankton analysis of water samples collected from 0, 5, 10 to 20 feet depths in the reservoirs suggests that plankton species are dominated by cyanobacteria (or blue-green algae). The water quality concern in the hypolimnion is the accumulation of metals as anoxic conditions form and persist throughout the summer months. Results of tailwater samples collected from J.E. Roush, Salamonie, and Mississinewa Lakes in 2021 analyzed for total and dissolved metals suggest that the tailwater meets state water quality standards.

The trophic status of each reservoir is determined by calculating a trophic state index (TSI) using measured water quality parameters. The TSI provides the level of eutrophication of a waterbody and is an indicator of where a reservoir is in the natural process of lake aging. A description of trophic state and expected fishery and recreation impacts are included in Table 13. TSIs were calculated using total phosphorus, total nitrogen, chlorophyll *a,* and secchi depth values found within each reservoir in 2021 (USACE, 2021). Mississinewa Lake exhibits eutrophic conditions based on water quality parameters analyzed. The average chlorophyll *a* concentration found in the lake in 2021 is 26.7 mg/m^3, the average total phosphorus and total nitrogen found in the lake is 411 µg/L and 3.1 mg/L, respectively, resulting in an average TSI of 57. J.E. Roush Lake exhibits eutrophic conditions based on water quality parameters analyzed. The average chlorophyll a concentration found in the lake is 23.5 mg/m^3, the average total phosphorus and total nitrogen found in the lake is 122 µg/L and 2.3 mg/L, respectively, resulting in an average TSI of 62. Salamonie Lake exhibits eutrophic conditions based on water quality parameters analyzed. The average chlorophyll a concentration found in the lake is 4.9 mg/m^3, the average total phosphorus and total nitrogen found in the lake is 135 µg/L and 2.8 mg/L, respectively , resulting in an average TSI of 51.

Table 13. Trophic State Index attributes.

TSI	Attributes	Fisheries & Recreation
<30	Oligotrophic: clear water, oxygen throughout the year in the hypolimnion.	Salmonid fisheries dominate.
30-40	Hypolimnia of shallower lakes may become anoxic.	Salmonid fisheries in deep lakes only.
40-50	Mesotrophic: water moderately clear; increasing probability of hypolimnetic anoxia during summer.	Hypolimnetic anoxia results in loss of salmonids. Walleye may dominate.
50-60	Eutrophic: anoxic hypolimnia, macrophyte problems possible.	Warm-water fisheries only. Bass may dominate.
60-70	Blue-green algae dominate, algal scums and macrophyte problems.	Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating.
70-80	Hypereutrophic: (light limited productivity). Dense algae and macrophytes.	Rough fish dominate; summer fish kills possible.
>80	Algal scums, few macrophytes.	

The IDEM, Indiana DNR, Indiana State Department of Health (ISDH), and the Board of Animal Health (BOAH) work together to provide information about Harmful Algal Blooms (HABs) throughout Indiana. IDEM collects water samples near the public beaches at Mississinewa and Salamonie Lakes. Samples are analyzed for blue-green algae and four algal toxins. While significant algae problems have not been reported recently at any of the Upper Wabash projects requiring limitations in recreational use, HABs have been reported on all three project reservoirs. Beach advisories were issued at Salamonie and Mississinewa Lakes in 2022 encouraging users to avoid contact with algae and avoid swallowing water while swimming. A summary of cell counts per milliliter (cell/ml) and toxins detected in 2022 in the Salamonie and Mississinewa swimming areas are summarized in Table 14.

Table 14. IDEM 2022 sampling results - Cyanobacteria Cell Counts, Identification, and Cyanotoxin Results.

Date	Location	Cells/ml**	Microcystin	Anatoxin-a	Saxitoxin	Cylindrospermopsin
			(µg /l)	(µg /l)	(µg /l)	(µg /l)
30-Aug	Salamonie Lake – Lost Bridge West SRA*	360,000	ND	ND	ND	ND
30-Aug	Mississinewa Lake – Miami SRA	390,000	0.630	ND	ND	ND
16-Aug	Salamonie Lake – Lost Bridge West SRA	240,000	ND	ND	ND	ND
16-Aug	Mississinewa Lake – Miami SRA	170,000	ND	ND	ND	ND
2-Aug	Salamonie Lake – Lost Bridge West SRA	240,000	ND	ND	ND	ND
2-Aug	Mississinewa Lake – Miami SRA	190,000	ND	ND	ND	ND
19-Jul	Salamonie Lake – Lost Bridge West SRA	220,000	0.420	ND	0.066	ND
19-Jul	Mississinewa Lake – Miami SRA	160,000	0.780	ND	ND	ND
5-Jul	Salamonie Lake – Lost Bridge West SRA	NR	0.580	ND	ND	NR
5-Jul	Mississinewa Lake – Miami SRA	NR	3.350	ND	ND	NR
21-Jun	Salamonie Lake – Lost Bridge West SRA	180,000	0.975	NR	NR	NR
21-Jun	Mississinewa Lake – Miami SRA	110,000	1.110	NR	NR	NR
24-May	Salamonie Lake – Lost Bridge West SRA	4,650	ND	ND	ND	NR
24-May	Mississinewa Lake – Miami SRA	4,400	ND	ND	ND	NR
Human Recreation Advisory			8.000	80.0	0.800	6
Human Recreation Prohibited			20.000	30.0	3.000	15
Dog Recreation Prohibited			0.800	0.4	0.050	1

*SRA = state recreation area

***Beach advisory issued when cell counts are greater than 100,000 cells/mL*

ND = not detected

NR = not reported

3.3.5 Potential for Operations to Influence Water Quality

Reservoirs with selective withdrawal capabilities provide an opportunity for selective release of water from different depths within the reservoir. These capabilities can be important to properly maintain reservoir and tailwater water quality characteristics during operations. Mimicking a natural temperature regime in the tailwater is critical for wildlife downstream of the reservoir. Additionally, the maintenance of cold water within the reservoir is important as it is a limited resource and can serve to mitigate other water quality problems. There is an opportunity to selectively release water from the Mississinewa Lake using the multi-level bypasses at the reservoir.

When a reservoir has limited selective withdrawal capability, such as at Salamonie and J.E. Roush Lakes, an unnatural and potentially harmful temperature regime can be created in the tailwater. Limitations in selective withdrawal capabilities may result in thermal depression in the tailwater in the spring and summer, lower than pre-dam flows, and elevated temperatures in tailwater releases in the fall. Unnatural temperature releases in the tailwater can be harmful for ecological resources downstream of the reservoirs by interrupting breeding cues, impacting an aquatic organism's growth, and feeding habits, and increasing the harmfulness of some water quality parameters (such as ammonia, metals, and dissolved oxygen) on aquatic wildlife.

If a reservoir's selective withdrawal capabilities are limited, water will mostly be released from the hypolimnion of the reservoir. Over time, this depletes the volume of cold water in the reservoir resulting in tailwaters and reservoirs that are too warm during the fall and early winter. Release of water from the hypolimnion results in increased temperature in the reservoir during the summer which promotes algae growth. Eventually, excessive algae blooms will die and be consumed by bacteria. The bacteria that consume the algae will deplete oxygen levels in the reservoir, which could potentially cause fish kills within the reservoir body, as well as the tailwater.

3.4 Riparian and Riverine Plant Communities

The term riparian refers to areas that are in some way connected to the river. Riparian areas and their plant communities are not always directly impacted by seasonal flooding, deposition, and erosion, but are influenced by the river at least periodically (Benke et al., 2000). The shifting habitat mosaic, as described by Sanford et al. (2005), explains that the floodplain is a dynamic mosaic of various habitat patches that change spatially and temporally due to flooding, channel avulsion, cut and fill alluviation, and recruitment and regeneration of vegetation. Natural flow regimes provide critical flows needed to shape the floodplain landscape (Hauer et al., 2003), and flood duration has been shown to drive floodplain species composition (Richter et al., 2000). To maintain the diverse mosaic of habitat and vegetation communities in the river corridor, natural flow regimes must be implemented. For example, high flows will induce erosion and promote formation of new channels and pools, while low flows promote deposition and formation of islands, point bars, and other riverine habitat features. The most overarching and important aspect of restoring natural flows is restoring river-floodplain connectivity.

Floodplain-riverine connectivity allows natural riverine processes to interact with the floodplain. Streamflow is seen as the master variable (Power et al., 1995) controlling riverine and floodplain ecosystems. Floodplain areas located closer to the river or at lower elevations tend to be disturbed more often and are often dominated by r-selected species, which tend to be more opportunistic, short-lived, fast-growing species that rely on quick and abundant reproduction strategies. This makes these communities more resilient to disturbance. Plant communities situated farther from the river or at higher elevations within the floodplain tend to be disturbed less often, and are usually dominated by K-selected species, which tend to be long-lived, reach maturity at a later age, and produce fewer offspring. Riparian plant communities are usually resilient to perturbations since they are in the floodplain.

Much of the floodplain along the Upper Wabash River is now used for commercial agriculture, and there are few native species present in those areas. However, before conversion to agriculture, or in areas where native vegetation is still present, the most highly disturbed areas, usually along the river, tend to be dominated by herbaceous vegetation including sedge species (*Carex spp.*), prairie cordgrass (*Spartina pectinata)*, jewel weed (*Impatiens capensis*), and other flood-tolerant forbs, grasses, sedges, and rushes. Many of these species are somewhat dependent on periodic disturbance and inputs from the river to persist. Moving outward away from the river, the next habitat type is dominated by shrubs and r-selected tree species including willow species (*salix spp.*), silver maple (*Acer saccharinum*), and eastern cottonwood (*populus deltoides*). Areas still within the 100-year floodplain, but farthest from the river tend to be dominated by species including American basswood (*Tilia americana*), eastern black walnut (*Juglans nigra*), American beech (*Fagus grandifolia*), swamp white oak (*Quercus bicolor*), American sycamore (*Plantanus occidentalis*), box elder (*Acer negundo*)*,* hackberry (*Celtis occidentalis*)*,* and green ash (*Fraxinus pennsylvanica*). Finally, species on the edge of the floodplain and transitioning into more upland areas tend to be dominated by species such as bur oak (*Quercus macrocarpa*), white oak (*Quercus alba*), red oak (Quercus rubra), shagbark hickory (*Carya ovata*), ash spp. (*Fraxinus spp.*), sugar maple (*acer saccharum*), and tulip poplar (*Liriodenron tulipifera*).

According to the National Wetlands Inventory (NWI), there are many wetlands within the Upper Wabash watershed, but most are situated along the major waterways. These wetlands are mostly riverine systems with shallow to deep water habitats containing a channel, and dominated by trees, shrubs, and persistent emergent plants. The dominant wetland types are lake (manmade), freshwater emergent wetland, freshwater forested/scrub wetland, freshwater pond, and riverine (Figure 27). Wetlands serve important water quality and wildlife habitat functions. Typical wetland flora may include various sedges, cattail, spikerush, smartweed, arrowhead, pickerelweed, pondweed, watermilfoil, duckweed, and waterlily. Wetlands provide habitat for many animals, including red-winged blackbird, muskrats, mink, beaver, reptiles, amphibians, and fishes, as well as a wide range of waterfowl.

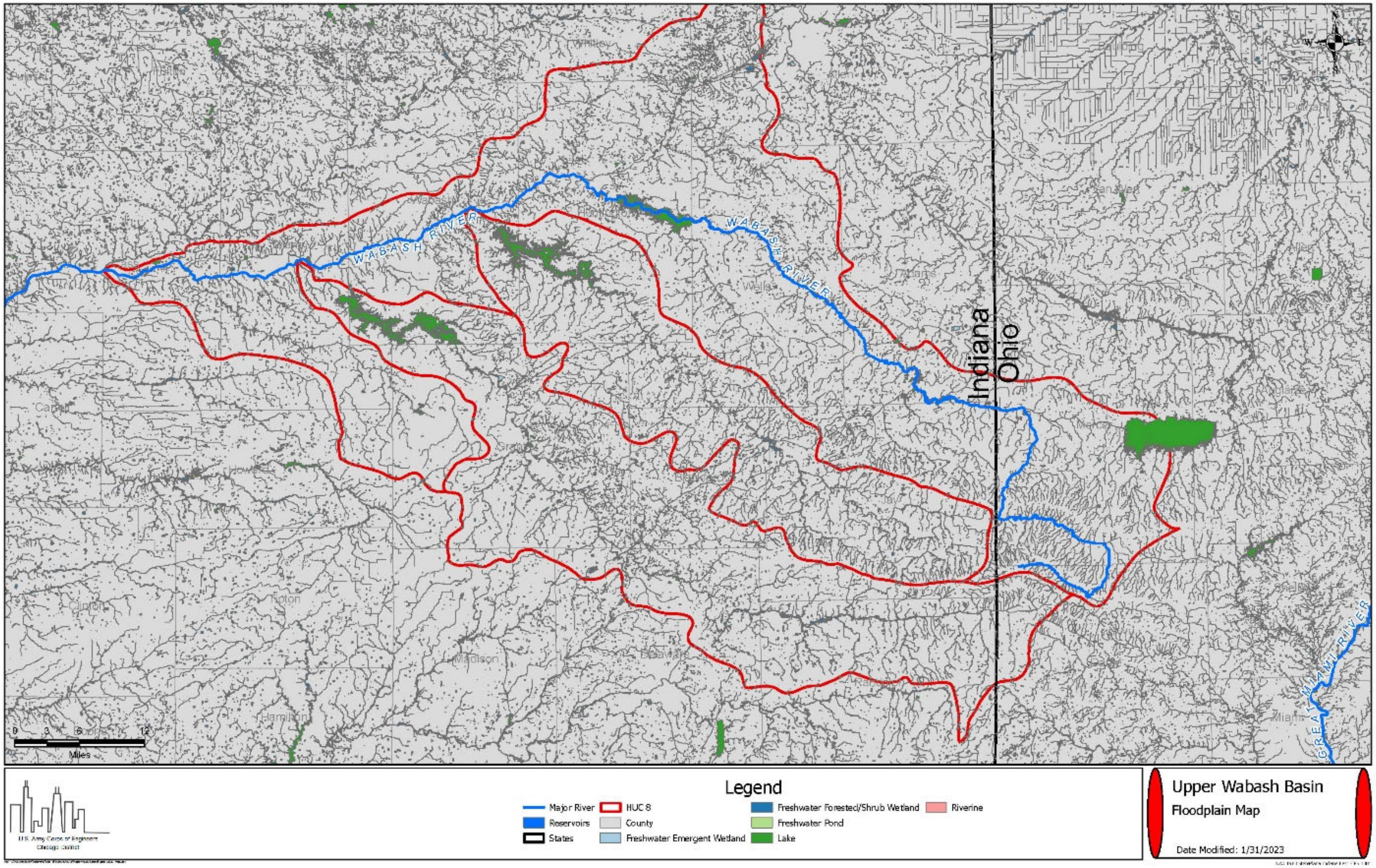


Figure 27. Wetlands in the Upper Wabash study area.

3.5 Riverine Habitat

Several surveys, reports, and repositories provide an illustration of riverine habitat for the Wabash River system. The IDNR Wabash River fisheries survey report (1999) collected Qualitative Habitat Evaluation Index (QHEI)/habitat parameters and water quality data. Pyron and Lauer (2004) examined 28 sites where habitat data was collected in QHEI format. Frimpong et al. (2005) investigated stream health correlation to riverine habitat, geomorphic, and other parameters. Sample site locality is not provided within the publication where only sub-basins receive study treatments (site data comes from T.P. Simon's Cornbelt IBI survey, 2006). The IDNR Wabash River fisheries survey report (2008) collected QHEI/habitat parameters and water quality data. There may be more IDNR basin surveys and data, but these were not found during the literature search. The IDEM houses the most complete collection of data for all Indiana streams including the Wabash River (Figure 28). All of these data could possibly be incorporated into a plan for monitoring habitat response to flow regime adjustments.

A visual observation of QHEI overarching score categories mapped on Figure 28 gives indication that in general riverine habitat is moderate (IDEM, 2022). There are numerous reaches of good habitat (60-74 points), with few reaches of poor habitat (less than 60 points), and there were a couple sites classified as excellent habitat (greater than 75 points) (exhibiting most characters of a natural river). Riverine habitat of the upper Wabash River is adversely affected cumulatively via impacts originally caused by agriculture. The foundation of agricultural impacts would be stripping native vegetation from the landscape, draining wetlands, and channelizing streams. These three acute actions have caused the Wabash River to experience abnormal hydrology, hydraulics, sediment inputs, and organic matter inputs. Hydrology became so abnormal at one point, the 3 flood control projects were needed to maintain human uses within an ever-enlarging floodplain.

One important concept for restoring riverine habitat under this study would be altering streamflow to promote natural riverine processes. Streamflow coupled with the river's slope dictates how much work, or earth moving, the river can do, which is called stream power. Ultimately the expression of stream power, especially during large magnitude floods, creates riffles, pools, meanders, backwaters, oxbows, new channels, islands, wetlands, large woody debris, and diverse and clean substrates. Therefore, implementing more natural streamflow can restore stream power and improve in stream habitat for riverine species.

Another important concept for restoring riverine habitat is altering flow dynamics to more closely mimic natural flow conditions. Once the large floods have reorganized channel materials and put a bunch of new material into the channel, the lower flows now must make way through this new obstacle course. In doing so, the water will flow at different velocities and manners that create the "hydraulic habitat" within a river channel. Riverine fishes spent thousands of years adapting to these hydraulic variations of flowing water, and abruptly taking them away through damming, channelization, or flow alternations typically means the immediate loss of a certain suite of specialist species and long chronic impairment for the rest. For example, for a diverse assemblage of caddisfly species to be established, hydraulic habitat over a riffle crest or large piece of wood needs to be at or near critical flow (Froude# of 1; or the point between black and white water). Another example is Lake Sturgeon spawning, where velocities over spawning beds need to between 2 and 5 feet per second (ft/s). Other important flow dynamic characteristics include critical flow, super critical flow, sub critical flow, helical flow, velocities, slack water, and eddies. So, adjusting flow dynamics back to these more natural conditions would improve habitat for the riverine species that have evolved under these conditions.

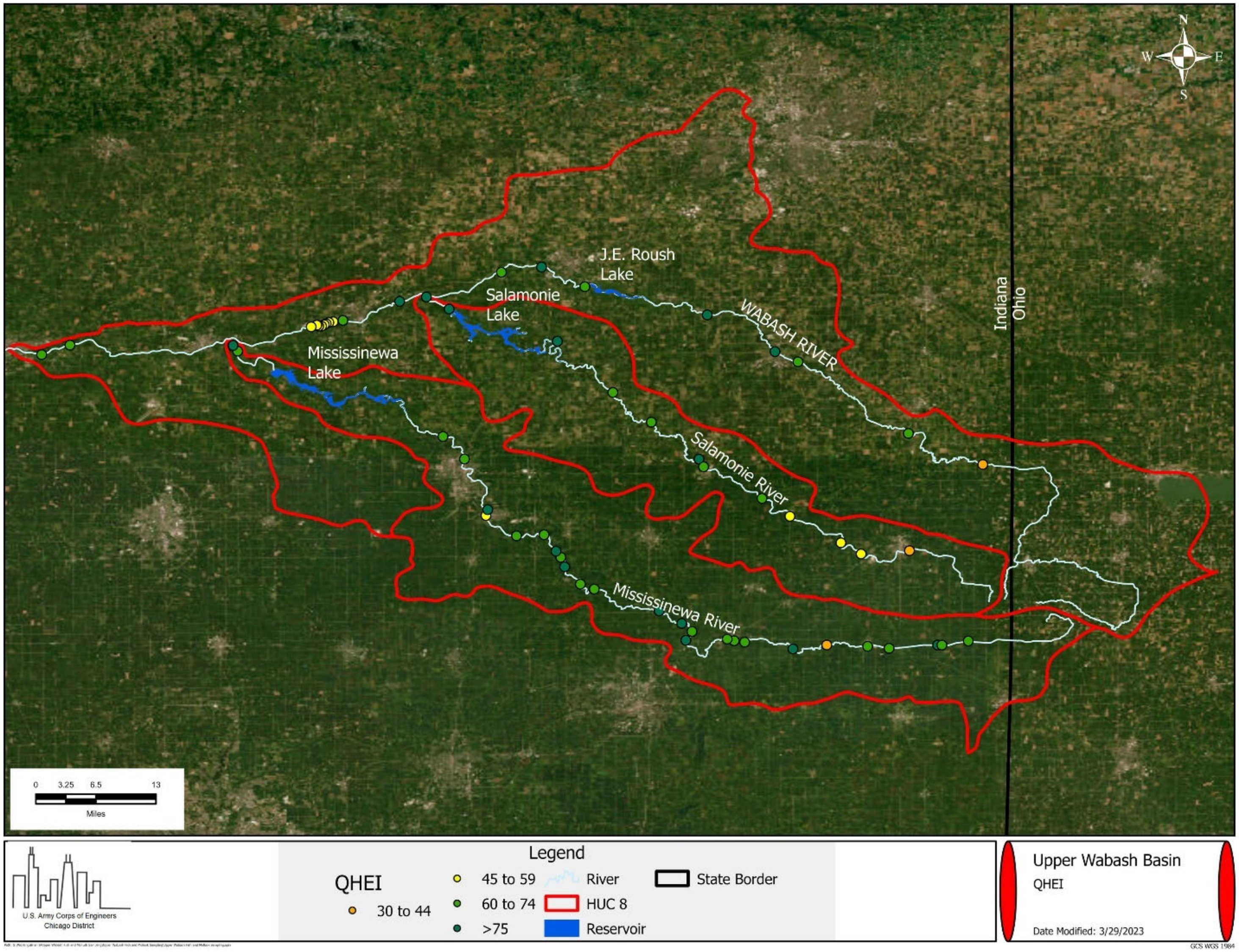


Figure 28. Indiana Department of Environmental Management Qualitative Habitat Evaluation Index sampling locations (Gaston, 2022, personal communication).

A third important concept for restoring riverine habitat is sediment inputs and transport. The two main ways sediment enters a river channel is through surface erosion or mass wasting (Hauer and Lamberti, 1996). The Wabash River system suffers greatly from abnormal surface erosion due to agriculture. This condition inputs a large amount of soil in the form of clays and silts. This source of sedimentation to a river is not good. These fine materials are mostly transported in the wash load, or within the water column as evidenced by turbidity during normal to low flows. In general, large mass wasting does not occur in the upper Wabash system due to the relatively flat terrain and stream channelization; however, minor wasting in the form of bank erosion does occur. This source of sedimentation to a river is good, whereas it provides the right amount of substrate input and the right kind of sediment/material, such as hardpan, sand, gravel, cobbles, and boulders. This material is typically transported as bedload, and forms the basis of benthic habitat, substrates, and channel features. The three flood risk mitigation dams are likely to disrupt the sediment transport continuum and have been sequestering bedload sediment while flushing wash loads downstream since being built.

There may be more components for consideration, but the last one discussed here is the importance of organic matter input. As well as energy sources (food), coarse particulate organic matter (CPOM) and fine (FPOM) inputs also provide physical habitat. Live plants and trees, large woody debris, rootwads, rootmats, sticks, leaves, detritus, and muck all provide different riverine organisms with different physical habitat structure and substrates. The influence of high quality native riparian plant communities is imperative to a diverse riverine habitat. Streamflow alterations can adversely affect native riparian community species composition, structure, coverage, and connectivity with the river; as well as alter influx from upstream sources.

3.6 Freshwater Mussels

Decline in freshwater mussel biodiversity in North America, including the Wabash River, is generally attributed to the influences of overharvesting, certain types of sedimentation, water quality perturbations, loss of habitat due to channel homogenization, fragmentation by dams/impoundments, and smothering by other invasive mussel species such as the Zebra Mussel (*Dreisenna* spp.). Similarly, most freshwater mussels are indirectly affected by alteration to fish communities as recruitment is dependent on an intermediate host for successful reproduction.

Mussel fauna within the Wabash River basin historically supported 75 species of freshwater mussels; however, diversity has declined significantly in the last century (Haag, 2012; Fisher, 2006). A compendium of survey information presented in Fisher (2006) indicated only half of the species known to occur in the Wabash River are likely still extant and reproducing. The current known mussel distribution in the Upper Wabash, per IDNR data (B. Fisher, pers. Comm., 2023), notes 35 live species records for the Wabash River downstream of Logansport and 29 species with recent live records between Roush and Logansport (Appendix D, Table D.7). Mussel communities in the Upper Wabash River basin are faced with many challenges. Factors influencing recruitment and persistence include physical habitat availability and water quality perturbations, their reproductive potential via host fish availability, and climate and hydrologic influences affecting their brooding strategies (Gates et al., 2015). Mussel assemblage decline in the Wabash River drainage has also been attributed to commercial harvest of freshwater mussels, which was halted in 1991 (Anderson et al., 1993).

The three life history strategies described for freshwater mussels with respect to their adaptability include opportunistic, equilibrium, and periodic, which are differentiated by a mussels' life span, age at reproductive maturity, fecundity, and to some extent its relative size[1]. Opportunistic species are short

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[1] Life history strategies of mussels are categorized generally based on ordination and is detailed in Haag (2012, Chapter 6). Strategy assignment is uniform for a few species; however, a species strategy can change and overlap strategies based on population, habitat, and river system of occurrence. For example, Threeridge (*Amblema plicata*) exhibits an equilibrium strategy in one river system but trends to more periodic strategy in another.

lived, have high fecundity at an earlier age, and are medium to large in size. Species within the Anodontinae family are generally opportunistic species, such as the Giant Floater (*Pyganodon grandis).* Equilibrium strategists are long-lived species and mature later in life with low fecundity. Species in the Ambleminae family are identified as mostly equilibrium strategists. Lastly, periodic strategists have a moderate to high growth rate but are not generally long lived and mature younger with lower fecundity and are small in body size. Mostly species within the Lampsilinae and Anodontinae subfamily are periodic strategists, such as *Alasmidonta spp*. and *Epioblasma spp*., respectively. Species with current distribution in the Upper Wabash River exhibit all three life history strategies.

Mussels are unique in that most species require a fish host for successful reproduction during their parasitic larval stage. Mussel larvae (glochidia) attach to fish gills, fins and tails, and complete their development attached to the fish. During this development period, the glochidia transform into juveniles and fall off the fish and drift to the river bottom. Mussels are species specific for host fish, as some species have a limited number of fish hosts that produce viable offspring. For example, the Elephantear, a mussel species known from the Upper Wabash River below Logansport, uses the Skipjack Herring as a fish host; no other hosts are known for this mussel species (Freshwater Mussel Host Database, 2017).

Mussels are generally categorized as long-term or short-term brooders, which refers to the time the larvae are brooded by female mussels until the point at which they are mature and are dispersed or released for encounter with a host fish. Brooding strategies are signaled by environmental conditions such as temperature and streamflow. Short-term brooders are typically fertilized in the spring and hold glochidia for a short time (e.g.: weeks up to two months). Long-term brooders are fertilized in the late summer or fall and hold their glochidia over the winter and release sometime in the late spring or summer.

Unnaturally high turbidity, a known water quality issue in the Upper Wabash River, may influence mussel populations as well as potential host fishes. Additionally, sedimentation stemming from agriculture and sewage affect mussel habitat as well as physically cause stress or even death (Haag, 2012 citing Marking and Bills, 1980 and Aldridge et al., 1987). Haag (2012) cautions that studies lack evidence for the effect of accumulated natural sediment over time as a contributor to their decline, but the acute effects of an abrupt deposition event (building an impoundment, for example) do suggest a negative response by mussels. The embedding of substrates by anthropogenically created sediments likely influences species assemblage and diversity, favoring species that are more tolerant of degraded substrates and water quality and having no specificity of fish hosts.

Evaluations of mussel assemblages pre- and post-dam eras in large river systems suggest species composition and abundances have shifted in response to highly altered physical habitat incurred by dams. A common theme among impounded river systems is the documented species loss post dam construction; mussels possess unique life history characteristics that affect their ability to adapt to these changes in physical habitat (Haag, 2012). Unfortunately, mussel assemblage data upstream of the reservoirs for the Mississinewa, Salamonie and Wabash Rivers pre- and post-project construction is lacking.

Mussels are "thermoconformers" and do not regulate their own temperature rendering them susceptible to stress during extreme fluctuations in water temperature (Gates et al., 2015). Impoundment tolerance of mussels is associated with their life-history strategy and is summarized and described by Haag (2012). As described in the General Water Quality section of this report, the most significant physical condition affecting water quality at each upper Wabash reservoir is thermal stratification.

Adverse environmental effects of altered streamflow regimes are evident at other SRP sites throughout the country, indicating that opportunities may exist for e-flows modifications to have a positive effect within the Upper Wabash River system. Environmental benefits may include cleaner and less embedded substrates, more diverse substrates, more natural flood and low-streamflow conditions, improved water quality and improved host fish presence. These results can improve biophysical conditions for freshwater mussel populations, which could increase their distributional breadth and overall persistence within the watershed.

3.7 Macroinvertebrates

Macroinvertebrate sampling data was provided to USACE by IDEM (Owens, personal communication, 2022). Macroinvertebrate samples were gathered using IDEM's Multihabitat Macroinvertebrate, Kick net, and Hester-Dendy collection procedures (Owens, personal communication, 2022). Family-level data was provided for most of the sampling sites, and much of the data is from more than 20 years ago, but this data is still helpful to understand the existing conditions in the Upper Wabash, Mississinewa, and Salamonie Rivers downstream from the dams. QHEI data (Appendix D, Table D.8) was also collected at each of the macroinvertebrate sampling locations and is mapped in the Riverine Habitat section (Figure 28) (Owens, personal communication, 2022).

Aquatic macroinvertebrates are small invertebrate organisms that are visible to the naked eye that live in aquatic environments such as rivers, streams, and lakes. They include insects, snails, clams, worms, crayfish, and other crustaceans. Macroinvertebrates are often used as indicators for the health of an aquatic ecosystem due to their prevalence in aquatic habitats and their differing sensitivities to chemical pollution and physical disturbances. Table 15 shows examples of macroinvertebrates and their generalized pollution sensitivity levels that can aid in analyses on ecosystem health.

Table 15. Examples of Macroinvertebrates and their pollution sensitivity levels (EPA, 2021).

Macroinvertebrate	Pollution Sensitivity
Stonefly	Intolerant
Mayfly	Intolerant
Crayfish	Moderately Tolerant
Leech	Tolerant
Aquatic Worm	Tolerant

The Upper Wabash basin has been sampled extensively over the years for macroinvertebrates as shown in . Most of the samples are in the upper reaches of the Mississinewa, Salamonie, and Wabash rivers, or within the main stem of the Wabash River far from the influence of the reservoirs. Additionally, these samples were collected over many years, often spanning decades, and can provide a general characterization of the macroinvertebrate community in the Upper Wabash basin.

For the purposes of this report, the sampling locations that will be discussed are the locations downstream of the three reservoirs. These locations, along with additional information is listed below in Table 16, Table 17, andTable 18. This historical data can provide a generalization of the ecosystem, however, as these are often more than ten years old, the conditions of the macroinvertebrate communities within these streams may have changed over time. More recent data was not available at the time of writing this report for the locations discussed.

The macroinvertebrate sampling that occurred downstream of the reservoirs resulted in macroinvertebrate Index of Biotic Integrity (mIBI) scores that provide indications of ecosystem health. The IDEM uses these metric scores to indicate whether streams are considered impaired or unimpaired. The mIBI score for multi-habitat collection method utilizes a scale from 0 to 60 with scores less than 36 indicating impaired streams (Table 16), whereas the kick net (Table 17) and Hester-Dendy (Table 18) collection methods utilize a scale from 0 to 8 with scores less than 1.8 indicating impaired streams (Owens, 2022, personal communication). The majority of the sites are considered unimpaired. There were nine sites below Salamonie Lake that used the Hester-Dendy collection method with replicates, therefore the resulting mIBI scores are presented as averages (Table 18; Owens, 2022, personal communication). The taxa collected from all of these sites are in the taxa list shown in Appendix D, Table D.8. The Mississinewa sites were considered to be unimpaired in 1991, 2008, and 2015. The Salamonie sites had one impaired location in 2016, with unimpaired locations in 1991, 2008, and 2015. The Wabash site (below J.E. Roush Lake) had one impaired location in 2004 and one unimpaired location in 1991.

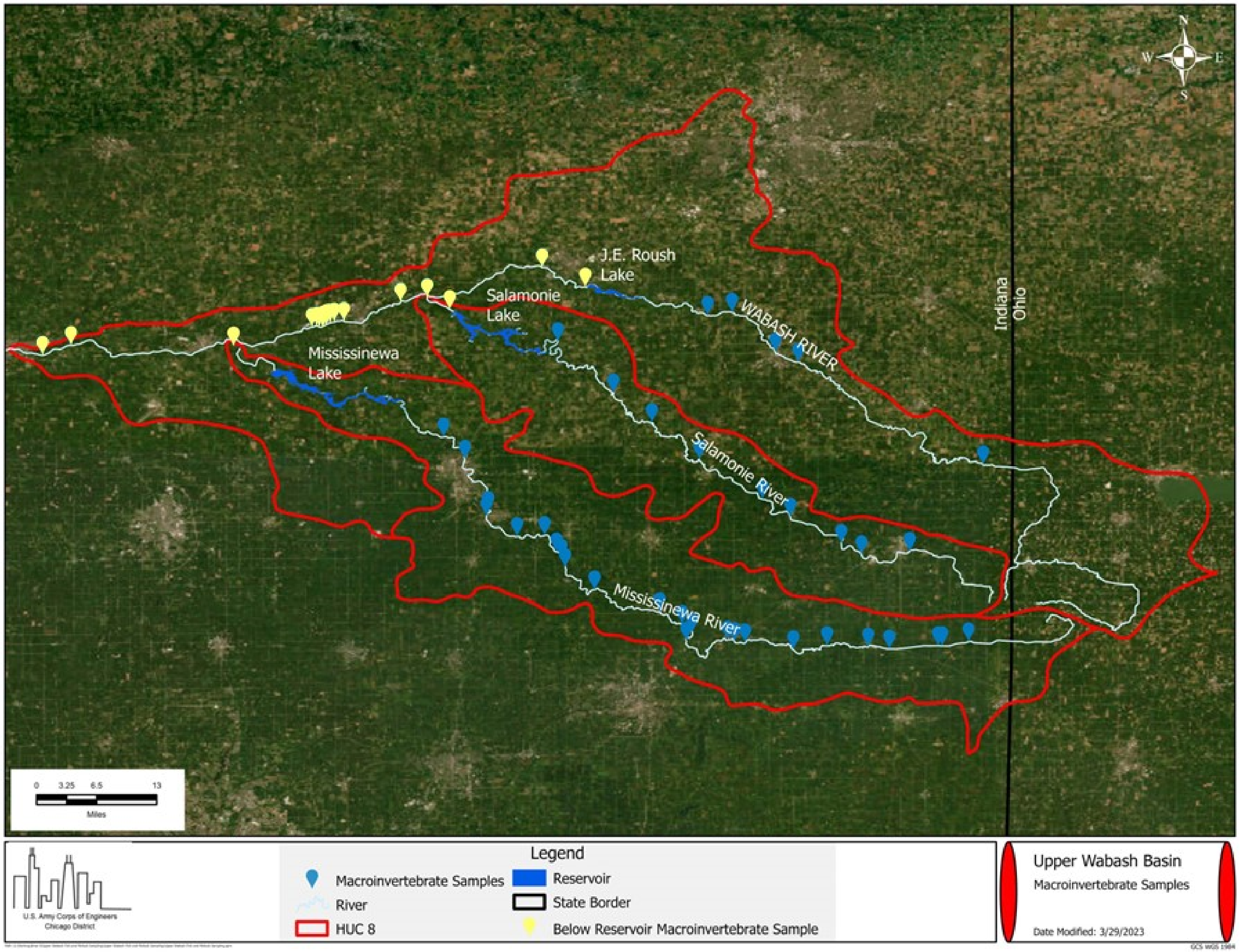

Figure 29. Indiana Department of Environmental Management macroinvertebrate sampling locations (Owens, 2022, personal communication).

Table 16. Historical Macroinvertebrate samples via Multi-Habitat Collection Method (Owens, 2022, personal communication).

Site	Location	River	Sample Date	Collection Method	mIBI Score (0 – 60)
WMI-06-0006	Downstream of Mississinewa Lake	Mississinewa	25 August 2015	Multi-Habitat	40
WUW180-0009	Downstream of Mississinewa Lake	Wabash River	28 July 2008	Multi-Habitat	50
WUW150-0008	Downstream of Salamonie Lake	Wabash River	28 July 2008	Multi-Habitat	42
WUW090-0004	Downstream of J.E. Roush Lake	Wabash River	21 September 2004	Multi-Habitat	26

* Blue shaded mIBI score = unimpaired stream, red shaded mIBI score = impaired stream

Table 17. Historical Macroinvertebrate samples via Kick net Collection Method (Owens, 2022, personal communication).

Site	Location	River	Sample Date	Collection Method	mIBI Score (0 – 8)
WMI060-0014	Downstream of Mississinewa Lake	Mississinewa	26 August 1991	Kick net	4.2
WUW180-0002	Downstream of Mississinewa Lake	Wabash River	28 August 1991	Kick net	4.2
WUW180-0002	Downstream of Mississinewa Lake	Wabash River	28 August 1991	Kick net	3.6
WSA040-0010	Downstream of Salamonie Lake	Salamonie River	30 July 1991	Kick net	3.2
WSA040-0011	Downstream of Salamonie Lake	Wabash River	01 August 1991	Kick net	50.0
WUW140-0005	Downstream of J.E. Roush Lake	Wabash River	09 July 1991	Kick net	4.2

* Blue shaded mIBI score = unimpaired stream, red shaded mIBI score = impaired stream

Table 18. Historical Macroinvertebrate samples via Hester-Dendy Collection Method (Owens, 2022, personal communication).

Site	Location	River	Sample Date	Collection Method	Average mIBI Score (0 – 8)
WUW-14-0003	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	6.3
WUW-14-0004	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	3.3
WUW-14-0005	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	5.7
WUW-14-0006	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	**1.3
WUW-14-0007	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	1.9
WUW-14-0008	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	2.2
WUW-14-0009	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	2.1
WUW-14-0010	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	2.0

Site	Location	River	Sample Date	Collection Method	Average mIBI Score (0 – 8)
WUW-14-0011	Downstream of Salamonie Lake	Wabash River	06 September 2016	Hester-Dendy	2.7

* Blue shaded mIBI score = unimpaired stream, red shaded mIBI score = impaired stream
** Hester-Dendy equipment may have been exposed to air for some time during sampling contributing to lower mIBI score

There are macroinvertebrate samples that were collected downstream of each reservoir (Mississinewa, Salamonie, and Roush), however there were no macroinvertebrate samples collected within the reservoirs themselves. Even though these reservoirs are within river systems, they exhibit more lake-like habitats due to the deeper depths and slower flow of water. These lotic and lentic habitat differences would present themselves within the macroinvertebrate communities, however IDEM only examines the lotic macroinvertebrate communities downstream of the reservoirs at this time.

When examining the taxa community of the sites, the sites below Mississinewa and Salamonie Lakes have a high presence of Mayfly (Ephemeroptera), as compared to the sites below J.E. Roush Lake. Mayflies (Ephemeroptera) are a relatively pollution intolerant group and an indicator of good water quality. Given that the Mississinewa and Salamonie had mIBI scores that were in the unimpaired category, this observation of high mayfly presence is consistent. The combined taxa richness for the Mississinewa sites and Salamonie sites are 95 taxa and 81 taxa, respectively. This variety of taxa for these sites include: aquatic worms, leech, mite, limpet, fingernail clam, crustaceans, mayflies, moth, beetles, dobsonfly, caddisflies, flies, and non-biting midges (Appendix D, Table D.8).

For the sites below J.E. Roush Lake, there were only two sample events, one indicating an impaired stream and one indicating unimpaired stream. Even though one site scored in the unimpaired condition, the combined J.E. Roush sites had a taxa richness of 31, with 10 of those taxa within the Chironomidae family (non-biting midge). Taxa include the following: flatworm, leech, limpets, snails, mayfly, beetle, caddisflies, flies, and non-biting midges (Appendix D, Table D.8). Flatworms and non-biting midges are relatively pollution tolerant species. The relatively low taxa richness and pollution tolerant taxa that were present at the sites corresponds with the low mIBI score indicating impaired stream.

When discussing the macroinvertebrate data for this report, it needs to be noted that this data was collected between 1991 and 2016 and would have reflected the stream conditions and macroinvertebrate communities at that time. Habitat and water quality have likely changed within the past 20 to 30 years from when these data were collected. Even for the sites with the healthier ecosystem statuses, confirmation of those conditions would be recommended for analysis and discussion. Therefore, if more recent data is made available, it is recommended to reevaluate and discuss the macroinvertebrate conditions for the Upper Wabash basin streams below their respective reservoirs.

3.8 Riverine Fishes

Several surveys, reports, and repositories provide an illustration of the Wabash River fish assemblage, and stream health based on fish occurrence and abundance. The Indiana DNR published a Wabash River fisheries survey in 1999. That publication provides sampling locality data, fish species occurrence, and a summary of individual data. Pyron and Lauer (2004) examined middle Wabash River fish assemblages in correlation to hydrological variation and other environmental parameters. Although general site locality for data collection is identified on a map for the 28 sites, no specific locality data is provided. Patterns of fish assemblage change were found to be different between relatively natural reaches and reaches with modifications. Simon (2006) provides a status of fish species within the Wabash River system, what types of water body they are found in, and recommendations for indicator species. No specific data is provided other than a checklist of current and historic fishes. Kennedy et al. (2007) provides a Wabash River population survey of an important riverine species, Shovelnose Sturgeon. Locality data is provided for survey stations. It is uncertain whether other species were recorded during the survey. In 2021, Robins and Pyron correlated riverine geomorphic units to fish species assemblage, which provides insight into potential indicator species for future monitoring of flow regime restoration measures. The IDEM houses the most complete collection of data for all Indiana streams including the Wabash River. Fish sample locations from IDEM can be seen on Figure 30. All these data could possibly be incorporated into a plan for monitoring fish community response(s) to flow regime adjustments.

