# GLMRIS

Great Lakes and Mississippi River Interbasin Study

Aquatic Nuisance Species | Ecosystems | Navigation | Recreation | Flood Risk Management | Water Use

## Aquatic Nuisance Species Controls Report

## Wabash-Maumee Basin Connection

## Fort Wayne, Indiana

# APPENDIX A
# Aquatic Pathway Assessment Report

US Army Corps of Engineers®
BUILDING STRONG®

This page is intentionally blank.

# Executive Summary

Two Great Lakes and Mississippi River Interbasin Study (GLMRIS) interim reports are being released by the U.S. Army Corps of Engineers (USACE) in 2012 for the Eagle Marsh, or Wabash-Maumee, potential aquatic pathway. This pathway assessment is the first of these reports and characterizes the likelihood that a viable aquatic pathway exists at the Eagle Marsh Wetland Preserve just southwest of Fort Wayne, Indiana, and could allow transfer of aquatic nuisance species (ANS) between the Great Lakes and Mississippi Rivers Basins. The second report is an ANS Controls Report which builds upon the findings of the pathway assessment and evaluates the available options and technologies that may be available at Eagle Marsh to prevent the transfer of ANS from occurring at this location. Eagle Marsh is surrounded by flood-prone agricultural lands and spans the Great Lakes and Mississippi River Basins, allowing surface water to flow in either direction during flood events. Flooding occurs at Eagle Marsh from back water inundation of the St. Marys River (Great Lakes Basin) into Junk ditch and from the Graham-McCullough Ditch (Mississippi River Basin). Depths of inundation during this flooding can range from a couple feet (0.6 m) to close to ten feet (3 m), depending on the level of storm event and location. The flooding of these two ditches converges in Eagle Marsh creating the aquatic pathway. Drainage from this location to the Great Lakes Basin is through Junk Ditch to the St. Marys River while drainage toward the Mississippi River Basin is through Graham-McCullough Ditch to the Little River.

This site was determined to be capable of conveying water across the basin divide for days to weeks, multiple times per year. A surface water pathway between the basins occurs most frequently during late winter to early summer, and sporadically during heavy rain events during other times of the year. The hydrologic connection between the two watersheds at Eagle Marsh can occur through the culverts in the agricultural berm on the south bank of Graham McCulloch Ditch or by overtopping of the crest of the berm. The culvert connection may occur while the flap gate on the culverts are jammed or from back water inundation of the St. Marys River into Eagle Marsh from Junk Ditch. Based on hydrologic modeling, overtopping of the berm will occur from a ten percent annual recurrence interval flood event on the Graham-McCulloch Ditch or from a three percent annual recurrence interval event on the St. Marys River. Since it was determined early on that an aquatic pathway exists at Eagle Marsh, a chain link fence was installed in 2010 by the State of Indiana as a temporary measure to reduce the likelihood of ANS (specifically adult Asian carp species) moving into the Great Lakes Basin.

| Aquatic Nuisance Species of Concern | |
|---|---|
| **Species** | **Common Name** |
| *Hypophthalmichthys molitrix* | silver carp |
| *Hypophthalmichthys nobilis* | bighead carp |
| *Mylopharyngodon piceus* | black carp |
| *Menidia beryllina* | inland silverside |
| *Channa argus* | northern snakehead |
| *Gasterosteus aculeatus* | threespine stickleback |
| *Gymnocephalus cernua* | ruffe |
| *Proterorhinus semilunaris* | tubenose goby |
| *Novirhabdovirus sp* | viral hemorrhagic septicemia virus (VHSv) |
| *Neoergasilus japonicus* | parasitic copepod |

Since interbasin flow can occur at this location, an interagency team of biologists collaborated to develop the list of 10 ANS of concern for interbasin spread through the Eagle Marsh aquatic pathway and are listed in the table above. This team then conducted a systematic analysis of the biological characteristics and capabilities of each of the selected ANS relative to the aquatic habitat in proximity and leading up to Eagle Marsh from Lake Erie and the Mississippi River.

Based on the hydrology of the aquatic pathway and consideration of the above species, the biological evaluation found that ANS transfer between the basins could occur in either direction at Eagle Marsh. For transfer into the Great Lakes Basin, five fish species (Northern snakehead, Asian carps [i.e., silver carp, bighead carp, and black carp], and inland silverside) were identified to be a potential threat and were each assigned medium ratings for their ability to arrive at, and cross through, the aquatic pathway into the Mississippi

Basin. These ratings were limited largely by either the inability of these species to arrive at the pathway within the next 20 years and/or by a lack of suitable habitat near the pathway which would limit the ability of these species to establish a population in close proximity to be able to cross through the pathway into the adjacent basin during a relatively short window of time when the pathway forms.

For transfer into the Mississippi River Basin, the parasitic copepod, viral hemorragic septicemia virus (VHSv), and the threespine stickleback were found to be the most likely potential threats and, except for VHSv, were also assigned medium ratings for their ability to arrive at, and cross through, the aquatic pathway when it forms. Viral hemorragic septicemia virus is a systemic disease of fish that can result in mortality and has been affecting some Great Lakes freshwater fish populations since approximately 2005. The rating for VHSv was determined to be high and this was the only ANS for which this pathway was given an overall aquatic pathway viability rating of high. The parasitic copepod and VHSv are able to be transported on numerous potential host fish species, including the common carp (*Cyprinus carpio*), which is more likely to be tolerant of the lower water quality found in the ditches connecting to the pathway. The parasitic copepod, however, ended up being rated lower than VHSv due largely to its slower rate of spread through the Great Lakes and its presumed inability to reach the Eagle Marsh pathway within the next 20 years.

In addition, the threespine stickleback was also determined to be a potential threat to the Mississippi River Basin due to a lack of obstructions between the Eagle Marsh and the Great Lakes, its tolerance of a variety of habitats, and the likelihood that sufficient forage would be available in connecting streams. However, if the threespine stickleback were able to reach the vicinity of the pathway it would likely be in only small numbers due to limited habitat and water quality at the pathway.

There is some level of uncertainty with these ratings associated with particular ANS abilities to arrive at the pathway and establish a populations. The collection of additional information about this pathway and connecting streams would reduce the level of uncertainty, such as additional information on the life history requirements of specific ANS and the suitability of the habitat within the connecting waterways to allow for ANS movement and survival. Both structural and non-structural opportunities exist at and downstream of this site to reduce or eliminate the potential for ANS transfer. Such opportunities include the construction of physical barriers at or near Eagle Marsh to sever the aquatic connection, public education on the identification and threats posed by ANS, and increased and improved ANS monitoring to track the potential movement of ANS in streams connecting to this pathway. Some of these potential opportunities are being assessed in greater detail as part of the ANS Controls Report for Eagle Marsh.

# Table of Contents


1 Introduction . . . 1
1.1 Study Purpose . . . 1
1.2 Summary of 2010 Preliminary Risk Characterization for Eagle Marsh, Indiana . . . 2
1.3 Aquatic Pathway Team . . . 7
2 Study Methodology . . . 7
2.1 Coordination . . . 8
2.2 Identification of Potential Pathways . . . 8
2.3 Aquatic Nuisance Species of Concern . . . 8
2.3.1 Lists of Non-indigenous Species in Great Lakes and Mississippi River Basins . . . 9
2.3.2 List of ANS of Concern for GLMRIS . . . 9
2.3.3 List of ANS of Specific Concern at the Eagle Marsh Location . . . 9
2.3.4 Key Attributes of Selected Organisms . . . 15
2.4 Pathway Assessment Process . . . 15
2.5 Example Calculation of Overall Aquatic Pathway Viability . . . 17
3 Aquatic Pathway Characterization . . . 19
3.1 Location . . . 20
3.2 Climate . . . 20
3.3 Location Specific Surface Water Features . . . 20
3.4 Groundwater . . . 25
3.5 Aquatic Pathway Temporal Characteristics . . . 25
3.6 Probability Aquatic Pathway Exists . . . 33
3.7 Aquatic Pathway Habitat . . . 34
3.7.1 Terrestrial and Riparian Plants and Land Use . . . 34
3.7.2 Aquatic Resources . . . 34
3.7.3 Water Quantity and Quality . . . 38
3.7.4 Aquatic Organisms . . . 39
3.8 Connecting Streams to Great Lakes and Mississippi or Ohio Rivers . . . 40
4 Aquatic Pathway Viability for ANS of Concern . . . 44
4.1 Probability of Target ANS being within Either Basin . . . 44
4.2 Probability Target ANS Survives Transit to Reach Aquatic Pathway . . . 47
4.2.1 Probability ANS Survives Transit to Aquatic Pathway Through Connecting Streams . . . 47
4.2.2 Probability ANS Survives Transit to Aquatic Pathway Through Other Means . . . 50
4.3 Probability of ANS Establishment at the Aquatic Pathway . . . 51
4.4 Probability of ANS Spreading Across Pathway into the New Basin . . . 53
5 Overall Aquatic Pathway Viability . . . 54
6 Conclusions . . . 56
6.1 Eagle Marsh Problem Statements . . . 56
6.2 Eagle Marsh Opportunity Statements . . . 57
7 References . . . 60
Appendix A: Depth Grids for Various Flood Events at Eagle Marsh
Appendix B: Evaluation Forms

# List of Tables

Table 1: ANS of Concern for GLMRIS . . . 10
Table 2: ANS of Concern Threatening the Mississippi River Basin . . . 12
Table 3: ANS of Concern Threatening the Great Lakes Basin . . . 12
Table 4: ANS of Greatest Concern at Eagle Marsh . . . 15
Table 5. Example Calculation of Pathway Viability for ANS Spreading from Mississippi River Basin to the Great Lakes Basin. . . . 19
Table 6. Example Calculation of Pathway Viability for ANS Spreading from Great Lakes Basin to the Mississippi River Basin. . . . 19
Table 7. Overall Pathway Viability Rating (Mississippi River Basin to Great Lakes Basin) . . . 55
Table 8. Overall Pathway Viability Rating (Great Lakes Basin to Mississippi River Basin) . . . 55

# List of Figures

Figure 1. Potential Other Aquatic Pathway Locations Identified in the GLMRIS Study. . . . 3
Figure 2. Photo of the Temporary Fence in Eagle Marsh . . . 5
Figure 3. Location of Temporary Fence . . . 6
Figure 4. Map of ANS Occurrences Near Eagle Marsh. . . . 13
Figure 5. Map of ANS Occurrences Near Lake Erie. . . . 14
Figure 6. Diagram of the Derivation of the GLMRIS Focus Area 2 Aquatic Pathway Assessment Model . . . 18
Figure 7. Location of Eagle Marsh.. . . . 21
Figure 8. Digital Elevation Mapping of Eagle Marsh and the Surrounding Area. . . . 22
Figure 9. Eagle Marsh with FEMA One Percent Annual Recurrence Interval Floodplain. . . . 23
Figure 10. Looking Upstream at Graham McCulloch from within Eagle Marsh . . . 24
Figure 11. Graham-McColloch Ditch on November 3, 2010.. . . . 24
Figure 12. Graham-McCulloch Ditch at the Same Location as Shown in Figure 11 on April 16, 2011. . . . 25
Figure 13. Sample Cross Section Through Eagle Marsh Left Bank Berm and Southern Storage Area. . . . 28
Figure 14. Graham-McCulloch Ditch Flood Event Surface Profiles . . . 29
Figure 15. St. Marys Flood Water Surface Elevations behind Graham-McCulloch Ditch Berm . . . 30
Figure 16. 18-inch Pipes Through Graham McCulloch Ditch Left Bank Berm. . . . 31
Figure 17. Coordinated Discharges Graph used for Graham-McCulloch Ditch Flows. . . . 32
Figure 18. Pond at Eagle Marsh. . . . 35
Figure 19. Irrigation Pond at Eagle Marsh. . . . 35
Figure 20. Flooding Across the Entrance Road to Eagle Marsh. . . . 36
Figure 21. Flooding at the Temporary ANS Barrier within Eagle Marsh.. . . . 36
Figure 22. Map of Eagle Marsh Habitat Types . . . 37
Figure 23. Dams Located Downstream of Eagle Marsh Within Both Basins.. . . . 41
Figure 24. Low Head Dam, Little River at Huntington Indiana During Summer Low Flow. . . . 42
Figure 25. Low Head Dam, Little River in Huntington Indiana During Normal Flow.. . . . 42
Figure 26. Looking Upstream at Little River from Abandoned Railway Bridge, Huntington, Indiana.. . . . 43
Figure 27. Small Low Head Dam on the Little River Downstream of S. Jefferson St. Bridge.. . . . 43

# Acronyms

ANS . . . . . Aquatic Nuisance Species
ANSTF. . . . Aquatic Nuisance Species Task Force
CAWS . . . . Chicago Area Waterway System
CEQ. . . . . Council on Environmental Quality
CMP. . . . . Corrugated Metal Pipe
DEM. . . . . Digital Elevation Model
FEMA. . . . . Federal Emergency Management Agency
FIS. . . . . Flood Insurance Study
GIS . . . . . Geographic Information System
GLB . . . . . Great Lakes Basin
GLFC. . . . . Great Lakes Fishery Commission
GLMRIS. . . Great Lakes and Mississippi River Interbasin Study
HUC. . . . . Hyrdologic Unit Codes
INDNR . . . . Indiana Department of Natural Resources
LDB . . . . . Left Descending Bank
LRWP . . . . Little River Wetlands Project
MNDNR . . . Minnesota Department of Natural Resources
MRB. . . . . Mississippi River Basin
NAS . . . . . Nonindigenous Aquatic Species
NCDC . . . . National Climatic Data Center
NEPA. . . . . National Environmental Policy Act
NHD. . . . . National Hydrography Database
NID . . . . . National Inventory of Dams
NOAA. . . . . National Oceanic and Atmospheric Administration
NRCS . . . . Natural Resources Conservation Service
RCP. . . . . Reinforced Concrete Pipe
RM. . . . . River Mile
USACE . . . U.S. Army Corps of Engineers
USFWS . . . U.S. Fish and Wildlife Service
USGS . . . . U.S. Geological Survey
WRDA . . . . Water Resources Development Act

# 1 Introduction

The Great Lakes and Mississippi River Interbasin Study (GLMRIS) was authorized in Section 3061(d) of the Water Resources Development Act of 2007 (WRDA, 2007), and therein, it prescribes the following authority to the Secretary of the Army and the U.S. Army Corps of Engineers (USACE).

> *"(d) FEASIBILITY STUDY. - The Secretary, in consultation with appropriate Federal, State, local, and nongovernmental entities, shall conduct, at Federal expense, a feasibility study of the range of options and technologies available to prevent the spread of aquatic nuisance species between the Great Lakes and Mississippi River Basins through the Chicago Sanitary and Ship Canal and other aquatic pathways."*

This GLMRIS Focus Area 2 Aquatic Pathway Assessment report addresses the Eagle Marsh location, in Allen County, Indiana. This location is one of 18 locations identified in the Great Lakes and Mississippi River Interbasin Study Other Pathways Preliminary Risk Characterization (USACE, 2010) as a potential aquatic pathway spanning the watershed divide between the Great Lakes and Mississippi River Basins other than the Chicago Area Water System (CAWS). This report is downloadable from the GLMRIS web site (glmris.anl.gov/).

The dashed line in Figure 1 depicts the nearly 1,500-mile (2,414 kilometer) basin from the New York - Pennsylvania state line to north eastern Minnesota, and it depicts each of the 18 potential aquatic pathway locations that were previously identified. The Eagle Marsh location is shown as location 6 on Figure 1 in northeast Indiana.

The GLMRIS is a very large and complicated task involving multiple USACE Districts and Divisions. Program Management of the study is conducted by the Great Lakes and Ohio River Division. The study considers several aquatic nuisance species (ANS) of concern, however, the proximity of Asian carp in the Mississippi River Basin to the basin divide near two locations lend a sense of urgency and national significance to completion of the GLMRIS. These two locations are the CAWS in Chicago, Illinois and Eagle Marsh in Fort Wayne, Indiana. To help accelerate completion of the feasibility study, the Great Lakes and Ohio River Division split management of the GLMRIS into two separate focus areas. Focus Area 1 is managed by the USACE, Chicago District and addresses the CAWS that open to Lake Michigan. Focus Area 2 is managed by the USACE, Buffalo District and evaluates all other potential aquatic pathways that exist or are likely to form across the basin divide separating precipitation that flows into the Mississippi River and its tributaries from precipitation that flows into the Great Lakes and its tributaries.

## 1.1 Study Purpose

The preliminary report from 2010 and the subsequent analysis contained in this report have been produced for a broad audience ranging from the scientific community to the general public, and are specifically intended to identify any locations where an aquatic pathway exists or may form between the basins, and to evaluate the probability that specific ANS would be able arrive at that pathway and cross into the new basin. The information in this and the other Focus Area 2 reports are intended to provide a sound scientific basis for helping to prioritize future funding of GLMRIS and/or other actions at these potential aquatic pathway locations.

This report is part of a tiered approach to assess the likelihood of ANS spreading between the Great Lakes and Mississippi River Basins via aquatic pathways, and it was prepared in accordance with the detailed procedures and criteria specified in the GLMRIS Focus Area 2 Study Plan (USACE, 2011a). The primary purpose of this report is to present the evidence and explain the procedures used to qualitatively estimate the likelihood that a viable aquatic pathway exists at the Eagle Marsh location that will enable the interbasin spread of ANS. It is also intended to contribute to the accomplishment of each of the four objectives identified in the plan by including the following:

- A definitive determination of whether the Eagle Marsh, Indiana location should be included

in the inventory of locations where a viable surface water connection between headwater streams on both sides of the drainage divide exists or is likely to form between the Great Lakes and the Mississippi River basins;

- A standalone report that characterizes the probability of aquatic pathway formation and the probability that a viable aquatic pathway exists at the Eagle Marsh, Indiana location and will enable the interbasin spread of ANS;

- Development of clear problem statements that frame the means, constraints, and likelihood of the interbasin spread of ANS via the potential aquatic pathway at the Eagle Marsh, Indiana location; and

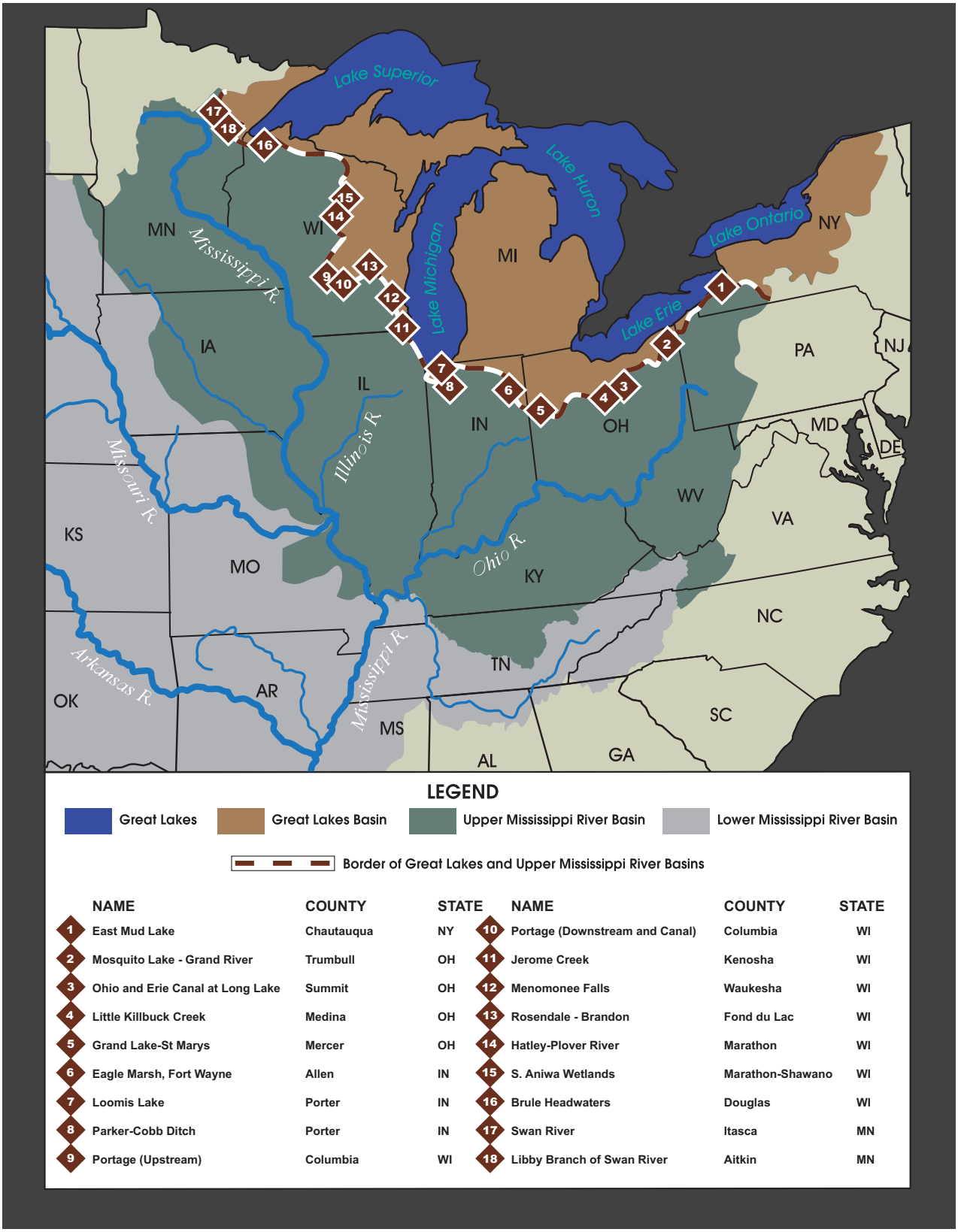
- Development of clear opportunity statements that illustrate how the collective authorities, resources and capabilities of USACE and other applicable federal, state, local and non-governmental stakeholder organizations may best be coordinated and applied to prevent the interbasin spread of ANS through the Eagle Marsh, Indiana location.

## 1.2 Summary of 2010 Preliminary Risk Characterization for Eagle Marsh, Indiana

The Great Lakes and Mississippi River Interbasin Study Other Pathways Preliminary Risk Characterization was designed as the first step of a tiered approach to rapidly conduct a study intended to accomplish two objectives (USACE, 2010). The first and primary objective was to determine if there were any locations within the GLMRIS, aside from the CAWS, where a near term risk for the interbasin spread of ANS exists. Near term, in this case, indicates that implementation of some measure(s) might be warranted to reduce the potential for ANS transfer at that particular location in the short term versus setting that site aside for further analysis. The second objective was to refine the scope of the other aquatic pathways portion of the GLMRIS by developing a list of potential aquatic pathways that could form anywhere along the divide separating the Great Lakes and Mississippi River Basins, and help provide a basis for prioritizing future feasibility study efforts based upon relative risk.

The USACE solicited the input and collaborated with the U.S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS), U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), Great Lakes Fishery Commission (GLFC) and the natural resource agencies in the states of Minnesota, Wisconsin, Indiana, Ohio, Pennsylvania, and New York. A total of 36 potential locations were initially identified along the divide where it appeared that interbasin flow could occur. These were locations situated in a mixture of rural, forested, suburban, and urban areas, and included locations where surface water flow patterns have been modified through the building of navigation canals, excavation of ditches, and construction of sewers to facilitate storm water management for agricultural, flood damage reduction, or other water management purposes. Also, many of the potential aquatic pathways identified in 2010 were locations where extensive natural wetlands exist in close proximity to, and in some instances appear to span, the basin divide. The lack of prior hydrologic studies and the level of uncertainty in the hydrology information led to a conservative approach in assigning the individual qualitative aquatic pathway risk ratings.

At 18 of these locations the interagency group determined that it would likely require an epic storm and flooding event for an aquatic pathway to ever form across the basin divide. These were not recommended for further investigation because this was considered a low level of risk. However, at the remaining 18 locations the group did recommend that a more detailed assessment be conducted (Figure 1). Only one location, Eagle Marsh in Fort Wayne, Indiana, was determined to pose a near term risk for the potential spread of Asian carp into the Great Lakes Basin, and this led to the installation of a temporary barrier by Indiana Department of Natural Resources (INDNR) until a more complete assessment and remedy could be implemented.




| | NAME | COUNTY | STATE |
|---|---|---|---|
| 1 | East Mud Lake | Chautauqua | NY |
| 2 | Mosquito Lake - Grand River | Trumbull | OH |
| 3 | Ohio and Erie Canal at Long Lake | Summit | OH |
| 4 | Little Killbuck Creek | Medina | OH |
| 5 | Grand Lake-St Marys | Mercer | OH |
| 6 | Eagle Marsh, Fort Wayne | Allen | IN |
| 7 | Loomis Lake | Porter | IN |
| 8 | Parker-Cobb Ditch | Porter | IN |
| 9 | Portage (Upstream) | Columbia | WI |
| 10 | Portage (Downstream and Canal) | Columbia | WI |
| 11 | Jerome Creek | Kenosha | WI |
| 12 | Menomonee Falls | Waukesha | WI |
| 13 | Rosendale - Brandon | Fond du Lac | WI |
| 14 | Hatley-Plover River | Marathon | WI |
| 15 | S. Aniwa Wetlands | Marathon-Shawano | WI |
| 16 | Brule Headwaters | Douglas | WI |
| 17 | Swan River | Itasca | MN |
| 18 | Libby Branch of Swan River | Aitkin | MN |

Figure 1. Potential aquatic pathway locations identified in the GLMRIS Preliminary Risk Characterization Study (USACE, 2010).

Eagle Marsh is a remnant of glacial Lake Maumee, a precursor to Lake Erie and has been a natural area where interbasin flow occurs since the retreat of the glaciers. Based upon local observations, the INDNR reported that noticeable flow through Eagle Marsh between Junk Ditch (Great Lakes Basin) and Grand-McCulloch Ditch (Mississippi River Basin) could occur from the annual storm event. The USGS estimated that a 10 percent annual recurrence interval storm (see next paragraph for explanation of this terminology) is sufficient to establish a surface water connection to depth sufficient for Asian carp to move through the marsh. It was also found that at times of low water, small ponds were interspersed across the marsh which appeared to be groundwater fed. The estimated dimensions of the interbasin connection during high water were reported to be between 3,000 and 4,000 feet (914 and 1,219 meters) wide with a maximum water depth of about 6 feet (1.8 m) at the one percent annual recurrence interval storm. The preliminary findings for Eagle Marsh were based on data from a 2009 Flood Insurance Study (FIS) that showed there to be backflow from the Saint Marys and Saint Joseph's Rivers upstream through Junk Ditch. Additional information was obtained from the National Hydrography Database (NHD), National Inventory of Dams (NID), Bing and Google Earth aerial photography, expert inter-agency analyses, and area-specific facts provided by members of the USGS, INDNR, NRCS, USGS, and Little River Wetlands Project (LRWP). Based on these findings and the relatively close proximity of Asian carp in the Wabash River Watershed, the Eagle Marsh interbasin connection was determined to pose a near term risk where ANS, specifically Asian carp, may transfer between basins.

A recurrence interval relates any given storm, through statistical analysis, to the historical records of rainfall and runoff for a given area. The recurrence interval is based on the statistical probability that a given intensity storm event will be equaled or exceeded in any given year. For instance, a one percent annual recurrence interval storm is a rainfall event that has a one percent probability, one chance in 100, of being equaled or exceeded in any given year. This level of storm event was commonly referred to as a 100-year storm event, but this term has led people to incorrectly conclude that a 100-year storm event is one that only occurs once in any given 100 year period. A ten percent annual return frequency storm (formerly referred to as a ten year event) is a smaller event that has a one in ten chance of being exceed during any given year, and a 0.2 percent annual return frequency storm (formerly referred to as a 500-year event) is a larger event that has a one in 500 chance of being exceeded in any given year.

Due to the near term risk at the Eagle Marsh location, a chain link fence was installed in Eagle Marsh to prevent the movement of adult silver and bighead carp through the marsh toward the Great Lakes Basin until a permanent barrier could be designed and constructed (Figures 2 and 3). Based on available information regarding the life history of silver and bighead Carp, it was determined at the time that juvenile silver and bighead carp (individuals small enough to pass through the fence) lacked the ability to reach Eagle Marsh and no spawning would occur within the marsh. Construction of the fence was completed by October 1, 2010. The fence is a temporary measure and it is scheduled to be removed, due to permitting requirements, five years from the date of installation. Though no evidence has been found to support the presence of Asian carp in Eagle Marsh, common carp (*Cyprinus carpio*) have been reported at the divide. A video taken by INDNR employees (http://www.in.gov/dnr/video/carp.wmv) demonstrates how the fence is designed to work as it is shown preventing common carp from crossing the watershed divide.

In addition to this temporary measure, INDNR is also monitoring Asian carp in the Wabash River. An Asian carp spawn was reported in late May 2011. Very few eggs were found in Peru, Indiana, which is approximately 40 miles (64 km) downstream of the J. Edward Roush Dam, located near Huntington, Indiana. Peru, Indiana is located approximately 55 miles (88 km) downstream of Eagle Marsh. The eggs were also very young (few embryonic cell divisions had taken place). Substantial numbers of eggs were found in Logansport and Lafayette, Indiana, which are located approximately 70 miles (113 km) and 105 miles (169 km) downstream of Eagle Marsh respectively (Doug Keller, INDNR, personal communication, August 16, 2011). The species identity of the eggs were DNA verified. Contrary to previous observations of conditions that may initiate spawning, spawning events have been documented on the Wabash River without any concomitant rise and fall in

Figure 2. Photo of the temporary fence in Eagle Marsh constructed in 2010. Photo from USACE.

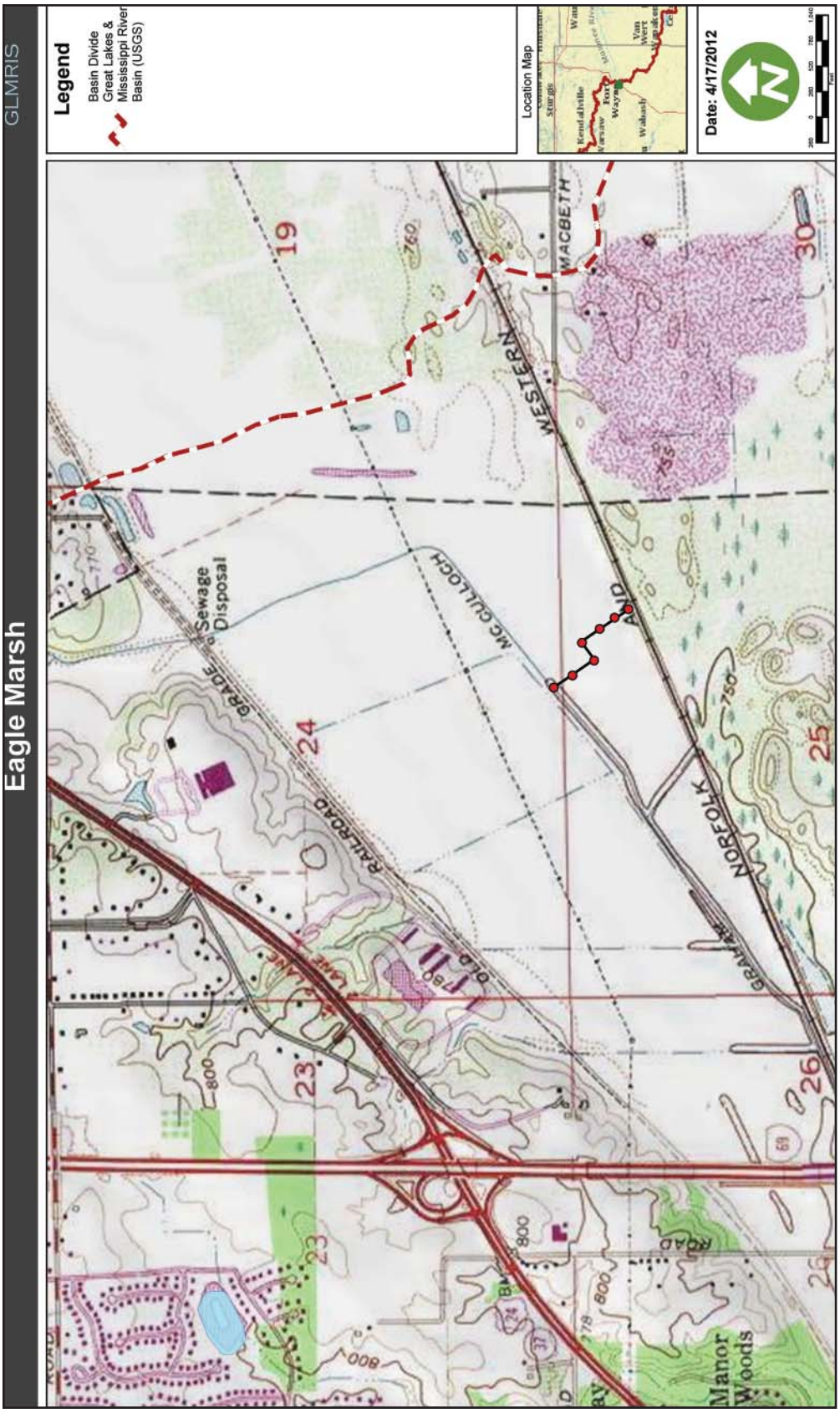



Figure 3. Location of temporary fence overlaid on USGS topographic base mapping, with red dots representing handheld GPS coordinates taken in the field.

the hydrograph (Dr. Reuben Goforth, Purdue University, personal communication, June 18, 2012). The INDNR has also funded Purdue University to conduct a two year ultrasonic telemetry study on Asian carp movement. One hundred silver carp were collected, tagged, and re-released in the Wabash River. Attempts were made to collect fish for tagging as far upstream as possible. Only a few individuals were collected in or above Peru, Indiana due to low densities. Monitoring stations are in place along the Wabash River and Little River to monitor the carp movements. To date, no tagged fish have been detected in the Little River. One tagged fish has been detected in the Wabash River near the mouth of Little River (Doug Keller, INDNR, personal communication, August 16, 2011).

Although the Eagle Marsh location was identified as posing a near term risk for interbasin transfer of ANS and temporary measures were taken by INDNR, a more detailed assessment of this location was still recommended. This was subsequently done in collaboration with the INDNR, USFWS, USGS, and other government agencies. The following actions were taken:

- Federal, State, and local stakeholders (i.e., USGS, INDNR, County Surveyor, and local NRCS representatives) were briefed on the preliminary risk characterization results. Detailed site visits to observe the location were conducted and the available modeling, topographic mapping, and flood hazard information was compiled and reviewed.

- The dams on the connecting streams to the Great Lakes and the Mississippi River were evaluated relative to the potential for ANS passage through, around, or over each in-stream structure in both directions.

- Habitat and abiotic conditions in proximity to the location were analyzed relative to the needs and preferences of specific ANS in proximity to the location.

- The aquatic pathway viability and assessments of the likelihood of interbasin spread for each of the ANS of concern were completed based on this information.

- Measures that could potentially be implemented were identified to mitigate the likelihood of ANS spread across the Mississippi River Basin-Great Lakes Basin divide, although this is being done in more detail as part of the separate USACE report entitled the “Eagle Marsh ANS Controls Report”.

## 1.3 Aquatic Pathway Team

Due to the large amount of unknowns and natural variability associated with the hydrology and the biology of such a large geographic area, the Study Plan specified formation of a “team of teams,” combining the best available local, state, and national hydrologists and biologists to assess conditions at each potential aquatic pathway. The results of this assessment reflect the collective experience, expertise, and focused effort of these biologists and hydrologists from Indiana Department of Natural Resources, NRCS, USACE, USFWS, and USGS. The results also reflect the guidance, input, review comments, and concurrence of the multi-organization Agency Technical Review of experts from GLFC Illinois Department of Natural Resources, USACE, and USFWS.

# 2 Study Methodology

The GLMRIS risk analysis process is an adaptation of the generic model and process described in the Generic Nonindigenous Aquatic Organisms Risk Analysis Review Process (For Estimating Risk Associated with the Introduction of Nonindigenous Aquatic Organisms and How to Manage for that Risk) (ANSTF, 1996). The Aquatic Nuisance Species Task Force (ANSTF) defines the first step in this process as identification of interested parties and solicitation of input.

## 2.1 Coordination

The USACE identified interested parties and solicited input early in the process for Focus Area 2 and has included individual visits and discussions with the state agencies responsible for water resources, and fish and wildlife management in the eight states bordering the Great Lakes. The process used for the Focus Area 2 assessments has also been discussed in meetings with representatives of the Council on Environmental Quality (CEQ), USGS, USFWS, NOAA, NRCS, and GLFC. Development of this plan also included input from the public and interested non-governmental organizations received during formal National Environmental Policy Act (NEPA) public scoping meetings which were held at 12 locations across the region in both basins between December 2010 and March 2011. The USACE requested the support and participation of the best available experts from the State and Federal agencies responsible for water resources, and fish and wildlife management in the states along the Great Lakes and Mississippi River Basin divide to address the critically important issue of preventing interbasin transfer of ANS. The USGS, NRCS, and each state DNR assigned personnel to assist each USACE pathway assessment team. In addition, a technical review team comprised of 16 senior level experts from the USACE and these external partner agencies, including NOAA and GLFC, was assembled to review and guide the work of these teams. Overall, extensive collaboration among partner agencies, the review team, and other subject matter experts has led to detailed Focus Area 2 pathway assessments.

## 2.2 Identification of Potential Pathways

At 18 of the potential aquatic pathways identified during the 2010 Preliminary Risk Characterization, it was determined it would likely require an epic storm and flooding event (i.e., greater than a one percent annual recurrence interval storm event) for an aquatic pathway to ever form across the basin divide. These locations were not recommended for further investigation because areas that might require a flooding event in excess (greater magnitude, less frequency) of the one percent annual recurrence interval flood are less likely, and therefore present a low level of risk. This one percent threshold criterion was established through collaboration with the USGS, USFWS, NRCS, GLFC, and the departments of natural resources in the states of MI, MN, WI, IL, IN, OH, PA, and NY. This threshold is also widely used in flood risk management and is typically aligned with most readily available hydrologic information. The one percent annual recurrence interval threshold only indicates at what level event an aquatic connection can begin to form and would indicate a location that should then be subjected to a more labor intensive evaluation of the probability of ANS being able to utilize that pathway. At the remaining 18 locations, it was recommended that a more detailed assessment be conducted (Figure 1). This was subsequently done in 2011-2012 in collaboration with USGS, NRCS, USFWS, state natural resource agencies, and county surveyors (where applicable), and the results are presented in this report.

Although the focus of this assessment is on aquatic pathways, it should also be mentioned that there are other non-aquatic pathways that may enable ANS to transit across the aquatic pathway or across the basin divide. Although these other pathways do not influence the overall pathway rating outlined in this report, they are included to point out potential other pathways (e.g., anthropogenic) and their potential influence on the same list of ANS as evaluated in Section 4 of this report. Any further analysis of these non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from the list of ANS evaluated as part of this aquatic pathway report.

## 2.3 Aquatic Nuisance Species of Concern

This report addresses the problem of ANS invading, via surface-water pathways, the Great Lakes Basin from the Mississippi River Basin and vice versa. ANS is defined by the ANSTF as "… nonindigenous species that threaten the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or

recreational activities dependent on such waters." The USGS Nonindigenous Aquatic Species (NAS) information resource http://nas.er.usgs.gov/about/faq.aspx defines NAS as "…a species that enters a body of water or aquatic ecosystem outside of its historic or native range." (USGS, 2012). Based on discussions between the USACE, USGS, and USFWS the following definitions were established for the purposes of the GLMRIS. All nonindigenous aquatic species (per the USGS definition above), that are present in the Great Lakes but not known to be present in the Mississippi River and its tributaries are defined as ANS of concern for GLMRIS. Likewise, all nonindigenous aquatic species present in the Mississippi River or its tributaries but not known to be present in the Great Lakes are also considered as ANS of concern for the GLMRIS. Therefore, the term ANS is synonymous with the term nonindigenous aquatic species in this report.

### 2.3.1 Lists of Non-indigenous Species in Great Lakes and Mississippi River Basins

The list of ANS of concern for a particular location was developed by first consulting the USACE white paper titled, Non-Native Species of Concern and Dispersal Risk for the Great Lakes and Mississippi River Interbasin Study released in September 2011 (USACE, 2011b). This technical paper, prepared by a multi-disciplinary USACE natural resources team, took a broad look at the potential range of species that could be of concern to the GLMRIS. The paper is Appendix C of the GLMRIS Focus Area 2 Study Plan and it is an integral component of the plan. This USACE white paper included a review of 254 aquatic species that are either nonindigenous to either basin or native species that occur in one basin or the other. The list of 254 aquatic species were iteratively screened to identify all potential ANS that could be of concern in either basin and to systematically focus the study toward those species judged to pose the highest potential risk of ecological impacts if they became established in the other basin.

In the first screening iteration, 119 of the 254 aquatic species reviewed were determined to pose a potential threat of infiltrating the other basin and were carried into the second iteration of the analysis. The other 135 species were rejected for further analysis for several reasons. Initially, 104 species were dropped from further consideration because they were determined to already be established in both basins. Another 31 species were removed from further analysis because they were not yet located in either basin, could bypass any aquatic control mechanism by terrestrial movement, or had no potential to cause adverse affects to the invaded ecosystem.

