Division of Planning Research On-Call Task#8 - Assessment and Prioritization of Culverts for Enhanced Fish Passage

Prepared by:
Natalie Kruse Daniels
Jen Bowman
Nora Sullivan
Amy Mackey
Daniel Che
Binay Sapkota

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16. Abstract			
Culverts can be an impediment to fish passage, impacting fish populations and spawning of both migratory and non-migratory species. With increased opportunities to invest in both water resources and infrastructure, prioritizing and selecting potential locations for culvert replacement to remove fish barriers is timely. In this project, we engaged with stakeholders in the eastern basin of Lake Erie to discuss and visit both potential and completed culvert replacement project sites; these stakeholders would be strong potential partners for ODOT in the future. The OHIO team also reviewed approved NPS-IS plans for identification of fish passage barriers that may be useful planning and design-ready project sites for ODOT to pursue if funding were available. The OHIO team also developed a method to prioritize and identify potential culvert replacement project locations using a GIS-based analysis. Culverts in target, high quality watersheds on perennial or intermittent streams are identified. Their openness ratio is then calculated; a low openness ratio is poor for fish passage and suggests that the site could be a good candidate. Aerial imagery and LiDAR data are then used to calculate an average slope of the culvert from the streambed upstream to the streambed downstream of the culvert. A high average slope would suggest either a highly sloped culvert or a low to moderate slope culvert with a vertical disconnection on the downstream end; either case would be poor for fish passage. Natural breaks in the data suggested that sites with high slope (>10%) and sites with moderate slope (4-10%) should be field verified as potential project sites.			
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Prepared by:

Natalie Kruse Daniels
Jen Bowman
Nora Sullivan
Amy Mackey
Energy and Environment Team
Voinovich School of Leadership and Public Service
Ohio University

Daniel Che
Binay Sapkota
Ohio Research Institute for Transportation and the Environment
Ohio University

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Prepared in cooperation with the Ohio Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration

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Introduction

Problem Statement

The Ohio Department of Transportation (ODOT) is responsible for thousands of culverts that convey streams in the Lake Erie watershed. Some culverts are recognized as impediments to fish passage, acting akin to low head dams, particularly at periods of low stream flow. Culverts that experience high velocities at certain flow regimes may also serve as a barrier for certain fish species. Culverts and other similar structures that limit aquatic organism passage can lead to a reduction in fish species upstream compared to those found downstream (Favaro & Moore, 2015, Briggs & Galarowicz, 2013). Barriers to upstream migration can reduce the quality of the fish community and reduce the potential for improvement in fish communities due to other watershed restoration work. Conversely, culverts preventing aquatic organism passage may also be preventing upstream migration of invasive fish species from Lake Erie into tributary streams.

Goals and Objectives

The goal of Task #8 is to identify the scale of culvert related aquatic organism barriers in the Lake Erie watershed, target key high-quality watershed focus areas, and identify potential project locations for culvert conversion to allow for aquatic organism passage.

The specific objectives for Task #8 are to: 1) identify high quality watersheds in the Lake Erie watershed that could benefit from improved aquatic organism passage; 2) using a geographic information systems (GIS) approach, identify culverts that are likely impeding aquatic organism passage in the target watersheds; and 3) produce a technical brief to report the findings of the research including options for improved aquatic organism passage, discussion of risks, and prioritization of potential projects.

Research Background

A previous study conducted by Youngstown State University in 2013 funded by ODOT (Baral & Tritico, 2013) found that fish connectivity in 6 northeast Ohio counties (in Lake Erie Watershed) was restricted and, in some places, completely blocked. Of the 90 culverts modeled using HEC-RAS and FishXing for 10 specific species, 23 culverts were partial barriers during certain flow regimes while 67 culverts were complete barriers to fish at all flow regimes. Of interest, the 23 partial barrier culverts were at 0.6% slope while the complete blockage culverts were at 1.6% slope. The height of the culvert outlet above the streambed on the downstream side proved to be a significant predictor of a culvert being a barrier (Baral & Tritico, 2013).

While over the past several decades much work has been conducted to inventory and restore passage in the western United States on aquatic resources that support salmon and trout populations (Kanzler et. al., 2021), the Midwest began paying more attention to the Great Lakes Region during the Obama Administration under The Great Lakes Restoration Initiative (GLRI, https://www.glri.us/) that started in 2010. This initiative was created to control for invasive species, protect waterways and increase passage of fish between bodies of water, among other things. Fish passage projects funded through this initiative focused on reconnecting tributaries that support the highest quality aquatic life (GRLI, 2017). Many projects to restore culvert passage have been funded across the 8 states part of the

Great Lakes Region. For example, in 2013 the U.S. Fish and Wildlife Service awarded $645,000 to Midwest Region's Great Lakes Basin to support the removal of 12 fish passage barriers, reconnecting 91 miles of stream (U.S. Fish and Wildlife Service, 2013).

Now in Ohio with the focus on Lake Erie restoration and H2Ohio funding under the DeWine administration alongside the potential for Federal grants and infrastructure investment, this presents a timely opportunity to inventory and identify restoration projects that increase the aquatic habitat and fish passage throughout Ohio's Lake Erie watershed.

Report Structure

This final report for Task 8 details a review of the literature on aquatic organism passage, invasive species control, and GIS-based methods for project prioritization (Task 8.1); selection of priority watersheds for fish passage projects (Task 8.2) including geographic data-based filtering of target watersheds (8.2.1), the results of extensive stakeholder outreach (8.2.2), and an evaluation of fish species to direct management decisions (8.2.3); methods for selection of potential project sites for culvert replacement using GIS and LiDAR (Task 8.3), and recommendations based on the findings of this study (Task 8.4).

Task 8.1 Literature Review

Habitat fragmentation and alteration are often unintended consequences of transportation infrastructure in streams and rivers and are correlated with low species richness in fish and aquatic organisms (Edge et al., 2016, McManamay et al., 2016, Goodrich et al., 2018). Road culverts are historically designed with cost and water conveyance in mind (Baral & Tritico, 2013), not the needs of aquatic organisms. Road culverts, which require maintenance and replacement, therefore represent a place where infrastructure managers have opportunities to reduce or eliminate barriers, allowing for natural movement and migration of species with aquatic life cycles. Much work has been done identifying the factors contributing to reduced access to necessary habitats, with blocked passage being identified as a driver of habitat fragmentation (Favaro & Moore, 2015 Jones et al., 2020).

Here we investigate previous work and research in three specific areas surrounding culvert barriers to fish passage: 1) culvert designs that promote aquatic organism passage; 2) risk of invasive species movement with culvert removal; and 3) project prioritization methods for culvert replacement or modification, particularly methods using geographic information systems (GIS).

Goodrich et al. describe culverts as "instream structures that act as hydrological barriers to fish movement by altering water turbulence, increasing water velocities and disrupting connectivity" (p. 115, 2018). While this is an ecologically centered view, when it comes to how well culverts are able to support upstream fish passage, the range of culvert designs is broad. There has been a fair amount of study surrounding culvert design with researchers attempting to identify conditions that allow, promote, and prevent passage. Some studies compared modeled culvert designs to known fish leaping and swimming abilities (Baral, 2013, Bourne et al., 2011), others trialed fish in a variety of simulated conditions from perched height, to slope, to flow velocity, in controlled laboratory conditions (Leng & Chanson, 2020, Shiau et al., 2020, Watson et al., 2018, Goodrich et al., 2018, Jones et al., 2020,), and still others observed fish behavior in the field (Eisenhour & Floyd, 2013, Fleming & Neeson, 2020, Favaro & Moore, 2015, Briggs & Galarowicz, 2013). Slope is not a variable with categorical cutoff values, rather the slope of the culvert should not exceed the slope of the stream itself. No universally passable design, material, or condition emerged from these efforts, but rather, most researchers conclude that conditions and goals at each culvert installation or replacement should dictate design.

Most models and studies identify three basic challenges that culverts present to fish: slope, which includes both connected upstream to downstream elevation changes, and perched height that disconnects flow and requires fish to jump to subsequent levels; flow velocity increases; and water level changes (Goodrich, 2018, Bourne et al., 2011, Shiau et al., 2020, Leng & Chanson, 2020, Jones et al., 2021). While length is not identified in the top three barriers of most studies, a study in Michigan showed that in first order agricultural streams where slope and velocity are not a factor, culvert length of greater than 17 meters increased barrier probability by 50% (Briggs & Galarowicz, 2013), and in the Ozarks, length was identified as a factor influencing fish communities upstream of culverts (Flemming & Neeson, 2020). Culverts designed for fish passage try to overcome all of these challenges.

Baral & Tritico, (2013) compared a variety of parameters in selected culverts including length, slope, and embeddedness, to known fish swimming abilities in FishXing (US Fish and Wildlife Service) and HEC-RAS (US Army Corps of Engineers Hydrologic Engineering Center River Analysis System) software, all of the selected circular culverts were found to be at least partial barriers to fish passage.

Further modeling changes to slope, culvert diameter, length, and bed roughness suggested improved passage possibilities for certain species by reducing flow velocity, since high velocity can be problematic for all but the larger, stronger swimmers. Widening the channel, however, also lowered flow depth, which then impeded the larger bodied fish. Embedding the culverts to achieve a rougher bottom achieved the largest improvements in passability in the model (Baral & Tritico, 2013).

Open bottom and embedded closed bottom structures, regardless of shape or material can improve passability, when the culvert is the full width of the streambed, requirements of target fish are also met. The Canadian Ministry of Forests, Lands and Natural Resource Operations gives specific guidance on designing culverts with natural bottoms: "The embedment methodology (also known as stream simulation) consists of selecting a culvert (pipe) of adequate opening to encompass the stream channel width and emulating the streambed within the culvert by lining the bottom with representative streambed substrate. The natural substrate materials are supplemented with additional larger material to help retain the substrate within the culvert and assist fish passage" (B.C. Ministry of Forests 2012, p. 25). Achieving the recommended embeddedness and width of a culvert may necessitate the selection of a larger culvert than a traditional design guideline may suggest.

Non-embedded, closed culverts, like four-sided box culverts, can be adapted to assist fish passage by either increasing or decreasing flow velocity by installing baffles. Even in significantly increased flows, wall baffles installed on one wall of a box culvert created enough change in flow near the baffles to allow some fish passage. A downside to baffles, however, is that they may trap sediments at low flow and larger debris after flood events, requiring regular monitoring and maintenance (Leng & Chanson, 2020). In closed bottom, non-embedded culverts with seasonal or climate change induced low flow, there is little that can be done to help fish passage (Shiau et al., 2020).

Corrugated metal pipe (CMP) has been widely used as culverts but are not recommended for fish passage unless heavily embedded (B.C. Ministry of Forests, 2002). Compared to traditional culvert design, this will result in a larger diameter culvert. One study, however, found that when weathered, CMP assisted some crayfish passage, as the lower bumps provided refuge from high velocity flow, and theorized that smaller, lower profile fish also benefit (Foster & Keller, 2011).

The North Atlantic Aquatic Connectivity Collaborative (NAACC) at the University of Massachusetts Amherst maintains a website with data and resources for environmental managers working to improve stream connectivity. NAACC lists culvert design criteria for connectivity which match the findings of this review. The six most important standards noted are:

- Use of an open bottom span-type structure
- Culvert embedment a minimum of 2 feet into the stream bed
- Spanning the stream and its banks at least 1.25 times natural bankfull width, where bankfull width is measured by field survey
- An "openness ratio" (cross sectional area of culvert / crossing length) of about 1-1.5 feet
- Substrate (rocks, gravel, etc.) within the culvert that matches upstream and downstream substrate
- Water depth and velocity within the culvert that match those in the natural channel (North Atlantic Aquatic Connectivity Collaborative, 2019).

Since no single culvert design will allow passage for every potential organism, each culvert should be designed for the targeted species, or set of species, with a slope to maintain a low enough flow velocity, width to control flow depth, and substrate similar to natural stream conditions.

Plans for ecosystem reconnection projects, such as culvert replacement, must balance the benefits of improving native species passage with protecting ecosystems from the risk of invasive species. The risk of invasive species movement after barrier removal is an area of concern for invasive species control. Species like the sea lamprey and the round goby are harmful invasives in Lake Erie and the other Great Lakes. Round gobies have become established in areas of the Great Lakes and their tributaries, and may compete with native species, particularly the mottled sculpin. Control currently focusses on educating boaters and anglers to reduce the spread of the fish by not transporting them as bait or in bilge (Crosier et al., 2021).