The fish community is an assemblage of species inhabiting a given area, in this case a reach of river. In terms of flow alterations, fish community characteristics most applicable are species richness, abundance, physical morphology, and reproductive and trophic guilds, which agrees with the literature base established by Dr. Mark Pyron and his colleagues. Although there are many aspects that contribute to shaping a given fish community, the purpose of this study drives towards those aspects that are affected in some way by the river's hydrography. Periodical disturbance by large floods and changes in resulting habitat drive fish community composition up and down the river. Even with hydrology functioning in its natural state, these flood conditions can be harsh, which is why it is important to have a diverse habitat mosaic within the river channel and connectivity with floodplains to serve as refugia. Invasive fish species not only influence the native fish community, but their presence or high abundance is often attributed to a disturbed environmental condition. For example, conditions are greatly enhanced for the nonnative invasive *Hypophthalmicthys* spp. where a sluggish reach of river flows directly into an impounded lake, only to further be exacerbated by high phosphorous levels that provide algal and turbidity conditions these fish are adapted to. Considerations for restoring and preserving native fish community structure should not only include adjustments to the hydrologic regime and sediment transport, but to provide adequate fish passage, enlarge riparian zones of native vegetation, reestablish floodplain connectivity, reduce acres of drained lands, prevent agricultural sedimentation, and eradicate nonnative fish species.

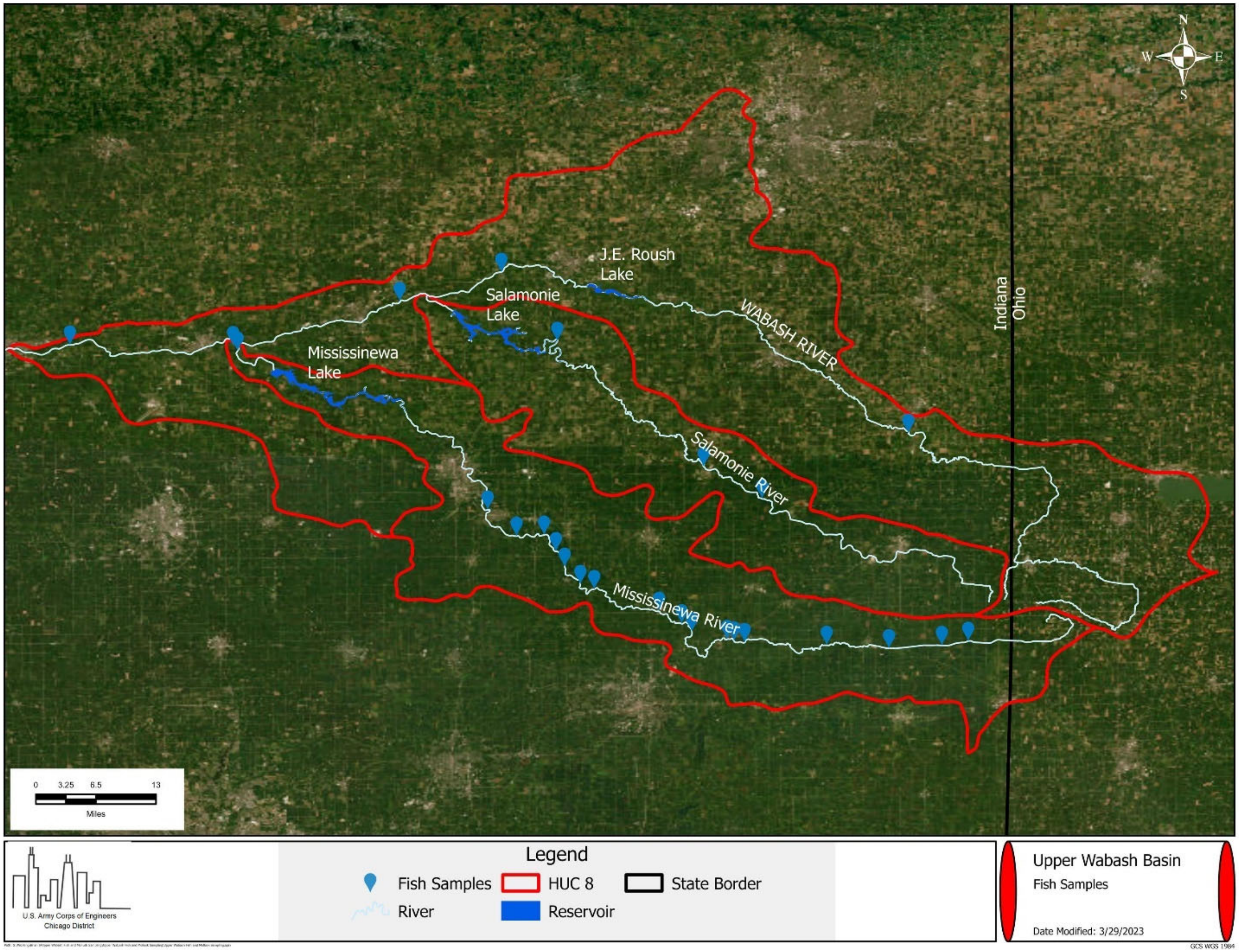

Figure 30. Indiana Department of Environmental Management fish sampling locations.

Fish populations within the Wabash River are relatively diverse. Per communication with IDNR biologists (2023), 97 different fish species are commonly found within the Wabash River, with an additional 13 species occasionally found in tributaries (Appendix D, Table D.9). Since the dispersion of Silver Carp (*Hypopthalmichthys molitrix*) in the mid-1990s some fish populations were reported declined such as Gizzard Shad (*Dorosoma cepedianum*) likely due to competing for resources (Shields et al., 2021). The Wabash River supports several commercial fishing opportunities such as Flathead Catfish (*Pylodictis olivaris*), Channel Catfish (*Ictalurus punctatus*), and Blue Catfish (*Ictalurus furcatus*) as well as a Shovelnose Sturgeon (*Scaphirhynchus platorynchus*) caviar fishery.

Species of Concern

Only two fish species from the Indiana Species of Greatest Conservation Need (SGCN) are found in the Upper Wabash: American Eel (*Anguilla rostrata*) (Indiana Species of Special Concern) and Redside Dace (*Clinostomus elongatus*) (Indiana Endangered Species) (Appendix D, Table D.10). The American Eel population decline is well documented (Haro et al., 2000), due to this species unique life cycle; adults reproducing in the Sargasso Sea, larvae drifting within the ocean, the glass eel stage initiate migration into estuaries and then inland to streams, rivers and lakes (MacGregor et al., 2008). Overall, the American Eel must battle a variety of challenges that can lead to mortality at each life stage (MacGregor et al., 2008). Redside Dace are headwater stream species in areas of slower current near woody debris (Tiemann and Sabaj Pérez, 2012). These habitats have been associated with habitat degradation from human activities across its range (Novinger and Coon, 2000). Given the parameters that Redside Dace requires along with communication with Indiana Department of Natural Resources, it is unlikely to find a Redside Dace within the mainstem of the Wabash River but possible to find individuals within its tributaries.

Potential Fishes to Monitor for Flow Responses

The use of fish species surrogates for evaluating geomorphic change as illustrated by Robbins and Pyron (2021) has good potential for obtaining discernable results from changes in streamflow regime parameters. Robbins and Pyron (2021) divided the Wabash River into three geomorphological units or Functional Process Zones (FPZ). FPZ A is a narrow stream channel, high down valley slope, and an expansive floodplain, FPZ B contains a wide river channel and wide floodplain, and finally FPZ C contains wide river channel and a constrained floodplain. The following are eight (8) of the nine (9) species of fish that were found to be significant indicators of specific FPZs. Spotted Bass (*Micropterus punctulatus*) was excluded from the potential list because they are not likely to be found in the study reach. These fish are:

FPZ A

- Tadpole Madtom (*Noturus gyrinus)*
- Central Stoneroller (*Campostoma anomalum)*
- River Redhorse (*Moxostoma carinatum)*

FPZ B

- Mountain Madtom (*Noturus eleutherus*)
- Golden Redhorse (*Moxostoma erythrurum*)
- River Shiner (*Notropis blennius*)

FPZ C

- Emerald Shiner (*Notropis atherinoides*)
- Freshwater Drum (*Aplodinotus grunniens*)
- Invasives*

- Common Carp (*Cyprinus carpio*)
- Silver Carp (*Hypophthalmicthys molitrix*)

* Invasives were not included within the original publication but added due to significant environmental impact.

Tadpole Madtom

Tadpole Madtoms are widespread through the Atlantic and Gulf slope drainages and Mississippi River basin (Page and Burr, 2011). Tadpole Madtoms live in rock, mud, or detritus bottomed pools and backwaters of lowland creeks and small to large rivers (Page and Burr, 2011). Tadpole Madtoms are typically abundant in areas with dense vegetation for cover (Pflieger et al., 1975). Spawning typically occurs during early to late summer depending on range, and has been documented to occur in metal cans found on the river bottom like many other Madtom species (Case, 1970; Clark, 1978; Whiteside and Burr, 1986). Literature suggests that typically nests are under some form of cover and are guarded by at least one adult Tadpole Madtom (Whiteside and Burr, 1986), this same study found primary diet items of Tadpole Madtom from an Illinois river was chironomids, but isopods, and other crustaceans were present.

Central Stoneroller

Central Stonerollers are widespread across most of the eastern and central U.S. in Atlantic, Great Lakes, Mississippi River, and Hudson Bay basins (Page and Burr, 2011). Central Stonerollers live in rocky riffles, runs, and pools of headwaters, creeks, and small to medium rivers with preference to shallow riffle habitats (Lewis and Elder, 1953; Page and Burr, 2011; Smith, C. L. and Powell, 1971). Central Stonerollers create spawning nests generally in mid spring in pit like nests dug out by large males which are often used by other species (various shiners, dace and minnow species) for spawning (Peoples et al., 2016). Peoples et al. (2016) also documented Stoneroller nests to be created around 63 °F near pool tails where oxygen rich water flows past the nest, however other studies did find spawning to occur at lower temperatures around 55 °F (Jenkins and Burkhead, 1994). Central Stonerollers diets mainly consist of detritus and some plants (Fowler and Taber, 1985). Central Stonerollers are typically found in fast flowing environments, and Scalet (1977) found that lower flows lead to increased mortality indirectly by forcing Central Stonerollers into marginal habitats, such as shallow pools, where they could be vulnerable to predation. However, extremely high flows could cause mortality either directly by movement of bedload or elimination of suitable habitat (Orth and Maughan, 1982).

River Redhorse

River Redhorse are found in the Great Lakes and Mississippi River basins commonly found in rocky pools and swift runs of small to large rivers (Page and Burr, 2011). However, River Redhorse has experienced declines in range and abundance during the last century (Butler and Wahl, 2017). River Redhorse are thought to be negatively affected by pollution, habitat fragmentation, and flow regulation, and appear to be particularly intolerant of sedimentation (Boschung and Mayden, 2004; Butler and Wahl, 2017; Jenkins and Burkhead, 1994; Trautman et al., 1981). Movements vary across seasons with large movements occurring during spring (mainly upstream movement) and ranging up to 14.4 miles (Butler and Wahl, 2017). Preville (2019) found movements as great of distance as 31 miles. Preville (2019) also found that telemetry tagged River Redhorse predominately occupied deep runs (>5 feet) with moderate to swift currents (>1.3 ft/s) over gravel, cobble, or boulder substrates however there was some variance with seasons as River Redhorse occupied faster current velocities in the winter and spring than summer and fall. Spawning aggregations tend to be found in shallow, gravel/cobble riffles (Butler and Wahl, 2017; Straight et al., 2015). Spawning for River Redhorse generally occurs when water temperatures reach 61 to 68 °F (Reid, 2006), however years with high spring flows can delay upstream migrations and spawning by as much as three to four weeks compared to stable low flow years of many redhorse species (Cooke and Bunt, 1999; Curry and Spacie, 1984; Harbicht, 1990). Literature suggests that once out of the spawning season, River Redhorse favor more of the slow current sections in deep channels (Campbell, 2002; Mongeau et al., 1992; Reid, 2003). Primary diet items of River Redhorse are Chironomids, Ephemeroptera larvae, and Trichopterans (Meyer, 1962)**.**

Mountain Madtom

Mountain Madtoms are native to the Ohio River, Missouri, Mississippi and Red River drainages (Page and Burr, 2011). Literature suggests that Mountain Madtoms show a year round preference for riffle habitats and may move into more moderate flows for spawning. The preferred nonspawning habitat of the Mountain Madtom is similar for all age groups, as all were found associated with clean-swept, gravel-rubble riffles. Adults typically were found in smooth, laminar flow areas above riffles, but also in riffles (Starnes and Starnes, 1985). Starnes and Starnes (1985) also found that Mountain Madtoms prefer stream velocities that range from 1.6 to 2.3 ft/sec making it unique of the Madtom species as this is not a usual requirement for other Madtom species. Mountain Madtoms are a nocturnal feeding insectivore with a diet consisting mainly of aquatic insects, specifically mayfly species (Etnier and Starnes, 1993; Starnes and Starnes, 1985). Mountain Madtom spawning occurs during early summer months primarily on fine gravel behind some form of rock cover, and similar to most other Madtom species, the nest is typically guarded by the male (Starnes and Starnes, 1985).

Golden Redhorse

Golden Redhorse are native to the Great Lakes, Hudson Bay, and Mississippi River basins, as well as some Atlantic coast rivers, typically found in large streams and rivers (Page and Burr, 2011). Redhorse species, overall, are negatively affected by dams (Reid, et al., 2008). Literature suggests that Golden Redhorse are strongly associated with areas of gravel-cobble and cobble-bolder (Nelson and Franzin, 2000). A study in Ohio found similar results that Golden Redhorse were most abundant in moderately clear, unpolluted streams with large permanent pools and well defined rocky-riffles (Trautman et al., 1981), and once this habitat disappeared, the Golden Redhorse had a substantial reduction in abundance (Trautman et al., 1974). Spawning of Golden Redhorse typically occurs on riffles similar to other Redhorse species (Curry and Spacie, 1984). Reid (2006) found that Golden Redhorse spawning typically occurs at 55 to 68 °F, but generally spawning occurs in late spring to early summer as water temperatures hit the preferred threshold. Diets of Golden Redhorse typically consist of invertebrates such as mayflies, caddisflies and midges (Etnier and Starnes, 1993).

River Shiner

River Shiner are a schooling species native to the Hudson Bay and Mississippi River drainages and occur as far east as West Virginia and as far west as Colorado (Page and Burr, 2011). River Shiners primarily are found in flowing waters or main channel habitat with moderate streamflow over sand substrate (Robison and Buchanan, 2020), while avoiding quiet backwaters and strong streamflow (Hudson and Buchanan, 2001). River Shiners have been found in a wide variety of habitats, substrates and depths within the Wabash River (Mueller Jr and Pyron, 2010). Spawning of River Shiners usually occurs during the summer based on watershed (Hatch and Elias, 2002; Hudson and Buchanan, 2001). Diets of River Shiner vary across regions but primary diet items are invertebrates and zooplankton (Hudson and Buchanan, 2001; Whitaker Jr, 1977).

Freshwater Drum

Freshwater Drum are native to the Great Lakes, Hudson Bay and Mississippi River basins, as well as the Gulf Coast drainages in Georgia through east Mexico in both river and lake systems (Page and Burr, 2011). Literature suggests that since Freshwater Drum are benthic feeders, they are likely to remain near prey sources (Bur, 1984). Although in a lake setting, research from Lake Winnipeg found that Freshwater Drum showed a strong association for fine substrates during both summer and winter (Rudolfsen et al., 2021). Within the Wabash River specifically, Freshwater Drum diets were found to mainly consist (greater than 65 percent) of invertebrate families (hydropsychidae and pleuroceridae) independent of river location (Jacquemin et al., 2014); however, Freshwater Drum have been known to feed on fish, crayfish and mollusks as adults (French III and Bur, 1996; Morrison et al., 1997). Within the Missouri River, tagging of Freshwater Drum determined them to be "mobile" and found that some were documented moving several hundred kilometers within a year (Funk, 1957). Although studies showing the preferred flow regime for Freshwater Drum are limited, one study found that minimum streamflow events were associated with slower growth rates, and reduced body length in Freshwater Drum, although this may be likely due to overall biotic changes due to lower streamflows (Jacquemin et al., 2015). Spawning generally occurs during the summer when water temperatures range from 65 to 75 °F (Swedberg and Walburg, 1970), and often occurs in open water (Pflieger et al., 1975)

Emerald Shiner

Emerald Shiner are native to the St. Lawrence, Hudson Bay, Great Lakes, Mississippi River and Gulf basins (Page and Burr, 2011). In some systems the Emerald Shiner is considered a keystone species and is used as a bioindicator for ecosystem health (Johnson, 2017). Emerald Shiners are commonly found in both lake and river systems, commonly in the pools or runs of medium to large rivers, in clear water over sand and gravel (Page and Burr, 2011). Emerald Shiners are a planktivore consuming mainly zooplankton but are also known to consume invertebrates (Pothoven et al., 2009). Spawning of Emerald Shiners typically occurs in the summer when water temperatures are around 68 to 72 °F (Campbell, and MacCrimmon, 1970). Within lake systems there has been some documentation of "migrations" involving Emerald Shiners moving to find the warmest water during early spring and then moving back into main lake areas once the water warms (Campbell, and MacCrimmon, 1970). Following a dam removal in Wisconsin, Emerald Shiners were found 76 miles upstream of previously recorded locations within new areas upstream of the dam (Catalano et al., 2007).

Common Carp

Common Carp are native to Eurasia and were introduced in 1831 to North America and are widely distributed around the continental United States (Page and Burr, 2011). Common Carp are widely adaptive in the ability to inhabit warm, deep, slow flowing waters, as well as faster moving large rivers and large lakes (Freyhof and Kottelat, 2007). Typically Common Carp select for woody debris and areas with lower stream velocity during most seasons except the winter when Common Carp tend to aggregate in deeper water (Butler and Wahl, 2010; García-Berthou, 2001; Johnsen and Hasler, 1977; Penne and Pierce, 2008; Verrill and Berry JR, 1995). During rising river streamflows, Common Carp generally move laterally into the floodplain possibly to take advantage of newly available resources (Jones and Stuart, 2009). Common Carp are mobile and can make large migrations for spawning to suitable backwaters and flooded vegetated areas (Banet et al., 2022). Reproductive success can be restricted to years when the water level starts rising in May and when high temperature and flooding of terrestrial vegetation last for a long period during May and June (Freyhof and Kottelat, 2007). Once water temperatures average over 61 °F spawning may occur (Smith, B. B. and Walker, 2004). Adults and juvenile Common Carp typically feed on benthic organisms and plant matter.

Silver Carp

Silver Carp are native to Eastern China and were introduced for aquaculture purposes to the U.S. in 1973. The current range of Silver Carp expands through the middle and lower Mississippi and Ohio River Basins (Page and Burr, 2011). Silver Carp show preference for backwaters and lower velocity areas, however the Wabash may be limited in this (Calkins et al., 2012; DeGrandchamp et al., 2008; Kolar et al., 2007; Prechtel et al., 2018) type of habitat. Silver Carp can make large movements upstream and downstream within large rivers, with mainly upstream movement in the spring followed in the fall by downstream movements (Coulter et al., 2016). Previous studies from the Wabash River found that acoustically tagged Silver Carp were most often found over sand which is the dominant substrate in the river segment sampled (Prechtel et al., 2018) and that fish movements were often associated with rises in streamflows in June and early July (Goforth and Coulter, 2011). General areas that Silver Carp congregate are around creek mouths and island side channels (Goforth and Coulter, 2011). Adults breed in rivers or tributaries over shallow rapids with gravel or sand bottom, in upper water layers or even at the surface during floods when the water level increases by 1.6 to 3.9 feet above normal level. Conditions for spawning include high current (1.6 to 5.6 ft/s), turbid water, temperatures above 59 °F (usually 65 to 79 °F) and high oxygen concentrations (Freyhof and Kottelat, 2007). Silver Carp diets consist of cyanobacteria, chlorophyta, and euglena, which overlaps with native filter feeders such as Gizzard Shad and Bigmouth Buffalo (*Ictiobus cyrpinellus*, (Minder and Pyron, 2018).

3.9 Threatened & Endangered Species

There are many species in the Upper Wabash watershed that are on the federal and state list of threatened and endangered species. Species become imperiled for a variety of reasons including over-hunting, overfishing, and habitat loss because of human development and pollution. Of these, habitat loss is the main contributor that imperils most of the species listed in Table 19. A threatened species is one that is likely to become endangered within the foreseeable future. An endangered species is one in danger of extinction throughout all or a significant portion of its range.

In the Upper Wabash, there are 10 species that are listed as either threatened or endangered and have the potential to occur in the watershed according to the U.S. Fish and Wildlife Service (USFWS). No critical habitat has been established in the Upper Wabash watershed counties, but some of the listed species that may be present in the watershed do have designated critical habitat in Indiana. The Bald Eagle (*Haliaeetus leucocephalus*) is common during the winter months and some stay year-round. Although the Bald Eagle was delisted by the USFWS in 2007 due to recovery of the species, both the Bald and Golden Eagles are still protected in accordance with the Bald and Golden Eagle Protection Act.

Three federally listed bat species are known to occur in the watershed: Northern Long-eared Bat (*Myotis septentrionalis*), Indiana Bat (*Myotis septentrionalis*), and Tricolored Bat (*Perimyotis subflavus*). These three species are not directly impacted by stream flows, but a more diverse and natural riverine system would likely benefit these bat species by supporting healthy insect populations, which are a food source for the bats. The Indiana Bat has critical habitat in Crawford and Greene Counties.

Federally listed mussels are known to occur in the Upper Wabash. While there are additional species found in the lower reaches of the Wabash, the primary focus will be on the Upper Wabash from the upper extent of J.E. Roush Lake extending downstream to Logansport. Fisher (2006) documented 75 species historically from the Wabash River; however, only 30 species are still reproducing in the mainstem, and 18 species are now restricted to tributaries. There are four federally endangered or threatened freshwater mussel species identified for counties within the Upper Wabash watershed (Cass, Miami, Huntington, and Wabash Counties): Fanshell (*Cyprogenia stegaria*; endangered), Rabbitsfoot (*Theliderma cylindrica*; threatened), Round Hickorynut (*Obovaria subrotunda*; threatened), and the Snuffbox Mussel (*Epioblasma triquetra*; endangered). If present, all these endangered or threatened mussels are dependent on adequate streamflows and all are susceptible to sedimentation and poor water quality. The Rabbitsfoot and Round Hickorynut have designated critical habitat in the Tippecanoe River.

One insect species, the Monarch Butterfly (*Danaus plexippus*), is listed as a candidate for federal listing, but is not officially threatened or endangered.

The species list in Table 19 was generated from data obtained through the USFWS Information for Planning and Consultation (IPaC) tool, which generates federally listed species lists based on areal extent of proposed actions.

Table 19. Federally threatened and endangered species with the potential of occurring.

Threatened and Endangered Species		
Mammals		
Common Name	Scientific Name	Federal Status
Indiana Bat	*Mytotis sodalist*	Endangered
Northern Long-Eared Bat	*Myotis septentrionalis*	Endangered
Tricolored Bat	*Perimyotis subflavus*	Proposed Endangered
Reptiles		
Common Name	Scientific Name	Federal Status
Eastern Massasauga (Rattlesnake)	Sistrurus catenatus	Threatened
Clams		
Common Name	Scientific Name	Federal Status
Fanshell	*Cyprogenia stegaria*	Endangered
Rabbitsfoot	*Theliderma cylindrica*	Threatened
Round Hickorynut	*Obovaria subrotunda*	Threatened
Snuffbox Mussel	*Epioblasma triquetra*	Endangered
Insects		
Common Name	Scientific Name	Federal Status
Monarch Butterfly	*Danaus plexippus*	Candidate

4.0 Riverine Flow Restoration

4.1 Purpose and Need for Restoration

The negative impacts of dams on stream ecosystems is well documented, and many researchers have published research specific to the Upper Wabash ecosystem. Below is a brief discussion of some of the more prominent work that has been completed on the Upper Wabash River in addition to other work that has been completed to document impacts of dams and altered flow regimes on stream ecology. The hydrologic regime of a stream has a cascading effect on almost all other ecological aspects of that stream (Richter et al., 1998; Revenga et al., 2000; Bunn and Arthington, 2002). The magnitude, timing, duration, and frequency of floods, high flows, and low flows each have implications for the floodplain and streambed morphology, water quality, and riverine habitat. Flora and fauna life histories have evolved over time along with the natural hydrologic regimes of streams and rivers in their native habitat.

As discussed in Hart et al. (2022), “previous studies that examine the effects of dams on fish assemblages may provide important insight into flow-ecology relationships for fishes. Larval fish abundance was more than three times higher in a non- regulated river (77 percent of fish collected) than a regulated, hydropeaking river in Alabama (Scheidegger and Bain, 1995). Minnows comprised 71 percent of larval fish in the reference stream but comprised only 12 percent at the regulated river. The regulated system had a much higher proportion of Centrarchidae (stronger, faster swimmers that can quickly find flow refuges behind logs, undercut banks, etc.) close to the dam (7.5 miles downstream) more than likely because of the hydropeaking nature of the system (sub-daily fluctuations), and proportional abundance declined far downstream of the dam (i.e., 38.5 miles downstream). The greatest concentration of larval fish was in the river margin, and the vast majority of larva, especially cyprinids, were collected from shallow, slow, nearshore habitats. Microhabitat use showed that catostomid larvae were most abundant in shallow habitats adjacent to the stream banks with vegetation. Many fluvial specialist species are sensitive to the effects of dams (e.g., Bain et al., 1988; Quinn and Kwak, 2003), and many of the species use shallow, slow water areas (Bain et al., 1988; Aadland, 1993) that disappear with frequent discharge changes. In a companion study (Kingsolving and Bain, 1993), abundance of juvenile and adult fishes was greater than 6.5 times higher in the river with the natural flow regime compared to the regulated river with altered hydrology. This study noted a riverine recovery gradient along the regulated river with fluvial specialist species increasing with distance downstream. This study noted much lower abundance of several native minnows in the regulated river, including *Campostoma oligolepis*, *Cyprinella spp., Notropis ammophilus, Notropis volucellus, Pimephales vigilax.* In contrast, more *Lepomis macrochirus* and *Gambusia affinis* were collected in the regulated river. Several generalist species had similar abundances among rivers, including *Lepomis megalotis*, Black Basses, and *Fundulus olivaceus*."

As discussed in Hart et al. (2022), "Walburg et al. (1983) compared water quality, macroinvertebrates, and fish downstream of seven USACE Dams, including two flood control projects with warm-water releases (Pine Creek Dam, Oklahoma, and Gillham Dam, Arkansas), two flood control dams with cold-water releases (Barren River and Green River Dams, Kentucky), and three hydropower facilities with cold-water releases (Beaver, Hartwell, and Narrows Dams). Macroinvertebrates were sampled with drift and Hess samplers. Sample results suggest that a riverine recovery gradient exists below dams, and sites upstream are dominated by tolerant taxa and downstream sites have more Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa."

Pyron, et al. (2006) showed that the overall fish assemblage in the Wabash River changed from 1974 to 1998, which is directly after construction of the J.E. Roush, Mississinewa, and Salamonie Dams. Hydrologic alterations on the Upper Wabash, including J.E. Roush, Mississinewa, and Salamonie Dams have undoubtedly led to ecological degradation and changes to river-dependent species assemblages (Pyron and Neumann, 2008). As shown in this report, and as described by others, construction of the dams has increased minimum flows, decreased maximum flows, increased fall rates, decreased summer monthly flows, and decreased high pulse counts as compared to pre-dam flows (Pyron and Neumann, 2008). Several studies on the Wabash River recommend that restoration of historical natural hydrologic patterns downstream of the dams would improve habitat and species diversity (Pyron and Lauer, 2004; Pyron, et al., 2020).

Jacquemin, et al., 2014 found that high magnitude flow events were positively correlated with increased growth rates of freshwater drum in the Wabash River, and that the magnitude, rather than timing of flow events, was more closely related to fish growth. Reduced high-flow magnitudes and elevated low flows below the three dams are hypothesized to be associated with riverine habitat degradation. Hart et al. (2022) points out that "Carlisle et al. (2010) examined the biological alteration associated with stream flow alteration at 2,888 sites throughout the United States. This study reported 86 percent of sites had altered minimum and maximum flow magnitude. Diminished flow magnitudes were predictors of biological impairment (i.e., IBI scores), and systems with depleted flows tend to have generalist species that are tolerant of silt substrate and lentic habitats. Streams with diminished minimum or maximum flows shifted from simple nesting to nest- guarding or broadcast-spawning strategies and active swimmers replaced benthic-oriented streamlined fish species. Poff and Zimmerman (2010) in their review of ecological responses to altered flows also noted that fish diversity consistently declined where flow magnitudes exceeded 50 percent change."

4.2 Flow Alteration Description, Effects, and Ecological Responses

Flow-ecology hypotheses are designed to describe how specific taxa and ecological process are expected to respond to changes to the flow regime. Related hypotheses can be aggregated based on similar timing, flow-sensitive life stages and ecosystem function into a set of related flow needs that combine one or more responses of a group of taxa expected to respond similarly to a change in flow conditions.

In Midwestern rivers, high streamflow events and floods provide cues for fish migration, maintain channel and floodplain habitats, inundate submerged and floodplain vegetation, transport organic matter and fine sediment, and help maintain temperature and DO concentrations. These events range from relatively small, flushing pulses of water (e.g., after a summer rain) to extremely large events that reshape floodplains but historically have occurred infrequently (e.g., large snowmelt or rain-on-snow events, and/or major regional spring and summer storm events such as what occurred in 2019). For the purposes of defining e-flow components as per Matthews and Richter (2007), we distinguish between high flow pulses, small floods, and large floods. High flow pulses refer to low rises above seasonal flows that remain within the channel. "Small floods" are those that typically exceed bankfull streamflow, when flood waters allow fish and other organism's access to floodplains or flooded wetlands, secondary channels, backwaters, sloughs, and other off-channel habitats. In the Midwest, these typically occur on a 2- to 5-year recurrence interval. "Large" or "extreme" floods will often re-shape the physical structure of the channel and floodplain, scouring some areas and depositing sediment in others to form new channels, point bars, and off-channel habitats. We represent these floods as those with a 5 percent probability or lower (20-year recurrence interval or more). Increased magnitude and/or frequency on any of these types of events can lead to channel instability, floodplain, and riparian disturbance, and/or prolonged floodplain inundation. Reduced frequency of these events typically leads to channel aggradation, loss of floodplain inundation, and altered vegetation communities. Although the bankfull and overbank events that provide channel and floodplain maintenance commonly occur in May to July in the Upper Wabash River system, these events can occur in any season.

Seasonal flows provide habitat for spring, summer, and fall spawning fishes and mussels; ensure that eggs in nests, redds, and various substrates are wetted; provide overwinter habitat and prevent formation of anchor ice; maintain bank habitat for nesting and hibernating mammals/herpetofauna; and maintain a range of persistent habitat types. Naturally occurring variability within seasons helps maintain a variety of habitats and provides conditions suitable for multiple species and life stages.

Seasonal flows, often represented by median daily and monthly streamflows, are correlated with area and persistence of critical fish habitat, juvenile abundance and year-class strength, juvenile and adult growth, and overwinter survival. These streamflows represent a "typical" range of streamflows in each month and are useful for describing variation between seasons (e.g., summer and fall). Most of the time, in all but the wettest and driest portions of the streamflow record, streamflows are within this range.

Low streamflows provide habitat for aquatic organisms during dry periods, maintain floodplain soil moisture and connection to the hyporheic zone, and maintain water temperature and DO. Although low streamflow events naturally occur, decreases in streamflow magnitude, and increases in frequency or duration of low streamflow events affect species abundance and diversity, habitat persistence and connectivity, water quality, increase competition for refugia and food resources, and decrease individual species' fitness. When they do occur, extreme low streamflows enable recruitment of certain aquatic and floodplain plants; these periodic disturbances help maintain populations of a variety of species adapted to different conditions. Decreases in low streamflow magnitude have been correlated with changes to abundance and diversity of aquatic insects, mussels, and fish. Low streamflows also influence habitat persistence and connectivity, including riffle, pool, backwater and hyporheic habitats critical for fish, aquatic insect, crayfish, mussel, and reptile reproduction and juvenile and adult growth. Water quality, specifically DO concentrations, is directly correlated to low streamflow magnitudes. Streamflow ecology hypotheses are designed to describe how specific taxa and ecological processes are expected to respond to changes to the streamflow regime. Related hypothesis can be aggregated, based on similar timing, streamflow-sensitive life stages, and ecosystem function, into a set of related streamflow needs that combine one or more responses of a group of taxa that are expected to respond similarly to streamflow condition changes.

4.2.1 Regulated and Unregulated Flows

We compared regulated (modified) and unregulated (natural) streamflows to determine the change in streamflow regime. This analysis was completed for periods before and after dam construction using the Indicators of Hydrologic Alteration (IHA) software, developed by TNC. The IHA calculates a total of 67 statistical parameters, subdivided into two groups: 33 IHA parameters and 34 E-flow Component (EFC) parameters. Given that the observed streamflow datasets are likely skewed, the parameters were calculated using non-parametric statistics. When analyzing the change between two time periods, the IHA software enables users to implement the Range of Variability Approach (RVA; Richter et al., 1997). The RVA uses the pre-project natural variation of IHA parameter values as a reference to determine the extent to which the natural streamflow regime has been modified. RVA analysis also generates a series of Hydrologic Alteration factors, calculated as:

(Observed Frequency – Expected Frequency) / Expected Frequency

This calculation determines the degree of alteration of the 33 IHA streamflow parameters. A positive Hydrologic Alteration value means that the frequency of values in the category has increased from the pre-construction to the post-construction period, while a negative value means that the frequency of values has decreased (The Nature Conservancy, 2009). Summaries of the greatest hydrologic alteration values for each of the six gages are shown in Figure 31 through Figure 36.

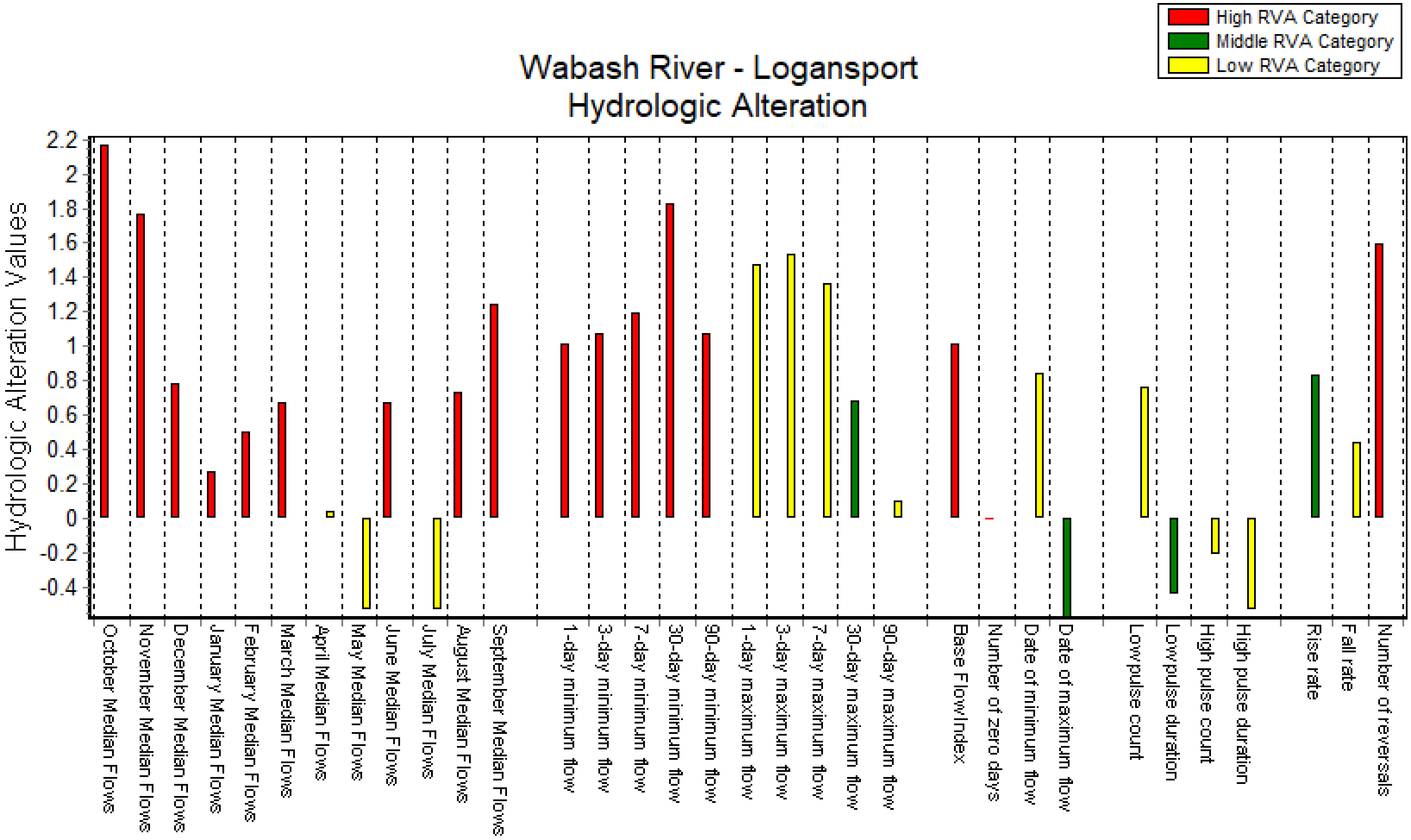

Figure 31. Greatest Indicators of Hydrologic Alteration – 'Wabash River at Logansport'

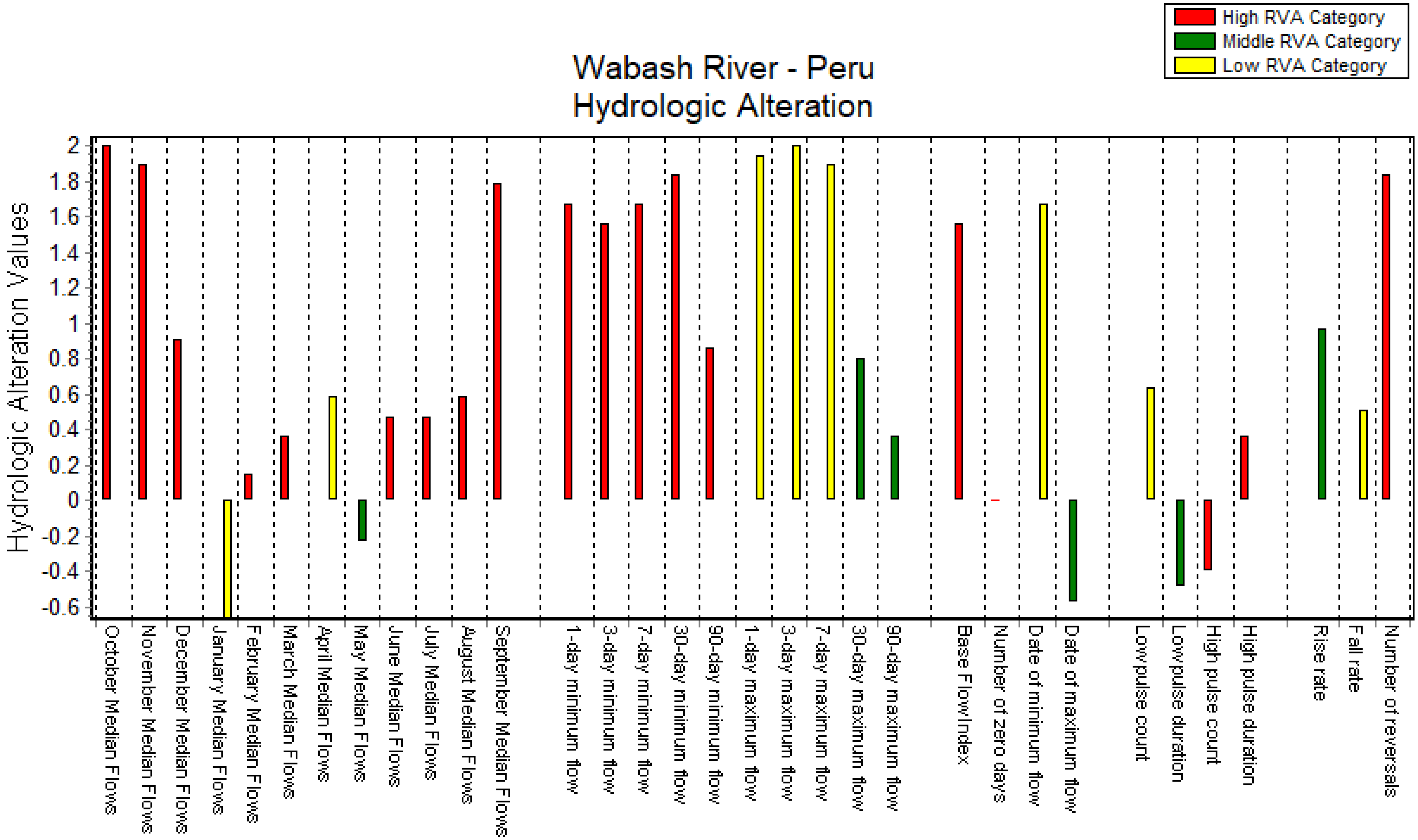

Figure 32. Greatest Indicators of Hydrologic Alteration – 'Wabash River at Peru'.