### 2.3.2 List of ANS of Concern for GLMRIS

To determine species of concern that are pertinent for the GLMRIS from the list of 119 species, the USACE natural resources team compiled, reviewed, and analyzed the best available information. Literature reviews, species proximity to aquatic interbasin connections (in particular the CAWS), ecological tolerances and needs, and vagility of the species were all included in the analysis. The team ranked each species as high, medium, or low risk according to these parameters. The result was the establishment of a list of 39 species, each identified as having both a high level of potential risk for both transferring from one basin to another, and potentially a high risk in that if they do disperse, and the invaded ecosystem could be moderately to severely affected by their colonization (Table 1). A fact sheet was developed for each of these species of concern detailing morphological characteristics useful for identification, including color photographs of the species, information on their ecology, habitat, distribution, and current status in the Mississippi River or Great Lakes Basins.

### 2.3.3 List of ANS of Specific Concern at the Eagle Marsh Location

The Eagle Marsh aquatic pathway team then subdivided the set of species listed in Table 1 into two groups: ANS threatening the Great Lakes, and ANS threatening the Mississippi River and its tributaries. Each of these two lists was then sorted into subgroups in accordance with

| Table 1: ANS of Concern for GLMRIS. | | | | |
|---|---|---|---|---|
| **Taxon** | **Scientific Name** | **Common Name** | **Basin** | **Interbasin Dispersal Mechanism** |
| fish | *Alosa aestivalis* | blueback herring | GL | swimmer |
| fish | *Alosa chrysochloris* | skipjack herring | MS | swimmer |
| fish | *Alosa psuedoharengus* | Alewife | GL | swimmer |
| crustacean | *Apocorophium lacustre* | a scud | MS | ballast water |
| algae | *Bangia atropupurea* | red macro-algae | GL | ballast / rec. boating |
| annelid | *Branchuris sowerbyi* | tubificid worm | GL | sediment transport |
| crustacean | *Bythotrephes longimanus* | spiny waterflea | GL | ballast water/sediment transport |
| plant | *Carex acutiformis* | swamp sedge | GL | recreational boating & trailers |
| crustacean | *Cercopagis pengoi* | fish-hook water flea | GL | ballast / rec. boating |
| fish | *Channa argus* | northern snakehead | MS | swimmer |
| algae | *Cyclotella cryptica* | cryptic algae | GL | unknown / any water |
| algae | *Cyclotella pseudostelligera* | cylindrical algae | GL | unknown / any water |
| crustacean | *Daphnia galeata galeata* | water flea | GL | ballast water |
| crustacean | *Echinogammarus ischnus* | a European amphipod | GL | ballast water |
| algae | *Enteromorpha flexuosa* | grass kelp | GL | ballast / rec. boating |
| fish | *Gasterosteus aculeatus* | threespine stickleback | GL | swimmer |
| plant | *Glyceria maxima* | reed sweetgrass | GL | recreational boating & trailers |
| fish | *Gymnocephalus cernua* | Ruffe | GL | swimmer |
| crustacean | *Hemimysis anomala* | bloody red shrimp | GL | ballast water |
| fish | *Hypophthalmichthys molitrix* | silver carp | MS | swimmer |
| fish | *Hypophthalmichthys nobilis* | bighead carp | MS | swimmer |
| plant | *Landoltia (Spirodela) punctata* | dotted duckweed | MS | recreational boating & trailers |
| bryozoan | *Lophopodella carteri* | bryozoans | GL | with aquatic plants |
| fish | *Menidia beryllina* | inland silverside | MS | swimmer |
| plant | *Murdannia keisak* | marsh dewflower | MS | recreational boating & trailers |
| fish | *Mylopharyngodon piceus* | black carp | MS | swimmer |
| crustacean | *Neoergasilus japonicus* | a parasitic copepod | GL | parasite to fish |
| plant | *Oxycaryum cubense* | Cuban bulrush | MS | recreational boating & trailers |
| fish | *Petromyzon marinus* | sea lamprey | GL | swimmer |
| mollusk | *Pisidium amnicum* | greater European pea clam | GL | ballast water |
| fish | *Proterorhinus semilunaris* | tubenose goby | GL | swimmer |
| protozoan | *Psammonobiotus communis* | testate amoeba | GL | ballast water |
| protozoan | *Psammonobiotus dziwnowi* | testate amoeba | GL | ballast water |
| protozoan | *Psammonobiotus linearis* | testate amoeba | GL | ballast water |
| crustacean | *Schizopera borutzkyi* | parasitic copepod | GL | ballast water |
| mollusk | *Sphaerium corneum* | European fingernail clam | GL | ballast water |
| algae | *Stephanodiscus binderanus* | Diatom | GL | ballast water |
| plant | *Trapa natans* | water chestnut | GL | recreational boating & trailers |
| mollusk | *Valvata piscinalis* | European stream valvata | GL | ships |

taxonomy and common dispersal mechanism. Table 2 and Table 3 reflect these groupings of species that were found to pose a significant risk to the Mississippi River and its tributaries, and to the Great Lakes and its tributaries, respectively (USACE, 2011b).

Additionally, the Eagle Marsh aquatic pathway team reviewed the information on the 119 species initially determined to pose a potential threat of infiltrating the other basin to see if any were in close enough proximity to the Eagle Marsh location to be of concern. The team reviewed information on the NOAA Watchlist of species threatening the Great Lakes from international waters, and information on other species cited by the review team as high risk potential invaders not yet in either basin (NOAA, 2011). No additional species from the NOAA Watchlist were added to the species of concern for the Eagle Marsh location. However, the NOAA Watchlist was utilized as a resource, at the recommendation of agency team members, to identify any additional potential future species that could be introduced into either basin and possibly spread from there to the other basin.

Each aquatic pathway team was granted flexibility in determining whether to add additional species to their assessment based on their review of available information and the actual location of the potential pathway relative to the known location of those ANS being considered. Based on concerns from local agencies and from within the Great Lakes region about the potential for spread of viral hemorrhagic septicemia virus (VHSv, Novirhabdovirus spp), the project team elected to include it on the list of species of concern for Eagle Marsh. Although VHSv has been found in both basins (though infrequently and very localized in the Mississippi River Basin) (USGS, 2011), minimizing the spread of VHSv remains a priority for local stakeholders. Therefore, it has been included under the grouping of species which would potentially threaten the Mississippi River Basin.

Mapping was produced, using available USGS occurrence data, to show the relative location of ANS to Eagle Marsh. Bighead and silver carp are currently the only known ANS within a 25 mile (40 km) radius of Eagle marsh (Figure 4). Since the data used for this map on Figure 4 was compiled, silver carp have been detected even closer to the Eagle Marsh pathway in the Wabash River as far upstream as Huntington Dam, which presents a barrier to upstream movement at low flows. Though they have traveled past the mouth of Little River, there is no known evidence that they have moved into the Little River. Any ANS must travel up Little River and into Graham-McCulloch Ditch to reach Eagle Marsh. The nearest occurrence records for ANS in the Great Lakes Basin are from Lake Erie (Figure 5). Lake Michigan is also near Eagle Marsh, but no aquatic pathway via Eagle Marsh exists between Lake Michigan and the Mississippi River Basin.

Each of the three subgroups in Tables 2 and 3 were evaluated based on the dispersal mechanisms and general mobility of the species within each group. Since this location is positioned on the basin divide, well upstream of any know ANS listed here, any organism that moves solely through the aquatic pathway must possess either: self-propelled mobility the ability to “hitchhike” on other organisms to travel upstream. This eliminates organisms that rely on current for dispersal such as plants and algae.

Based on the evaluation by subgroups, only fish, or fish pathogens, were considered to have the requisite means of reaching the Eagle Marsh divide from either direction. To facilitate determination of the overall aquatic pathway viability of this site, the team of biologists then selected a smaller group of representative species for a more focused assessment. The species selected may be those most likely to arrive at the divide, pose the greatest possibility of ecological damage, and/or exhibit a broad range of biological characteristics that provides a more thorough evaluation (and more conservative) of potential probability that ANS could spread between the basins at this location. Of all the species considered, the Eagle Marsh aquatic pathway team determined that five ANS were potentially significant threats to the Great Lakes Basin, and five ANS were potential significant threats to the Mississippi River Basin (Table 4).

No fishing or boating is allowed within Eagle Marsh which virtually eliminates the threat of ANS transfer via water craft, associated equipment or fishing gear. Dumping of ANS (discarded aquarium pets, religious ceremonies, etc.) within the Marsh is considered unlikely because of the controlled use and access to the location. The only

| Table 2: ANS of Concern Threatening the Mississippi River Basin. | | | |
|---|---|---|---|
| **Taxa** | **Species** | **Common Name** | **Interbasin Dispersal Mechanism** |
| fish | *Alosa aestivalis* | blueback herring | swimmer |
| fish | *Alosa psuedoharengus* | Alewife | swimmer |
| fish | *Gasterosteus aculeatus* | threespine stickleback | swimmer |
| fish | *Gymnocephalus cernua* | Ruffe | swimmer |
| fish | *Petromyzon marinus* | sea lamprey | swimmer |
| fish | *Proterorhinus semilunaris* | tubenose goby | swimmer |
| crustacean | *Neoergasilus japonicus* | a parasitic copepod | parasite to fish |
| crustacean | *Bythotrephes longimanus* | spiny waterflea | ballast water/sediment |
| crustacean | *Cercopagis pengoi* | fish-hook water flea | ballast / rec. boating |
| crustacean | *Daphnia galeata galeata* | water flea | ballast water |
| crustacean | *Echinogammarus ischnus* | a European amphipod | ballast water |
| crustacean | *Hemimysis anomala* | bloody red shrimp | ballast water |
| crustacean | *Schizopera borutzkyi* | parasitic copepod | ballast water |
| mollusk | *Pisidium amnicum* | greater European pea clam | ballast water |
| mollusk | *Valvata piscinalis* | European stream valvata | ships |
| mollusk | *Sphaerium corneum* | European fingernail clam | ballast water |
| protozoan | *Psammonobiotus communis* | testate amoeba | ballast water |
| protozoan | *Psammonobiotus dziwnowi* | testate amoeba | ballast water |
| protozoan | *Psammonobiotus linearis* | testate amoeba | ballast water |
| annelid | *Branchuris sowerbyi* | tubificid worm | sediment transport |
| plant | *Carex acutiformis* | swamp sedge | recreational boats & trailers |
| plant | *Glyceria maxima* | reed sweetgrass | recreational boats & trailers |
| plant | *Trapa natans* | water chestnut | recreational boats & trailers |
| bryozoan | *Lophopodella carteri* | bryozoans | with aquatic plants |
| algae | *Bangia atropupurea* | red macro-algae | ballast / rec. boating |
| algae | *Cyclotella cryptica* | cryptic algae | unknown / any water |
| algae | *Cyclotella pseudostelligera* | cylindrical algae | unknown / any water |
| algae | *Enteromorpha flexuosa* | grass kelp | ballast / rec. boating |
| algae | *Stephanodiscus binderanus* | Diatom | ballast water |

| Table 3: ANS of Concern Threatening the Great Lakes. | | | |
|---|---|---|---|
| **Taxa** | **Species** | **Common Name** | **Interbasin Dispersal Mechanism** |
| fish | *Alosa chrysochloris* | skipjack herring | swimmer |
| fish | *Channa argus* | northern snakehead | swimmer |
| fish | *Hypophthalmichthys molitrix* | silver carp | swimmer |
| fish | *Hypophthalmichthys nobilis* | bighead carp | swimmer |
| fish | *Menidia beryllina* | inland silverside | swimmer |
| fish | *Mylopharyngodon piceus* | black carp | swimmer |
| crustacean | *Apocorophium lacustre* | a scud | ballast water |
| plant | *Landoltia (Spirodela) punctata* | dotted duckweed | recreational boats and trailers |
| plant | *Murdannia keisak* | marsh dewflower | recreational boats and trailers |
| plant | *Oxycaryum cubense* | Cuban bulrush | recreational boats and trailers |

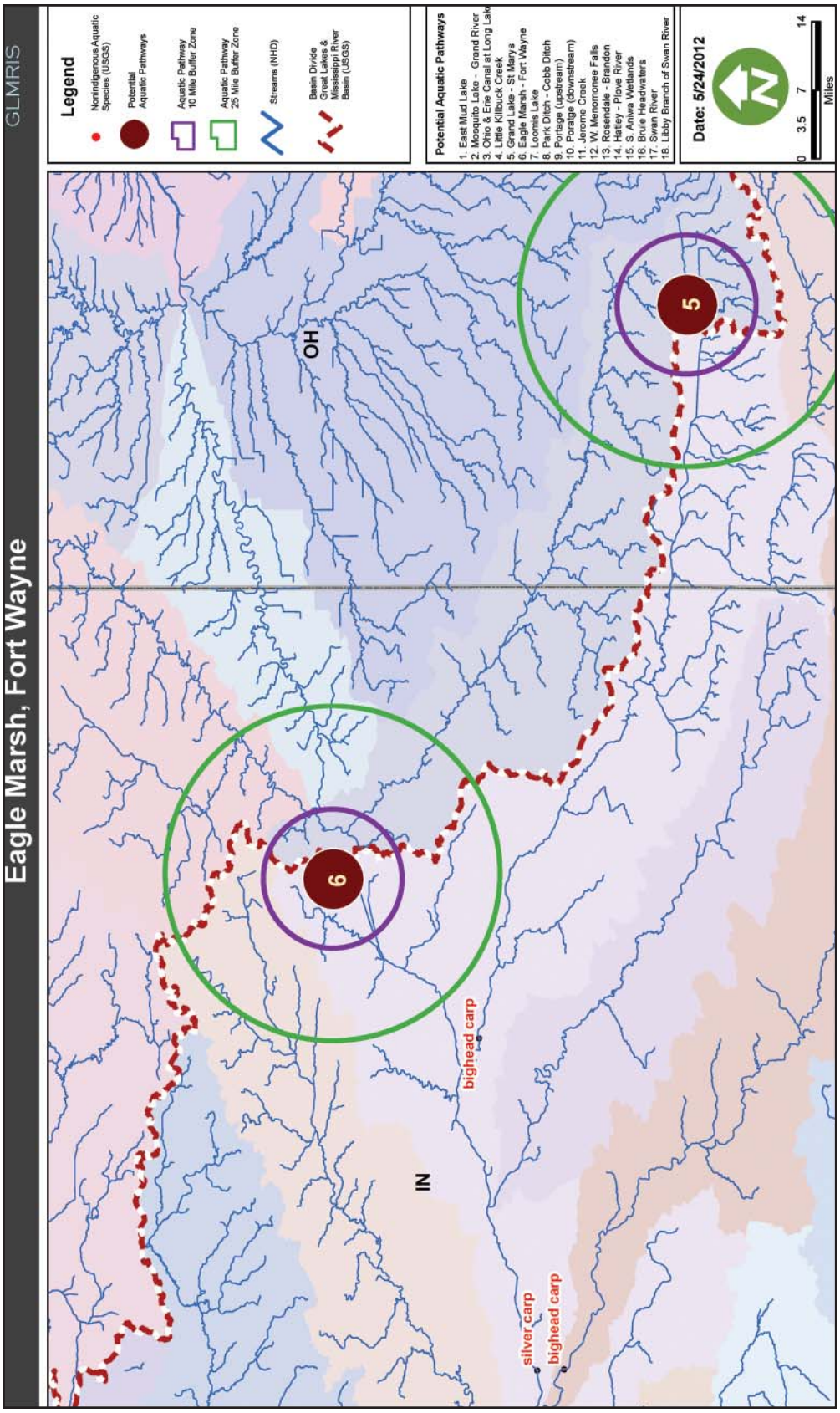



Figure 4. Map of ANS occurrences near Eagle Marsh. Since this map was produced, silver carp have been detected within a 25 mile (40 km) radius of Eagle Marsh from the same location bighead carp were reported from (USGS, 2011).

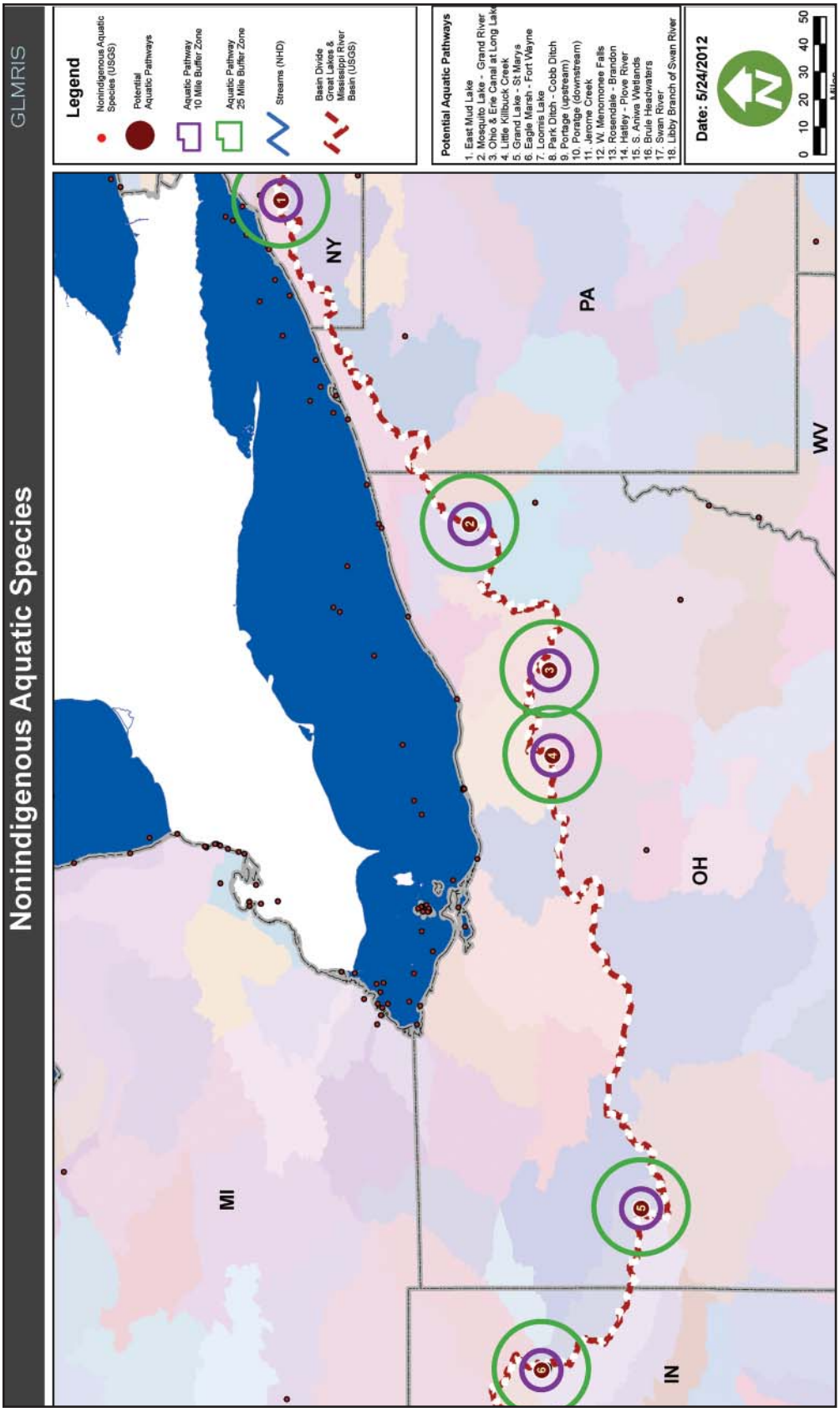



Figure 5. Map of ANS occurrences near Lake Erie at 10 mile (16 km) and 25 mile (40 km) radius. Eagle Marsh is location number 6 (USGS, 2011)

| Table 4: ANS of Greatest Concern at Eagle Marsh | | | | |
|---|---|---|---|---|
| **Taxa** | **Species** | **Common Name** | **Basin** | **Interbasin Dispersal Mechanism** |
| fish | *Hypophthalmichthys molitrix* | silver carp | MS | swimmer |
| fish | *Hypophthalmichthys nobilis* | bighead carp | MS | swimmer |
| fish | *Mylopharyngodon piceus* | black carp | MS | swimmer |
| fish | *Menidia beryllina* | inland silverside | MS | swimmer |
| fish | *Channa argus* | northern snakehead | MS | swimmer |
| fish | *Gasterosteus aculeatus* | threespine stickleback | GL | swimmer |
| fish | *Gymnocephalus cernua* | ruffe | GL | swimmer |
| fish | *Proterorhinus semilunaris* | tubenose goby | GL | swimmer |
| virus | *Novirhabdovirus sp* | VHSv | GL | Pathogen to Fish/Water Column |
| copepod | *Neoergasilus japonicus* | parasitic copepod | GL | Pathogen to Fish |

road into Eagle Marsh is closed and gated outside the normal hours of operation. Though a trail system exists, it is highly unlikely that aquatic ANS would be packed and carried into Eagle Marsh for release. Additionally, dumping of exotic pets is just as likely to occur in either basin or elsewhere along the basin divide. Organisms that possess the ability to hitchhike over land (e.g., on boat trailers, birds' feet, etc.) and therefore would be able to bypass an obstacle in the aquatic pathway were not included in the final list or evaluated in this report .

### 2.3.4 Key Attributes of Selected Organisms

Excluding the information for VHSv, a significant amount of ANS information was obtained from the USACE White Paper listing the non-native species of concern and dispersal risk for GLMRIS (USACE, 2011b). The VHSv was not identified as a species of concern in this white paper. However, during interagency coordination VHSv was identified as a species of concern for Brule Headwaters. Additional information was obtained from the USGS Nonindigenous Aquatic Species (NAS) website (USGS, 2011).

## 2.4 Pathway Assessment Process

The GLMRIS risk analysis process is an adaptation of the generic model and process described in the Generic Nonindigenous Aquatic Organisms Risk Analysis Review Process (For Estimating Risk Associated with the Introduction of Nonindigenous Aquatic Organisms and How to Manage for that Risk) (ANSTF, 1996). ANSTF defines the risk associated with an ANS as:

**Equation 1**

$$R_{Establishment} = P_{Establishment} \times C_{Establishment}$$

Where:

$R_{Establishment}$ = Risk of Establishment

$P_{Establishment}$ = Probability of Establishment

$C_{Establishment}$ = Consequence of Establishment

Note the risk is defined as a multiplicative function. That means, if either of these components is zero or low, the overall risk will also be zero or low. In order to work most efficiently given the large number of potential pathways, the GLMRIS Other Aquatic Pathways Team (Focus Area 2) concentrated its effort on characterizing the probability of establishment, while the GLMRIS Focus Area 1 Team for the CAWS is focusing on both components. An estimate of the consequences of any ANS establishment from the Focus Area 2 aquatic pathways will be deferred until possible future study by USACE or others.

ANSTF divides the probability of establishment component shown in Equation 1 into four basic elements which describe the basic events that must occur for an ANS to establish in the new environment:

**Equation 2**

$P_{Establishment} = [P_1 \times P_2 \times P_3 \times P_4]$

Where:

$P_1 = P_{ANS\ associated\ with\ pathway}$

$P_2 = P_{ANS\ survives\ transit}$

$P_3 = P_{ANS\ colonizes\ in\ new\ environment}$

$P_4 = P_{ANS\ spreads\ beyond\ colonized\ area}$

Each of the four elements of Equation 2 is qualitatively rated a High (H), Medium (M), or Low (L) based on the available evidence. They are also qualitatively assigned a level of certainty [Very Certain (VC), Reasonably Certain (RC), Moderately Certain (MC), Reasonably Uncertain (RU), Very Uncertain (VU)]. The overall probability rating is the rating of the element with the lowest probability. Thus, in a quartet of HLHH the overall probability rating is "L". The multiplicative nature of the function assures this is actually a somewhat conservative estimate. With actual numbers the overall probability would always be smaller than the smallest of the four factors. These elements have been modified for use in GLMRIS (Equation 3) to describe the basic sequence of events that must occur for an ANS to successfully cross the basin divide through an aquatic pathway and establish in the new basin:

**Equation 3 [FA1 Model]**

$P_{Establishment} = [P_0 \times P_1 \times P_2 \times P_3 \times P_4]$

Where:

$P_0 = P_{Pathway\ exists}$

$P_1 = P_{ANS\ has\ access\ to\ pathway}$

$P_2 = P_{ANS\ transits\ pathway}$

$P_3 = P_{ANS\ colonizes\ in\ new\ waterway}$

$P_4 = P_{ANS\ spreads\ in\ new\ waterway}$

This model works well in areas where a viable pathway is already known to exist, such as the CAWS. However, for many of the 18 locations identified in GLMRIS Focus Area 2, it was uncertain at the outset whether or not an aquatic pathway does in fact ever form. The team recognized that formation of a pathway at these locations would likely be infrequent, and with a limited duration and magnitude (width, depth, and rate of surface water flow across the basin divide). Consequently, the model in Equation 3 was modified further for Focus Area 2.

Greater efficiency in analysis can be gained by modifying Equation 3 by eliminating evaluation of the last two elements because if a pathway does not exist there is no reason to collect data on colonization ($P_3$) and spread ($P_4$) in the new basin. In addition, the third element of Equation 3, ANS transits pathway ($P_2$), is broken down into its own sequence of necessary events to characterize in greater detail those variables being evaluated to determine whether or not a viable pathway exists. In setting aside the last two elements in Equation 3 ($P_3$ and $P_4$) no attempt is therefore made in this report to assess the probability that an ANS will colonize in or spread through the receiving waterway or basin. USACE or others may assess the last two elements of Equation 3 in the future when evaluating specific measures that could be taken to eliminate the probability of transfer at certain aquatic pathways.

Once again, in order to work efficiently in assessing ANS risk for Focus Area 2, the initial assessment focuses narrowly on the question of whether or not a viable aquatic pathway exists. Equation 4 shows how the third element of Equation 3 has been broken down to provide greater resolution for evaluating the pathway itself:

**Equation 4 [Modification of Equation 3 – P2 Element]**

$P_2 = [P_{2a} \times P_{2b} \times P_{2c}]$

Where:

$P_2 = P_{ANS\ transits\ pathway}$

$P_{2a} = P_{ANS\ surviving\ transit\ to\ aquatic\ pathway}$

$P_{2b} = P_{ANS\ establishing\ at\ the\ aquatic\ pathway}$

$P_{2c} = P_{ANS\ spreading\ across\ aquatic\ pathway\ into\ new\ basin}$

Delaying consideration of the last two elements of Equation 3 and substituting the more detailed consideration of the third element as expressed in Equation 4 yields the following model used in the GLMRIS Focus Area 2 assessments:

**Equation 5 [FA2 Modified]**

$P_{Viable\ pathway} = [P_0 \times P_{1'} \times P_{2a} \times P_{2b} \times P_{2c}]$

Where:

$P_0$ = $P_{Pathway\ exists}$

$P_{1'}$ = $P_{ANS\ occurring\ within\ either\ basin}$

$P_{2a}$ = $P_{ANS\ surviving\ transit\ to\ aquatic\ pathway}$

$P_{2b}$ = $P_{ANS\ establishing\ at\ the\ aquatic\ pathway}$

$P_{2c}$ = $P_{ANS\ spreading\ across\ aquatic\ pathway\ into\ new\ basin}$

Notice the overall probability is now the "probability a viable pathway exists" ($P_{Viable\ pathway}$) and is no longer the original "probability of establishment" ($P_{Establishment}$) from Equation 3. The probability of establishment for certain aquatic pathways may be assessed in future studies by USACE or others, but likely only for those pathways with an unacceptable rating for the "probability of a viable pathway" existing. Note also that ($P_1$), ANS has access to pathway from Equation 3 has been renamed ($P_{1'}$), ANS occurring within either basin". This did not change the element being evaluated but made it clearer to team members what "access to the pathway" actually meant.

This model remains consistent with the overall GLMRIS risk assessment approach and the ANSTF methodology, and the refinements enabled the assessors to focus more appropriately on the relevant evidence. At those locations along the basin divide where the first element in Equation 5 (i.e., likelihood that an aquatic pathway exists at up to a one percent annual recurrence interval event) was estimated to be low, no further assessment of that location was necessary. The low rating of this initial element assures that the overall probability of a viable pathway existing (Equation 5), the overall probability of establishment (Equation 3), and the ANS risk potential (Equation 1), will all be low because of the multiplicative nature of the model. This approach assured a more prudent use of public resources in data collection and assessment by minimizing the collection of unnecessary data and the conduct of unnecessary analyses. It should also be understood that a low rating for probability of a pathway existing ($P_0$) is not necessarily the same as there being no probability of a pathway existing. At those locations where the probability of a pathway existing ($P_0$) was determined to be medium or high which includes the Eagle Marsh pathway, the remaining four elements in Equation 5 were evaluated for each ANS of concern specific to that particular location over a 50 year period of analysis.

## 2.5 Example Calculation of Overall Aquatic Pathway Viability

As described in Section 2.2, a list of ANS of concern for the Eagle Marsh pathway was developed with input from Federal, State, and local agencies responsible for water resources, and fish and wildlife management in the state of Indiana, and neighboring states along the Great Lakes and Mississippi River Basin divide. ANS of concern were grouped according to which basin they were currently established in to determine the viability of the aquatic pathway to transfer species across the divide in either direction. The determination of the likelihood of a viable aquatic pathway for each ANS of concern is the product of five probability elements (Equation 5). Thus, the probability of a viable pathway for a particular ANS of concern is equal to the lowest rating determined for each of the five probability elements (Table 5 and Table 6). The overall pathway viability for transferring ANS of concern from the Mississippi River Basin to the Great Lakes Basin was equal to the highest probability of a viable pathway for each ANS of concern in Table 5. In this example, all were rated low and thus the overall pathway viability for transferring species from the Mississippi River Basin to the Great Lakes Basin is "low". The overall pathway viability for transferring species from the Great Lakes Basin is calculated the same way and is shown in Table 6. In this example, the overall pathway viability for transferring species from the Great Lakes Basin to the Mississippi River Basin is "medium".

The last calculation is to determine the overall pathway viability for interbasin spread of ANS which is calculated by taking the highest of the overall ANS ratings for unidirectional transfer which were calculated in Tables 5 and 6. Thus, in Table 6, the overall probability that a viable aquatic pathway exists is "medium". The ratings given for each element as well as the overall pathway viability ratings shown in Tables 5 and 6 were coordinated amongst the members of the pathway team

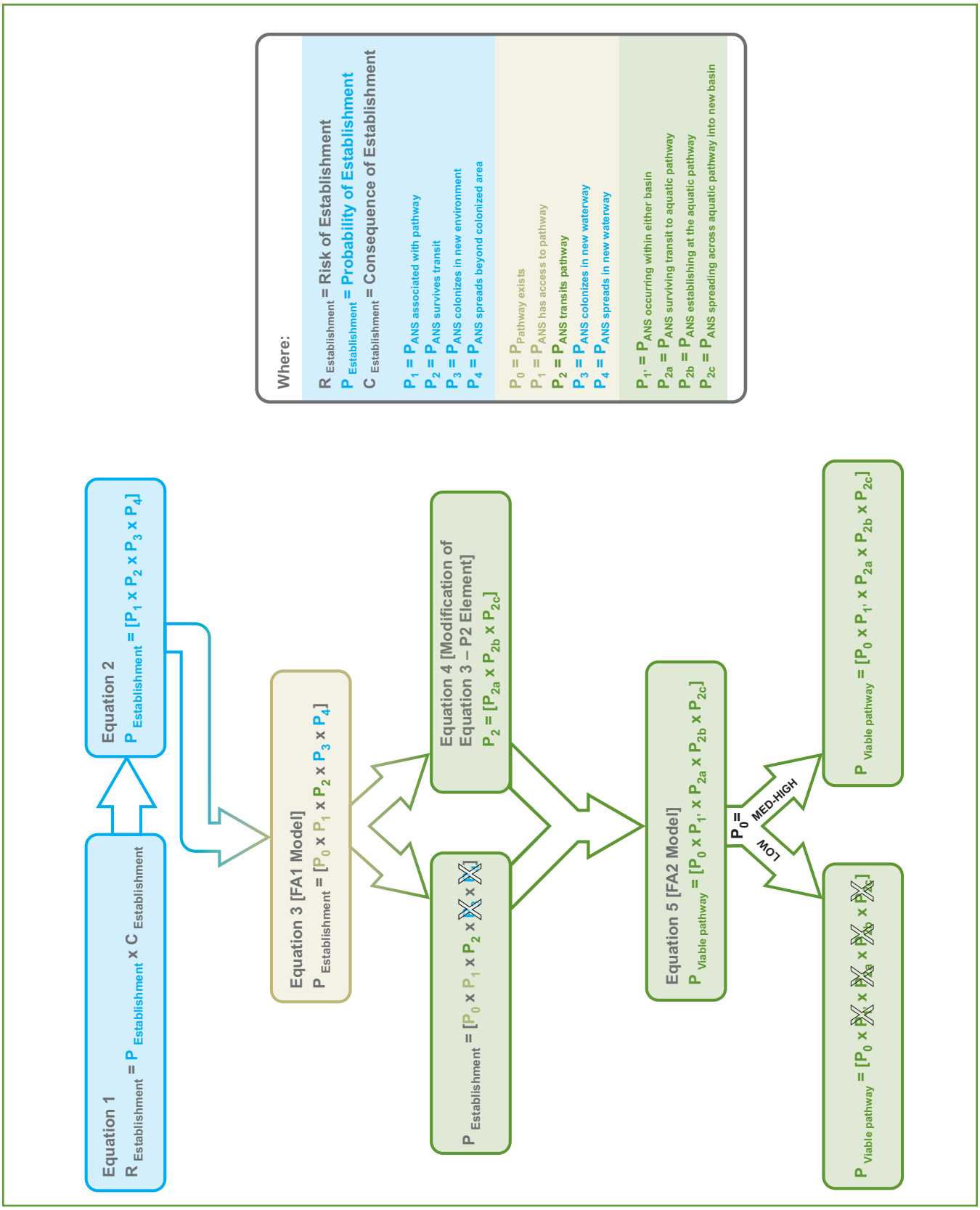



Figure 6. Diagram of the derivation of the GLMRIS Focus Area 2 aquatic pathway assessment model.

**Table 5. Example calculation of Pathway Viability for ANS Spreading from Mississippi River Basin to the Great Lakes Basin.**

| | | | Form 1 $P_0$ | Form 2 $P_1$ | Form 3 $P_{2a}$ | Form 4 $P_{2b}$ | Form 5 $P_{2c}$ | $P_{viable\ pathway}$ |
|---|---|---|---|---|---|---|---|---|
| **Group** | **Common Name** | **Mode of Dispersal** | **Pathway Exists?** | **ANS Occuring Within Either Basin?** | **ANS Surviving Transit to Pathway?** | **ANS Establishing at Aquatic Pathway?** | **ANS Spread-ing Across Aquatic Pathway into New Basin?** | **ANS/Path-way Viability Rating** |
| fish | Asian carp, silver carp, bighead carp, black carp | swimmer | M (RC) | M (RC) | L (RC) | L (MC) | M (RU) | L |
| fish | inland silverside | swimmer | | M (VC) | L (MC) | L (RC) | L (RC) | L |
| **Overall Pathway Viability for Spread of ANS from Mississippi River Basin to Great Lakes Basin** | | | | | | | | **L** |

VC=Very Certain (as certain as going to get), RC=Reasonably Certain (reasonably certain), MC=Moderately Certain (more certain than not), RU=Relatively Uncertain (reasonably uncertain), VU=Very Uncertain (a guess)

**Table 6. Example calculation of Pathway Viability for ANS Spreading from Great Lakes Basin to the Mississippi River Basin.**

| | | | Form 1 $P_0$ | Form 2 $P_1$ | Form 3 $P_{2a}$ | Form 4 $P_{2b}$ | Form 5 $P_{2c}$ | $P_{viable\ pathway}$ |
|---|---|---|---|---|---|---|---|---|
| **Group** | **Common Name** | **Mode of Dispersal** | **Pathway Exists?** | **ANS Occuring Within Either Basin?** | **ANS Surviving Transit to Pathway?** | **ANS Establishing at Aquatic Pathway?** | **ANS Spread-ing Across Aquatic Pathway into New Basin?** | **ANS/Path-way Viability Rating** |
| fish | threespine stickleback | swimmer | M (RC) | M (VC) | L (RC) | L (MC) | L (MC) | L |
| pathogen | VHSv | fish pathogen / water column | | H (VC) | H (MC) | H (RC) | H (RU) | M |
| **Overall Pathway Viability for Spread of ANS from Great Lakes Basin to Mississippi River Basin** | | | | | | | | **M** |

regarding the probability rating (H, M, or L) and the level of certainty (VC, RC, MC, RU, or VU). Final agreement was reached on team ratings for each element through collaboration and sharing of applicable information with all team members. The level of certainty in these ratings was modified during these discussions to reflect the range of opinion.

# 3 Aquatic Pathway Characterization

This section describes and illustrates the topography and features in the vicinity of the Eagle Marsh Pathway and is intended to help inform the biological evaluations contained later in this report with a compilation of any readily available and applicable information of this area as it may influence local hydrology and aquatic habitat. Maps, photographs, and figures are included to aid understanding of the significant hydrologic and hydraulic conditions near the drainage divide. Also, this section identifies any significant data gaps and uncertainties

related to the available topographic information and hydrologic modeling in the area of interest.

## 3.1 Location

The Eagle Marsh study area encompasses the headwaters of the Wabash and Maumee Rivers, located primarily in Allen County, near the city of Fort Wayne, in northeast Indiana (Figure 7). Eagle Marsh is a major unit of the Little River Watersheds Project (LRWP) and is part of the Wabash-Erie Channel. The Wabash-Erie Channel is the formal geologic name given to the broad valley that extends southwestward for about 17 miles (27 km) from the western apex of the Maumee Lake Plain through downtown Fort Wayne and southwest Allen County, to just west of the city of Huntington where it joins the main stem of the Wabash River. Eagle Marsh is located at the upstream portion of the Wabash-Erie Channel near Fort Wayne. The channel was carved by glacial outwash during the last ice age, and later filled with river sediments and organic peat and muck. The valley now generally consists of alluvial silts, sands, and clays with areas of organic sediment and overlying glacial till (Trafalgar Formation). The Wabash-Erie Channel is naturally poorly drained and of low relief (Little River Wetlands Project, 2011a). The Eagle Marsh area has some of the lowest elevations in Allen County (USDA 1969). The elevations of Eagle Marsh and the surrounding area are shown in Figure 8.

## 3.2 Climate

Climate is looked at in this section just in terms of identifying any applicable elements of climate (e.g., temperature, rainfall) and how they may influence the likelihood of an aquatic connection forming at the subject pathway that could be utilized by ANS to spread between basins. Allen County is located within the humid continental climate zone and experiences four distinct seasons per year. Weather patterns in Allen County are influenced by the Great Lakes. The seasonal range of temperature is a daily winter minimum of approximately 20º F (-6.6º C) to a daily summer maximum of approximately 85º F (29º C). Snowfall is prevalent in the winter months, with an average cumulative annual snowfall of approximately 33 inches (84 cm). The average annual precipitation is approximately 36 inches (91 cm), with annual evapotranspiration of approximately 27 inches (69 cm). The vegetative growing season is approximately 156 days (USDA, 1969). The last freezing temperature in spring usually occurs about May 7, and the first freezing temperature in the fall is usually about October 10. Heavy precipitation and flooding is most likely to occur at Eagle Marsh during winter and spring. In winter flood events, a significant portion of the water column may freeze leading to significant sheets of ice developing on top of flood waters. Dry conditions are most prevalent during summer and fall. Since temperatures at this location are below freezing during a portion of the year, these might also represent times during which interbasin flow is less likely to occur because of frozen conditions.

## 3.3 Location Specific Surface Water Features

Eagle Marsh extends across the natural drainage divide between the Lake Erie Watershed and the Wabash River Watershed and is flanked by two drainage ditches: Graham-McCulloch Ditch and Junk Ditch (Figures 7-9). The Graham-McCulloch Ditch (Mississippi River Basin) drains to the west into the Little River and eventually the Wabash River near Huntington, Indiana, while Junk Ditch (Great Lakes Basin) drains northeast into the St. Marys River and then the Maumee River, which empties into Lake Erie at Toledo, Ohio.