In the Atlantic Ocean, their native habitat, sea lamprey feed on ocean host species without killing them. The smaller sized fish in the Great Lakes, however, cannot sustain lamprey and survive. Since the 1960s The Great Lakes Fishery Commission (GLFC) has been engaged in sea lamprey population control, and report that the population has been reduced by 90%. Past loosening of control measures has shown, however, that the fish will make a fast comeback if tight controls are not maintained (CFLG, 2014). Sea lamprey controls include lampricides application in tributaries where the fish spawn and larva develop, and physical barriers to prevent access to suitable spawning tributaries. Inflatable barriers not only block access for the sea lamprey, which do not have good jumping abilities, but they also block other species that cannot jump.

While there are around 70-80 fishways and structures intended to help fish overcome barriers in the Great Lakes basin, none are in the study area (Zielinski & Freiburger, 2020). Such structures, like wetted ramps and fish ladders, tend to favor one species over another (Goodrich et al., 2018). Some argue that even small barriers affect native smaller bodied fish, and the installation of invasive species control measures is biased toward salmonids with greater leaping ability (Jones et al., 2021). Dodd et al. found that streams with barriers inflated for sea lamprey run season average 3.4 fewer species of fish upstream than downstream of barriers (2003).

Milt et al. looked at opportunity costs of sea lamprey controls in the Great Lakes, comparing modeled gains for native species and sea lamprey, with and without sea lamprey controls in place. Their regressions showed that while some species did benefit from blocking sea lamprey gains, “more species are affected by lost access to tributary spawning grounds” (Milt et al., 2018). In spite of this, many believe any connectivity restorations should include sea lamprey management strategies in Great Lakes tributaries (Zielinski & Freiburger, 2020). While the researchers on this project were touring culvert and fish passage projects and potential projects in the Greater Cleveland area in October of 2021, project partners at 8 sites were asked their concerns about projects allowing sea lamprey passage. On tributaries or mainstems to the Chagrin River, Euclid Creek, West Creek, Chippewa Creek, Johnsons Creek and Furnace Run, none expressed concern that sea lamprey posed a threat. The only area of concern were direct tributaries to Lake Erie (for example, Red Brook). The Chagrin River/West Creek have not recorded sea lamprey activity.

Many studies have utilized GIS to help identify and select fish passage barriers for study, modeling, modification, removal, or replacement, primarily utilizing GIS database inventories of infrastructure such as road crossings, low-head dams, culverts, and bridges to locate potential barriers by overlaying ranked stream flowlines (Favaro & Moore, 2015, Kroon & Phillips, 2015). Because of the large amount of inventory, these searches frequently yield a large number of selections, requiring further information to down select to smaller samples. The ODOT conduit (includes culverts and storm sewers under pavement) inventory (referred to as the "ODOT culvert geodatabase" in ODOT Task 8 proposal) (Ohio Department of Transportation, 2021), for example, contains over 95,500 entries. The ODOT conduit inventory contained 23,201 records within the Lake Erie Basin, at the time of this study.

Some studies have further utilized GIS to downsize selection, using drainage area, digital elevation models (DEM), flow velocities, and rarely, LiDAR (Sun et al., 2020) layers to identify problematic aquatic passage barriers. Other searches utilizing GIS included elevation changes in DEMs or LiDAR data sets indicating perched culverts, dams with elevation changes, barrier height, or outfalls, or used attribute data to narrow selections using attributes such as slope, flow, or other available data (Fleming & Neeson, 2020 Shiau et al., 2020, Baral & Tritico, 2013, McKay et al., 2013). Other studies employed GIS for modeling, in combination with known or observed organism passage data, using FishXing and HEC-RAS, while others used GIS to begin searches where observational on-site study and fish collection could be performed (Fleming & Neeson, 2020, Favaro & Moore, 2015, Briggs & Galarowicz, 2013).

Baral & Tritico (2013) selected 40 circular culverts in perennial streams in ODOT District 4 to assess for fish passage. Culverts were initially selected by a variety of attributes in the ODOT culvert inventory database, including capturing the recorded culvert slope. The authors note that culverts with a slope of zero were excluded because it was uncertain if the slope was actually zero, or that data was just not recorded (Baral & Tritico, 2013). This uncertainty may have excluded culverts viable for study.

The researchers in that study selected culverts from the ODOT database meeting attribute criteria, including slope, shape, and possessing "all the data necessary to carry out the fish passage analysis" (Baral & Tritico, 2013 p. 18). Abundance of circular culverts was noted as the justification for selection of only culverts with that shape. USGS Topographic maps were used to try to "select culverts which had a high likelihood of carrying a perennial stream" (Baral & Tritico, 2013 p. 18). ArcGIS analysis was performed using 1/9 arc second Digital Elevation Model (DEM) to extract a cross section at each culvert outlet to verify existence of a stream channel. According to researchers, ground truthing these selection results ultimately verified 55 intact, single celled, circular culverts in perennial streams, with a span of 24 inches or greater, with corresponding attributes of slope greater than zero, length, and tributary information. (Baral & Tritico, 2013).

GIS searches have primarily been only a starting point in barrier selection because they are limited by accuracy and data completeness and can be complicated by issues such as the resolutions of topographical representations. Inherent positioning of culverts below road surfaces, and discrete differences between perched culverts and plunge pools hide those transitions in digital representations. A USGS analysis of fish passage issues acknowledges that even intermittent streams can be important to fish migration (Hoffman & Dunham, 2007), yet flowline datasets do not always map those streams. An Australian GIS barrier selection study used GIS to intersect digitally mapped bridges, culverts, and causeways, with waterways and land use. In that study, only road and rail influenced potential barriers were included in what they called a "logical first step" in barrier inventory, acknowledging that this was an incomplete list of potential barriers, but the only readily available georeferenced data for the study area (Kroon & Phillips, 2015). A study in Canada attempted to quantify barrier passability with a combination of watershed connectivity assessment and passability modeling in FishXing. Underscoring the need for ground-truthing, the study found that the computer modeling tended to show more passability than field evaluations (Bourne et al., 2011).

GIS-based project site selection can be fraught with difficulty resulting from layers with blank, incomplete, unclear, or inconsistent data and may falsely eliminate or fail to identify barriers at culverts. Topographic layers are data heavy, taking time and requiring powerful systems to manage efficiently. Many Digital Elevation Models (DEM) do not have the resolution to pinpoint elevation upstream and downstream of a culvert, so identification of characteristics like perched culvert outlets or excessive slope can be difficult to ascertain. Even LiDAR, known for its high resolution potential, can be unreliable, and have difficulty finding such close changes as in a perched culvert. Researchers ground-truthed the National Barrier Inventory, compiled using LiDAR and Synthetic Aperture Radar (SAR), for two watersheds in England. In the basins studied, the researchers concluded that only 22.7% of barriers were captured in the inventory, leading the writers to recommend that barriers always be ground-truthed following map-based identification (Sun et al., 2020). Nearly all studies, in fact, required ground-truthing GIS results for final selection where site specific data was necessary (Oregon, 1999, Sun et al., 2020, Kroon & Phillips, 2015, Baral, 2013, Fleming & Neeson, 2020).

Field identification, selection, and surveying of culverts is a vital part of any fish passage improvement project. While GIS analysis can help narrow potential passage barriers based on available data, current data does not have the degree of accuracy that ground-truthing provides. In addition to being essential to the design process, care must be taken to collect, record, and preserve complete credible data. The Youngstown State study (Baral & Tritico, 2013) excluded sites from the culvert/conduit inventory with null values. Because both null and zero entries occurred in fields, such as slope, it was unclear if a lack of numerical data meant the value was zero, or meant the data was not recorded. While the lack of data did help to significantly reduce the potential number of sites, it also may have excluded viable sites in need of remediation. Complete and accurate data will increase the chances of accurately down-selecting sites virtually.

Establishing a data collection protocol and procedure to use in the field, such as in the Great Lakes Stream Crossing Inventory Instructions manual (Michigan Dept of Natural Resources, 2011), ensures uniform data that can easily be interpreted. Highlighting this point, the document states “The single most important piece of guidance in this document is to completely fill out the data sheet at each site” (p.3). this inventory reduces the need for subjective ranking of conditions such as scour and erosion by also requiring a sketch of the conditions. It also includes a fish passage assessment that establishes conditions used to score each barrier for passability. Photos are taken at specified locations at each site (Michigan Dept of Natural Resources, 2011). These features help identify and rank site suitability for projects when multiple sites are assessed.

Even small increases in passage can lead to large increases in connectivity (McKay et al., 2013). Careful consideration when replacing and maintaining road culverts has been shown to help reconnect or maintain ecological connectivity in streams and waterbodies. Using GIS has been shown to be a good first step in selecting appropriate culverts for remediation or fish passage improvement. The design of the culverts must be considered carefully and compared to the goals for species to allow passage. The risk of allowing invasive species to pass upstream should always be part of the design discussion.

Task 8.2 Identification of Priority Watersheds for Culvert Projects

Within the Lake Erie Basin, the researchers sought to identify key areas to focus further analysis for project prioritization. This was done in two primary ways: 1) analysis based on publicly available water quality and fish population data (Section 8.2.1) and 2) stakeholder outreach to groups active in the Lake Erie Basin who have identified culverts impeding fish passage or who have completed culvert replacement projects (Section 8.2.2). Additionally, the OHIO team has identified key fish species present in the high quality HUC12s in ODOT Districts 4 and 12 that may be identified for management goals since some of the culvert design criteria may be based on what fish species are being managed for (Section 8.2.3).

8.2.1 Selection of Priority Watersheds

While designing new culverts to support aquatic organism passage is good practice, prioritization of replacement of existing culverts to improve aquatic organism passage should be done based on the ability to support high quality fish communities. The Ohio Environmental Protection Agency (Ohio EPA) publishes a biannual Integrated Water Quality Monitoring and Assessment Report (Ohio EPA, 2020) which details water bodies' beneficial use attainment status. Using the geographically referenced data available from Ohio EPA (https://www.arcgis.com/apps/webappviewer/index.), watersheds at a HUC12 level were selected for prioritization based on the presence of sites designated as meeting warmwater habitat (WWH), exceptional warmwater habitat (EWH), or cold-water habitat (CWH) criteria. HUC12s with at least one site meeting WWH, EWH, or CWH were prioritized for further analysis. This is based on the assumption that a HUC12 with at least one site meeting WWH, EWH, or CWH has the habitat features and water quality to support a high quality fish population.

While the OHIO team did try to use the fish data available from Ohio EPA to determine where in these watersheds culverts may be impairing fish populations, the nature of the Ohio EPA sampling locations is such that they are more likely to be on waterbodies large enough for bridges rather than culverts to be predominant. With this limitation in mind, we used the set of high quality HUC12s shown in Figure 1 for further GIS-based analysis of potential fish passage barriers due to culverts.