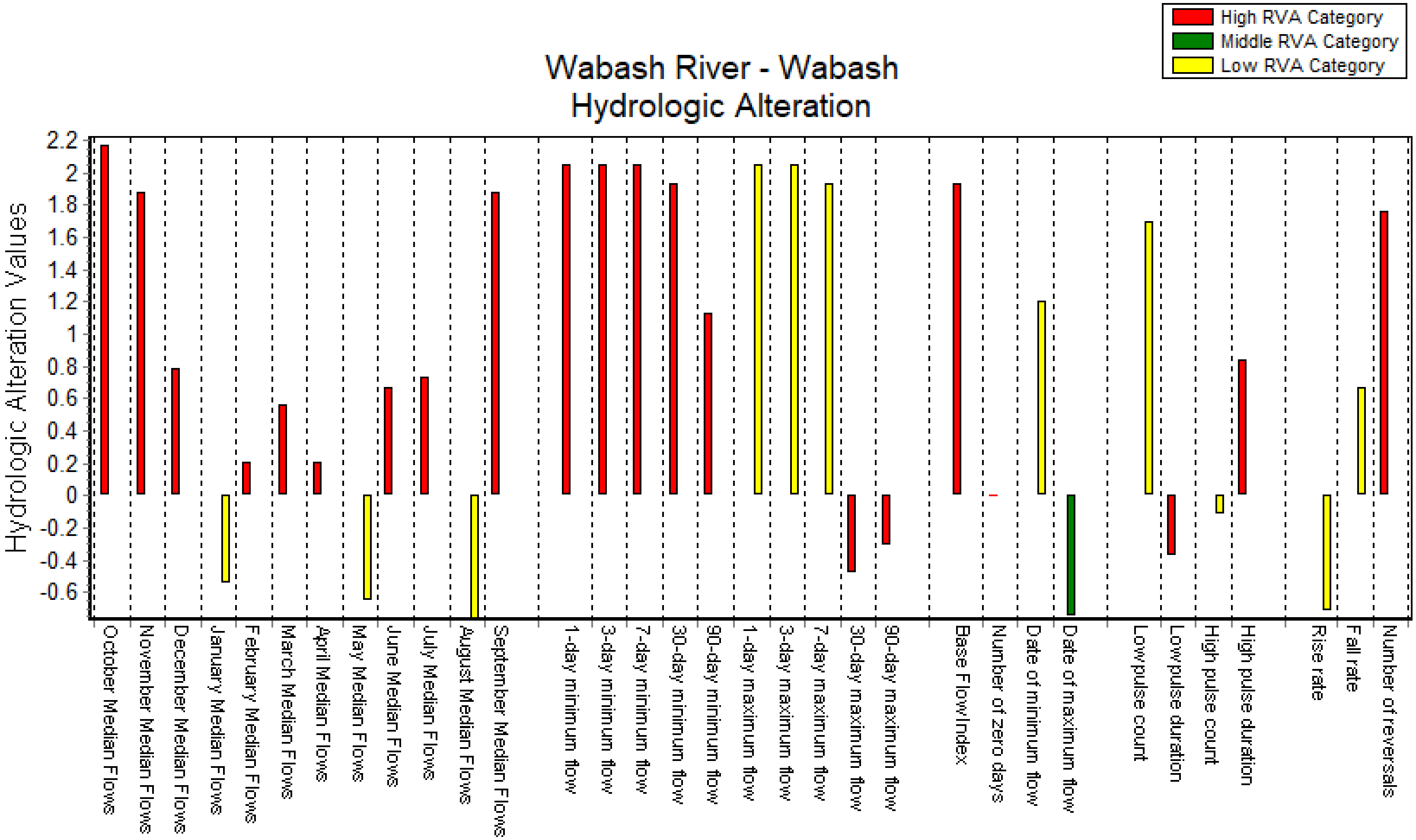

Figure 33. Greatest Indicators of Hydrologic Alteration – 'Wabash River at Wabash'.

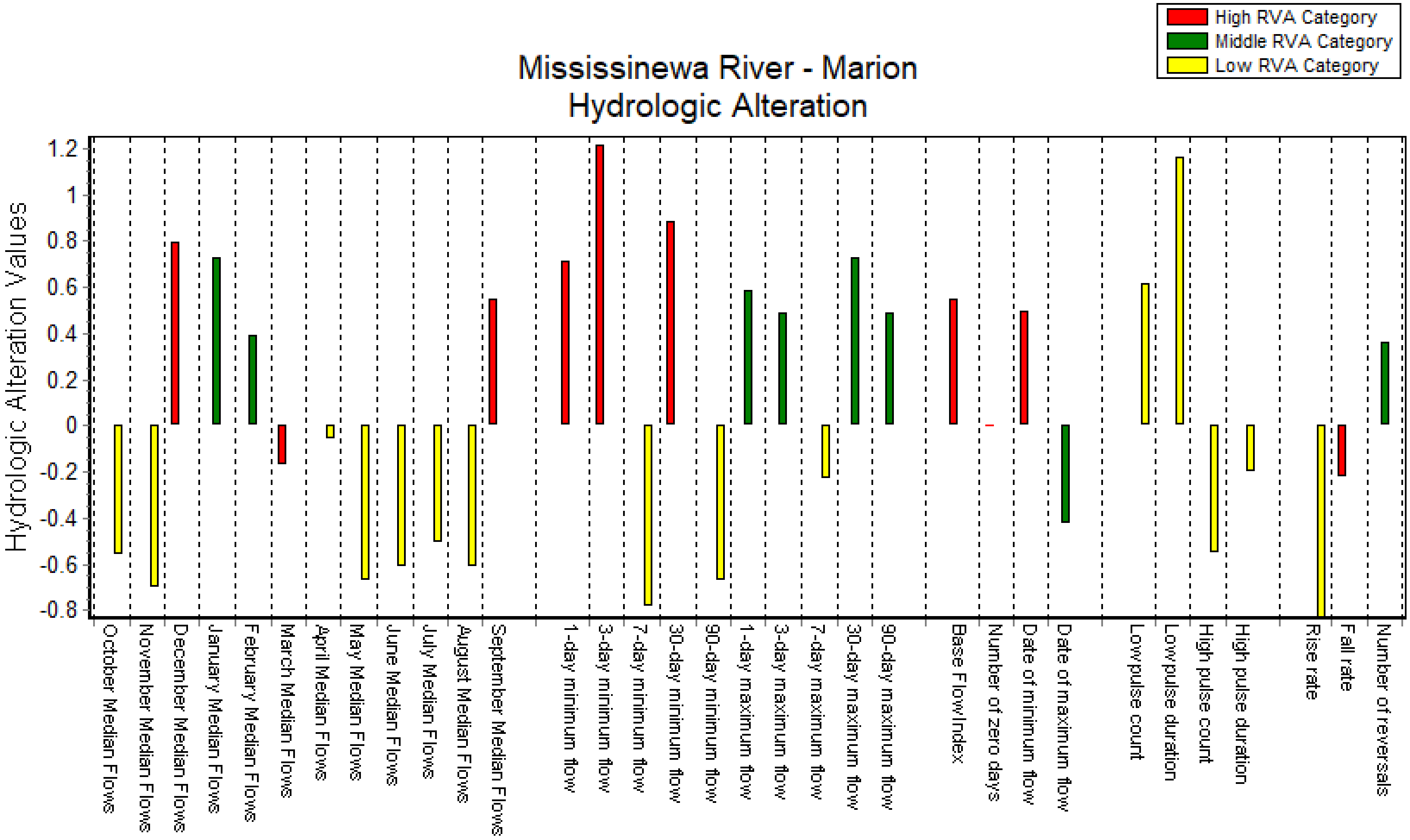

Figure 34. Greatest Indicators of Hydrologic Alteration – 'Mississinewa River at Marion'.

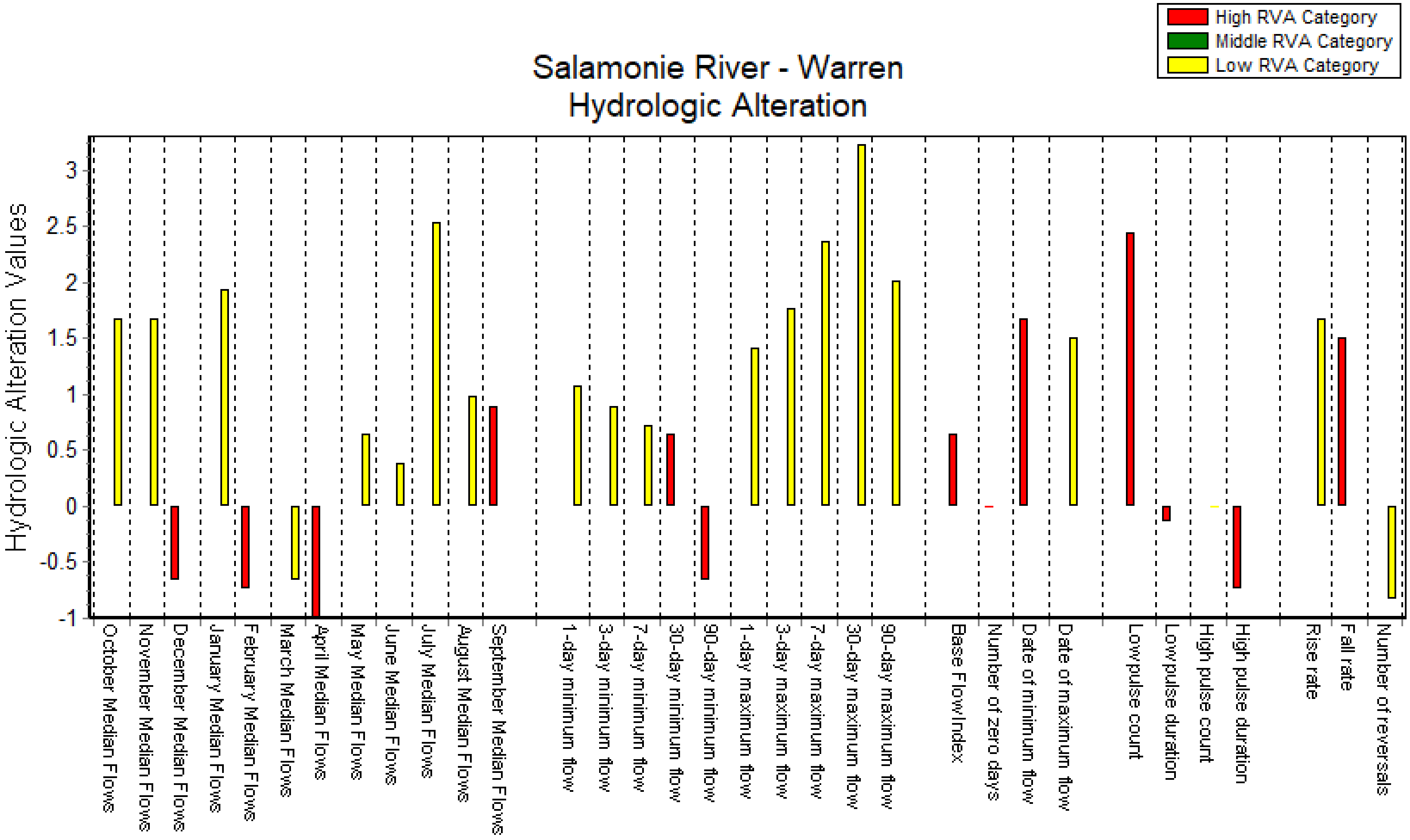

Figure 35. Greatest Indicators of Hydrologic Alteration – 'Salamonie River near Warren'.

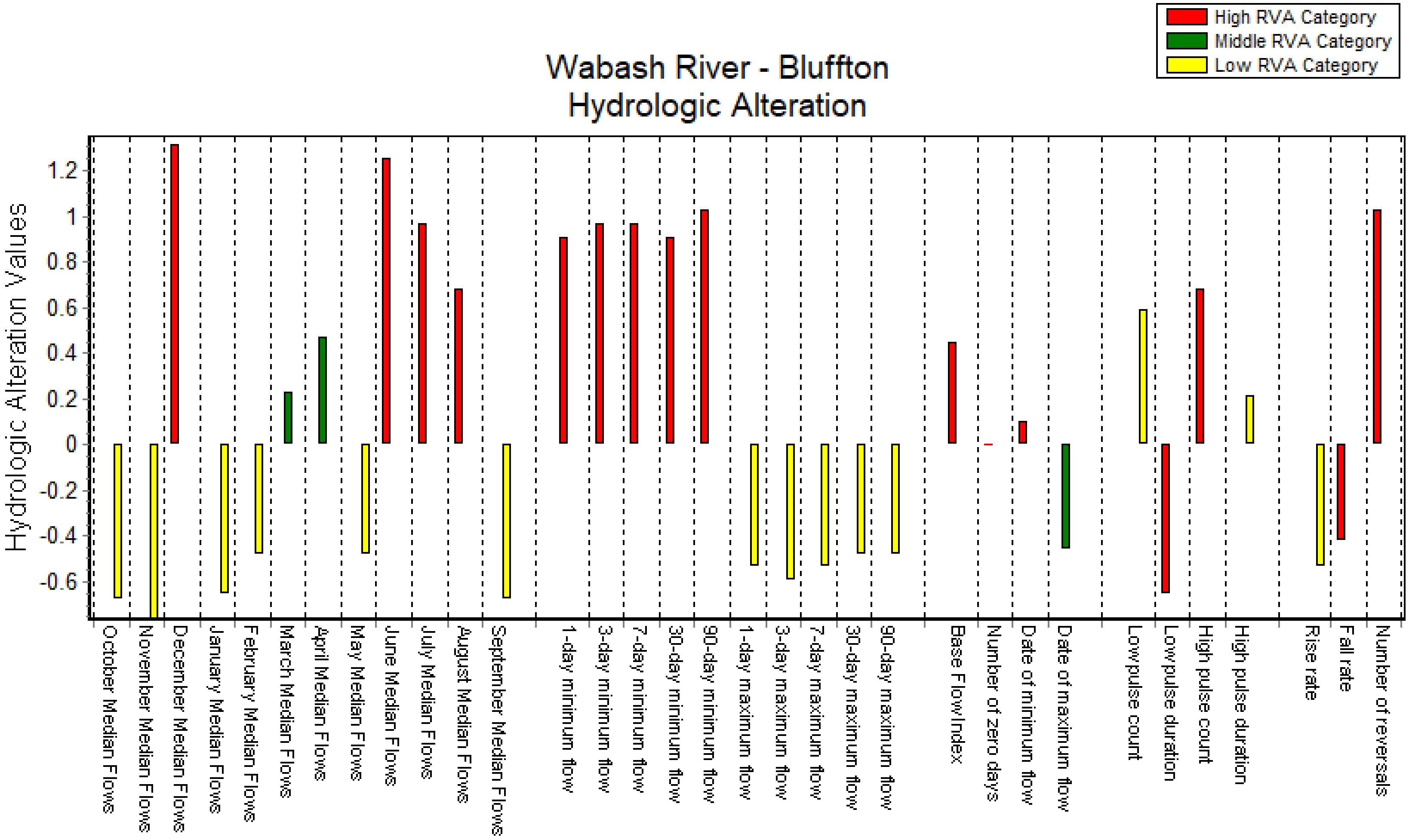

Figure 36. Greatest Indicators of Hydrologic Alteration – 'Wabash River at Bluffton'.

4.2.2 Indicators of Hydrologic Alteration

The 33 calculated IHA parameters are divided into five parameter groups: magnitude of monthly water conditions, magnitude and duration of annual extreme water conditions, timing of annual extreme water conditions, frequency and duration of high and low pulses, and rate and frequency of water condition changes.

Parameter Group 1 represents the magnitude of monthly water conditions and consists of 12 parameters. Changes in the mean or median monthly streamflow can impact the habitat and food/cover for aquatic and semiaquatic organisms, reliability of water supplies for terrestrial animals, and water quality (e.g., temperature, oxygen level, photosynthesis in the water column).

Parameter Group 2, the magnitude and duration of annual extreme water conditions, describes these changes through a set of 12 parameters consisting of the annual minima and maxima of mean values aggregated over various time periods. Hydrograph attenuation is an intentional consequence of dams which potentially has deleterious impacts on downstream ecosystems. Changes in natural streamflows can alter the structure of river channel morphology and physical habitat conditions or the balance of competitive, ruderal and stress-tolerant organisms.

Parameter Group 3 consists of 2 parameters – the Julian date of each annual 1-day maximum and minimum. In addition to the magnitude and duration of annual extreme conditions, hydrograph attenuation can also impact the timing of these events. This may potentially impact the compatibility of life cycles of organisms within the waterway or the ability for species to access unique habitats during reproduction or to avoid predation.

Parameter Group 4 characterizes the frequency and duration of low and high pulses. Periodic flood pulses are a natural occurrence that can influence soil moisture, induce anaerobic stress in floodplain vegetation, and increase availability of floodplain habitats for aquatic organisms. Larger pulses transport more sediment, which impacts nutrient and organic matter cycling in the river and the inundated floodplain.

Parameter Group 5 consists of three parameters describing the rate of rise and fall of streamflow values and the number of hydrologic reversals. Rapid changes in streamflow conditions can result in drought stress in plants, organisms becoming trapped on islands within the waterway or floodplain or induce desiccation stress on low mobility stream-edge organisms.

4.2.3 E-flow Components

The IHA calculates parameters for five different types of EFCs: low streamflows, extreme low streamflows, high pulse streamflows, small floods, and large floods. This delineation of EFCs is based on the realization by research ecologists that river hydrographs can be divided into a repeating set of hydrographic patterns that are ecologically relevant. It is the full spectrum of flow conditions represented by these five types of flow events that must be maintained to sustain riverine ecological integrity. Not only is it essential to maintain adequate streamflows during low streamflow periods, but higher streamflows and floods and also extreme low streamflow conditions perform important ecological functions (The Nature Conservancy, 2009).

Low streamflows represent the dominant streamflow condition in most rivers. In natural rivers, after a rainfall event or snowmelt has passed and associated surface runoff from the catchment has subsided, the river returns to its base- or low-streamflow level. These low streamflow levels are sustained by groundwater discharge into the river. The seasonally varying low-streamflow levels in a river impose a fundamental constraint on the river's aquatic communities because it determines the amount of aquatic habitat available for most of the year. This has a strong influence on the diversity and number of organisms that can live in the river (The Nature Conservancy, 2009).

During drought periods, rivers drop to very low levels that can be stressful for many organisms but may provide necessary conditions for other species. Water chemistry, temperature, and DO availability can become highly stressful to many organisms during extreme low streamflows, to the point that these conditions can cause considerable mortality. On the other hand, extreme low streamflows may concentrate aquatic prey for some species or may be necessary to dry out low-lying floodplain areas and enable certain species of plants such as bald cypress to regenerate (The Nature Conservancy, 2009).

During small floods, fish and other mobile organisms can move upstream, downstream, and out into floodplains or flooded wetlands to access additional habitats such as secondary channels, backwaters, sloughs, and shallow flooded areas. These usually inaccessible areas can provide substantial food resources. Shallow flooded areas are typically warmer than the main channel and full of nutrients and insects that fuel rapid growth in aquatic organisms. As used here, a “small flood” includes all river rises that overtop the main channel but does not include more extreme, and less frequent floods (The Nature Conservancy, 2009).

Extreme floods will typically re-arrange both the biological and physical structure of a river and its floodplain. These large floods can literally flush away many organisms, thereby depleting some populations but in many cases also creating new competitive advantages for other species. Extreme floods may also be important in forming key habitats such as oxbow lakes and floodplain wetlands (The Nature Conservancy, 2009).

Although streamflow statistics were calculated for all the gages, only those downstream of the projects are considered in the following analyses since they are impacted by the construction of the dams. For these analyses, the streamflow data was separated into two periods, one representing the historical period prior to the construction of the dams (pre-project, natural) and the other representing the period after construction had been completed (post-project, modified). Streamflow characteristics representing each of the IHA and EFC parameter groups are described in further detail in the following sections.

4.2.4 Magnitude of Monthly Water Conditions

Magnitude is an important aspect of the streamflow regime as it has frequently been linked to ecological impairment (Poff and Zimmerman 2010, as referenced in Carlisle et al., 2010) and has clear implications for water management (Postel and Richter 2003, as referenced in Carlisle et al., 2010). Although there were increases across all months, the most notable changes occurred for the October, November and December median flows, as shown in Figures C.31, C.32, and C.33. This is to be expected, however, as drawdown from summer pool to winter pool occurs during this period.

4.2.5 Magnitude and Duration of Annual Extreme Water Conditions

Under unregulated (natural) conditions, a waterway is susceptible to not only extreme flood conditions, but also drought. Periods of relatively dry weather result in low streamflow in the waterway. When regulated (modified), however, water managers are better able to maintain a minimum streamflow in the channel from the projects. This occurrence is observed in Figure C.34, where the modified streamflow of the 90-day minimum discharge is double or more than that of the natural condition. Conversely, flows from storm events are attenuated, decreasing peak annual values, as shown in Figures C.35 and C.36.

4.2.6 Timing of Extreme Water Conditions

While the timing of extreme water conditions will be dependent on varying meteorologic conditions from year to year, trends may still emerge when comparing datasets from unregulated (natural) and regulated (modified) conditions. As shown in Figure C.35, not only was the maximum annual discharge decreased after the construction of the dams, it also began to occur earlier in the year by approximately ten days (C.37). The minimum low flow condition continuing to occur at or near the same time each year for both periods is not unexpected (Figure C.38). While low flow releases from the project would drive the average annual value, inflows from unregulated subbasins downstream could continue to lessen the average annual value at or about the same time each year.

3.5.6.7 Frequency and Duration of High and Low Pulses

The attenuation of flood pulses will dampen peak discharges and sustained minimum releases will augment natural flows to low streamflow pulses. It is also to be expected that the duration of regulated (modified) flood pulses to be protracted compared to the unregulated (natural) event because of attenuation, although the number of pulses will largely remain unchanged. As shown in Figure C.39, it is observed across two of the three gages that the low pulse count after dam construction is approximately 66 percent of the pre-dam condition.

4.2.7 Rate and Frequency of Water Condition Changes

There were relatively minor differences between the natural and modified rise rates at the downstream gage locations, although a more pronounced difference was seen at the Wabash gage (Figure C.40). Fall rates, however, were seen to increase by 33 to 50 percent (Figure C.41). Similarly, the number of reversals, as seen in Figure C.42, was seen to increase across all three gages.

4.2.8 Low Streamflows

Changes between the natural and modified low streamflow values along the Wabash River were most pronounced in December through February, consistent with the values shown in Figure C.43. Differences persist in the remaining months to a lesser extent and, in some instances, presenting as a decrease in regulated (modified) low streamflows.

4.2.9 Extreme Low Streamflows

The occurrence of extreme low streamflow values is a natural occurrence, present in the stream, prior to the construction of the dams. As shown in Figure C.44, however, these are no longer presented in the regulated (modified) stream. Sustained minimum releases from the projects ensure a base flow persists throughout the summer.

4.2.10 High-Flow Pulses

The characteristics describing high streamflow pulses – peak, duration, timing, frequency, and rise/fall rates – were most impacted by the regulation of the waterway by the Mississinewa, Salamonie, and J.E. Roush dams. The high streamflow peak values were suppressed but occurred for slightly longer periods of time during the high streamflow events. The rise rate decreased, as shown in Figure C.45, consistent with the attenuation of the hydrographs.

4.2.11 Small Floods

The characteristics of small floods showed a consistent modification as did the high flow pulses. Peak flows and peak flow durations were suppressed and occurred for slightly longer periods of time. The small flood rise rates were also decreased (Figure C.46).

4.3 Flow Restoration Goals & Objectives

The goals and objectives of flow restoration implemented at SRP sites is dependent on the potential and realized environmental opportunities. As mentioned in this report, the primary mission for the Mississinewa, Salamonie, and J.E. Roush dams is FRM, so e-flow modifications will always be limited to streamflows that still maintain the FRM mission. For example, an e-flows prescription could include timing high-flow releases to coincide with high water events to help supplement flows and to achieve a higher flow volume in the mainstem. Alternatively, streamflow releases could be minimized during low streamflow events to more accurately mimic natural low streamflow events that have been all but eliminated since construction of the three dams. Warner et al. (2014) referred to this as "episodic implementation driven by changing hydrologic conditions in the watershed—such as a large storm event or an extended period of drought— that in turn allow for or require changes in reservoir releases." The overall goal of streamflow restoration work at the Upper Wabash will be to investigate, test, and monitor restorative flow recommendations and the associated ecological and environmental responses if restorative flows are feasible.

The next steps in the SRP process for the Upper Wabash are to:

- Convene and gather feedback from Subject Matter Experts on this report,
- Conduct an Environmental Flows Workshop to test flow regimes of wet, dry and normal flow conditions of several reaches, and
- Pursue feasibility of implementing a flow prescription at one or more of the reaches.

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Appendix A – Important Studies & Reports

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Poff, N. L., Tharme, R. E., and Arthington, A. H. (2017) Chapter11: Evolution of environmental flows assessment science, principles, and methodologies in Water for the Environment: from Policy and Science to Implementation and Management: eds A. Horne, J. Webb, M. Stewardson, M. Acreman, and B. D. Richter, Cambridge, MA: Elsevier, 203-236.

Pyron, M. and Neumann, K. (2008). Hydrologic alterations in the Wabash River Watershed, USA. River Research and Applications 24:1175-1184

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Appendix B – Summary Table of Data Gathered

Data Used for State of the Science Report

Subject	Source	Dates
Macroinvertebrate Sampling	Indiana Department of Environmental Management	1990-current
Fish Sampling	Indiana Department of Environmental Management	1998-2022
Fish Species	Indiana Department of Natural Resources	1990-current
QHEI	Indiana Department of Environmental Management 2022	1998-
Water Quality Impairments (303(d))	Indiana Department of Environmental Management	2022
Water Quality data, algal, reservoirs	Indiana Department of Environmental Management	2022
Water Quality data, reservoirs	Annual Water Quality Monitoring, USACE	2021

Appendix C – Hydrology

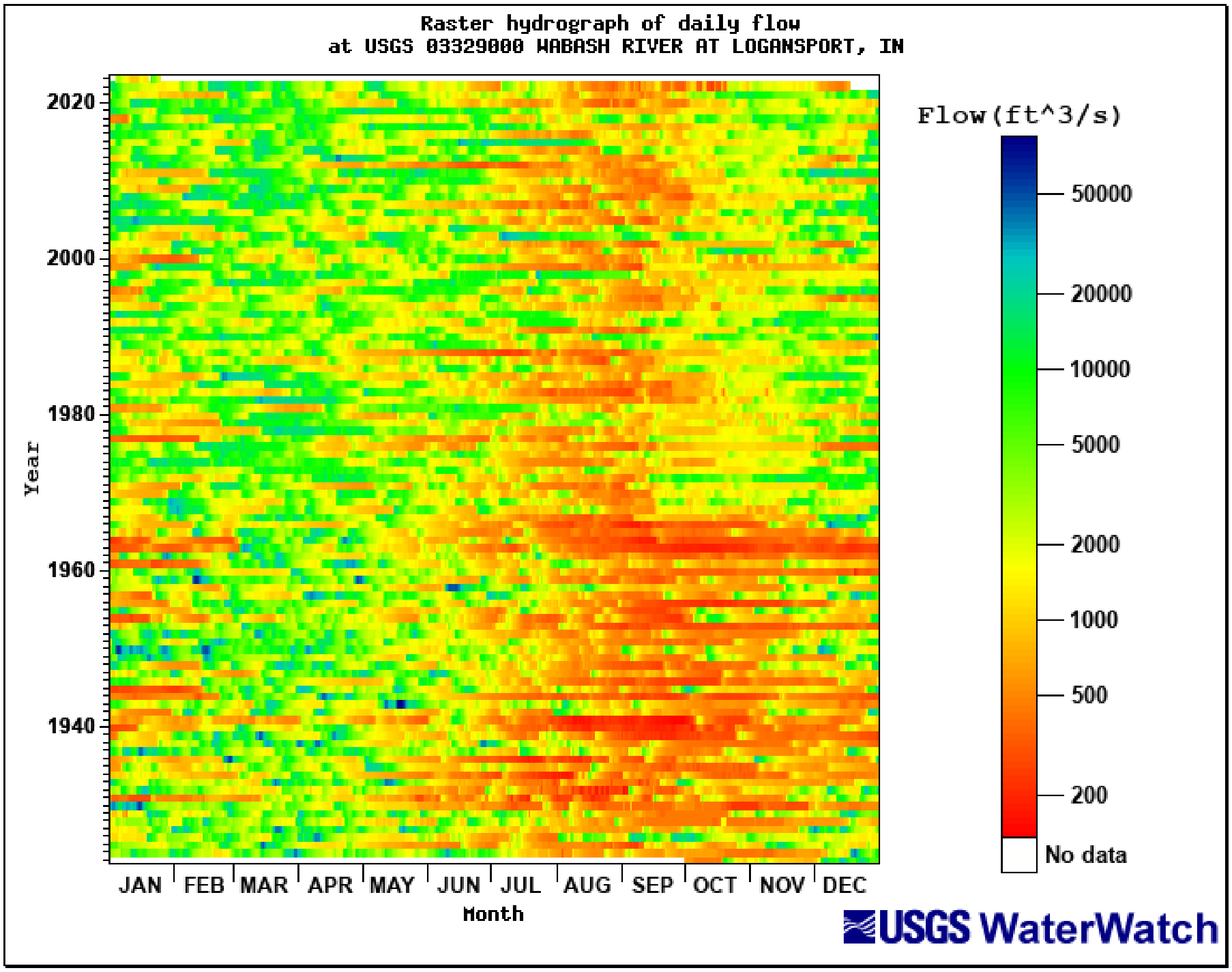


Figure C.1.Wabash River at Logansport, Indiana, daily streamflow data. Plot obtained from the National Weather Service River Forecast Center.

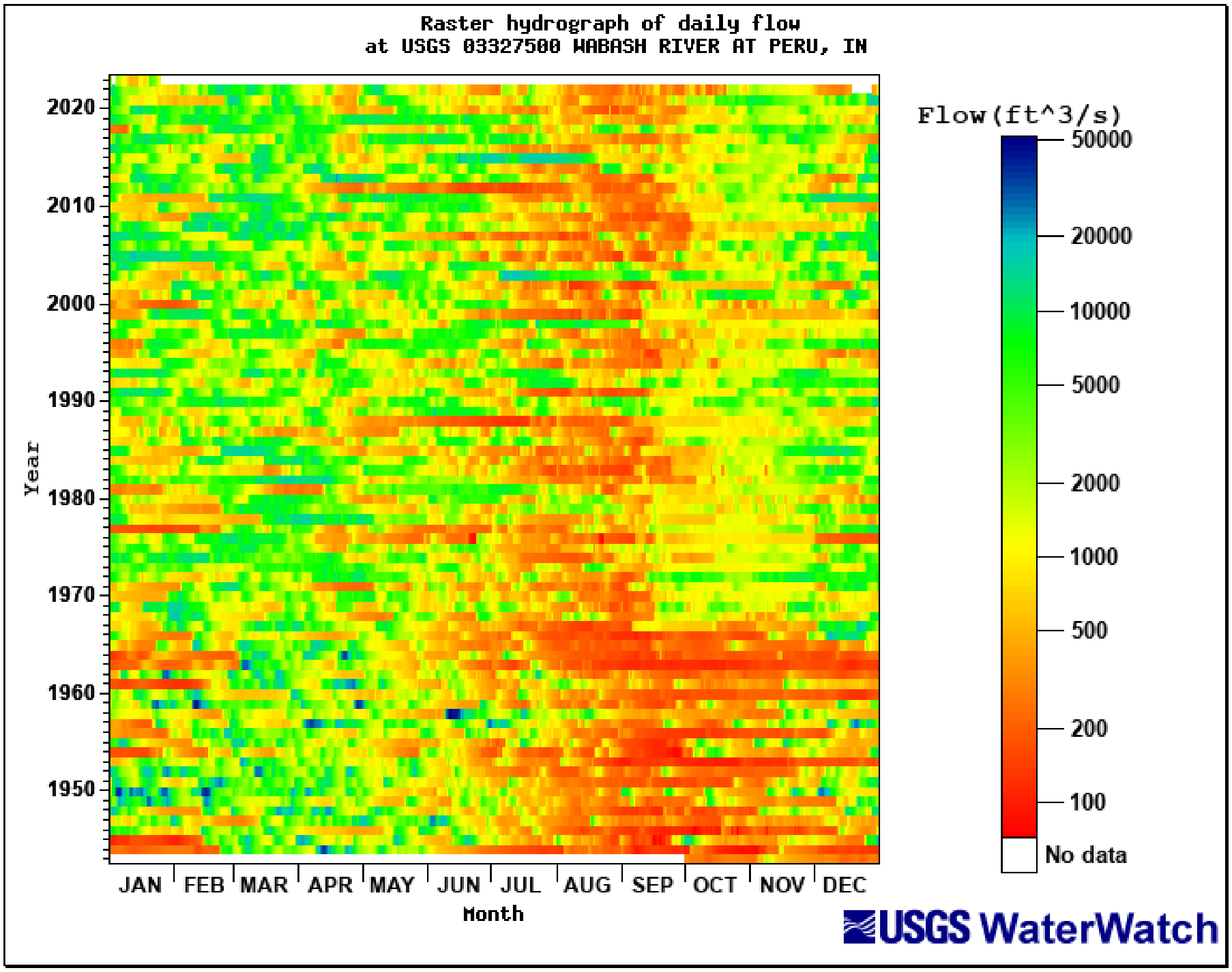


Figure C.2. Wabash River at Peru, Indiana, daily streamflow data. Plot obtained from the National Weather Service River Forecast Center.

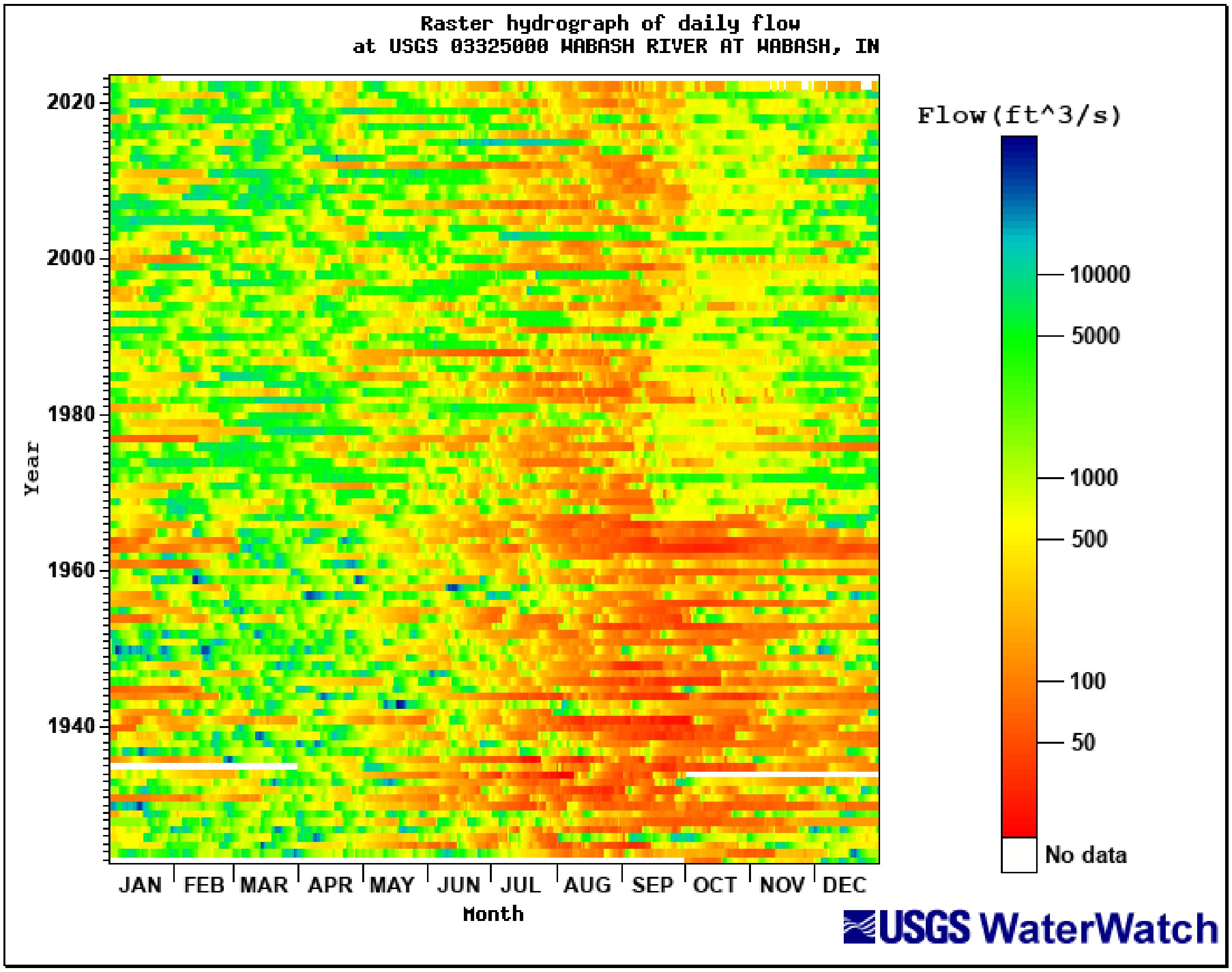


Figure C.3. Wabash River at Wabash, Indiana, daily streamflow data. Plot obtained from the National Weather Service River Forecast Center.

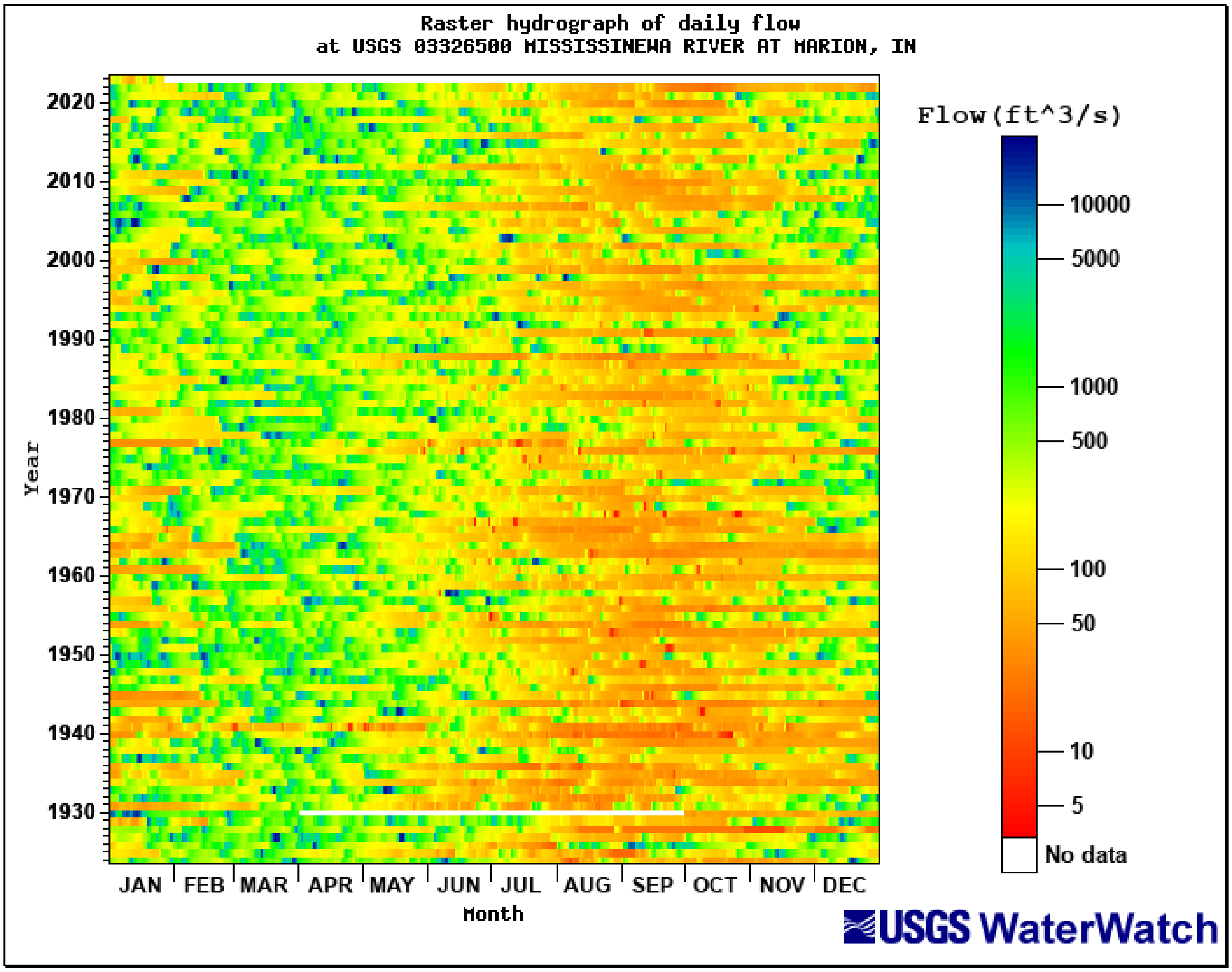


Figure C.4 Mississinewa River at Marion, Indiana, daily streamflow data. Plot obtained from the National Weather Service River Forecast Center.