The valley now drained by Junk Ditch and the Graham-McCulloch Ditch historically (prior to modification) drained to the west toward the Wabash River Watershed, and the valley served as a “relief valve” for floods in the St. Marys, St. Joseph, and Maumee River Basins. The headwaters of Graham-McCulloch Ditch upstream of Engle Road (main east-west road on north side of Eagle Marsh) were previously known as Cranberry Creek (Fleming, 2006). To improve drainage for development of arable land, Junk Ditch and the Graham-McCulloch Ditch were excavated to more efficiently and effectively drain the surrounding lands. Berms were constructed on both banks of the Graham-McCulloch Ditch in an effort to isolate the fields from regular inundation by Graham-McCulloch flood waters. Typical photos of

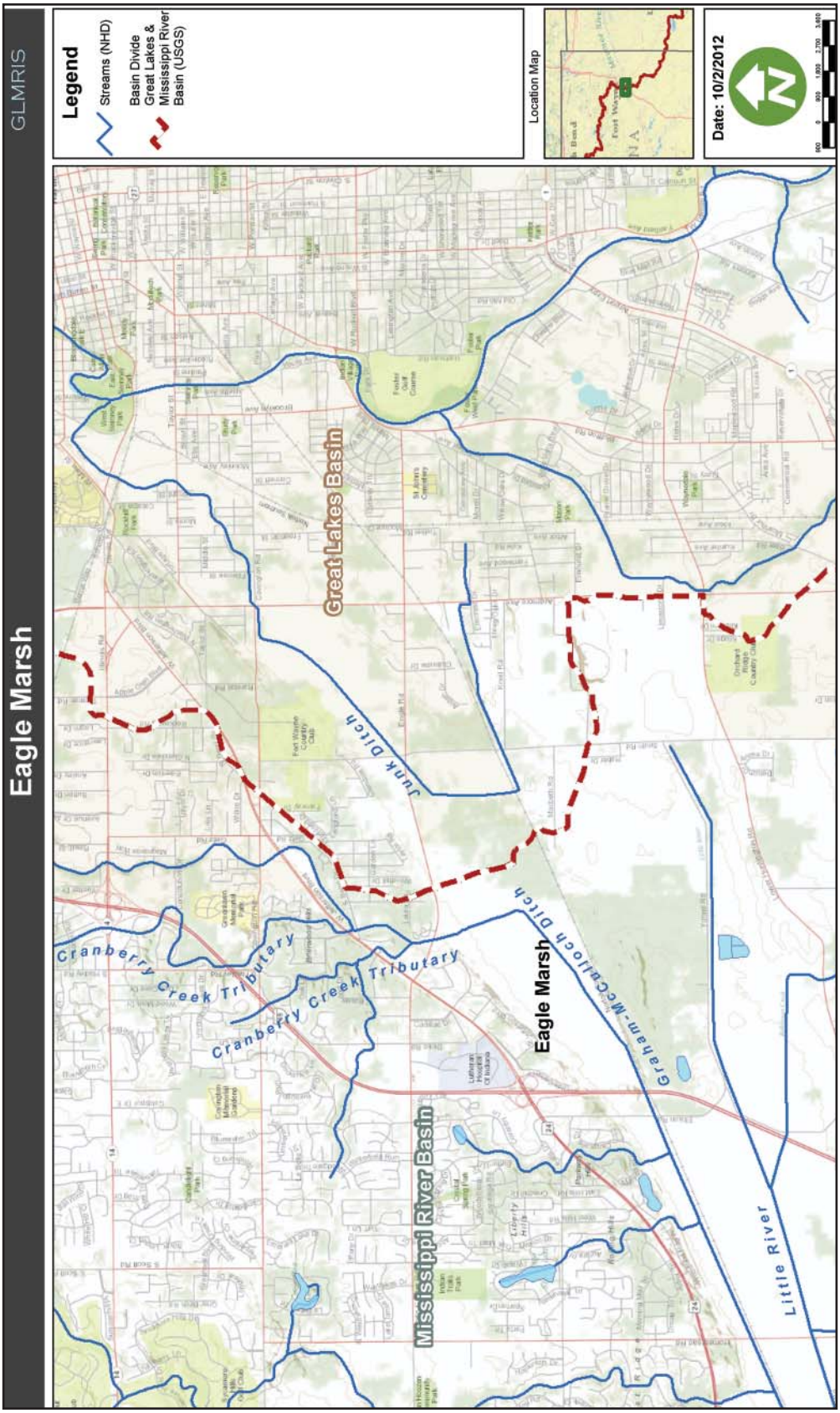



Figure 7. Location of Eagle Marsh relative to Fort Wayne, Indiana. The approximate divide between the Great Lakes Basin and Mississippi River Basin is shown by the red-white line. Base imagery courtesy of Bing Maps.

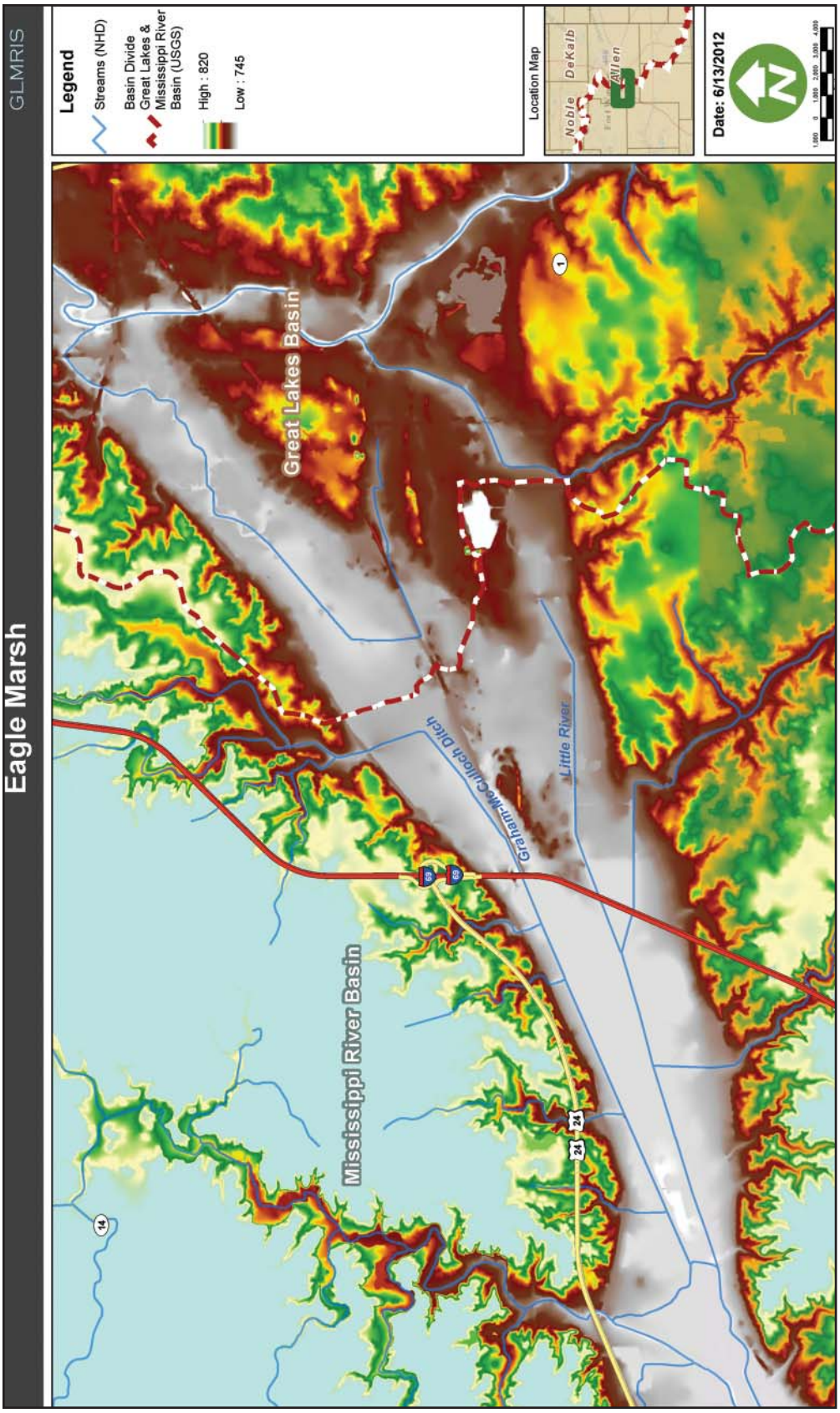



Figure 8. Digital elevation mapping of Eagle Marsh and the surrounding area showing long narrow valley oriented southwest to northeast (Data Source: USGS 10m DEM).

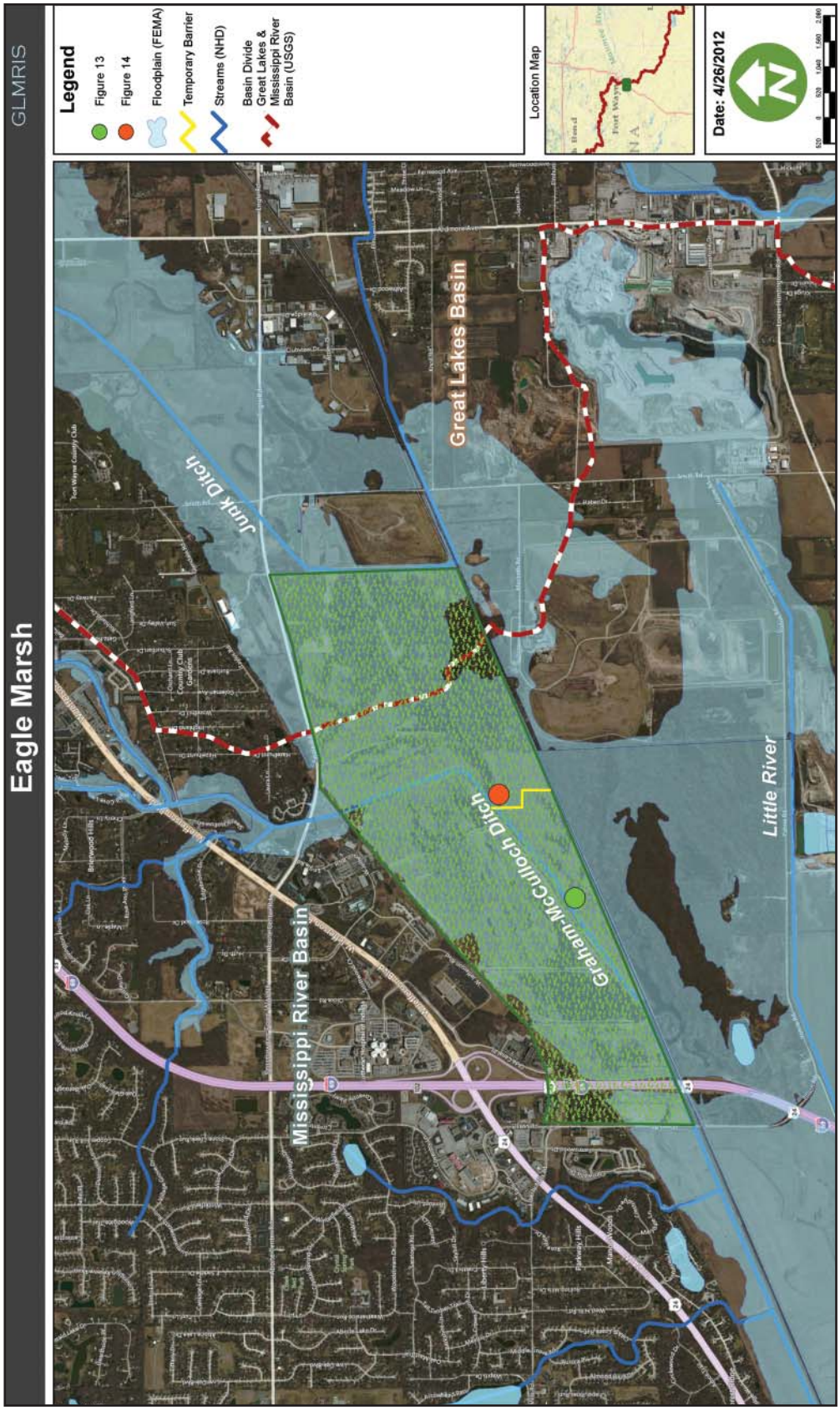



Figure 9. Eagle Marsh (green) with overlay of FEMA one percent annual recurrence interval floodplain (blue), along with connecting Junk Ditch (toward Great Lakes Basin) and Graham-McCulloch Ditch (toward Mississippi River Basin). Also shown are the basin divide and the location of the temporary fence installed by INDNR in 2010. Background image courtesy of Bing Maps.

Figure 10. Looking upstream at Graham-McCulloch from within Eagle Marsh 4/16/11. Photo by USACE.

Figure 11. Graham-McColloch Ditch on November 3, 2010. Photo by USACE.

Figure 12. Graham-McCulloch Ditch at the same location as shown in Figure 11 on April 16, 2011. Photo by USACE.

Graham-McColloch Ditch are shown in Figures 10, 11, and 12. Flooding occurs less regularly on the Maumee River and its tributaries, but during such events Junk Ditch is inundated and water surface elevations can reach and extend to the southwest across the natural drainage divide and flow into the area currently known as Eagle Marsh.

## 3.4 Groundwater

A groundwater section is included in this report since groundwater can sometimes be a source of base flow for streams. Water levels in aquifers normally fluctuate seasonally in response to variations in groundwater recharge and discharge. Groundwater levels commonly rise in spring, when areal recharge is greatest because of snowmelt, spring rain, and minimal evapotranspiration losses. This means that heavier rainfall events, when they coincide with frozen ground conditions, snowmelt, and higher groundwater conditions, might result in higher volumes of water in the area ditches/streams. Groundwater within Eagle Marsh and the surrounding areas is generally shallow or emergent. It appears that groundwater may provide some seasonal base flow into Eagle Marsh but is not likely the primary source of water for the marsh. In nearby areas, several springs and seeps exist that feed into the southeast part of the Eagle Marsh property (Fleming, 2006). The shallowness of the groundwater in this area may be a contributing element in the establishment of a surface water connection at this location, especially when heavier rainfall events coincide with frozen ground conditions and snowmelt.

## 3.5 Aquatic Pathway Temporal Characteristics

Characterizing the temporal variability of the pathway hydrology is an important aspect of understanding the likelihood of interbasin spread of ANS across the Eagle Marsh because there is not an aquatic pathway spanning the basin divide at this location most of the time. Hydrology and hydraulics modeling was used to estimate the relative frequency, duration and magnitude of this

intermittent aquatic pathway between the Great Lakes and Mississippi River Basins. Based upon this modeling, a connection between the Great Lakes and Mississippi River Basins appears to occur for storm events on the Graham-McCulloch Ditch with a 10 percent annual recurrence interval and from less frequent events by way of overtopping the left descending bank (LDB) berm of Graham-McCulloch Ditch in low areas near the berm's most downstream section (Figures 13 and 14). Annual flood events (99 percent annual recurrence interval) on the St. Marys River make flow reverse direction in Junk Ditch toward the southwest and cross the natural drainage divide, and thus enter a storage area created by the LDB berm and the railroad embankment to the south ("Eagle Marsh southern storage area") (Figure 15; Appendix A, Figure 1). Additional storage is connected to this area in Fox Island Park south of the railroad embankment by way of a four foot (1.2 m) diameter culvert through the railroad embankment.

A sample cross section and water surface profiles depicting the relative elevations for select storm events on the two watersheds are provided in Figures 13 through 15. From the computed water surface profiles for these events, surface water depth grids have been computed and are represented in Appendix A as Figures 1-8. A composite map also shows the depths from the one percernt annual recurrence interval flood events on each watershed plotted on the same map (Appendix A, Figure 9). It should be noted that Figure 9 of Appendix A does not represent the same depths as would occur if the one percent annual recurrence interval events from each watershed peaked concurrently. This is because the amount of flow that crosses the left bank berm would be dependent on the extent to which the Eagle Marsh and surrounding storage areas are filled. Please note that when examining these depth charts in Appendix A that the depths have been broken into classifications for easier interpretation, but this results in a conservative representation. For example, an actual depth of 1.6 feet (0.5 m) will appear the same on the figure as a depth of 3 feet (0.9 m) because they have both been classified within the same depth category (depths of 1.5–3 feet).

Please also note that as a relic of the categorization of depth values and the initial flows on Junk Ditch necessary for model stability, the depths in Eagle Marsh behind the left bank berm are small and do not appear to change for the 99 percent, 10 percent, and even 25 percent floods on the Graham-McCulloch Ditch. From the cross sections and profiles, it is evident that at the 10 percent annual recurrence interval flood on the Graham-McCulloch Ditch, there is almost negligible flow overtopping the left bank berm. It is only slightly more flow at the 25 percent recurrence interval event, such that the difference gets lost in the categorization of the values.

Two approximately 18-inch (46 cm) diameter pipes connect the Graham-McCulloch Ditch to this southern storage area, but have flap-gates on the ditch side of the berm (Figure 16). It is believed that these flap-gates are effective in preventing flow from the Graham-McCulloch Ditch into this Eagle Marsh southern storage area until the LDB berm is overtopped. The 18-inch (46 cm) pipes are in poor condition, but it is believed that they are still functional for draining of water that are ponded within the Eagle Marsh southern storage area. A third pipe through the LDB berm was capped with riprap on the south side of the berm as part of the temporary fence construction by INDNR in 2010. Storm events less frequent than the approximately three percent annual recurrence interval event on the St. Marys River are required to overtop the LDB berm. Definition of the LDB Berm profile was based upon survey data provided by the NRCS collected in 2006 when the property was purchased for the re-development of the wetlands. This data was believed to be of greater accuracy than the 2009 light detection and ranging (LIDAR) data provided by the USGS and Allen County, and the 2006 NRCS survey data for the LDB berm is higher than the 2009 LIDAR on the order of 1-2 feet (30-61 cm). It is noted that the head differential across the LDB berm predicted by the USACE model for frequent floods on the Graham-McCulloch Ditch was circumstantially confirmed during storm events in the spring of 2011. Riprap placed by INDNR on the inlet of the third culvert mentioned above was dislodged during two different storm events in the spring of 2011, indicating high head pressures and resulting velocities through that culvert. This seems to confirm the relative isolation of the south Eagle Marsh storage area from the Graham-McCulloch Ditch provided by the LDB berm for relatively frequent events.

As indicated above, the USACE hydraulic modeling (unsteady state) indicates that the greatest potential

of a hydraulic connection results from a flooding event on the Graham-McCulloch Ditch at a frequency of approximately a 10 percent annual recurrence interval event, or slightly less frequent. Very little data is available to help determine the frequency of flooding events at Eagle Marsh as the nearest flow or stage gage in this watershed is approximately 28 miles (45 km) downstream (southwest) in Huntington, Indiana. Peak flows used for the ten percent, four percent, two percent, and one percent annual recurrence interval flood events came from the coordinated discharge graph "Ungaged Streams in Allen County" dated March, 1982 (Figure 17).

Values for peak flows not shown on this figure were either interpolated or extrapolated from these values. These coordinated discharges were likely developed from regression equations and therefore do not take into account the specific hydrology of the Graham-McCulloch Watershed. Even if these discharges were relatively accurate when they were created, the watershed has undergone significant development since that the time. The shape of the hydrograph that was used in the USACE model also had to be estimated. Data are available from the numerous gages in the Ft. Wayne area for the St. Marys River and other rivers and tributaries in that area, although several have very limited periods of record. There is therefore a greater confidence in the flow information on the St. Marys River due to this large amount of information for that watershed that was made available by INDNR. The USACE model was therefore able to be calibrated to historic events on the St. Marys River, with numerous high water marks available for one event.

The timing of peak flood flows for events on the two watersheds could not be fully examined. As stated above there is no available hydrologic data to properly define the hydrograph for flows on the Graham-McCulloch Ditch. For this study, it is assumed that the two watersheds act independently because of the very different size of the watersheds. The drainage area of the Graham-McCulloch Ditch at Eagle Marsh is approximately 12 square miles (31 square kilometers) while the drainage area of the St. Marys River at Main Street is over 820 square miles (2,124 square kilometers). It is therefore assumed that a flood on the Graham-McCulloch Watershed will peak and recede significantly faster than a flood on the St. Marys Watershed; therefore, the two peaks do not coincide for these USACE modeling simulations.

The frequency of overtopping of the LDB berm of the Graham-McCulloch Ditch is completely dependent upon the assumption that the profile of the LDB berm does not change. Multiple engineers who have visited the site agree that the integrity of the LDB berm is questionable; several slope failures, steep slopes, rodent burrows and other defects are visible, and there is no information regarding the level of design or construction methods that were used. It is expected that as time progresses, additional failures or a breach will occur.

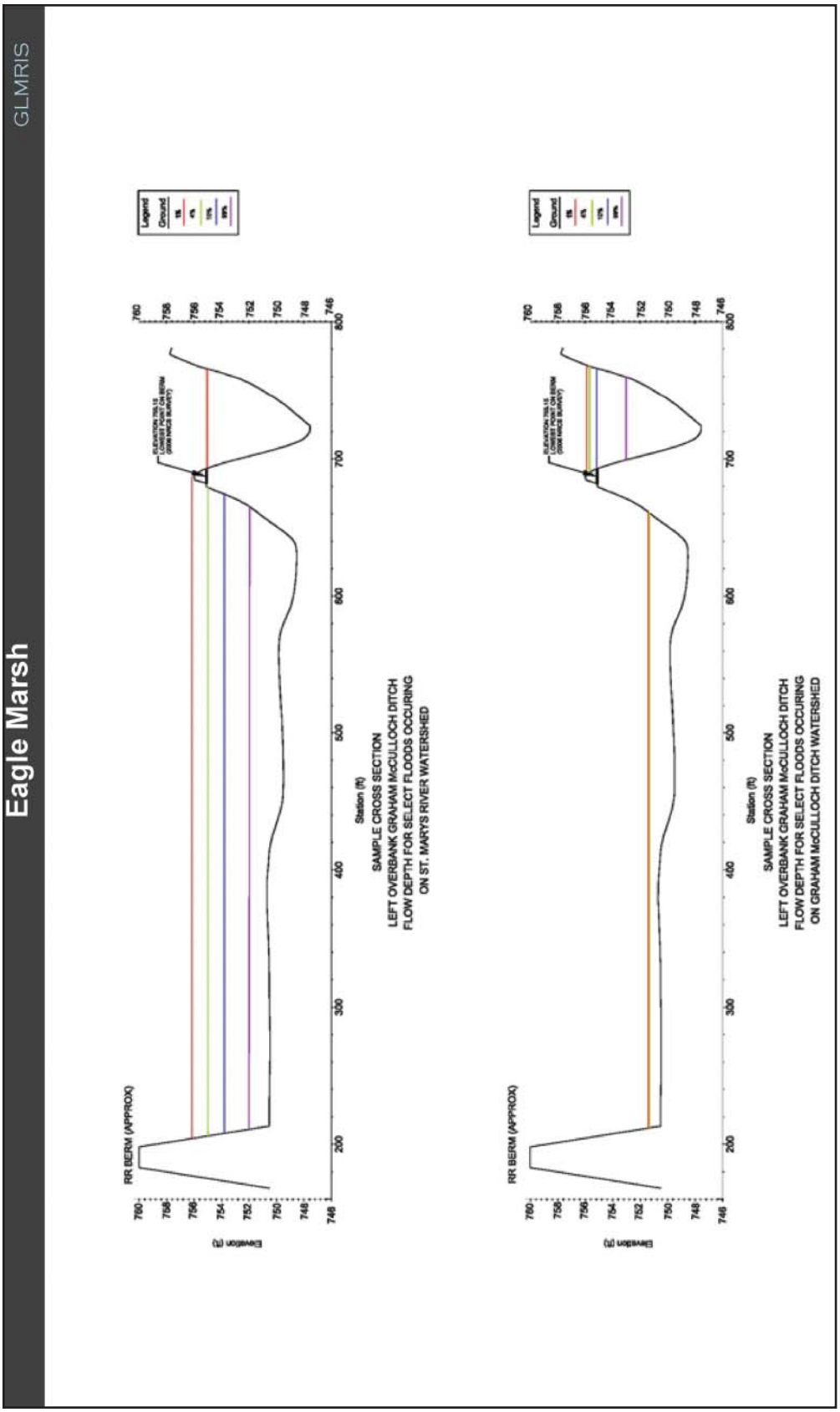



Figure 13. Sample cross section through Eagle Marsh left bank berm and southern storage area (USACE ANS Controls Report, 2012).

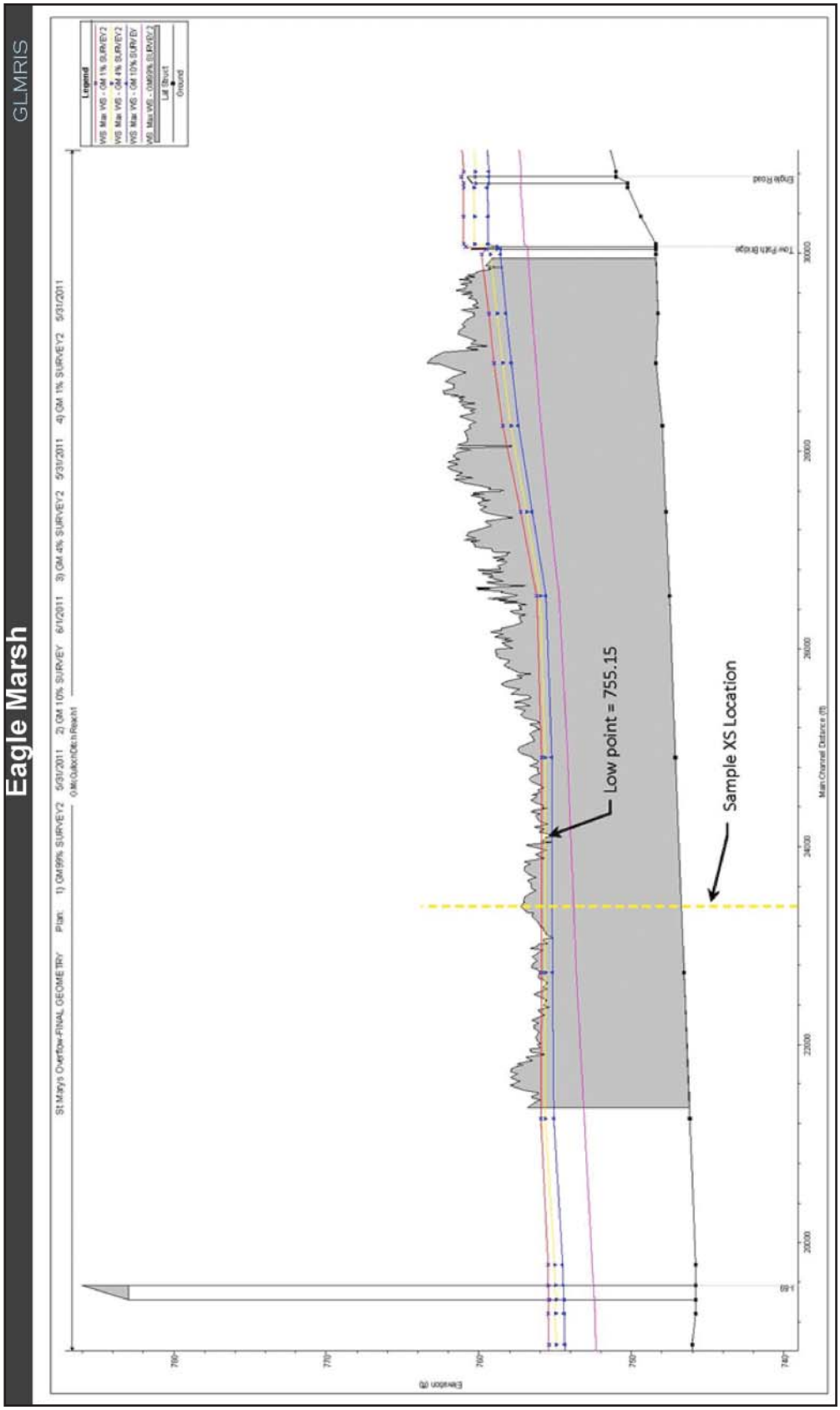



Figure 14. Graham-McCulloch Ditch flood event surface profiles relative to left bank berm elevation (2006 NRCS survey).

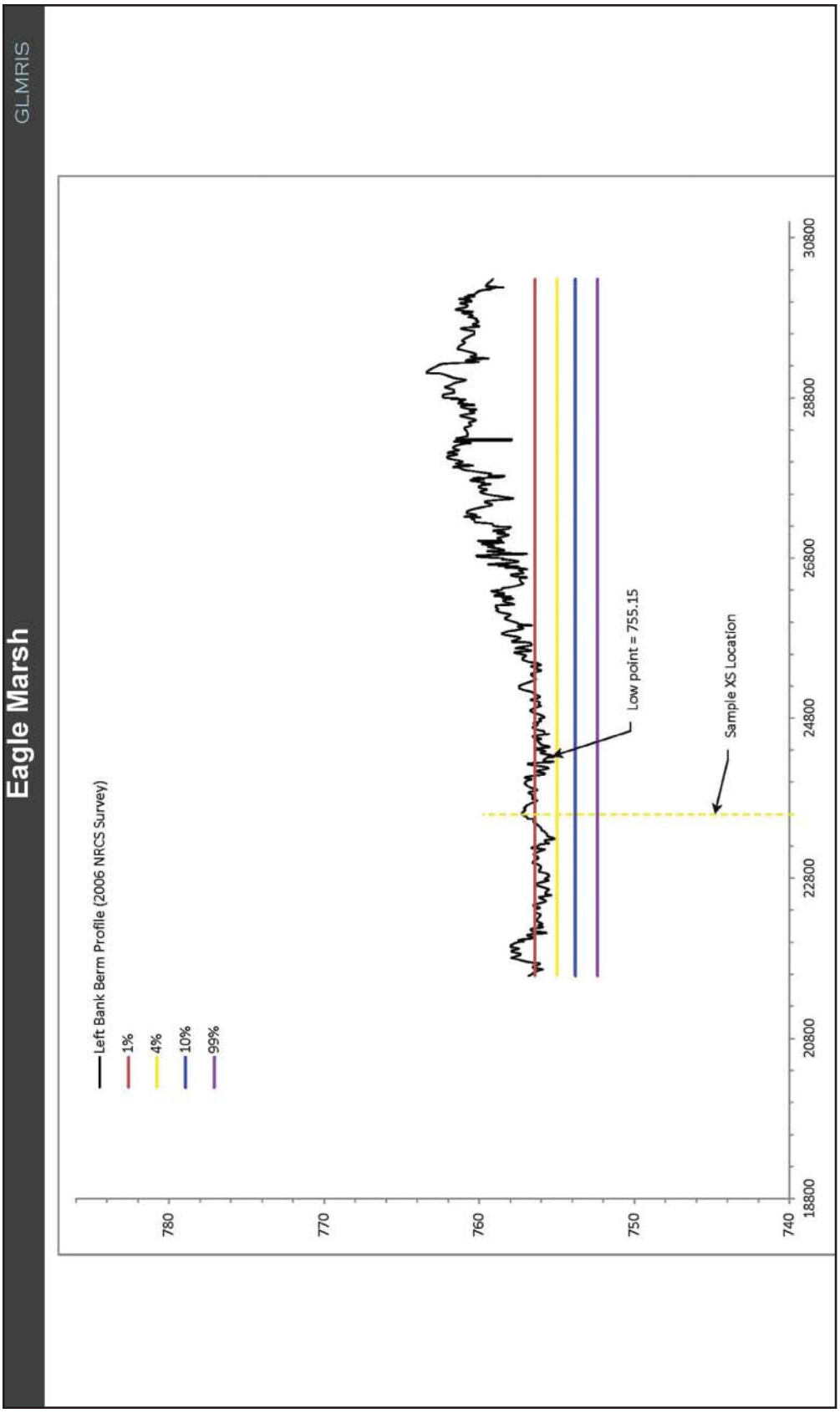



Figure 15. St. Marys flood water surface elevations behind Graham-McCulloch Ditch left bank berm (2006 NRCS survey).

Figure 16. 18-inch pipes through Graham McCulloch Ditch left bank berm.

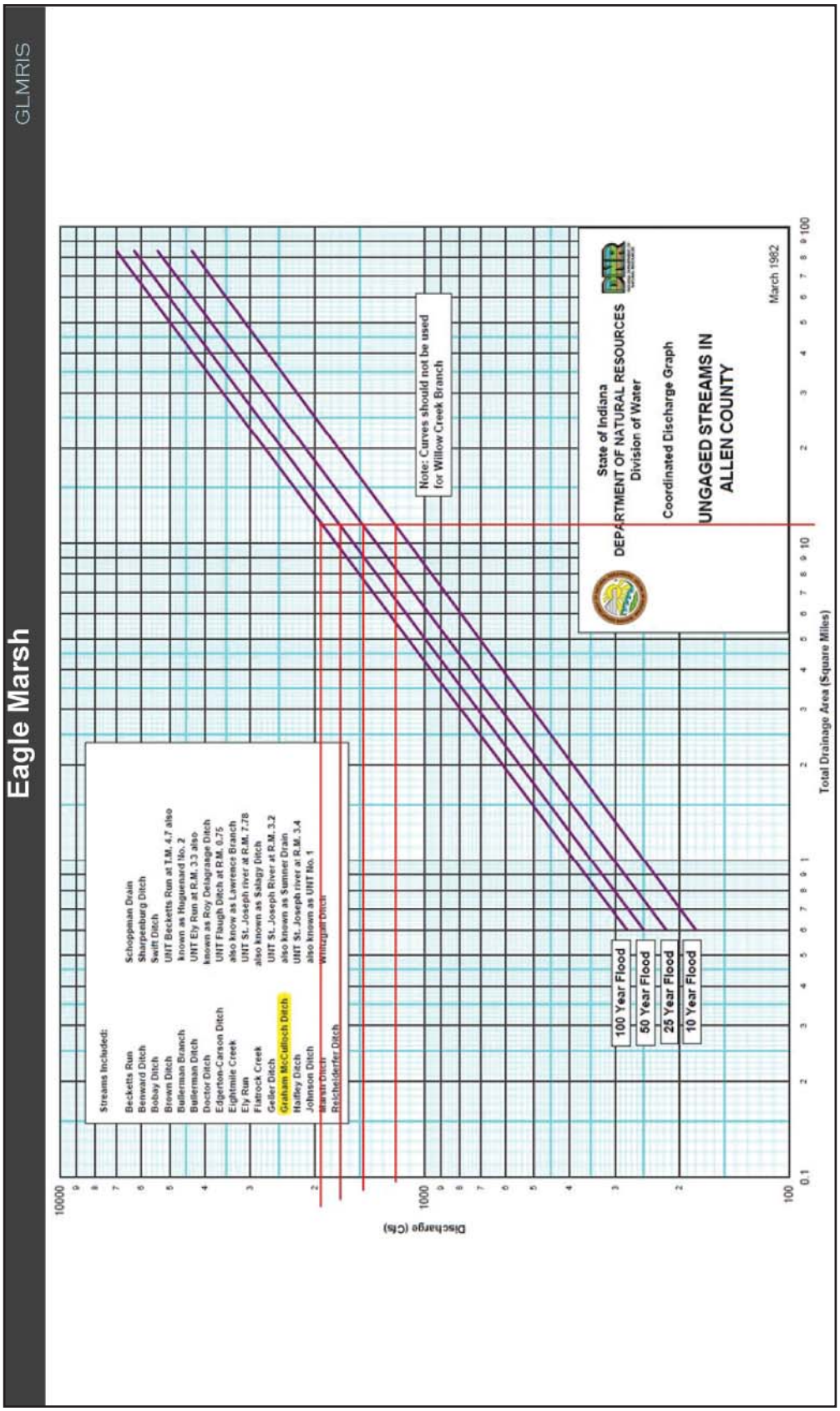



Figure 17. Coordinated discharges graph used for Graham-McCulloch Ditch flows (INDNR – Marsh 1982).

## 3.6 Probability Aquatic Pathway Exists

The rating discussed in this section is only for the likelihood of an aquatic connection existing ($P_0$) at this potential pathway at up to a one percent annual recurrence interval flood event. A surface water connection could form between the Great Lakes and Mississippi River Basins at the Eagle Marsh aquatic pathway based on the following:

- Numerical modeling by the USACE (unsteady state) indicates that floods on the Graham-McCulloch Ditch will create an aquatic connection between the basins by overtopping of the LDB berm for events greater than a 10 percent annual recurrence interval.

- Numerical modeling by the USACE (unsteady state) indicates that annual floods (99 percent annual recurrence interval) on the St. Marys River cause backwater flooding which causes water to cross the basin divide and connect with Graham-McColloch Ditch by way of culverts through the LDB berm of the ditch.

- USACE modeling shows a significant area and depth of inundation across the basin divide from the 10 percent annual recurrence interval flood event (Appendix A).

The interagency pathway assessment team determined that an aquatic connection exists between the two basins at Eagle Marsh because of a perennial wetland and connecting tributaries (Graham-McCulloch and Junk Ditches) that are known to convey water across the basin divide for multiple days from a ten percent annual recurrence interval event. Consequently, the probility of the existence of an aquatic pathway at Eagle Marsh is rated “high” in either direction (Appendix B). The frequency of overtopping by a Graham-McCulloch Ditch ten percent annual recurrence interval flood event (or greater magnitude) would normally warrant a rating of “medium” for flows into the Great Lakes Basin, but this site is given a rating of “high” due to the expectation that failures of the LDB berm are likely, which if happened would increase the frequency of aquatic pathway development. Likewise, existing culverts through the LDB berm provide a connection for annual floods on the St. Marys Watershed. Even if these pathways were removed, the poor integrity of the berm warrants a higher rating due to the increased likelihood of pathway formation at more frequent events than the USACE modeling currently predicts.

This rating is considered “reasonably certain” based on the following:

- Lack of site specific flow or stage gage data for Eagle Marsh for calibration of flood flows and frequency on Graham-McCulloch Ditch limits the level of confidence in modeling.

- The age of the hydrologic information used for Graham-McColloch Ditch (1982) and developments within the watershed since that time may result in a certain level of error in using this information today, thus source of uncertainty.

- Availabilty of site-specifice hydrologic modeling significantly increases the level of confidence in the high rating for the likelihood of aquatic pathway formation.

- The presence of a large perennial wetland spanning the basin divide and that is maintained as a natural area increases the amount of available data for this location and accordingly the level of confidence in the rating.

## 3.7 Aquatic Pathway Habitat

### 3.7.1 Terrestrial and Riparian Plants and Land Use

Eagle Marsh provides a variety of fish and wildlife habitats in a predominately urban and agricultural area. Aquatic habitat types present within Eagle Marsh include ditches, ponds, and wetlands. Both Junk Ditch and Graham-McCulloch Ditch are degraded due to historic straightening and runoff from nearby urban and agricultural areas. Despite their degraded condition, they still provide habitat for aquatic and semi-aquatic organisms. Ponds within Eagle Marsh are generally shallow, and most dry up in prolonged periods of dry weather (Figure 18). However, there is an irrigation pond within Eagle Marsh that holds water year-round (Figure 19). The ponds and wetlands within Eagle Marsh provide important habitat to many species of wildlife. During flood events, Eagle Marsh can become inundated by several feet of water (Figure 20 and 21). As the flood waters recede, fish can become trapped in the ponds and wetlands of Eagle Marsh allowing fish species to reestablish in Eagle Marsh even after prolonged dry periods.

Eagle Marsh features four main habitats: marshy, sedge meadow, forest, and prairie (Figure 22). Many endangered or special concern wildlife species need one or more wetland habitats to survive. Eagle Marsh has about 154 acres (62 ha) of marsh habitat including ponds and other areas that are wet more than half the year. Special adapted plants thrive in marsh areas and Indiana has lost many native rushes, grasses, and sedges. Eagle Marsh has several species such as Frank's sedge, soft rush, and wool grass as well as flowering plants such as swamp milkweed, New England aster, Joe Pye weed, monkey flower, and obedient plant (Little River Wetlands Project, 2011b). Several areas within Eagle Marsh have been replanted with native trees and shrubs to augment the existing forest. These areas provide habitat and forage for many species that utilize the marsh.

The area to the southwest of Eagle Marsh and adjacent to Graham-McCulloch Ditch is used almost exclusively for agricultural purposes. Habitat diversity is much lower in this area than in Eagle Marsh due to removal of natural vegetation for agricultural production. In areas immediately adjacent to the Graham-McCulloch Ditch, a narrow strip of riparian vegetation is typically present. Aquatic habitat within Graham-McCulloch Ditch is degraded due to channel straightening and runoff. Locations within this area that would naturally hold water have been drained for agricultural planting. Ponds present within in this area are farm ponds that were most likely constructed to provide water for live stock, provide recreation, for aesthetic value, or for a combination of these purposes.

Both Eagle Marsh and the surrounding area should provide adequate habitats and food sources to harbor ANS for various periods od time. However, some of these species, such as Asian carp, may not be able to complete their life cycle in the tributaries surrounding Eagle Marsh, such as Little River, Junk Ditch or Graham-McCulloch Ditch. Ponds and wetlands in the area could, however, provide sufficient habitat to sustain adult Asian carp. Though native and naturalized potential competitors and/or predators to ANS exist throughout both the Great Lakes and Mississippi River Basins, the impacts they would have on invading ANS would most likely be minimal. The ANS of concern to Eagle Marsh have already successfully established themselves within either the Great Lakes or Mississippi River Basin.

### 3.7.2 Aquatic Resources

Any ANS invading the Mississippi River Basin from the Great Lakes Basin by way of Eagle Marsh would encounter a wide range of habitat types. Lake Erie is one of the largest lakes in the world by surface area. Despite its large size, it is shallower than the other Great Lakes and is also the warmest and most biologically productive of the Great Lakes and it therefore supports a healthy fishery (ODNR, 2011a). The Maumee River empties into the western basin of Lake Erie which has an average depth of 24 feet (7.3 meters) (ODNR, 2011a). Lake St. Clair is located to the north of the western basin of Lake Erie and connects to Lake Erie via the Detroit River. Both Lake Erie and Lake St. Clair are highly productive.

Figure 18. Pond at Eagle Marsh. Photo by USACE dated April 16, 2011.

Figure 19. Irrigation pond at Eagle Marsh. Photo by USACE dated November 2, 2010.

Figure 20. Flooding across the entrance road to Eagle Marsh. Photo by USACE.

Figure 21. Flooding at the temporaryANS barrier within Eagle Marsh. Photo by USACE dated April 28, 2011.