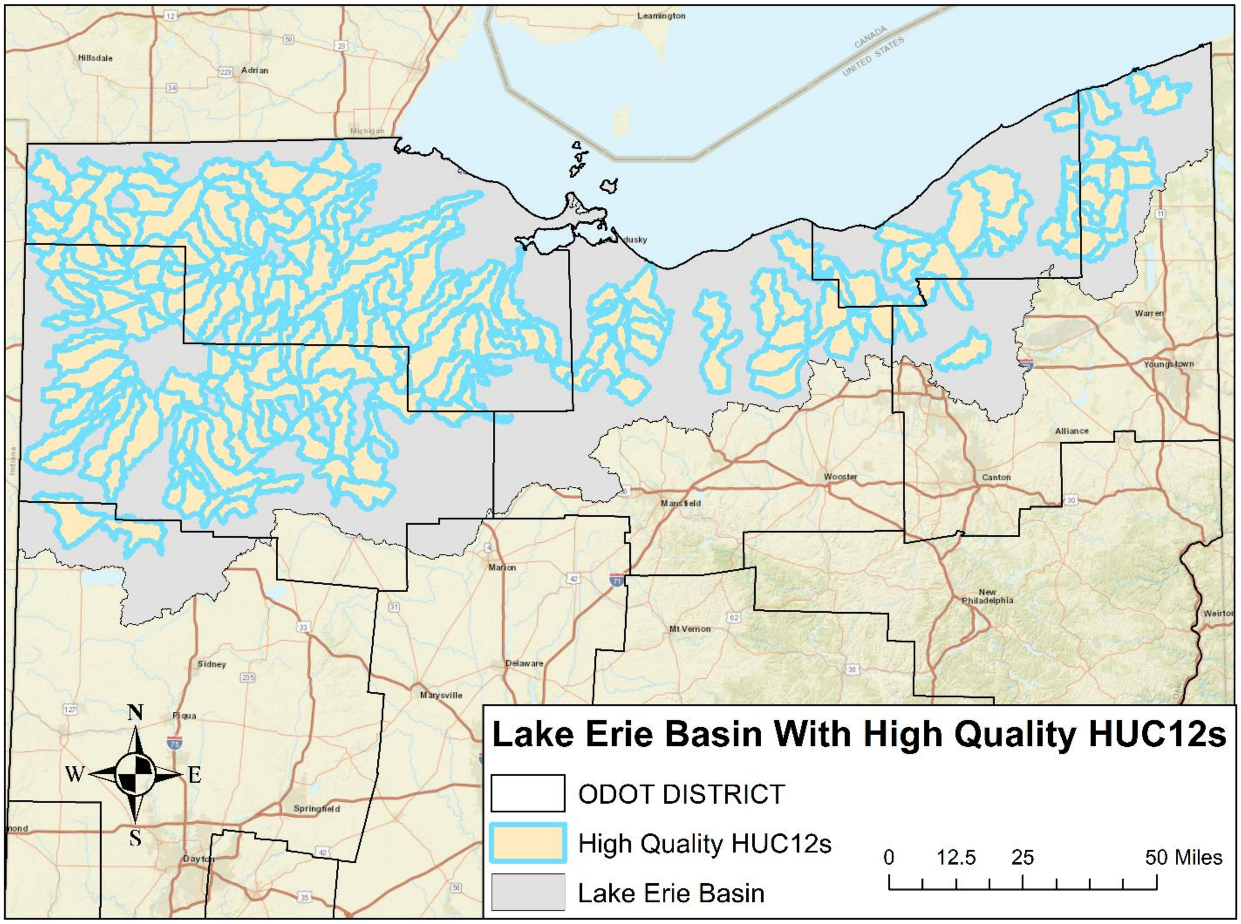


Figure 1 High quality HUC12s in the Lake Erie Basin.

8.2.2 Stakeholder Outreach

The goal of the stakeholder outreach part of this project was to engage and learn from watershed partners in the Lake Erie Watershed, obtain information about high quality streams where fish passage barriers exist, and to learn where restoration projects have previously been implemented. The two-fold approach conducted to compile this information were: 1) Identify existing Ohio EPA Non-point Source-Implementation Strategies (NPS-IS) plans in the high-quality watersheds in the Lake Erie Basin (LEB) and review the plans for mention of fish passage impairment, perched culverts, and elevation drop structures, and 2) Identify watershed partners and visit specific site locations where fish passage problems exist and where projects have been planned or implemented.

A tour with partners was organized and conducted on October 1, 2021, to visit eight sites (Figure2). The goal of the site visits was to engage Lake Erie Basin stakeholder groups, visit their field sites and hear about their completed, planned, and project needs that demonstrate the fish passage issues. This visit emphasized that fish blockage problems exist and are an important issue to the Lake Erie stakeholders.

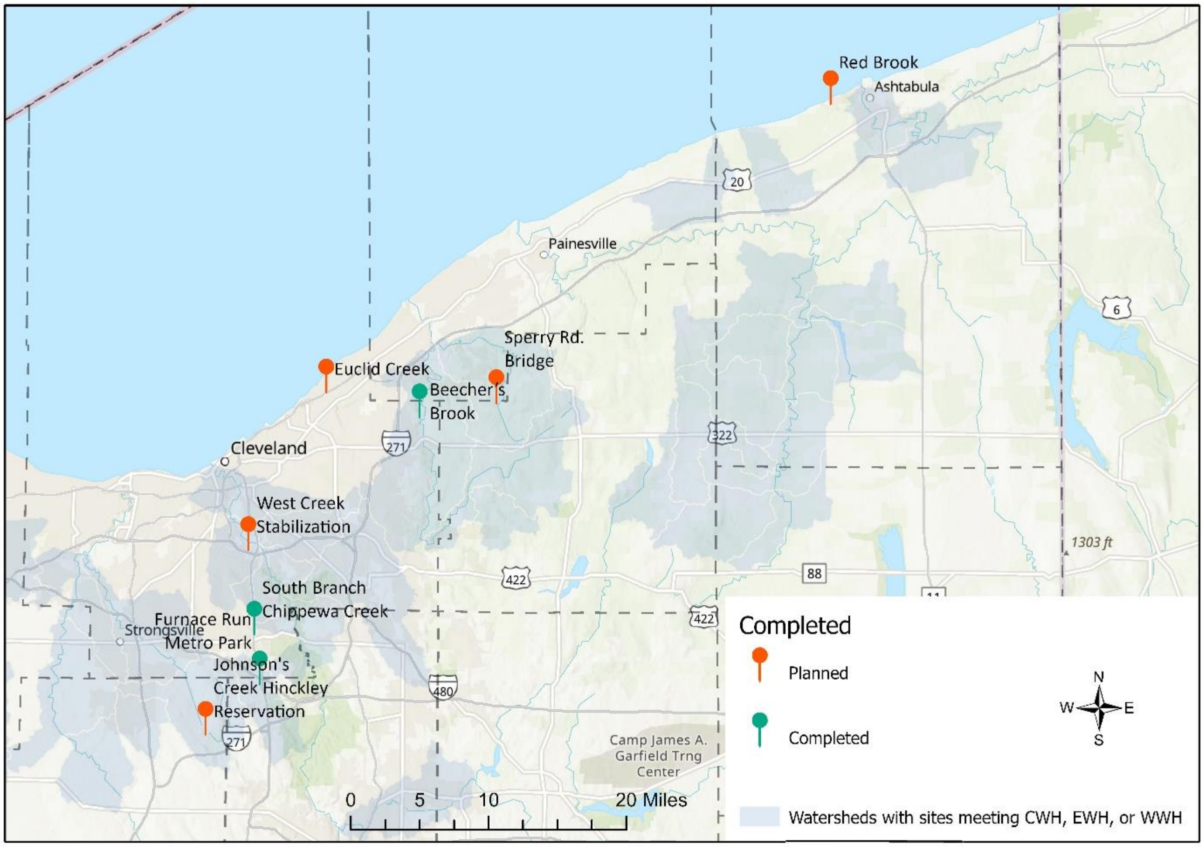


Figure 2 Lake Erie Basin fish passage tour locations.

Eight sites were visited with personnel from The Western Reserve Land Conservancy, Chagrin River Watershed Partners, Cleveland Metroparks, Northeast Ohio Regional Sewer District, and Summit Metro Park. The sites represented a variety of fish passage projects. Some were in the early identification planning stages, others in design and funding phase, and a couple fully complete. Each of these projects share a common goal to restore fish passage to upstream sections of the waterway among other water quality improvements. Most of the sites visited were on county and township roads or in the Metroparks. However, these sites represent fish passage issues the Lake Erie Basin stakeholders addressed or plan to address to meet water quality goals. Projects have either been identified in watershed NPS-IS plans or are listed as an "Area of Concern" in the Great Lakes Quality Agreement. Each of the eight sites visited during October 1, 2021, tour are described below.

Field Visit Site Summary

Site 1 – Red Brook in Ashtabula County, 41.881111, -80.841760, Carpenter Road (Township Rd), owner: Board of park commissioners of the & Ashtabula County Metroparks

Brett Rodstrom with Western Reserve Land Conservancy provided a tour of this site. Red Brook is located on the site of a 150-acre golf course that closed in 2016 and was purchased by the Park District. The site visited is a double barrel perched culvert approximately 90 feet long, culverts are perched about one foot above the water level at base flow (Figure 3). During high flow larger fish may be able to manage passage through the culvert but not the small and medium size fish due to the high velocity through the culvert at high flow. Red Brook is a direct tributary to Lake Erie; Sea Lamprey are a risk to migrate from the lake upstream. The Park District is doing a stream restoration project on this site downstream of the culvert utilizing Great Lake Restoration Initiative (GLRI) funds.

Figure 3 Red Brook site in Ashtabula County.

Site 2 - Sperry Road Bridge at RM 15.35 on an unnamed tributary to the East Branch of the Chagrin, 41.56604, -81.31117, Township road, privately owned

Josh Meyers and Kevin Saracino with Chagrin River Watershed Partners provided an overview of this site. A large structure with a series of drops, this project is identified in the NPS-IS plan but no plans yet for implementation (Figure 4). The elevation difference from downstream to upstream is substantial, the project would require regrading and upgrading the culvert to a bridge structure. Sea Lamprey are not found in the Chagrin, they are not a risk or concern at this time. This section of stream meets Coldwater Habitat and Scenic Designation in sections. The upstream section could support Brook Trout habitat, however, no fish data has been collected upstream.

Figure 4 Perched culvert at Sperry Road Bridge. Photo Source: Chagrin River Watershed Partners – East Branch Chagrin.

Site 3 - Beecher's Brook a tributary to the Chagrin River, 41.550712, -81.418481, Cleveland Metro Park owns the road and property

Jenn Grieser and Josh Phillips with Cleveland Metroparks provided a site tour at Beecher's Brook a project located in the Cleveland Metropark. This is a completed project constructed in 2021. Implementation included bridge installation, stream restoration of five pools and riffles installed to grade, and streambank stabilization plantings. Previously this site was a large box culvert with a two-foot plunge pool and bank scour downstream (Figure 5). Upstream fish survey showed only one species (Creek Chub – very tolerant) and downstream showed 15 different species, representing good diversity. Migration was blocked at the drop structure from downstream to upstream. The goal for implementation was to address streambank erosion and fish passage. Beecher's Brook project was funded by Ohio EPA 319 grants and Northeast Ohio Regional Sewer District. There was not a concern of Sea Lamprey migration since they are not found in the Chagrin River. The post construction monitoring is scheduled for 2022.

Figure 5 Pre-construction photo of drop-structure at Beechers Brook. Photo source: Chagrin River Watershed Partners – Griswold Creek.

Site 4 - Euclid Creek Project, 41.576336, -81.549465, culvert under multiple rail lines, property owned by the Railroad and Marathon gas station

Paul Kovalick and Jon Brauer with Northeast Regional Sewer District (NEORSD) provided a project overview. Jenn Grieser, Cleveland Metroparks, and Mark Carpenter, ODOT accompanied the tour visit. This site is a direct tributary to Lake Erie consisting of a 900 ft concrete channel and a drop culvert structure (Figure 6). NEORSD partnered with the Army Corps of Engineers on a Feasibility Report for passage over the concrete culvert structure. This site has been identified as an 'Area of Concern' therefore allowing access to GLRI funds. NEORSD is the local sponsor and will hold the easement with the railroad while Ohio EPA and Army Corps of Engineers partnership allows access to GLRI funds. The goal is to allow fish connectivity upstream and downstream of this blockage. Timeline for this project is 60% design by spring 2022. Easements will be secured after 50% design is complete. Note: NOERSD inventories 450 miles of stream and 4000 crossings, focusing on flooding, erosion, and water quality.

Figure 6 Euclid Creek Project under design with partners.

Site 5 - West Creek Stabilization/Brooklyn Heights, 41.410589, -81.659480, West Creek adjacent to Interstate 480, owner: State of Ohio

Ivan Valentic and Jon Brauer, NEORSD provided a project overview. Jenn Grieser, Cleveland Metropark, and Mark Carpenter, ODOT accompanied the tour. The planned project site consists of a 6,500 ft long channel restoration along I-77, with the removal of a 1,000 ft long concrete 'flume' (Figure

7). West Creek has been historically moved, filled, channelized, stripped of riparian corridor, and reinforced with concrete to control the lateral migration of the creek within this urbanized area. The goals of this restoration project are to improve habitat, water quality, and fish passage and protect infrastructure of I-77. The approach is to raise the grade (4-5 ft), reconnection to the floodplain, create a large cross-sectional area, install woody debris, remove the concrete walls and flume, and replant the riparian corridor. Many partners including Ohio Regional Sewer District and ODOT are involved in this project estimated to cost $15-16M and to be completed in 2024 (ODOT PID 113210, March 2020).

Figure 7 West Creek Project site under design with partners.