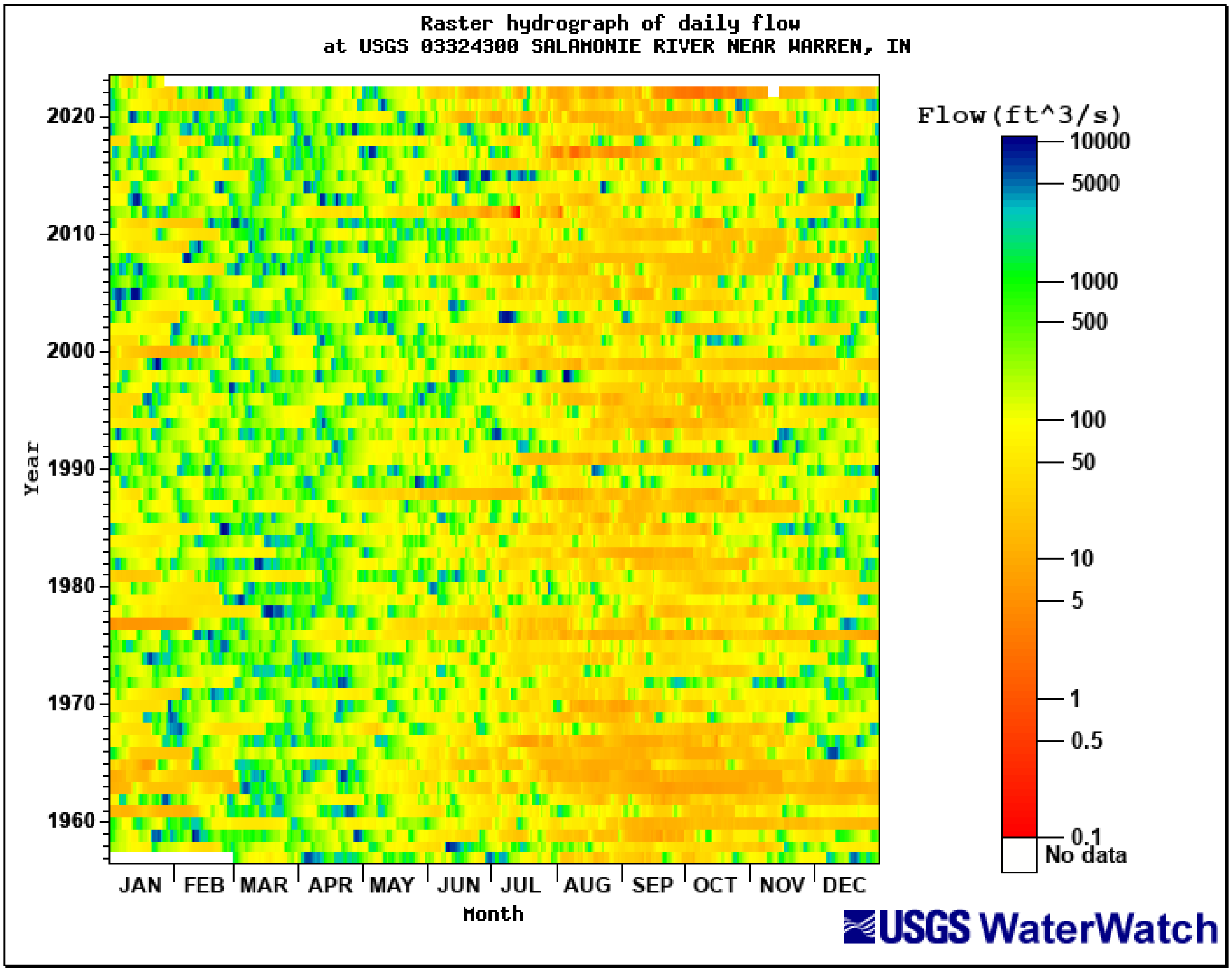


Figure C.5. Salamonie River near Warren, Indiana, daily streamflow data. Plot obtained from the National Weather Service River Forecast Center.

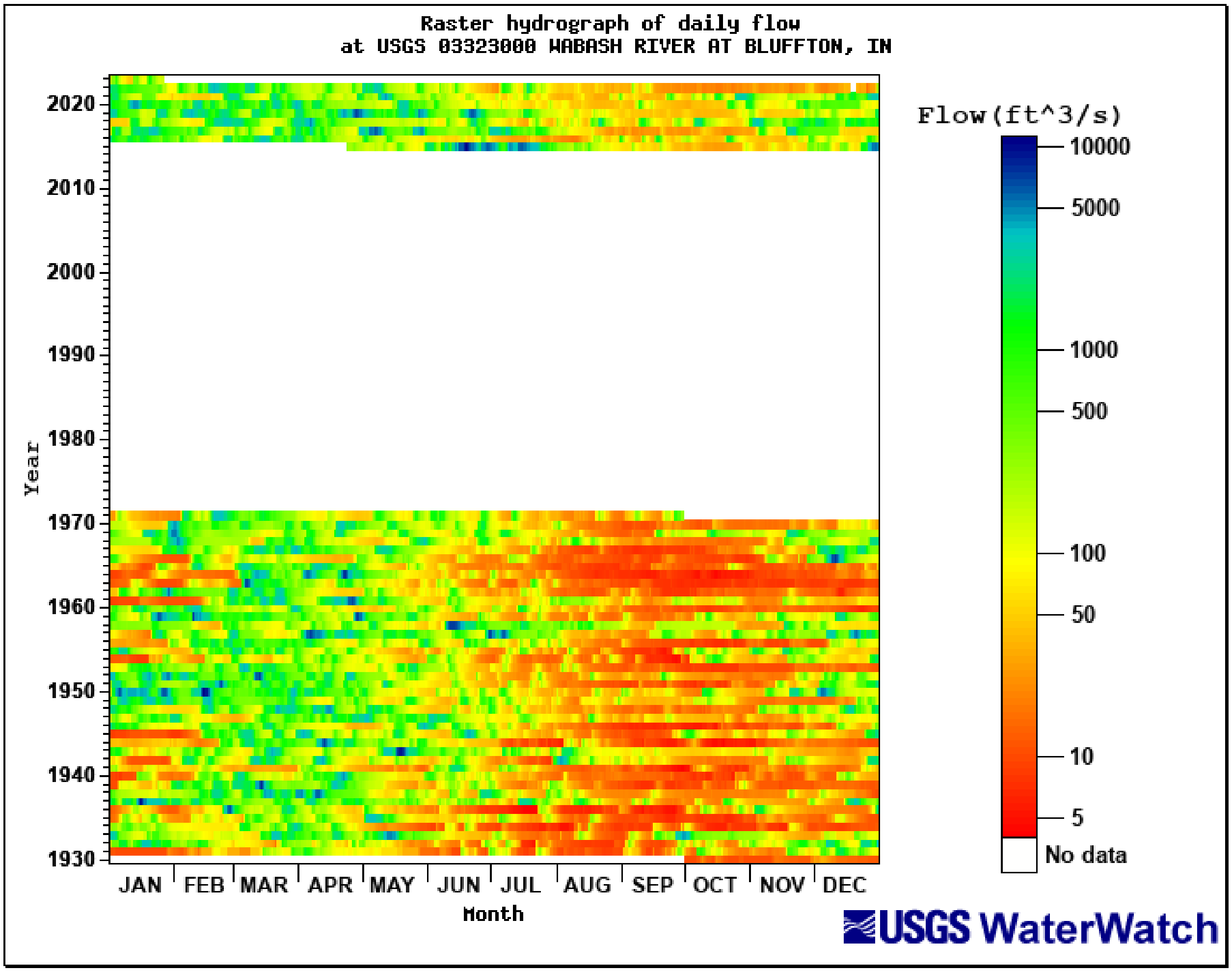


Figure C.6. Wabash River at Bluffton, Indiana, daily streamflow data. Plot obtained from the National Weather Service River Forecast Center.

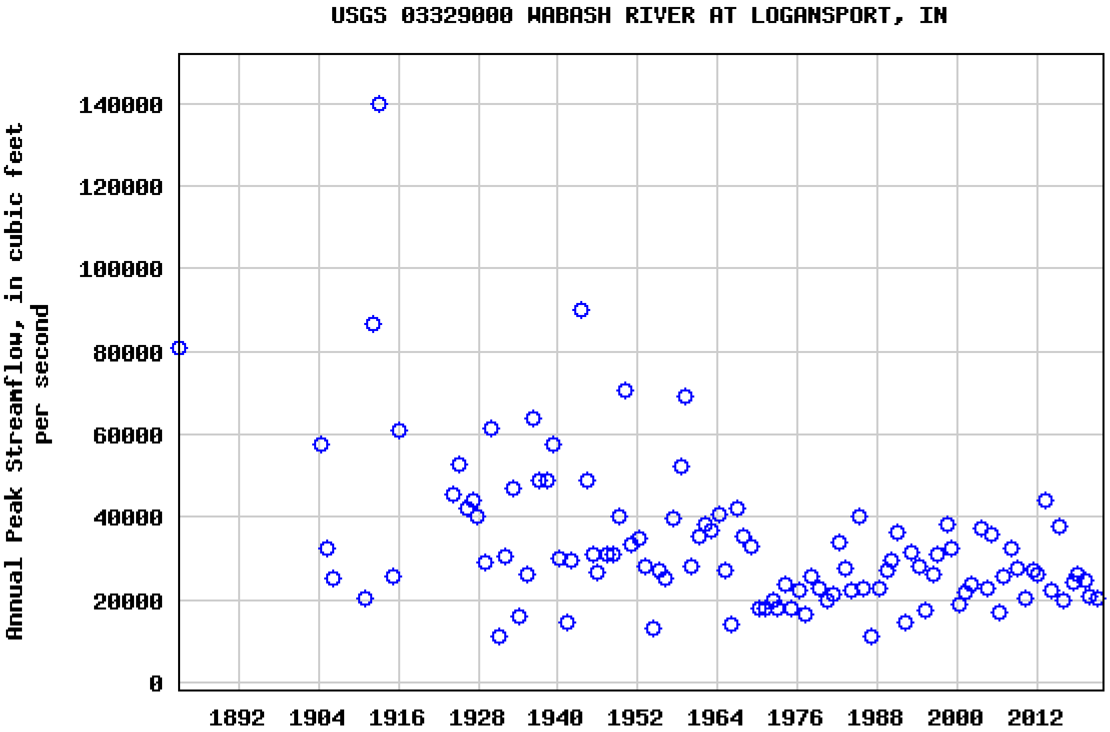


Figure C.7. Wabash River at Logansport, Indiana, peak flow data. Plot obtained from U.S. Geological Survey National Water Dashboard.

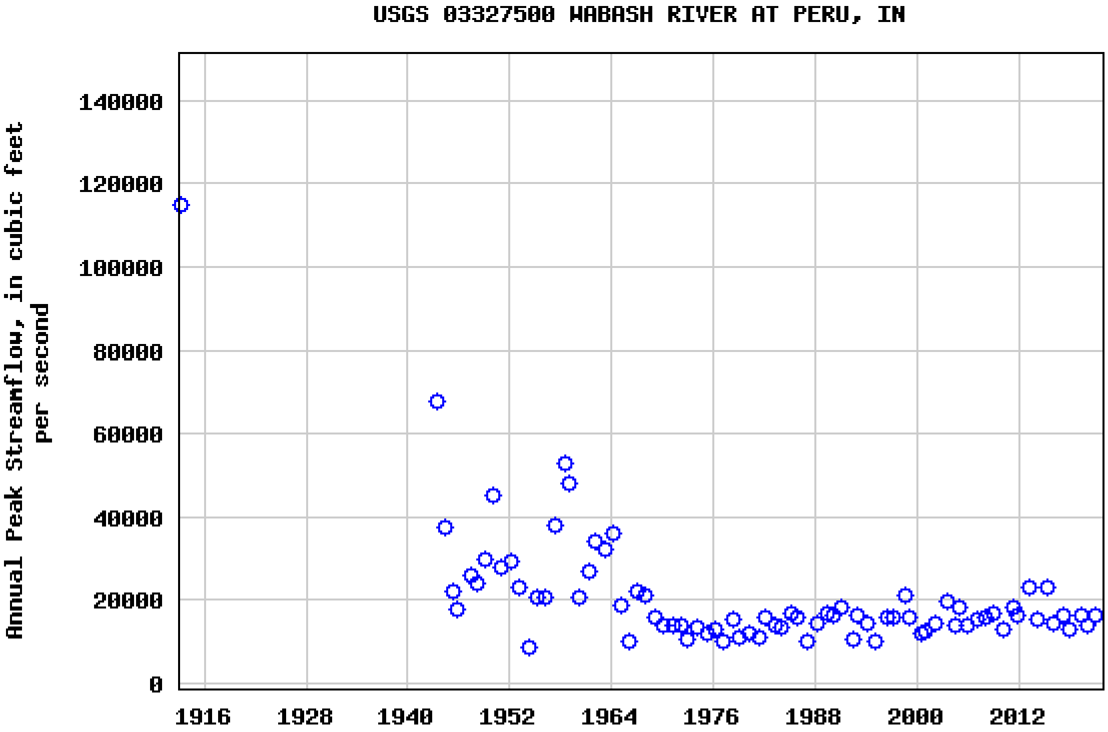


Figure C.8. Wabash River at Peru, Indiana, peak flow data. Plot obtained from U.S. Geological Survey National Water Dashboard.

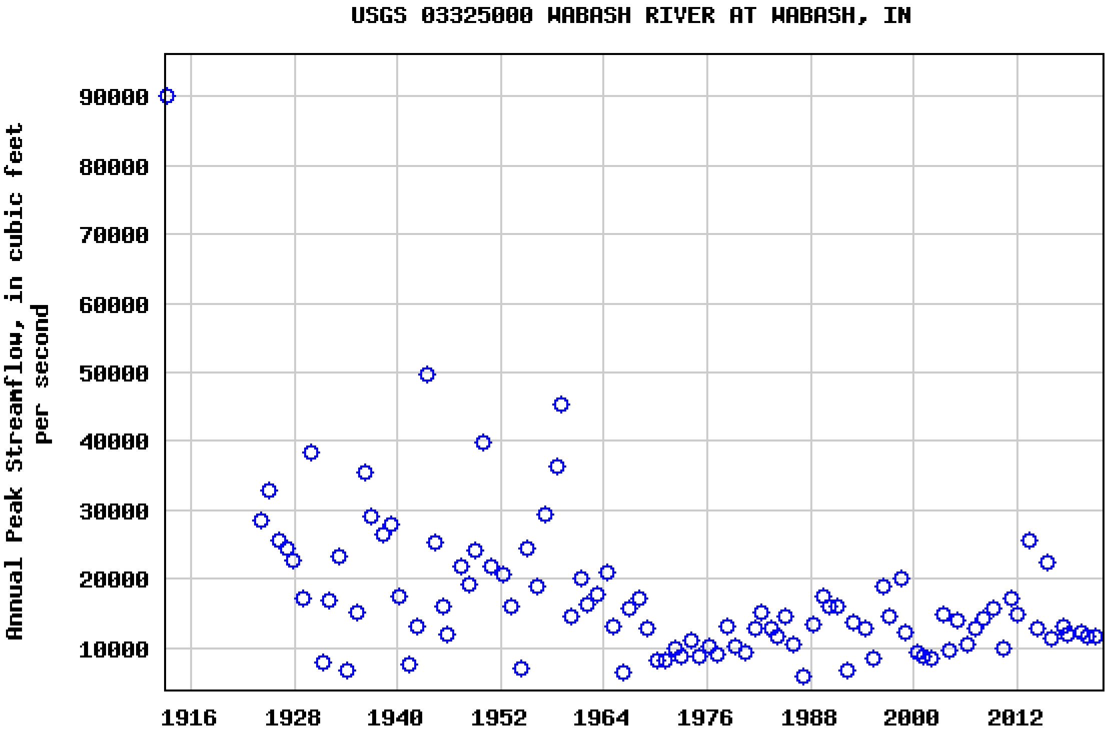


Figure C.9. Wabash River at Wabash, Indiana, peak flow data. Plot obtained from U.S. Geological Survey National Water Dashboard.

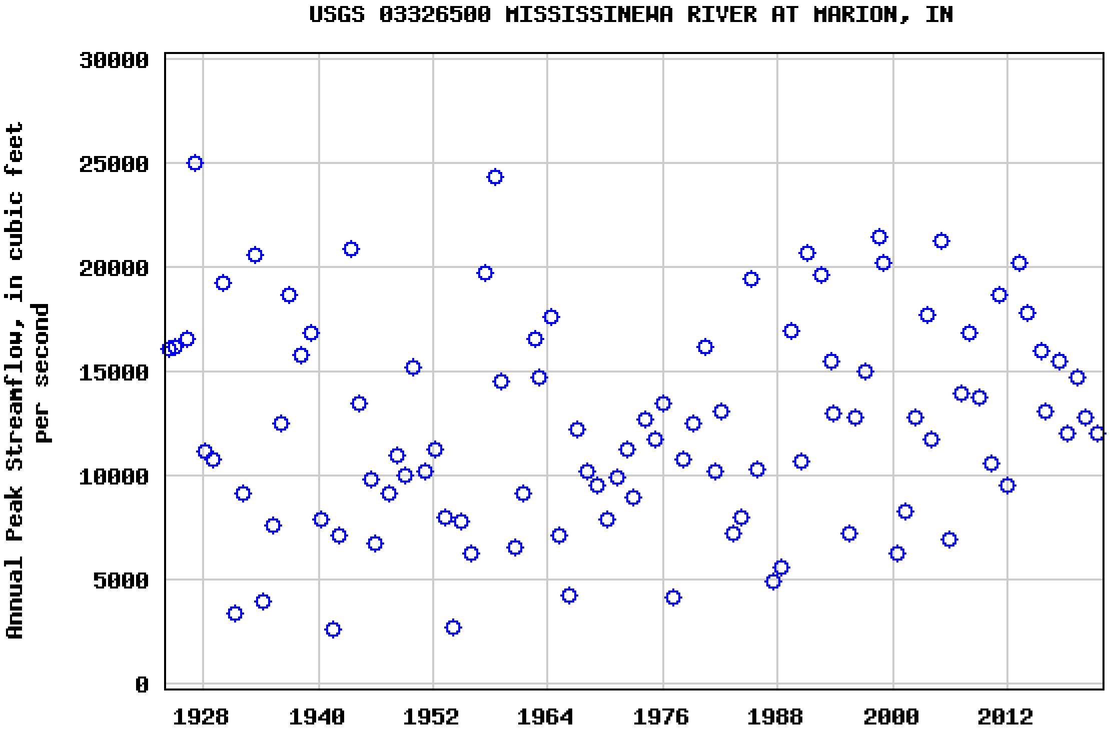


Figure C.10. Mississinewa River at Marion, Indiana, peak flow data. Plot obtained from U.S. Geological Survey National Water Dashboard.

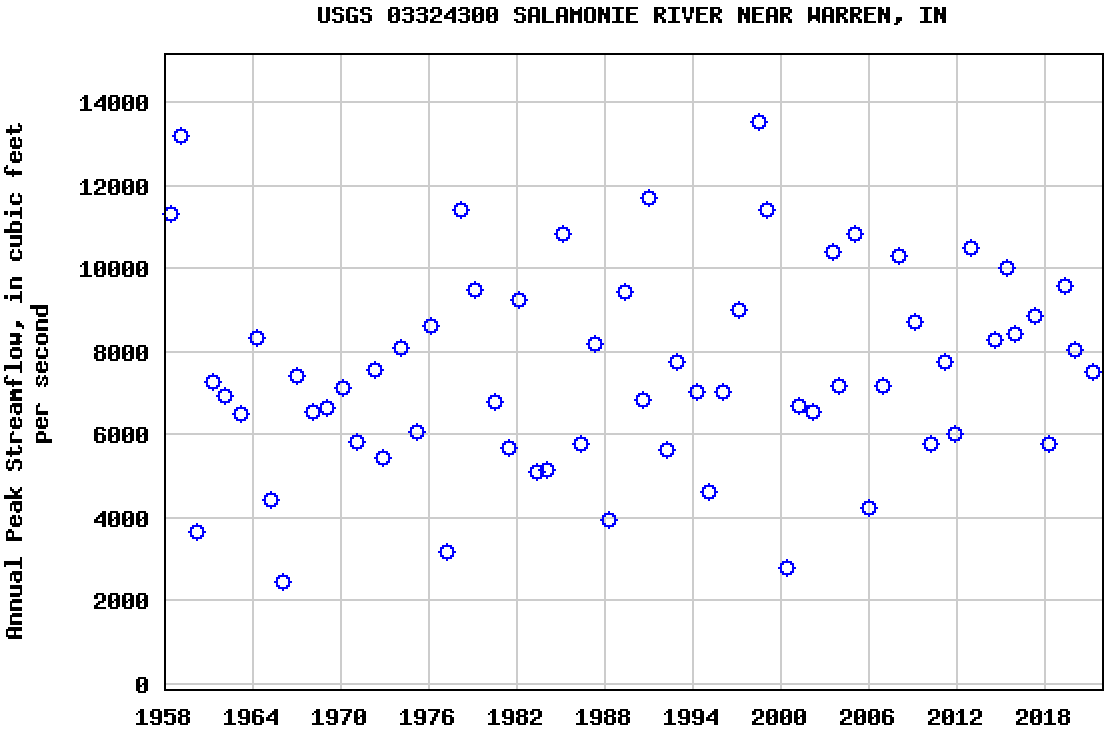


Figure C.11. Salamonie River near Warren, Indiana, peak flow data. Plot obtained from U.S. Geological Survey National Water Dashboard.

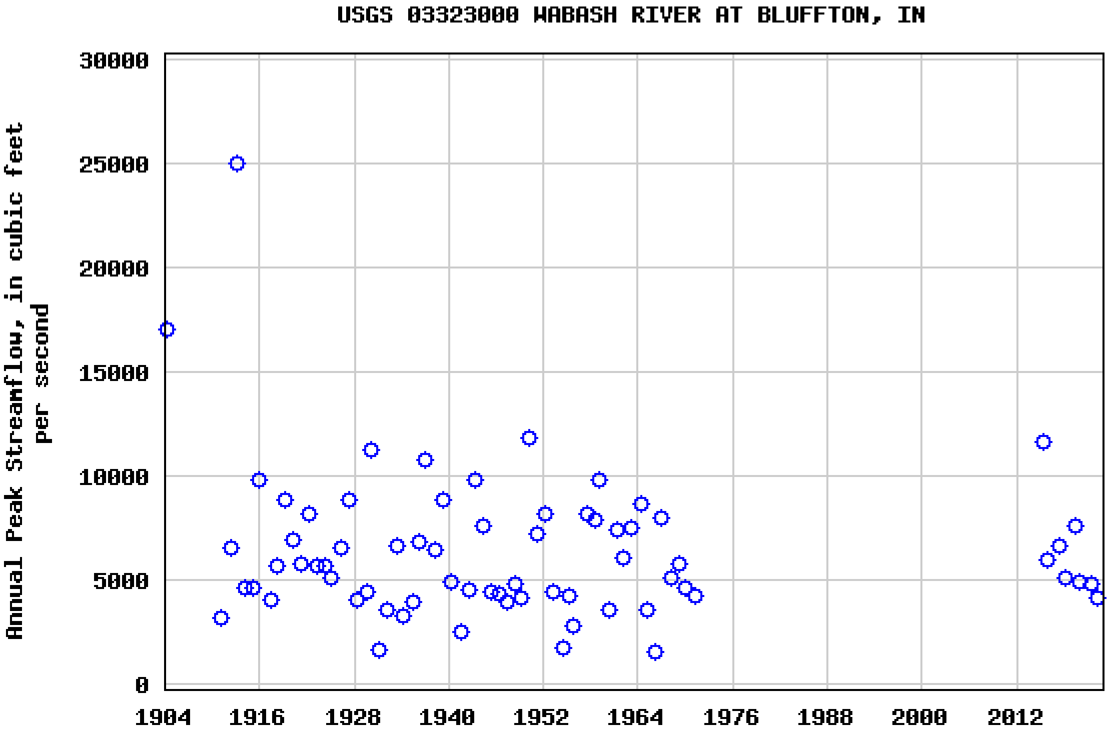


Figure C.12. Wabash River at Bluffton, Indiana, peak flow data. Plot obtained from U.S. Geological Survey National Water Dashboard.

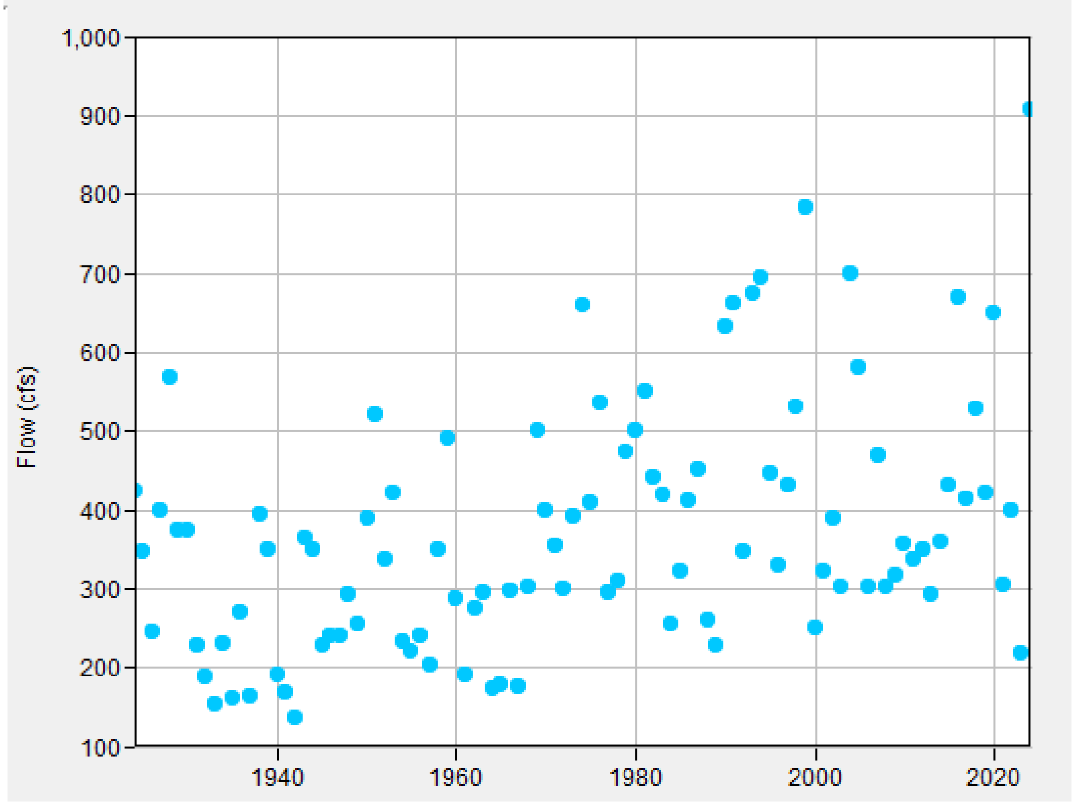


Figure C.13. Wabash River at Logansport, Indiana, annual minimum 1-day flow data.

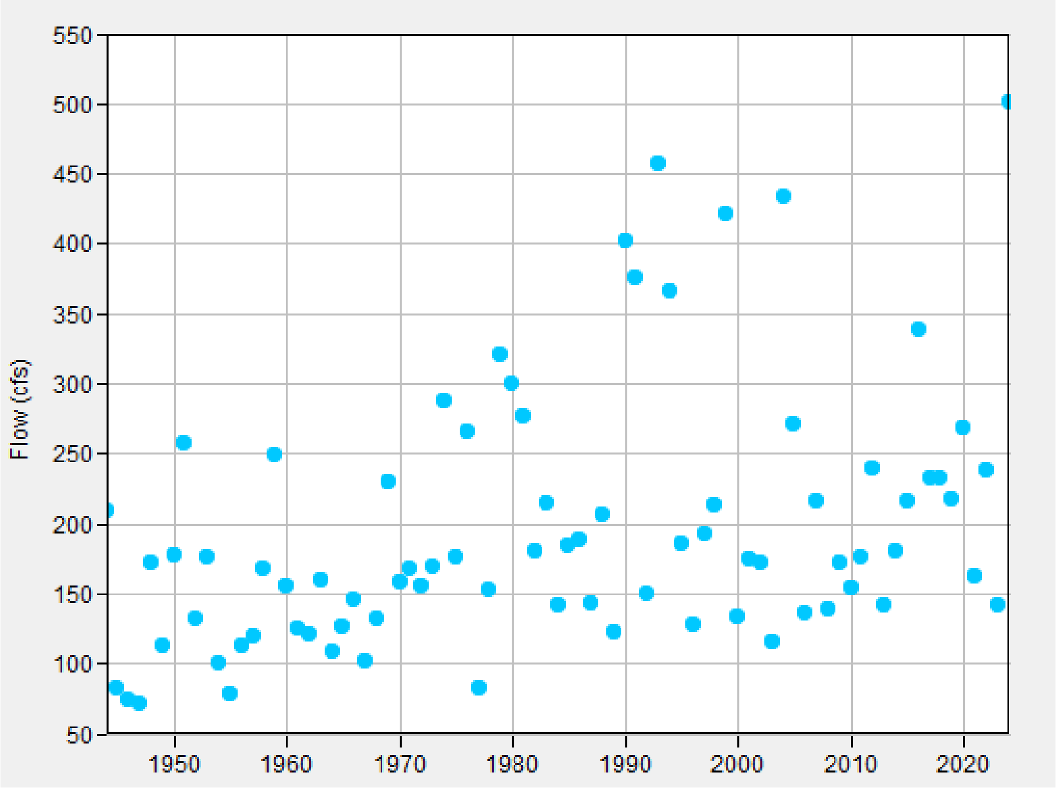


Figure C.14. Wabash River at Peru, Indiana, annual minimum 1-day flow data.

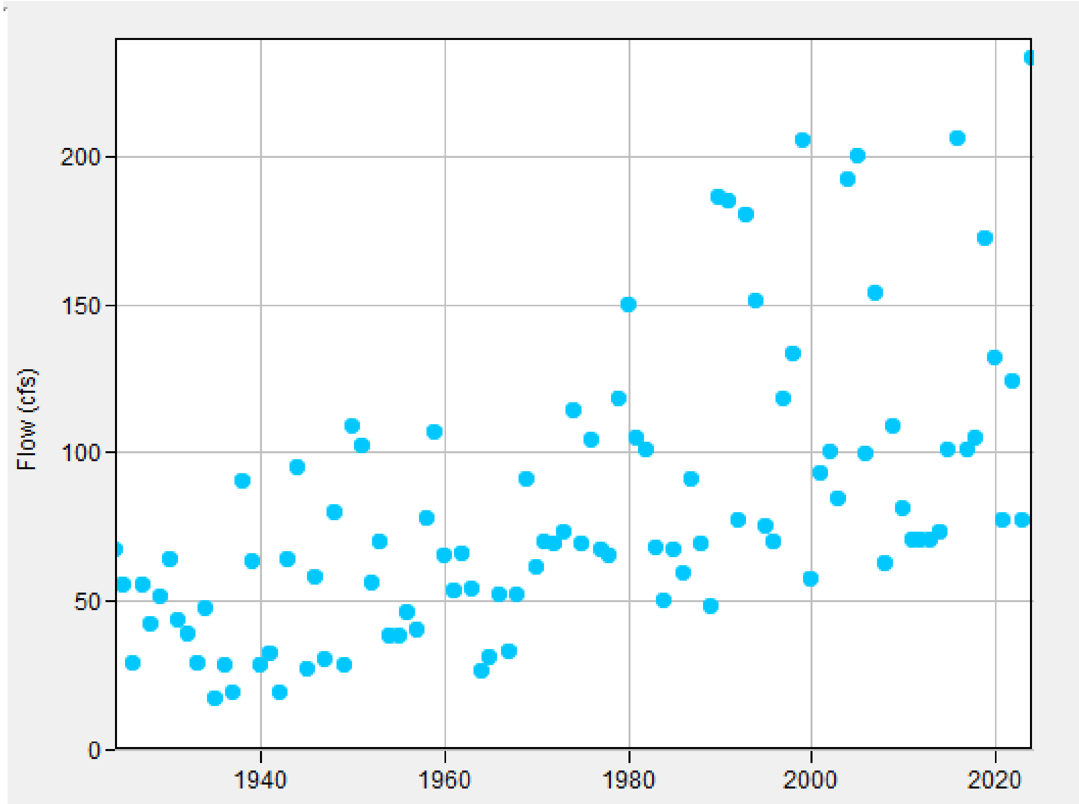


Figure C.15. Wabash River at Wabash, Indiana, annual minimum 1-day flow data.

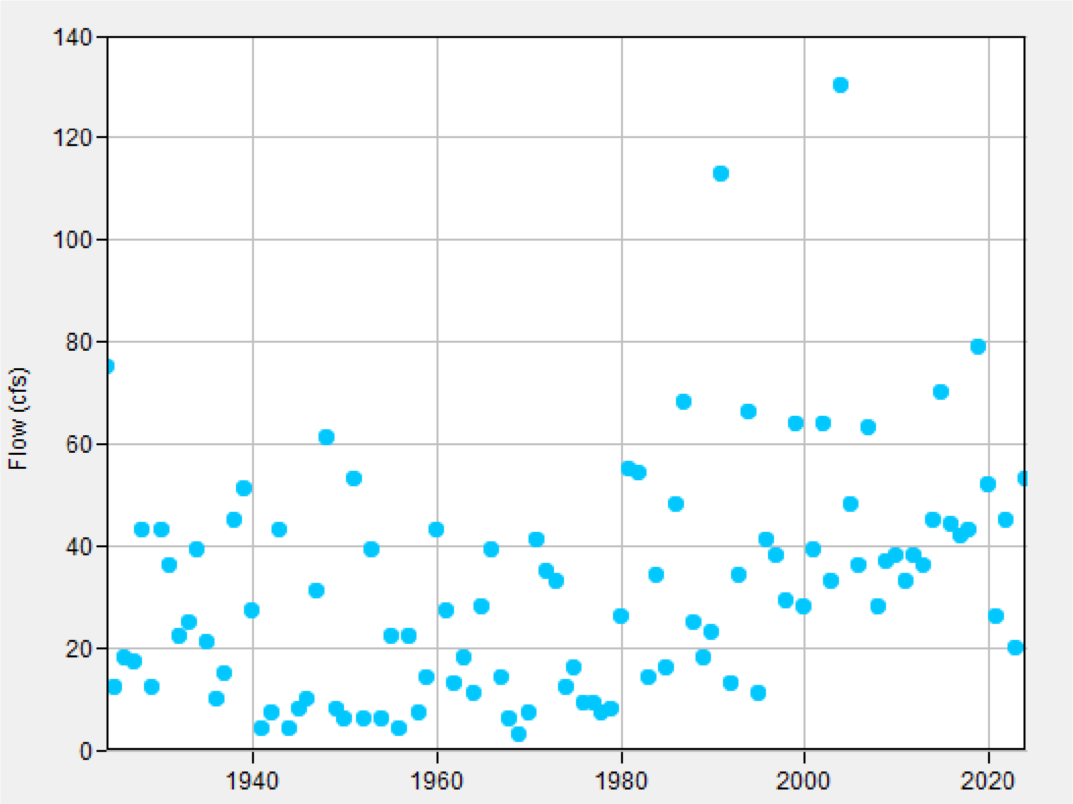


Figure C.16. Mississinewa River at Marion, Indiana, annual minimum 1-day flow data.

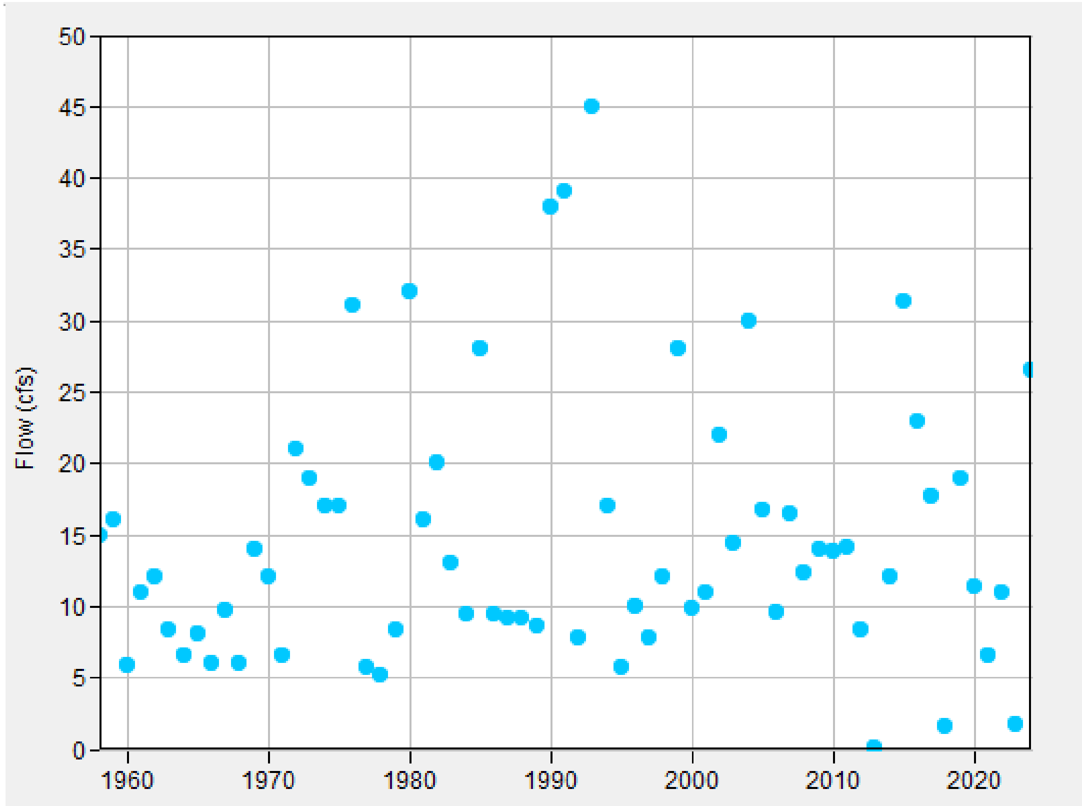


Figure C.17. Salamonie River at Warren, Indiana, annual minimum 1-day flow data.

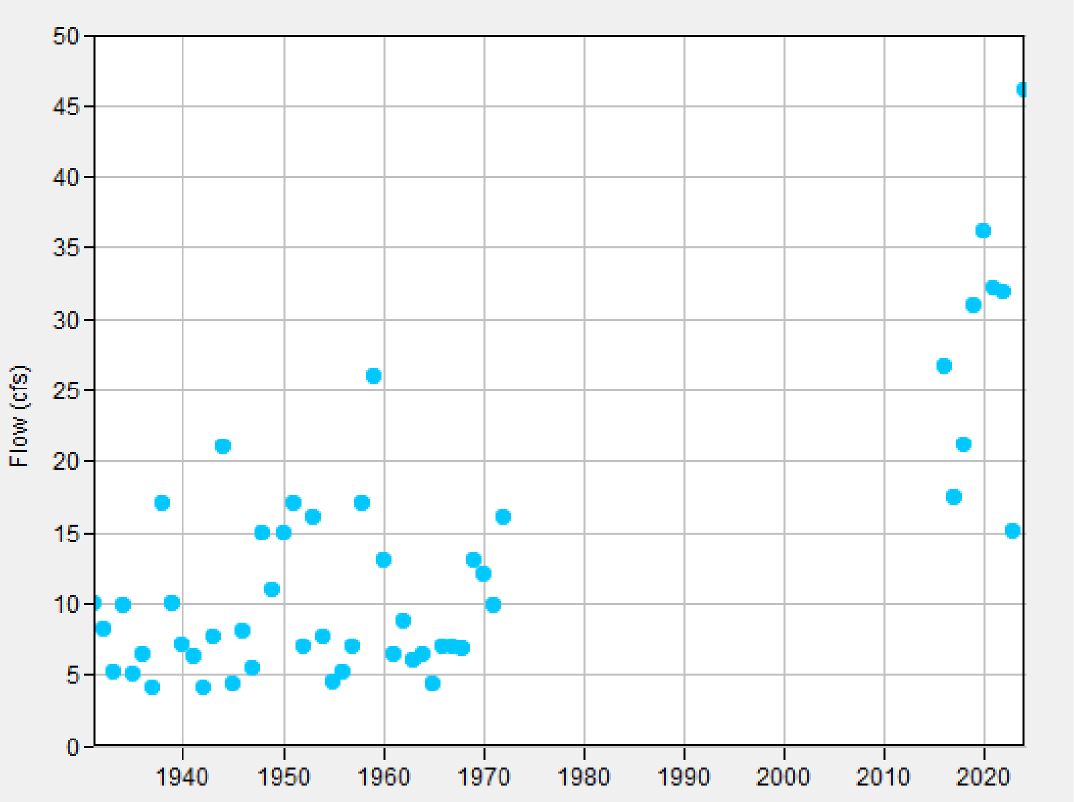


Figure C.18. Wabash River at Bluffton, Indiana, annual minimum 1-day flow data.