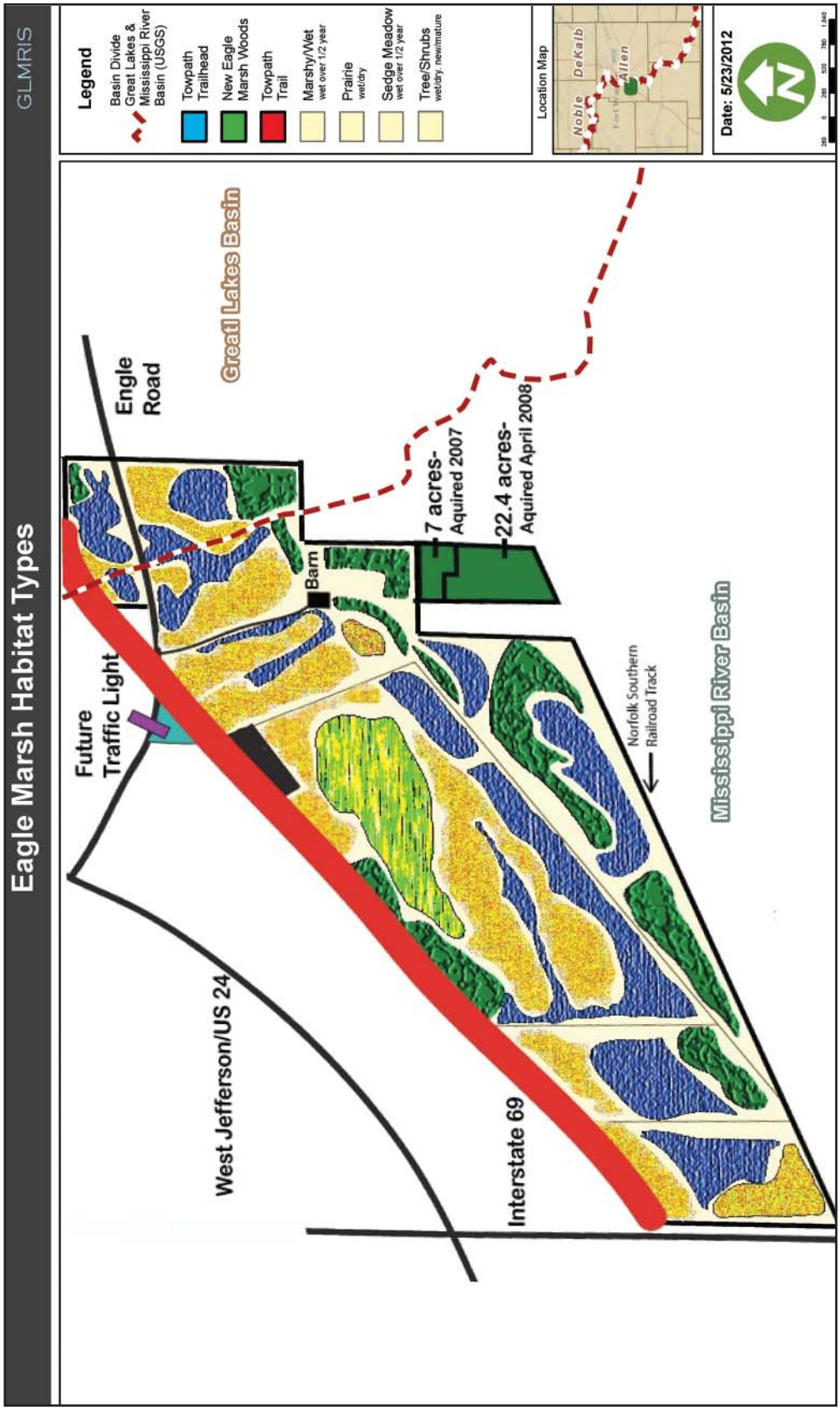



Figure 22. Map of Eagle Marsh Habitat types (Little River Wetlands Project, 2011b).

To get to Eagle Marsh from Lake Erie, an ANS would need to travel up the Maumee River. The Maumee is a large river that flows through several major cities including Toledo and Defiance, Ohio and Fort Wayne, Indiana. Typical riverine habitats are present throughout the course of the Maumee River, which vary from deep pools to backwater eddies and shallow riffles. Water quality within the Maumee River tends to become more degraded as it flows towards Lake Erie. The Ohio EPA has issued fish consumption advisories from the Indiana state line downstream to Waterville, Ohio and from Waterville to the mouth of the Maumee River at Toledo, Ohio. The stretch of the Maumee River from the Ohio state line to Defiance Ohio is considered a state scenic river (ODNR, 2011b). Despite water pollution, this stretch of the river generally provides quality habitat for a variety of fish species. Within Indiana the Maumee River is considered to have average water quality. This is due to the mixing of the St. Joseph River which has good water quality, and the St. Marys River which has degraded water quality (INDNR, 2006).

The confluence of the St. Marys River and St. Joseph River form the Maumee River in Fort Wayne, Indiana. In order to cross the basin divide at Eagle Marsh, from the Maumee River an ANS would need to travel upstream via the Saint Marys River into Junk Ditch and then to the watershed divide during a suitable flood event. The St. Marys River is similar to the Maumee River in regard to habitat. Upon successfully travelling several miles up the St. Marys River, an ANS would then need to travel up Junk Ditch to reach the basin divide at Eagle Marsh. Junk Ditch is a small tributary of the St. Marys River that has been channelized and relocated from its natural course. In dry periods water levels can become low and the temperature of the ditch can rise considerably. Junk Ditch also has areas that are very shallow even during times of normal flow.

The Mississippi River and its major eastern tributary, the Ohio River, contain similar large-river habitat types. These include, but are not limited to, large open water, deep pools, long reaches, slow-moving impounded areas, channels, backwaters, and vast floodplains. From the Ohio River, ANS traveling upstream would enter the 503 mile (810 km) Wabash River and then the 23 mile (27 km) Little River. Both of these offer abundant habitats for a myriad of aquatic organisms. Water quality within the Wabash River is often impacted by increased levels of nitrates and total dissolved solid loads and most stretches are healthy enough to support aquatic life (McFall et al., 2000). Graham-McCulloch Ditch is the final stream leading to Eagle Marsh from the Mississippi River Basin. This ditch exhibits poor water quality due to urban and agricultural runoff. Habitat quality within the stream has also been degraded due to channelization. It is unlikely that degraded water quality alone would deter the establishment of many ANS. One reason most invasive species are successful is the fact that many are able to tolerate a wide range of environmental parameters.

### 3.7.3 Water Quantity and Quality

Surface drainage in Eagle Marsh is divided between the Wabash River Basin and the Maumee River Basin. Water that falls in the area either enters the Graham-McCulloch Ditch and flows towards the Wabash River and ultimately into the Mississippi River, or it enters Junk Ditch and flows towards the Maumee River Basin and ultimately into Lake Erie.

Both the Graham-McCulloch Ditch and Junk Ditch have been moved from their natural alignments and straightened. Water quality in Junk Ditch and Graham-McCulloch Ditch is poor due to much of the drainage area for these streams occurring within the city of Fort Wayne and other developed areas. Both ditches also suffer from channelization and agricultural runoff. A wastewater treatment plant is located on the Graham-McCulloch Ditch just upstream of the study area, and the effluent from this plant is often of better quality than the receiving water. As a result of this, both ditches are subject to low dissolved oxygen levels, relatively high water temperatures in the summer, and algal blooms when flow velocities are low. The threat of ANS establishing in the Graham-McCulloch or Junk Ditches is low relative to the surrounding rivers that generally demonstrate more stable habitat characteristics. Once at the drainage divide, self-mobile ANS are more likely to be able to move downstream to the larger rivers which exhibit better water quality, greater densities of potential forage, and a greater opportunity to complete life cycle requirements.

Downstream of Eagle Marsh in the Great Lakes Basin, the Maumee River flows 130 river miles to Lake Erie. The Maumee River has the largest drainage area of any Great Lakes river, at 6,586 square miles (17,057 square kilometers), of which roughly 85 percent is agricultural. The lower 22.8 miles (36.7 km) of the Maumee River is classified as an "Area of Concern" due to heavy metals and organic chemical sediment contamination, but also contributes the largest tributary load of suspended sediments and phosphorus to Lake Erie (Maumee RAP, 2006). Some of the specific beneficial use impairments include restrictions on fish and wildlife consumption and populations, fish tumors or other deformities, eutrophication, and loss of fish and wildlife habitat (Maumee RAP, 2006).

Since reclamation by LRWP, Eagle Marsh has provided excellent wetland habitat for native plants and animals. This wetland habitat may be susceptible to invasive aquatic organisms (particularly plants), if they are transferred or spread to this location. During low water periods, water quality in Eagle Marsh declines, as disconnected ponds can become stagnant and exhibit low dissolved oxygen levels.

### 3.7.4 Aquatic Organisms

Due to intermittent low water levels, fish species diversity is very limited within Eagle Marsh. Common carp and possibly a few native sunfish (*Lepomis* spp.) are sometimes able to survive within the few pools that do not dry up between rains and flood events. When heavy rains fill the marsh and connect the two basins, an abundance of food becomes available to these fish and provides an aquatic pathway for these and other fish into the Graham-McColluch and Junk Ditches. Despite both ditches suffer from channelization and urban and agriculture run-off, they are able to support some tolerant fish species such as sunfish, common carp, and a few other minnow species. Both ditches are subject to low dissolved oxygen levels and algal blooms when flow velocities are low. Aquatic invertebrates inhabiting the ditches and ponds include oligochaetes, dipterans, and pulmonates, all of which are indicators of poor water quality.

The Wabash River supports a diverse fishery. Fish species range from small darters to large paddlefish. Sport species present include blue catfish (*Ictalurus furcatus*), channel catfish (*I. punctatus*), flathead catfish (*Pylodictis olivaris*), white bass (*Morone chrysops*), striped bass (*M. saxatilis*), hybrid striped bass (*M. saxatilis* x *M. chrysops*), smallmouth bass (*Micropterus dolomeiu*), spotted bass (*M. punctatus*), largemouth bass (*M. salmoides*), white crappie (*Pomoxis annularis*), black crappie (*P. nigromaculatus*), bluegill (*Lepomis macrochirus*), freshwater drum (*Aplodinotus grunniens*), and sauger (*Sander canadensis*). Fish species that typically make up the forage base include spotfin shiner (*Cyprinella spiloptera*), emerald shiner (*Notropis atherinoides*), gizzard shad (*Dorosoma cepedianum*), and bullhead minnow (*Pimephales vigilax*) (Pyron and Lauer, 2004). Common carp, grass carp (*Ctenopharyngodon idella*), bighead carp, and silver carp are also present. Historically, the Wabash River has supported 27 state threatened or endangered mussel species, including eight which are Federally endangered. Mussel populations are greatly reduced in numbers of individuals and species in the Wabash River. Cummings et al., (1992) reported 62 species of mussels in the Wabash River, but of those 25 were represented by dead specimens only. The Little River has similar fauna with fewer mussels and likely lacks larger fish species like paddlefish and striped bass. There has been no evidence of Asian carp species in the Little River based on environmental DNA (eDNA) analysis or from the Wabash River Asian carp fish tracking study (Keller, Doug. Indiana DNR, personal communication, August 16, 2011). The eDNA technique is useful for detection of the presence of Asian carp DNA in water when species populations are at very low levels of abundance (Jerde et al., 2011; Dejean et al., 2011; and Minamoto et al., 2011). A positive eDNA sample indicates the presence of Asian carp DNA and the potential presence of live fish. At present, eDNA evidence cannot verify whether live Asian carp are present, whether the DNA may have come from a dead fish, or whether water containing Asian carp DNA may have been transported from other sources, such as bilge water. The U.S. Army Corps of Engineers is leading an Asian Carp eDNA Calibration Study with the U.S. Geological Survey and the U.S. Fish and Wildlife Service to reduce the uncertainty surrounding eDNA results and investigate alternative sources and pathways for eDNA detections beyond a live fish.

The Maumee River also supports a diverse fishery. The Maumee is known mostly for the exceptional numbers of walleye (Sander vitreus) that run up the river to spawn in early spring (ODNR, 2011c). White bass also demonstrate a large spawning run up the Maumee River. In addition, smallmouth bass, multiple sunfish species, channel catfish, and flathead catfish are among the most abundant predatory species. The Maumee River also has a diverse freshwater mussel population.

The USFWS lists the Eastern Massasauga rattlesnake (*Sistrurus catenatus catenatus*) as a candidate species and is recorded from Allen County, Indiana. This species could potentially be present in the study area as it preferred habitats are wetlands and adjacent uplands. The rayed bean mussel (*Villosa fabalis*) is proposed for listing and has been recorded from Allen County; however, no areas within Eagle Marsh provide suitable habitat for this species. The LRWP maintains records of species detected within the Eagle Marsh. No Federally endangered species have been observed within the marsh.

The state of Indiana maintains lists of threatened and endangered species in Indiana. This list includes flora and fauna whose occurrence in Indiana is or may be in jeopardy, or with known or perceived threats or population declines. These species are not necessarily the same as those protected by the Federal government under the Endangered Species Act. Several species that occur within Eagle Marsh are listed by the state of Indiana. A complete listing of all state listed species reported from Allen County is available from the INDNR (2010). Since suitable habitat for several state listed species is present within the Eagle Marsh, some species that may be present but have not yet been observed include Upland Sandpiper (*Bartramia longicauda*), Blanding's turtle (*Emydoidea blandingii*), Least Bittern (*Ixobrychus exilis*), Gray Petaltail (*Tachopteryx thoreyi*) among others.

The restoration of Eagle Marsh has led to the creation of a variety of wetland habitats from what was once agricultural land that provided only marginal habitat value. The availability of natural habitat types at Eagle Marsh has lead to the return of many native species that would have inhabited the area before it was converted to agriculture.

The establishment of ANS within or around Eagle Marsh may affect some listed species, even though most listed species in the area are terrestrial. Aquatic nuisance species are known to upset the balance of an ecosystem's food web dynamics, and sensitive species are usually the first to be affected. They can also negatively affect higher trophic levels in the food chain by outcompeting lower level species for food or habitat, or by direct predation.

## 3.8 Connecting Streams to Great Lakes and Mississippi or Ohio River

The pathway from Eagle Marsh to the Mississippi River is from the Graham-McCulloch Ditch which flows approximately six miles (9.6 km) from Eagle Marsh to the Little River. The Little River then flows approximately 21 miles (34 km) before joining the Wabash River at river mile (RM) 93. The Wabash River continues for approximately 410 miles (660 km) until it meets the Ohio River at RM 494. The Ohio River then flows another 135 miles (217 km) before entering the Mississippi River at RM 953.

The pathway from Eagle Marsh to the Great Lakes is from Junk Ditch which flows approximately 4.5 miles (7.2 km) from Eagle Marsh before joining the St. Marys River, which joins with the St. Joseph River (approximately 2.4 miles (3.9 km) downstream) at St. Marys RM 99. This confluence then forms the Maumee River that flows 137 miles (220 km) before entering Lake Erie.

Any ANS moving through the aquatic pathway from Lake Erie to Eagle Marsh is likely to encounter several obstacles that may impede their further upstream movement (Figure 23). Near Waterville, Ohio, rapids that are created by a weir may impede movement of some ANS. Any impedence offered by this structure though would likely be less effective at higher flows because of the diminishing turbulence of the rapids. Further upstream in Defiance, Ohio, are two small dams on either side of Howard Island called the General Motors Primary and Secondary Dams. Again, these may be

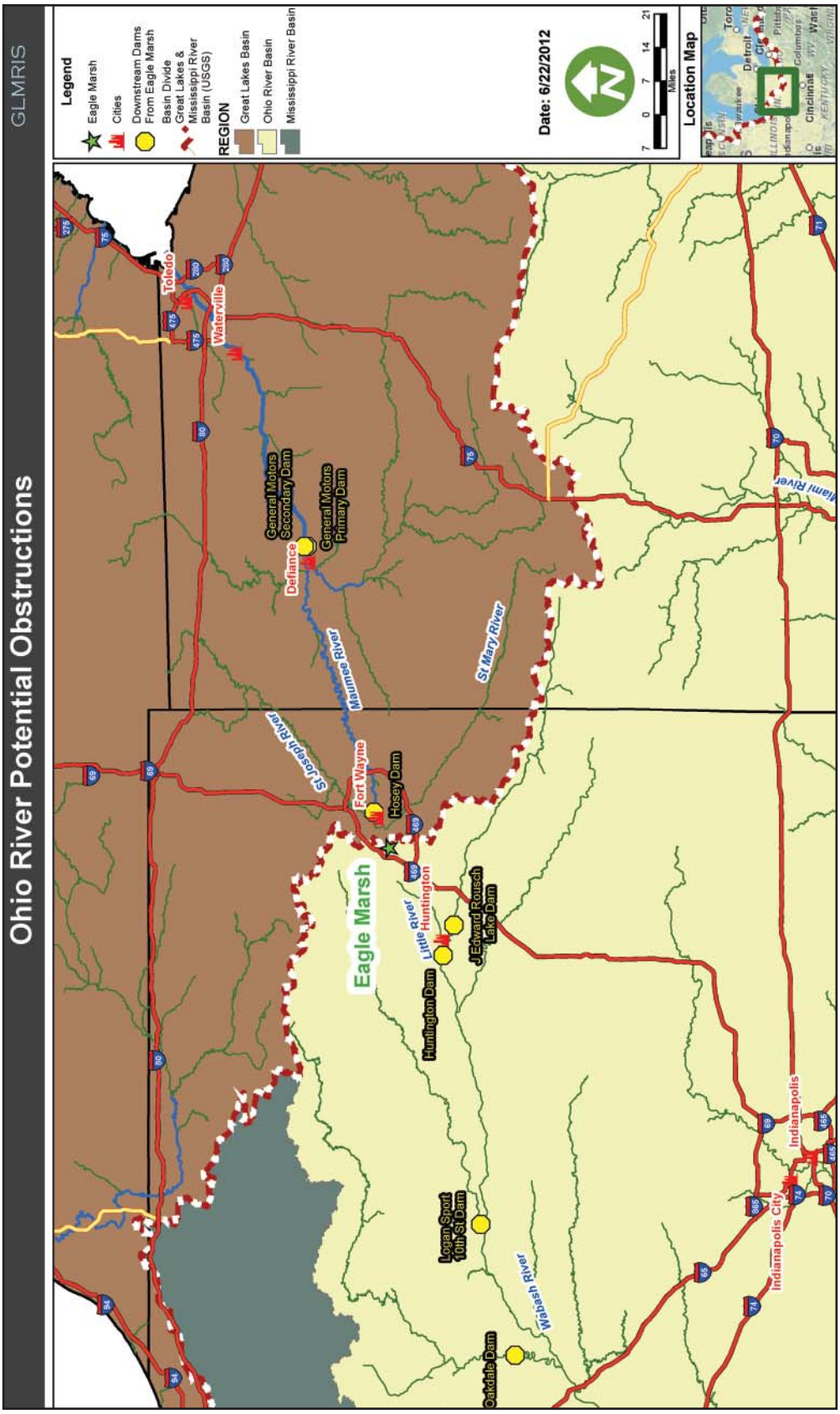



Figure 23. Dams located downstream of Eagle Marsh within both basins.

Figure 24. Low head dam, Little River at Huntington, Indiana during summer low flow. Photo by USACE dated July 9, 2010.

Figure 25. Low head dam, Little River in Huntington, Indiana during normal flow. Photo by USACE taken April 16, 2011.

Figure 26. Looking upstream at Little River from abandoned railway bridge, Huntington, Indiana. Photo by USACE taken April 16, 2011.

Figure 27. Small low head dam on the Little River downstream of S. Jefferson St. Bridge. Photo by USACE.

effective during low flows, but are easily over topped as flows increase. Hosey Dam in Allen County near Fort Wayne, Indiana, is the final potential obstacle moving upstream through the Maumee River. This concrete dam is 10 feet (3 m) high and may be a formidable obstacle during low flow. However, it is regularly overtopped during high flow events.

The only obstacle that might impede ANS movement from the Mississippi River Basin to the aquatic pathway at Eagle Marsh is the dam on the Little River in Huntington, Indiana (Figures 23, 24, and 25). Located roughly 500 feet (152 m) upstream of the South Jefferson Street (State Road 224) bridge, the concrete spillway dam is approximately six feet (1.8 m) high and appears to block most upstream fish passage during low flow. As with the obstacles on the Maumee River though, this dam is less effective at stopping ANS upstream movement as water levels rise. A smaller low head dam or submerged pipe crossing is also present on the Little River approximately 625 feet (190 m) downstream of the South Jefferson Street Bridge, but provides only a minimal barrier even at low flow (Figure 27). Also located downstream of Eagle Marsh within the Mississippi River Basin are the J. Edward Roush Dam, the Logansport 10th St. Dam, and the Oakdale Dam. Graham-McCulloch Ditch is a tributary to the Little River which joins the Wabash River downstream of the J. Edward Roush Dam, so this dam is not an impediment for upstream movement of ANS toward Eagle Marsh. The Logansport and Oakdale Dams are both located on side tributaries to the Wabash River and are also not obstructions to ANS upstream movement.

# 4 Aquatic Pathway Viability for ANS of Concern

The viability of the aquatic pathway was assessed by the project team for the ANS of concern for Libby Branch Swan River location in accordance with the procedures outlined in the Methodology Section of this report. This potential was characterized as high, medium, or low for the following categories:

- Probability that pathway exists (Section 3)
- Probability of the target ANS occurring within either basin
- Probability target ANS survive transit to reach aquatic pathway
- Probability of ANS establishment at the aquatic pathway
- Probability of ANS spreading across aquatic pathway into new basin

The criteria for designating probabilities of high, medium, or low are provided under each category. In addition, a certainty rating is also assigned with each probability assessment. Certainty ratings associated with any given probability ratings include:

- Very Certain (As certain as we will get with this effort)
- Reasonably Certain
- Moderately Certain (More certain than not)
- Reasonably Uncertain
- Very Uncertain (An educated guess)

A team rating is provided based on the professional collaboration of the interagency team of biologists. These characterizations were completed by a team of agency biologists for each species under consideration. A team probability and certainty rating also is provided. The rating represents the most conservative probability assessment for each category considered. The forms describing the probability and certainty ratings from all agency professionals participating in this assessment is included at Attachment A.

## 4.1 Probability of the ANS being within either basin

**General Considerations for Assigning Probability Ratings:**

> **High** - Target ANS exists on connected waterways in close enough proximity to be capable of moving to the aquatic pathway within 20 years.
>
> **Medium** - Target ANS exists on connected waterways, but based on current proximity and mobility, is considered incapable of moving to the aquatic pathway within 20 years.
>
> **Low** - Target ANS is not known to exist on a connected waterway.

Certainty ratings were applied as outlined above.

**Asian Carp**

Silver carp and bighead carp are established in the middle and lower Mississippi River Basin, including the Wabash River. Single individuals have been collected from the Mississippi River at a number of places upstream of this, but there is no evidence of successful reproduction or self-sustaining populations. Both silver carp and bighead carp have been recorded in the Wabash River near the mouth of the Little River which leads to Graham-McCulloch Ditch (USGS, 2011). Neither species have been detected in the Little River or Graham-McCulloch Ditch. Black carp may be established in portions of the lower Mississippi River Basin and they have also been reported in the Mississippi River upstream of the mouth of the Ohio River. The known distribution of black carp is not as extensive as that of the silver and bighead carp.

Team Rating: **High**
Certainty rating: Very Certain

**Inland Silverside**

The inland silverside's native range is eastern North America, including the Atlantic and Gulf Slopes (mostly near the coast) from Massachusetts to the Rio Grande drainage in Texas and southeastern New Mexico; north from the Mississippi River and major tributaries (mainly Arkansas and Red Rivers) to southern Illinois and eastern Oklahoma (Page & Burr, 1991). It is a marine species that ascends rivers and prefers estuaries, lagoons, brackish seas, and rivers (Fishbase, 2011). The inland silverside is currently found in the Wabash River and was collected in 2003 in Mt. Carmel, Indiana which is in southwestern Indiana (USGS, 2011). The species has also been collected in Illinois from Lake Baldwin, Lake of Egypt, Rend Lake, Cache River, Wabash River, and the Mississippi, Ohio, and Kankakee Rivers (Laird & Page, 1996). It is believed that the presence of the species in the Mississippi River in southern Illinois and in the lower Ohio River in Illinois and Kentucky are a result of natural dispersal (Fuller and Nico, 2012).

Team Rating: **High**
Certainty rating: Reasonably Certain

**Northern Snakehead**

The northern snakehead was found in 2008 in Arkansas and has since established a reproducing population in the area. Although in a different basin, this species is also established in the Potomac River in Maryland and Virginia (USGS, 2011). While northern snakehead is in the Mississippi River Watershed, it does not seem to be spreading at a high rate at this time (USGS, 2011).

Team Rating: **Medium**
Certainty rating: Reasonably Certain

**Parasitic Copepod**

The parasitic copepod (*Neoergasilus japonicus*) has a life cycle in which the female adopts a parasitic phase on several fish species, including members of the minnow family, sunfish family, catfish family, and potentially other fish species. The common carp is a frequent host of the parasite (Hudson and Bowen, 2002). The females can detach and re-attach to host species. The parasitic copepod has been established in Lake Huron since 1994. The common carp is established in Lake Erie, as well as the rivers and streams leading to Eagle Marsh from Lake Erie. While other host fish species are known to exist in the pathway system, the common carp was selected as the most likely host species because of the life cycle capabilities of the common carp and the likelihood the common carp would use and survive in the pathway habitats. The parasitic copepod and a necessary host species are in the pathway. The males are free living

but do not have the capability of movement upstream. The literature indicates that the copepod is small and relatively easy to miss in field surveys, even by trained biologists. Therefore, it may be much more prevalent than the distribution maps depict.

Team Rating: **Medium**
Certainty rating: Reasonably Certain

**Viral Hemorrhagic Septicemia Virus (VHSv)**

Viral hemorrhagic septicemia virus can infect a wide range of host fish causing a variety of external and internal symptoms, sometimes leading to death of the host fish (WDNR, 2012). Variables such as host fish species and water temperature can impact the virulence of the virus. Seemingly healthy individuals that have been previously infected with VHSv can have chronic infections and be carriers of the disease (Skall et al., 2005). This virus has been reported from throughout the Great Lakes Basin including Lake Erie (USGS, 2011). Viral hemorrhagic septicemia virus is active at water temperatures less than 60º F (15.5º C) (WDNR, 2012). As such, it may be less likely to persist in areas like Eagle Marsh during much of the year. Viral hemorrhagic septicemia virus has been found in many species of fish including common carp. The common carp is established in Lake Erie, as well as the rivers and streams leading to Eagle Marsh from Lake Erie. While other host fish species are known to exist in the pathway system, the common carp was selected as the most likely host species because of the life cycle capabilities of the common carp and the likelihood the common carp would use and survive in the pathway habitats. Viral Hemorrhagic Septicemia virus and a necessary host species are in the pathway.

Team Rating: **High**
Certainty rating: Reasonably Certain

**Ruffe and Tubenose Goby**

The ruffe and tubenose goby are located within the Great Lakes and associated with river mouths and estuaries of large river systems entering the Great Lakes. The ruffe exists in northern Lake Michigan in Green Bay, but is not widespread and there are no high density populations in Lake Michigan (Bowen and Goehle, 2011). Literature reviews and actual fish survey data have not documented the collection of the ruffe in smaller upstream tributaries. The ruffe has been found in, Lake Michigan, Lake Superior, and Lake Huron (USGS, 2011). The ruffe is an aggressive species that possesses the ability to feed in darkness, cold temperatures and turbid conditions.

The tubenose goby's introduced range includes Lake St. Clair, Lake Erie and Lake Huron, Lake Superior, and Lake Ontario (USGS, 2011). It has been collected in the lower reaches of large tributaries to the Great Lakes and estuaries. The tubenose goby is a benthic species that consumes a wide variety of invertebrates (USGS, 2011). They are found in the open waters and estuaries of slow flowing rivers and are often quite abundant in backwaters and lakes and seem to prefer dense vegetation. Tubenose gobies have exhibited a much slower rate of expansion in the Great Lakes than the round goby (*Neogobius melanostomus*), also an invasive species in the Great Lakes and now located within both the Great Lakes Basin and the Mississippi River Basin. The tubenose goby's nearest locations are in Lake Superior and Lake Huron.

Team Rating: **High**
Certainty rating: Reasonably Certain

**Threespine stickleback**

The threespine stickleback is found in each of the Great Lakes except Lake Ontario and has been collected in some inland river systems (USGS, 2011). Literature indicates this species prefers to live in smaller streams but may occur in a variety of habitat including lakes and large rivers (USGS, 2011). The threespine stickleback was first encountered in lower Green Bay and the Lower Fox River (below DePere Dam) about 25 years ago, but has never been seen upstream from this area. Great Lakes populations of this species tend to be potamodromous (truly migratory but within fresh water only) and only enter the lower reaches of streams briefly during spring spawning.

Team Rating: **High**
Certainty rating: Very Certain

## 4.2 Probability ANS surviving transit to aquatic pathway

### 4.2.1 Probability of ANS Surviving Transit to Aquatic Pathway through Connecting Streams.

**High** - Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to successfully navigate through the connecting streams to arrive at the subject pathway within 10 to 20 years.

**Medium** - Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through the connecting streams to arrive at the subject pathway within 20 to 50 years.

**Low** - Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations through the connectin streams to arrive at the subject pathway within next 50 years.

**Asian Carp**

Spawning of silver and bighead carp is initiated by rising water levels following heavy rains (Jennings 1988; Verigin et al., 1978). Both species are strong swimmers and silver carp are capable of jumping considerable distances out of the water [up to 12 feet (3.6 m)]. There are no obstacles in the Little River that would permanently prevent upstream movement of silver carp. The low head dam at Huntington, Indiana could possibly be jumped by the silver carp and offers even less prevention as flow increases. All Asian carp species in the Mississippi River Basin would likely be able to bypass the dam during high flow events when it becomes completely inundated. The proximity of the silver carp to Eagle Marsh downstream on the Wabash River, combined with their history of dispersal throughout the Mississippi River Basin, indicates that Asian carp are capable of utilizing this pathway if hydrologic conditions allow. Habitat present within most of the Little River and all of Graham-McCulloch Ditch is not ideal habitat for silver and bighead carp, which are native to and thrive in large rivers, but it is not known to what extent this may prevent movement or passage. Bighead and silver carp need 35-40 miles (56-64 km) of open river to successfully spawn (Jennings, 1988; Verigin et al., 1978; Nico and Jelks, 2011). While silver and bighead carp are highly opportunistic on their diet, bighead carp are primarily zooplanktivorous, whereas silver carp primarily consume smaller phytoplankton and fine particulate organic matter (Dong and Li, 1994; Jirasek et al., 1981; Williamson and Garvey, 2005).

Adult black carp are primarily molluscivores. However, they will opportunistically consume a wide variety of food items (USFWS, 2002). Juvenile black carp have a diet more similar to silver and bighead carp, consisting primarily of zooplankton (USACE, 2011b). The diet of juvenile black carp may allow them to survive in areas unsuitable for adults. The habitat of black carp is very similar to the grass carp (Nico et al., 2005). It is believed that black carp should be able to colonize the same areas of the United States where the grass carp have established (USFWS, 2002). Sufficient forage is likely available throughout the Wabash River and Little River for both silver and bighead carp. Forage abundance and diversity decreases moving up the Graham-McCulloch Ditch and into Eagle Marsh as water quality and volume decrease.

After discussion and expert coordination by the interagency pathway assessment team, Asian carp were assigned a team rating of medium/high for their ability to reach the Eagle Marsh connection. This rating was given to address concerns about the unknown physiological and habitat limits to Asian carp movement. Juvenile Asian carp have been observed in the uppermost reaches of small tributaries to large rivers attempting to pass over barriers, such as dams, to continue their upstream movement (D. Chapman-USGS, personal communication, September 12, 2011;N. Caswell-USFWS, personal communication September 12, 2011). The state of Indiana has conducted two eDNA sampling events (fall 2010 and early summer 2011) and has not had a positive detection for Asian carp DNA in Little River or Graham-McCulloch Ditch. The gradient

needed to prevent juvenile Asian carp from moving up stream is unknown. Thus it is unclear if the gradient of the Upper Wabash River and Little River are sufficient to prevent potential future upstream movement of juvenile bighead and silver carp. It is important to note that young Asian carp tend to move laterally away from the river in which they were spawned and not back upstream (D. Chapman- -USGS, personal communication, September 12, 2011). It has also been observed that Asian carp, as small as advanced fingerlings, have traveled up to 37 miles (60 km) though tributaries of the lower Missouri River. These tributaries were located laterally to the Missouri river segment in which these fish hatched (D. Chapman-USGS, personal communication, September 12, 2011). Sexually mature adult Asian carp have occasionally been found in very small streams, which appear scarcely large enough to support the fishes at low water (D. Chapman-USGS, personal communication, September 12, 2011). The age these fishes arrived at these locations is unknown. The state of Indiana is funding a study to evaluate the movement and spawning of Asian carp in the upper Wabash. In 2011, one hundred fish (99 silver carp and one bighead) were collected from the Wabash River then tagged and returned to the river. Data from the 2011 spring and summer season have shown no evidence of Asian carp in the Little River and only one tagged fish venturing upstream of Logansport, Indiana on the Wabash River near the mouth of the Little River (D. Keller-INDNR, personal communication, August 16, 2011).

In summary, there are uncertainties one must take into account when attempting to predict the temporal and spatial movement patterns of Asian carp. While ongoing research by INDNR and Purdue University may suggest the tagged Asian carp have no interest in ascending the Little River, more long term studies are needed, and even these may not help explain the seemingly random movements of young 12-18 inch (30-46 cm) Asian carp that have been witnessed in Midwestern rivers and their tributaries (Coulter and Goforth, 2012; D. Chapman, personal communication, September 12, 2011). In addition, the temporary fence at eagle Marsh may eventually have to be removed. This structure was installed to provide protection against adult Asian Carp entering the Great Lakes Basin should they get into Eagle Marsh. Based on current knowledge of the reproductive traits and life history of Asian carp, there is no evidence to support that juveniles small enough to pass through the fence would ever reach Eagle Marsh or that spawning would occur within Eagle Marsh.

Additional comments from INDNR: Since the bulk of Asian carp spawning in the Wabash River occurs downstream from Logansport, Indiana, juvenile fish at this time only occur in the tributaries and backwaters of the middle and lower Wabash River (Coulter and Goforth, 2012). Only adults seeking spawning areas appear to venture to the upper Wabash River. It is unknown if these adult fish will have any “motivation” to spread into Little River and eventually to Graham-McCulloch Ditch.

Team Rating: **Medium / High**
Certainty rating: Reasonably Certain

**Inland Silverside**

The inland silverside moves in large schools that can number in the thousands and they can travel far up streams and rivers, especially in southern part of their range (NatureServe, 2010). The species’ natural spread rate through the Mississippi River Basin is not known because they have been actively stocked in lakes. The average lifespan of the inland silverside is about 16 months, with few surviving their second winter (NatureServe, 2010). It is capable of producing 30,000 eggs per month (Stoeckel, 1988). The dam on the Little River at Huntington, Indiana will impede the upstream movment of ANS at low and normal flow. The effectiveness of this barrier declines during high flow events when the dam can become inundated. It is possible that inland silversides could be able to bypass the dam during high flow and travel up the Little River and Graham-McCulloch Ditch to Eagle Marsh. As a relatively small fish at only approximately five inches (13 cm) in total length at maturity, it is likely that this species would seek refuge from high water velocities during flood events, instead of attempting to move upstream. The current chain-link fence in the marsh would not prevent movement of this species from the Mississippi River Basin to the Great Lakes Basin. Available information about habitat preference for this species suggests the inland silverside will colonize within rivers and streams but are usually found in clear, quiet water over sand or gravel. The Graham-McCulloch Ditch and Eagle Marsh

do not provide this described habitat.

Team Rating: **Medium**
Certainty rating: Moderately Certain

**Northern Snakehead**

The northern snakehead utilizes specialized structures (suprabranchial organ and a bifurcate ventral aorta) that permits aquatic and aerial respiration (Ishimatsu and Itazaw 1981, Graham 1997). This species thrives in stagnant, oxygen depleted back-waters and marshes (Courtenay, Jr. and Williams, 2004). The northern snakehead likely possesses the ability to spread through the Eagle Marsh pathway. However, its preferred habit is not flowing waters, which may slow its spread up the Mississippi River and to the tributaries connecting to Eagle Marsh. Despite its preferences for stagnant, oxygen-depleted back waters and marshes, the northern snakehead has been consistently caught by anglers in the Potomac River near Great Falls, Virginia during spring high flow events (J. Newhard-USFWS, December 22, 2011). Based on data from external tags recaptured by anglers, in rare instances, northern snakehead have been found to move as far as 50 river miles (80 km) upstream at a rate of approximately one mile (1.6 km) per day. This extensive movement typically occurs in the spring with the fish returning back downstream to slower moving water in the summer (J. Newhard-USFWS, December 22, 2011). The northern snakehead has no established populations near Eagle Marsh but is located on connecting waters in the Mississippi River Basin.

Team Rating: **Medium**
Certainty rating: Reasonably Certain

**Parasitic Copepod**

The parasitic copepod (*Neoergasilus japonicus*) has been found on common carp. During spring run-off events in April and May, common carp move into the shallow waters of bays and river systems to spawn. Within the rivers, common carp move upstream to spawn in suitable habitat such as marshes and even drainage ditches with as little as or less than one foot (30 cm) depth of water. Common carp are strong swimmers and though they cannot jump like members of the salmon family, they can move upstream during moderate flow events.

The aquatic pathway from the Great Lakes to Eagle Marsh consists of marsh, small stream, and river connections to Lake Erie. While there are in-stream obstacles on the Maumee River, these become less effective at impeding upstream movement as flow increases. It is possible that common carp could spread to the watershed divide under certain discharge events.

The surface water connection from Lake Erie to Eagle Marsh provides suitable habitat for common carp during run-off events. Eagle Marsh is shallow, but also contains man-made ponds of unknown depth. Common carp have been documented on both sides of the temporary fence in the spring prior to the normal spawning season. Common carp are a very resilient species and are capable of surviving a wide range of water quality parameters, and it is highly likely they are able to overwinter in the ponds within Eagle Marsh. It is also likely that if the common carp arrived with the parasitic copepod attached, it would survive in the ponds and transfer to the Mississippi River Basin via the Graham-McCulloch Ditch under a suitable runoff event.

Team Rating: **Medium**
Certainty rating: Reasonably Certain

**Viral Hemorrhagic Septicemia Virus**

Viral hemorrhagic septicemia virus has been found to infect common carp (USGS, 2011). During spring run-off events in April and May, common carp move into the shallow waters of bays and river systems to spawn. Within the rivers, common carp move upstream to spawn in suitable habitat such as marshes and even drainage ditches with less than one foot (30 cm) depth of water. Common carp are strong swimmers that can reach sustained speeds of 1.3-3.9 fps (0.4-1.2 mps) and burst speed of 3.9-8.5 fps (1.2-2.6 mps). Though they cannot jump like members of the salmon family (maximum height six feet or 1.8 m), they can move upstream during moderate flow events.

The aquatic pathway from the Great Lakes to Eagle Marsh during certain discharge events consists of marsh and small stream, and river connections and

provides suitable habitat for common carp during run-off events. While there are potential in-stream obstacles on the Maumee River, these become less effective at impeding upstream movement as flows increase. It is therefore possible that common carp could move to the watershed divide under higher discharge events. Eagle Marsh is a shallow marsh, but also contains constructed ponds of unknown depth. Common carp have been documented on both sides of the temporary fence in the spring prior to the normal spawning season. Common carp are a very resilient species and are capable of surviving a wide range of water quality parameters, and it is highly likely they are able to overwinter in the ponds within Eagle Marsh. It is also likely that if the common carp arrived infected with VHSv, the carp would survive in the ponds and transfer to the Mississippi River Basin via the Graham-McCulloch Ditch under a suitable runoff event.

Team Rating: **High**
Certainty rating: Very Certain

**Ruffe and Tubenose Goby**

The ruffe prefers deep waters of lakes and pools of rivers, usually over sand and gravels but has a tolerance for different habitats and environmental conditions (Gray and Best 1989). The ruffe has a high reproductive rate and spawns in clean water. Females produce up to 200,000 eggs in the first batch, and up to 6,000 eggs per subsequent batch (Global Invasive Species Database, 2012). Ballast water transport has been the key means for the spread of ruffe in the Great Lakes (USFWS, 1996). Natural rates of dispersion are not well known and ruffe have not spread beyond Green Bay in the nine years since its detection in that area, and populations have been trending down (Bowen and Goehle, 2011). The ruffe's ability to swim upstream during high flow events and move over dams is questionable, especially since it prefers still or slow moving water (Fishbase, 2011). The tubenose goby is found in the open waters and estuaries of slow flowing rivers. The tubenose goby appears to be more capable of living in more varied types of riverine habitat than the ruffe.

Team Rating: **Low**
Certainty rating: Reasonably Certain

**Threespine Stickleback**

The threespine stickleback has been found in the Great Lakes and in smaller river systems. While not having been identified within the upper Maumee River system, its close proximity in the Great Lakes and particularly Lake Erie, indicate potential for access and transfer to the Mississippi River Basin via the Eagle Marsh connection. Instream obstacles downstream of Eagle Marsh should be sufficient in impeding movement of the threespine stickleback at normal and low flows. As these obstacles become inundated during higher flow events, the stickleback may have ample opportunity to move upstream. However, it is likely that this species will seek refuge from higher velocities instead of expending energy attempting to move upstream. It is likely that sufficient forage and habitat is available throughout the Maumee River basin for the threespine stickleback. Also, the fish could potentially survive in emergent wetland areas during a storm runoff event as they are tolerant of low dissolved oxygen down to two parts per million (ppm) and temperatures up to 68ºF (20ºC) (Wootton, 1976).