Site 6 – South Branch Chippewa Creek I-77, 41.320722, -81.648395, Interstate 77, owner: State of Ohio

This site was recommended by NEORSD to drive by and visit on the way to the next site at Hinckley Reservation. The drop structure shown in Figure 8 is blocking fish passage upstream.

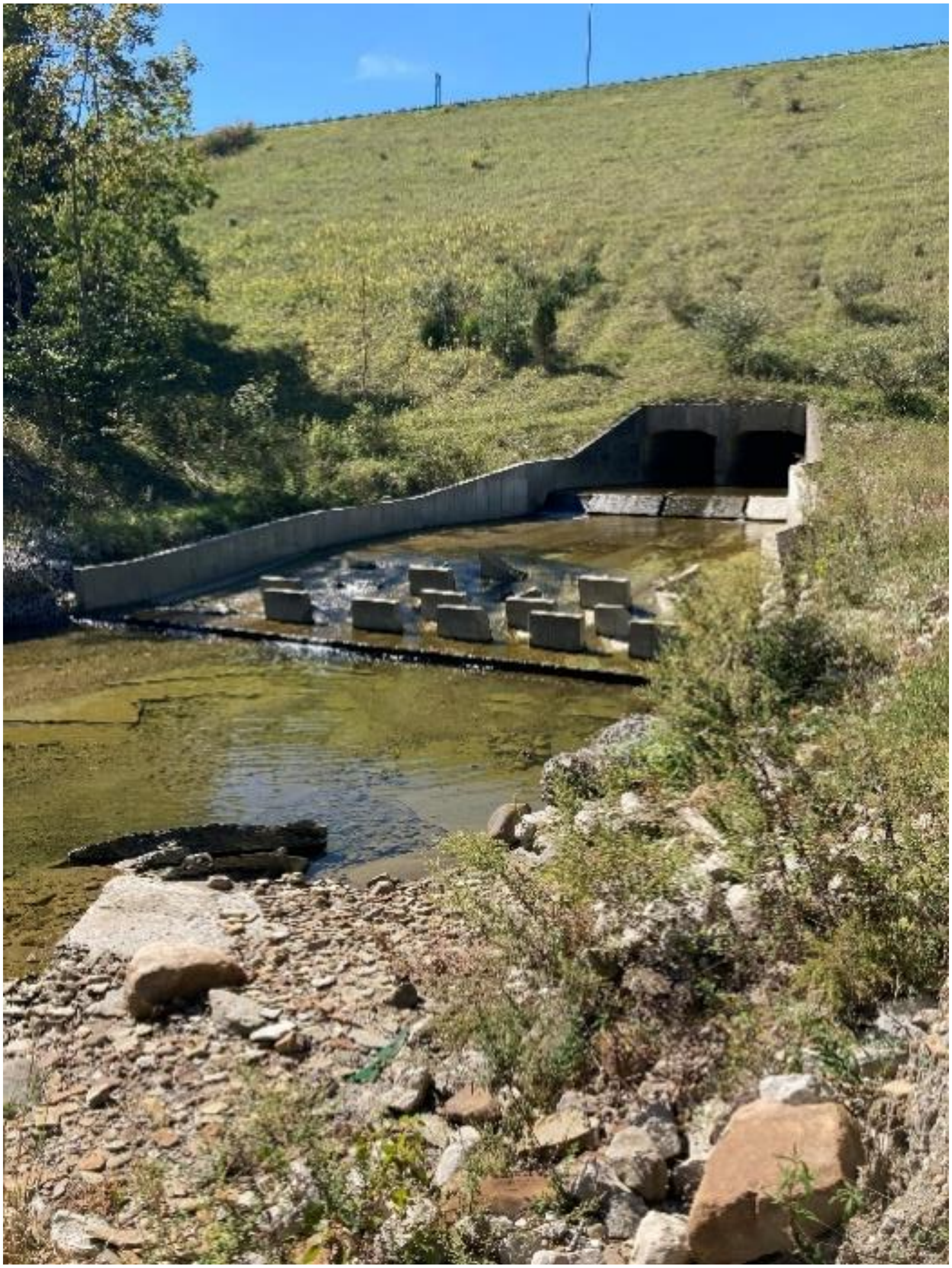


Figure 8 South Branch Chippewa Creek fish passage blockage drop structure

Site 7 – Johnsons Creek/Hinckley Reservation, 41.215365, -81.714782, Cleveland Metropark owns road and property

Jenn Grieser and Mike Duralec with Cleveland Metropark provided a site visit. Mike Johnson with Summit Metro Park accompanied the tour. This site located in the Cleveland Metropark- Hinckley Reservation, consists of a box culvert blocking fish passage from downstream (Figure 9) to upstream (Figure 10). The creek sustained a large precipitation event that created a substantial 'down cut' in 2014, causing lateral migration and disconnection of upstream and downstream portions of the creek at the culvert. According to data Michael Durkalec with the Cleveland Metropark shared the upstream portion only had 3 species of fish while downstream had higher species diversity (15 species) and four times the biomass. This project goal is to restore fish passage, reduce erosion, and fix the culvert that failed inspection. The approach is to replace the culvert with a 4-sided box culvert with the bottom buried by one foot of natural substrate. The project is funded by Ohio EPA 319 and has 30% design complete and the culvert replacement will be constructed and surrounding area revegetated in 2022.

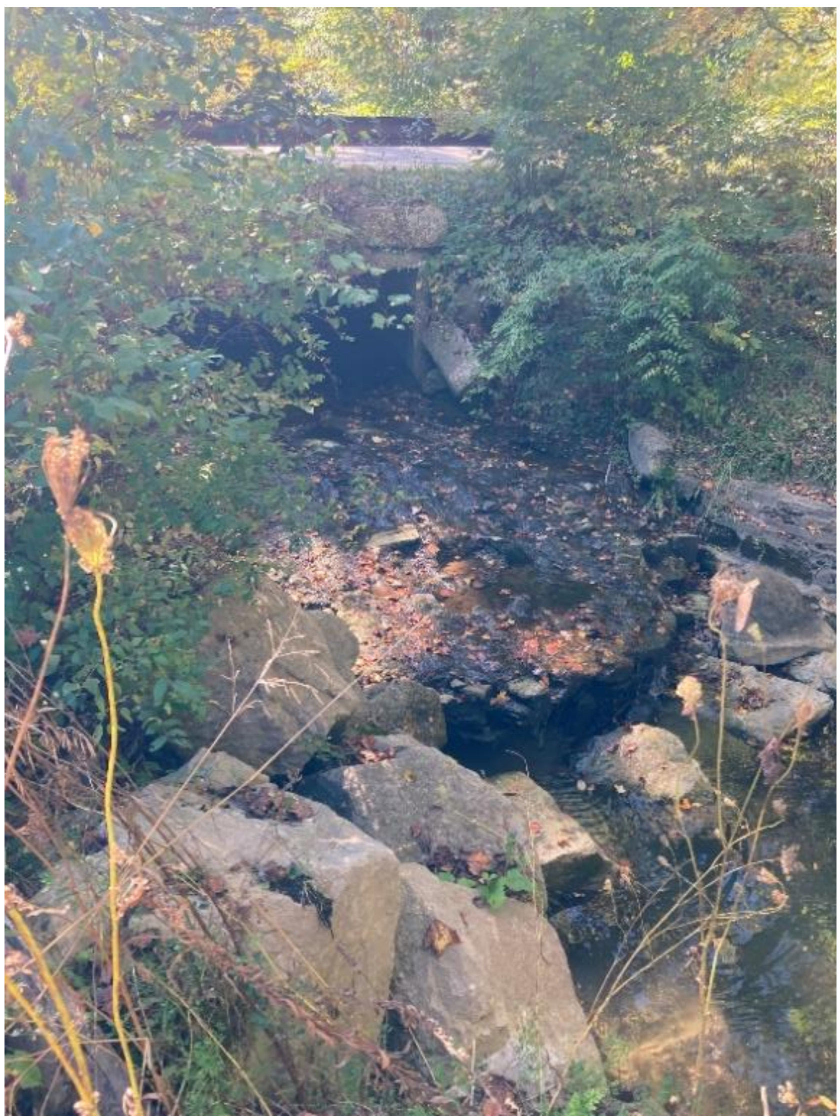


Figure 9 Johnsons Creek downstream of the culvert.


Figure 10 Johnsons Creek upstream of the culvert.

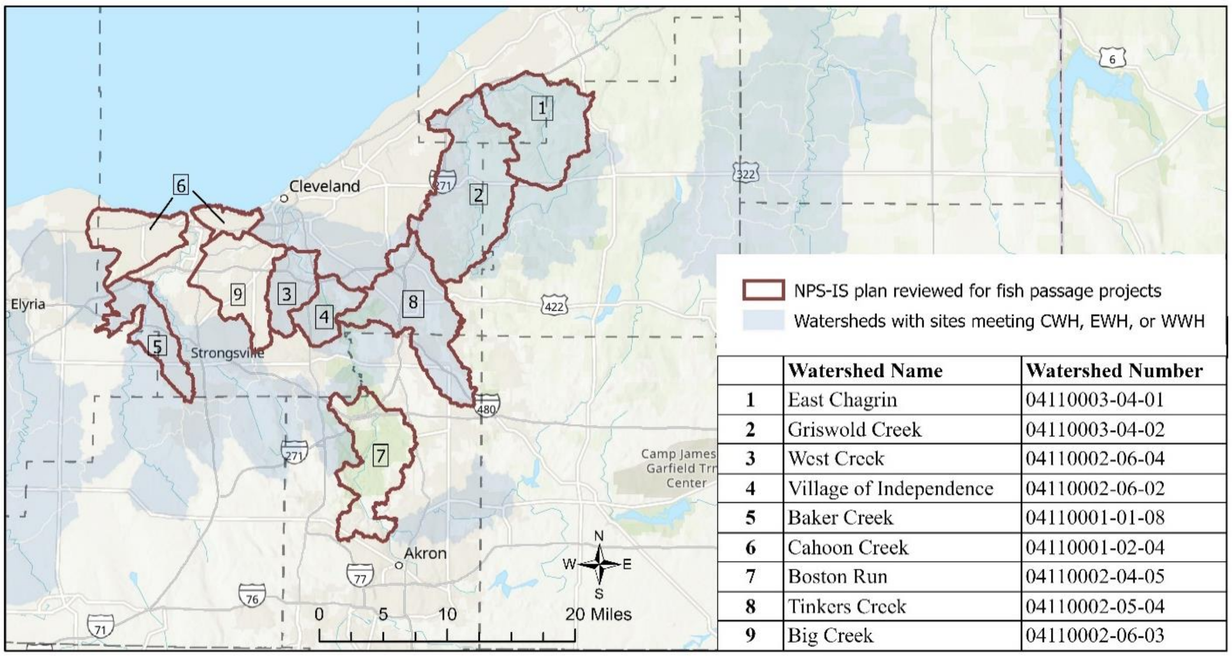
Site 8 -Furnace Run, Summit Metro Park, 41.257710, -81.633258, Cuyahoga County Road Breckersville Road, land owner: Summit Metro Park

Mike Johnson, Summit Metro Park, provided a tour of the Furnace Run previously constructed project. Furnace Run is a tributary to the Cuyahoga River. At low flow no fish can migrate upstream, although at high flow this one-foot elevation difference is passable. Six grade control structures were installed downstream to raise the grade up to the upstream bed elevation as shown in the Figure 11. This project was funded by Ohio EPA 319 grant in 2014. No post construction monitoring has been conducted.

Figure 11 Furnace Run Project in the Summit Metro Park.

NPS-IS Plan Review

The nine NPS-IS plans reviewed for previously identified fish passage problems, or where projects have been planned or implemented were East Branch Chagrin, Griswold Creek, Cuyahoga River at the Village of Independence, West Creek, Baker Creek- West Branch Rocky River, Cahoon Creek – Frontal Lake Erie, Boston Run, Tinker's Creek, Big Creek (Figure 12). These plans revealed 27 structures are blocking fish passage, identified as a 'drop structure' (e.g. Figure 5) or perched culvert (e.g. Figure 4). Three of these sites were visited on October 1, 2021, tour (Figure 2). A complete summary of the NPS-IS plan review showing maps, photos, number of barriers, and water quality data from each plan can be found in Appendix A. A separate, ODOT requested list of fish passage barriers created by low-head dams as opposed to culverts and 'drop structures' is included in Appendix A.