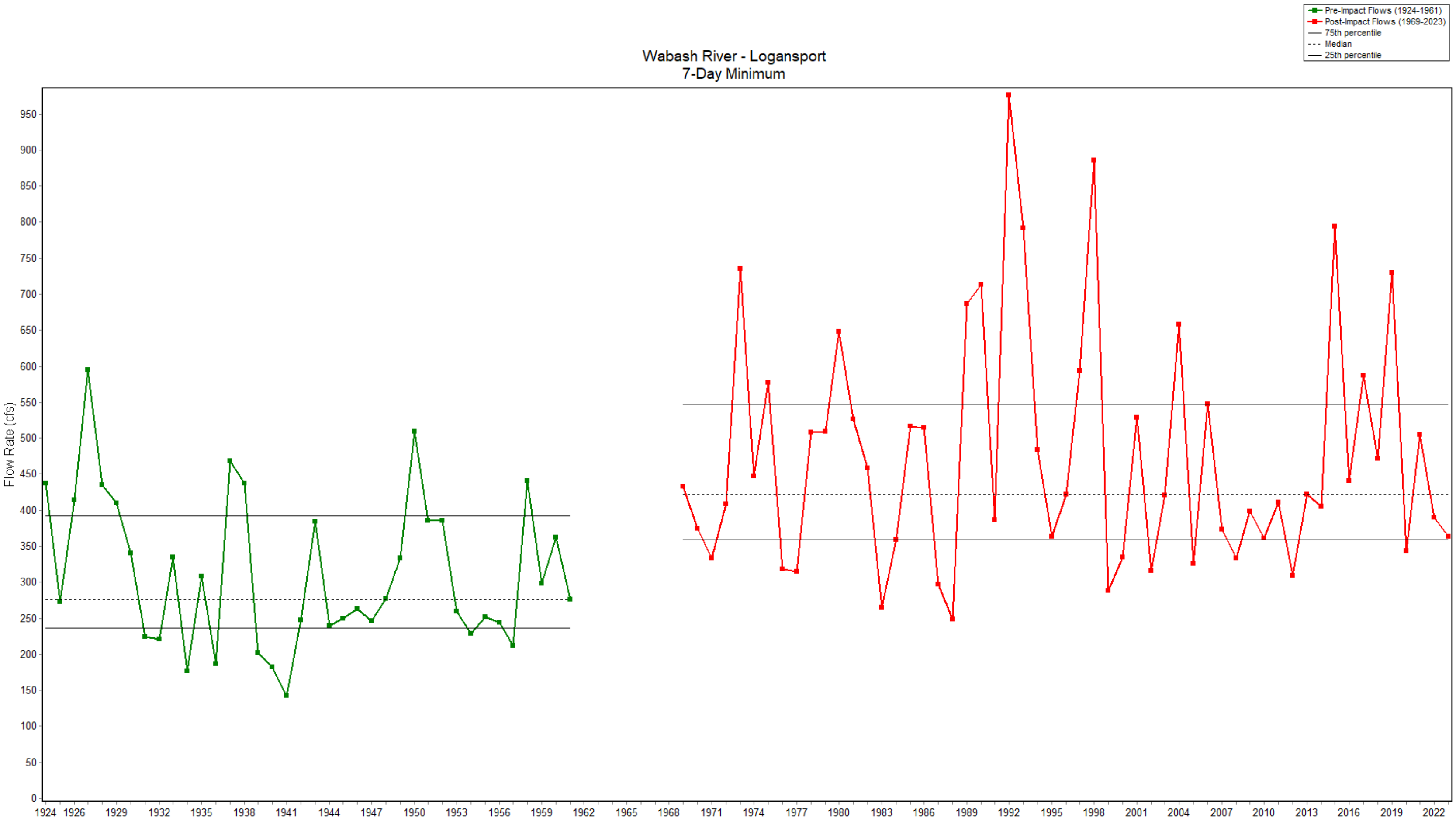


Figure C.19. Wabash River at Logansport, Indiana, annual minimum 7-day flow data.

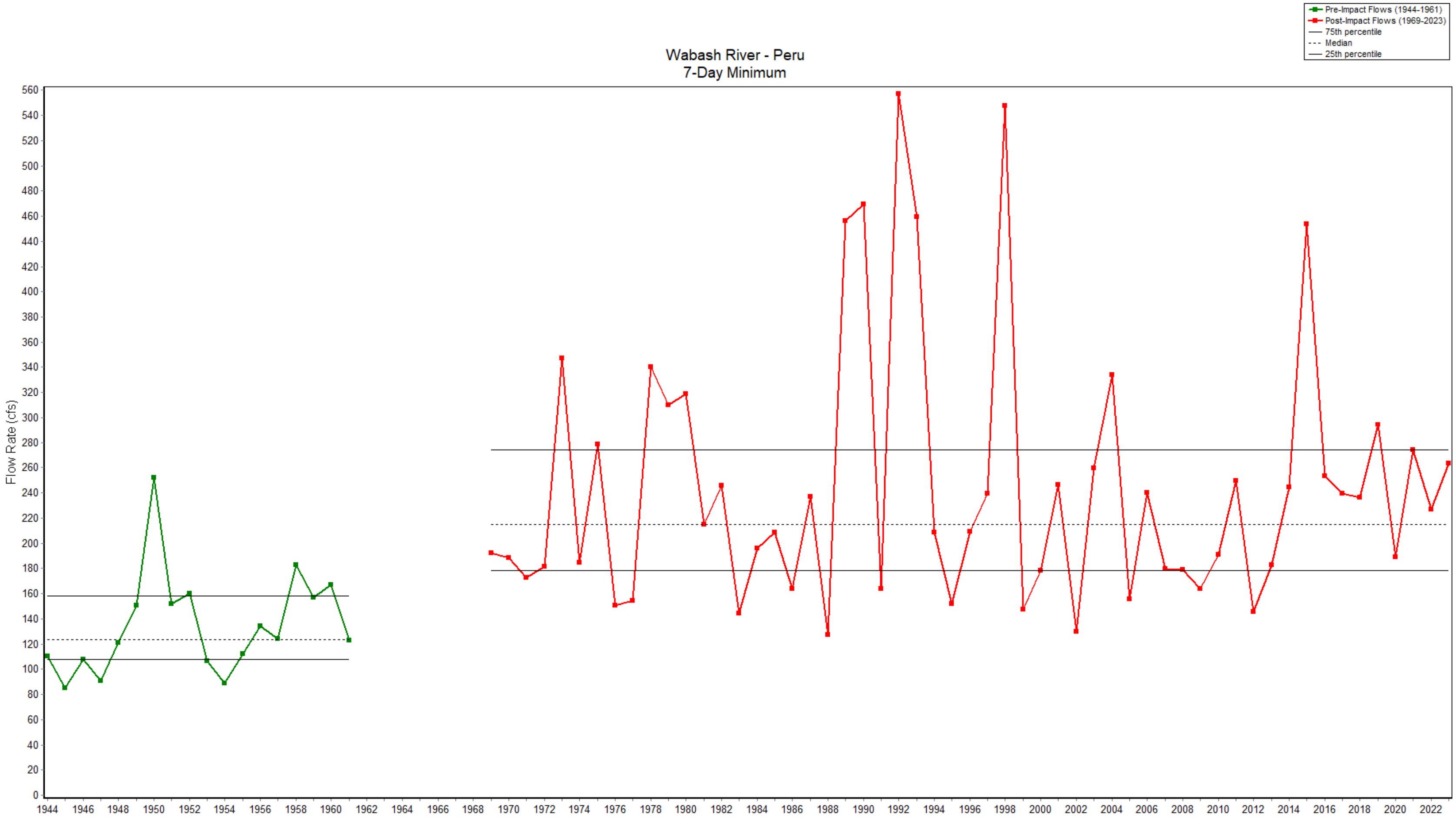


Figure C.20. Wabash River at Peru, Indiana, annual minimum 7-day flow data.

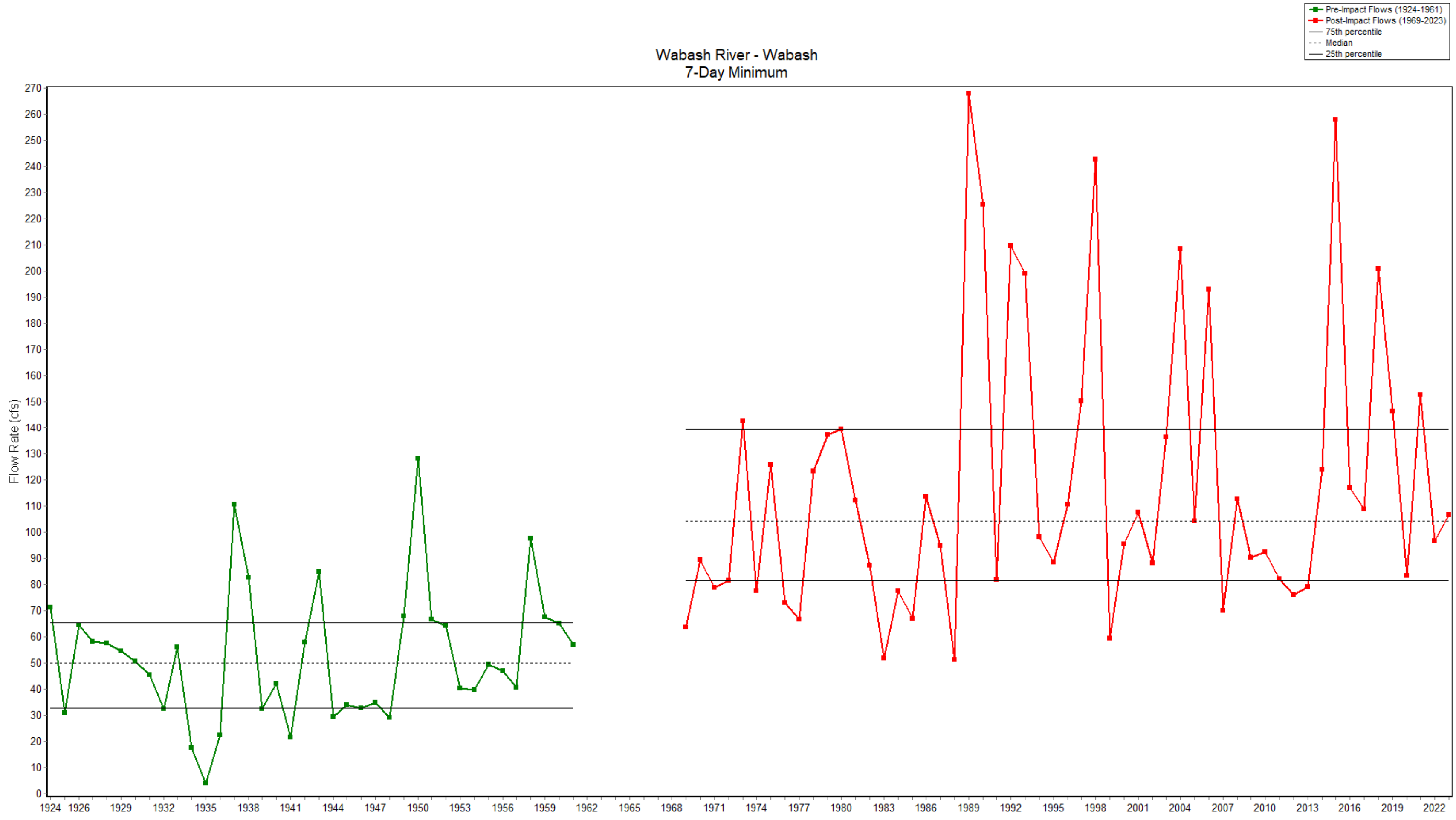


Figure C.21.Wabash River at Wabash, Indiana, annual minimum 7-day flow data.

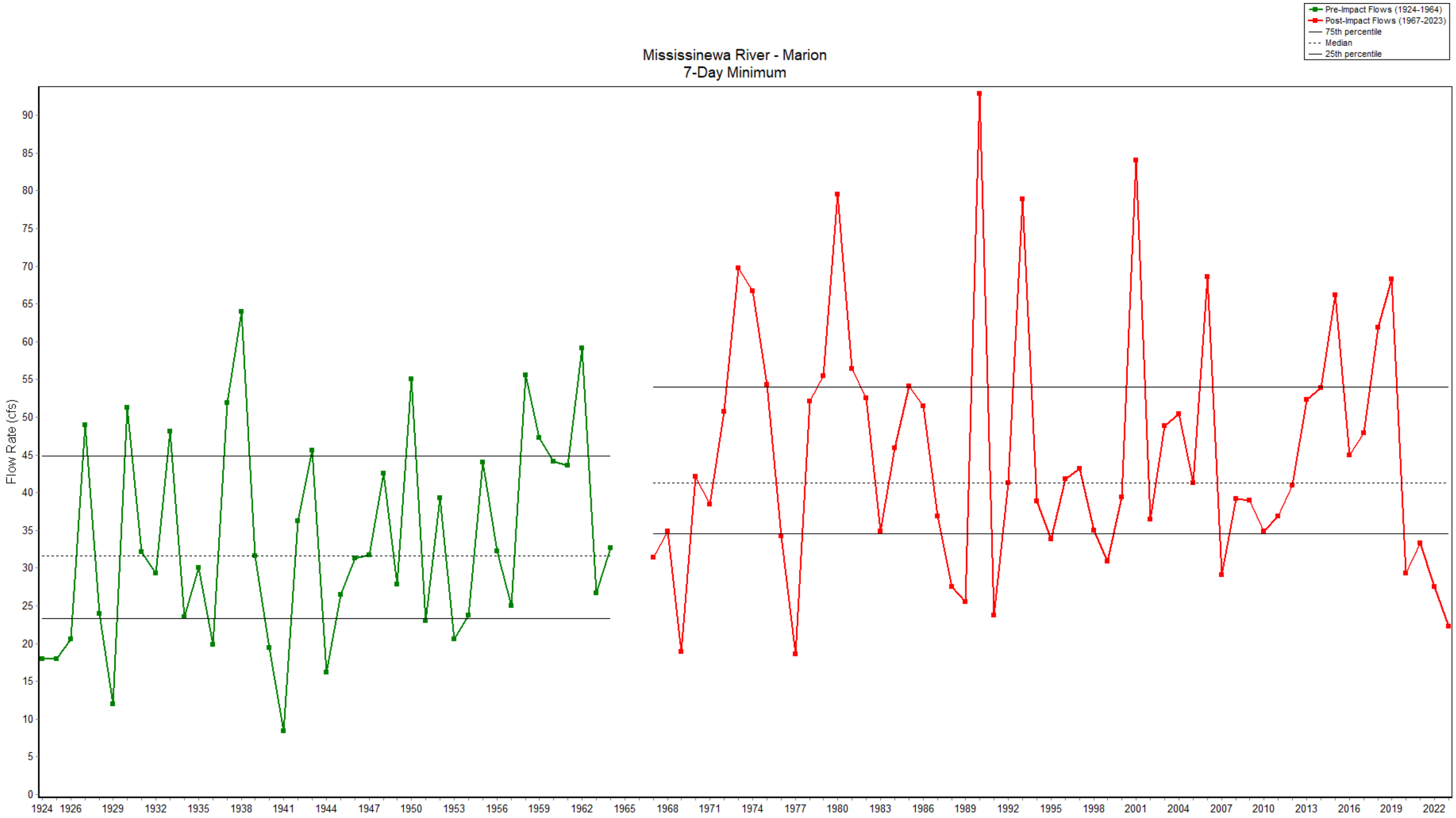


Figure C.22. Mississinewa River at Marion, Indiana, annual minimum 7-day flow data.

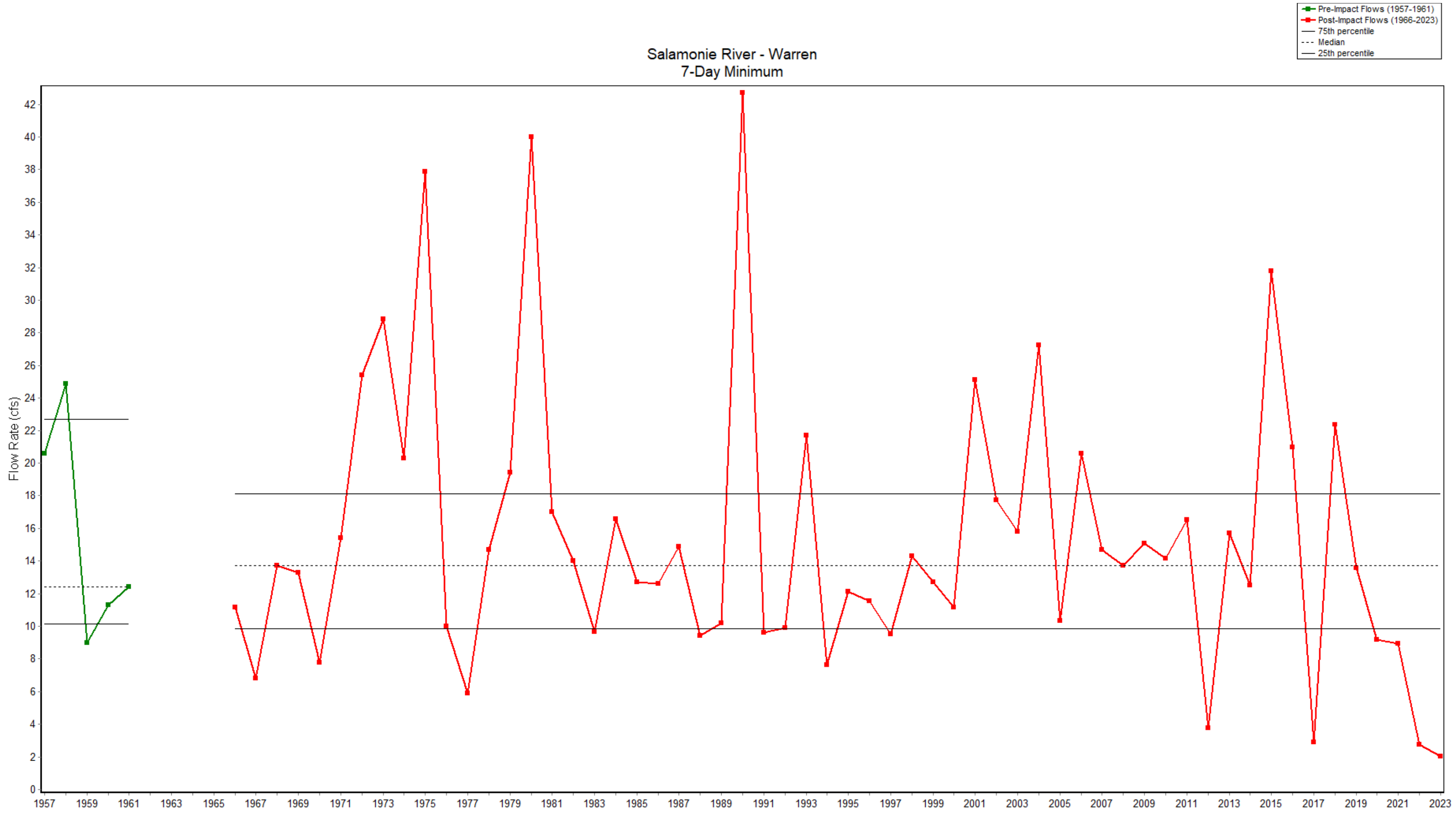


Figure C.23. Salamonie River at Warren, Indiana, annual minimum 7-day flow data.

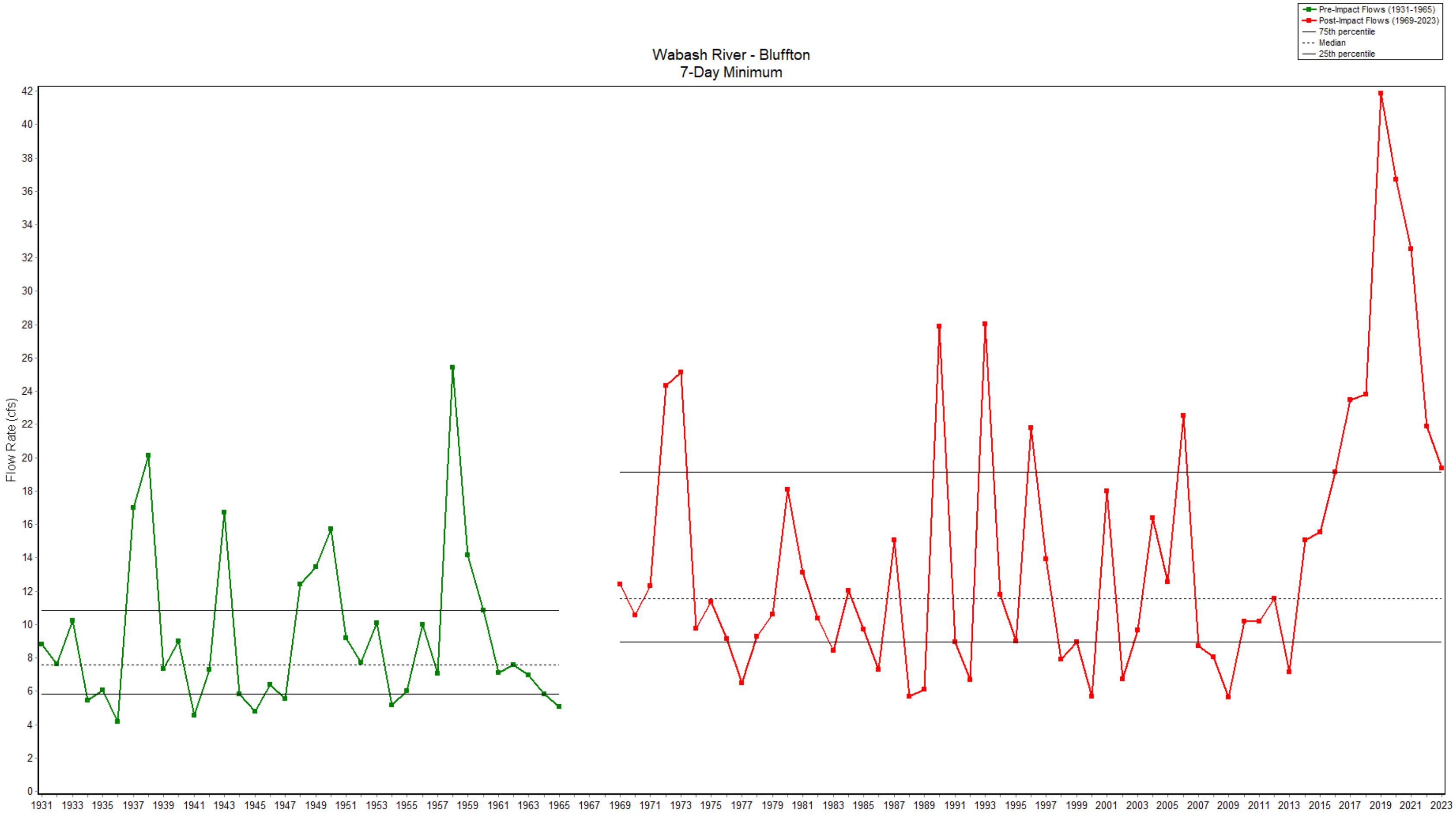


Figure C.24. Wabash River at Bluffton, Indiana, annual minimum 7-day flow data.

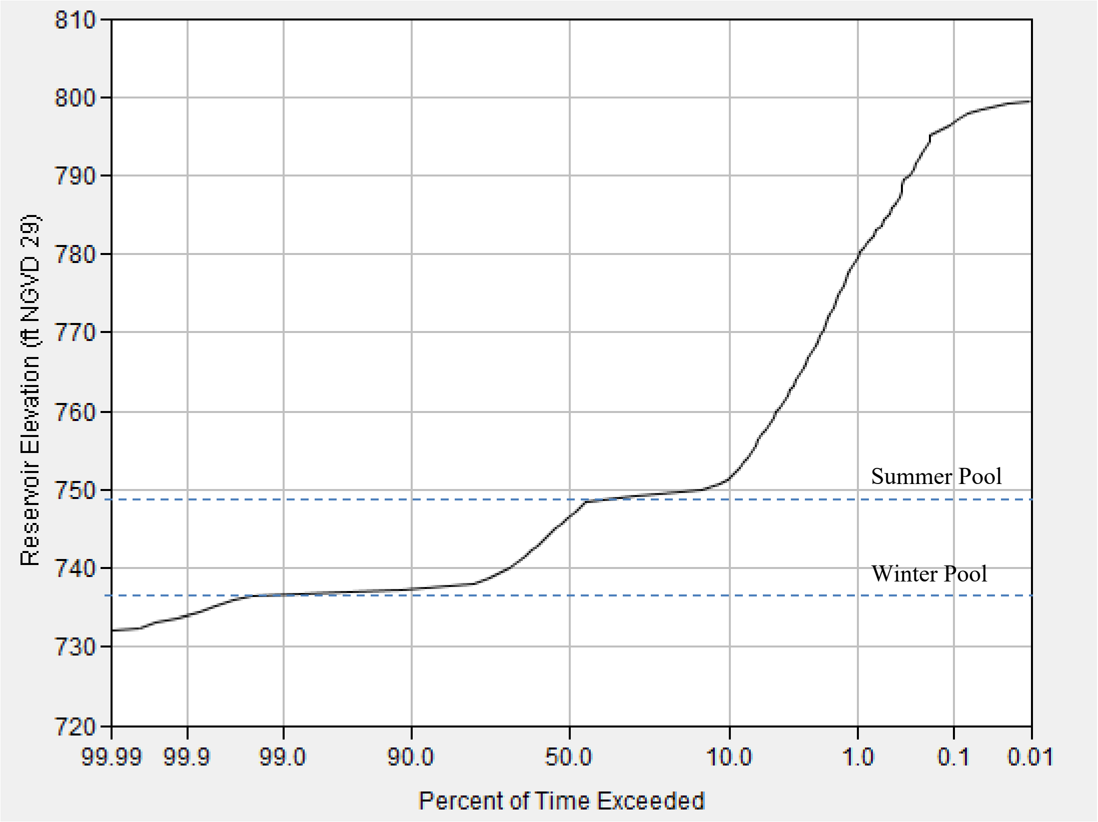


Figure C.25. J.E Roush Lake elevation percent exceedance.

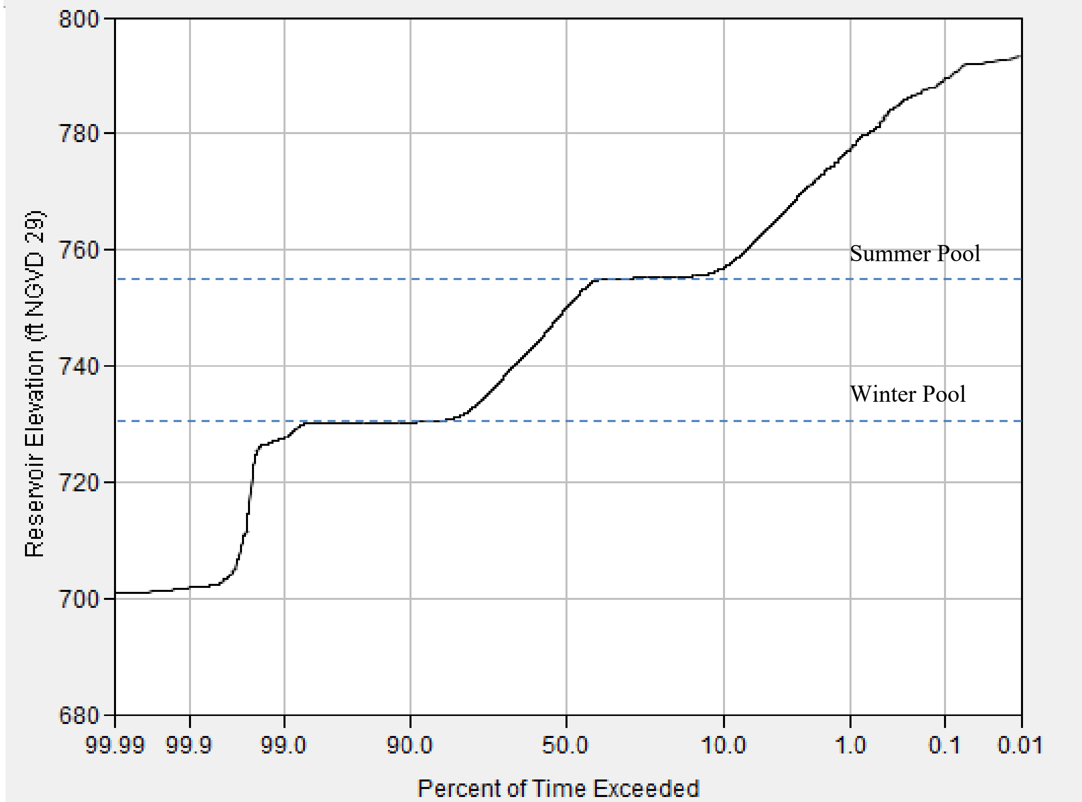


Figure C.26. Salamonie Lake elevation percent exceedance.

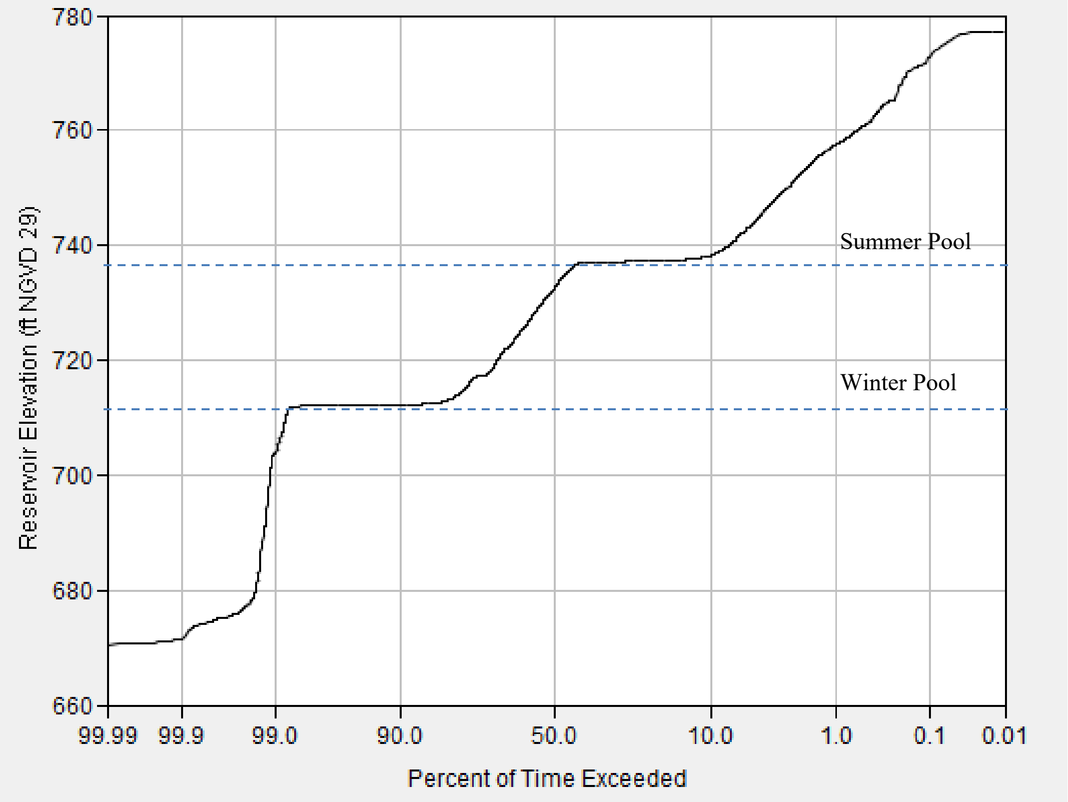


Figure C.27. Mississinewa Lake elevation percent exceedance.

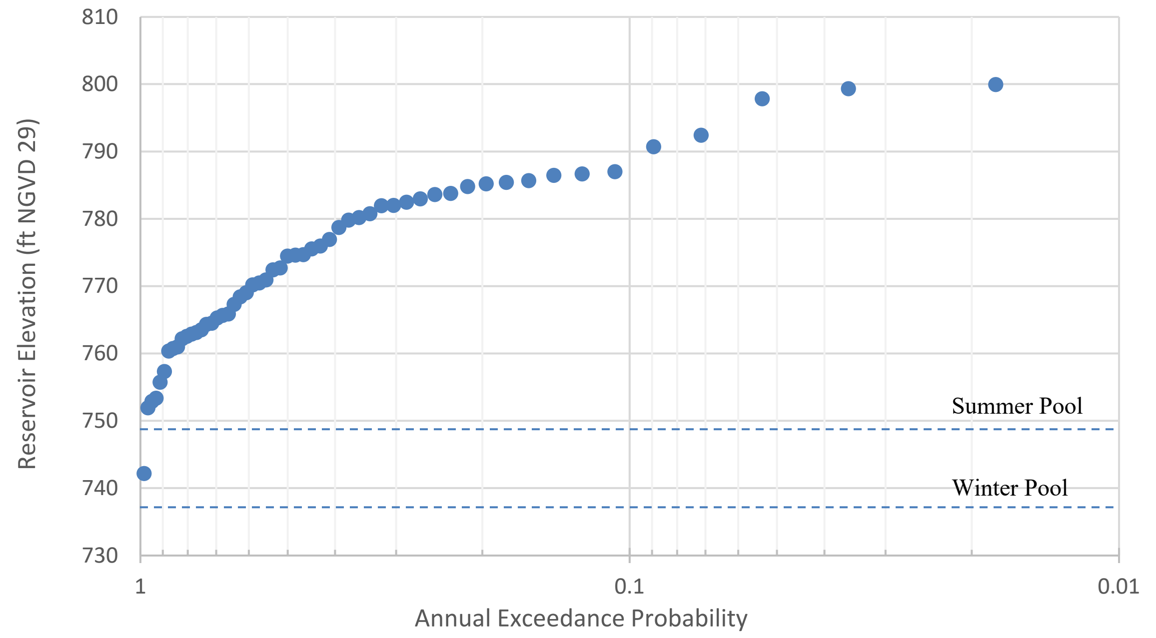


Figure C.28. J.E. Roush Lake elevation annual exceedance probability.

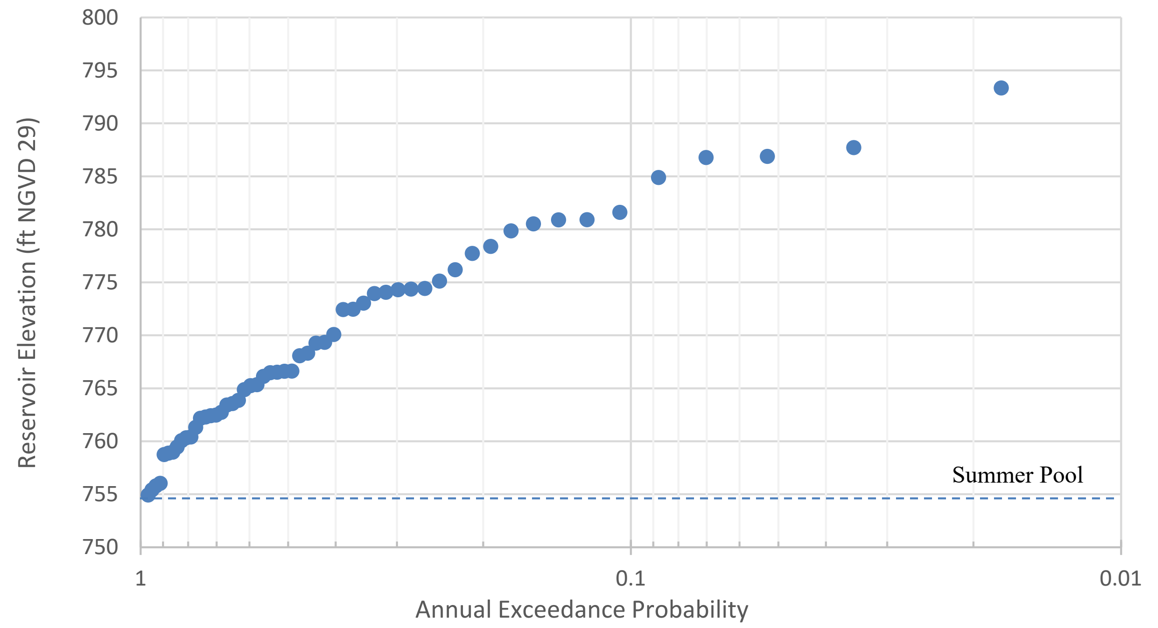


Figure C.29. Salamonie Lake elevation annual exceedance probability.

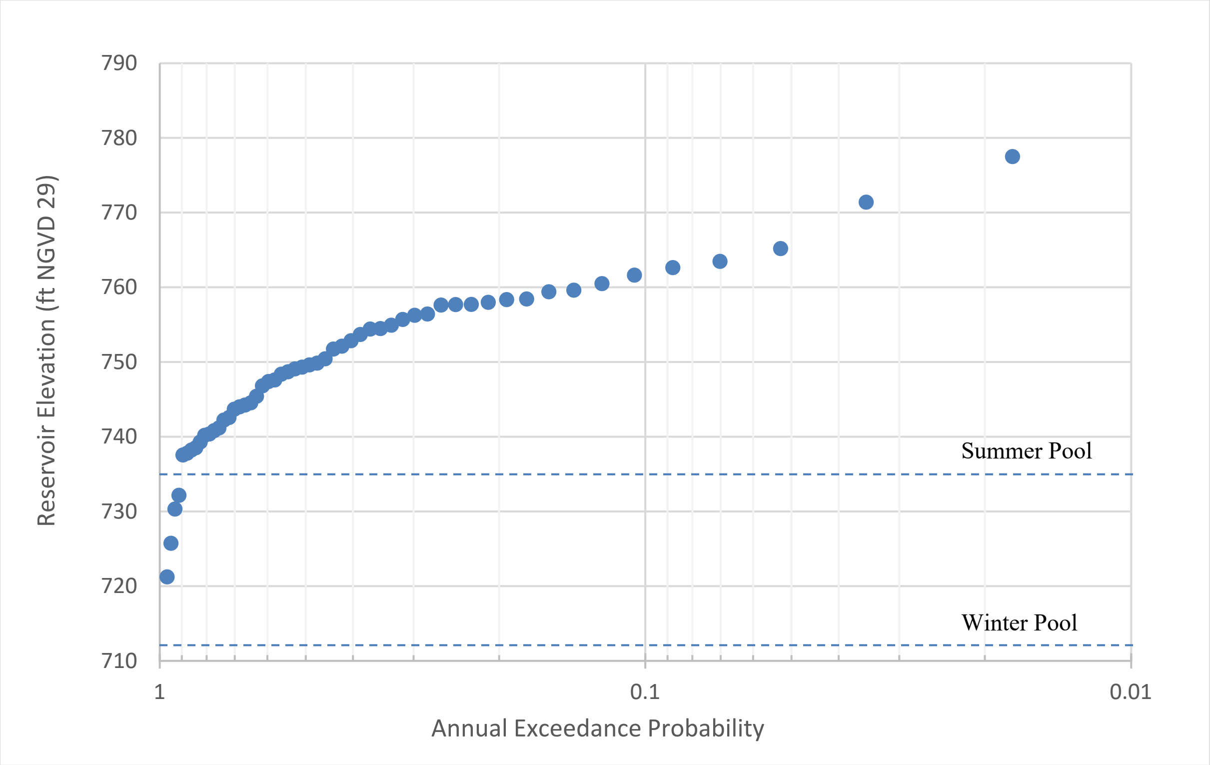


Figure C.30. Mississinewa Lake elevation annual exceedance probability.

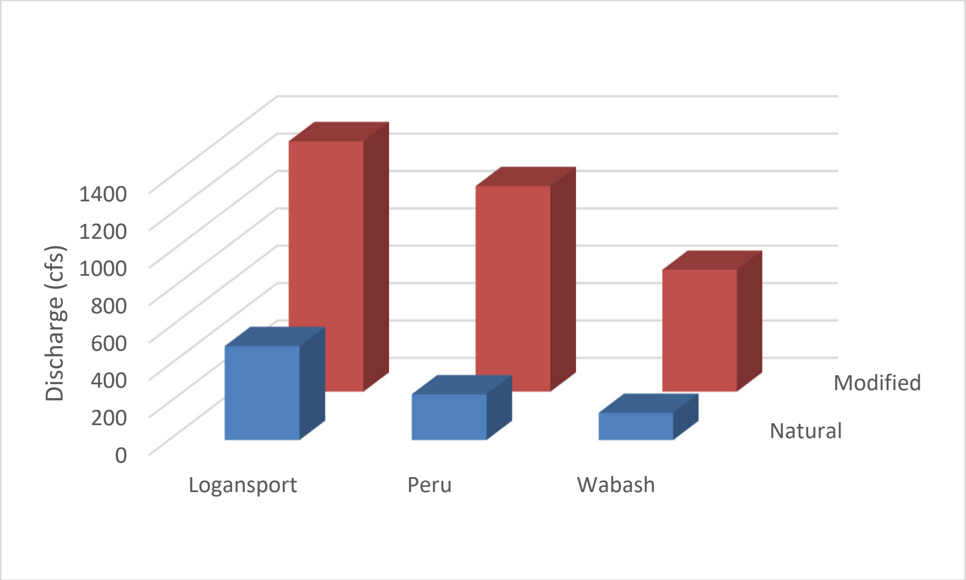


Figure C.31. October Median Flow prior to and after dam construction.

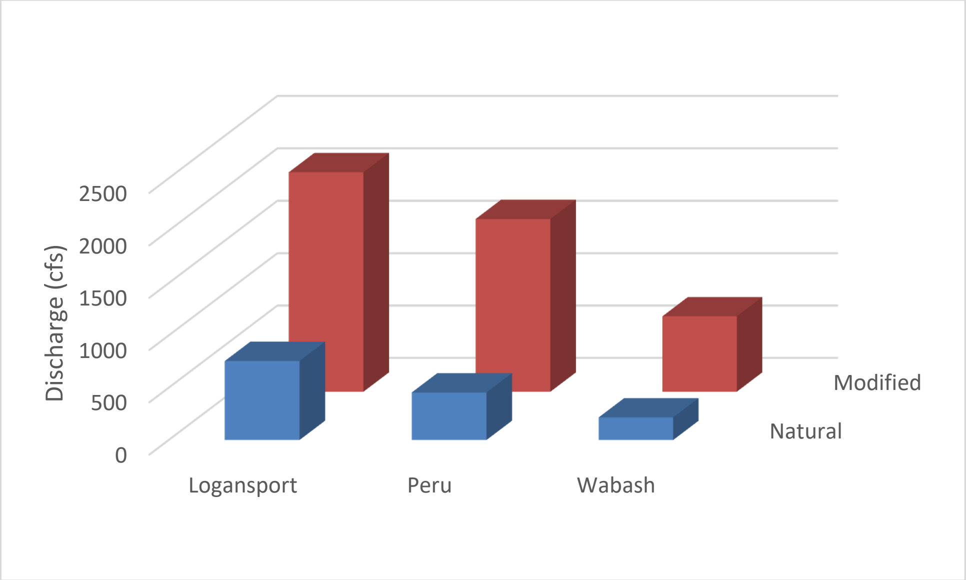


Figure C.32. November Median Flow prior to and after dam construction.