Team Rating: **Medium**
Certainty rating: Reasonably Certain

### 4.2.2 Probability of ANS Surviving Transit to Aquatic Pathway through Other Means

This section does not influence the overall pathway rating outlined in this report and is only included to point out other potential pathways (e.g., anthropogenic) that may be important to different audiences. Any further analysis of non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from those which may exploit the aquatic pathway.

**General considerations for assigning probability ratings:**

**High** - Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to

successfully navigate through a non-aquatic pathway to arrive at the subject pathway within 10 to 20 years.

**Medium** - Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through a non-aquatic pathway to arrive at the subject pathway within 20 to 50 years.

**Low** - Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations through a non-aquatic pathway to arrive at the subject pathway within next 50 years.

**Asian Carp, Northern Snakehead, Parasitic Copepod (*Neoergasilus japonicus*), VHSv, Threespine Stickleback, and Ruffe, and Tubenose Goby**

Fishing and boating are unlikely to occur in Eagle marsh. The ditches are too small to support sport fishing and are also too small for boating or kayaking. The small size of the ditches virtually eliminates the threat of ANS transfer via watercraft, associated equipment, or fishing gear. Dumping of ANS (discarded aquarium pets, religious ceremonies, etc.) within the area is also considered unlikely. The pathway vicinity is located on a wetland preserve and therefore has regulated access. Possession of Asian carp in Indiana is prohibited which would aid in reducing the likelihood of human movement of this species. It is probable that bait-bucket transport has aided in the movement of the threespine stickleback in the past and Indiana state regulations do not prohibit transport or possession of this species. However, as fishing and boating are unlikely at this location the probability of anthropogenic transport of this species would also be low.

Team Rating: **Low**
Certainty rating: Reasonably Certain

## 4.3 Probability of ANS Establishment at the Aquatic Pathway

**General Considerations for Assigning Probability Ratings:**

**High** - Sources of food and habitat suitable to the ANS are plentiful in close proximity to support all life stages from birth to adult, abiotic conditions align with native range, and there are no known predators or conditions that would significantly impede survivability or reproduction.

**Medium** - Limited and disconnected areas and sources of food and habitat suitable to the ANS are available in proximity, abiotic conditions are within latitude limits of native range, but only a portion of the healthy individuals arriving at location can be expected to effectively compete and survive.

**Low** - Habitat and abiotic conditions in proximity are outside the range where the target ANS has been known to survive; there is very limited availability habitat area suitable for ANS cover, sustainable food supply and reproduction; or native predators or competition with native species would likely prevent establishment of a sustainable population.

**Asian Carp**

Silver and bighead carp are fast growing species that are capable of surviving in a wide range of water temperatures and reproducing quickly, providing suitable habitat is available. Life history and habitat requirements generally include diverse needs for current areas, backwater habitats, deep overwintering holes, and other habitat types needed for survival (Nico et al., 2005). In some stretches of the Illinois River, silver and bighead carp make up as much as 90% of the biomass. While the ponds within Eagle Marsh can experience ice cover in winter and high temperatures and depleted dissolved oxygen levels in summer, it may be possible for silver and bighead carp to survive until another high water event connects the basins. If silver or bighead carp were able to survive in the ponds of Eagle Marsh, successful spawning and recruitment is highly unlikely and would inhibit establishment. It is believed that silver and bighead carp require sufficient flow to keep fertilized eggs suspended for successful

reproduction (Gorbach and Krykhtin, 1980). Black carp reach sexual maturity in as little as five years and adult females can produce up to one million eggs per spawning event. It is unlikely that spawning would occur within Eagle Marsh. However, if adult black carp reach the marsh they would most likely be able to survive for long periods of time within the marsh. The availability of food sources in any of the waters around Eagle Marsh would likely be sufficient to sustain these species for several years. However, habitat that is suitable for reproduction is the limiting factor in the establishment of a breeding population within Eagle Marsh.

Team Rating: **Medium**
Certainty rating: Reasonably Certain

**Inland Silverside**

As a size-selective, planktivore, the inland silverside relies primarily on sight for feeding, which could be limited within and around the wetlands at the divide (Elston and Bachen, 1976). Spawning occurs in shallow water in areas with abundant vegetation, and includes all forms of plants, including dead leaves, tree roots, algal mats, or rooted aquatic plants of marshes (Hildebrand, 1922; Weinstein, 1986). The divide location might not be able to support the species because of winter freeze-out and/or low dissolved oxygen levels in the summer. Hubbs, et al. (1971) inferred that the native inland range for the inland silverside does not extend beyond the confluence of the Ohio and Mississippi Rivers because it cannot withstand winters farther north. However, Richards (1977) showed that the inland silverside can survive for at least two weeks at 34.7º F (1.5º C). Stoeckel and Heidinger (1988) demonstrated that inland silversides can be maintained over winter in aquaculture systems at temperatures above 59º F (15º C), when they were fed a prepared diet. They also demonstrated that inland silversides have a high mortality during extended periods of cold during the winter in unheated ponds and reservoirs. Overwintering mortality in the 80-90 percent range has been reported for the inland silverside in Rhode Island waters (Bengtson, 1982). Turbid water in the Graham-McCulloch Ditch and Junk Ditch may severely limit the ability of this species to forage, but Eagle Marsh does lie within the latitudinal boundaries of the inland silversides' native range thereby potentially limiting any effect freezing temperatures might have to prevent them from overwintering.

Team Rating: **Medium**
Certainty rating: Moderately Certain

**Northern Snakehead**

The northern snakehead's native range (latitude 24-53º N) and temperature tolerance 32º F – 86º F (0-30º C) indicates a species that, if introduced, could establish populations throughout most of the contiguous United States (Courtenay, Jr. and Williams, 2004). Northern snakeheads are naturally aggressive predators that could easily acclimate to the conditions in and around Eagle Marsh as long as there is an ample food supply, which appears to be the case. The snakehead's preference for shallow aquatic and wetland habitats, coupled with its ability to breathe air, make it more possible for this species to colonize the deeper wetlands in the divide location. It still may succumb to winter freeze-out, but it does have the ability to survive under the ice. They can be very opportunistic in their feeding habits, preying on everything from insect larvae to fish, frogs, and crustaceans. Northern snakeheads prefer shallow ponds and marshes with aquatic vegetation, which is similar to the aquatic habitat within Eagle Marsh. Additionally, northern snakeheads aggressively defend their nest and young fry, reducing predation on young snakehead by other fish.

Team Rating: **High**
Certainty rating: Reasonably Certain

**Parasitic Copepod**

The parasitic copepod (*Neoergasilus japonicus*) is very capable of persisting in eutrophic and polluted waters. The copepod demonstrates a rapid reproductive cycle and is capable of utilizing many different host species. It is highly likely that the copepod would be successful in establishing in Eagle Marsh, providing a host is available.

Team Rating: **High**
Certainty rating: Reasonably Certain

**Viral Hemorrhagic Septicemia Virus**

Survival and reproduction of common carp as a potential carrier of VHSv is considered high at this location during the spring. During spring runoff, the wetland divide and connecting ditches/streams would provide the necessary

habitat for occupation of any VHSv carrier/host fish species, at least temporarily. The adjacent rivers provide suitable habitat for all life stages of the common carp. The virus is capable of persisting outside of a host for several days when water temperatures are 37º F - 54º F (2.8º C - 12.2º C). It also demonstrates a rapid reproductive cycle and is capable of utilizing up to 28 known fish species in the Great Lakes Basin, including common carp (WDNR, 2012). However, the higher water temperatures that likely occur in the summer months at Eagle Marsh might prevent the establishment of VHSv during that time. It is highly likely that VHSv would be successful in establishing in fish populations already in Eagle Marsh, and nearby water ways, when water temperatures are appropriate.

Team Rating: **High**
Certainty rating: Reasonably Certain

**Ruffe and Tubenose Goby**

The ruffe is an aggressive species that possesses the ability to feed in darkness, cold temperatures and turbid conditions. Tubenose gobies are benthic species that consume a wide variety of invertebrates (USGS, 2011). They are often quite abundant in backwaters and lakes and seem to prefer dense vegetation. However, survival of a viable, reproducing population of ruffe and tubenose goby within the small ponds of Eagle Marsh may be unlikely due low water quality and high temperatures in summer months. However, the ponds within Eagle Marsh could provide the necessary habitat for occupation of these species until a suitable storm event occurred and the fish could pass into the Graham-McCulloch Ditch and move downstream.

Team Rating: **Medium**
Certainty rating: Moderately Certain

**Threespine Stickleback**

As a visual predator, the turbid ponds of Eagle Marsh and the Graham-McCulloch Ditch may be unsuitable for the threespine stickleback (Walker, 1997). Survival of a viable, reproducing population of threespine stickleback within the marsh is unlikely. However, the ponds may provide sufficient habitat for occupation of any of this species until a suitable storm event occurred and the fish could pass into the Graham-McCulloch Ditch within the Mississippi River Basin.

Team Rating: **Medium**
Certainty rating: Moderately Certain

## 4.4 Probability of ANS Spreading Across Aquatic Pathway into the New Basin

**General Considerations for Assigning Probability Ratings:**

> **High** - Sources of food and habitat suitable to the ANS are available, and the species has demonstrated capabilities to significantly expand range from locations where initially introduced.
>
> **Medium** - There are limited sources of food and suitable habitat, and/or the species has demonstrated limited ability to spread significant distances beyond areas where it has been introduced.
>
> **Low** - There are severely limited sources of food and suitable habitat, and/or the species has demonstrated very limited ability to spread beyond areas where it has been introduced.

**Asian Carp**

During a flood event there would likely be favorable conditions for a sufficient period of time to allow Asian carp to move through the pathway, especially since common carp have been observed on both sides of the temporary fence in 2011. Asian carp have demonstrated exceptional capabilities of spreading through large river systems, and will likely continue to do so. It is still uncertain whether they will attempt to travel up the Little River and Graham-McCulloch Ditch, but if these species reach the basin divide and surface water connections permit, it is highly likely that they would spread beyond the aquatic pathway into the larger waters of the Great Lakes Basin.

Team Rating: **High**
Certainty rating: Very Certain

**Inland Silverside**

Because of its small size, the inland silverside may be capable of utilizing minor hydrologic connections to spread. It is likely that if inland silversides were established in Eagle Marsh, they would be able to move downstream into the Great Lakes Basin during high flow events.

Team Rating: **High**
Certainty rating: Reasonably Certain

**Northern Snakehead**

It is very likely that the northern snakehead possesses the ability to spread from Eagle Marsh across the basin divide into the Great Lakes Basin if a population were established in close proximity to the pathway even though it is less certain if or how quickly the northern snakehead could reach the pathway. As an air breather that has even been known to move short distances over land, it is likely this species would be able to quickly move into Junk Ditch from the marsh. Under proper environmental conditions, this species could potentially transfer in either direction from Graham-McCulloch Ditch to Junk Ditch even if a hydrologic connection is not present.

Team Rating: **High**
Certainty rating: Very Certain

**Parasitic Copepod**

During the periodic surface water connections between the basins at Eagle Marsh, it is likely that a common carp hosting the parasitic copepod (*Neoergasilus japonicus*) could spread beyond the pathway to the Mississippi River Basin. The female copepod can detach and re-attach to another host fish. The time it takes and how often this happens is not certain. However, if common carp were on both sides of the temporary barrier, it is possible that a female copepod could detach, flow with the waters across/through the fence and re-attach to a new host fish across the divide. The likelihood is uncertain, but with spawning carp on both sides of the barrier movement of the copepod across the basin divide is possible.

Team Rating: **High**
Certainty rating: Reasonably Certain

**Viral Hemorrhagic Septicemia Virus**

This virus is capable of persisting outside of a host for several days, demonstrates a rapid reproductive cycle, and is capable of utilizing many different host species. It is highly probable that VHSv would be successful in spreading into exposed fish populations already on both sides of the wetland basin divide in the event infected fish reached the Portage Upstream pathway. During the the periodic surface water connection between the basins at Eagle Marsh, it is likely that the VHSv could spread beyond the pathway to the Mississippi River Basin. Since common carp were on both sides of the temporary barrier, it is possible that the virus could be passed through water on both sides of the temporary fence to new host fish across the divide.

**Table 7. Summary of individual probability elements and overall pathway viability rating (Mississippi River Basin to Great Lakes Basin). Certainty ratings for each element are in parentheses.**

| | | | Form 1 | Form 2 | Form 3a | Form 4 | Form 5 | |
|---|---|---|---|---|---|---|---|---|
| **Group** | **Common Name** | **Mode of Dispersal** | **Pathway Exists? (Sect. 3.6)** | **ANS Occurring Within Either Basin? (Sect. 4.1)** | **ANS Surviving Transit to Pathway? (Sect. 4.2.1)** | **ANS Establishing at Pathway? (Sect. 4.3)** | **ANS Spreading Across Aquatic Pathway into New Basin? (Sect. 4.4)** | **Aquatic Pathway Viability Rating** |
| fish | *Asian carp, silver carp, bighead carp, black carp* | swimmer | H (RC) | H (VC) | M/H (RC) | M (RC) | H (VC) | M |
| fish | *northern snakehead* | swimmer | | M (RC) | M (RC) | H (RC) | H (VC) | M |
| fish | *inland silverside* | swimmer | | H (RC) | M (MC) | M (MC) | H (RC) | M |
| **Overall Pathway Viability for Spread of ANS from Mississippi River Basin to Great Lakes Basin:** | | | | | | | | **M** |

**Table 8. Summary of individual probability elements and overall pathway viability rating (Great Lakes Basin to Mississippi River Basin). Certainty ratings for each element are in parentheses.**

| | | | Form 1 | Form 2 | Form 3a | Form 4 | Form 5 | |
|---|---|---|---|---|---|---|---|---|
| **Group** | **Common Name** | **Mode of Dispersal** | **Pathway Exists? (Sect. 3.6)** | **ANS Occurring Within Either Basin? (Sect. 4.1)** | **ANS Surviving Transit to Pathway? (Sect. 4.2.1)** | **ANS Establishing at Pathway? (Sect. 4.3)** | **ANS Spreading Across Aquatic Pathway into New Basin? (Sect. 4.4)** | **Aquatic Pathway Viability Rating** |
| fish | *threespine stickleback* | swimmer | H (RC) | H (VC) | M (RC) | M (MC) | H (RC) | M |
| fish | *Benthic fish ruffe and tubenose goby* | swimmer | | H (RC) | L (RC) | M (MC) | H (RC) | L |
| crustacean | *parasitic copepod* | parasite | | M (RC) | M (RC) | H (RC) | H (RC) | M |
| virus | *VHSv* | fish pathogen/ water column | | H (RC) | H (VC) | H (MC) | H (VC) | H |
| **Overall Pathway Viability for Spread of ANS from Great Lakes Basin to Mississippi River Basin:** | | | | | | | | **H** |

Team Rating: **High**
Certainty rating: Very Certain

**Ruffe and Tubenose Goby**

Ruffe and the tubenose goby have not been found in river systems similar to the Graham- McCulloch Ditch and Junk Ditch. If the fish were introduced into the wetlands and ditch network at the basin divide, they would likely be successful in passing through Eagle Marsh aquatic pathway into the Mississippi River Basin.

Team Rating: **High**
Certainty rating: Reasonably Certain

**Threespine Stickleback**

The threespine stickleback has been found in smaller river systems and downstream movement through the Graham McCulloch Ditch would be likely. If the threespine stickleback were introduced into the streams, ditches and wetlands at the divide, it is highly likely that the fish would survive and pass through Eagle Marsh pathway into the Mississippi River Basin during a suitable flood event.

Team Rating: **High**
Certainty rating: Reasonably Certain

# 5 Overall Aquatic Pathway Viability

As discussed in Sections 2.4 and 2.5, the determination of the likelihood of a viable aquatic pathway occurring at the Eagle Marsh location for each ANS of concern is the product of five probability elements (Equation 5). Thus, the probability of a viable pathway for a particular ANS of concern is equal to the lowest rating determined for each of the five probability elements (Table 7 and Table 8). The overall pathway viability for transferring ANS of concern from the Mississippi River Basin to the Great Lakes Basin was equal to the highest probability of a viable pathway for each ANS of concern in Table 7. At the Eagle Marsh location, all five species were rated “medium” and thus the overall pathway viability for transferring species from the Mississippi River Basin to the Great Lakes Basin is “medium”. The overall pathway viability for transferring species from the Great Lakes Basin is calculated the same way and is shown in Table 8. At the Eagle Marsh location, the overall pathway viability for transferring species from the Great Lakes Basin to the Mississippi River Basin is “high”. The last calculation is to determine the overall pathway viability for interbasin spread of ANS which is calculated by taking the highest of the overall ANS ratings for unidirectional transfer which were calculated in Tables 7 and 8. Thus, the overall probability that a viable aquatic pathway exists at the Eagle Marsh Pathway is “high”.

# 6 Conclusions

An aquatic pathway exists at Eagle Marsh because of a perennial wetland and connecting tributiaries within both the Mississippi and Great Lakes Basins (Graham-McCulloch and Junk Ditches, respectively) that are known to convey water across the basin divide for multiple days from a ten percent annual recurrence interval flood event. The overall pathway viability rating for Eagle Marsh is high because of the likelihood that VHSv would be able to transfer from the Great Lakes Basin through this pathway into the Mississippi River Basin by an infected fish (e.g., common carp); although this rating does not account for the potential for VHSv to establish and spread throughout the Mississippi River Basin. Two additional ANS threatening the Mississippi River Basin (i.e., threespine stickleback and parasitic copepod) were also assessed and given probability ratings of medium, largely due to a lower likelihood of them being able to arrive at and establish at the Eagle Marsh pathway. A total of three species (or groups) were found to pose a medium threat to the Great Lakes Basin from the Mississippi River Basin through Eagle Marsh: Asian carp (i.e., black carp, silver carp, and bighead carp), inland silverside, and northern snakehead. The limiting factor on these ANS was either their ability to arrive at the pathway (i.e., northern snakehead and inland silverside) or to be able to establish at the pathway (i.e., Asian carp and inland silverside).

## 6.1 Eagle Marsh Problem Statements

This section uses the results of the assessment to develop a list of statements that define and frame the nature and extent of the problems associated with the potential for spread of ANS through Eagle Marsh, in either direction between the Great Lakes and Mississippi River Basins.

- The interagency team evaluating the hydrology of Eagle Marsh rated it as a location where there is a high probability for the occurrence of an aquatic pathway between the basins, and estimated it to have a depth of up to 4.5 feet (1.4 m) at the basin divide from a ten percent annual recurrence interval storm event. For a larger storm event, between a 10 percent and 25 percent annual recurrence interval storm, surface water will overtop the non-engineered levee along the left descending bank of the Graham-McCulloch Ditch in several locations. In addition, the interagency pathway assessment team determined this levee to be in disrepair and unreliable to maintain a separation of the basins from a storm smaller than a ten percent annual recurrence interval storm.

- The primary ANS of concern for interbasin transfer from the Great Lakes Basin through Eagle Marsh into the Mississippi River basin are: VHSv, a pathogen; threespine stickleback, a small fish; and the parasitic copepod (Neoergasilus japonicus), a parasitic crustacean. The interagency team that evaluated the hydrology and conducted the biological evaluations rated the likelihood of ANS transfer from the Great Lakes through Eagle Marsh into the Mississippi River Basin as high. The rating was agreed to after collaboration among the interagency team, which assigned a high rating for VHSv, and a medium rating for parasitic copepod and threespine stickleback.

- The primary ANS of concern for interbasin transfer from the Mississippi River Basin through Eagle Marsh into the Great Lakes Basin are fish. The interagency team that evaluated the hydrology and conducted the biological evaluations rated the likelihood of ANS transfer from the Mississippi River Basin through Eagle Marsh into Great Lakes Basin as medium. This rating was also achieved through collaboration among the interagency team which assigned a medium rating to three types of fish: the Asian carps (i.e., silver, bighead and black carp), the inland silverside, and the northern snakehead.

- Asian carp have become well established in the Lower Wabash River, and adult Asian carp have been observed since 2004 below the Roush Dam on the Wabash River approximately 22 miles (35 km) downstream of Eagle Marsh. Although Asian carp have never been observed in the Little River or Graham-McCulloch Ditch, or detected by eDNA sampling in fall 2010 and summer 2011 in the streams that connect the Wabash River to Eagle Marsh, Asian carp do pose a threat for transfer into the Lake Erie Basin.

- There is a scarcity of stream gages and real data on water levels at, and in proximity to, the basin divide. Due to these uncertainties, additional and better information would be needed to support design and construction of any structural measure to prevent ANS movement through this location.

- There was uncertainty associated with biological ratings due to a variety of unknowns and uncertainties regarding the location and distribution of the large array of ANS that have been introduced to the waters of the U. S., as well as the life history requirements of each of these ANS, and the suitability of the habitat within the waterways between the current nearest locations of the ANS and Eagle Marsh.

- There are other pathways or vectors whereby human beings, terrestrial animals, and avifauna could facilitate ANS arriving at Eagle Marsh and transferring between the basins. These include, but not limited to: collection of bait in one basin and release in the adjacent basin; ANS adhering to recreational boats in one basin and then being released when the vessel is placed in a water body in the adjacent basin; release of imported aquaria fish and other exotic species; attachment of ANS to waterfowl or other migratory species, etc.

## 6.2 Eagle Marsh Opportunity Statements

While it is not the purpose of this assessment to produce and evaluate an exhaustive list of potential actions to prevent ANS transfer at this location, some opportunities were still identified that, if implemented, could prevent or reduce the probability of ANS spread between the basins at Eagle Marsh. The following list of opportunities is not specific to the USACE, but incorporates a wide range of possible applicable authorities, capabilities, and jurisdictions at the Federal, state, and local levels:

- Structural solutions could provide the highest level of confidence in preventing interbasin transfer of ANS through the Eagle Marsh from either direction, provided adverse flood impacts can be avoided. After extensive collaboration and coordination with interested Federal, state, and local stakeholders, the USACE has identified several structural opportunities or measures that could be implemented by someone to prevent or reduce the likelihood of ANS transfer between the basins through Eagle Marsh. These measures are presented in a separate USACE report entitled "Eagle Marsh ANS Controls Report".

- There are other broad categories of technology for potential active measures that may or may not require a structure to prevent ANS transfer at this location, such as:

    - Chemical deterrents to establish non-habitable environment at or within connecting streams.

    - Biological control measures that prevent ANS reproduction or prevent the ability of ANS to establish a sustainable population.

    - Physical removal of ANS at their current locations.

  In addition to the above structural opportunities for Eagle Marsh, there are other opportunities that may prevent the spread of ANSbetween the basins, many of which are beyond the jurisdiction of the Corps to implement but that might be implementable by other governmental and non-governmental organizations. These include, but are not limited to, the following:

- New or modified regulations or ordinances prohibiting the establishment of drainage ways that connect the Mississippi River tributaries with tributaries of Lake Michigan and Lake Erie.

- Explore and support measures to reduce the potential source populations of ANS.

    - Increase commercial and recreational harvest, specifically bighead and silver carp.

    - Implement measures to interfere with successful reproduction of ANS.

    - Introduce biological controls such as diseases specific to particular ANS.

- Public education to:

    - Prevent bait bucket transfers of ANS.

    - Prevent transfer via boating and recreational equipment.

    - Prevent transfer due to religious or cultural ceremonies.

    - Identify and report the observation and collection of ANS to the appropriate authorities.

- Support research on the biology of ANS so that risk of ANS transfer can be better understood

    - Life history.

    - Habitat requirements.

    - History of invasiveness.

- Improve and increase field sampling and monitoring for the presence of ANS to support

better informed water resource management decisions within the state and region.

  - Develop integrated ANS sampling and analysis plan utilizing eDNA and conventional biological sampling events at times when ANS would be expected to be present in the area, such as during flood events.

  - Target, encourage, and train recreational fishermen, boaters and other direct users of the surface waters of the state of Indiana to identify, report, collect and deliver ANS to the appropriate agencies.

- Prevent introductions of additional ANS

  - Improve regulations for bilge releases.

  - Improve regulations on the pet industry.

  - Impose regulations on the live bait industry.

  - Improve regulations on the aquaculture industry.

None of the opportunities identified above are exclusive of the others. In fact, any single structural measure to prevent ANS transfer through Eagle Marsh would likely benefit from corresponding development and implementation of one or more of the other types of opportunities identified. The results of this assessment may also aid in the implementation of, and future updates to, the Indiana Aquatic Nuisance Species (ANS) Management Plan.

# 7 References:


ANSTF. (1996). Generic Nonindigineous Aquatic Organisms Risk Analysis Review Process for Estimating Risk Associated with the Introduction of Nonindigineous Aquatic Organisms and How to Manage for that Risk. Report to the Aquatic Nuisance Species Task Force. Risk Assessment and Management Committee, Aquatic Nuissance Species Task Force.

Bengtson, D.A. (1982). Resource partitioning by *Menidia menidia* (L.) and *Menidia beryllina* (Cope) in two Rhode Island estuaries. Ph. D. dissertation. University of Rhode Island, Kingston, RI.

Bowen, A.K. and M.A. Goehle. (2011). Surveillance for ruffe in the Great Lakes, 2011. http://www.fws.gov/midwest/alpena/documents/2011-GL-Ruffe-Report.pdf

Courtenay, Jr., W.R., and J.D. Williams. (2004). Snakeheads (*Pisces, Channidae*)— A Biological Synopsis and Risk Assessment. USGS Circular 1251.

Cummings, K.S., C.A. Mayer & L.M. Page. (1992). Survey of the freshwater mussels (*Mollusca: Unionidae*) of the Wabash River drainage. Final Report to the Nongame and Endangered Wildlife Program, Division of Fish & Wildlife, Indiana Department of Natural Resources. Indianapolis. 201 pp.

Dejean, T., A. Valentini, A. Duparc, S. Pellier-Cuit, F. Pompanon, P. Taberlet, and C. Miaud. (2011). Persistence of environmental DNA in freshwater ecosystems. PLoS One 6(8): e23398.

Dong, S., and D. Li. (1994). Comparative studies of the feeding selectivity of silver carp, Hypophthalmichthys molitrix, and bighead carp, Aristichthys nobilis. Journal of Fish Biology. 44:621-626.

Elston, R.A. and B. Bachen. (1976). Diel feeding cycles and some effects of light on feeding intensity of the Mississippi silverside, *Menidia audens*, in Clear Lake, California. Transactions of the American Fisheries Society. 105: 84-88.

Fishbase. (2011). Froese, R. and D. Pauly. Editors. World Wide Web electronic publication: www.fishbase.org.

Fleming, T. (2006). Some Hydrogeological Observations at Eagle Marsh. Unpublished report

Fuller, P. and L. Nico. (2012). *Menidia beryllina*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=321

Global Invasive Species Database. Accessed May 24, 2012: http://www.issg.org/database/species/ecology.asp?si=544&fr=1&sts=sss&lang=EN.

Gorbach, E.I., and M.L. Krykhtin. (1980). Maturation rate of the white amur *Ctenopharyngodon idella* and silver carp *Hypophthalmichthys molitrix* in the Amur River. Journal of Ichthyology 21(4):835–843.

Graham, J.B. (1997). Air-breathing fishes: evolution, diversity, and adaptation. Academic Press. San Diego, California. xi +. 299 pp.

Gray, J.A.B., and A.C.G. Best. (1989). Patterns of excitation of the lateral line of the ruffe. Journal of the Marine Biological Association of the United Kingdom 69:289-306.

Hildebrand, S.F. (1922). Notes on habits and development of eggs and larvae of the silversides *Menidia menidia* and *Menidia beryllina*. Bulletin of the U.S. Bureau of Fisheries, vol.38, pp.113-120.

Hudson, P.L., and C.A. Bowen II. (2002). First record of *Neoergasilus japonicus* (*Poecilostomatoida: rgasilidae*), a parasitic copepod new to the Laurentian Great Lakes. Journal of Parasitology. 88(4):657-663.

INDNR. (2006). Water Resource Availability in the Maumee River Basin, Indiana - Executive Summary. Internet resource: http://www.in.gov/dnr/water/files/maumee_basinsums.pdf

INDNR. (2010). Indiana County Endangered, Threatened and Rare Species List, County: Allen. Online Resource:http://www.in.gov/dnr/naturepreserve/files/np_allen.pdf

Ishimatsu, A. and Y. Itazaw. (1981). Ventilation of the air-breathing organ in the snakehead *Channa argus*. Japanese Journal of Ichthyology. 28(3): 276–282.

Jennings, D.P. (1988). Bighead carp (*Hypophthalmichthys nobilis*): a biological synopsis. Biological Report. U.S. Fish and Wildlife Service. 88(2): 1-35

Jerde, C.L., A.R. Mahon, L. Chadderton, and D.M. Lodge. (2011). “Sight-unseen” detection of rare aquatic species using environmental DNA. Conservation Letters. 00: 1-8.

Jirasek, J., A. Hampl, and D. Sirotek. (1981). Growth morphology of the filtering apparatus of silver carp (Hypophthalmichthys molitrix). Gross anatomy state. Aquaculture. 26:41-48.

Laird, C.S., and L.M. Page. (1996). Non-native fishes inhabiting the streams and lakes of Illinois. Illinois Natural History Survey Bulletin, vol.35(1), pp.1-51.

Little River Wetlands Project. (2011a). Geography of the Little River Valley. Online Resource: http://www.lrwp.org/geo.php

Little River Wetlands Project. (2011b). Habitats and Wildlife at LRWP’s Project. Online Resource: http://www.lrwp.org/habitats.php

Maumee RAP. (2006). Draft Maumee Area of Concern Stage 2 Watershed Restoration Plan, Volume I. Maumee Remedial Action Plan, January 2006. Prepared by Maumee RAP and Duck & Otter Creeks Partnership, Inc.

McFall, L., S. Martin, and C. Christensen. (2000). 1998 Upper Wabash River Basin Sampling Sites and Stream Standard Violations. Indiana Department of Environmental Management, Office of Water Management, Assessment Branch, Surveys Section, Indianapolis, Indiana. 46206-6015. IDEM 032/02/022/2000

Minamoto, T., H. Yamanaka, T. Takahara, M.N. Honjo, and Z. Kawabata. (2011). Surveillance of fish species composition using environmental DNA. Limnology. DOI: 10.1007/s10201-011-0362-4.

NatureServe. (2010). NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Accessed: July 18, 2011. http://www.natureserve.org/explorer

Nico, L.G., J.D. Williams, and H.L. Jelks. (2005). Black Carp: biological synopsis and risk assessment of an introduced fish. American Fisheries Society, Special Publication 32. Bethesda, Maryland.

Nico, L.G., and H.L. Jelks. (2011). The Black Carp in North America: An Update. American Fisheries Society Symposium 74: 89-104. Bethesda, Maryland.

NOAA. (2011). Great Lakes Nonindiginous Aquatic Species Information System (GLANSIS). National Oceanic and Atmospheric Administration. http://www.glerl.noaa.gov/res/Programs/glansis/watchlist.html.

ODNR. (2011a). Lake Erie Facts. Internet resource: http://www.dnr.state.oh.us/tabid/7828/default.aspx.

ODNR. (2011b). Maumee State Scenic River Internet resource: http://www.dnr.state.oh.us/tabid/1863/default.aspx

ODNR. (2011c). Maumee and Sandusky River Spawning Runs: Walleye Fishing Forecast for 2011. http://www.dnr.state.oh.us/Home/FishingSubhomePage/FishingProspectsandReports/fishingfreportwalleyeprospects/tabid/6434/Default.aspx

Page, L.M., and B.M. Burr. (1991). A Field Guide to Freshwater Fishes of North America North of Mexico. The Peterson Field Guide Series. Houghton Mifflin Harcourt. Boston, MA. 688 pp.

Pyron, M., and T.E. Lauer (2004). Hydrological variation and fish assemblage structure in the middle Wabash River. Hydrobiologia. 525: 203–213.

Skall, H.F., N.J. Olesen, and S. Mellergaard. (2005). Viral hemorrhagic septicemia virus in marine fish and its implications for fish farming – a review. Journal of Fish Diseases. 28:509-529.

Stoeckel, J.N. and R.C. Heidinger. (1988). Overwintering of the inland silverside in southern Illinois. North American Journal of Fisheries Management. 8(1): 127-131.

USACE. (2010). Great Lakes and Mississippi River Interbasin Study Other Pathways Preliminary Risk Characterization. Great Lakes and Ohio River Division. United States Army Corps of Engineers.

USACE. (2011a). GLMRIS Focus Area 2 Study Plan. Great Lakes and Ohio River Division. United States Army Corps of Engineers.

USACE. (2011b). Non-Native Species of Concern and Dispersal Risk for the Great Lakes and Mississippi River Interbasin Study.

USFWS. (1996). Ruffe control plan. Submitted to the Aquatic Nuisance Species Task Force by the Ruffe Control Committee. Available at: http://www.fws.gov/midwest/ashland/ruf_cont.html

USFWS. (2002). Black Carp Invasive Species Program Fact sheet. Accessed March 23, 2012: http://www.fws.gov/southeast/hotissues/Black_Carp_FS.pdf

USDA. (1969). Soil Survey of Allen County Indiana. USDA Soil Conservation Service in cooperation with Purdue Agricultural Experiment Station.

USGS. (2011). Nonindigenous Aquatic Species (NAS) website. Retrieved from http://nas.er.usgs.gov. United States Geological Survey.

USGS. (2012). Nonindigenous Aquatic Species (NAS) website http://nas.er.usgs.gov/about/faq.aspx

Verigin, B.V., A.P. Makeyeva, and M.I. Zaki Mokhamed. (1978). Natural spawning of the silver carp (Hypophthalmichthys nobilis), the bighead carp (Aristichthys nobilis), and the grass carp (Ctenopharyngodon idella) in the Syr-Dar'ya River. Journal of Ichthyology. 18(1):143-146.

Walker, J. (1997). Ecological morphology of lacustrine threespine stickleback *Gasterosteus aculeatus* L. Biological Journal of the Limnean Society. 61: 3-50.

WDNR. (2012). VHS 101 Fact Sheet. Wisconsin Department of Natural Resources. Website accessed April 10, 2012: http://dnr.wi.gov/fish/vhs/vhsfacts.html#3a

Weinstein, M.P. (1986). Habitat suitability index models: inland silverside. U.S. Fish and Wildlife Service Biol. Rep. 82(10.120). 25 pp.

Williamson, C.J., and J.E. Garvey. (2005). Growth, fecundity, and diets of newly established silver carp in the middle Mississippi River. Transactions of the American Fisheries Society 134(6): 1423-1430.

Wootton, R.J. (1976). The Biology of the Stickleback. Academic Press. London.

# Appendix A

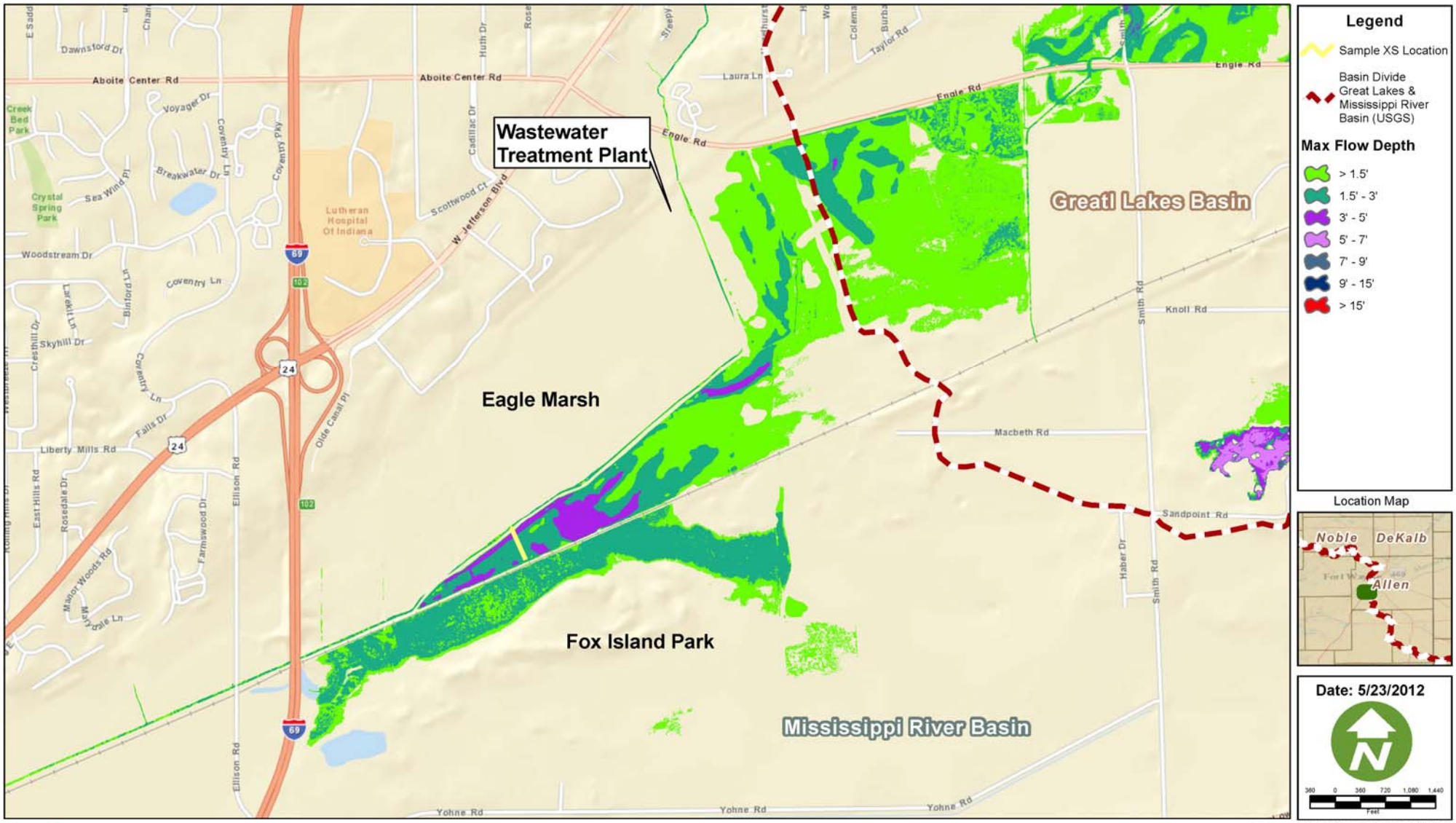
# Depth Grids for Eagle Marsh at Various Flood Events

Eagle Marsh Report

November 2012

# St. Marys 99% Flood - Flow Depths

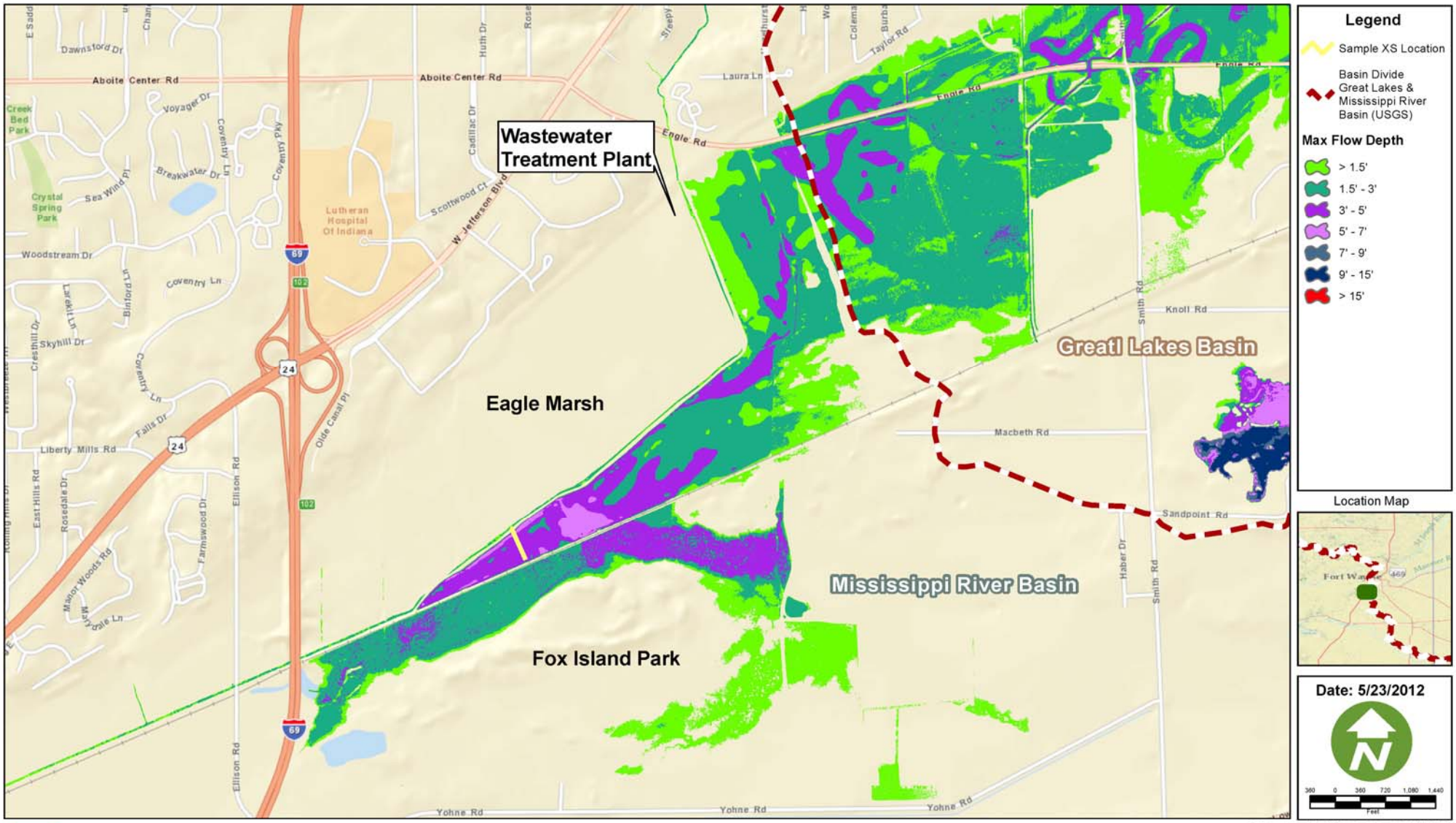
GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# St. Marys 10% Flood - Flow Depths