	Watershed Name	Watershed Number
1	East Chagrin	04110003-04-01
2	Griswold Creek	04110003-04-02
3	West Creek	04110002-06-04
4	Village of Independence	04110002-06-02
5	Baker Creek	04110001-01-08
6	Cahoon Creek	04110001-02-04
7	Boston Run	04110002-04-05
8	Tinkers Creek	04110002-05-04
9	Big Creek	04110002-06-03

Figure 12 Lake Erie Basin NPS-IS plans reviewed for fish passage blockages and projects.

8.2.3 Management for Fish Species

Culvert design to favor fish passage will depend upon the species being managed. For example, stronger swimmers will be able to traverse higher velocity flows, while larger sport fish may need deeper waters than small species. For this reason, it is important to understand the fish population in the target watershed and to understand design characteristics that would favor target management species. Broadly, a culvert that maintains the width, slope, substrate, and velocity of the surrounding stream will favor fish passage.

The fish populations of high quality water bodies in ODOT Districts 4 and 12 were used to demonstrate the variety of fish species and their management potential when considering culvert improvements for fish passage. Specific species of interest and potential impacts of culverts are highlighted for intolerant taxa, cold water systems, migratory species, economically valuable species, and invasive species. Culverts can impair fish populations including migratory and non-migratory species; in this section we focus on particular classes of fish that may be management priorities or particularly affected by culverts.

Based on the occurrence of fish species that meet the management goals of a particular project, watershed, or community, specific watersheds may be prioritized for management.

Fish occurrence in the Lake Erie basin (Northeast Ohio)

The Ohio Environmental Protection Agency has documented 85 distinct fish species and 6 hybrids in 11 high quality sub watersheds in Northeast Ohio; Conneaut Creek, Ashtabula River, Cuyahoga (Rockwell), Silver, Mill Creek, Chagrin (Aurora Branch), Mud, Yellow Creek, Furnace Run, Chippewa, Cuyahoga (Willow Lake) (Table 1) which represent the highest quality HUC12s in ODOT Districts 4 and 12 (Capuzzi, 2021). Of the 85 distinct species observed, 12 species are non-native; introduced unintentionally via ballast water, bait buckets, floods, canals, or contaminated equipment; or intentionally as a food fish or for recreational opportunities / sport fishing (Rice & Zimmerman, 2019). Table 1 below includes all of the fish species documented by OEPA in all of the target watersheds combined.

Table 1. Fish species documented by OEPA in Conneaut Creek, Ashtabula River, Cuyahoga (Rockwell) Silver, Mill Creek, Chagrin (Aurora Branch), Mud, Yellow Creek, Furnace Run, Chippewa, Cuyahoga (Willow Lake) (Capuzzi, 2021). *An asterisk (*) denotes a non-native species, a carrot (^) denotes hybrid fish* (Rice & Zimmerman, 2019). *Table continues next page.*

Species	**Species**	**Species**
Alewife*	Fathead Minnow	Redfin Shiner
American Brook Lamprey	Flathead Catfish	Redside Dace
Bigeye Chub	Freshwater Drum	River Chub
Bigmouth Buffalo	Gizzard Shad	River Chub x Stoneroller ^
Black Bullhead	Golden Redhorse	River Redhorse
Black Crappie	Golden Shiner	Rock Bass
Black Redhorse	Goldfish*	Rosyface Shiner

Species	Species	Species
Blacknose Dace	Grass Carp*	Round Goby*
Blackside Darter	Green SF x Bluegill SF ^	Sand Shiner
Bluegill SF x Pumpkinseed SF ^	Green SF x Warmouth SF ^	Shorthead Redhorse
Bluegill Sunfish	Green Sunfish	Silver Redhorse
Bluntnose Minnow	Greenside Darter	Silver Shiner
Bowfin	Hornyhead Chub	Silverjaw Minnow
Brindled Madtom	Johnny Darter	Smallmouth Bass
Brook Silverside	Largemouth Bass	Smallmouth Buffalo
Brook Stickleback	Logperch	South. Redbelly Dace
Brook trout	Northern Sunfish	Spotfin Shiner
Brown Bullhead	Longnose Dace	Spottail Shiner
Brown Trout*	Longnose Gar	Spotted Sucker
Central Mudminnow	Mimic Shiner	Stonecat Madtom
Central Stoneroller	Mottled sculpin	Striped Shiner
Channel Catfish	North Brook Lamprey	Striped Shiner x Rosyface Shiner ^
Coho Salmon*	Northern Hog Sucker	Walleye
Common Carp*	Northern Pike	Warmouth Sunfish
Common Carp x Goldfish* ^	Pumpkinseed Sunfish	White Bass
Common Shiner	Quillback	White Crappie
Creek Chub	Rainbow Darter	White Perch*
Eastern Banded Killifish*	Rainbow Smelt*	White Sucker
Emerald Shiner	Rainbow Trout*	Yellow Bullhead
Fantail Darter	Redfin Pickerel	Yellow Perch

Intolerant Taxa

Though some of the documented species are tolerant generalists, fish that can be found regardless of water quality, habitat, and environmental stressors; other species are indicative of high-quality water bodies. These intolerant species are negatively impacted by pollution, siltation, high temperatures, low dissolved oxygen, and instream barriers (Table 2). Three state listed species were documented in the target watersheds; the longnose dace (species of concern), brook trout (threatened), and northern brook lamprey (endangered). Table 2 below includes moderately to extremely intolerant taxa documented in the target watersheds. These species are especially sensitive to human disturbances and are the most impacted by disconnection caused by culverts (Rice & Zimmerman, 2019).

Table 2. Moderately to extremely intolerant fish species documented by OEPA in target watersheds (Capuzzi, 2021)*. An asterisk (*) denotes a non-native* species (Rice & Zimmerman, 2019).

Species	**Species**	**Species**
American Brook Lamprey	Golden Redhorse	Redside Dace
Bigeye Chub	Greenside Darter	River Chub
Bigmouth Buffalo	Hornyhead Chub	River Redhorse
Black Redhorse	Logperch	Rock Bass
Blacknose Dace	Northern Sunfish	Rosyface Shiner
Blackside Darter	Longnose Dace	Shorthead Redhorse
Brindled Madtom	Mimic Shiner	Silver Redhorse
Brook Silverside	Mottled Sculpin	Silver Shiner
Brook Stickleback	North Brook Lamprey	Smallmouth Bass
Brook Trout	Northern Hog Sucker	South. Redbelly Dace
Brown Bullhead	Northern Pike	Spottail Shiner
Brown Trout*	Rainbow Darter	Spotted Sucker
Common Shiner	Rainbow Smelt*	Stonecat Madtom
Fantail Darter	Rainbow Trout*	

Protecting Cold Water Systems

Cold water habitat is limited in Ohio. The Ohio EPA 2016 Integrated report interactive web map identifies only 26 watersheds designated at Cold Water Habitat (CWH), with 16 of those attaining the designation (OEPA, 2016). Streams supporting cold water taxa are especially sensitive to degradation resulting from human disturbances. Logging, agriculture, urbanization, and industrial development often result in destruction of riparian habitat. A healthy, intact riparian is critical in maintaining the cool water temperature and excellent water quality these taxa need to survive and reproduce (Rice & Zimmerman, 2019). Infrastructure and development surrounding these water bodies should be designed to minimize impact on riparian health and in-stream habitat. Projects that improve connectedness in cold water systems can improve the populations of these sensitive species. Table 3 below includes cool/cold water taxa documented in the target watersheds.

Table 3. Fish species documented by OEPA in target watersheds that are indicative of cool/cold water systems (Capuzzi, 2021). *An asterisk (*) denotes a non-native species (Rice & Zimmerman, 2019).*

Species	**Species**	**Species**
Brook Stickleback	Common Shiner	Rainbow Trout*
Brook Trout	Mottled Sculpin	Redside Dace
Brown Trout*	Rainbow Smelt*	Southern Redbelly Dace

Migratory Species

Many fish species rely on connectivity of streams and rivers within a larger watershed system. The most common reason for fish to migrate into larger or smaller bodies of water is access to spawning habitat. These species are directly impacted by poorly designed culverts and in-stream barriers. Often, in a fragmented system, adults will survive and persist, but recruitment will be limited due to lack of access to appropriate spawning habitat. Other reasons for migration or movement throughout a watershed include access to food, and refuge from temperature extremes. Fish typically inhabiting small, headwater streams will often move downstream to deeper water during the summer to escape drought and rising temperatures. In the winter, fish residing in small drainages may overwinter in deep, sheltered waters of larger streams (Rice & Zimmerman, 2019). Impassable culverts and in-stream barriers disrupt these natural processes and are often causes for decline in migratory species. Table 4, below, includes migratory species documented in the target watersheds.

Table 4. Fish species documented by OEPA in target watersheds that are migratory species (Capuzzi, 2021). *These species may be highly impacted by culverts and other in-steam barriers. An asterisk (*) denotes a non-native species (Rice & Zimmerman, 2019). Table continues next page.*

Species	**Comments**
River Redhorse	Inhabits large rivers with clean gravel and cobble substrate but migrates into smaller rivers and streams to spawn. Historically low populations are increasing with improvements to water quality and removal of in-stream barriers. Require long deep runs in fast flowing pools.

Species	Comments
Rainbow Smelt*	Deep cold waters. Inhabits lakes and large rivers but spawn over sand and gravel of small tributaries.
American Brook Lamprey	Very limited range. Adults spawn in small streams with clear, swift water and sand/gravel substrate. Larvae drift down to larger streams and burrow into soft substrates where they filter feed.
Bigmouth Buffalo	A filter feeder inhabiting larger rivers and streams. Some value as a sport fish (bow fishing). Typically spawn in flooded fields and backwaters but may spawn over sand and gravel in shallow streams if better habitat not available.
Golden Redhorse	Highly migratory species. A stream fish that spawns over gravel riffles and run and lives in pools and slower runs. They need clean substrate to spawn. Slightly more tolerant than other redhorse, but still sensitive to water quality. Move into smaller tributaries to spawn.
Northern Hog Sucker	Somewhat migratory species. Resides in large creeks and small rivers. Prefers higher gradient, clean substrate, clear water. Not found in headwater or non-perennial streams. This species migrates into smaller streams with gravel riffles to spawn. Sensitive to pollution, populations increasing with improvements in water quality.
Northern Pike	Inhabits larger streams with clear water and sluggish pools. May migrate into smaller streams to spawn. Negatively impacted by dams and impoundments.
Quillback	Migrates to smaller streams to spawn. Requires quiet waters with soft substrate and moderate to low gradient.

Species	Comments
Redside Dace	Spawn over gravel in riffles. Inhabit small high-gradient streams with cool water. They live in pools and slower water but move to swifter water for spawning. Need intact riparian to shade water. Intolerant to turbidity and silt. Do not migrate, will live in same stream for entire life. Difficulties recolonizing if extirpated from a stream. Very sensitive species, indicative of exceptional water quality.
Rosyface Shiner	Migrates to larger streams/deeper water during winter. Inhabits medium sized streams with clear water, clean substrate and swift currents. Intolerant of silt.
Silver Redhorse	Resides in deep slow pools of large to medium rivers and migrates to small streams to spawn over shallow riffles. Requires sand, gravel, cobble substrate that is free of silt. Indicator of healthy stream with clear water and clean substrate. Extremely sensitive to changes in water quality and turbidity.
Smallmouth Bass	Populations negatively impacted by dams and impoundments. This species prefers clear, moderate to high gradient streams with well-developed channel morphology and clean gravel cobble substrate. A popular sport fish, sought after by many anglers.
Smallmouth Buffalo	This species lives in large rivers with clear water. Dams and in-stream barriers reduce access to spawning habitat in shallower waters.
Walleye	A very popular sport fish that resides in the lake but migrates up into streams to spawn until stopped by a dam or impoundment.
White Bass	Dams and impoundments on Lake Erie tributaries contribute to population decline by blocking upstream spawning habitat. This sport fish resides in open water of large lakes and

Species	Comments
	rivers with clear water and firm substrate. White bass move into tributaries to spawn.

Economically Valuable Species (Sportfish and Commercial Species)

The Great Lakes (Lake Erie specifically) are an important commercial and recreational fishing resource. Yellow perch and walleye are the primary species commercially harvested from Lake Erie. In the past, white bass was also a commercially important species. According to the Ohio Department of Natural Resources 2021 Ohio Trap Net Industry Yellow Perch Quota and Harvest Summary for October (Ohio Department of Natural Resources, 2021), 497,511 pounds of yellow perch have been commercially harvested in Ohio waters in 2021 (through October 31, 2021).