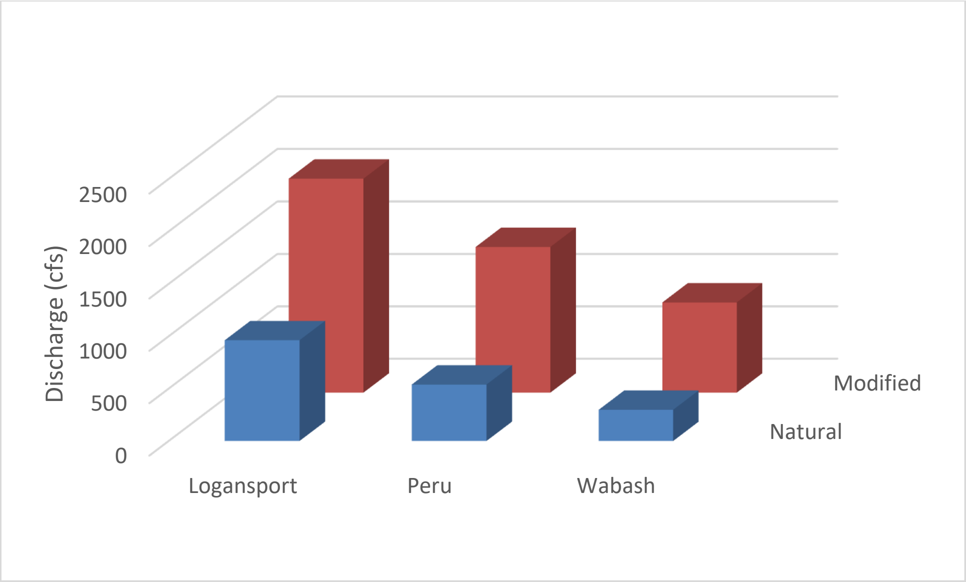


Figure C.33. December Median Flow prior to and after dam construction.

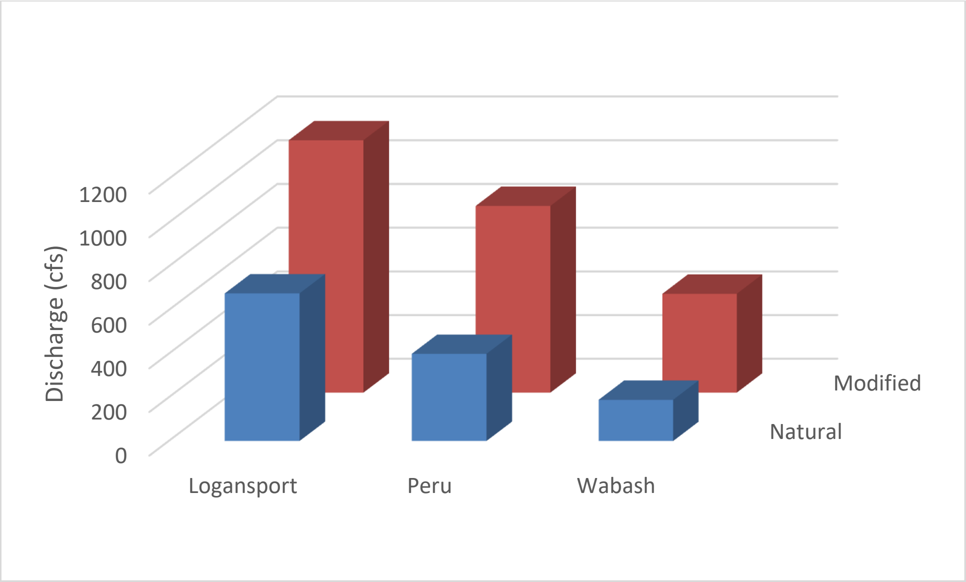


Figure C.34. 90-Day Minimum Flows prior to and after dam construction.

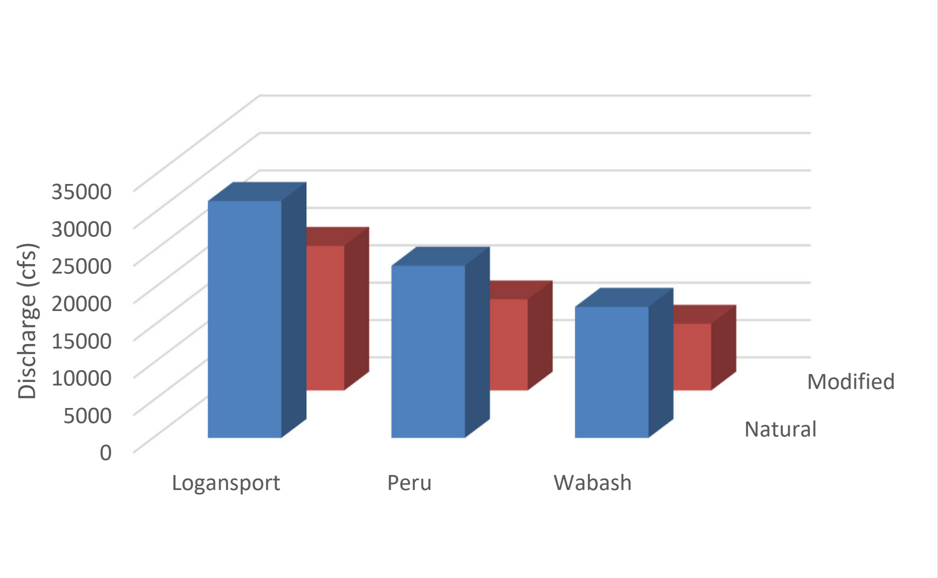


Figure C.35. 1-Day Maximum Flows prior to and after dam construction.

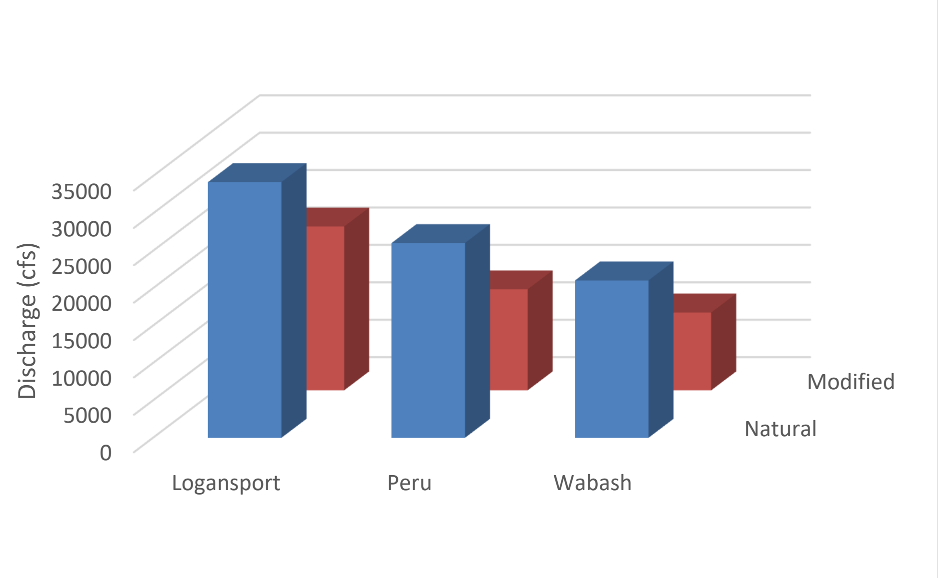


Figure C.36. 3-Day Maximum Flows prior to and after dam construction.

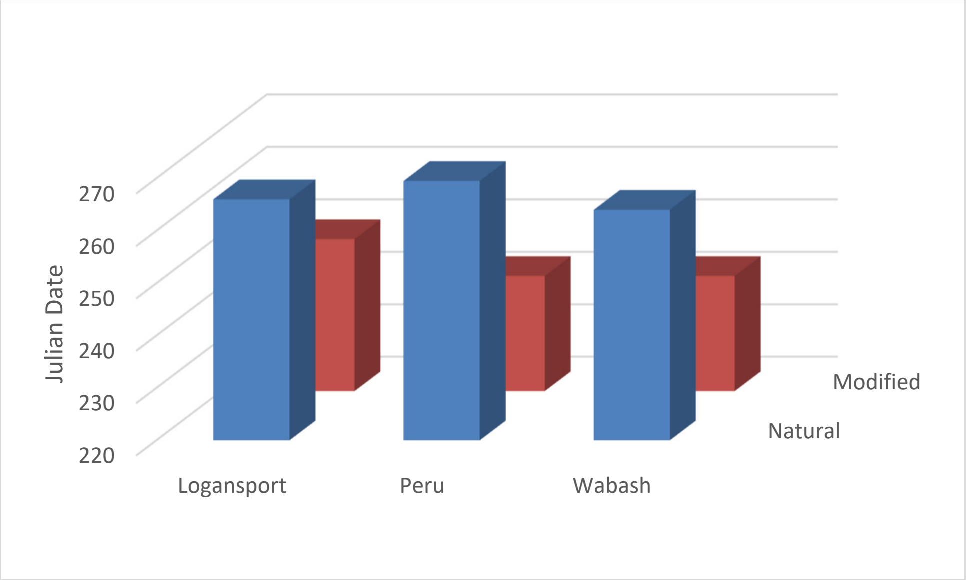


Figure C.37. Julian Date of Maximum Annual Discharge prior to and after dam construction.

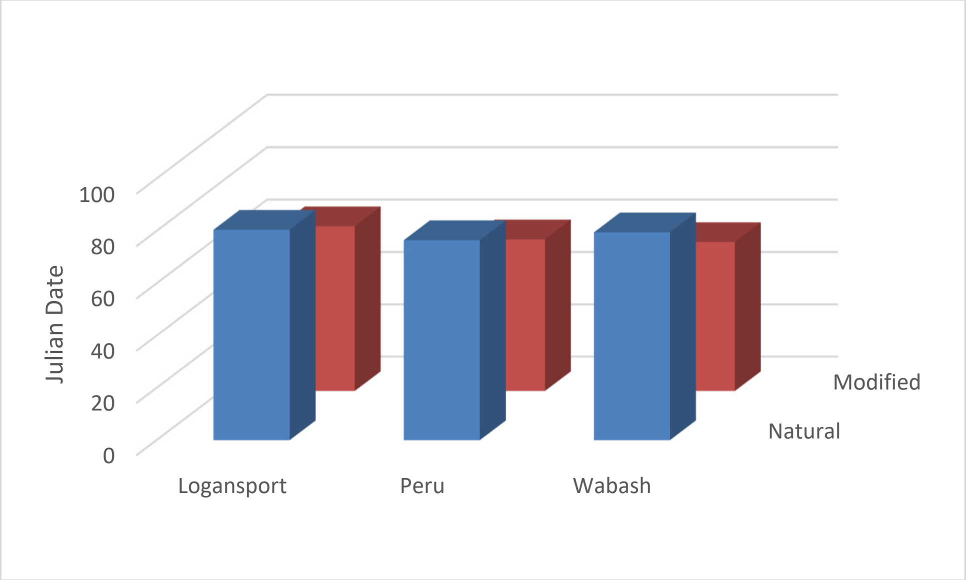


Figure C.38. Julian Date of Minimum Annual Discharge prior to and after dam construction.

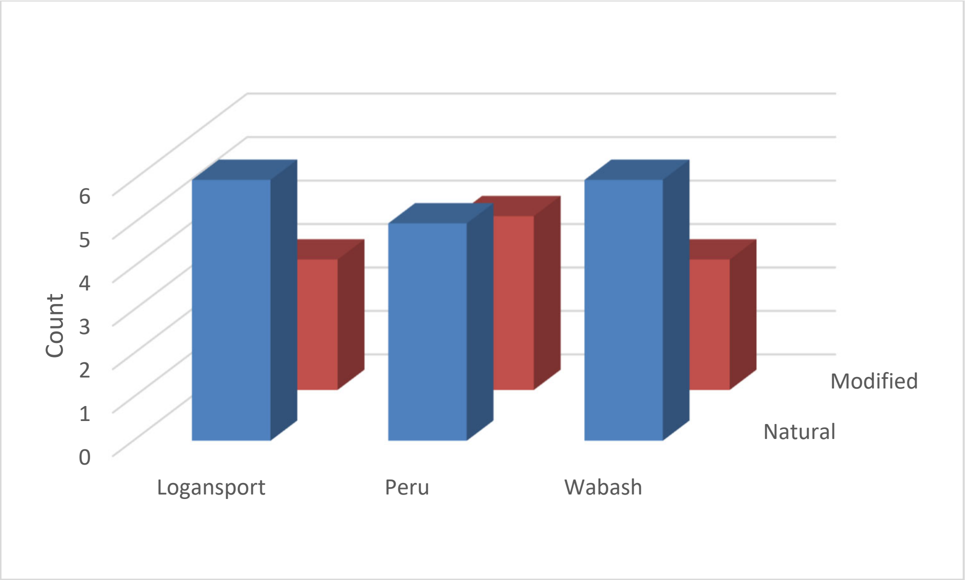


Figure C.39. Low Flow Pulse Count prior to and after dam construction.

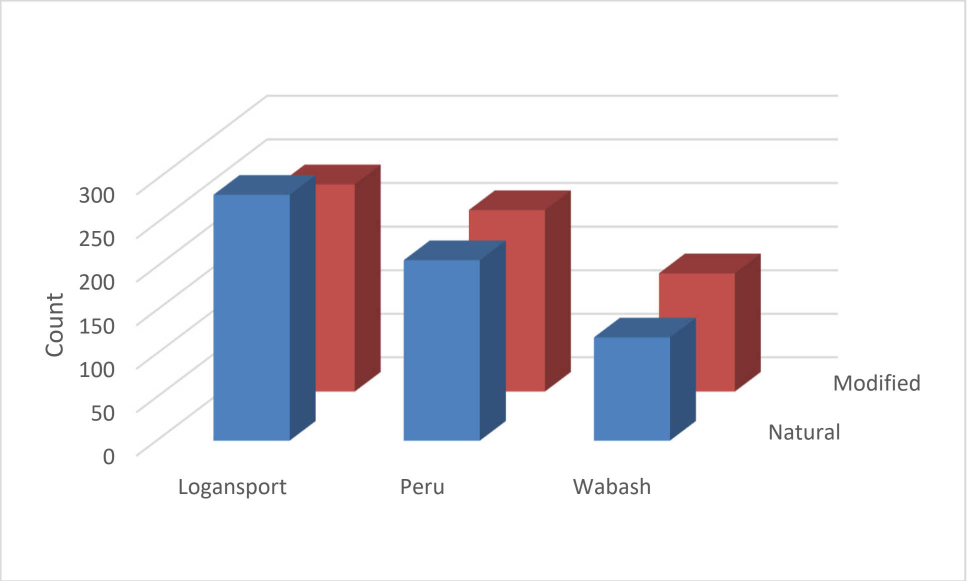


Figure C.40. Rise Rate prior to and after dam construction.

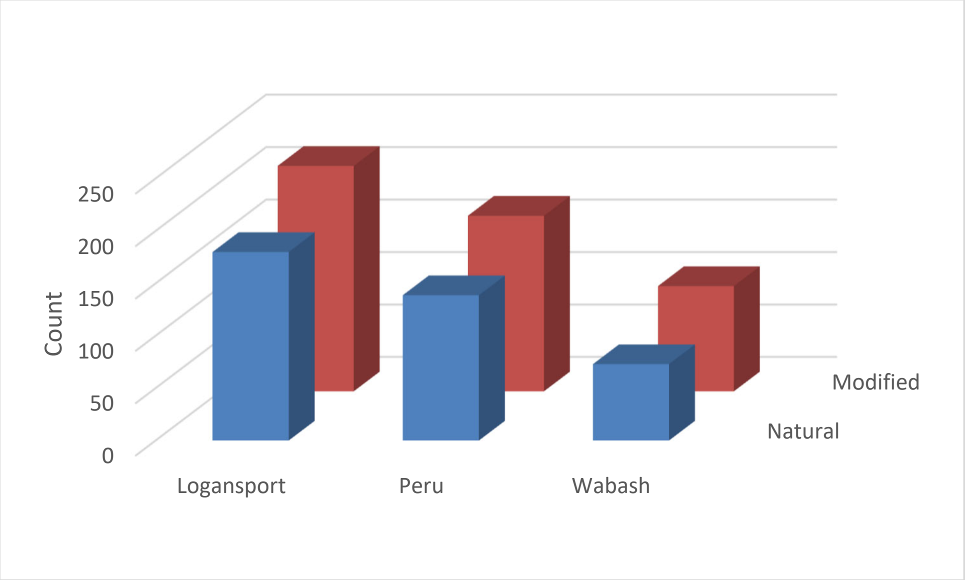


Figure C.41. Fall Rate prior to and after dam construction.

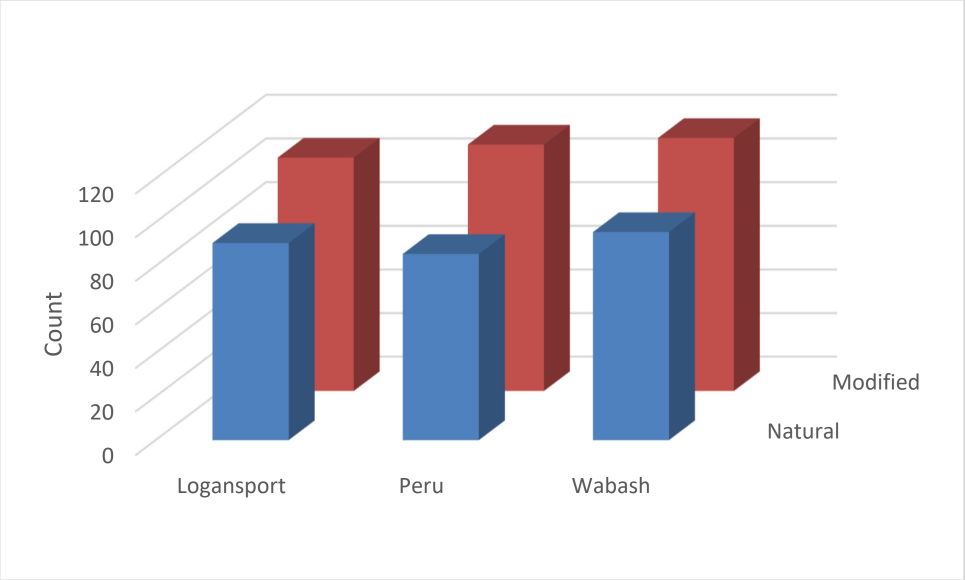


Figure C.42. Number of Reversals prior to and after dam construction.

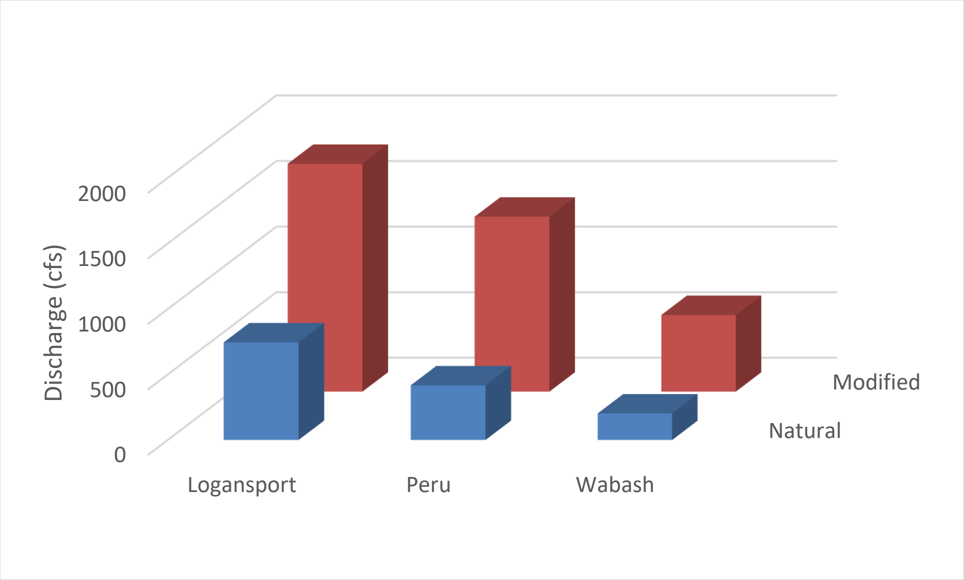


Figure C.43. November Low Flow prior to and after dam construction.

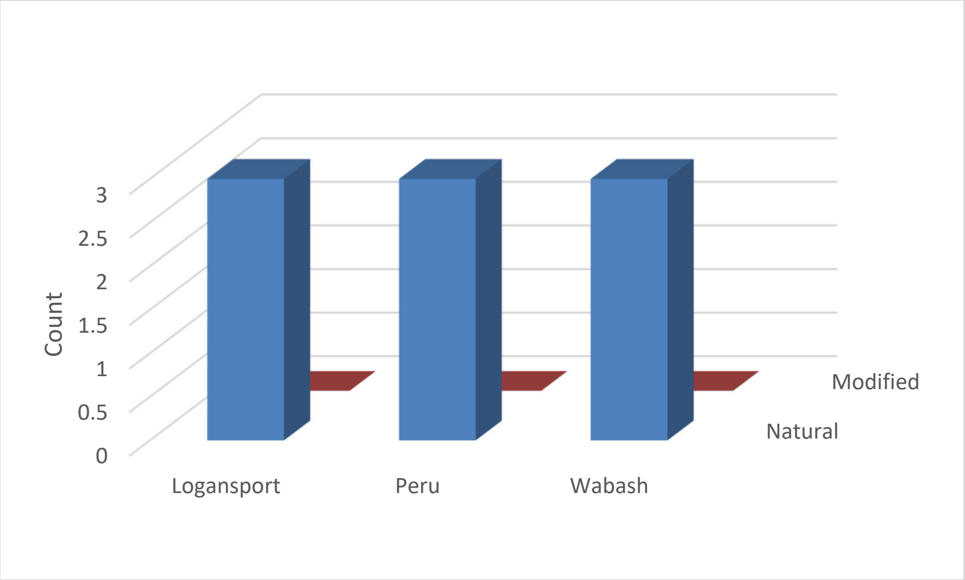


Figure C.44. Extreme Low Frequency prior to and after dam construction.

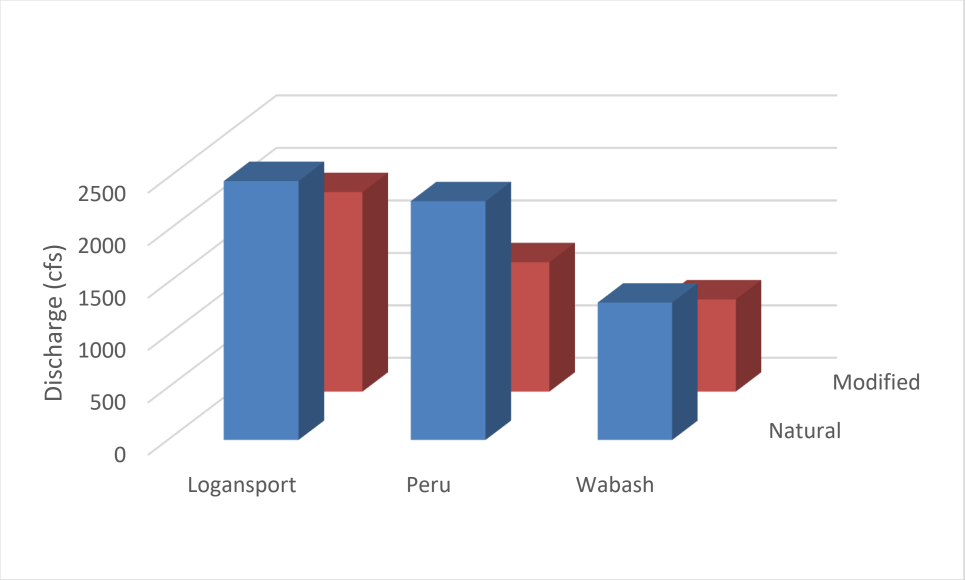


Figure C.45. High Flow Rise Rate prior to and after dam construction.

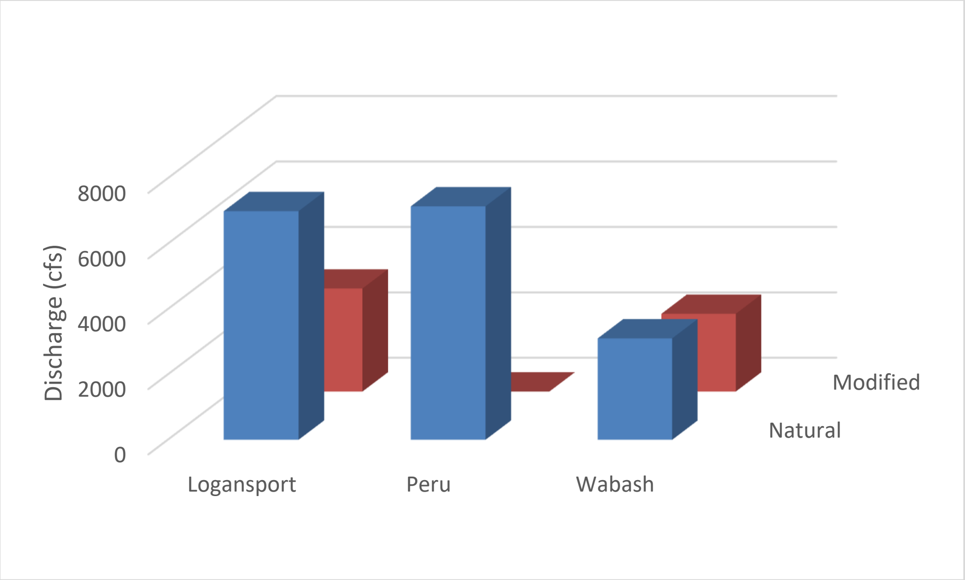


Figure C.46. Small Flood Rise Rate prior to and after dam construction.

Table C.1. Indicators of Hydrologic Alteration Values – 'Wabash River at Logansport'.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Median Flow	502.5	1340	0.9114	0.5	1.667	0.4514	0	0.1301
November Median Flow	755.5	2095	1.338	0.6492	1.773	0.515	0	0.1131
December Median Flow	962	2040	1.558	2.377	1.121	0.526	0.001001	0.1381
January Median Flow	1925	2200	1.408	2.35	0.1429	0.6694	0.6426	0.1391
February Median Flow	2765	3610	1.269	1.54	0.3056	0.2137	0.4064	0.5536
March Median Flow	3940	5810	1.01	1.043	0.4746	0.0332	0.02603	0.9089
April Median Flow	2865	3025	1.423	1.64	0.05585	0.1521	0.7778	0.5636
May Median Flow	2120	2310	1.031	1.736	0.08962	0.6843	0.3483	0.1802
June Median Flow	1498	2185	0.8144	2.142	0.4591	1.63	0.004004	0.00801
July Median Flow	869	1100	0.9652	1.001	0.2658	0.03701	0.08509	0.9359
August Median Flow	607.5	724	0.5609	0.8702	0.1918	0.5514	0.08308	0.1612
September Median Flow	472	865.5	0.8181	0.933	0.8337	0.1405	0	0.6396
1-day minimum flow	244.5	392	0.682	0.4668	0.6033	0.3155	0	0.2192
3-day minimum flow	259	410	0.5946	0.4317	0.583	0.2739	0	0.2352
7-day minimum flow	276.3	422.3	0.5604	0.4489	0.5284	0.1989	0	0.4585
30-day minimum flow	380.9	575.5	0.5086	0.6101	0.511	0.1995	0	0.6096
90-day minimum flow	676.4	1155	0.939	0.9659	0.7078	0.02858	0	0.9089
1-day maximum flow	34200	21900	0.5336	0.3196	0.3596	0.401	0	0.08609
3-day maximum flow	31730	19370	0.5825	0.3133	0.3897	0.4622	0	0.03203
7-day maximum flow	22990	16610	0.569	0.2941	0.2774	0.4832	0	0.05305
30-day maximum flow	11940	12220	0.643	0.4311	0.02389	0.3295	0.7297	0.1051
90-day maximum flow	7590	7734	0.5287	0.493	0.01899	0.06748	0.9139	0.7227
No. of zero days	0	0	0	0				
Base flow index	0.09168	0.1136	0.3419	0.5487	0.2386	0.6049	0.005005	0.05105
Date of minimum flow	266	249	0.07992	0.08197	0.0929	0.02564	0.002002	0.961
Date of maximum flow	80.5	63	0.1667	0.2377	0.09563	0.4262	0.1562	0.1091
Low Pulse Count	6	3	0.6667	1	0.5	0.5	0.04304	0.0951
Low Pulse Duration	7.5	6	0.6833	1.167	0.2	0.7073	0.3834	0.08509
High Pulse Count	11	12	0.5682	0.5	0.09091	0.12	0.1321	0.4925
High Pulse Duration	5	6	0.625	0.75	0.2	0.2	0.08108	0.5285
Rise Rate	282.5	238	1.577	0.9307	0.1575	0.4098	0.6807	0.1381
Fall Rate	-180	-215	-0.7882	-0.7163	0.1944	0.09124	0.1982	0.6897
Number of Reversals	90.5	107	0.2017	0.1308	0.1823	0.3512	0	0.1051

Table C.2. E-flow Component Values – ‘Wabash River at Logansport’.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Low Flow	555	1300	0.7586	0.4231	1.342	0.4423	0	0.1041
November Low Flow	746	1738	0.9246	0.3475	1.329	0.6242	0	0.05806
December Low Flow	884	1475	0.9243	0.7458	0.6686	0.1932	0	0.4955
January Low Flow	1365	1400	0.9011	0.8143	0.02564	0.09634	0.8889	0.7237
February Low Flow	1920	1770	0.7422	0.5565	0.07813	0.2502	0.5385	0.2893
March Low Flow	2260	2050	0.5022	0.4707	0.09292	0.06268	0.3954	0.8208
April Low Flow	1905	1715	0.3491	0.4315	0.09974	0.2361	0.1622	0.3754
May Low Flow	1318	1680	0.9089	0.2619	0.2751	0.7119	0.007007	0.01001
June Low Flow	1228	1500	0.5738	0.49	0.222	0.1461	0.005005	0.5996
July Low Flow	871.5	977	0.6971	0.6643	0.1211	0.04705	0.3203	0.8609
August Low Flow	664	718	0.4575	0.7228	0.08133	0.5801	0.3403	0.1091
September Low Flow	564	854.5	0.4433	0.7817	0.5151	0.7636	0	0.02202
Extreme low peak	336.8	333.5	0.17	0.1147	0.009651	0.3254	0.7558	0.3724
Extreme low duration	5.5	4	1.182	0.9375	0.2727	0.2067	0.5245	0.6116
Extreme low timing	266.3	246	0.1574	0.0806	0.1107	0.4881	0.009009	0.2623
Extreme low freq.	3	0	1.667	0	1	1	0	0.06406
High flow peak	7685	7850	0.5992	0.5357	0.02147	0.1061	0.8649	0.7187
High flow duration	4.75	6	0.6579	0.75	0.2632	0.14	0.008008	0.6937
High flow timing	95	73	0.1872	0.2582	0.1202	0.3796	0.2252	0.1562
High flow frequency	10	12	0.625	0.4167	0.2	0.3333	0.02703	0.2102
High flow rise rate	2470	1903	0.4079	0.4308	0.2293	0.05609	0.008008	0.8278
High flow fall rate	-1451	-1017	-0.3087	-0.3457	0.2995	0.1197	0	0.5976
Small Flood peak	42550	37100	0.2497	0.1179	0.1281	0.5277	0.1872	0.3994
Small Flood duration	24.5	39.5	0.449	1.063	0.6122	1.368	0	0.0961
Small Flood timing	102	138	0.2111	0.3251	0.1967	0.5405	0.1281	0.3534
Small Flood freq.	0	0	0	0				
Small Flood rise rate	6995	3153	1.178	2.685	0.5492	1.279	0.3073	0.02302
Small Flood fallrate	-3060	-1119	-0.7479	-0.7371	0.6343	0.01441	0.06206	0.974
Large flood peak	67700		0.2718					
Large flood duration	42		2.643					
Large flood timing	41		0.3689					
Large flood freq.	0	0	0	0				
Large flood rise rate	7497		2.283					
Large flood fallrate	-1586		-2.898					

Table C.3. Indicators of Hydrologic Alteration Values – ‘Wabash River at Peru’.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Median Flow	244.5	1100	1.182	0.4755	3.499	0.5978	0	0.08008
November Median Flow	454.3	1650	1.565	0.7182	2.632	0.5412	0	0.1461
December Median Flow	538.5	1390	1.573	2.158	1.581	0.3722	0.001	0.4364
January Median Flow	1415	1460	1.74	2.466	0.0318	0.4172	0.996	0.3233
February Median Flow	1598	2240	2.001	1.781	0.4022	0.1097	0.4585	0.7988
March Median Flow	3875	4160	0.8639	1.091	0.0736	0.2633	0.7127	0.3854
April Median Flow	2603	1610	1.317	2.164	0.3814	0.6433	0.3644	0.1021
May Median Flow	1405	1540	0.8203	1.878	0.0961	1.289	0.7317	0.1021
June Median Flow	962.3	1320	0.8724	2.717	0.3718	2.114	0.2042	0.03704
July Median Flow	574.5	646	0.6097	1.051	0.1245	0.724	0.5806	0.04805
August Median Flow	318.5	365	0.4819	1.003	0.146	1.081	0.1662	0.2082
September Median Flow	181.5	568.5	0.8492	1.082	2.132	0.2739	0	0.5015
1-day minimum flow	120	186	0.4958	0.5054	0.55	0.01925	0	0.958
3-day minimum flow	121.2	188.7	0.4574	0.5177	0.5571	0.1319	0	0.6947
7-day minimum flow	123.4	214.6	0.4079	0.4467	0.7394	0.09513	0	0.7197
30-day minimum flow	153.3	311.1	0.5097	0.5354	1.03	0.05038	0	0.8519
90-day minimum flow	399.3	854.6	0.9613	0.8832	1.14	0.08122	0.0040	0.8118
1-day maximum flow	26050	13500	0.619	0.2	0.4818	0.6769	0	0.2262
3-day maximum flow	23080	12210	0.7245	0.3057	0.4709	0.5781	0	0.1642
7-day maximum flow	17490	11160	0.7711	0.277	0.3617	0.6408	0	0.05405
30-day maximum flow	9790	8259	0.6376	0.3645	0.1564	0.4282	0.1692	0.1091
90-day maximum flow	6348	5511	0.538	0.5192	0.1319	0.03483	0.2873	0.8869
No. of zero days	0	0	0	0				
Base flow index	0.05557	0.0849	0.2266	0.515	0.5271	1.272	0	0.00601
Date of minimum flow	269.5	242	0.0499	0.0902	0.1503	0.8082	0.001	0.1331
Date of maximum flow	76.5	58	0.1783	0.2022	0.1011	0.1341	0.3213	0.6717
Low Pulse Count	5	4	0.6	1.25	0.2	1.083	0.5536	0.04605
Low Pulse Duration	7	5	1.286	1.05	0.2857	0.1833	0.2452	0.7277
High Pulse Count	13	11	0.5385	0.4545	0.1538	0.1558	0.3794	0.5455
High Pulse Duration	5	6	0.525	0.75	0.2	0.4286	0.1301	0.2983
Rise Rate	207.5	208.5	1.376	0.8177	0.00482	0.4057	0.9389	0.1311
Fall Rate	-138.8	-167.5	-0.7369	-0.7164	0.2072	0.02784	0.5085	0.9369
Number of Reversals	85.5	113	0.2749	0.1327	0.3216	0.517	0	0.2182

Table C.4. E-flow Component Values – 'Wabash River at Peru'.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Low Flow	305	1070	0.6852	0.386	2.508	0.4367	0	0.2282
November Low Flow	417.5	1335	1.284	0.4082	2.198	0.6821	0	0.02603
December Low Flow	493.8	944.5	0.9119	0.9112	0.9129	0.00077	0	0.999
January Low Flow	890	933.3	1.112	0.8642	0.0486	0.2231	0.8218	0.4254
February Low Flow	915	1125	1.141	0.5722	0.2295	0.4984	0.2903	0.1011
March Low Flow	1450	1335	0.5276	0.5234	0.07931	0.007919	0.6246	0.98
April Low Flow	1390	881	0.3795	0.5865	0.3662	0.5456	0.01902	0.07708
May Low Flow	1045	1005	0.6744	0.5127	0.03876	0.2398	0.8038	0.4655
June Low Flow	695	909	0.5326	0.562	0.3079	0.05533	0.04204	0.8559
July Low Flow	552.5	610	0.5317	0.7918	0.1041	0.4893	0.6747	0.0981
August Low Flow	331.8	347	0.4827	0.781	0.04597	0.618	0.6086	0.2523
September Low Flow	268	556	0.3442	1.01	1.075	1.934	0	0
Extreme low peak	157	157.3	0.2197	0.1518	0.001592	0.3091	0.965	0.5175
Extreme low duration	5	3	1	1.208	0.4	0.2083	0.2693	0.7327
Extreme low timing	271	240.8	0.1475	0.06148	0.1653	0.5833	0.02102	0.2322
Extreme low freq.	3	0	1.333	0	1	1	0	0
High flow peak	5930	5630	0.5051	0.6696	0.05059	0.3258	0.5856	0.2002
High flow duration	4.5	6	0.5	0.75	0.3333	0.5	0.005005	0.1932
High flow timing	99.5	80	0.1448	0.2268	0.1066	0.566	0.4464	0.1191
High flow frequency	11.5	11	0.6957	0.4545	0.04348	0.3466	0.6767	0.1652
High flow rise rate	2278	1235	0.4821	0.4418	0.4577	0.08367	0.001001	0.8078
High flow fall rate	-1160	-825.5	-0.32	-0.3082	0.2881	0.03688	0	0.9129
Small Flood peak	29000		0.3888					
Small Flood duration	23		0.3804					
Small Flood timing	41		0.2883					
Small Flood freq.	0.5	0	2.5	0	1	1	0	0
Small Flood rise rate	7142		0.816					
Small Flood fallrate	-1922		-0.4743					
Large flood peak	50900							
Large flood duration	22							
Large flood timing	163							
Large flood freq.	0	0	0	0				
Large flood rise rate	12610							
Large flood fallrate	-2573							

Table C.5. Indicators of Hydrologic Alteration Values – 'Wabash River at Wabash'.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Median Flow	142.5	652	1.246	0.5506	3.575	0.558	0	0.02503
November Median Flow	216	720.5	1.878	1.006	2.336	0.4647	0	0.2553
December Median Flow	297.5	861	2.191	2.799	1.894	0.2777	0	0.5976
January Median Flow	775	877	1.782	2.714	0.1316	0.5227	0.5015	0.1812
February Median Flow	1083	1500	1.557	1.81	0.3854	0.1622	0.2963	0.6537
March Median Flow	1695	2580	1.249	1.252	0.5221	0.002142	0.03804	0.996
April Median Flow	991.3	1110	1.938	1.957	0.1198	0.009569	0.6507	0.982
May Median Flow	650	875	1.6	2.095	0.3462	0.309	0.1171	0.6246
June Median Flow	464.3	831.5	1.184	2.597	0.7911	1.192	0.001001	0.00701
July Median Flow	237.5	339	1.045	1.265	0.4274	0.2107	0.02302	0.5506
August Median Flow	126	210	1.21	1.371	0.6667	0.1331	0.003003	0.8298
September Median Flow	88	368.5	1.077	0.9986	3.188	0.0725	0	0.8268
1-day minimum flow	42.5	89.1	0.7294	0.5499	1.096	0.246	0	0.3313
3-day minimum flow	45.67	90.6	0.688	0.5923	0.9839	0.139	0	0.5956
7-day minimum flow	49.93	104.4	0.6574	0.5527	1.092	0.1593	0	0.5375
30-day minimum flow	67.13	161.4	0.8556	0.8499	1.405	0.006671	0	0.987
90-day minimum flow	188.8	452.9	1.474	1.164	1.4	0.2099	0	0.5155
1-day maximum flow	21050	10400	0.5475	0.3327	0.5059	0.3923	0	0.3103
3-day maximum flow	17570	8947	0.5488	0.3245	0.4907	0.4087	0	0.3073
7-day maximum flow	12910	7701	0.5667	0.3328	0.4034	0.4128	0	0.1672
30-day maximum flow	5789	5623	0.6148	0.3772	0.02863	0.3865	0.4444	0.1802
90-day maximum flow	3879	3612	0.4951	0.4379	0.0688	0.1157	0.4114	0.6667
No. of zero days	0	0	0	0				
Base flow index	0.03222	0.05791	0.5	0.6936	0.7973	0.3872	0	0.2342
Date of minimum flow	264	242	0.1038	0.09016	0.1202	0.1316	0	0.5726
Date of maximum flow	79.5	57	0.1646	0.2705	0.123	0.6432	0.07908	0.03003
Low Pulse Count	6	3	0.8333	1.333	0.5	0.6	0.1131	0.1241
Low Pulse Duration	6.25	5	0.72	1	0.2	0.3889	0.1051	0.2523
High Pulse Count	13	13	0.5	0.4615	0	0.07692	0.6116	0.7407
High Pulse Duration	5	6	0.525	0.5833	0.2	0.1111	0.01602	0.5445
Rise Rate	118.8	136	1.389	0.761	0.1453	0.4523	0.3824	0.1171
Fall Rate	-73	-100.5	-0.863	-0.796	0.3767	0.07763	0.02402	0.7528
Number of Reversals	95.5	116	0.233	0.1293	0.2147	0.445	0	0.2012