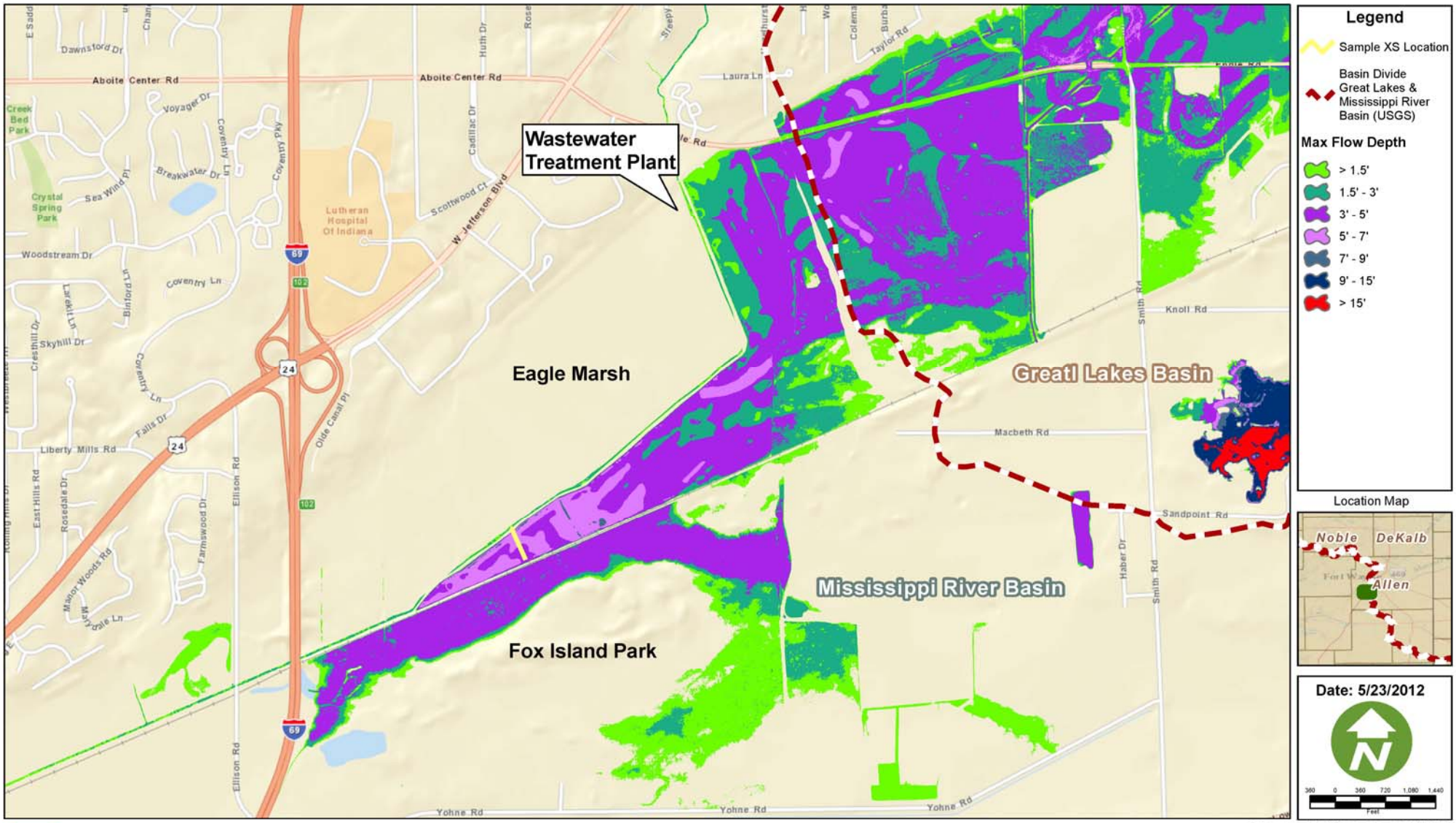
GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# St. Marys 4% Flood - Flow Depths

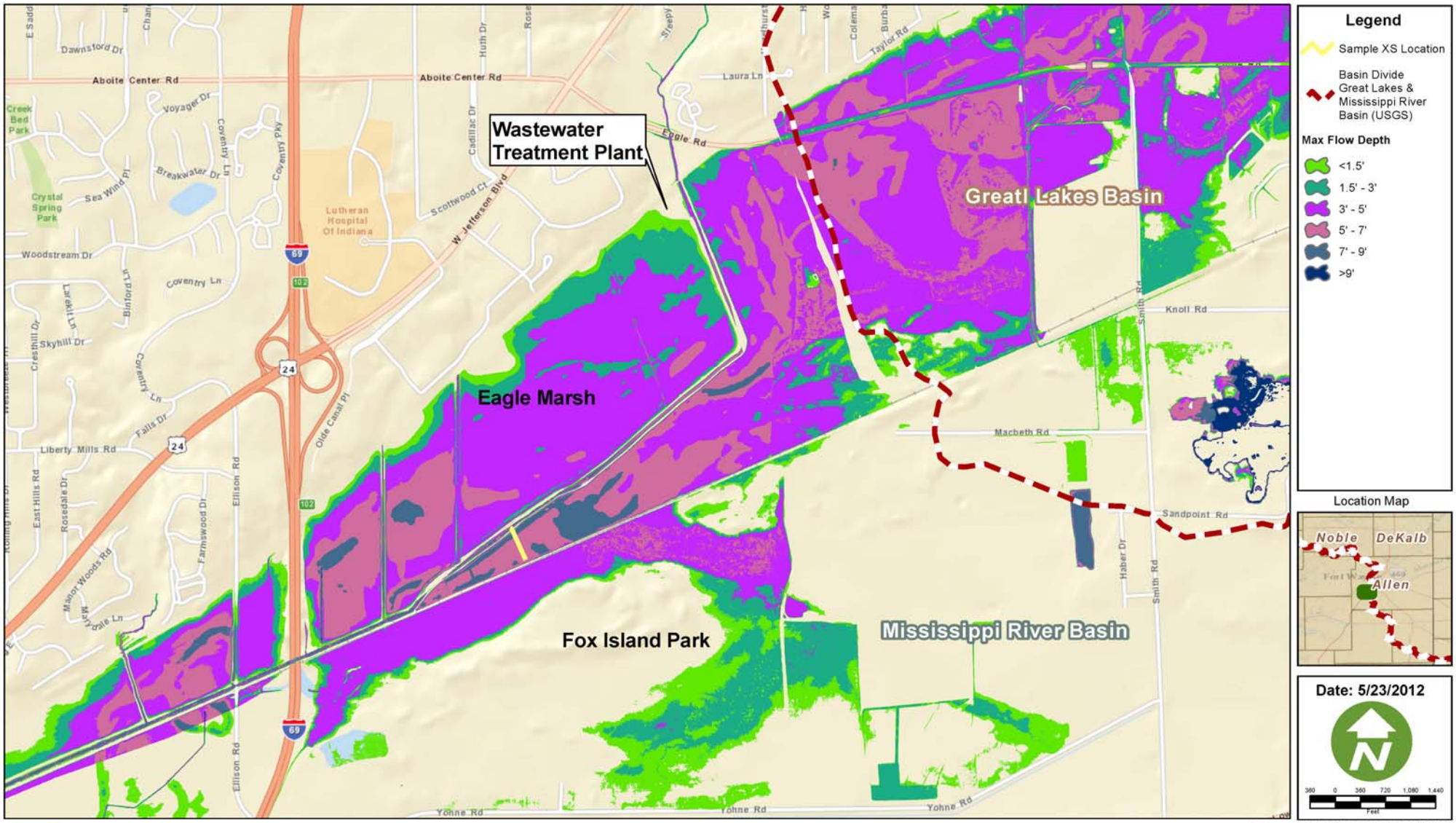
GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# St. Marys 1% Flood - Flow Depths

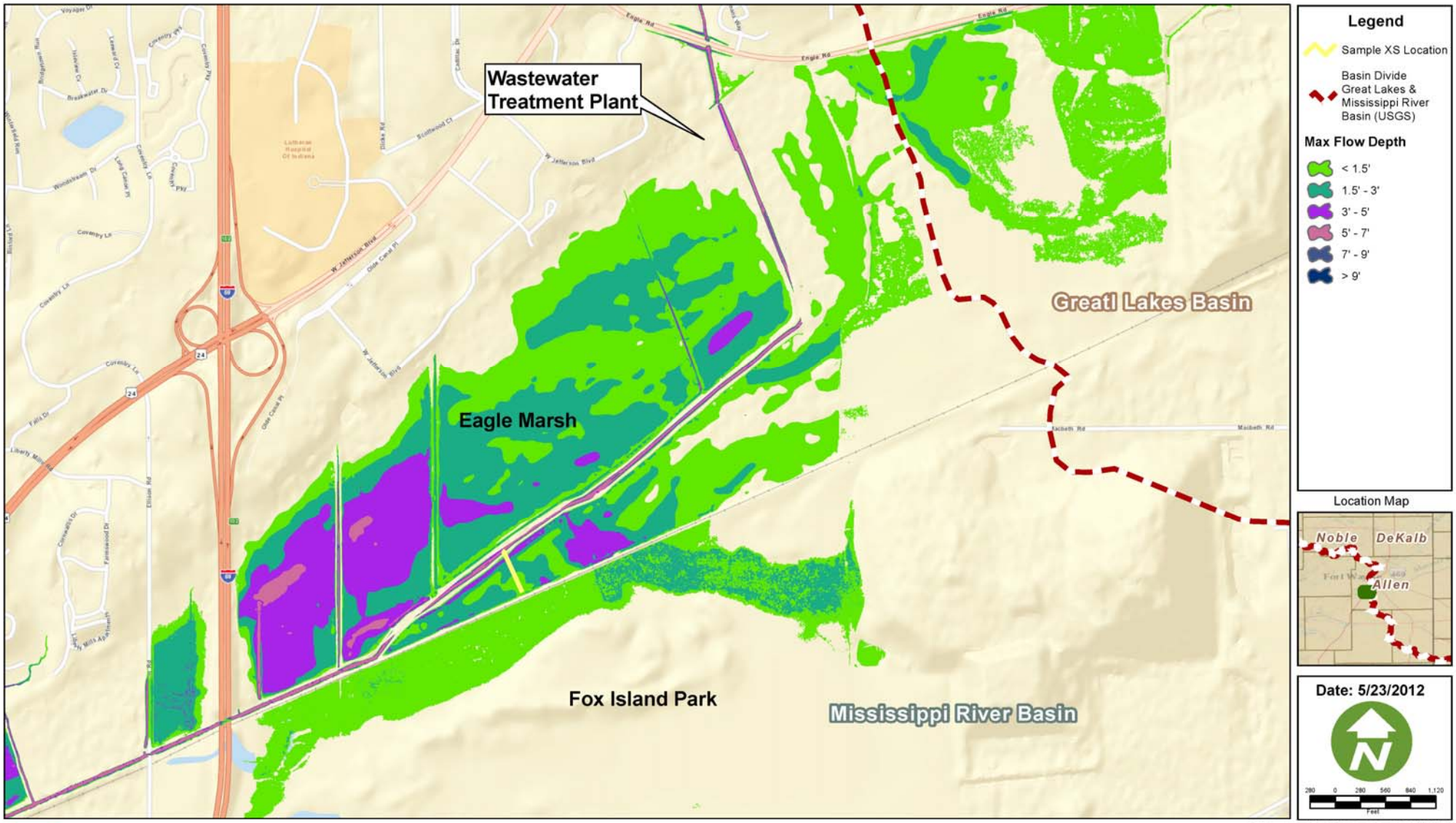
GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# Graham McCulloch 99% Flood - Flow Depths

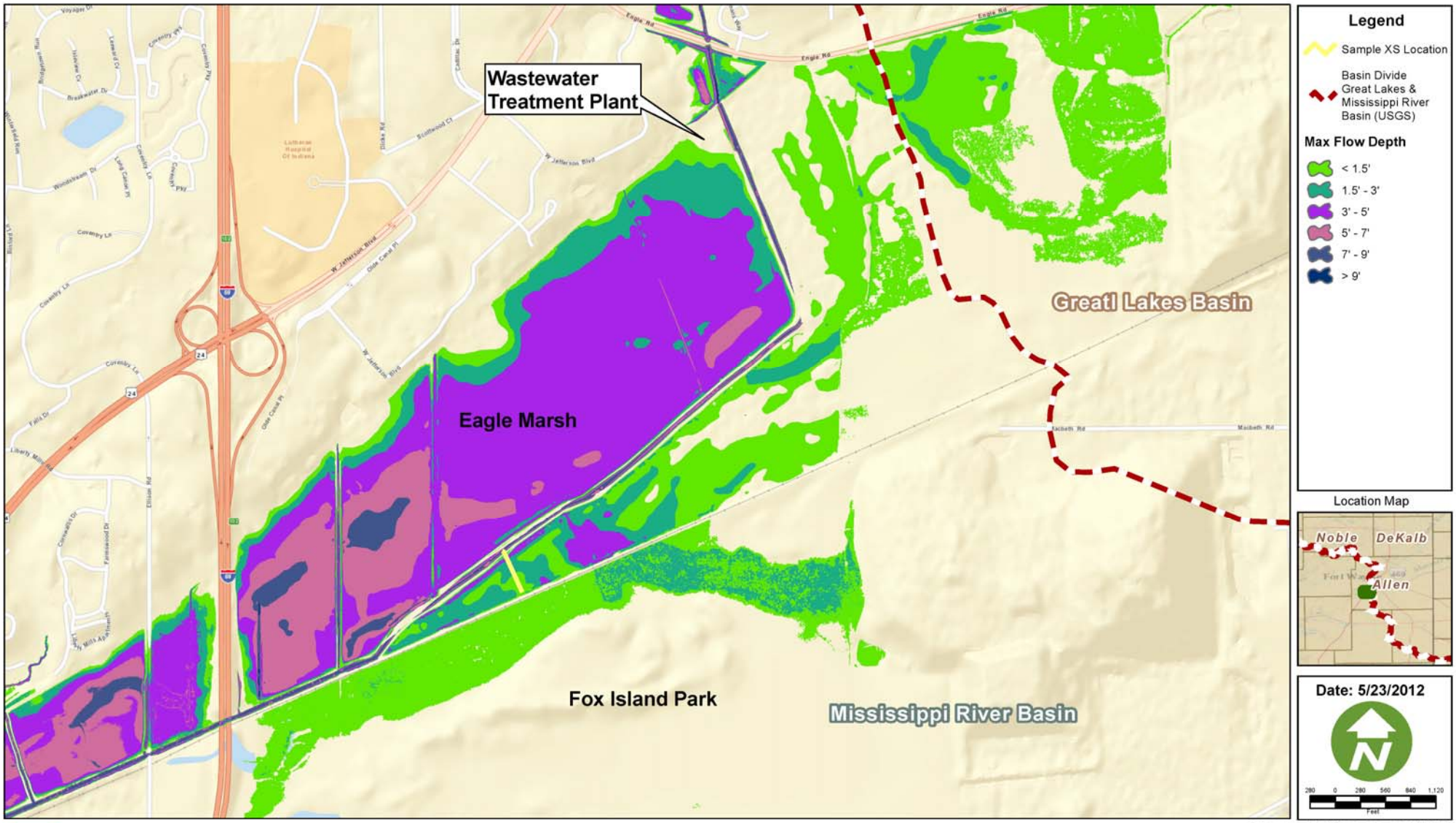
GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# Graham McCulloch 10% Flood - Flow Depths

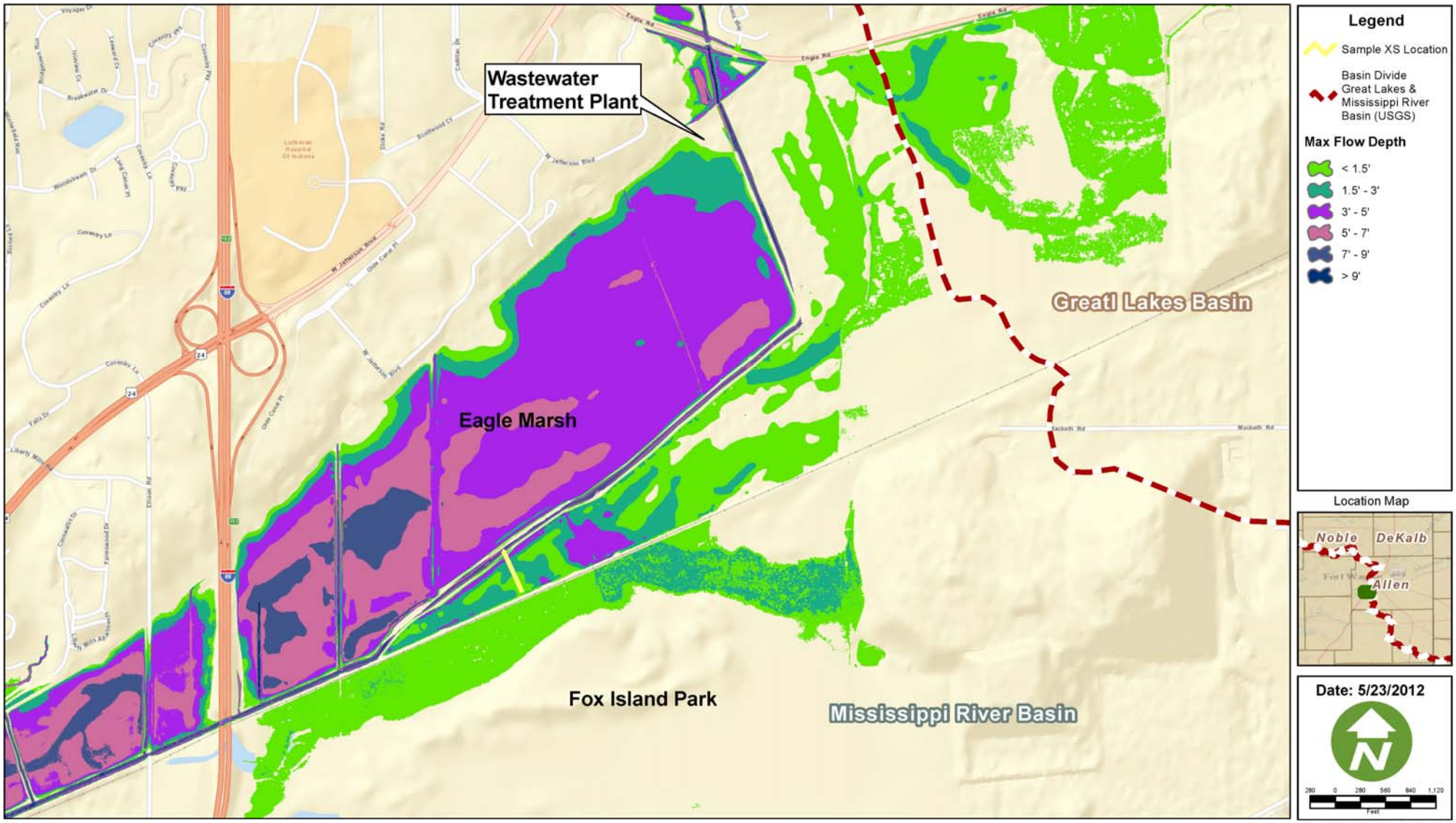
GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# Graham McCulloch 4% Flood - Flow Depths

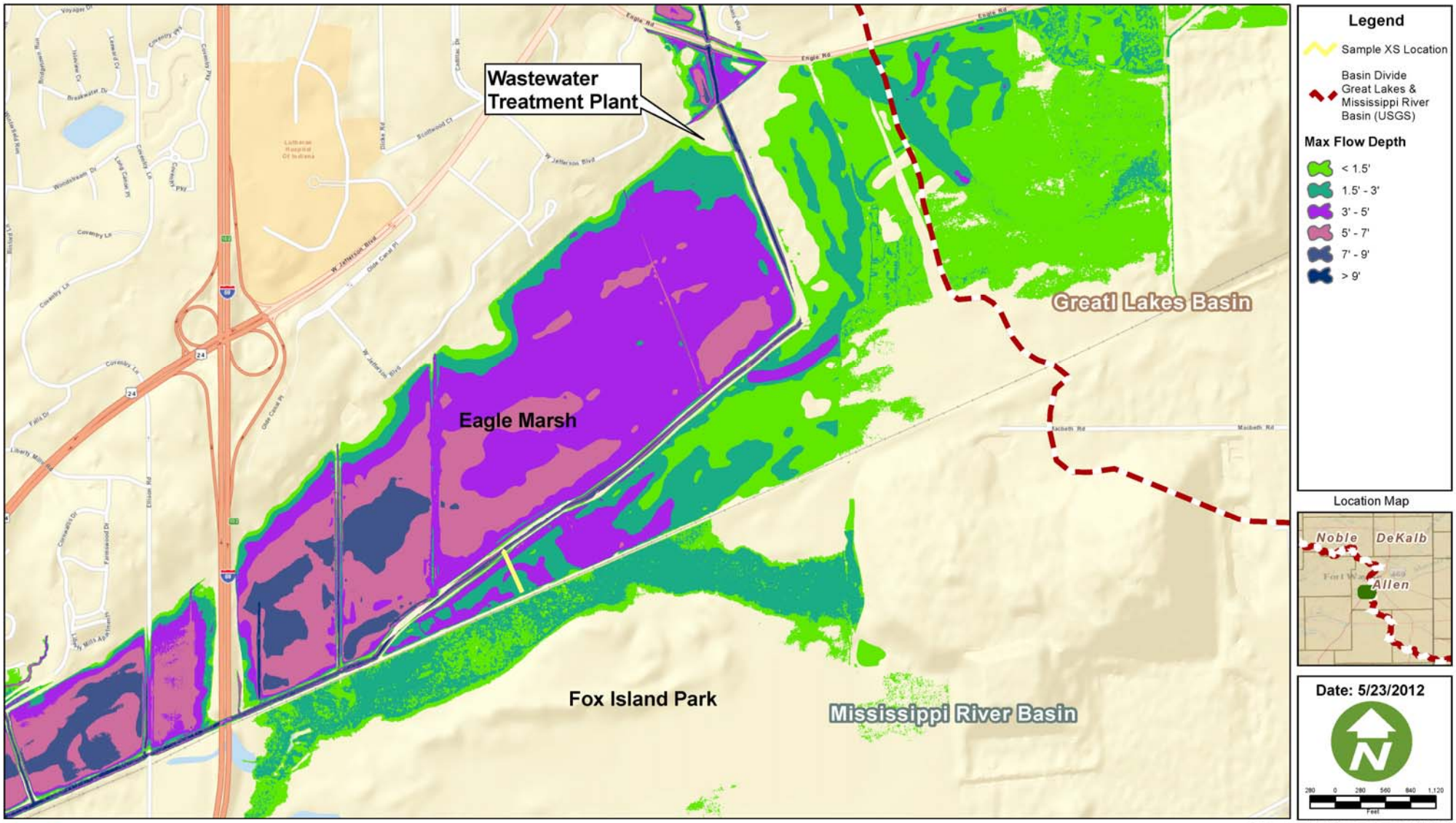
GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# Graham McCulloch 1% Flood - Flow Depths

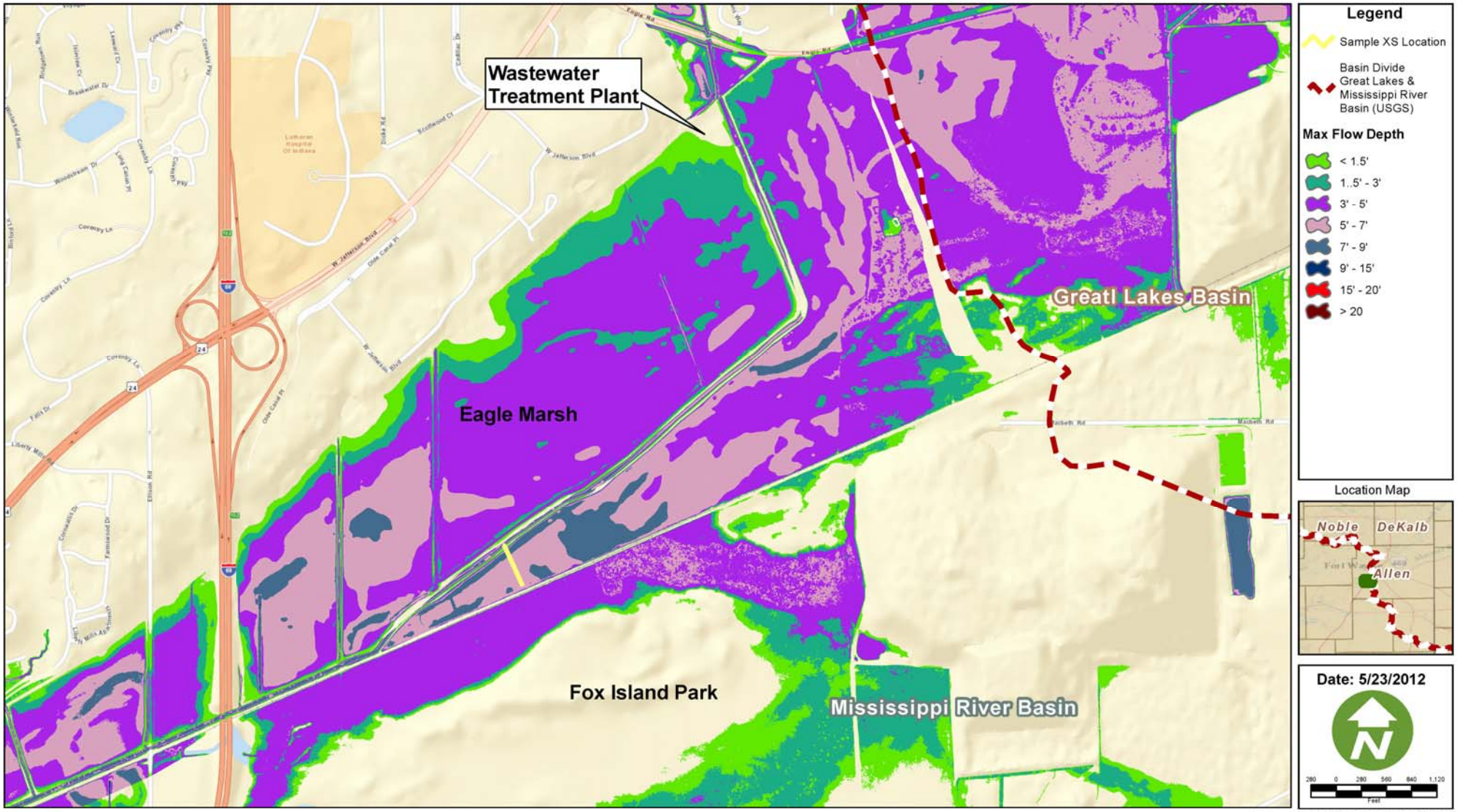
GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# 1% Flood Depths for Events both Graham McCulloch and St. Marys Watershed

GLMRIS




Coordinate System: NAD 1983 StatePlane Indiana East FIPS 1301 Feet
Projection: Transverse Mercator
Datum: North American 1983

# Appendix B

# Evaluation Forms for each ANS of Concern Selected for Eagle Marsh

## Eagle Marsh, Allen County, IN - Asian Carp

### 1. Probability of aquatic pathway existence

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating Flow into GLB | Certainty | Rating Flow into MRB | Certainty |
|---|---|---|---|---|---|
| | USACE, Detroit - Hydraulic Engineer | High | RC | High | RC |
| | USACE, Louisville - Hydraulic Engineer | High | RC | High | RC |
| | USGS - Hydrologist | High | RC | High | RC |
| | INDNR - Engineering Geologist | High | RC | High | RC |
| | **Team Ratings** | **High** | **RC** | **High** | **RC** |

**1. How do you rate the likelihood of the existence of a viable aquatic pathway at the subject location? Assume a viable aquatic pathway is any location where untreated surface water flow across the divide is deemed likely to occur and connect headwater streams in both basins from any storm up to the 1% annual return frequency storm.**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Perennial streams and wetlands or intermittent stream known/documented to convey significant volumes of water across the basin divide for days to weeks multiple times per year. |
| Medium | Intermittent stream capable of maintaining a surface water connection to streams on both sides of the basin divide continuously for multiple days from a 10% annual return frequency storm; or, location of wetland spanning basin divide which maintains significant ponds that are likely to become inter connected and connect with streams on both sides of the basin divide from a 10% annual return frequency storm. |
| Low | Intermittent stream or marsh forming a surface water connection between streams on either side of the basin divide from larger than a 1.0% annual return frequency storm. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: USACE: Based upon numerical modeling developed as part of the parallel ANS Controls Report for the existing conditions, a connection appears to occur for storm events on the Graham McCulloch Ditch with a 10% chance annual exceedence event and less frequent events by way of overtopping the left descending bank (LDB) berm in low areas near the berms downstream-most section. Annual events on the St. Marys River make flow reverse direction in the Junk Ditch, and will cross the natural drainage divide, entering storage created by the LDB berm and the railroad embankment to the south ("Eagle Marsh southern storage area"). Additional storage is connected to this area in the Fox Island Park south of the railroad embankment, by way of a 4-foot diameter culvert through the railroad embankment. Two 18-inch (approximate) diameter pipes connect the Graham McCulloch Ditch to this storage area, but have flap-gates on the Graham McCulloch side of the berm; it is assumed that they are effective in preventing flow from the Graham McCulloch Ditch into this Eagle Marsh southern storage area until the LDB berm is overtopped. The 18-inch pipes are in poor condition, but it is assumed that they are still functional to drain waters ponding in the Eagle Marsh southern storage area. Storms events equal to or less frequent than the 1% chance exceedence event on the St Marys River are required to overtop the LDB berm.

As indicated above, the unsteady HEC-RAS modeling indicates that the greatest risk of a hydraulic connection results from flooding on the Graham McCulloch Ditch, and the frequency of occurrence is estimated as a 10% chance exceedence event or less frequent. Little data is available to support the definition of these frequency events, as the nearest flow or stage gage in this watershed is many miles downstream in Huntington, Indiana. Peak flows used for the 10%-, 4%-, 2%-, and 1%-chance annual exceedence events came from the Coordinated Discharge Graph "Ungaged Streams in Allen County", dated March 1982. Values for other frequency event peak flows were interpolated or extrapolated from these values. It is believed that these Coordinated Discharges were developed from regression equations, and therefore do not take into account the specific hydrology of the Graham McCulloch watershed. Even if relatively accurate upon creation of these Coordinated Discharges, it is believed that the watershed has undergone significant development. The shape of the hydrograph also had to be estimated. Significant data is available from the numerous gages in the Ft. Wayne area for the St. Marys River and other rivers and tributaries in that area, although several have very limited periods of record; however, there is significantly greater confidence in the flow information on the St. Marys River due to the large amount of information for that watershed that was made available by IDNR. The HEC-RAS model was able to be calibrated to historic events on the St. Marys River, with numerous high water marks available for one event. Definition of the LDB Berm profile used survey data provided by the NRCS of the berm and the Eagle Marsh area as a whole from 2006 when the property was purchased for the re-development of the wetlands. This data was believed to be of greater accuracy than the 2009 LIDAR data provided by the USGS and Allen County, although the 2006 survey data for the LDB berm is higher than the 2009 LIDAR on the order of 1-2 feet.

The frequency of a hydraulic pathway by overtopping described above is completely dependent upon the assumption that the profile of the LDB berm does not change. Multiple engineers who have visited the site agree that the integrity of the LDB berm is questionable; several slope failures, steep slopes, rodent burrows and other defects are visible, and there is no information regarding the level of design or construction methods. The berm therefore does not meet current geotechnical standards. It is expected that as time progresses, additional failures or a breach will occur. While the frequency of overtopping by a Graham McCulloch Ditch 10% chance exceedence event or greater would normally warrant a rating of Medium for flows into the Great Lakes Basin per the above criteria, this site is given a rating of High due to the expectation that failures of the LDB berm are likely, increasing the frequency of aquatic pathway development. Likewise, existing culverts through the LDB berm provide an annual connection for floods on the St. Marys watershed. Even if these pathways were removed, the poor integrity of the berm warrants a higher rating due to the increased likelihood of interconnection at more frequent events than modeling currently predicts

USGS: The H and H evaluation provides compelling indications for the high potential of a connection to develop between the MRB and GLB basins through overtopping of the berm along the Graham McCullough Ditch. The lack of discharge measurements on Graham McCulloch Ditch prevents a more refined analysis of flood stages. Flooding from the St Marys River appears to be a less probable cause of a connection at frequencies greater than 1 percent. The poor berm integrity as a levee, in combination with recurrent flooding, increases the probability of an interbasin connection to an unknown extent.

## Eagle Marsh, Allen County, IN - Asian Carp

### 2. Probability of ANS occurring within either basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Detroit - Biologist | High | VC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | VC | | |
| | USFWS - Fish Biologist | High | VC | | |
| | **Team Rating** | **Medium** | **VC** | | |

### 2. How do you rate the probability of ANS occuring within either basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS exists on connected waterways in close enough proximity to be capable of moving to the aquatic pathway within 20 years. |
| Medium | Target ANS exists on connected waterways, but based on current proximity and mobility, is considered incapable of moving to the aquatic pathway within 20 years. |
| Low | Target ANS is not known to exist on a connected waterway. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: Silver carp and bighead carp are established throughout the Mississippi River basin, and occur on the Wabash River. Both silver carp and bighead carp have been recorded in the Wabash River near the mouth of the Little River (USGS 2011) which leads to Graham McCulloch Ditch. Neither species have been detected in the Little River or Graham McCulloch Ditch. Black carp may be established in portions of the lower Mississippi River basin. Black carp have also been reported in the Mississippi River upstream of the mouth of the Ohio River. The known distribution of black carp is not as extensive as that of the silver and bighead carp.

## Eagle Marsh, Allen County, IN - Asian Carp

### 3. Probability of ANS surviving transit to aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | 3A Rating | Certainty | 3B Rating | Certainty |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Detroit - Biologist | Medium | RC | Low | RC |
| | INDNR - AIS Coordinator | Medium | RC | Low | RC |
| | USGS - Fishery Biologist | High | RC | Medium | MC |
| | USFWS - Fish Biologist | High | MC | Low | RC |
| | **Team Ratings** | **High/Med** | **RC** | **Low** | **RC** |

**3A. How do you rate the probability of ANS surviving transit to aquatic pathway through connecting streams?**

**3B. How do you rate the probability of ANS surviving transit to aquatic pathway through other means?**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to successfully navigate through the aquatic pathway and/or through other means to arrive at the subject pathway within 10-20 years. |
| Medium | Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through the aquatic pathway or through other means to arrive at the subject pathway within 20-50 years. |
| Low | Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations by aquatic pathway or other means to arrive at subject pathway within next 50 years. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: 3A. Probability of ANS Surviving Transit to Aquatic Pathway Through Connecting Streams.

Spawning of silver and bighead carp is initiated by rising water levels following heavy rains (Jennings 1988; Verigin 1978). Both species are strong swimmers and silver carp are capable of jumping considerable distances out of the water (up to 12 feet). There are no obstacles in the Little River that would permanently prevent upstream migration of silver carp. The low head dam at Huntington, Indiana (Section 2.7) could possibly be jumped by the silver carp and offers even less prevention as flow increases. All Asian carp species in the Mississippi River basin would likely be able to bypass the dam during high flow events when it becomes completely inundated. The proximity of the silver and bighead carp to Eagle Marsh, combined with their history of dispersal throughout the Mississippi River basin, indicates these species are capable of utilizing this pathway if hydrological conditions allow. Habitat present within most of Little River and all of Graham McCulloch Ditch is not ideal habitat for silver and bighead carp, which are native to and thrive in large rivers, but it is not known to what extent this may prevent migration or passage. Bighead carp are zooplanktivorous, while silver carp consume smaller phytoplankton and fine particulate organic matter (Williamson and Garvey 2005). Sufficient forage is available throughout the Wabash River and Little River for both silver and bighead carp. Forage abundance and diversity decreases moving up the Graham McCulloch Ditch and into Eagle Marsh as water quality and volume decrease. Adult black carp are primarily molluscivores. However, they will opportunistically consume a wide variety of food items (USFWS, 2002). Juvenile black carp have a diet more similar to silver and bighead carp, consisting primarily of zooplankton (USACE, 2011b). The diet of juvenile black carp may allow them to survive in areas unsuitable for adults. The habitat of black carp is very similar to the grass carp (Ctenopharyngodon idella) (Nico et al, 2005). It is believed that black carp should be able to colonize the same areas of the United States where the grass carp have established ( USFWS, 2002)." The rating of Medium/High for their ability to reach the Eagle Marsh connection was assigned to address concerns about the unknown physiological and habitat limits to Asian carp movement.

Juvenile, sexually immature Asian carp have been observed in the uppermost reaches of small tributaries to large rivers attempting to pass over barriers, such as dams, to continue their upstream movement (Chapman, Duane. USGS, personal communication, September 12, 2011 and Caswell, Nate. USFWS, personal communication September 12, 2011). However, the state of Indiana has conducted two eDNA sampling events (fall 2010 and early summer 2011) and has not had a positive test for Asian carp eDNA in Little River or Graham McCulloch Ditch. The gradient needed to prevent juvenile fish from moving up stream is unknown. Thus it is unclear if the gradient of the Upper Wabash River and Little River are sufficient to prevent potential future upstream movement of young carp. It is important to note that young Asian carp tend to move laterally away from the river in which they were spawned and not back upstream (Chapman, Duane. USGS, personal communication, September 12, 2011). Newly hatched fry are not known to move significant distances upstream; however, they may move long distances up small tributaries and side channels in the vicinities of where they hatch. It has also been noted that 12-18 inch Asian carp have been known to travel long distances, throughout river systems, for no apparent reason (Chapman, Duane. USGS, personal communication, September 12, 2011). Adult, sexually mature Asian carp have also been found in very small streams, which appear scarcely large enough to support the fishes at low water (Chapman, Duane. USGS, personal communication, September 12, 2011). The age these fishes arrived at these locations is unknown. The state of Indiana is funding a study to evaluate the movement and spawning of Asian carp in the upper Wabash. In 2011, one hundred fish were collected from the Wabash River then tagged and returned to the river. This project will continue in 2012 with an additional one hundred tagged fish. Data from the 2011 spring and summer season have shown no evidence of Asian carp in the Little River and only a very small number of tagged fish venturing upstream of Logansport, IN on the Wabash River (Keller, Doug. Indiana DNR, personal communication, August 16, 2011). These findings are also supported by field observations during the tagging process of low numbers of Asian carp above Logansport, IN (Keller, Doug. IDNR, personal communication, Aug. 16, 2011).

In summary, there are many uncertainties one must take into account when attempting to predict the temporal and spatial migration patterns of Asian carp within the Wabash River watershed. While ongoing research by IDNR may suggest the tagged Asian carp have no interest in ascending the Little River, more long term studies are needed, and even these may not help explain the seemingly random movements of young 12-18 inch Asian carp that have been witnessed. Additionally the temporary fence at eagle Marsh will eventually have to be removed. This structure provides protection against Adult Asian Carp. Based on current knowledge of the reproductive traits and life history of Asian carp, there is no evidence to support that juveniles small enough to pass through the fence would ever reach Eagle Marsh or that spawning would occur within Eagle Marsh.

State DNR: Since the bulk of Asian carp spawning in the Wabash River occurs from Logansport, IN and downstream, juvenile fish, at this time, only occur in the tributaries and backwaters of the middle and lower Wabash River. Only adults seeking spawning areas appear to venture to the upper Wabash River. It is unknown if these adult fish will have any "motivation" to spread into Little River and eventually to Graham McCulloch Ditch and thus far that motivation has not been observed.

Remarks: 3B. Probability of ANS Surviving Transit to Aquatic Pathway Through Other Means

The rating for the ANS in this section does not influence the overall pathway rating outlined in this report and is only included to point out potential other pathways (e.g., anthropogenic) and their potential influence on the same list of ANS as evaluated in Section 4.2.1 above that may be important to different stakeholders. Any further analysis of these non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from those which may exploit the aquatic pathway. Fishing and boating are unlikely to occur in Eagle marsh. The ditches are too small to support sport fishing and are also too small for boating or kayaking. The small size of the ditches virtually eliminates the threat of ANS transfer via water craft, associated equipment, or fishing gear. Dumping of ANS (discarded aquarium pets, religious ceremonies, etc.) within the area is also considered unlikely. The pathway vicinity is located on a wetland preserve and therefore has regulated access. Possession of Asian carp in Indiana is prohibited which would aid in reducing the likelihood of human movement of this species.