Recreationally, Lake Erie and its tributaries are sportfishing hotspots, destinations for anglers across the country. Tourism surrounding sport fishing is a vital source of revenue for communities near water bodies inhabited by these species. Maintaining healthy sportfish populations combines state stocking efforts with proper watershed management (Rice & Zimmerman, 2019). Table 5 below includes economically valuable species (commercial species and sportfish) documented in the target watersheds. Understanding the occurrence of sport fish can help in culvert project planning.

Table 5. Commercially harvested species and sportfish documented by OEPA in target watersheds (Capuzzi, 2021). An asterisk (*) denotes a non-native species (Rice & Zimmerman, 2019).

Species	Species	Species
Black Crappie	Flathead Catfish	Walleye
Bluegill Sunfish	Largemouth Bass	White Bass
Brook Trout*	Northern Pike	White Crappie
Brown Trout*	Rainbow Trout*	White Perch*
Channel Catfish	Smallmouth Bass	Yellow Perch
Coho Salmon*		

Controlling Invasive Species

Watershed management decisions are often a multi-pronged approach. Waterbodies are managed to promote survival and reproduction of desirable species, while attempting to control unwanted non-native/invasive species. Twelve species (11 distinct species and 1 hybrid) of non-native fish were documented by OEPA in the target watersheds in ODOT Districts 4 and 12. Three of these species are sportfish intentionally stocked (or in the case of the coho salmon, historically stocked) in select watersheds; coho salmon, brown trout, and rainbow trout. Many non-native species such as common carp, alewife, rainbow smelt, and white perch were introduced in the 1800s and early 1900s and have become naturalized into Ohio water bodies. Minimal efforts are made to control these species. Other species, such as the round goby, sea lamprey, and Asian carp, are more recent introductions or pose a more serious threat to native ecology. These species are subject to active monitoring and control efforts (lampricide, electronic barriers, eDNA detection, tagging, etc) and their presence (or potential to invade) should be considered when planning infrastructure or development in a watershed. Canals, drainage ditches, and other forms of land modification that serve to connect previously disjoined waterbodies can become easy routes of spread for aquatic invasive species (Rice & Zimmerman, 2019). In some water bodies, dams and in-stream structures are built (or not removed) to serve as a barrier to invasive species. In water bodies where sensitive species and invasive species are both present, efforts should be made to manage for both. Table 6 below includes non-native and invasive species documented in the target watersheds.

Table 6. Non-native and invasive species documented by OEPA in target watersheds. A carrot (^) denotes a sportfish species stocked by ODNR (Capuzzi, 2021)

Species	**Species**	**Species**
Alewife	Common Carp x Goldfish	Rainbow Smelt
Brown Trout^	Eastern Banded Killifish	Rainbow Trout^
Coho Salmon	Goldfish	Round Goby
Common Carp	Grass Carp	White Perch

Summary of Impacts of Culverts on Fish Populations

The impact a culvert has on an aquatic system is extremely variable based on the type, size, and installation of the culvert, as well as the assemblage of fish species living upstream and downstream of the culvert (Baral & Tritico, 2013, Goodrich, 2018, Bourne et al., 2011, Shiau et al., 2020, Leng & Chanson, 2020). When considering infrastructure or development surrounding streams inhabited by intolerant taxa, special care should be taken to minimize disturbance to the watershed. Increased sedimentation, turbidity, and pollution (via chemical contaminants or nutrients) will negatively impact survivability and reproduction of these species.

Taxa most likely to be impacted by culverts and other instream barriers include (Rice and Zimmerman, 2019):

- Declining species, species of concern, threatened species, and endangered species
    - Species with declining/low numbers of individuals will be at risk for further/more rapid decline if their specialized habitat is fragmented by culverts and instream barriers.
    - Three state listed species were documented in the target subwatersheds: the longnose dace (species of concern), brook trout (threatened), and northern brook lamprey (endangered).
- Highly sensitive species intolerant to:
    - Environmental disturbances
    - Siltation/sedimentation
    - Pollution

- Migratory species
  - Species that travel throughout the watershed to access spawning sites. These species are directly impacted by culverts and instream barriers. Adults can survive and persist, but recruitment will be limited due to lack of access to appropriate spawning habitat.
  - Species that migrate to seek shelter from temperature extremes in pools and deeper water.
- Benthic (bottom-dwelling) species
  - Many benthic species are weak swimmers but require high levels of dissolved oxygen found in fast moving water. These taxa are reliant on interstitial spaces and eddies created by gravel, cobble, boulder substrate to shelter them from high velocities. Culverts with high velocities and no substrate would be barriers to passage of these benthic species. (Rice & Zimmerman, 2019)

Task 8.3 Develop Identification and Prioritization Methods for Culvert Barriers

Prioritization of culverts using a GIS analysis approach began with an evaluation of the available data. While ODOT's Conduit Inventory available from ODOT's TIMS system does have a broad range of attributes, ODOT personnel suggested that the slope was a field estimate rather than a measured value and often left blank; therefore, the slope included in the Conduit Inventory was not used in the analysis. Rather, the location, the shape, the span, length, and the height were included in the analysis. Those that were indicated to be storm sewers were excluded from this analysis since those would not be good candidates for replacement projects.

Because culverts are typically used to convey smaller water bodies under roads, many are built for ephemeral waterways or those that only flow in response to precipitation. While these streams are important for water supply and water quality, they do not support fish populations. In order to screen out the culverts on ephemeral waterways, the culvert database was clipped to a 20 foot buffer from the flowlines included in the National Hydrography Dataset (NHD). Since the waterways mapped in the NHD are primarily perennial or intermittent, this approach would tend to isolate those culverts that are on perennial or intermittent waterways within a range of GPS and data error.

The openness ratio of the subset of culverts that were assumed to be on intermittent or perennial waterbodies was then calculated for each culvert based on its shape, dimensions, and length in the Conduit Inventory database. The openness ratio compares the area of the culvert opening to the length of the culvert and is a key variable noted in the North Atlantic Aquatic Connectivity Collaborative Planning and Implementing Project Design recommendations (North Atlantic Aquatic Connectivity Collaborative, 2019). The openness ration is suggestive of a culvert with width and clearance great enough to accommodate the natural width of the channel. There are fewer than ten culverts in the filtered dataset that meet the target of an openness ration of greater than one (Figure 13).

To determine which of the remaining culverts may be priorities for replacement, the OHIO team developed a method of utilizing aerial imagery, NHD, the Conduit Inventory, and LiDAR downloaded from the Ohio Geographically Referenced Information Program (OGRIP). Since the imagery and LiDAR data are not high enough resolution to visualize plunge pools or specific disconnection at the downstream end of the culvert, we instead measured an average slope by selecting 2-3 points on the streambed upstream and 2-3 points of elevation on the streambed downstream of the culvert and dividing by the length of the culvert. This yields the average slope of the stream including the culvert from upstream to downstream of the culvert, and represents the average slope of the culvert including any drop from the outlet to the streambed (Figure 14). A high average slope could indicate either a high culvert slope or a low to moderate culvert slope with a disconnection between the downstream end of the culvert and the stream. Either scenario could impede fish passage and could suggest a need for culvert replacement, although it does not point to either the high slope or the disconnection mechanism. For a single HUC12 with 5-10 culverts of interest, the GIS analysis takes approximately one hour.

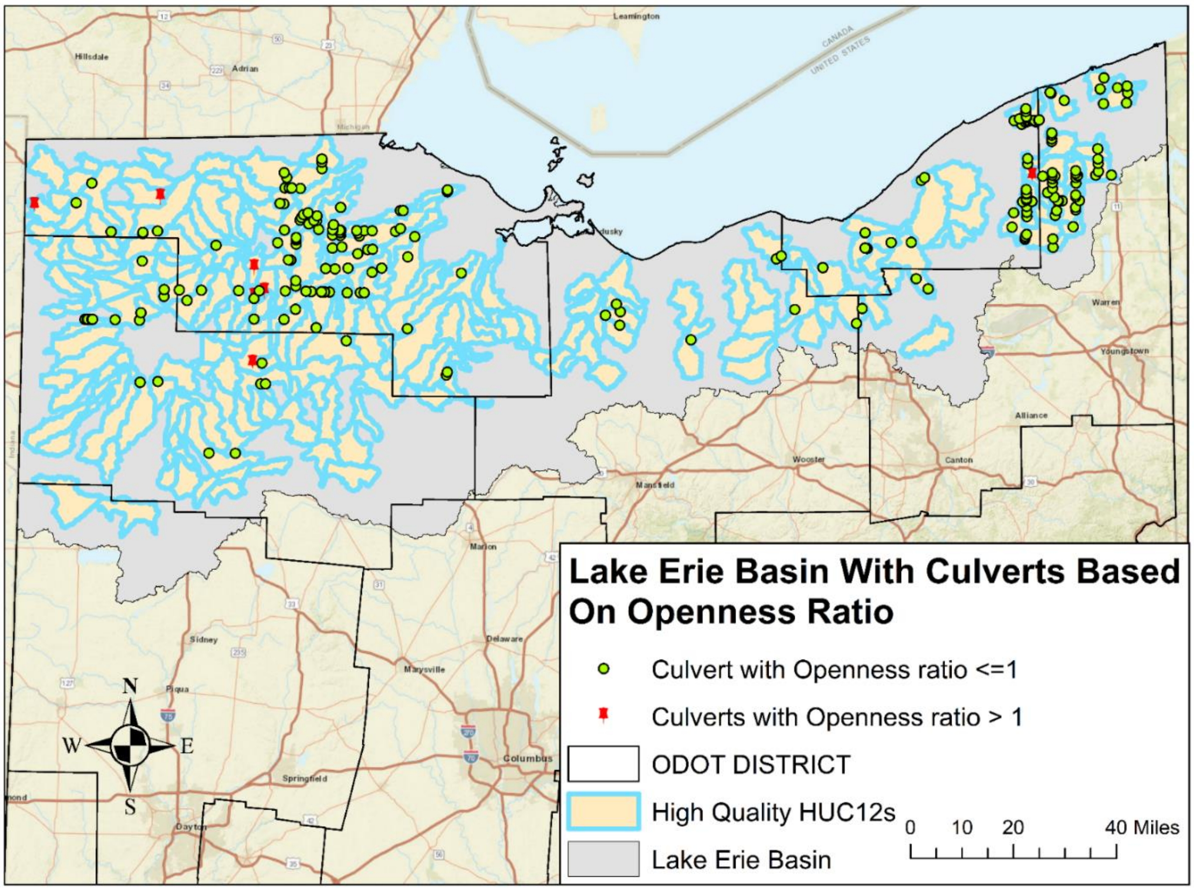


Figure 13 High quality watersheds in the Lake Erie Basin with culverts an openness ratio above one (1) in red and below one (1) in green.

Based on natural breaks in the data, the OHIO team mapped culverts with average slopes of <4%, 4-10%, and greater than 10%. This analysis suggests that field review of those culverts with the greatest average slope and ideally those with average slope greater than 4% would be warranted.

There are some sources of error involved in using LiDAR data for this analysis:

- The available imagery is not of high definition.
- The LiDAR data shows fluctuation in elevation in small distances in some places (maybe presence of trees in some places, unidentifiable by imagery)
- Hard to locate exact point at upstream and downstream for average slope computation with LiDAR.

If the use of LiDAR following this methodology is not conclusive, ground truthing is recommended prior to project selection.

A detailed technical illustration of this method is included below in Section 8.3.1 and flowchart describing the decision tree is shown in Figure 15.