Table C.6. E-flow Component Values – ‘Wabash River at Wabash’.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Low Flow	174	610.3	0.852	0.3349	2.507	0.6069	0	0.02302
November Low Flow	202.8	585.3	1.505	0.3827	1.887	0.7457	0	0.08208
December Low Flow	273.8	525	1.295	0.8819	0.9178	0.319	0	0.2182
January Low Flow	555	612.3	1.017	0.7038	0.1032	0.3078	0.5776	0.3183
February Low Flow	669	651	0.96	0.4846	0.02691	0.4952	0.6997	0.1101
March Low Flow	806.5	816.5	0.5197	0.4672	0.0124	0.1009	0.7608	0.6977
April Low Flow	657.5	527	0.4924	0.6779	0.1985	0.3767	0.04204	0.04605
May Low Flow	404	524.3	1.229	0.5789	0.2976	0.5288	0.03103	0.02903
June Low Flow	336	504.5	0.7682	0.665	0.5015	0.1344	0	0.6176
July Low Flow	237.5	290.5	0.7884	0.7022	0.2232	0.1093	0.1321	0.7467
August Low Flow	150	182	0.8533	0.8187	0.2133	0.04061	0.1251	0.8759
September Low Flow	139	295	0.8022	1.19	1.122	0.4833	0	0.1091
Extreme low peak	59.25	69	0.1941	0.06957	0.1646	0.6416	0	0.03403
Extreme low duration	4.5	2	1.778	2	0.5556	0.125	0.2022	0.8158
Extreme low timing	249.5	241	0.1482	0.1052	0.04645	0.2903	0.1822	0.5445
Extreme low freq.	3	0	2	0	1	1	0	0.00901
High flow peak	3608	3680	0.649	0.4932	0.0201	0.24	0.7918	0.2563
High flow duration	4.75	6	0.6316	0.5833	0.2632	0.07639	0.02302	0.8368
High flow timing	96	82	0.1742	0.179	0.0765	0.02745	0.1481	0.9319
High flow frequency	12	13	0.5417	0.4615	0.08333	0.1479	0.1351	0.5546
High flow rise rate	1312	880.5	0.6124	0.3277	0.329	0.465	0	0.06106
High flow fall rate	-707.5	-557.7	-0.3006	-0.3407	0.2117	0.1332	0	0.6787
Small Flood peak	25350	22000	0.2505		0.1321		0.1161	
Small Flood duration	21	32	0.869		0.5238		0.1652	
Small Flood timing	75.5	109	0.2234		0.1831		0.3564	
Small Flood freq.	0	0	0	0				
Small Flood rise rate	3104	2379	1.411		0.2337		0.6577	
Small Flood fallrate	-2128	-880	-0.8033		0.5864		0.1431	
Large flood peak	38600		0.3705					
Large flood duration	32		0.5313					
Large flood timing	41		0.3689					
Large flood freq.	0	0	0	0				
Large flood rise rate	12470		0.9146					
Large flood fallrate	-1039		-2.068					

Table C.7. Indicators of Hydrologic Alteration Values – 'Mississinewa River at Marion'.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Median Flow	63	75	1.262	1.18	0.1905	0.06491	0.1451	0.8268
November Median Flow	99	162	1.881	1.296	0.6364	0.311	0.01201	0.2452
December Median Flow	150	324	1.877	1.335	1.16	0.2887	0.005005	0.4124
January Median Flow	292	270	1.932	1.289	0.07534	0.3327	0.8088	0.2663
February Median Flow	408.5	419	1.387	1.103	0.0257	0.2049	0.8619	0.4014
March Median Flow	692	647	0.8367	1.017	0.06503	0.2155	0.7407	0.3604
April Median Flow	516	492.5	0.8944	0.8863	0.04554	0.00904	0.6747	0.98
May Median Flow	250	383	1.37	0.7023	0.532	0.4873	0.002002	0.02803
June Median Flow	172.5	281.5	1.226	1.021	0.6319	0.167	0.007007	0.5175
July Median Flow	125	136	0.964	0.9449	0.088	0.01986	0.3644	0.973
August Median Flow	66	88	0.8485	0.75	0.3333	0.1161	0.03103	0.6126
September Median Flow	53	77.5	1.066	1.135	0.4623	0.06514	0.02202	0.8649
1-day minimum flow	21	33	1	0.7576	0.5714	0.2424	0.008008	0.2723
3-day minimum flow	24	38	1.09	0.5614	0.5833	0.4851	0	0.02302
7-day minimum flow	31.57	41.29	0.6833	0.4706	0.3077	0.3113	0.01001	0.1411
30-day minimum flow	46.67	61.6	0.4229	0.563	0.32	0.3315	0	0.2112
90-day minimum flow	87.13	136.7	0.9894	1.011	0.5694	0.02228	0.004004	0.9499
1-day maximum flow	10400	11700	0.7894	0.5205	0.125	0.3406	0.2773	0.1822
3-day maximum flow	8370	9390	0.7391	0.429	0.1219	0.4196	0.2442	0.09109
7-day maximum flow	5324	5817	0.6778	0.4606	0.09257	0.3204	0.4505	0.2292
30-day maximum flow	2413	2517	0.8935	0.3488	0.04296	0.6096	0.6346	0.05105
90-day maximum flow	1561	1574	0.5633	0.3887	0.008921	0.31	0.9239	0.1652
No. of zero days	0	0	0	0				
Base flow index	0.05536	0.06441	0.5408	0.4525	0.1636	0.1633	0.06807	0.5756
Date of minimum flow	247	264	0.1421	0.1093	0.0929	0.2308	0.08008	0.4264
Date of maximum flow	80	54	0.2773	0.2746	0.1421	0.009852	0.2012	0.966
Low Pulse Count	5	5	0.9	0.9	0	0	0.1542	0.9449
Low Pulse Duration	7.5	4	1.767	1.75	0.4667	0.009434	0.05606	0.985
High Pulse Count	13	14	0.5385	0.3929	0.07692	0.2704	0.2012	0.4184
High Pulse Duration	4	5	0.5625	0.4	0.25	0.2889	0	0.4154
Rise Rate	48	65.5	1.75	1.229	0.3646	0.2977	0.2633	0.3654
Fall Rate	-32	-30	-0.7109	-0.6333	0.0625	0.1092	0.4605	0.5485
Number of Reversals	101	99	0.1881	0.1111	0.0198	0.4094	0.5736	0.06106

Table C.8. E-flow Component Values – 'Mississinewa River at Marion'.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Low Flow	68	79	0.8934	1.089	0.1618	0.2185	0.2693	0.4254
November Low Flow	90	126.3	1.311	0.8416	0.4028	0.3581	0.01802	0.2292
December Low Flow	125	218	1.162	0.8716	0.744	0.2499	0.002002	0.3063
January Low Flow	183	215	1.191	0.6267	0.1749	0.4739	0.3584	0.1602
February Low Flow	239.8	274.8	1.014	0.652	0.146	0.3568	0.2332	0.1171
March Low Flow	319.8	314	0.5313	0.4013	0.01798	0.2447	0.9279	0.2332
April Low Flow	305	310	0.4	0.2879	0.01639	0.2802	0.6476	0.3303
May Low Flow	206	295.5	0.8386	0.3841	0.4345	0.542	0.001001	0.02002
June Low Flow	154	222	0.6104	0.5766	0.4416	0.0554	0.001001	0.7608
July Low Flow	112	133	0.9955	0.7124	0.1875	0.2844	0.1281	0.3023
August Low Flow	75	88	0.475	0.7102	0.1733	0.4952	0.06406	0.1031
September Low Flow	74	82.5	0.4966	0.803	0.1149	0.617	0.3133	0.1261
Extreme low peak	3	3	2	1.667	0	0.1667	0.4585	0.8839
Extreme low duration	265	257	0.168	0.0929	0.04372	0.4472	0.3373	0.1241
Extreme low timing	4	1	1.875	2.5	0.75	0.3333	0.06807	0.3644
Extreme low freq.	1395	1760	1.027	0.6974	0.2616	0.3208	0.04104	0.1792
High flow peak	4	4.5	0.5625	0.4444	0.125	0.2099	0.07107	0.6026
High flow duration	91	105	0.1592	0.2049	0.0765	0.2876	0.6787	0.2843
High flow timing	12	13	0.5833	0.4615	0.08333	0.2088	0.2563	0.3844
High flow frequency	582.7	637.5	0.6054	0.4341	0.09411	0.2829	0.1612	0.3243
High flow rise rate	-326	-374	-0.4971	-0.4183	0.1472	0.1586	0.07608	0.4444
High flow fall rate	14350	12250	0.2578	0.2388	0.1463	0.07394	0.05205	0.8088
Small Flood peak	24.5	17	0.5102	0.7059	0.3061	0.3835	0.04204	0.1001
Small Flood duration	71	61	0.2336	0.2746	0.05464	0.1754	0.6086	0.5445
Small Flood timing	0	1	0	1				
Small Flood freq.	3190	2532	0.9981	1.047	0.2062	0.04918	0.4464	0.8709
Small Flood rise rate	-876.1	-1210	-0.6708	-0.6392	0.3817	0.04717	0.03203	0.8889
Small Flood fallrate	20730	20200	0.1562	0.05941	0.02533	0.6197	0.5345	0.5025
Large flood peak	26	24.5	0.5577	0.7041	0.05769	0.2625	0.8418	0.6466
Large flood duration	135	17	0.1107	0.4536	0.6448	3.099	0.2673	0.06907
Large flood timing	0	0	0	0				
Large flood freq.	2508	2690	1.91	2.537	0.07233	0.3283	0.961	0.5706
Large flood rise rate	-1101	-2004	-0.442	-0.6009	0.8202	0.3595	0.1251	0.4104
Large flood fallrate	3	3	2	1.667	0	0.1667	0.4585	0.8839

Table C.9. Indicators of Hydrologic Alteration Values – ‘Salamonie River near Warren’.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Median Flow	66	31	7.273	1.852	0.5303	0.7453	0.1702	0.2533
November Median Flow	121	66.53	4.041	1.43	0.4502	0.6462	0.1932	0.2633
December Median Flow	190	144	3.879	1.781	0.2421	0.5408	0.6547	0.2833
January Median Flow	258	123.5	2.025	1.635	0.5213	0.1928	0.3654	0.7137
February Median Flow	252	199.3	3.119	1.294	0.2093	0.5851	0.6426	0.2112
March Median Flow	216	309	3.63	0.9345	0.4306	0.7425	0.1111	0.1391
April Median Flow	288.5	220.5	5.681	1.174	0.2357	0.7933	0.5445	0.1812
May Median Flow	150	164	0.9233	0.7256	0.09333	0.2141	0.7618	0.972
June Median Flow	81.5	100.6	5.669	1.563	0.2344	0.7243	0.3944	0.2933
July Median Flow	78	54.15	2.128	1.008	0.3058	0.5262	0.4434	0.3033
August Median Flow	54	32.1	2.435	1.168	0.4056	0.5203	0.2673	0.2492
September Median Flow	28	32.15	1.33	0.9226	0.1482	0.3065	0.7437	0.6517
1-day minimum flow	12	12	0.5917	0.6646	0	0.1232	0.973	0.8689
3-day minimum flow	12	12.12	0.7194	0.6369	0.009722	0.1148	0.97	0.8659
7-day minimum flow	12.43	13.71	1.013	0.605	0.1029	0.4026	0.6406	0.4434
30-day minimum flow	14.17	21.02	1.723	0.9069	0.4834	0.4737	0.1932	0.2102
90-day minimum flow	101.7	72.29	2.249	1.21	0.2893	0.4619	0.4975	0.3083
1-day maximum flow	6760	6700	0.7604	0.4179	0.008876	0.4504	0.96	0.2262
3-day maximum flow	6480	5682	0.5543	0.4613	0.1232	0.1678	0.5165	0.6757
7-day maximum flow	4874	3880	0.569	0.5174	0.2039	0.09076	0.2482	0.8228
30-day maximum flow	2341	1691	0.4206	0.4048	0.2775	0.03763	0.04805	0.9379
90-day maximum flow	1305	994	0.4057	0.3987	0.2386	0.01741	0.05105	0.979
No. of zero days	0	0	0	0				
Base flow index	0.02964	0.03274	0.7272	0.809	0.1046	0.1125	0.6937	0.8308
Date of minimum flow	255	265	0.3757	0.1311	0.05464	0.6509	0.6006	0.07107
Date of maximum flow	95	59.5	0.2022	0.2432	0.194	0.2027	0.5245	0.6236
Low Pulse Count	5	7	0.3	0.75	0.4	1.5	0.2252	0.002
Low Pulse Duration	8	8	1.188	0.7969	0	0.3289	0.958	0.959
High Pulse Count	11	16	0.8182	0.4063	0.4545	0.5035	0.01301	0.2252
High Pulse Duration	4	3	0.625	0.1667	0.25	0.7333	0.005005	0.3123
Rise Rate	35	25.23	2.414	1.194	0.2793	0.5053	0.4525	0.2973
Fall Rate	-25	-18	-0.94	-0.5764	0.28	0.3868	0.2052	0.3864
Number of Reversals	87	96.5	0.3621	0.1477	0.1092	0.5922	0.02703	0.1461

Table C.10. E-flow Component Values – 'Salamonie River near Warren'.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Low Flow	49	43.6	0.9158	1.181	0.1102	0.2898	0.7437	0.5526
November Low Flow	53.5	68.5	1.523	1.004	0.2804	0.3412	0.2482	0.4615
December Low Flow	91.25	113.5	1.474	1.24	0.2438	0.1587	0.4414	0.7177
January Low Flow	148.5	113	0.702	0.8546	0.2391	0.2174	0.5305	0.6597
February Low Flow	90.5	144.5	2.36	1.1	0.5967	0.5341	0.06406	0.3153
March Low Flow	166	213	1.557	0.5622	0.2831	0.639	0.1341	0.1411
April Low Flow	158	170.5	1.453	0.6188	0.07911	0.574	0.7247	0.1361
May Low Flow	116	128.3	0.9052	0.4834	0.1056	0.4659	0.5355	0.5315
June Low Flow	62	93.5	0.746	0.9973	0.5081	0.337	0.02703	0.5355
July Low Flow	71	54.65	1.011	0.715	0.2303	0.2925	0.4004	0.6376
August Low Flow	54	42.25	1.546	0.6976	0.2176	0.5488	0.6186	0.1992
September Low Flow	29	36.78	0.8707	0.673	0.2681	0.227	0.3403	0.7057
Extreme low peak	15	14.7	0.2333	0.307	0.02	0.3156	0.8428	0.6787
Extreme low duration	3	4.5	8.083	0.8889	0.5	0.89	0.2823	0.01401
Extreme low timing	255	257.5	0.1557	0.1452	0.01366	0.06798	0.8849	0.8899
Extreme low freq.	3	4	1.5	1.25	0.3333	0.1667	0.5215	0.7257
High flow peak	1525	1895	0.5016	0.4169	0.2426	0.169	0.1081	0.7007
High flow duration	3	3	0.8333	0.3333	0	0.6	0.2252	0.4054
High flow timing	114	79.5	0.3846	0.1209	0.1885	0.6856	0.03704	0.1241
High flow frequency	11	15.5	0.7273	0.4516	0.4091	0.379	0.02102	0.3624
High flow rise rate	638.5	909	0.2901	0.4268	0.4236	0.471	0.006006	0.1882
High flow fall rate	-442	-621.4	-0.0707	-0.4523	0.4059	5.397	0.006006	0
Small Flood peak	7745	7940	0.2544	0.2336	0.02518	0.0815	0.7778	0.8358
Small Flood duration	11	10	0.3636	0.9	0.09091	1.475	0.6567	0.2272
Small Flood timing	87	61	0.04372	0.2828	0.1421	5.469	0.7037	0.01702
Small Flood freq.	0	0	0	0				
Small Flood rise rate	2948	2151	0.896	0.7013	0.2704	0.2172	0.6356	0.5896
Small Flood fallrate	-843	-1459	-0.5301	-0.526	0.7305	0.007614	0.03704	0.9079
Large flood peak	10400	10750		0.03721	0.03365		0.009009	
Large flood duration	16	9		1.222	0.4375		0.1862	
Large flood timing	162	38		0.4706	0.6776		0.1261	
Large flood freq.	0	0	0	0				
Large flood rise rate	3446	4264		0.6554	0.2376		0.1972	
Large flood fallrate	-708.4	-1568		-0.5991	1.214		0.05906	

Table C.11. Indicators of Hydrologic Alteration Values – 'Wabash River at Bluffton'.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Median Flow	19	28.04	2.674	1.784	0.4755	0.3327	0.2653	0.4875
November Median Flow	30.5	86.35	2.328	1.89	1.831	0.1883	0.005005	0.5746
December Median Flow	43	210	2.953	1.706	3.884	0.4223	0	0.2813
January Median Flow	157	269.1	3	1.646	0.7143	0.4514	0.09409	0.1982
February Median Flow	225	386.9	1.933	1.204	0.7195	0.3773	0.03403	0.2302
March Median Flow	685	527	0.9912	1.058	0.2307	0.06692	0.5506	0.8328
April Median Flow	261.5	349.9	2.539	1.194	0.338	0.5298	0.2072	0.07407
May Median Flow	118	186.2	1.966	1.199	0.5776	0.3903	0.008008	0.2212
June Median Flow	80	164.8	1.65	1.275	1.061	0.2275	0.003003	0.4755
July Median Flow	43	78.5	1.233	1.286	0.8256	0.04313	0.005005	0.9109
August Median Flow	20	34.09	1.2	1.776	0.7045	0.4803	0.009009	0.4344
September Median Flow	13	26.35	2.369	1.313	1.027	0.4459	0.005005	0.1251
1-day minimum flow	6.9	9.868	0.6957	0.9364	0.4302	0.346	0.001001	0.4204
3-day minimum flow	7.167	10.26	0.6605	0.9107	0.4318	0.3789	0	0.3594
7-day minimum flow	7.6	11.55	0.6617	0.8791	0.5202	0.3287	0	0.3483
30-day minimum flow	10.11	16.63	0.841	0.9281	0.6459	0.1036	0	0.8849
90-day minimum flow	38.2	75.44	1.321	1.324	0.9749	0.002394	0.005005	0.993
1-day maximum flow	4820	5810	0.7552	0.4517	0.2054	0.4019	0.1101	0.08909
3-day maximum flow	4400	5230	0.672	0.4417	0.1885	0.3426	0.1932	0.1231
7-day maximum flow	3267	3962	0.5982	0.3932	0.2126	0.3427	0.06106	0.07407
30-day maximum flow	1602	1841	0.7301	0.437	0.1487	0.4014	0.04004	0.08208
90-day maximum flow	1109	1211	0.5894	0.4055	0.09232	0.312	0.4314	0.1662
No. of zero days	0	0	0	0				
Base flow index	0.0236	0.02689	0.5831	0.7623	0.1394	0.3072	0.3363	0.1672
Date of minimum flow	274	274	0.07923	0.07104	0	0.1034	0.9089	0.7638
Date of maximum flow	103	58	0.1913	0.276	0.2459	0.4429	0.06807	0.1011
Low Pulse Count	5	4	1	1.5	0.2	0.5	0.4384	0.1161
Low Pulse Duration	8.25	5.5	1.015	0.8182	0.3333	0.194	0.03303	0.6066
High Pulse Count	11	14	0.5455	0.4286	0.2727	0.2143	0.01001	0.4274
High Pulse Duration	4	4	0.5	0.75	0	0.5	0.3203	0.1321
Rise Rate	40	43.5	1.538	1.366	0.0875	0.1113	0.6997	0.6677
Fall Rate	-13	-18.78	-1.231	-0.7761	0.4449	0.3694	0.05806	0.1562
Number of Reversals	87	94	0.1609	0.1596	0.08046	0.008359	0.007007	0.982

Table C.12. E-flow Component Values – 'Wabash River at Bluffton.

	Medians		Coeff of Disp.		Deviation Factor		Significance Count	
	Pre	Post	Pre	Post	Medians	C.D.	Medians	C.D.
October Low Flow	29.5	29.1	1.466	1.352	0.01356	0.07786	0.986	0.8388
November Low Flow	27	51.15	1.329	1.592	0.8944	0.1984	0.008008	0.5686
December Low Flow	40.5	117.7	2.148	1.418	1.907	0.34	0.002002	0.3473
January Low Flow	80	154.8	1.619	1.21	0.9344	0.2524	0.02102	0.3764
February Low Flow	77	174.4	1.578	0.9086	1.265	0.4242	0	0.08909
March Low Flow	150.5	177.7	0.9743	0.5881	0.181	0.3964	0.1622	0.1662
April Low Flow	154.3	173.8	0.9125	0.6452	0.1269	0.293	0.3654	0.1461
May Low Flow	88	147.4	0.5227	0.6356	0.6749	0.2159	0	0.4224
June Low Flow	61	123	0.7213	0.5972	1.016	0.1721	0	0.4084
July Low Flow	46	65.24	0.9348	0.8328	0.4183	0.1091	0.009009	0.6166
August Low Flow	22.5	32.52	1	1.414	0.4454	0.4138	0.03604	0.3363
September Low Flow	23.5	25.79	1.362	1.027	0.09755	0.2455	0.5465	0.3223
Extreme low peak	8.8	9.42	0.1932	0.1984	0.07044	0.02718	0.3273	0.9179
Extreme low duration	8	4	0.875	1.219	0.5	0.3929	0.07508	0.2823
Extreme low timing	260	268.5	0.1339	0.08846	0.04645	0.3393	0.2192	0.2472
Extreme low freq.	2	1	2	3	0.5	0.5	0.2482	0.1642
High flow peak	902.5	1026	0.4321	0.5968	0.1368	0.381	0.07007	0.2683
High flow duration	4	3.5	0.5	0.5714	0.125	0.1429	0.3463	0.4134
High flow timing	101	111	0.1598	0.2596	0.05464	0.6239	0.5105	0.02503
High flow frequency	10	12	0.6	0.5	0.2	0.1667	0.03403	0.4705
High flow rise rate	318	399.7	0.4746	0.4167	0.257	0.1221	0.002002	0.6046
High flow fall rate	-204.5	-238.6	-0.3405	-0.2919	0.1667	0.1427	0.003003	0.5846
Small Flood peak	6890	5854	0.1858	0.2179	0.1503	0.1729	0.01001	0.5526
Small Flood duration	27	30	0.6667	0.7417	0.1111	0.1125	0.2913	0.8559
Small Flood timing	79.5	57.5	0.1257	0.2596	0.1202	1.065	0.2422	0.01401
Small Flood freq.	0	1	0	1				
Small Flood rise rate	920.8	855.9	1.147	0.9389	0.07041	0.1816	0.7708	0.5726
Small Flood fallrate	-335	-265.4	-0.6928	-1.043	0.2078	0.5054	0.4254	0.1191
Large flood peak	10200	9936	0.1775	0.1685	0.02591	0.05035	0.7057	0.9329
Large flood duration	50	38.5	1.62	0.7857	0.23	0.515	0.6957	0.4304
Large flood timing	45	123.5	0.3388	0.3962	0.429	0.1694	0.4865	0.5395
Large flood freq.	0	0	0	0				
Large flood rise rate	847.5	1544	0.8828	1.167	0.8217	0.322	0.1071	0.5285
Large flood fallrate	-241.1	-337.5	-0.9529	-1.557	0.3998	0.634	0.4354	0.3273

Appendix D – Summary Tables of Upper Wabash Species

Table D.1. Mississinewa Lake Phytoplankton Species List and Relative Abundance (USACE, 2022)

Division	Genus	Species	Percent of total Abundance
Bacillariophyta	Achnanthidium	minutissimum	0.03%
Bacillariophyta	Aulacoseira	granulata	0.21%
Bacillariophyta	Cyclotella	meneghiniana	0.05%
Bacillariophyta	Fragilaria	capucina	0.09%
Bacillariophyta	Fragilaria	crotonensis	0.05%
Bacillariophyta	Nitzschia	fruticosa	0.32%
Bacillariophyta	Nitzschia	inconspicua	0.05%
Bacillariophyta	Stephanodiscus	hantzschii	0.03%
Bacillariophyta	Stephanodiscus	parvus	0.20%
Bacillariophyta	Stephanodiscus		0.03%
Bacillariophyta	Synedra	tenera	0.44%
Chlorophyta	Characium		0.01%
Chlorophyta	Chlamydomonas		0.30%
Chlorophyta	Chlorella		1.30%
Chlorophyta	Coelastrum		0.04%
Chlorophyta	Cosmarium		0.04%
Chlorophyta	Crucigenia		0.09%
Chlorophyta	Desmodesmus	communis	0.07%
Chlorophyta	Elakatothrix		0.02%
Chlorophyta	Gonium		0.11%
Chlorophyta	Kirchneriella		0.14%
Chlorophyta	Oocystis		0.02%
Chlorophyta	Scenedesmus		0.18%
Chlorophyta	Sphaerocystis	schroeteri	0.57%
Cryptophyta	Cryptomonas	erosa	0.21%
Cryptophyta	Plagioselmis	nannoplanctica	2.30%
Cryptophyta	Rhodomonas	lacustris	0.27%
Cyanobacteria	Anabaena	flos-aquae	0.27%
Cyanobacteria	Aphanizomenon		0.28%

Division	Genus	Species	Percent of total Abundance
Cyanobacteria	Aphanocapsa	delicatissima	7.85%
Cyanobacteria	Chroococcus	microscopicus	20.35%
Cyanobacteria	Chroococcus		0.41%
Cyanobacteria	Cyanodictyon		0.73%
Cyanobacteria	Cylindrospermopsis	raciborskii	35.71%
Cyanobacteria	Merismopedia	tenuissima	6.97%
Cyanobacteria	Merismopedia		4.81%
Cyanobacteria	Microcystis		0.97%
Cyanobacteria	Planktolyngbya	limnetica	9.19%
Cyanobacteria	Pseudanabaena	limnetica	0.29%
Cyanobacteria	Pseudanabaena		2.19%
Cyanobacteria	Raphidiopsis	curvata	2.80%
Euglenophyta	Euglena		0.004%
Pyrrophyta	Ceratium	cornutum	0.01%
Pyrrophyta	Glenodinium		0.01%

Table D.2. Mississinewa Lake Zooplankton Species List and Relative Abundance (USACE, 2022)

Division	Genus	Species	Percent of total Abundance
Cladocera	Bosmina	longirostris	0.16%
Cladocera	Ceriodaphnia	spp.	0.47%
Cladocera	Daphnia	lumholtzi	4.35%
Cladocera	Diaphanosoma	brachyurum	11.02%
Cladocera	Ilyocryptus	spp.	0.16%
Cladocera	Moina	micrura	1.24%
Copepoda	calanoid	copepodid	12.58%
Copepoda	cyclopoid	copepodid	9.47%
Copepoda	Ergasilus	spp.	16.30%
Copepoda	Leptodiaptomus	siciloides	0.93%
Copepoda	nauplii		5.75%
Copepoda	Skistodiaptomus	reighardi	1.86%
Copepoda	Tropocyclops	prasinus	0.93%

Division	Genus	Species	Percent of total Abundance
Ostracoda	ostracod		0.47%
Rotifera	Asplanchna	spp.	31.06%
Rotifera	Brachionus	calyciflorus	1.09%
Rotifera	Brachionus	caudatus	1.24%
Rotifera	Ploesoma	truncatum	0.16%
Rotifera	Polyarthra	vulgaris	0.62%
Rotifera	Synchaeta	spp.	0.16%

Table D.3. Salamonie Lake Phytoplankton Species List and Relative Abundance (USACE, 2022)

Division	Genus	Species	Percent of total Abundance
Bacillariophyta	Acanthoceras		0.002%
Bacillariophyta	Aulacoseira	granulata	0.033%
Bacillariophyta	Aulacoseira		0.045%
Bacillariophyta	Cyclotella	meneghiniana	0.002%
Bacillariophyta	Cyclotella		0.352%
Bacillariophyta	Fragilaria		0.238%
Bacillariophyta	Lindavia	antiqua	0.005%
Bacillariophyta	Lindavia		0.014%
Bacillariophyta	Navicula		0.005%
Bacillariophyta	Nitzschia	oregona	0.002%
Bacillariophyta	Nitzschia		0.135%
Bacillariophyta	Thalassiosira		0.002%
Bacillariophyta	Urosolenia		0.019%
Chlorophyta	Actinastrum		0.017%
Chlorophyta	Carteria		0.010%
Chlorophyta	Chlamydomonas	globosa	0.005%
Chlorophyta	Chlamydomonas		0.090%
Chlorophyta	Chlorella		0.321%
Chlorophyta	Chlorococcum	minutum	0.002%
Chlorophyta	Closteriopsis		0.002%
Chlorophyta	Coelastrum	microporum	0.010%

Division	Genus	Species	Percent of total Abundance
Chlorophyta	Coelastrum		0.026%
Chlorophyta	Crucigenia		0.029%
Chlorophyta	Crucigeniella		0.019%
Chlorophyta	Dictyochloris	fragrans	0.002%
Chlorophyta	Dictyochloris		0.002%
Chlorophyta	Dictyosphaerium		0.052%
Chlorophyta	Eudorina		0.019%
Chlorophyta	Golenkinia		0.002%
Chlorophyta	Kirchneriella	obesa	0.002%
Chlorophyta	Kirchneriella		0.057%
Chlorophyta	Micractinium		0.014%
Chlorophyta	Monoraphidium	arcuatum	0.002%
Chlorophyta	Monoraphidium	contortum	0.005%
Chlorophyta	Monoraphidium		0.007%
Chlorophyta	Nautococcus		0.005%
Chlorophyta	Oocystis	borgei	0.002%
Chlorophyta	Oocystis	parva	0.002%
Chlorophyta	Oocystis		0.024%
Chlorophyta	Pandorina		0.067%
Chlorophyta	Planktosphaeria		0.002%
Chlorophyta	Raphidocelis		0.002%
Chlorophyta	Scenedesmus		0.105%
Chlorophyta	Schroederia		0.002%
Chlorophyta	Tetrastrum		0.019%
Chrysophyta	Mallomonas	akrokomos	0.002%
Chrysophyta	Mallomonas		0.007%
Chrysophyta	Ochromonas		0.005%
Cryptophyta	Chroomonas	coerulea	0.002%
Cryptophyta	Cryptomonas	erosa	0.005%
Cryptophyta	Cryptomonas	marssonii	0.031%
Cryptophyta	Cryptomonas	ovata	0.010%
Cryptophyta	Cryptomonas		0.121%

Division	**Genus**	**Species**	**Percent of total Abundance**
Cryptophyta	Plagioselmis	nannoplanctica	0.171%
Cryptophyta	Rhodomonas		0.169%
Cyanobacteria	Anabaena	flos-aquae	0.753%
Cyanobacteria	Anabaena		2.179%
Cyanobacteria	Aphanizomenon		2.248%
Cyanobacteria	Aphanocapsa	delicatissima	1.528%
Cyanobacteria	Aphanocapsa	planctonica	0.430%
Cyanobacteria	Aphanocapsa		13.251%
Cyanobacteria	Chroococcus	microscopicus	8.188%
Cyanobacteria	Chroococcus	minutus	0.190%
Cyanobacteria	Chroococcus		0.675%
Cyanobacteria	Cuspidothrix		0.086%
Cyanobacteria	Cylindrospermopsis	raciborskii	3.144%
Cyanobacteria	Cylindrospermopsis		2.621%
Cyanobacteria	Cylindrospermum		0.309%
Cyanobacteria	Eucapsis		0.568%
Cyanobacteria	Komvophoron		0.219%
Cyanobacteria	Merismopedia	punctata	0.152%
Cyanobacteria	Merismopedia		5.265%
Cyanobacteria	Microcystis	wesenbergii	0.242%
Cyanobacteria	Microcystis		1.549%
Cyanobacteria	Oscillatoria		0.746%
Cyanobacteria	Phormidium		3.787%
Cyanobacteria	Planktolyngbya	contorta	0.283%
Cyanobacteria	Planktolyngbya	limnetica	11.667%
Cyanobacteria	Planktolyngbya		16.020%
Cyanobacteria	Planktothrix		6.625%
Cyanobacteria	Pseudanabaena		5.085%
Cyanobacteria	Raphidiopsis		9.217%
Cyanobacteria	Romeria		0.014%
Cyanobacteria	Snowella		0.145%
Euglenophyta	Euglena	clara	0.002%

Division	Genus	Species	Percent of total Abundance
Euglenophyta	Euglena		0.002%
Euglenophyta	Lepocinclis		0.002%
Euglenophyta	Phacus		0.002%
Euglenophyta	Strombomonas		0.002%
Euglenophyta	Trachelomonas		0.010%
Haptophyta	Chrysochromulina		0.466%
Pyrrophyta	Ceratium		0.007%
Pyrrophyta	Glenodinium		0.005%
Pyrrophyta	Gymnodinium		0.002%
Pyrrophyta	Peridinium		0.010%

Table D.4. Salamonie Lake Zooplankton Species List and Relative Abundance (USACE, 2022)

Division	Genus	Species	Percent of total Abundance
Cladocera	Bosmina	longirostris	0.11%
Cladocera	Ceriodaphnia	spp.	0.90%
Cladocera	Daphnia	retrocurva	1.24%
Cladocera	Daphnia	spp.	0.90%
Cladocera	Diaphanosoma	brachyurum	27.83%
Cladocera	Leptodora	kindtii	0.57%
Copepoda	Acanthocyclops	robustus	0.34%
Copepoda	calanoid	copepodid	26.36%
Copepoda	cyclopoid	copepodid	15.50%
Copepoda	Ergasilus	spp.	2.49%
Copepoda	Leptodiaptomus	siciloides	2.49%
Copepoda	Mesocyclops	edax	1.36%
Copepoda	nauplii		6.56%
Copepoda	Skistodiaptomus	pallidus	1.92%
Copepoda	Skistodiaptomus	reighardi	4.30%
Copepoda	Tropocyclops	prasinus	6.33%
Rotifera	Asplanchna	spp.	0.23%
Rotifera	Conochiloides	dossuarius	0.11%

Division	**Genus**	**Species**	**Percent of total Abundance**
Rotifera	Conochilus	unicornis	0.45%

Table D.5. Roush Lake Phytoplankton Species List and Relative Abundance (USACE, 2022)

Division	**Genus**	**Species**	**Percent of total Abundance**
Bacillariophyta	Achnanthidium	minutissimum	0.01%
Bacillariophyta	Aulacoseira	granulata	0.07%
Bacillariophyta	Cocconeis	placentula	0.01%
Bacillariophyta	Cyclotella	meneghiniana	0.37%
Bacillariophyta	Cyclotella	ocellata	0.08%
Bacillariophyta	Fragilaria	crotonensis	0.05%
Bacillariophyta	Navicula	veneta	0.00%
Bacillariophyta	Nitzschia	fonticola	0.04%
Bacillariophyta	Nitzschia	fruticosa	0.04%
Bacillariophyta	Stephanodiscus	hantzschii	0.28%
Bacillariophyta	Stephanodiscus	parvus	0.37%
Bacillariophyta	Synedra	tenera	0.07%
Chlorophyta	Characium		0.04%
Chlorophyta	Chlamydomonas		0.18%
Chlorophyta	Chlorella		0.50%
Chlorophyta	Cosmarium		0.00%
Chlorophyta	Crucigenia		0.02%
Chlorophyta	Gonium		0.07%
Chlorophyta	Kirchneriella		0.29%
Chlorophyta	Micractinium		0.02%
Chlorophyta	Monoraphidium		0.00%
Chlorophyta	Oocystis		0.06%
Chlorophyta	Pandorina		0.14%
Chlorophyta	Scenedesmus		0.22%
Chlorophyta	Selenastrum		0.00%
Chlorophyta	Sphaerocystis	schroeteri	0.26%
Chlorophyta	Staurastrum		0.00%

Division	**Genus**	**Species**	**Percent of total Abundance**
Cryptophyta	Cryptomonas	erosa	0.27%
Cryptophyta	Plagioselmis	nannoplanctica	2.41%
Cryptophyta	Rhodomonas	lacustris	0.36%
Cyanobacteria	Aphanizomenon		1.01%
Cyanobacteria	Aphanocapsa	delicatissima	10.52%
Cyanobacteria	Chroococcus	microscopicus	39.38%
Cyanobacteria	Chroococcus		0.04%
Cyanobacteria	Cyanodictyon		6.03%
Cyanobacteria	Cylindrospermopsis	raciborskii	0.40%
Cyanobacteria	Merismopedia	tenuissima	22.95%
Cyanobacteria	Merismopedia		0.22%
Cyanobacteria	Myxobaktron		0.03%
Cyanobacteria	Phormidium		0.22%
Cyanobacteria	Planktolyngbya	limnetica	10.20%
Cyanobacteria	Pseudanabaena	limnetica	1.05%
Cyanobacteria	Raphidiopsis	curvata	1.64%
Euglenophyta	Euglena		0.05%
Euglenophyta	Phacus		0.01%
Pyrrophyta	Glenodinium		0.02%

Table D.6. Roush Lake Zooplankton Species List and Relative Abundance (USACE, 2022)

Division	**Genus**	**Species**	**Percent of total Abundance**
Cladocera	Diaphanosoma	brachyurum	43%
Cladocera	Disparalona	hamata	0.16%
Cladocera	Moina	micrura	4%
Copepoda	Acanthocyclops	robustus	2%
Copepoda	calanoid	copepodid	7%
Copepoda	cyclopoid	copepodid	2%
Copepoda	Leptodiaptomus	siciloides	1%
Copepoda	Microcyclops	rubellus	0.16%

Division	**Genus**	**Species**	**Percent of total Abundance**
Copepoda	nauplii		0.16%
Copepoda	Skistodiaptomus	pallidus	1%
Copepoda	Skistodiaptomus	reighardi	0.80%
Ostracoda	ostracod		0.16%
Rotifera	Asplanchna	spp.	24%
Rotifera	Brachionus	angularis	0.32%
Rotifera	Brachionus	budapestinensis	0.16%
Rotifera	Brachionus	calyciflorus	8%
Rotifera	Brachionus	caudatus	3%
Rotifera	Brachionus	urceolaris	0.16%
Rotifera	Collotheca	spp.	0.32%
Rotifera	Conochiloides	dossuarius	3%
Rotifera	Filinia	brachiata	0.16%

Table D.7. *Mussels of the Upper Wabash (Fisher, personal communication, 2023).*

Common Name	Distribution[1]		Status[2]	Tolerance[3]	Life History[4]	Primary Habitat[5]
	Downstream of Logansport	Logansport to Roush				
Spectaclecase	extirpated	NR	EX, FE	MT	Equilibrium	Mainstem
Elktoe	live	live	-	INT	Periodic	Mainstem
Slippershell Mussel	live – trib.	live – trib.	SC	INT	Periodic	Trib
Cylindrical Papershell	live – trib.	Live	-	-	-	-
Rock Pocketbook	live	NR	-	TOL	Equilibrium	Mainstem, Rare
White Heelsplitter	live	live	-	TOL	Opportunistic	Mainstem
Creek Heelsplitter	live – trib.	live – trib.	-	-	-	Trib
Flutedshell	live	live	-	MT	Periodic	Mainstem
Giant Floater	live	live	-	TOL	Opportunistic	Mainstem
Salamander Mussel	extirpated	NR	SC (proposed SE)	-	-	-
Creeper	live	live	-	INT	Periodic	Mainstem
Paper Pondshell	live	live	-	TOL	Opportunistic	Mainstem
Flat Floater	live	-	-	-	-	Backwaters
Mucket	live	live	-	TOL	Equilibrium	Mainstem
Threeridge	live	live	-	TOL	Equilibrium	Mainstem
Rainbow	extirpated	extirpated	SC	INT	Periodic	-
Wartyback	live	-	-	TOL	Equilibrium	Mainstem
Pimpleback	live	live	-	TOL	Equilibrium	Mainstem
Purple Wartyback	live	live	-	TOL	Equilibrium	Mainstem
Fanshell	possibly extirpated	possibly extirpated	SE, FE	INT	Equilibrium	Mainstem
Butterfly	extirpated	-	-	TOL	Periodic	Mainstem-NR
Elephantear	live	possibly extirpated	SC	MT	Equilibrium	Mainstem – R
Leafshell	extirpated	-	EX	INT	Periodic	-
White Catspaw	extirpated	-	SE, FE	INT	Periodic	-
Round Combshell	extirpated	-	EX	INT	Periodic	-

Tennessee Riffleshell	extirpated	-	EX	INT	Periodic	-
Northern Riffleshell	extirpated	extirpated	SE, FE	INT	Periodic	-
Wabash Riffleshell	extirpated	-	EX	INT	Periodic	-
Tubercled Blossom	extirpated	extirpated	EX, FE	INT	Periodic	-
Snuffbox	extirpated	extirpated	SE, FE	INT	Periodic	-
Spike	extirpated	extirpated	SC	MT	Periodic	-
Wabash Pigtoe	live	live	-	TOL	Equilibrium	Mainstem
Longsolid	extirpated	-	EX, proposed FT	INT	Equilibrium	Mainstem-NR
Cracking Pearlymussel	extirpated	-	EX, FE	INT	Periodic	Mainstem-NR
Pink Mucket	extirpated	-	EX, FE	TOL	Periodic	Mainstem-NR
Plain Pocketbook	live	live	-	TOL	Periodic	Mainstem
Wavyrayed Lampmussel	possibly extirpated	possibly extirpated	SC	INT	Periodic	Mainstem – R
Pocketbook	live	live	SC	TOL	Periodic	Mainstem
Fatmucket	live	live	-	TOL	Periodic	Mainstem
Yellow Sandshell	live	live	-	TOL	Opportunistic	Mainstem
Little Spectaclecase	-	-	SC	-	-	Trib
Black Sandshell	live	live	SC	TOL	Periodic	Mainstem
Washboard	live	extirpated	-	TOL	Equilibrium	Mainstem – R
Threehorn Wartyback	live	live	-	-	-	Mainstem
Hickorynut	live	live	-	-	Periodic	Mainstem
Ring Pink	extirpated	-	EX, FE	INT	Periodic	-
Round Hickorynut	extirpated	extirpated	SE, proposed FT	INT	Periodic	-
Rayed Bean	extirpated	extirpated	SE, FE	-	-	-
White Wartyback	extirpated	-	EX, FE	MT	Equilibrium	-
Orangefoot Pimpleback	extirpated	-	EX, FE	MT	Equilibrium	-
Sheepnose	extirpated	extirpated	SE, FE	MT	Equilibrium	-
Clubshell	extirpated	extirpated	SE, FE	INT	Equilibrium	-
Ohio Pigtoe	extirpated	extirpated	SC (proposed SE)	MT	Equilibrium	-
Rough Pigtoe	extirpated	extirpated	SE, FE	MT	Equilibrium	-
Pyramid Pigtoe	extirpated	extirpated	EX	INT	Equilibrium	-
Round Pigtoe	live	live	-	MT	Equilibrium	Mainstem

Pink Heelsplitter	live	live	-	TOL	Opportunistic	Mainstem
Fat Pocketbook	live	NR	SE, FE	MT	Opportunistic	Mainstem – R
Fragile Papershell	live	live	-	TOL	Opportunistic	Mainstem
Scaleshell	extirpated	NR	EX, FE	INT	Opportunistic	-
Pink Papershell	live	live	-	-	-	Mainstem
Kidneyshell	extirpated	extirpated	SC	TOL	Periodic	-
Winged Mapleleaf	extirpated	NR	EX, FE	INT	Equilibrium	-
Mapleleaf	live	live	-	TOL	Equilibrium	Mainstem
Ebonyshell	live	NR	SC	MT	Equilibrium	Mainstem – R
Pondmussel	-	-	-	-	-	Trib
Rabbitsfoot	extirpated	extirpated	SE, FT	MT	Periodic	-
Monkeyface	live	live	-	TOL	Equilibrium	Mainstem
Purple Lilliput	extirpated	extirpated	SC	MT	Opportunistic	-
Lilliput	live	live	-	TOL	Opportunistic	Mainstem
Texas Lilliput	-	-	SC	-	-	Trib
Pistolgrip	live	live	-	-	-	Mainstem
Fawnsfoot	live	live	-	TOL	Opportunistic	Mainstem
Deertoe	live	live	-	TOL	Opportunistic	Mainstem
Pondhorn	-	-	-	-	-	Trib
Total Species	75					
Total Extant Species[6]	35	29				31

[1] Species known to occur in the Indiana portion of the Wabash River basin. Status denotes species occurrences reported by IDNR for the Wabash River downstream of Logansport and upper Wabash River from Logansport to Roush, which includes Salamonie and Mississinewa river below dams.