## Eagle Marsh, Allen County, IN - Asian Carp

### 4. Probability of ANS establishing at the aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | MC | | |
| | USACE, Louisville - Biologist | Medium | RC | | |
| | USACE, Detroit - Biologist | Medium | RC | | |
| | INDNR - AIS Coordinator | Medium | RC | | |
| | USGS - Fishery Biologist | Low | MC | | |
| | USFWS - Fish Biologist | Medium | RC | | |
| | **Team Ratings** | **Medium** | **RC** | | |

### 4. How do you rate the probability of ANS establishing at the aquatic pathway?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are plentiful in close proximity to support all life stages from birth to adult, abiotic conditions align with native range and there are no known predators or conditions that would significantly impede survivability or reproduction. |
| Medium | Limited and disconnected areas and sources of food and habitat suitable to the ANS are available in proximity, abiotic conditions are within latitude limits of native range, but only a portion of the healthy individuals arriving at location can be expected to effectively compete and survive. |
| Low | Habitat and abiotic conditions in proximity are outside the range where ANS has been known to survive; there is very limited availability habitat area suitable for ANS cover, sustainable food supply and reproduction; or native predators or competition with native species would likely prevent establishment of a sustainable population. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: Marsh can experience ice cover in winter and high temperatures and depleted dissolved oxygen levels in summer, it may be possible for silver and bighead carp to survive until another high water event connects the basins. If silver or bighead carp were able to survive in the ponds of Eagle Marsh, successful spawning and recruitment is highly unlikely and would prevent establishment. It's believed that silver and bighead carp require sufficient flow to keep fertilized eggs suspended for successful reproduction (Gorbach and Krykhtin 1980). Black carp reach sexual maturity in as little as 5 years and adult females can produce up to one million eggs per spawning event. It is unlikely that spawning would occur within Eagle Marsh; however, if adult black carp reach the marsh they would most likely be able to survive for long periods of time within the marsh. The availability of food sources in any of the waters around Eagle Marsh would likely be sufficient to sustain these species for several years; however, habitat that is suitable for reproduction is the limiting factor in the establishment of a breeding population within Eagle Marsh.

## Eagle Marsh, Allen County, IN - Asian Carp

### 5. Probability of ANS spreading across aquatic pathway into the new basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Detroit - Biologist | High | VC | | |
| | INDNR - AIS Coordinator | High | VC | | |
| | USGS - Fishery Biologist | High | RC | | |
| | USFWS - Fish Biologist | High | VC | | |
| | **Team Ratings** | **High** | **VC** | | |

### 5. How do you rate the probability of ANS spreading across aquatic pathway into the new basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are available, and the species has demonstrated capabilities to significantly expand range from locations where initially introduced. |
| Medium | There are limited sources of food and suitable habitat, and/or the species has demonstrated limited ability to spread significant distances beyond areas where it has been introduced. |
| Low | There are severely limited sources of food and suitable habitat, and/or the species has demonstrated very limited ability to spread beyond areas where it has been introduced. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: Asian carp have demonstrated exceptional capabilities of spreading through large river systems, and will likely continue to do so. It is still uncertain whether they will attempt to travel up the Little River and Graham McCulloch Ditch, but if these species reach the basin divide and surface water connections permit, it is highly likely that they would spread beyond the aquatic pathway into the Great Lakes Basin.

## Eagle Marsh, Allen County, IN - Inland Silverside (*Menidia beryllina* )

### 1. Probability of aquatic pathway existence

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating Flow into GLB | Certainty | Rating Flow into MRB | Certainty |
|---|---|---|---|---|---|
| | USACE, Detroit - Hydraulic Engineer | High | RC | High | RC |
| | USACE, Louisville - Hydraulic Engineer | High | RC | High | RC |
| | USGS - Hydrologist | High | RC | High | RC |
| | INDNR - Engineering Geologist | High | RC | High | RC |
| | **Team Ratings** | **High** | **RC** | **High** | **RC** |

**1. How do you rate the likelihood of the existence of a viable aquatic pathway at the subject location? Assume a viable aquatic pathway is any location where untreated surface water flow across the divide is deemed likely to occur and connect headwater streams in both basins from any storm up to the 1% annual return frequency storm.**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Perennial streams and wetlands or intermittent stream known/documented to convey significant volumes of water across the basin divide for days to weeks multiple times per year. |
| Medium | Intermittent stream capable of maintaining a surface water connection to streams on both sides of the basin divide continuously for multiple days from a 10% annual return frequency storm; or, location of wetland spanning basin divide which maintains significant ponds that are likely to become inter connected and connect with streams on both sides of the basin divide from a 10% annual return frequency storm. |
| Low | Intermittent stream or marsh forming a surface water connection between streams on either side of the basin divide from larger than a 1.0% annual return frequency storm. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: USACE: Based upon numerical modeling developed as part of the parallel ANS Controls Report for the existing conditions, a connection appears to occur for storm events on the Graham McCulloch Ditch with a 10% chance annual exceedence event and less frequent events by way of overtopping the left descending bank (LDB) berm in low areas near the berms downstream-most section. Annual events on the St. Marys River make flow reverse direction in the Junk Ditch, and will cross the natural drainage divide, entering storage created by the LDB berm and the railroad embankment to the south ("Eagle Marsh southern storage area"). Additional storage is connected to this area in the Fox Island Park south of the railroad embankment, by way of a 4-foot diameter culvert through the railroad embankment. Two 18-inch (approximate) diameter pipes connect the Graham McCulloch Ditch to this storage area, but have flap-gates on the Graham McCulloch side of the berm; it is assumed that they are effective in preventing flow from the Graham McCulloch Ditch into this Eagle Marsh southern storage area until the LDB berm is overtopped. The 18-inch pipes are in poor condition, but it is assumed that they are still functional to drain waters ponding in the Eagle Marsh southern storage area. Storms events equal to or less frequent than the 1% chance exceedence event on the St Marys River are required to overtop the LDB berm.

As indicated above, the unsteady HEC-RAS modeling indicates that the greatest risk of a hydraulic connection results from flooding on the Graham McCulloch Ditch, and the frequency of occurrence is estimated as a 10% chance exceedence event or less frequent. Little data is available to support the definition of these frequency events, as the nearest flow or stage gage in this watershed is many miles downstream in Huntington, Indiana. Peak flows used for the 10%-, 4%-, 2%-, and 1%-chance annual exceedence events came from the Coordinated Discharge Graph "Ungaged Streams in Allen County", dated March 1982. Values for other frequency event peak flows were interpolated or extrapolated from these values. It is believed that these Coordinated Discharges were developed from regression equations, and therefore do not take into account the specific hydrology of the Graham McCulloch watershed. Even if relatively accurate upon creation of these Coordinated Discharges, it is believed that the watershed has undergone significant development. The shape of the hydrograph also had to be estimated. Significant data is available from the numerous gages in the Ft. Wayne area for the St. Marys River and other rivers and tributaries in that area, although several have very limited periods of record; however, there is significantly greater confidence in the flow information on the St. Marys River due to the large amount of information for that watershed that was made available by IDNR. The HEC-RAS model was able to be calibrated to historic events on the St. Marys River, with numerous high water marks available for one event. Definition of the LDB Berm profile used survey data provided by the NRCS of the berm and the Eagle Marsh area as a whole from 2006 when the property was purchased for the re-development of the wetlands. This data was believed to be of greater accuracy than the 2009 LIDAR data provided by the USGS and Allen County, although the 2006 survey data for the LDB berm is higher than the 2009 LIDAR on the order of 1-2 feet.

The frequency of a hydraulic pathway by overtopping described above is completely dependent upon the assumption that the profile of the LDB berm does not change. Multiple engineers who have visited the site agree that the integrity of the LDB berm is questionable; several slope failures, steep slopes, rodent burrows and other defects are visible, and there is no information regarding the level of design or construction methods. The berm therefore does not meet current geotechnical standards. It is expected that as time progresses, additional failures or a breach will occur. While the frequency of overtopping by a Graham McCulloch Ditch 10% chance exceedence event or greater would normally warrant a rating of Medium for flows into the Great Lakes Basin per the above criteria, this site is given a rating of High due to the expectation that failures of the LDB berm are likely, increasing the frequency of aquatic pathway development. Likewise, existing culverts through the LDB berm provide an annual connection for floods on the St. Marys watershed. Even if these pathways were removed, the poor integrity of the berm warrants a higher rating due to the increased likelihood of interconnection at more frequent events than modeling currently predicts

USGS: The H and H evaluation provides compelling indications for the high potential of a connection to develop between the MRB and GLB basins through overtopping of the berm along the Graham McCullough Ditch. The lack of discharge measurements on Graham McCulloch Ditch prevents a more refined analysis of flood stages. Flooding from the St Marys River appears to be a less probable cause of a connection at frequencies greater than 1 percent. The poor berm integrity as a levee, in combination with recurrent flooding, increases the probability of an interbasin connection to an unknown extent.

## Eagle Marsh, Allen County, IN - Inland Silverside (*Menidia beryllina* )

### 2. Probability of ANS occurring within either basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Detroit - Biologist | High | VC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | Medium | RC | | |
| | USFWS - Fish Biologist | High | VC | | |
| | **Team Rating** | **High** | **RC** | | |

### 2. How do you rate the probability of ANS occuring within either basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS exists on connected waterways in close enough proximity to be capable of moving to the aquatic pathway within 20 years. |
| Medium | Target ANS exists on connected waterways, but based on current proximity and mobility, is considered incapable of moving to the aquatic pathway within 20 years. |
| Low | Target ANS is not known to exist on a connected waterway. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: The inland silverside is currently established in the Wabash River. It has been collected in 2003 in Mt. Carmel, Indiana which is in southwestern Indiana (USGS 2009a).

## Eagle Marsh, Allen County, IN - Inland Silverside (*Menidia beryllina* )

### 3. Probability of ANS surviving transit to aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | 3A Rating | Certainty | 3B Rating | Certainty |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Louisville - Biologist | Medium | RU | Low | RC |
| | USACE, Detroit - Biologist | Low | MC | Low | RC |
| | INDNR - AIS Coordinator | Medium | MC | Low | RC |
| | USGS - Fishery Biologist | Low | RC | Low | RC |
| | USFWS - Fish Biologist | Medium | MC | Low | RC |
| | **Team Ratings** | **Medium** | **MC** | **Low** | **RC** |

**3A. How do you rate the probability of ANS surviving transit to aquatic pathway through connecting streams?**

**3B. How do you rate the probability of ANS surviving transit to aquatic pathway through other means?**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to successfully navigate through the aquatic pathway and/or through other means to arrive at the subject pathway within 10-20 years. |
| Medium | Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through the aquatic pathway or through other means to arrive at the subject pathway within 20-50 years. |
| Low | Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations by aquatic pathway or other means to arrive at subject pathway within next 50 years. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: 3A. Probability of ANS Surviving Transit to Aquatic Pathway Through Connecting Streams.

The dam on the Little River at Huntington, IN provides impedance for upstream migration at low and normal flow rates. The effectiveness of this barrier lessens during high flow events when the dam can become inundated. It is plausible that inland silversides could be able to bypass the dam during high flow and travel up the Little River and Graham-McCulloch Ditch to Eagle Marsh. As a relatively small fish (approximately five inches in total length at maturity), it is likely that this species would seek refuge from high water velocities during flood events, instead of attempting to migrate upstream. The current chain-link fence in the marsh would not prevent movement of this species from the MRB to the GLB. The habitat data suggests the inland silverside will colonize within rivers and streams but are usually found in clear, quiet water over sand or gravel. The Graham-McCulloch Ditch and Eagle Marsh do not provide this described habitat.

Remarks: 3B. Probability of ANS Surviving Transit to Aquatic Pathway Through Other Means

The rating for the ANS in this section does not influence the overall pathway rating outlined in this report and is only included to point out potential other pathways (e.g., anthropogenic) and their potential influence on the same list of ANS as evaluated in Section 4.2.1 above that may be important to different stakeholders. Any further analysis of these non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from those which may exploit the aquatic pathway.

## Eagle Marsh, Allen County, IN - Inland Silverside (*Menidia beryllina* )

### 4. Probability of ANS establishing at the aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | MC | | |
| | USACE, Louisville - Biologist | Medium | RC | | |
| | USACE, Detroit - Biologist | Medium | MC | | |
| | INDNR - AIS Coordinator | Medium | MC | | |
| | USGS - Fishery Biologist | Medium | MC | | |
| | USFWS - Fish Biologist | Medium | MC | | |
| | **Team Ratings** | **Medium** | **MC** | | |

### 4. How do you rate the probability of ANS establishing at the aquatic pathway?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are plentiful in close proximity to support all life stages from birth to adult, abiotic conditions align with native range and there are no known predators or conditions that would significantly impede survivability or reproduction. |
| Medium | Limited and disconnected areas and sources of food and habitat suitable to the ANS are available in proximity, abiotic conditions are within latitude limits of native range, but only a portion of the healthy individuals arriving at location can be expected to effectively compete and survive. |
| Low | Habitat and abiotic conditions in proximity are outside the range where ANS has been known to survive; there is very limited availability habitat area suitable for ANS cover, sustainable food supply and reproduction; or native predators or competition with native species would likely prevent establishment of a sustainable population. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: As a size-selective, planktivore, the inland silverside relies primarily on sight for feeding (Elston and Bachen 1976). In the marshes and ponds of Eagle Marsh, visibility may be severely restricted in the turbid water, hindering the silverside's ability to find prey. Turbid water in the Graham-McCulloch Ditch and Junk Ditch may have the same effect. Eagle Marsh does lie within the latitudinal boundaries of the inland silversides' native range.

## Eagle Marsh, Allen County, IN - Inland Silverside (*Menidia beryllina* )

### 5. Probability of ANS spreading across aquatic pathway into the new basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | Medium | MC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Ratings** | **High** | **RC** | | |

### 5. How do you rate the probability of ANS spreading across aquatic pathway into the new basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are available, and the species has demonstrated capabilities to significantly expand range from locations where initially introduced. |
| Medium | There are limited sources of food and suitable habitat, and/or the species has demonstrated limited ability to spread significant distances beyond areas where it has been introduced. |
| Low | There are severely limited sources of food and suitable habitat, and/or the species has demonstrated very limited ability to spread beyond areas where it has been introduced. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: Because of its small size, the inland silverside may be capable of utilizing minor hydrologic connections to migrate. It is likely that if inland silversides were established in Eagle Marsh, they would be able to migrate downstream into the Great Lakes basin during high flow events.

## Eagle Marsh, Allen County, IN - Northern Snakehead (*Channa argus* )

### 1. Probability of aquatic pathway existence

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating Flow into GLB | Certainty | Rating Flow into MRB | Certainty |
|---|---|---|---|---|---|
| | USACE, Detroit - Hydraulic Engineer | High | RC | High | RC |
| | USACE, Louisville - Hydraulic Engineer | High | RC | High | RC |
| | USGS - Hydrologist | High | RC | High | RC |
| | INDNR - Engineering Geologist | High | RC | High | RC |
| | **Team Ratings** | **High** | **RC** | **High** | **RC** |

**1. How do you rate the likelihood of the existence of a viable aquatic pathway at the subject location? Assume a viable aquatic pathway is any location where untreated surface water flow across the divide is deemed likely to occur and connect headwater streams in both basins from any storm up to the 1% annual return frequency storm.**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Perennial streams and wetlands or intermittent stream known/documented to convey significant volumes of water across the basin divide for days to weeks multiple times per year. |
| Medium | Intermittent stream capable of maintaining a surface water connection to streams on both sides of the basin divide continuously for multiple days from a 10% annual return frequency storm; or, location of wetland spanning basin divide which maintains significant ponds that are likely to become inter connected and connect with streams on both sides of the basin divide from a 10% annual return frequency storm. |
| Low | Intermittent stream or marsh forming a surface water connection between streams on either side of the basin divide from larger than a 1.0% annual return frequency storm. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: USACE: Based upon numerical modeling developed as part of the parallel ANS Controls Report for the existing conditions, a connection appears to occur for storm events on the Graham McCulloch Ditch with a 10% chance annual exceedence event and less frequent events by way of overtopping the left descending bank (LDB) berm in low areas near the berms downstream-most section. Annual events on the St. Marys River make flow reverse direction in the Junk Ditch, and will cross the natural drainage divide, entering storage created by the LDB berm and the railroad embankment to the south ("Eagle Marsh southern storage area"). Additional storage is connected to this area in the Fox Island Park south of the railroad embankment, by way of a 4-foot diameter culvert through the railroad embankment. Two 18-inch (approximate) diameter pipes connect the Graham McCulloch Ditch to this storage area, but have flap-gates on the Graham McCulloch side of the berm; it is assumed that they are effective in preventing flow from the Graham McCulloch Ditch into this Eagle Marsh southern storage area until the LDB berm is overtopped. The 18-inch pipes are in poor condition, but it is assumed that they are still functional to drain waters ponding in the Eagle Marsh southern storage area. Storms events equal to or less frequent than the 1% chance exceedence event on the St Marys River are required to overtop the LDB berm.

As indicated above, the unsteady HEC-RAS modeling indicates that the greatest risk of a hydraulic connection results from flooding on the Graham McCulloch Ditch, and the frequency of occurrence is estimated as a 10% chance exceedence event or less frequent. Little data is available to support the definition of these frequency events, as the nearest flow or stage gage in this watershed is many miles downstream in Huntington, Indiana. Peak flows used for the 10%-, 4%-, 2%-, and 1%-chance annual exceedence events came from the Coordinated Discharge Graph "Ungaged Streams in Allen County", dated March 1982. Values for other frequency event peak flows were interpolated or extrapolated from these values. It is believed that these Coordinated Discharges were developed from regression equations, and therefore do not take into account the specific hydrology of the Graham McCulloch watershed. Even if relatively accurate upon creation of these Coordinated Discharges, it is believed that the watershed has undergone significant development. The shape of the hydrograph also had to be estimated. Significant data is available from the numerous gages in the Ft. Wayne area for the St. Marys River and other rivers and tributaries in that area, although several have very limited periods of record; however, there is significantly greater confidence in the flow information on the St. Marys River due to the large amount of information for that watershed that was made available by IDNR. The HEC-RAS model was able to be calibrated to historic events on the St. Marys River, with numerous high water marks available for one event. Definition of the LDB Berm profile used survey data provided by the NRCS of the berm and the Eagle Marsh area as a whole from 2006 when the property was purchased for the re-development of the wetlands. This data was believed to be of greater accuracy than the 2009 LIDAR data provided by the USGS and Allen County, although the 2006 survey data for the LDB berm is higher than the 2009 LIDAR on the order of 1-2 feet.

The frequency of a hydraulic pathway by overtopping described above is completely dependent upon the assumption that the profile of the LDB berm does not change. Multiple engineers who have visited the site agree that the integrity of the LDB berm is questionable; several slope failures, steep slopes, rodent burrows and other defects are visible, and there is no information regarding the level of design or construction methods. The berm therefore does not meet current geotechnical standards. It is expected that as time progresses, additional failures or a breach will occur. While the frequency of overtopping by a Graham McCulloch Ditch 10% chance exceedence event or greater would normally warrant a rating of Medium for flows into the Great Lakes Basin per the above criteria, this site is given a rating of High due to the expectation that failures of the LDB berm are likely, increasing the frequency of aquatic pathway development. Likewise, existing culverts through the LDB berm provide an annual connection for floods on the St. Marys watershed. Even if these pathways were removed, the poor integrity of the berm warrants a higher rating due to the increased likelihood of interconnection at more frequent events than modeling currently predicts

USGS: The H and H evaluation provides compelling indications for the high potential of a connection to develop between the MRB and GLB basins through overtopping of the berm along the Graham McCullough Ditch. The lack of discharge measurements on Graham McCulloch Ditch prevents a more refined analysis of flood stages. Flooding from the St Marys River appears to be a less probable cause of a connection at frequencies greater than 1 percent. The poor berm integrity as a levee, in combination with recurrent flooding, increases the probability of an interbasin connection to an unknown extent.

## Eagle Marsh, Allen County, IN - Northern Snakehead (*Channa argus* )

### 2. Probability of ANS occurring within either basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | RC | | |
| | USACE, Louisville - Biologist | Medium | VC | | |
| | USACE, Detroit - Biologist | Medium | RC | | |
| | INDNR - AIS Coordinator | Medium | RC | | |
| | USGS - Fishery Biologist | Medium | VC | | |
| | USFWS - Fish Biologist | Medium | RC | | |
| | **Team Rating** | **Medium** | **RC** | | |

### 2. How do you rate the probability of ANS occuring within either basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS exists on connected waterways in close enough proximity to be capable of moving to the aquatic pathway within 20 years. |
| Medium | Target ANS exists on connected waterways, but based on current proximity and mobility, is considered incapable of moving to the aquatic pathway within 20 years. |
| Low | Target ANS is not known to exist on a connected waterway. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: The northern snakehead was found in 2008 in Monroe, Arkansas, and has since established a reproducing population in the area and therefore is located within the Mississippi River Basin. Although in a different basin, this species is also established in the Potomac River in Maryland and Virginia (USGS 2011).

## Eagle Marsh, Allen County, IN - Northern Snakehead (*Channa argus* )

### 3. Probability of ANS surviving transit to aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | 3A Rating | Certainty | 3B Rating | Certainty |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Detroit - Biologist | Medium | RC | Low | RC |
| | INDNR - AIS Coordinator | Medium | RC | Low | RC |
| | USGS - Fishery Biologist | Medium | RC | Low | RC |
| | USFWS - Fish Biologist | Medium | RC | Low | RC |
| | **Team Ratings** | **Medium** | **RC** | **Low** | **RC** |

**3A. How do you rate the probability of ANS surviving transit to aquatic pathway through connecting streams?**

**3B. How do you rate the probability of ANS surviving transit to aquatic pathway through other means?**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to successfully navigate through the aquatic pathway and/or through other means to arrive at the subject pathway within 10-20 years. |
| Medium | Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through the aquatic pathway or through other means to arrive at the subject pathway within 20-50 years. |
| Low | Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations by aquatic pathway or other means to arrive at subject pathway within next 50 years. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: 3A. Probability of ANS Surviving Transit to Aquatic Pathway Through Connecting Streams.

As obligate air breathers, northern snakeheads (Channa argus) obtain required oxygen directly from the atmosphere. This species thrives in stagnant, oxygen depleted back-waters and marshes (Courtenay, Jr. and Williams, 2004). The northern snakehead likely possesses the ability to migrate through the Eagle Marsh pathway. However, its preferred habit is not flowing waters, which may slow its spread up the Mississippi River and to the tributaries connecting to Eagle Marsh. Despite this species preferences for stagnant, oxygen depleted back-waters and marshes, the northern snakehead has been consistently caught by anglers in the Potomac River near Great Falls Virginia during spring high flow events (J. Newhard, U.S. Fish and Wildlife Service, December 22, 2011). Based on data from external tags recaptured by anglers, in rare instances, northern snakehead have been found to move as far as 50 river miles upstream at a rate of approximately one mile per day. This extensive movement typically occurs in the spring with the fish returning back downstream to slower moving water in the summer (J. Newhard, U.S. Fish and Wildlife Service, December 22, 2011). The northern snakehead has no established populations near Eagle Marsh.

Remarks: 3B. Probability of ANS Surviving Transit to Aquatic Pathway Through Other Means

The rating for the ANS in this section does not influence the overall pathway rating outlined in this report and is only included to point out potential other pathways (e.g., anthropogenic) and their potential influence on the same list of ANS as evaluated in Section 4.2.1 above that may be important to different stakeholders. Any further analysis of these non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from those which may exploit the aquatic pathway.

## Eagle Marsh, Allen County, IN - Northern Snakehead (*Channa argus* )

### 4. Probability of ANS establishing at the aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | RC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Ratings** | **High** | **RC** | | |

### 4. How do you rate the probability of ANS establishing at the aquatic pathway?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are plentiful in close proximity to support all life stages from birth to adult, abiotic conditions align with native range and there are no known predators or conditions that would significantly impede survivability or reproduction. |
| Medium | Limited and disconnected areas and sources of food and habitat suitable to the ANS are available in proximity, abiotic conditions are within latitude limits of native range, but only a portion of the healthy individuals arriving at location can be expected to effectively compete and survive. |
| Low | Habitat and abiotic conditions in proximity are outside the range where ANS has been known to survive; there is very limited availability habitat area suitable for ANS cover, sustainable food supply and reproduction; or native predators or competition with native species would likely prevent establishment of a sustainable population. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: The northern snakehead's native range (24-53º N) and temperature tolerance (0-30 ºC) indicates a species that, if introduced, could establish populations throughout most of the contiguous United States (Courtenay, Jr. and Williams 2004). Northern snakeheads are naturally aggressive predators that could easily acclimate to the conditions in and around Eagle Marsh as long as there is an ample food supply, which appears to be the case. They can be very opportunistic in their feeding habits, preying on everything from insect larvae to fish, frogs, and crustaceans. Northern snakeheads prefer shallow ponds and marshes with aquatic vegetation, which is similar to the aquatic habitat within Eagle Marsh. Additionally, northern snakeheads aggressively defend their nest and young fry, reducing predation on young snakehead by other fish.

## Eagle Marsh, Allen County, IN - Northern Snakehead (*Channa argus* )

### 5. Probability of ANS spreading across aquatic pathway into the new basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | VC | | |
| | USGS - Fishery Biologist | High | VC | | |
| | USFWS - Fish Biologist | High | VC | | |
| | **Team Ratings** | **High** | **VC** | | |

### 5. How do you rate the probability of ANS spreading across aquatic pathway into the new basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are available, and the species has demonstrated capabilities to significantly expand range from locations where initially introduced. |
| Medium | There are limited sources of food and suitable habitat, and/or the species has demonstrated limited ability to spread significant distances beyond areas where it has been introduced. |
| Low | There are severely limited sources of food and suitable habitat, and/or the species has demonstrated very limited ability to spread beyond areas where it has been introduced. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: It is very likely that the northern snakehead possesses the ability to spread from Eagle Marsh across the pathway if a population were established in close at, or in close proximity, to the pathway even though it is less certain if or how quickly the northern snakehead could reach the pathway. As an air breather that has even been known to move short distances over land, it is likely this species would be able to quickly move into Junk Ditch from the marsh. Under proper environmental conditions, this species could potentially transfer into Junk Ditch even if a hydrologic connection is not present.

## Eagle Marsh, Allen County, IN - Parasitic Copepod (*Neoergasilus japonicus* )

### 1. Probability of aquatic pathway existence

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating Flow into GLB | Certainty | Rating Flow into MRB | Certainty |
|---|---|---|---|---|---|
| | USACE, Detroit - Hydraulic Engineer | High | RC | High | RC |
| | USACE, Louisville - Hydraulic Engineer | High | RC | High | RC |
| | USGS - Hydrologist | High | RC | High | RC |
| | INDNR - Engineering Geologist | High | RC | High | RC |
| | **Team Ratings** | **High** | **RC** | **High** | **RC** |

**1. How do you rate the likelihood of the existence of a viable aquatic pathway at the subject location? Assume a viable aquatic pathway is any location where untreated surface water flow across the divide is deemed likely to occur and connect headwater streams in both basins from any storm up to the 1% annual return frequency storm.**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Perennial streams and wetlands or intermittent stream known/documented to convey significant volumes of water across the basin divide for days to weeks multiple times per year. |
| Medium | Intermittent stream capable of maintaining a surface water connection to streams on both sides of the basin divide continuously for multiple days from a 10% annual return frequency storm; or, location of wetland spanning basin divide which maintains significant ponds that are likely to become inter connected and connect with streams on both sides of the basin divide from a 10% annual return frequency storm. |
| Low | Intermittent stream or marsh forming a surface water connection between streams on either side of the basin divide from larger than a 1.0% annual return frequency storm. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: USACE: Based upon numerical modeling developed as part of the parallel ANS Controls Report for the existing conditions, a connection appears to occur for storm events on the Graham McCulloch Ditch with a 10% chance annual exceedence event and less frequent events by way of overtopping the left descending bank (LDB) berm in low areas near the berms downstream-most section. Annual events on the St. Marys River make flow reverse direction in the Junk Ditch, and will cross the natural drainage divide, entering storage created by the LDB berm and the railroad embankment to the south ("Eagle Marsh southern storage area"). Additional storage is connected to this area in the Fox Island Park south of the railroad embankment, by way of a 4-foot diameter culvert through the railroad embankment. Two 18-inch (approximate) diameter pipes connect the Graham McCulloch Ditch to this storage area, but have flap-gates on the Graham McCulloch side of the berm; it is assumed that they are effective in preventing flow from the Graham McCulloch Ditch into this Eagle Marsh southern storage area until the LDB berm is overtopped. The 18-inch pipes are in poor condition, but it is assumed that they are still functional to drain waters ponding in the Eagle Marsh southern storage area. Storms events equal to or less frequent than the 1% chance exceedence event on the St Marys River are required to overtop the LDB berm.

As indicated above, the unsteady HEC-RAS modeling indicates that the greatest risk of a hydraulic connection results from flooding on the Graham McCulloch Ditch, and the frequency of occurrence is estimated as a 10% chance exceedence event or less frequent. Little data is available to support the definition of these frequency events, as the nearest flow or stage gage in this watershed is many miles downstream in Huntington, Indiana. Peak flows used for the 10%-, 4%-, 2%-, and 1%-chance annual exceedence events came from the Coordinated Discharge Graph "Ungaged Streams in Allen County", dated March 1982. Values for other frequency event peak flows were interpolated or extrapolated from these values. It is believed that these Coordinated Discharges were developed from regression equations, and therefore do not take into account the specific hydrology of the Graham McCulloch watershed. Even if relatively accurate upon creation of these Coordinated Discharges, it is believed that the watershed has undergone significant development. The shape of the hydrograph also had to be estimated. Significant data is available from the numerous gages in the Ft. Wayne area for the St. Marys River and other rivers and tributaries in that area, although several have very limited periods of record; however, there is significantly greater confidence in the flow information on the St. Marys River due to the large amount of information for that watershed that was made available by IDNR. The HEC-RAS model was able to be calibrated to historic events on the St. Marys River, with numerous high water marks available for one event. Definition of the LDB Berm profile used survey data provided by the NRCS of the berm and the Eagle Marsh area as a whole from 2006 when the property was purchased for the re-development of the wetlands. This data was believed to be of greater accuracy than the 2009 LIDAR data provided by the USGS and Allen County, although the 2006 survey data for the LDB berm is higher than the 2009 LIDAR on the order of 1-2 feet.

The frequency of a hydraulic pathway by overtopping described above is completely dependent upon the assumption that the profile of the LDB berm does not change. Multiple engineers who have visited the site agree that the integrity of the LDB berm is questionable; several slope failures, steep slopes, rodent burrows and other defects are visible, and there is no information regarding the level of design or construction methods. The berm therefore does not meet current geotechnical standards. It is expected that as time progresses, additional failures or a breach will occur. While the frequency of overtopping by a Graham McCulloch Ditch 10% chance exceedence event or greater would normally warrant a rating of Medium for flows into the Great Lakes Basin per the above criteria, this site is given a rating of High due to the expectation that failures of the LDB berm are likely, increasing the frequency of aquatic pathway development. Likewise, existing culverts through the LDB berm provide an annual connection for floods on the St. Marys watershed. Even if these pathways were removed, the poor integrity of the berm warrants a higher rating due to the increased likelihood of interconnection at more frequent events than modeling currently predicts

USGS: The H and H evaluation provides compelling indications for the high potential of a connection to develop between the MRB and GLB basins through overtopping of the berm along the Graham McCullough Ditch. The lack of discharge measurements on Graham McCulloch Ditch prevents a more refined analysis of flood stages. Flooding from the St Marys River appears to be a less probable cause of a connection at frequencies greater than 1 percent. The poor berm integrity as a levee, in combination with recurrent flooding, increases the probability of an interbasin connection to an unknown extent.

## Eagle Marsh, Allen County, IN - Parasitic Copepod (*Neoergasilus japonicus* )

### 2. Probability of ANS occurring within either basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | Medium | MC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | Medium | MC | | |
| | USGS - Fishery Biologist | High | MC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Rating** | **Medium** | **RC** | | |

### 2. How do you rate the probability of ANS occuring within either basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS exists on connected waterways in close enough proximity to be capable of moving to the aquatic pathway within 20 years. |
| Medium | Target ANS exists on connected waterways, but based on current proximity and mobility, is considered incapable of moving to the aquatic pathway within 20 years. |
| Low | Target ANS is not known to exist on a connected waterway. |

| | Symbol | | | | | |
|---|---|---|---|---|---|---|
| Very Certain | VC | As certain as I am going to get. | | | | |
| Reasonably Certain | RC | Reasonably certain. | | | | |
| Moderately Certain | MC | More certain than not. | | | | |
| Reasonably Uncertain | RU | Reasonably uncertain | | | | |
| Very Uncertain | VU | A guess | | | | |

Remarks: N. japonicus has a life cycle in which the female adopts a parasitic phase on several fish species, including members of the minnow family, sunfish family, catfish family, and potentially other fish species. The common carp (Cyprinus carpio) is a frequent host of the parasite (Hudson and Bowen 2002). The females can detach and re-attach to host species. N. japonicus has been established in Lake Huron since 1994. The common carp is established in Lake Erie, as well as the rivers and streams leading to Eagle Marsh from Lake Erie. While other host fish species are known to exist in the pathway system, the common carp was selected as the most likely host species because of the life cycle capabilities of the common carp and the likelihood the common carp would use and survive in the pathway habitats. N. japonicus and a necessary host species are located on waterbodies connected with Eagle Marsh. The males are free living but do not have the capability of migration upstream. The literature indicates N. japonicus is small and relatively easy to miss in field surveys, even by trained biologists. Therefore, N. japonicus may be much more prevalent than the distribution maps depict.

## Eagle Marsh, Allen County, IN - Parasitic Copepod (*Neoergasilus japonicus* )

### 3. Probability of ANS surviving transit to aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | 3A Rating | Certainty | 3B Rating | Certainty |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | Low | RC |
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Detroit - Biologist | High | RC | Medium | RC |
| | INDNR - AIS Coordinator | Medium | MC | Low | RC |
| | USGS - Fishery Biologist | High | MC | Medium | RC |
| | USFWS - Fish Biologist | High | RC | Low | RC |
| | **Team Ratings** | **Medium** | **RC** | **Low** | **RC** |

**3A. How do you rate the probability of ANS surviving transit to aquatic pathway through connecting streams?**

**3B. How do you rate the probability of ANS surviving transit to aquatic pathway through other means?**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to successfully navigate through the aquatic pathway and/or through other means to arrive at the subject pathway within 10-20 years. |
| Medium | Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through the aquatic pathway or through other means to arrive at the subject pathway within 20-50 years. |
| Low | Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations by aquatic pathway or other means to arrive at subject pathway within next 50 years. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: 3A. Probability of ANS Surviving Transit to Aquatic Pathway Through Connecting Streams.

N. japonicus has been found on the common carp. During spring run-off events in April/May, common carp migrate into the shallow waters of bays and river systems to spawn. Within the rivers, common carp migrate upstream to spawn in suitable habitat such as marshes and even drainage ditches with as little as or less than one foot depth of water. Common carp are strong swimmers and though they cannot jump like members of the salmon family, they can migrate upstream during moderate flow events.

This Great Lakes aquatic pathway has a surface water connection during certain discharge events consisting of marsh, small creek/stream and river connections to Lake Erie. While there are obstacles on the Maumee River (see Section 2.7), these become less effective at impeding upstream migration as flow increases. It is possible that carp could migrate to the watershed divide under certain discharge events.

The surface water connection from Lake Erie to Eagle Marsh provides suitable habitat for carp during run-off events. Eagle Marsh is a shallow marsh, but also contains man-made ponds of unknown depth. Common carp have been documented on both sides of the temporary barrier in the spring prior to the normal spawning season. Common carp are a very resilient species and are capable of surviving a wide range of water quality parameters, and it is highly likely they are able to overwinter in the ponds within Eagle Marsh. It is also likely that if the carp arrived with N. japonicus attached, the carp would survive in the ponds and transfer to the Mississippi River Basin via the Graham McCulloch Ditch under a suitable runoff event.

Remarks: 3B. Probability of ANS Surviving Transit to Aquatic Pathway Through Other Means

The rating for the ANS in this section does not influence the overall pathway rating outlined in this report and is only included to point out potential other pathways (e.g., anthropogenic) and their potential influence on the same list of ANS as evaluated in Section 4.2.1 above that may be important to different stakeholders. Any further analysis of these non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from those which may exploit the aquatic pathway.

## Eagle Marsh, Allen County, IN - Parasitic Copepod (*Neoergasilus japonicus* )

### 4. Probability of ANS establishing at the aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | MC | | |
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | RC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Ratings** | **High** | **RC** | | |

### 4. How do you rate the probability of ANS establishing at the aquatic pathway?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are plentiful in close proximity to support all life stages from birth to adult, abiotic conditions align with native range and there are no known predators or conditions that would significantly impede survivability or reproduction. |
| Medium | Limited and disconnected areas and sources of food and habitat suitable to the ANS are available in proximity, abiotic conditions are within latitude limits of native range, but only a portion of the healthy individuals arriving at location can be expected to effectively compete and survive. |
| Low | Habitat and abiotic conditions in proximity are outside the range where ANS has been known to survive; there is very limited availability habitat area suitable for ANS cover, sustainable food supply and reproduction; or native predators or competition with native species would likely prevent establishment of a sustainable population. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: N. japonicus is very capable of persisting in eutrophic and polluted waters. N. japonicus demonstrates a rapid reproductive cycle and is capable of utilizing many different host species. It is highly likely that N. japonicus would be successful in establishing in Eagle Marsh, providing a host is available.

## Eagle Marsh, Allen County, IN - Parasitic Copepod (*Neoergasilus japonicus* )

### 5. Probability of ANS spreading across aquatic pathway into the new basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | RC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Ratings** | **High** | **RC** | | |

### 5. How do you rate the probability of ANS spreading across aquatic pathway into the new basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are available, and the species has demonstrated capabilities to significantly expand range from locations where initially introduced. |
| Medium | There are limited sources of food and suitable habitat, and/or the species has demonstrated limited ability to spread significant distances beyond areas where it has been introduced. |
| Low | There are severely limited sources of food and suitable habitat, and/or the species has demonstrated very limited ability to spread beyond areas where it has been introduced. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: Surface water connections have been documented at the divide. During these connections, it is likely that the carp with N. japonicus could spread beyond the pathway to the Mississippi River Basin. Note that the female N. japonicus can detach and re-attach to another host fish. The time it takes and how often this happens is not documented in the literature that has been reviewed. However, if common carp were on both sides of the temporary barrier, it is possible that a female N. japonicus could detach, flow with the waters across/through the fence and re-attach to a new host fish across the divide. The likelihood is unknown but with spawning carp on both sides of the barrier, movement or the dislodgement of a N. japonicus is possible.

## Eagle Marsh, Allen County, IN - Viral Hemorrhagic Septicemia (VHSv)

### 1. Probability of aquatic pathway existence

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating Flow into GLB | Certainty | Rating Flow into MRB | Certainty |
|---|---|---|---|---|---|
| | USACE, Detroit - Hydraulic Engineer | High | RC | High | RC |
| | USACE, Louisville - Hydraulic Engineer | High | RC | High | RC |
| | USGS - Hydrologist | High | RC | High | RC |
| | INDNR - Engineering Geologist | High | RC | High | RC |
| | **Team Ratings** | **High** | **RC** | **High** | **RC** |

**1. How do you rate the likelihood of the existence of a viable aquatic pathway at the subject location? Assume a viable aquatic pathway is any location where untreated surface water flow across the divide is deemed likely to occur and connect headwater streams in both basins from any storm up to the 1% annual return frequency storm.**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Perennial streams and wetlands or intermittent stream known/documented to convey significant volumes of water across the basin divide for days to weeks multiple times per year. |
| Medium | Intermittent stream capable of maintaining a surface water connection to streams on both sides of the basin divide continuously for multiple days from a 10% annual return frequency storm; or, location of wetland spanning basin divide which maintains significant ponds that are likely to become inter connected and connect with streams on both sides of the basin divide from a 10% annual return frequency storm. |
| Low | Intermittent stream or marsh forming a surface water connection between streams on either side of the basin divide from larger than a 1.0% annual return frequency storm. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: USACE: Based upon numerical modeling developed as part of the parallel ANS Controls Report for the existing conditions, a connection appears to occur for storm events on the Graham McCulloch Ditch with a 10% chance annual exceedence event and less frequent events by way of overtopping the left descending bank (LDB) berm in low areas near the berms downstream-most section. Annual events on the St. Marys River make flow reverse direction in the Junk Ditch, and will cross the natural drainage divide, entering storage created by the LDB berm and the railroad embankment to the south ("Eagle Marsh southern storage area"). Additional storage is connected to this area in the Fox Island Park south of the railroad embankment, by way of a 4-foot diameter culvert through the railroad embankment. Two 18-inch (approximate) diameter pipes connect the Graham McCulloch Ditch to this storage area, but have flap-gates on the Graham McCulloch side of the berm; it is assumed that they are effective in preventing flow from the Graham McCulloch Ditch into this Eagle Marsh southern storage area until the LDB berm is overtopped. The 18-inch pipes are in poor condition, but it is assumed that they are still functional to drain waters ponding in the Eagle Marsh southern storage area. Storms events equal to or less frequent than the 1% chance exceedence event on the St Marys River are required to overtop the LDB berm.