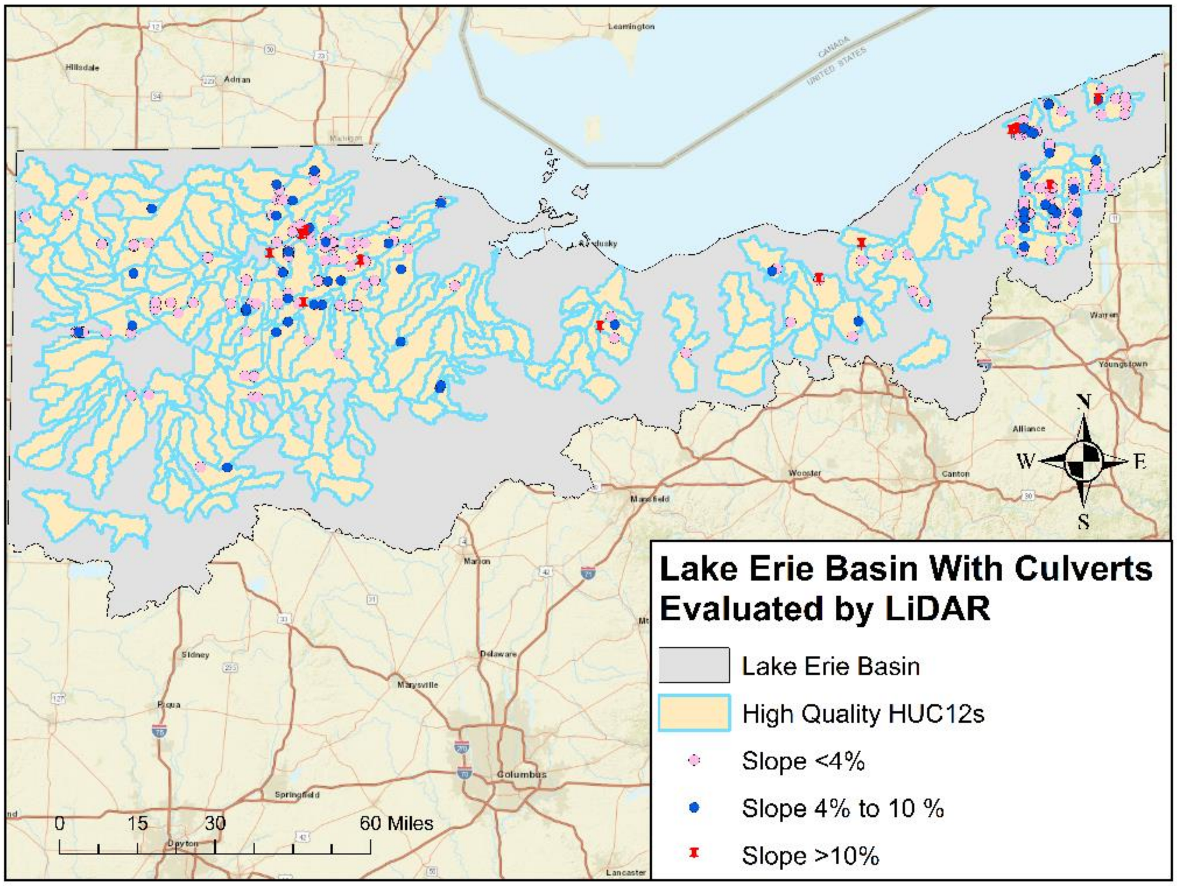


Figure 14 Selected culverts in the Lake Erie Basin high quality watersheds symbolized by slope.

8.3.1 Technical Approach

To begin the analysis, download the Conduit Inventory from the ODOT TIMS website. The other input dataset required for the analysis are NHD Flowlines (Geological Survey, U.S., 2021), high quality HUC12s under consideration, Ohio State Map, LiDAR at filtered culvert points, and aerial imagery (OGRIP, 2021). The OEPA Integrated Report Water Quality and Assessment Report data is used to select the HUC12s in which at least one TMDL point met Warmwater Habitat, Exceptional Warmwater Habitat, or Cold-Water Habitat (WWH, EWH or CWH) (Ohio EPA, 2018).

A flowchart of this analysis is shown in Figure 15.

The first filter used is to clip all the culverts that lie within the high quality HUC12s under the consideration. Next remove the “Storm Sewers” from the database. Among those culverts the dataset were selected based on the attribute named ‘FEATURE_IN’ which indicated that the culvert were storm sewers. Next step is to further filter culverts that are 20ft away from the NHD Flowlines. This step is used to remove culverts that do not convey intermittent or perennial streams.

Next calculate the openness ratio of the filtered Culvert dataset, using equation 1 (North Atlantic Aquatic Connectivity Collaborative, 2019):

Openness Ratio = Cross-sectional Area / Length   Equation 1

Calculate the cross-section area based on the shape of culvert listed in the attribute table. The attributes ‘Rise’ and ‘Span’ are used to compute the Area and the Length is from the attribute ‘length’.

*If ‘Openness Ratio’ > 1 (*North Atlantic Aquatic Connectivity Collaborative, 2019)*,*
No further check needed. (Further ground truthing recommended),
Else,
Calculate Average slope of the Culvert using LiDAR.

Next download the LiDAR dataset for the filtered Culverts from OGRIP. Locate the Upstream and Downstream points of culvert based on the aerial imagery. Use 2 to 3 points of LiDAR elevation at the Upstream and Downstream points of a culvert, as close to the outlets as possible. Calculate the average elevation and the difference in elevation from the Upstream to the Downstream. With the help of length from the attribute table the “Average slope of a Culvert” is calculated using LiDAR using Equation 2.

Average slope of a Culvert = Change in elevation / Length   Equation 2

If “Average slope of a Culvert” < 4%,
No Further check needed, (Further ground truthing recommended),
Else,
Ground truthing required, Appropriate action may be needed to ensure fish passage.

Figure 16 illustrates the GIS analysis for Acrola Creek in Northeast Ohio.

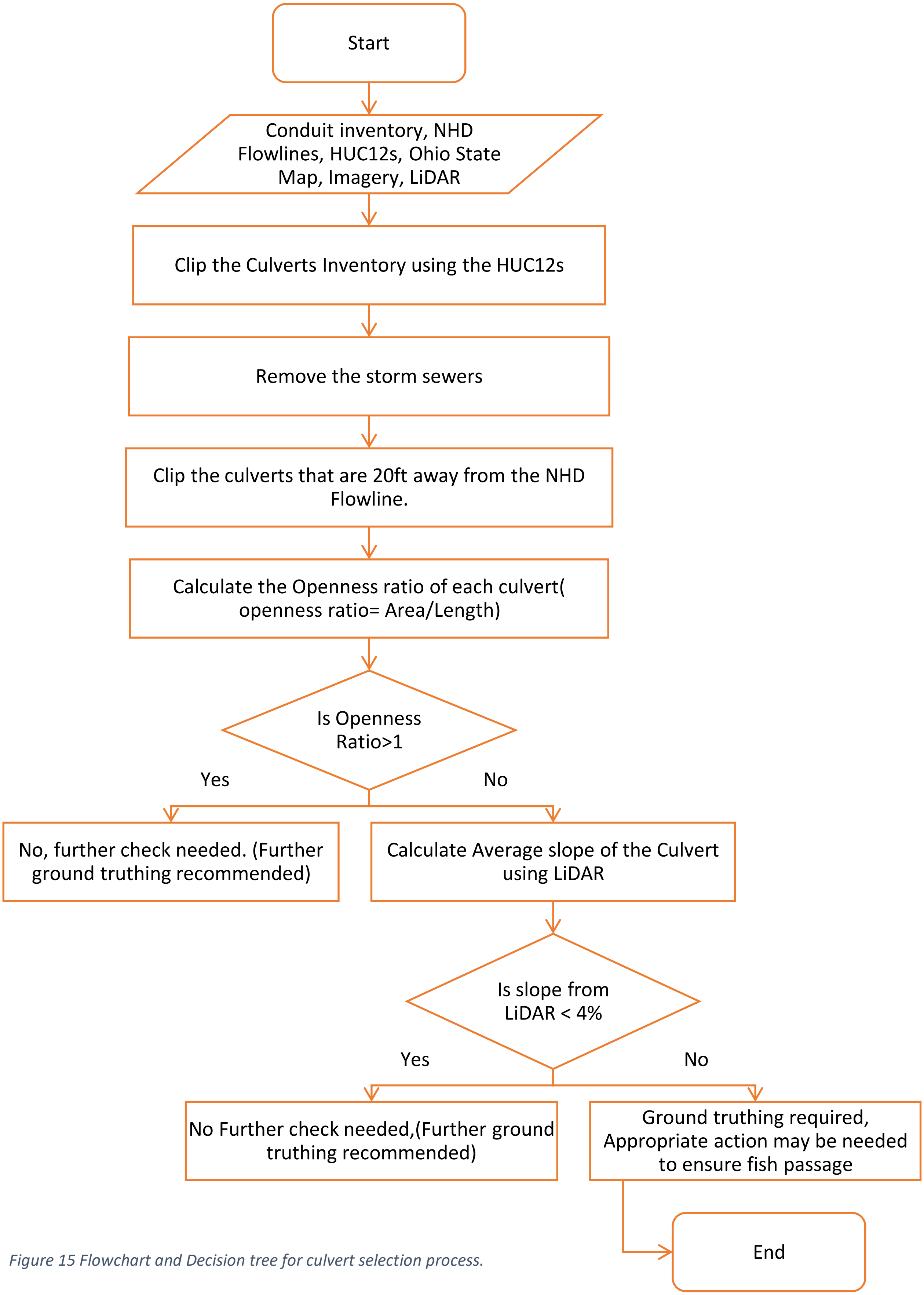


Figure 15 Flowchart and Decision tree for culvert selection process.

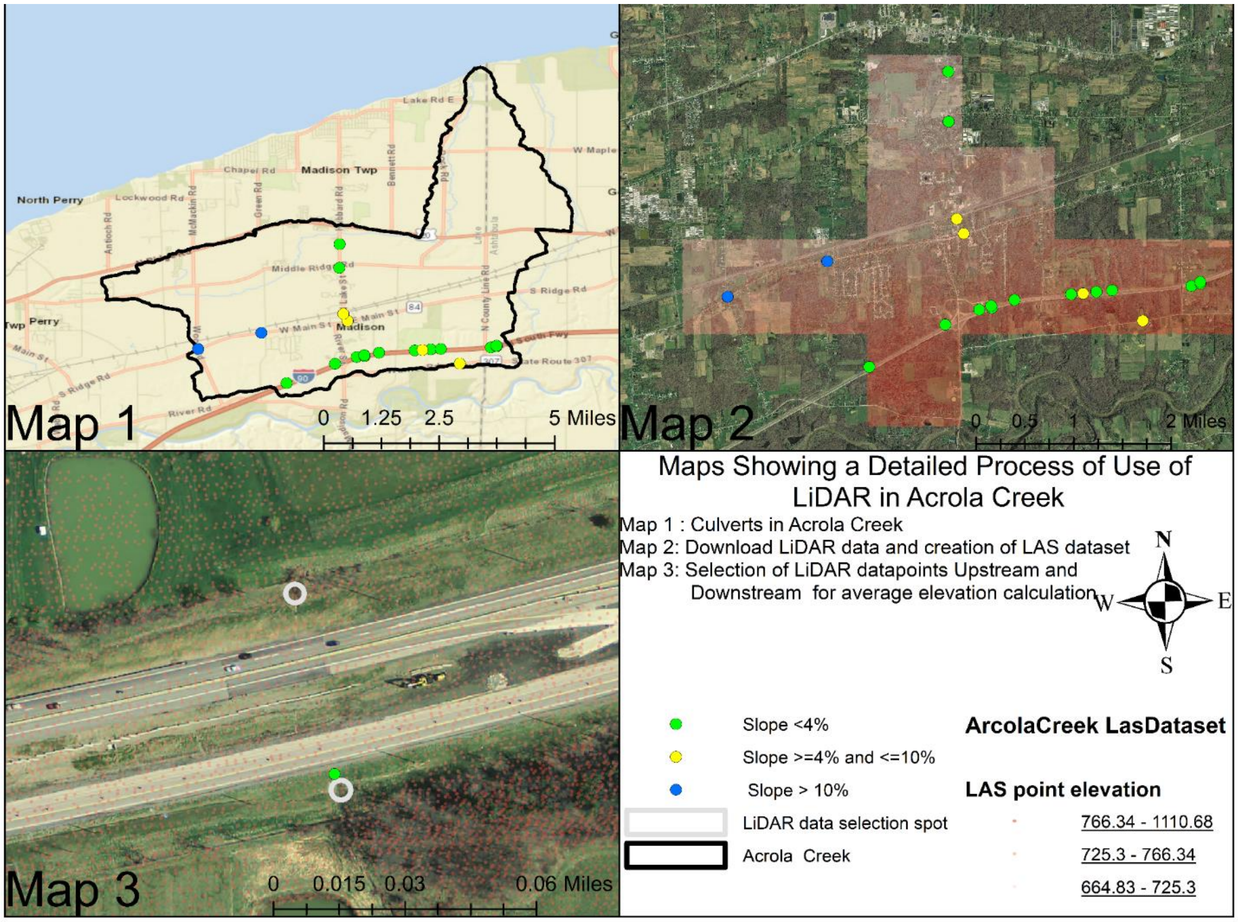


Figure 16 Graphic illustrating the LiDAR process for slope calculation.