[2] State Endangered (SE), Special Concern (SC), Federal Endangered (FE), Federal Threatened (FT), Extirpated (EX)

[3] Impoundment tolerance described in Haag (2012, Chapter 10): TOL = species well adapted to riverine portions of impounded rivers, MT = moderately tolerant, INT = intolerant and primarily periodic strategist species and limited host fish availability

[4] Haag (2012). Life history strategies as described in Haag (2012; Chapter 6): Opportunistic = short life span, early maturity, high fecundity, moderate to large body size, Equilibrium = long life span and late maturity, Periodic = moderate to high growth rate, low to intermediate life span, age at maturity, fecundity, generally small bodied.

[5] INDR Mussel Data, personal communication (2023). Mainstem = species occurs or potentially occurs in mainstem habitats of the Wabash River; Mainstem – R = Species possibly present but very rare, Mainstem – NR = Species can occur in mainstem habitats but has not been recorded near Logansport or upstream.

[6] Excludes species known only from tributaries.

Table D.8. Macroinvertebrate taxa present in the Mississinewa, Salamonie, and Wabash rivers below their respective reservoir (Owens, personal communication, 2022).

Group/Common Name	Family	Genus	Species	Below Mississinewa Lake	Below Salamonie Lake	Below J.E. Roush Lake
Worm	Annelid (Phylum)				X	
Worm	Branchiobdellidae			X	X	
Worm	Lumbriculidae				X	
Worm	Naidinae (Subfamily)				X	
Worm	Oligochaeta				X	
Worm	Tubificinae (subfamily)			X	X	X
Roundworms	Nematodes	Nemata			X	
Flatworm	Trepaxonemata (subclass)			X	X	X
Leech	Erpobdellidae			X	X	X
Mite	Acari (subclass)			X	X	X
Gastropod – snail	Gastropoda (Class)				X	
Gastropod – snail	Ancylidae				X	
Gastropod - pond snail	Lymnaeidae			X		
Gastropod – snail	Physidae				X	
Gastropod – snail	Physidae	Physella				X
Gastropod – limpet	Planorbidae	Ferrissia	rivularis	X	X	X
Gastropod - ram's horn snail	Planorbidae	Planorbella	trivolvis			X
Gastropod – snail	Pleuroceridae				X	

Group/Common Name	Family	Genus	Species	Below Mississinewa Lake	Below Salamonie Lake	Below J.E. Roush Lake
Gastropod – snail	Pleuroceridae	Elimia	semicarinata	X		
Bivalve – asiatic clam	Cyrenidae	Corbicula	fluminea	X		
Bivalve – fingernail clam	Sphaeriidae			X		
Bivalve – fingernail clam	Sphaeriidae	Sphaerium		X	X	
Crustacean – isopod	Asellidae	Caecidotea		X	X	
Crustacean – amphipod	Crangonyctidae	Crangonyx		X	X	
Crustacean - crayfish	Astacidae			X		
Crustacean- crayfish	Cambraridae				X	
Crustacean – calico crayfish	Cambaridae	Faxonius	immunis	X		
Crustacean- Northern clearwater crayfish	Cambaridae	Faxonius	propinquus		X	
Crustacean – rusty crayfish	Cambaridae	Faxonius	rusticus	X	X	
Crustacean- Virile crayfish	Cambaridae	Faxonius	virilis	X		
Springtails	Sminthuridae			X		
Grass moth	Pyralidae			X		
Mayfly	Ephemeroptera (Order)				X	
Mayfly – small minnow mayfly	Baetidae			X	X	X
Mayfly– small minnow mayfly	Baetidae	Baetis	Intercalaris	X	X	
Mayfly– small minnow mayfly	Baetidae	Callibaetis		X		
Mayfly– small minnow mayfly	Baetidae	Neocloeon		X		
Mayfly– small minnow mayfly	Baetidae	Procloeon		X		

Group/Common Name	Family	Genus	Species	Below Mississinewa Lake	Below Salamonie Lake	Below J.E. Roush Lake
Mayfly – small squaregill mayfly	Caenidae			X	X	
Mayfly – small squaregill mayfly	Caenidae	Caenis		X	X	
Mayfly – Say's small squaregill mayfly	Caenidae	Caenis	hilaris	X		
Mayfly – common small squaregill mayfly	Caenidae	Caenis	latipennis		X	
Mayfly – small squaregill mayfly	Caenidae	Sparbarus		X		
Mayfly – common burrower	Ephemeridae				X	
Mayfly – common burrower	Ephemeridae	Ephemera		X		
Mayfly – flat headed mayfly	Heptageniidae			X	X	X
Mayfly – flat headed mayfly	Heptageniidae	Leucrocuta		X	X	
Mayfly – flat headed mayfly	Heptageniidae	Maccaffertium			X	
Mayfly – pretty flat headed mayfly	Heptageniidae	Maccaffertium	pulchellum	X		
Mayfly – terminal flat headed mayfly	Heptageniidae	Maccaffertium	terminatum	X	X	
Mayfly – common flat headed mayfly	Heptageniidae	Stenacron	Interpunctatum	X	X	
Mayfly – howdy mayfly	Isonychiidae	Isonychia			X	
Mayfly – stout crawler mayfly	Leptohyphidae	Tricorythodes		X	X	X
Mayfly – brushlegged mayfly	Oligoneuriidae			X	X	
Mayfly – hackle-gilled burrown mayfly	Potamanthidae			X	X	

Group/Common Name	Family	Genus	Species	Below Mississinewa Lake	Below Salamonie Lake	Below J.E. Roush Lake
Mayfly – hackle-gilled burrown mayfly	Potamanthidae	Anthopotamus		X		
Mayfly	Leptohyphidae			X	X	X
Dragonfly – Fawn Darner	Aeshnidae	Boyeria	vinosa	X		
Dragonfly – flag-tailed spinyleg	Gomphidae	Dromogomphus	spoliatus	X		
Damselfly-narrow winged damselfly	Coenagrionidae			X	X	
Stonefly	Taeniopterygidae				X	
Beetle – predaceous diving beetle	Dytiscidae	Laccophilus	maculosus	X		
Beetle – riffle beetle	Elmidae			X	X	X
Beetle – riffle beetle	Elmidae	Dubiraphia		X		
Beetle – riffle beetle	Elmidae	Dubiraphia	bivittata	X		
Beetle – riffle beetle	Elmidae	Dubiraphia	minima	X		
Beetle – riffle beetle	Elmidae	Macronychus	glabratus	X		
Beetle – riffle beetle	Elmidae	Optioservus	fastiditus	X	X	
Beetle – riffle beetle	Elmidae	Stenelmis		X	X	
Beetle – riffle beetle	Elmidae	Stenelmis	Sexlineata	X	X	
Beetle – riffle beetle	Elmidae	Stenelmis	vittipennis	X		
Beetle – whirligig beetle	Gyrinidae	Gyrinus		X		
Beetle	Haliplidae	Peltodytes	duodecimpuntatus	X		
Beetle – Water scavenger	Hydrophilidae	Berosus				X
Beetle – water penny beetle	Psephenidae	Psephenus	Herricki	X	X	
True bugs – Water boatmen	Corixidae					
True bugs – Water boatmen	Corixidae	Sigara			X	

Group/Common Name	Family	Genus	Species	Below Mississinewa Lake	Below Salamonie Lake	Below J.E. Roush Lake
True bugs – Water striders	Gerridae				X	
True bugs – Water striders	Gerridae	Rheumatobates				
True bugs – Water striders	Gerridae	Metrobates	hesperius		X	
True bugs – Water striders	Gerridae	Trepobates	inermis	X		
True bugs – Pygmy backswimmer	Pleidae	Neoplea	striola	X		
True bugs – Water striders	Veliidae	Rhagovelia	obesa	X		
Dobsonfly	Corydalidae				X	X
Dobsonfly	Corydalidae	Corydalus	Cornutus	X	X	
Caddisfly	Trichoptera (Order)				X	
Net-spinning caddisfly	Hydropsychidae			X	X	X
Net-spinning caddisfly	Hydropsychidae	Ceratopsyche		X	X	
Net-spinning caddisfly	Hydropsychidae	Cheumatopsyche		X	X	X
Net-spinning caddisfly	Hydropsychidae	Hydropsyche	aerata	X	X	
Net-spinning caddisfly	Hydropsychidae	Hydropsyche	bidens	X		
Net-spinning caddisfly	Hydropsychidae	Hydropsyche	bronta		X	
Net-spinning caddisfly	Hydropsychidae	Hydropsyche	cheilonis		X	
Net-spinning caddisfly	Hydropsychidae	Hydropsyche	phalerata		X	
Caddisfly - microcaddisfly	Hydroptilidae			X	X	X
Caddisfly - microcaddisfly	Hydroptilidae	orthotrichia			X	
Caddisfly- long-horned caddisfly	Leptoceridae				X	
Caddisfly- long-horned caddisfly	Leptoceridae	Ceraclea		X		
Caddisfly- long-horned caddisfly	Leptoceridae	Oecetis		X		

Group/Common Name	Family	Genus	Species	Below Mississinewa Lake	Below Salamonie Lake	Below J.E. Roush Lake
Tube-making caddisfly	Polycentropdidae				X	
Tube-making caddisfly	Psychomyiidae				X	
Fly – Biting midge	Ceratopogonidae			X		X
Fly – Phantom midge	Chaoboridae					X
Fly – dagger fly	Empididae			X	X	X
Fly – Moth fly	Psychodidae				X	
Fly – Black fly	Simuliidae			X	X	
Fly – Black fly	Simuliidae	Simulium		X	X	X
Fly - Cranefly	Tipulidae				X	
Non-biting midge	Chironomidae			X	X	X
Non-biting midge	Chironomidae	Ablabesmyia	mallochi	X	X	
Non-biting midge	Chironomidae	Cardiocladius		X	X	
Non-biting midge	Chironomidae	Chironominae		X		
Non-biting midge	Chironomidae	Chironomini		X		
Non-biting midge	Chironomidae	Chironomus		X	X	
Non-biting midge	Chironomidae	Cladotanytarus		X	X	
Non-biting midge	Chironomidae	Cricotopus	bicinctus			X
Non-biting midge	Chironomidae	Cryptochironomus		X		
Non-biting midge	Chironomidae	Dicrotendipes		X		
Non-biting midge	Chironomidae	Eukiefferiella		X	X	
Non-biting midge	Chironomidae	Eukiefferiella	Gracei			X
Non-biting midge	Chironomidae	Glyptotendipes		X		
Non-biting midge	Chironomidae	Harnischia		X		
Non-biting midge	Chironomidae	Labrundinia	pilosella	X	X	
Non-biting midge	Chironomidae	Microtendipes	pedellus			X
Non-biting midge	Chironomidae	Phaenopsectra		X		
Non-biting midge	Chironomidae	Phaenopsectra	obediens			X
Non-biting midge	Chironomidae	Polypedilum	Fallax	X		
Non-biting midge	Chironomidae	Polypedilum	scalaenum	X	X	
Non-biting midge	Chironomidae	Polypedilum	flavum	X	X	X
Non-biting midge	Chironomidae	Polypedilum	illinoense	X	X	X
Non-biting midge	Chironomidae	Procladius		X	X	

Group/Common Name	Family	Genus	Species	Below Mississinewa Lake	Below Salamonie Lake	Below J.E. Roush Lake
Non-biting midge	Chironomidae	Rheotanytarsus		X	X	
Non-biting midge	Chironomidae	Rheotanytarsus	exiguous	X		X
Non-biting midge	Chironomidae	Saetheria			X	
Non-biting midge	Chironomidae	Stenochironomus		X		
Non-biting midge	Chironomidae	Tanytarsus		X		X
Non-biting midge	Chironomidae	Tarytarsini		X		
Non-biting midge	Chironomidae	Thienemannimyia				X

Table D.9. Fish species known to persist in the Upper Wabash River upstream of Logansport, IN (Fisher, personal communication, 2023).

Family		Genus	Species	Common Name	Comments
Petromyzontidae	lampreys	Ichthyomyzon	unicuspis	Silver Lamprey	
Acipenseridae	sturgeons	Scaphirhynchus	platorynchus	Shovelnose Sturgeon	
Polyodontidae	paddlefishes	Polyodon	spathula	Paddlefish	
Lepisosteidae	gars	Lepisosteus	osseus	Longnose Gar	
		Lepisosteus	platostomus	Shortnose Gar	
Anguillidae	freshwater eels	Anguilla	rostrata	American Eel	State Special Concern
Hiodontidae	mooneyes	Hiodon	alosoides	Goldeye	
		Hiodon	tergisus	Mooneye	
Clupeidae	herrings	Alosa	chrysochloris	Skipjack Herring	
		Dorosoma	cepedianum	Gizzard Shad	
Catostomidae	suckers	Carpiodes	carpio	River Carpsucker	
		Carpiodes	cyprinus	Quillback	
		Carpiodes	velifer	Highfin Carpsucker	
		Catostomus	commersonii	White Sucker	
		Cycleptus	elongatus	Blue Sucker	
		Hypentelium	nigricans	Northern Hog Sucker	
		Ictiobus	bubalus	Smallmouth Buffalo	
		Ictiobus	cyprinellus	Bigmouth Buffalo	
		Ictiobus	niger	Black Buffalo	

Family		Genus	Species	Common Name	Comments
		Minytrema	melanops	Spotted Sucker	
		Moxostoma	anisurum	Silver Redhorse	
		Moxostoma	carinatum	River Redhorse	
		Moxostoma	duquesnei	Black Redhorse	
		Moxostoma	erythrurum	Golden Redhorse	
		Moxostoma	macrolepidotum	Shorthead Redhorse	
Cyprinidae	carps	Carassius	auratus	Goldfish	non-native
		Cyprinus	carpio	Common Carp	non-native
Xenocyprididae	Asian carps	Ctenopharyngodon	idella	Grass Carp	non-native
		Hypophthalmichthys	molitrix	Silver Carp	non-native
		Hypophthalmichthys	nobilis	Bighead Carp	non-native
Leuciscidae	minnows	Campostoma	anomalum	Central Stoneroller	
		Cyprinella	spiloptera	Spotfin Shiner	
		Cyprinella	whipplei	Steelcolor Shiner	
		Erimystax	dissimilis	Streamline Chub	
		Erimystax	x-punctatus	Gravel Chub	
		Hybognathus	nuchalis	Mississippi Silvery Minnow	
		Hybopsis	amblops	Bigeye Chub	
		Luxilus	chrysocephalus	Striped Shiner	
		Luxilus	cornutus	Common Shiner	potentially in the mainstem Wabash River – in tributaries of upper Wabash River drainage
		Lythrurus	umbratilis	Redfin Shiner	potentially in the mainstem

Family	Genus	Species	Common Name	Comments
				Wabash River – in tributaries of upper Wabash River drainage
	Macrhybopsis	hyostoma	Shoal Chub	
	Macrhybopsis	storeriana	Silver Chub	
	Nocomis	biguttatus	Hornyhead Chub	not a common inhabitant; likely not upstream of Cass County
	Nocomis	micropogon	River Chub	
	Notemigonus	crysoleucas	Golden Shiner	not a common inhabitant
	Notropis	atherinoides	Emerald Shiner	
	Notropis	blennius	River Shiner	
	Notropis	buccatus	Silverjaw Minnow	
	Notropis	photogenis	Silver Shiner	not a common inhabitant; likely not upstream of Cass County
	Notropis	rubellus	Rosyface Shiner	
	Notropis	stramineus	Sand Shiner	
	Notropis	volucellus	Mimic Shiner	
	Notropis	wickliffi	Channel Shiner	
	Phenacobius	mirabilis	Suckermouth Minnow	
	Pimephales	notatus	Bluntnose Minnow	
	Pimephales	promelas	Fathead Minnow	
	Pimephales	vigilax	Bullhead Minnow	
	Rhinichthys	obtusus	Western Blacknose Dace	not a common inhabitant; found more commonly by tributary mouths
	Semotilus	atromaculatus	Creek Chub	not a common inhabitant; found

Family		Genus	Species	Common Name	Comments
					more commonly by tributary mouths
Ictaluridae	North American catfishes	Ameiurus	natalis	Yellow Bullhead	
		Ictalurus	punctatus	Channel Catfish	
		Noturus	eleutherus	Mountain Madtom	
		Noturus	flavus	Stonecat	
		Noturus	gyrinus	Tadpole Madtom	not a common inhabitant
		Noturus	miurus	Brindled Madtom	
		Pylodictis	olivaris	Flathead Catfish	
Atherinopsidae	New World silversides	Labidesthes	sicculus	Brook Silverside	
Poeciliidae	livebearers	Gambusia	affinis	Western Mosquitofish	introduced; not native to this part of the state
Percidae	perches and darters	Etheostoma	blennioides	Greenside Darter	
		Etheostoma	caeruleum	Rainbow Darter	
		Etheostoma	camurum	Bluebreast Darter	
		Etheostoma	flabellare	Fantail Darter	
		Etheostoma	nigrum	Johnny Darter	
		Etheostoma	spectabile	Orangethroat Darter	
		Etheostoma	tippecanoe	Tippecanoe Darter	
		Percina	caprodes	Logperch	
		Percina	maculata	Blackside Darter	

Family		Genus	Species	Common Name	Comments
		Percina	phoxocephala	Slenderhead Darter	
		Percina	sciera	Dusky Darter	
		Percina	shumardi	River Darter	
		Sander	canadensis	Sauger	
		Sander	vitreus	Walleye	
Cottidae	sculpins	Cottus	bairdii	Mottled Sculpin	
Centrarchidae	sunfishes	Ambloplites	rupestris	Rock Bass	
		Lepomis	cyanellus	Green Sunfish	
		Lepomis	gibbosus	Pumpkinseed	
		Lepomis	humilis	Orangespotted Sunfish	
		Lepomis	macrochirus	Bluegill	
		Lepomis	megalotis	Longear Sunfish	
		Lepomis	microlophus	Redear Sunfish	
		Micropterus	dolomieu	Smallmouth Bass	
		Micropterus	salmoides	Largemouth Bass	
		Pomoxis	annularis	White Crappie	
		Pomoxis	nigromaculatus	Black Crappie	
Moronidae	temperate basses	Morone	chrysops	White Bass	
		Morone	saxatilis	Striped Bass	
Sciaenidae	drums and croakers	Aplodinotus	grunniens	Freshwater Drum	

Table D.10. Indiana fish Species of Greatest Conservation Need (IDNR, 2023).

Indiana State Endangered		
Common Name	**Scientific Name**	**Federal Status**
Lake Sturgeon	*Acipenser fulvescens*	Not listed
Redside Dace	*Clinostomus elongatus*	Not listed
Pallid Shiner	*Hybopsis amnis*	Not listed
Greater Redhorse	*Moxostoma valenciennesi*	Not listed
Cisco	*Coregonus artedi*	Not listed
Hoosier Cavefish	*Amblyopsis hoosieri*	Not listed
Bantam Sunfish	*Lepomis symmetricus*	Not listed
Western Sand Darter	*Ammocrypta clara*	Not listed
Variegate Darter	*Etheostoma variatum*	Not listed
Channel Darter	*Percina copelandi*	Not listed
Gilt Darter	*Percina evides*	Not listed
Indiana Species of Special Concern		
Common Name	**Scientific Name**	**Federal Status**
Northern Brook Lamprey	*Ichthyomyzon fossor*	Not listed
Alligator Gar	*Atractosteus spatula*	Not listed
American Eel	*Anguilla rostrata*	Not listed
Pugnose Shiner	*Notropis anogenus*	Not listed
Bigmouth Shiner	*Notropis dorsalis*	Not listed
Longnose Dace	*Rhinichthys cataractae*	Not listed
Northern Madtom	*Noturus stigmosus*	Not listed
Trout-perch	*Percopsis omiscomaycus*	Not listed
Slimy Sculpin	*Cottus cognatus*	Not listed
Spotted Darter	*Etheostoma maculatum*	Not listed
Banded Pygmy Sunfish	*Elassoma zonatum*	Not listed

Appendix E – SME Summary Report

USACE photos

UPPER WABASH RIVER, INDIANA SUBJECT MATTER EXPERT ORIENTATION SUMMARY REPORT

Sustainable Rivers Program

May 2023

The US Army Corps of Engineers Chicago District (Corps) is partnering with The Nature Conservancy (TNC) to implement the Sustainable Rivers Program (SRP) for the Upper Wabash River from J.E. Roush Dam in Huntington, Indiana downstream to Logansport, Indiana. The study area includes three Corps-owned dams and their impoundments, J.E. Roush, Salamonie, and Mississinewa. The goal of the Upper Wabash River SRP program is to identify and implement environmental flow regimes to improve habitat and riverine function in the areas downstream of the dams.

The Corps and TNC engaged subject matter experts (SMEs) in an orientation meeting on November 2, 2022 (Figure 1). The event was held at the Indiana Department of Natural Resources' Salamonie Lake Nature Center, in Andrews, Indiana, on Salamonie Lake. Figure 2 shows the agenda from the SME orientation meeting and Table 1 is a list of participants. In-person attendance was strongly encouraged, but a virtual option was available for those who were unable to attend in-person. During the SME orientation the Corps gave an overview of the SRP and invited them to take part in the program through participation in the SME orientation, sharing data and information on the Upper Wabash River, reviewing the state of the science report, and attending the e-flows workshop. We also provided an overview of the existing hydrologic conditions and reservoir operations and discussed the goals and objectives for the SRP program and the Upper Wabash River.

One important aspect of the SME orientation was a Jamboard exercise. Jamboard is an interactive tool where participants can simultaneously access a digital message board to respond to prompts and provide thoughts and comments. Participants were given prompts to get them thinking about the Upper Wabash and the SRP. Prompts included "What are your thoughts on what you heard today", and "who is missing from this conversation?". As a second exercise in Jamboard participants were given prompts including "water quality issues throughout the basin" and "effects of Mississinewa, Salamonie, and J.E. Roush dams". Participants were encouraged to record their thoughts and questions on the Jamboard. The thoughts, concerns, and questions provided by participants were considered when drafting the state of the science report and formulating plans for the E-flows workshop. The Jamboard pages are shown in Figures 3 through 5.

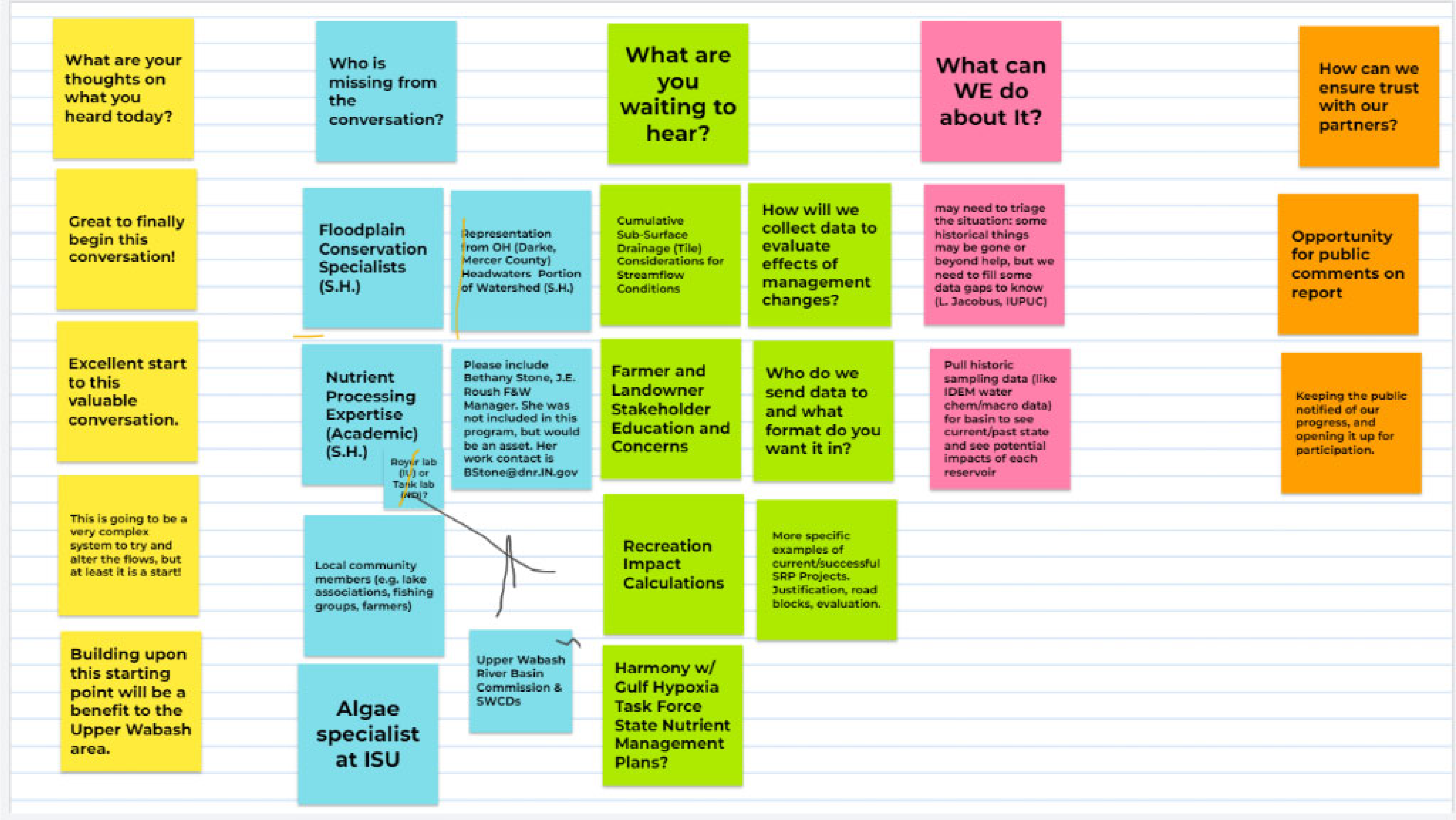
The orientation helped support the Upper Wabash SRP process by familiarizing SMEs with the SRP and communicating ways they could contribute to the success of the program. Following the orientation, multiple SMEs submitted data for the Upper Wabash River including fish and macroinvertebrate survey results, riverine habitat quality survey results, and water quality data (Table 2). This data was used as a basis for the state of the science report, which will served as the guiding document for the environmental flows workshop and the resulting modified flow prescription recommendations. The Corps and TNC will continue to engage SMEs throughout the SRP process as we work together to identify flow prescription recommendations to improve water quality, habitat, and riverine function in the Upper Wabash River.

Figure 37: SMEs at the orientation (USACE photo).

Agenda

- 10-10:45 Introductions & Welcome
- 10:45-11:45 Earthwork (Formal Presentation)
  - Overview of Sustainable Rivers Program
  - Overview of Existing Hydrologic Conditions
  - Overview of Reservoir Operations
  - Wabash River Goals & Objectives
- 11:45-12:00 BREAK
- 12:00-12:45 Working Lunch (Bring your own lunch as restaurants are a 40 minute drive from meeting place)
  - Request for Supporting Data
  - Expectations for Subject Matter Experts
- 12:45-1:00 Final Thoughts

Figure 38. SME Orientation Agenda



What are your thoughts on what you heard today?

Great to finally begin this conversation!

Excellent start to this valuable conversation.

This is going to be a very complex system to try and alter the flows, but at least it is a start!

Building upon this starting point will be a benefit to the Upper Wabash area.

Who is missing from the conversation?

Floodplain Conservation Specialists (S.H.)

Representation from OH (Darke, Mercer County) Headwaters Portion of Watershed (S.H.)

Nutrient Processing Expertise (Academic) (S.H.)

Royer lab (IU) or Tank lab (ND)?

Please include Bethany Stone, J.E. Roush F&W Manager. She was not included in this program, but would be an asset. Her work contact is BStone@dnr.IN.gov

Local community members (e.g. lake associations, fishing groups, farmers)

Upper Wabash River Basin Commission & SWCDs

Algae specialist at ISU

What are you waiting to hear?

Cumulative Sub-Surface Drainage (Tile) Considerations for Streamflow Conditions

How will we collect data to evaluate effects of management changes?

Farmer and Landowner Stakeholder Education and Concerns

Who do we send data to and what format do you want it in?

Recreation Impact Calculations

More specific examples of current/successful SRP Projects. Justification, road blocks, evaluation.

Harmony w/ Gulf Hypoxia Task Force State Nutrient Management Plans?

What can WE do about It?

may need to triage the situation: some historical things may be gone or beyond help, but we need to fill some data gaps to know (L. Jacobus, IUPUC)

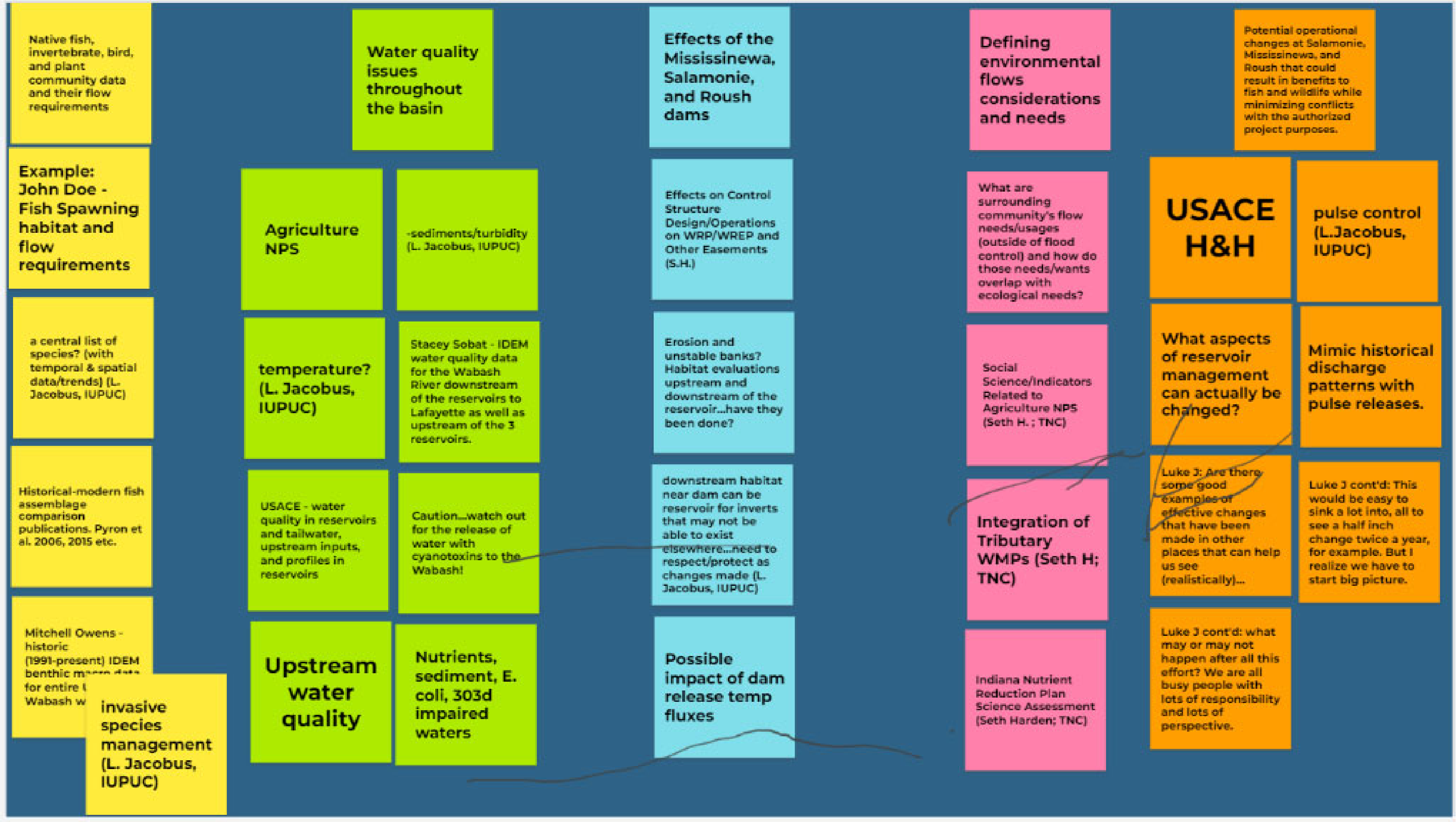
Pull historic sampling data (like IDEM water chem/macro data) for basin to see current/past state and see potential impacts of each reservoir

How can we ensure trust with our partners?

Opportunity for public comments on report

Keeping the public notified of our progress, and opening it up for participation.

Figure 39. Jamboard Page 1



Native fish, invertebrate, bird, and plant community data and their flow requirements

Example: John Doe - Fish Spawning habitat and flow requirements

a central list of species? (with temporal & spatial data/trends) (L. Jacobus, IUPUC)

Historical-modern fish assemblage comparison publications. Pyron et al. 2006, 2015 etc.

Mitchell Owens - historic (1991-present) IDEM benthic m for entire Wabash w

invasive species management (L. Jacobus, IUPUC)

Water quality issues throughout the basin

Agriculture NPS

-sediments/turbidity (L. Jacobus, IUPUC)

temperature? (L. Jacobus, IUPUC)

Stacey Sobat - IDEM water quality data for the Wabash River downstream of the reservoirs to Lafayette as well as upstream of the 3 reservoirs.

USACE - water quality in reservoirs and tailwater, upstream inputs, and profiles in reservoirs

Caution...watch out for the release of water with cyanotoxins to the Wabash!

Upstream water quality

Nutrients, sediment, E. coli, 303d impaired waters

Effects of the Mississinewa, Salamonie, and Roush dams

Effects on Control Structure Design/Operations on WRP/WREP and Other Easements (S.H.)

Erosion and unstable banks? Habitat evaluations upstream and downstream of the reservoir...have they been done?

downstream habitat near dam can be reservoir for inverts that may not be able to exist elsewhere...need to respect/protect as changes made (L. Jacobus, IUPUC)

Possible impact of dam release temp fluxes

Defining environmental flows considerations and needs

What are surrounding community's flow needs/usages (outside of flood control) and how do those needs/wants overlap with ecological needs?

Social Science/Indicators Related to Agriculture NPS (Seth H. ; TNC)

Integration of Tributary WMPs (Seth H; TNC)

Indiana Nutrient Reduction Plan Science Assessment (Seth Harden; TNC)

Potential operational changes at Salamonie, Mississinewa, and Roush that could result in benefits to fish and wildlife while minimizing conflicts with the authorized project purposes.

USACE H&H

pulse control (L.Jacobus, IUPUC)

What aspects of reservoir management can actually be changed?

Mimic historical discharge patterns with pulse releases.

Luke J: Are there some good examples of effective changes that have been made in other places that can help us see (realistically)...

Luke J cont'd: This would be easy to sink a lot into, all to see a half inch change twice a year, for example. But I realize we have to start big picture.

Luke J cont'd: what may or may not happen after all this effort? We are all busy people with lots of responsibility and lots of perspective.

Figure 40. Jamboard Page 2

Final Thoughts

What was the muddiest point that you felt/heard/saw today?

Specific input needed from "experts" (individually and collectively) and/or a question or questions we are addressing with that input (L. Jacobus, IUPUC)

What did you learn that was useful/helpful?

Good to see integrated big picture of operational philosophies and implementation (L. Jacobus, IUPUC)

Who else do you need to show/tell about what you learned?

Map of watershed boundary of project area that is being looked at.

Full Transcription of This Jamboard emailed out

At some point need to do media release

Figure 41. Jamboard Page 3

Table 20: SME Orientation Attendee List

Name	Title	Org	Email	Virtual (V) or In-person Attendance (P)
Aubrey Bunch	Supervisory Biologist	USGS	aurbunch@usgs.gov	P
Caleb Artz	Physical Scientist	USGS	cartz@usgs.gov	P
Paul McMurray	Integrated Report Coordinator	IDEM	PMCMURRA@idem.IN.gov	P
Jennifer Tank			jtank@nd.edu	No
Mark Pyron		Ball State	mpyron@bsu.edu	P
Jerry Sweeten, Ph.D.	Prof Emeritus of Biology	Manchester University	jesweeten@ecosystemsconnections.com	P
Doug Nusbaum	LARE Restoration Biologist	IDNR	DNusbaum@dnr.IN.gov	P
Rod Edgell	Aquatic Biologist	IDNR	redgell@dnr.in.gov	P
Phillip Kacmar	Big Rivers Fish Biologist	IDNR	PKacmar@dnr.IN.gov	P
Bethany Stone	Roush Property Manager	IDNR	BStone@dnr.IN.gov	V
Ian Haus, Ph.D.	Water Resources Engineer	Burke Engineering	ihahus@cbbel-in.com	P
Luke Jacobus			lmjacobu@iupuc.edu	V
Seth Harden		TNC	seth.harden@tnc.org	P
Becca Winterringer	SRP Project Advisor	TNC	b.winterringer@TNC.ORG	P
Tyler Delauder	D3 Fisheries Biologist	IDNR	TDelauder@dnr.IN.gov	P
Jordan Epp	Mississinewa Property Manager	IDNR	JEpp@dnr.IN.gov	P
Aron Showalter		IDNR	AShowalter@dnr.IN.gov	P
Daniel Sparks	Sr. Fish and Wildlife Biologist	USFWS	daniel_sparks@fws.gov	P
Stacey Sobat	Probabalistic Monitoring Chief	IDEM	SSOBAT@idem.IN.gov	V
Jit Weir	Technical Env Specialist	IDEM	JWeir@idem.IN.gov	P
Mitchell Owens		IDEM	Mowens@idem.in.gov	P
Kristi Todd				V
Teresa Rody		IDNR	trody@dnr.in.gov	P
Robert Barr		IU	rcbarr@iu.edu	P
Brant Fisher		IDNR	bfisher@dnr.in.gov	P

Paul Mazzeno	Chief of Operations	USACE LRC	William.P.Mazzeno@usace.army.mil	V
Frank Veraldi	Restoration Ecologist	USACE LRC	Frank.M.Veraldi@usace.army.mil	V
Ryan Johnson	Lead Planner/Biologist	USACE LRC	ryan.a.johnson@usace.army.mil	P
Akilah Martin	Public Involvement Specialist	USACE LRC	Akilah.R.Martin@usace.army.mil	P
Alex Hoxsie	Chief, Environmental Section	USACE LRC	Alex.R.Hoxsie@usace.army.mil	P
Jared Mobley	Operations Manager	USACE LRC	Jared.K.Mobley@usace.army.mil	P
Jeff Fuller	Hydraulic Engineer	USACE LRC	Jeff.A.Fuller@usace.army.mil	V
Casey Pittman	Environmental Engineer	USACE LRC	Casey.L.Pittman@usace.army.mil	V
Rheannon Hart	Hydrologist, SRP Specialist	USACE SWL	Rheannon.M.Hart@usace.army.mil	V
Wesley Millar	J.E. Roush Lake Manager	USACE LRC	Wesley.S.Millar@usace.army.mil	P
Larry Brown	Salamonie Lake Manager	USACE LRC	Larry.A.Brown@usace.army.mil	P
Chelsea Jones	Mississinewa Lake Manager	USACE LRC	Chelsea.J.Jones@usace.army.mil	P

Table 21: Data received from SMEs

Data Used for State of the Science Report		
Subject	**Source**	**Dates**
Macroinvertebrate Sampling	Indiana Department of Environmental Management	1990-current
Fish Sampling	Indiana Department of Environmental Management	1998-2022
Fish Species	Indiana Department of Natural Resources	1990-current
QHEI	Indiana Department of Environmental Management 2022	1998-
Water Quality Impairments (303(d))	Indiana Department of Environmental Management	2022
Water Quality data, algal, reservoirs	Indiana Department of Environmental Management	2022
Water Quality data, reservoirs	Annual Water Quality Monitoring, USACE	2021