As indicated above, the unsteady HEC-RAS modeling indicates that the greatest risk of a hydraulic connection results from flooding on the Graham McCulloch Ditch, and the frequency of occurrence is estimated as a 10% chance exceedence event or less frequent. Little data is available to support the definition of these frequency events, as the nearest flow or stage gage in this watershed is many miles downstream in Huntington, Indiana. Peak flows used for the 10%-, 4%-, 2%-, and 1%-chance annual exceedence events came from the Coordinated Discharge Graph "Ungaged Streams in Allen County", dated March 1982. Values for other frequency event peak flows were interpolated or extrapolated from these values. It is believed that these Coordinated Discharges were developed from regression equations, and therefore do not take into account the specific hydrology of the Graham McCulloch watershed. Even if relatively accurate upon creation of these Coordinated Discharges, it is believed that the watershed has undergone significant development. The shape of the hydrograph also had to be estimated. Significant data is available from the numerous gages in the Ft. Wayne area for the St. Marys River and other rivers and tributaries in that area, although several have very limited periods of record; however, there is significantly greater confidence in the flow information on the St. Marys River due to the large amount of information for that watershed that was made available by IDNR. The HEC-RAS model was able to be calibrated to historic events on the St. Marys River, with numerous high water marks available for one event. Definition of the LDB Berm profile used survey data provided by the NRCS of the berm and the Eagle Marsh area as a whole from 2006 when the property was purchased for the re-development of the wetlands. This data was believed to be of greater accuracy than the 2009 LIDAR data provided by the USGS and Allen County, although the 2006 survey data for the LDB berm is higher than the 2009 LIDAR on the order of 1-2 feet.

The frequency of a hydraulic pathway by overtopping described above is completely dependent upon the assumption that the profile of the LDB berm does not change. Multiple engineers who have visited the site agree that the integrity of the LDB berm is questionable; several slope failures, steep slopes, rodent burrows and other defects are visible, and there is no information regarding the level of design or construction methods. The berm therefore does not meet current geotechnical standards. It is expected that as time progresses, additional failures or a breach will occur. While the frequency of overtopping by a Graham McCulloch Ditch 10% chance exceedence event or greater would normally warrant a rating of Medium for flows into the Great Lakes Basin per the above criteria, this site is given a rating of High due to the expectation that failures of the LDB berm are likely, increasing the frequency of aquatic pathway development. Likewise, existing culverts through the LDB berm provide an annual connection for floods on the St. Marys watershed. Even if these pathways were removed, the poor integrity of the berm warrants a higher rating due to the increased likelihood of interconnection at more frequent events than modeling currently predicts

USGS: The H and H evaluation provides compelling indications for the high potential of a connection to develop between the MRB and GLB basins through overtopping of the berm along the Graham McCullough Ditch. The lack of discharge measurements on Graham McCulloch Ditch prevents a more refined analysis of flood stages. Flooding from the St Marys River appears to be a less probable cause of a connection at frequencies greater than 1 percent. The poor berm integrity as a levee, in combination with recurrent flooding, increases the probability of an interbasin connection to an unknown extent.

## Eagle Marsh, Allen County, IN - Viral Hemorrhagic Septicemia (VHSv)

### 2. Probability of ANS occurring within either basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | RC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Rating** | **High** | **RC** | | |

### 2. How do you rate the probability of ANS occuring within either basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS exists on connected waterways in close enough proximity to be capable of moving to the aquatic pathway within 20 years. |
| Medium | Target ANS exists on connected waterways, but based on current proximity and mobility, is considered incapable of moving to the aquatic pathway within 20 years. |
| Low | Target ANS is not known to exist on a connected waterway. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: Viral Hemorrhagic Septicemia can infect a wide range of host fish causing a variety of external and internal symptoms sometimes leading to death of the host fish. Variables such as host fish species and water temperature can impact the pathogenicity of the virus. Seemingly healthy individuals that have been previously infected with VHS can have chronic infections and be carriers of the disease (Skall et al. 2005). This virus has been reported from throughout the Great Lakes Basin including Lake Erie (USGS 2011). VHS is a virus that is active at water temperatures less than 60ºF. As such, it may be less likely to persist in areas like Eagle Marsh during much of the year. Viral Hemorrhagic Septicemia (VHS) has been found in many species of fish including common carp. The common carp is established in Lake Erie, as well as the rivers and streams leading to Eagle Marsh from Lake Erie. While other host fish species are known to exist in the pathway system, the common carp was selected as the most likely host species because of the life cycle capabilities of the common carp and the likelihood the common carp would use and survive in the pathway habitats. Viral Hemorrhagic Septicemia (VHS) and a necessary host species are capable of migrating to the pathway within the next 20 years.

## Eagle Marsh, Allen County, IN - Viral Hemorrhagic Septicemia (VHSv)

### 3. Probability of ANS surviving transit to aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | 3A Rating | Certainty | 3B Rating | Certainty |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | Low | RC |
| | USACE, Louisville - Biologist | High | VC | Low | RC |
| | USACE, Detroit - Biologist | High | VC | Medium | RC |
| | INDNR - AIS Coordinator | High | VC | Low | RC |
| | USGS - Fishery Biologist | High | RC | Medium | MC |
| | USFWS - Fish Biologist | High | RC | Low | RC |
| | **Team Ratings** | **High** | **VC** | **Low** | **RC** |

**3A. How do you rate the probability of ANS surviving transit to aquatic pathway through connecting streams?**

**3B. How do you rate the probability of ANS surviving transit to aquatic pathway through other means?**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to successfully navigate through the aquatic pathway and/or through other means to arrive at the subject pathway within 10-20 years. |
| Medium | Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through the aquatic pathway or through other means to arrive at the subject pathway within 20-50 years. |
| Low | Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations by aquatic pathway or other means to arrive at subject pathway within next 50 years. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: 3A. Probability of ANS Surviving Transit to Aquatic Pathway Through Connecting Streams.

VHS has been found to infect common carp (USGS 2011). During spring run-off events in April/May, common carp migrate into the shallow waters of bays and river systems to spawn. Within the rivers, common carp migrate upstream to spawn in suitable habitat such as marshes and even drainage ditches with as little as or less than one foot depth of water. Common carp are strong swimmers and though they cannot jump like members of the salmon family, they can migrate upstream during moderate flow events.
This Great Lakes aquatic pathway has a surface water connection during certain discharge events consisting of marsh, small creek/stream and river connections to Lake Erie. While there are obstacles on the Maumee River (see Section 2.7), these become less effective at impeding upstream migration as flow increases. It is possible that carp could migrate to the watershed divide under certain discharge event.

The surface water connection from Lake Erie to Eagle Marsh provides suitable habitat for carp during run-off events. Eagle Marsh is a shallow marsh, but also contains man-made ponds of unknown depth. Common carp have been documented on both sides of the temporary barrier in the spring prior to the normal spawning season. Common carp are a very resilient species and are capable of surviving a wide range of water quality parameters, and it is highly likely they are able to overwinter in the ponds within Eagle Marsh. It is also likely that if the carp arrived infected with VHS, the carp would survive in the ponds and transfer to the Mississippi River Basin via the Graham McCulloch Ditch under a suitable runoff event.

Remarks: 3B. Probability of ANS Surviving Transit to Aquatic Pathway Through Other Means

The rating for the ANS in this section does not influence the overall pathway rating outlined in this report and is only included to point out potential other pathways (e.g., anthropogenic) and their potential influence on the same list of ANS as evaluated in Section 4.2.1 above that may be important to different stakeholders. Any further analysis of these non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from those which may exploit the aquatic pathway.

## Eagle Marsh, Allen County, IN - Viral Hemorrhagic Septicemia (VHSv)

### 4. Probability of ANS establishing at the aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | MC | | |
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | MC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Ratings** | **High** | **RC** | | |

### 4. How do you rate the probability of ANS establishing at the aquatic pathway?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are plentiful in close proximity to support all life stages from birth to adult, abiotic conditions align with native range and there are no known predators or conditions that would significantly impede survivability or reproduction. |
| Medium | Limited and disconnected areas and sources of food and habitat suitable to the ANS are available in proximity, abiotic conditions are within latitude limits of native range, but only a portion of the healthy individuals arriving at location can be expected to effectively compete and survive. |
| Low | Habitat and abiotic conditions in proximity are outside the range where ANS has been known to survive; there is very limited availability habitat area suitable for ANS cover, sustainable food supply and reproduction; or native predators or competition with native species would likely prevent establishment of a sustainable population. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: VHS is capable of persisting outside of a host for several days when water temperatures are cool. However, as VHSv is active at water temperatures less than 60ºF, the higher water temperatures that likely occur in the summer months at Eagle Marsh might prevent the establishment and passage of VHSv during that time. The virus demonstrates a rapid reproductive cycle and is capable of utilizing many different host species. It is highly likely that VHS would be successful in establishing in fish populations already in Eagle Marsh, and nearby water ways, when water temperatures are appropriate.

## Eagle Marsh, Allen County, IN - Viral Hemorrhagic Septicemia (VHSv)

### 5. Probability of ANS spreading across aquatic pathway into the new basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Detroit - Biologist | High | VC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | RC | | |
| | USFWS - Fish Biologist | High | VC | | |
| | **Team Ratings** | **High** | **VC** | | |

### 5. How do you rate the probability of ANS spreading across aquatic pathway into the new basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are available, and the species has demonstrated capabilities to significantly expand range from locations where initially introduced. |
| Medium | There are limited sources of food and suitable habitat, and/or the species has demonstrated limited ability to spread significant distances beyond areas where it has been introduced. |
| Low | There are severely limited sources of food and suitable habitat, and/or the species has demonstrated very limited ability to spread beyond areas where it has been introduced. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: Surface water connections have been documented at the divide. During these connections, it is likely that the VHSv could spread beyond the pathway to the Mississippi River Basin. Since common carp were on both sides of the temporary barrier, it is possible that the virus could be passed through water on both sides of the temporary fence to new host fish across the divide. The likelihood is unknown but with spawning carp on both sides of the barrier, passing of VHSv is possible.

## Eagle Marsh, Allen County, IN - Ruffe (*Gymnochephalus cernuus*) / Tubenose Goby (*Proterorhinus semilunaris*)

### 1. Probability of aquatic pathway existence

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating Flow into GLB | Certainty | Rating Flow into MRB | Certainty |
|---|---|---|---|---|---|
| | USACE, Detroit - Hydraulic Engineer | High | RC | High | RC |
| | USACE, Louisville - Hydraulic Engineer | High | RC | High | RC |
| | USGS - Hydrologist | High | RC | High | RC |
| | INDNR - Engineering Geologist | High | RC | High | RC |
| | **Team Ratings** | **High** | **RC** | **High** | **RC** |

**1. How do you rate the likelihood of the existence of a viable aquatic pathway at the subject location? Assume a viable aquatic pathway is any location where untreated surface water flow across the divide is deemed likely to occur and connect headwater streams in both basins from any storm up to the 1% annual return frequency storm.**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Perennial streams and wetlands or intermittent stream known/documented to convey significant volumes of water across the basin divide for days to weeks multiple times per year. |
| Medium | Intermittent stream capable of maintaining a surface water connection to streams on both sides of the basin divide continuously for multiple days from a 10% annual return frequency storm; or, location of wetland spanning basin divide which maintains significant ponds that are likely to become inter connected and connect with streams on both sides of the basin divide from a 10% annual return frequency storm. |
| Low | Intermittent stream or marsh forming a surface water connection between streams on either side of the basin divide from larger than a 1.0% annual return frequency storm. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: USACE: Based upon numerical modeling developed as part of the parallel ANS Controls Report for the existing conditions, a connection appears to occur for storm events on the Graham McCulloch Ditch with a 10% chance annual exceedence event and less frequent events by way of overtopping the left descending bank (LDB) berm in low areas near the berms downstream-most section. Annual events on the St. Marys River make flow reverse direction in the Junk Ditch, and will cross the natural drainage divide, entering storage created by the LDB berm and the railroad embankment to the south ("Eagle Marsh southern storage area"). Additional storage is connected to this area in the Fox Island Park south of the railroad embankment, by way of a 4-foot diameter culvert through the railroad embankment. Two 18-inch (approximate) diameter pipes connect the Graham McCulloch Ditch to this storage area, but have flap-gates on the Graham McCulloch side of the berm; it is assumed that they are effective in preventing flow from the Graham McCulloch Ditch into this Eagle Marsh southern storage area until the LDB berm is overtopped. The 18-inch pipes are in poor condition, but it is assumed that they are still functional to drain waters ponding in the Eagle Marsh southern storage area. Storms events equal to or less frequent than the 1% chance exceedence event on the St Marys River are required to overtop the LDB berm.

As indicated above, the unsteady HEC-RAS modeling indicates that the greatest risk of a hydraulic connection results from flooding on the Graham McCulloch Ditch, and the frequency of occurrence is estimated as a 10% chance exceedence event or less frequent. Little data is available to support the definition of these frequency events, as the nearest flow or stage gage in this watershed is many miles downstream in Huntington, Indiana. Peak flows used for the 10%-, 4%-, 2%-, and 1%-chance annual exceedence events came from the Coordinated Discharge Graph "Ungaged Streams in Allen County", dated March 1982. Values for other frequency event peak flows were interpolated or extrapolated from these values. It is believed that these Coordinated Discharges were developed from regression equations, and therefore do not take into account the specific hydrology of the Graham McCulloch watershed. Even if relatively accurate upon creation of these Coordinated Discharges, it is believed that the watershed has undergone significant development. The shape of the hydrograph also had to be estimated. Significant data is available from the numerous gages in the Ft. Wayne area for the St. Marys River and other rivers and tributaries in that area, although several have very limited periods of record; however, there is significantly greater confidence in the flow information on the St. Marys River due to the large amount of information for that watershed that was made available by IDNR. The HEC-RAS model was able to be calibrated to historic events on the St. Marys River, with numerous high water marks available for one event. Definition of the LDB Berm profile used survey data provided by the NRCS of the berm and the Eagle Marsh area as a whole from 2006 when the property was purchased for the re-development of the wetlands. This data was believed to be of greater accuracy than the 2009 LIDAR data provided by the USGS and Allen County, although the 2006 survey data for the LDB berm is higher than the 2009 LIDAR on the order of 1-2 feet.

The frequency of a hydraulic pathway by overtopping described above is completely dependent upon the assumption that the profile of the LDB berm does not change. Multiple engineers who have visited the site agree that the integrity of the LDB berm is questionable; several slope failures, steep slopes, rodent burrows and other defects are visible, and there is no information regarding the level of design or construction methods. The berm therefore does not meet current geotechnical standards. It is expected that as time progresses, additional failures or a breach will occur. While the frequency of overtopping by a Graham McCulloch Ditch 10% chance exceedence event or greater would normally warrant a rating of Medium for flows into the Great Lakes Basin per the above criteria, this site is given a rating of High due to the expectation that failures of the LDB berm are likely, increasing the frequency of aquatic pathway development. Likewise, existing culverts through the LDB berm provide an annual connection for floods on the St. Marys watershed. Even if these pathways were removed, the poor integrity of the berm warrants a higher rating due to the increased likelihood of interconnection at more frequent events than modeling currently predicts

USGS: The H and H evaluation provides compelling indications for the high potential of a connection to develop between the MRB and GLB basins through overtopping of the berm along the Graham McCullough Ditch. The lack of discharge measurements on Graham McCulloch Ditch prevents a more refined analysis of flood stages. Flooding from the St Marys River appears to be a less probable cause of a connection at frequencies greater than 1 percent. The poor berm integrity as a levee, in combination with recurrent flooding, increases the probability of an interbasin connection to an unknown extent.

## Eagle Marsh, Allen County, IN - Ruffe (*Gymnochephalus cernuus* ) / Tubenose Goby (*Proterorhinus semilunaris* )

### 2. Probability of ANS occurring within either basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Detroit - Biologist | High | VC | | |
| | INDNR - AIS Coordinator | Medium | RC | | |
| | USGS - Fishery Biologist | Medium | RC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Rating** | **High** | **RC** | | |

### 2. How do you rate the probability of ANS occuring within either basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS exists on connected waterways in close enough proximity to be capable of moving to the aquatic pathway within 20 years. |
| Medium | Target ANS exists on connected waterways, but based on current proximity and mobility, is considered incapable of moving to the aquatic pathway within 20 years. |
| Low | Target ANS is not known to exist on a connected waterway. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: The ruffe and tubenose goby are located within the Great Lakes and associated with river mouths and estuaries of large river systems entering the Great Lakes. Literature reviews and actual fish survey data have not documented the collection of the ruffe in smaller upstream tributaries. The ruffe has been found in, Lake Michigan, Lake Superior, and Lake Huron (USGS 2011). The tubenose goby's introduced range includes Lake St. Clair, Lake Erie and Lake Huron, Lake Superior, and Lake Ontario (USGS 2011). It has been collected in the lower reaches of large tributaries to the Great Lakes and estuaries.

## Eagle Marsh, Allen County, IN - Ruffe (*Gymnochephalus cernuus* ) / Tubenose Goby (*Proterorhinus semilunaris* )

### 3. Probability of ANS surviving transit to aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | 3A Rating | Certainty | 3B Rating | Certainty |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Detroit - Biologist | Low | RC | Low | RC |
| | INDNR - AIS Coordinator | Low | RC | Low | RC |
| | USGS - Fishery Biologist | Low | MC | Low | RC |
| | USFWS - Fish Biologist | Medium | RC | Low | RC |
| | **Team Ratings** | **Low** | **RC** | **Low** | **RC** |

**3A. How do you rate the probability of ANS surviving transit to aquatic pathway through connecting streams?**

**3B. How do you rate the probability of ANS surviving transit to aquatic pathway through other means?**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to successfully navigate through the aquatic pathway and/or through other means to arrive at the subject pathway within 10-20 years. |
| Medium | Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through the aquatic pathway or through other means to arrive at the subject pathway within 20-50 years. |
| Low | Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations by aquatic pathway or other means to arrive at subject pathway within next 50 years. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: 3A. Probability of ANS Surviving Transit to Aquatic Pathway Through Connecting Streams.

The ruffe prefers deep waters of lakes and pools of rivers, usually over sand and gravels but has a tolerance for different habitats and environmental conditions (Gray and Best 1989). The ruffe has a high fecundity rate and spawns in clean water. The ruffe's ability to swim upstream during high flow events and migrate over dams is questionable. The tubenose goby is found in the open waters and estuaries of slow flowing rivers. The tube nose goby appears to be more capable of living in more varied types of riverine habitat than the ruffe.

Remarks: 3B. Probability of ANS Surviving Transit to Aquatic Pathway Through Other Means

The rating for the ANS in this section does not influence the overall pathway rating outlined in this report and is only included to point out potential other pathways (e.g., anthropogenic) and their potential influence on the same list of ANS as evaluated in Section 4.2.1 above that may be important to different stakeholders. Any further analysis of these non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from those which may exploit the aquatic pathway.

## Eagle Marsh, Allen County, IN - Ruffe (*Gymnochephalus cernuus* ) / Tubenose Goby (*Proterorhinus semilunaris* )

### 4. Probability of ANS establishing at the aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | MC | | |
| | USACE, Louisville - Biologist | Medium | MC | | |
| | USACE, Detroit - Biologist | Medium | MC | | |
| | INDNR - AIS Coordinator | Medium | MC | | |
| | USGS - Fishery Biologist | Medium | RC | | |
| | USFWS - Fish Biologist | Medium | MC | | |
| | **Team Ratings** | **Medium** | **MC** | | |

### 4. How do you rate the probability of ANS establishing at the aquatic pathway?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are plentiful in close proximity to support all life stages from birth to adult, abiotic conditions align with native range and there are no known predators or conditions that would significantly impede survivability or reproduction. |
| Medium | Limited and disconnected areas and sources of food and habitat suitable to the ANS are available in proximity, abiotic conditions are within latitude limits of native range, but only a portion of the healthy individuals arriving at location can be expected to effectively compete and survive. |
| Low | Habitat and abiotic conditions in proximity are outside the range where ANS has been known to survive; there is very limited availability habitat area suitable for ANS cover, sustainable food supply and reproduction; or native predators or competition with native species would likely prevent establishment of a sustainable population. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: The ruffe is an aggressive species that possesses the ability to feed in darkness, cold temperatures and turbid conditions. Tubenose gobies are benthic species that consume a wide variety of invertebrates (USGS 2011). They are often quite abundant in backwaters and lakes and seem to prefer dense vegetation. However, survival of a viable, reproducing population of ruffe and tubenose goby within the small ponds of Eagle Marsh may be unlikely due low water quality and high temperatures in summer months. However, the ponds within Eagle Marsh could provide the necessary habitat for occupation of these species until a suitable storm event occurred and the fish could pass into the Graham McCulloch Ditch and migrate downstream into the MRB.

## Eagle Marsh, Allen County, IN - Ruffe (*Gymnochephalus cernuus* ) / Tubenose Goby (*Proterorhinus semilunaris* )

### 5. Probability of ANS spreading across aquatic pathway into the new basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | Medium | RC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Ratings** | **High** | **RC** | | |

### 5. How do you rate the probability of ANS spreading across aquatic pathway into the new basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are available, and the species has demonstrated capabilities to significantly expand range from locations where initially introduced. |
| Medium | There are limited sources of food and suitable habitat, and/or the species has demonstrated limited ability to spread significant distances beyond areas where it has been introduced. |
| Low | There are severely limited sources of food and suitable habitat, and/or the species has demonstrated very limited ability to spread beyond areas where it has been introduced. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: Ruffe and the tubenose goby have not been found in river systems similar to the Graham McCulloch Ditch and Little River.

## Eagle Marsh, Allen County, IN - Threespine Stickleback (*Gasterosteus aculeatus* )

### 1. Probability of aquatic pathway existence

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating Flow into GLB | Certainty | Rating Flow into MRB | Certainty |
|---|---|---|---|---|---|
| | USACE, Detroit - Hydraulic Engineer | High | RC | High | RC |
| | USACE, Louisville - Hydraulic Engineer | High | RC | High | RC |
| | USGS - Hydrologist | High | RC | High | RC |
| | INDNR - Engineering Geologist | High | RC | High | RC |
| | **Team Ratings** | **High** | **RC** | **High** | **RC** |

**1. How do you rate the likelihood of the existence of a viable aquatic pathway at the subject location? Assume a viable aquatic pathway is any location where untreated surface water flow across the divide is deemed likely to occur and connect headwater streams in both basins from any storm up to the 1% annual return frequency storm.**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Perennial streams and wetlands or intermittent stream known/documented to convey significant volumes of water across the basin divide for days to weeks multiple times per year. |
| Medium | Intermittent stream capable of maintaining a surface water connection to streams on both sides of the basin divide continuously for multiple days from a 10% annual return frequency storm; or, location of wetland spanning basin divide which maintains significant ponds that are likely to become inter connected and connect with streams on both sides of the basin divide from a 10% annual return frequency storm. |
| Low | Intermittent stream or marsh forming a surface water connection between streams on either side of the basin divide from larger than a 1.0% annual return frequency storm. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: USACE: Based upon numerical modeling developed as part of the parallel ANS Controls Report for the existing conditions, a connection appears to occur for storm events on the Graham McCulloch Ditch with a 10% chance annual exceedence event and less frequent events by way of overtopping the left descending bank (LDB) berm in low areas near the berms downstream-most section. Annual events on the St. Marys River make flow reverse direction in the Junk Ditch, and will cross the natural drainage divide, entering storage created by the LDB berm and the railroad embankment to the south ("Eagle Marsh southern storage area"). Additional storage is connected to this area in the Fox Island Park south of the railroad embankment, by way of a 4-foot diameter culvert through the railroad embankment. Two 18-inch (approximate) diameter pipes connect the Graham McCulloch Ditch to this storage area, but have flap-gates on the Graham McCulloch side of the berm; it is assumed that they are effective in preventing flow from the Graham McCulloch Ditch into this Eagle Marsh southern storage area until the LDB berm is overtopped. The 18-inch pipes are in poor condition, but it is assumed that they are still functional to drain waters ponding in the Eagle Marsh southern storage area. Storms events equal to or less frequent than the 1% chance exceedence event on the St Marys River are required to overtop the LDB berm.

As indicated above, the unsteady HEC-RAS modeling indicates that the greatest risk of a hydraulic connection results from flooding on the Graham McCulloch Ditch, and the frequency of occurrence is estimated as a 10% chance exceedence event or less frequent. Little data is available to support the definition of these frequency events, as the nearest flow or stage gage in this watershed is many miles downstream in Huntington, Indiana. Peak flows used for the 10%-, 4%-, 2%-, and 1%-chance annual exceedence events came from the Coordinated Discharge Graph "Ungaged Streams in Allen County", dated March 1982. Values for other frequency event peak flows were interpolated or extrapolated from these values. It is believed that these Coordinated Discharges were developed from regression equations, and therefore do not take into account the specific hydrology of the Graham McCulloch watershed. Even if relatively accurate upon creation of these Coordinated Discharges, it is believed that the watershed has undergone significant development. The shape of the hydrograph also had to be estimated. Significant data is available from the numerous gages in the Ft. Wayne area for the St. Marys River and other rivers and tributaries in that area, although several have very limited periods of record; however, there is significantly greater confidence in the flow information on the St. Marys River due to the large amount of information for that watershed that was made available by IDNR. The HEC-RAS model was able to be calibrated to historic events on the St. Marys River, with numerous high water marks available for one event. Definition of the LDB Berm profile used survey data provided by the NRCS of the berm and the Eagle Marsh area as a whole from 2006 when the property was purchased for the re-development of the wetlands. This data was believed to be of greater accuracy than the 2009 LIDAR data provided by the USGS and Allen County, although the 2006 survey data for the LDB berm is higher than the 2009 LIDAR on the order of 1-2 feet.

The frequency of a hydraulic pathway by overtopping described above is completely dependent upon the assumption that the profile of the LDB berm does not change. Multiple engineers who have visited the site agree that the integrity of the LDB berm is questionable; several slope failures, steep slopes, rodent burrows and other defects are visible, and there is no information regarding the level of design or construction methods. The berm therefore does not meet current geotechnical standards. It is expected that as time progresses, additional failures or a breach will occur. While the frequency of overtopping by a Graham McCulloch Ditch 10% chance exceedence event or greater would normally warrant a rating of Medium for flows into the Great Lakes Basin per the above criteria, this site is given a rating of High due to the expectation that failures of the LDB berm are likely, increasing the frequency of aquatic pathway development. Likewise, existing culverts through the LDB berm provide an annual connection for floods on the St. Marys watershed. Even if these pathways were removed, the poor integrity of the berm warrants a higher rating due to the increased likelihood of interconnection at more frequent events than modeling currently predicts

USGS: The H and H evaluation provides compelling indications for the high potential of a connection to develop between the MRB and GLB basins through overtopping of the berm along the Graham McCullough Ditch. The lack of discharge measurements on Graham McCulloch Ditch prevents a more refined analysis of flood stages. Flooding from the St Marys River appears to be a less probable cause of a connection at frequencies greater than 1 percent. The poor berm integrity as a levee, in combination with recurrent flooding, increases the probability of an interbasin connection to an unknown extent.

## Eagle Marsh, Allen County, IN - Threespine Stickleback (*Gasterosteus aculeatus* )

### 2. Probability of ANS occurring within either basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Louisville - Biologist | High | VC | | |
| | USACE, Detroit - Biologist | High | VC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | RC | | |
| | USFWS - Fish Biologist | High | VC | | |
| | **Team Rating** | **High** | **VC** | | |

### 2. How do you rate the probability of ANS occuring within either basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS exists on connected waterways in close enough proximity to be capable of moving to the aquatic pathway within 20 years. |
| Medium | Target ANS exists on connected waterways, but based on current proximity and mobility, is considered incapable of moving to the aquatic pathway within 20 years. |
| Low | Target ANS is not known to exist on a connected waterway. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: The threespine stickleback is found in each of the Great Lakes except Lake Ontario and has been collected in some inland river systems (USGS 2011). Literature indicates this species prefers to live in smaller streams but may occur in a variety of habitat including lakes and large rivers.

## Eagle Marsh, Allen County, IN - Threespine Stickleback (*Gasterosteus aculeatus* )

### 3. Probability of ANS surviving transit to aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | 3A Rating | Certainty | 3B Rating | Certainty |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Louisville - Biologist | Medium | RC | Low | RC |
| | USACE, Detroit - Biologist | Medium | RC | Low | RC |
| | INDNR - AIS Coordinator | Medium | RC | Low | RC |
| | USGS - Fishery Biologist | Medium | RC | Low | RC |
| | USFWS - Fish Biologist | Medium | RC | Low | RC |
| | **Team Ratings** | **Medium** | **RC** | **Low** | **RC** |

**3A. How do you rate the probability of ANS surviving transit to aquatic pathway through connecting streams?**

**3B. How do you rate the probability of ANS surviving transit to aquatic pathway through other means?**

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Target ANS are established in relatively close proximity to location and have ample opportunity, capability and motivation to successfully navigate through the aquatic pathway and/or through other means to arrive at the subject pathway within 10-20 years. |
| Medium | Target ANS are established at locations in close enough proximity to location and have limited capability to survive passage through the aquatic pathway or through other means to arrive at the subject pathway within 20-50 years. |
| Low | Target ANS are not in proximity to the pathway, and/or it is highly unlikely that they could survive transit from current locations by aquatic pathway or other means to arrive at subject pathway within next 50 years. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: 3A. Probability of ANS Surviving Transit to Aquatic Pathway Through Connecting Streams.

The threespine stickleback has been found in the Great Lakes and in smaller river systems. While not having been identified within the upper Maumee River system, its close proximity in the Great Lakes and particularly Lake Erie, indicate potential for access and transfer to the Mississippi River Basin via the Eagle Marsh connection. Section 2.7 describes obstacles to upstream migration within the Maumee River. These should be sufficient in impeding migration of the threespine stickleback at normal and low flows. As these obstacles become inundated during high flow events, the stickleback may have ample opportunity to move upstream. However, it is likely that this species will seek refuge from high velocities instead of expending energy attempting to move upstream. It is likely that sufficient forage and habitat is available throughout the Maumee River basin for the threespine stickleback.

Remarks: 3B. Probability of ANS Surviving Transit to Aquatic Pathway Through Other Means

The rating for the ANS in this section does not influence the overall pathway rating outlined in this report and is only included to point out potential other pathways (e.g., anthropogenic) and their potential influence on the same list of ANS as evaluated in Section 4.2.1 above that may be important to different stakeholders. Any further analysis of these non-aquatic pathways outside of this study should develop a separate list of ANS that will likely differ from those which may exploit the aquatic pathway.

## Eagle Marsh, Allen County, IN - Threespine Stickleback (*Gasterosteus aculeatus* )

### 4. Probability of ANS establishing at the aquatic pathway

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | Medium | MC | | |
| | USACE, Louisville - Biologist | Medium | MC | | |
| | USACE, Detroit - Biologist | Medium | MC | | |
| | INDNR - AIS Coordinator | Medium | MC | | |
| | USGS - Fishery Biologist | Medium | RC | | |
| | USFWS - Fish Biologist | Medium | MC | | |
| | **Team Ratings** | **Medium** | **MC** | | |

### 4. How do you rate the probability of ANS establishing at the aquatic pathway?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are plentiful in close proximity to support all life stages from birth to adult, abiotic conditions align with native range and there are no known predators or conditions that would significantly impede survivability or reproduction. |
| Medium | Limited and disconnected areas and sources of food and habitat suitable to the ANS are available in proximity, abiotic conditions are within latitude limits of native range, but only a portion of the healthy individuals arriving at location can be expected to effectively compete and survive. |
| Low | Habitat and abiotic conditions in proximity are outside the range where ANS has been known to survive; there is very limited availability habitat area suitable for ANS cover, sustainable food supply and reproduction; or native predators or competition with native species would likely prevent establishment of a sustainable population. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: As a visual predator, the turbid ponds of Eagle Marsh and the Graham-McCulloch Ditch may be unsuitable for the threespine stickleback. Survival of a viable, reproducing population of threespine stickleback within the marsh is unlikely. However, the ponds may provide sufficient habitat for occupation of any of this species until a suitable storm event occurred and the fish could pass into the Graham McCulloch Ditch and migrate downstream into the MRB.

## Eagle Marsh, Allen County, IN - Threespine Stickleback (*Gasterosteus aculeatus* )

### 5. Probability of ANS spreading across aquatic pathway into the new basin

| Aquatic Pathway Team | Expertise<br>Position title or team role | Rating | Certainty | | |
|---|---|---|---|---|---|
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Louisville - Biologist | High | RC | | |
| | USACE, Detroit - Biologist | High | RC | | |
| | INDNR - AIS Coordinator | High | RC | | |
| | USGS - Fishery Biologist | High | RC | | |
| | USFWS - Fish Biologist | High | RC | | |
| | **Team Ratings** | **High** | **RC** | | |

### 5. How do you rate the probability of ANS spreading across aquatic pathway into the new basin?

| Qualitative Rating | Qualitative Rating Category Criteria |
|---|---|
| High | Sources of food and habitat suitable to the ANS are available, and the species has demonstrated capabilities to significantly expand range from locations where initially introduced. |
| Medium | There are limited sources of food and suitable habitat, and/or the species has demonstrated limited ability to spread significant distances beyond areas where it has been introduced. |
| Low | There are severely limited sources of food and suitable habitat, and/or the species has demonstrated very limited ability to spread beyond areas where it has been introduced. |

| | Symbol | |
|---|---|---|
| Very Certain | VC | As certain as I am going to get. |
| Reasonably Certain | RC | Reasonably certain. |
| Moderately Certain | MC | More certain than not. |
| Reasonably Uncertain | RU | Reasonably uncertain |
| Very Uncertain | VU | A guess |

Remarks: The threespine stickleback has been found in smaller river systems. It is possible that life history requirements of threespine stickleback could be met in the aquatic pathway leading from the Lake Erie to Eagle Marsh, resulting in the potential establishment of a viable population at Eagle Marsh that could then transfer into the Mississippi River Basin during a suitable flooding event.

# GLMRIS

Great Lakes and Mississippi River Interbasin Study

Aquatic Nuisance Species | Ecosystems | Navigation | Recreation | Flood Risk Management | Water Use

## Aquatic Nuisance Species Controls Report

## Wabash-Maumee Basin Connection

## Fort Wayne, Indiana

# Appendix B
# List of Acronyms/ Abbreviations

US Army Corps of Engineers®
BUILDING STRONG®

This page is intentionally blank.

# AQUATIC NUISANCE SPECIES CONTROLS REPORT
# WABASH-MAUMEE BASIN CONNECTION STUDY
# FORT WAYNE, INDIANA

## APPENDIX B
## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AE | Architectural Engineering |
| ANS | Aquatic Nuisance Species |
| APE | Area of Potential Effect |
| ATR | Agency Technical Review |
| ASTM | American Society for Testing Materials |
| CAA | Clean Air Act |
| CAWS | Chicago Area Waterway System |
| CELRD | Corps of Engineers, Great Lakes and Ohio Rivers Division |
| CEQ | Council on Environmental Quality |
| cfs | cubic feet per second |
| CMP | Corrugated Metal Pipe |
| CSSC | Chicago Sanitary Ship Canal |
| CWA | Clean Water Act |
| CWCCIS | Civil Works Construction Cost Index System |
| CY | cubic yard |
| dB | Decibel |
| DNL | Day-Night Average Sound Level |
| DS | Downstream |
| EC | Engineer Circular |
| eDNA | environmental Deoxyribonucleic Acid |
| EFARS | Engineering Federal Acquisition Regulation Supplement |
| EL | Elevation |
| EM | Engineer Manual |
| EMSS | Eagle Marsh South Storage |
| EP | Engineer Pamphlet |
| EPA | Environmental Protection Agency |
| ER | Engineer Regulation |
| ESA | Endangered Species Act |
| ETL | Engineer Technical Letter |
| F | Fahrenheit |
| FEMA | Federal Emergency Management Agency |
| FIRM | Flood Insurance Rate Map |
| fps | Feet Per Second |
| FS | Factor of Safety |
| ft | feet |
| GLMRIS | Great Lakes Mississippi River Inter-Basin Study |
| GPS | Global Positioning System |
| HEC-HMS | Hydrological Engineering Center, Hydrological Modeling System |

## APPENDIX B
## ABBREVIATIONS AND ACRONYMS
## (cont.)

| | |
|---|---|
| HDPE | High Density Polyethylene |
| HQ | Headquarters |
| HTRW | Hazardous, Toxic, & Radioactive waste |
| HUC | Hydrologic Unit Cycle |
| I | Interstate |
| I.D. | Inside Diameter |
| IDNR | Indiana Department of Natural Resources |
| IEPR | Independent External Peer Review |
| IN | Indiana |
| i.e. | for example |
| IN-SHPO | Indiana State Historic Preservation Officer |
| IPFW | Indiana University-Purdue University Fort Wayne |
| kw | kilowatt |
| kwh | kilowatt - hour |
| KY | Kentucky |
| LERRDS | Land, Easements, Right of Way, Relocation, & Disposal Areas |
| lf | linear feet |
| LRWP | Little River Wetlands Project |
| LS | Landside |
| MCACES | Micro Computer Aided Estimating System |
| MCC | Motor Control Center |
| MSL | Mean Sea Level |
| NAAQS | National Ambient Air Quality Standards |
| NAVD | North American Vertical Datum |
| NED | National Economic Development |
| NEIC | National Earthquake Information Center |
| NEPA | National Environmental Policy Act |
| NFIP | National Flood Insurance Program |
| NFS | Non-Federal Sponsor |
| NGVD | National Geodetic Vertical Datum |
| NHPA | National Historic Preservation Act |
| NMFS | National Marine Fisheries Service |
| No. | Number |
| NOAA | National Oceanic and Atmospheric Administration |
| NPL | National Priorities List |
| NRCS | Natural Resources Conservation Service |

# APPENDIX B
## ABBREVIATIONS AND ACRONYMS
## (cont.)

| | |
|---|---|
| NRHP | National Register of Historic Places |
| OHWM | Ordinary High Water Mark |
| OSHA | Occupational Safety and Health Administration |
| O&M | Operation and Maintenance |
| pcf | pounds per cubic foot |
| PDT | Project Delivery Team |
| PE | Professional Engineer |
| PS | Pump Station |
| psf | pounds per square foot |
| psi | pounds per square inch |
| RS | Riverside |
| RWCIE | Right of Way – Channel Improvement Easement |
| RWLVE | Right of Way – Levee/Floodwall Easement |
| RWRDE | Right of Way – Road Easement |
| RWTWE | Right of Way – Temporary Work Easement |
| RWUPE | Right of Way – Utility and Pipe Easement |
| SCS | Soil Conservation Service |
| UASFLA | Uniform Appraisal Standards for Federal Land Acquisition |
| UFGS | Unified Facilities Guide Specifications |
| US | Upstream |
| U.S. | United States |
| USACE | United States Army Corps of Engineers |
| USCS | Unified Soil Classification System |
| USDA | United Stated Department of Agriculture |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| USPAP | Uniform Standards of Professional Appraisal Practice |
| VHSV | Viral Hemorrhagic Septicemia Virus |
| WOPC | Without Project Condition |
| WRDA | Water Resources Development Act |
| WRP | Wetlands Reserve Program |
| VE | Value Engineering |
| WSEL | Water Surface Elevation |
| WWTP | Waste Water Treatment Plant |

# GLMRIS

Great Lakes and Mississippi River Interbasin Study

Aquatic Nuisance Species | Ecosystems | Navigation | Recreation | Flood Risk Management | Water Use

## Aquatic Nuisance Species Controls Report

## Wabash-Maumee Basin Connection

## Fort Wayne, Indiana

# APPENDIX C
# List of Preparers

US Army Corps of Engineers®
BUILDING STRONG®

This page is intentionally blank.

# AQUATIC NUISANCE SPECIES CONTROLS REPORT
# WABASH-MAUMEE BASIN CONNECTION STUDY
# FORT WAYNE, INDIANA

## APPENDIX C

## PREPARERS

The primary study team members who are familiar with the technical aspects of the study are listed below (all individuals are USACE Louisville District employees unless stated otherwise):

Environmental Studies.....Michael Turner (CELRD), Jesse Helton and Drew Russell

Cost Estimate .....Jim Vermillion and Justin Tabor

Cultural Resources.....Jan Marie Hemberger

Geotechnical Engineering...Matthew Whelan, PE

GIS and Mapping.....Jonathan Hall

Hydraulics & Hydrology.....Ken Lamkin, PE, Chris Ritz (USDA/NRCS), Dave Nance, PG (Indiana DNR)

Plan Formulation.....Gerard Edelen, PE, Nate Moulder and Harry Hottell

Public Affairs.....Carol Labashosky

Project/Civil Engineering....Bonnie Jennings, PE

Office of Counsel.....Barb Lollar

Value Engineering .....Ben Robertson, AVS

Real Estate .....Jason Meyer

Socioeconomic Analysis.....M. Alexander Ryan

Technical Drawings .....Charles Robinson

Technical Editors .....Roger Setters, PE (CELRD), Jane Ruhl, PE, Rhiannon Ryan and Jon Fleshman

Primary collaborators assisting in the preparation of this report include Sherman Liechty, USDA, NRCS, Betsy Yankowiak and Tony Fleming, LRWP and Doug Keller, Indiana DNR.