Task 8.4 Recommendations

With potential for federal funding for culvert replacement projects, this project suggests two key approaches for assessing potential locations for improving fish passage: consultation with local stakeholders and GIS-based analysis followed by field inspection.

During our stakeholder outreach efforts, it became clear that not only did potential partners have project sites in mind but were also eager to partner with ODOT on future projects. These local partners have significant knowledge of the water bodies, the fish communities, and the need for improved fish passage to meet aquatic use designations or other fish population management goals. The project partners identified and the NPS-IS reports summarized in Section 8.2.2, and those shown in the acknowledgements section would be appropriate initial connections for planning-ready projects.

The GIS-based analysis is an appropriate first step to take to broadly identify target project locations before field-based inspections by ODOT District personnel. While we applied the methodology to the ODOT Conduit Inventory, the same methodology could be applied to culverts in other locations, jurisdictions, or databases given adequate information available in the attribute table: length, shape, height, and span. Where greater resolution aerial imagery and LiDAR are available, accuracy of the methodology would be improved. As a screening method, the research team demonstrated how this method could be used to narrow down potential project locations in an area. ODOT personnel could build upon the analysis completed by the OHIO team to evaluate project areas of interest.

When redesigning culverts to improve fish passage, the overall goal is to make the substrate, slope, and width be as close as possible to that of the stream. This means that the culvert should be well embedded into natural substrate, wider than the bankfull width, and the slope similar to the stream itself. The OHIO team found the North Atlantic Aquatic Connectivity Climate Friendly Stream Crossings Toolkit (North Atlantic Aquatic Connectivity Collaborative, 2019) to be a comprehensive and well-organized source of information for both improving fish passage and building culverts that would be more resilient to the extreme weather events expected in a changing climate. Both of these goals may be met with similar design criteria. The Toolkit includes some resources specific to the Great Lakes Region (North Atlantic Aquatic Connectivity Collaborative, 2019).

While invasive species passage is a concern when removing fish passage barriers, it was not a concern expressed by any of the stakeholders we spoke to. There are several invasive species of concern that should be taken into account during project planning, however they tend to be “strong swimmers”, so would likely be able to pass existing barriers during high flow events.

References

Baral, D., & Tritico, H. M. (2013). *Computational Study of Fish Passage through Circular Culverts in Northeast Ohio* (FHWA/OH-2013/10; p. 166). Youngstown State University.

B.C. Ministry of Forests, Lands and Natural Resource Operations, & B.C. Ministry of Environment, and Fisheries and Oceans Canada. (2012). *Fish-stream crossing guidebook.* BC Ministry of Environment.

Bourne, C. M., Kehler, D. G., Wiersma, Y. F., & Cote, D. (2011). Barriers to fish passage and barriers to fish passage assessments: The impact of assessment methods and assumptions on barrier identification and quantification of watershed connectivity. *Aquatic Ecology*, *45*(3), 389–403. https://doi.org/10.1007/s10452-011-9362-z

Briggs, A. S., & Galarowicz, T. L. (2013). Fish Passage through Culverts in Central Michigan Warmwater Streams. *North American Journal of Fisheries Management*, *33*(3), 652–664. https://doi.org/10.1080/02755947.2013.788589, (

Capuzzi, K., (2021) OU_Fish_090321.xlsx. Ohio EPA DSW EA3 biological and chemical database. https://epa.ohio.gov/Portals/35/documents/SW-Sampling-Manual-2018-AppIV.pdf. Ohio Environmental Agency.

Coffman, J. (2005). *Evaluation of a Predictive Model for Upstream Fish Passage Through Culverts*. James Madison University.

Crosier, D., Malloy, D., & Jude, D. (n.d.). *ANS Task Force*. Round goby. Retrieved October 5, 2021, from https://www.fws.gov/anstaskforce/spoc/round_goby.php

Dodd, H. R., Hayes, D. B., Baylis, J. R., Carl, L. M., Goldstein, J. D., McLaughlin, R. L., Noakes, D. L. G., Porto, L. M., & Jones, M. L. (2003). Low-head Sea Lamprey Barrier Effects on Stream Habitat and Fish Communities in the Great Lakes Basin. *Journal of Great Lakes Research*, *29*, 386–402. https://doi.org/10.1016/S0380-1330(03)70502-4

Edge, C. B., Fortin, M.-J., Jackson, D. A., Lawrie, D., Stanfield, L., & Shrestha, N. (2016). Habitat alteration and habitat fragmentation differentially affect beta diversity of stream fish communities. *Landscape Ecology*, *32*(3), 647–662. https://doi.org/10.1007/s10980-016-0472-9

Eisenhour, D. J., & Floyd, M. A. (2013). A Culvert Acts as a Barrier for Blackside Dace (Chrosomus cumberlandensis) Movements in Lick Fork, Kentucky. *Southeastern Naturalist*, *12*(sp4), 82–91. https://doi.org/10.1656/058.012.s406

Favaro, C., & Moore, J. W. (2015). Fish assemblages and barriers in an urban stream network. *Freshwater Science*, *34*(3), 991–1005. https://doi.org/10.1086/681917

Fleming, P., & Neeson, T. M. (2020). Effects of transportation infrastructure on fishes in the Ozark and Ouachita Mountains. *Transportation Research Part D: Transport and Environment*, *86*. https://doi.org/10.1016/j.trd.2020.102451

Goodrich, H. R., Watson, J. R., Cramp, R. L., Gordos, M. A., & Franklin, C. E. (2018). Making culverts great again. Efficacy of a common culvert remediation strategy across sympatric fish species. *Ecological Engineering*, *116*, 143–153. https://doi.org/10.1016/j.ecoleng.2018.03.006

Great Lakes Restoration Initiative. (n.d.). *Great Lakes Restoration Initiative Report to Congress and the President*. Great Lakes Restoration Initiative. Retrieved November 13, 2021, from https://www.glri.us/sites/default/files/fy2017-glri-report-to-congress-201902-36pp.pdf.

Goss, C. W., Goebel, P. C., & Sullivan, S. M. P. (2014). Shifts in attributes along agriculture-forest transitions of two streams in central Ohio, USA. *Agriculture, Ecosystems & Environment*, *197*, 106–117. https://doi.org/10.1016/j.agee.2014.07.026

Hoffman, R., & Dunham, J. (2007). *Fish-Movement Ecology in High-Gradient Headwater Streams: Its Relevance to Fish Passage Restoration Through Stream Culvert Barriers* (OFR No. 1140; Open-File Report, p. 40). U.S. Geological Survey.

Jones, P. E., Champneys, T., Vevers, J., Börger, L., Svendsen, J. C., Consuegra, S., Jones, J., & Garcia de Leaniz, C. (2021). Selective effects of small barriers on river-resident fish. *Journal of Applied Ecology*, *58*(7), 1487–1498. https://doi.org/10.1111/1365-2664.13875

Jones, P. E., Svendsen, J. C., Börger, L., Champneys, T., Consuegra, S., Jones, J. A. H., & Garcia de Leaniz, C. (2020). One size does not fit all: Inter- and intraspecific variation in the swimming performance of contrasting freshwater fish. *Conservation Physiology*, *8*(1). https://doi.org/10.1093/conphys/coaa126

Kanzler, S., Romero, D., Prosser, K., Schmidt, T., & Hershfield, M., WSDOT FISH PASSAGE PERFORMANCE REPORT (2021). Department of Fish and Wildlife, WSDOT.

Keep, J. K., Watson, J. R., Cramp, R. L., Jones, M. J., Gordos, M. A., Ward, P. J., & Franklin, C. E. (2020). Low light intensities increase avoidance behaviour of diurnal fish species: Implications for use of road culverts by fish. *Journal of Fish Biology*, *98*(3), 634–642. https://doi.org/10.1111/jfb.14604

Kerr, J. R., Vowles, A. S., Crabb, M. C., & Kemp, P. S. (2021). Selective fish passage: Restoring habitat connectivity without facilitating the spread of a non-native species. *Journal of Environmental Management*, *279*. https://doi.org/10.1016/j.jenvman.2020.110908

Kornis, M. S., Sharma, S., & Jake Vander Zanden, M. (2012). Invasion success and impact of an invasive fish, round goby, in Great Lakes tributaries. *Diversity and Distributions*, *19*(2), 184–198. https://doi.org/10.1111/ddi.12001

Kroon, F. J., Phillips, S. (2015). Identification of human-made physical barriers to fish passage in the Wet Tropics region, Australia. *Marine and Freshwater Research*, *67*(5), 677–681. https://doi.org/10.1071/MF14397

Leng, X., & Chanson, H. (2020). Asymmetrical Wall Baffles to Assist Upstream Fish Passage in Box Culvert: Physical Modeling. *Journal of Irrigation and Drainage Engineering*, *146*(12). https://doi.org/10.1061/(ASCE)IR.1943-4774.0001514

McKay, S. K., Schramski, J. R., Conyngham, J. N., & Fischenich, J. C. (2013). Assessing upstream fish passage connectivity with network analysis. *Ecological Applications*, *23*(6), 1396–1409.

McManamay, R. A., Jett, R. T., Ryon, M. G., Gregory, S. M., Stratton, S. H., & Peterson, M. J. (2016). Dispersal limitations on fish community recovery following long-term water quality remediation. *Hydrobiologia*, *771*(1), 45–65. https://doi.org/10.1007/s10750-015-2612-7

Michigan Department of Natural Resources. (2011). *Great Lakes Road Stream Crossing Inventory Instructions*. Michigan.gov. Retrieved June 8, 2021, from https://www2.dnr.state.mi.us/Publications/pdfs/ArcGISOnline/Guides/Stream_Crossing/Great_Lakes_Stream_Crossing_Inventory_Instructions.pdf.

Mirati Jr., A. (1999). *Assessment of Road Culverts for Fish Passage Problems on State- and County-Owned Roads* [Statewide Summary Report]. Oregon Department of Fish and Wildlife.

North American Aquatic Connectivity Collaborative. (2019, August 30). *Planning and implementing projects*. Stream Continuity. Retrieved August 9, 2021, from https://streamcontinuity.org/naacc/toolkit/planning-and-implementing-projects

Ohio Department of Transportation, (2021). Conduit Inventory geodatabase file. Ohio Transportation Information Mapping System, downloaded from https://gis.dot.state.oh.us/tims/Data/Download October 14, 2012.

Ohio Department of Natural Resources. (2021, October 31). Ohio Commercial Yellow Perch Quota Update_10312021. Retrieved October 31, 2021, from https://ohiodnr.gov/static/documents/wildlife/fish-management/October+2021+Commercial+Yellow+Perch+Quota+Update.pdf.

Ohio EPA (Ohio Environmental Protection Agency). 2018. Ohio 2018 Integrated Water Quality Monitoring and Assessment Report -June 2018 Published at: https://www.freshlawblog.com/wp-content/uploads/sites/15/2018/06/4-2018-impaired-water-listing.pdf

Ohio Geographically Referenced Information Program(OGRIP). (2021). Ohio Geological Survey. Downloaded from https://gis5.oit.ohio.gov/geodatadownload/

Perillo, J., & Butler, L. (2009). Evaluating The Use of Fairmount Dam Fish Passage Facility With Application To Anadromous Fish Restoration In The Schuylkill River, Pennsylvania. *Journal of the Pennsylvania Academy of Science*, *83*(1), 24–33.

Reinfelds, I. V., Keenan, H., & Walsh, C. T. (2020). Fish passage modelling for environmental flows: Hawkesbury-Nepean River, NSW, Australia. *River Research and Applications*, *36*(4), 595–606. https://doi.org/10.1002/rra.3445

Rice, D., & Zimmerman, B. (2019). A Naturalist's Guide to the Fishes of Ohio. Ohio Biological Survey

Richer, E. E., Fetherman, E. R., Krone, E. A., Wright, F. B., & Kondratieff, M. C. (2020). Multispecies Fish Passage Evaluation at a Rock-Ramp Fishway in a Colorado Transition Zone Stream. *North American Journal of Fisheries Management*, *40*(6), 1510–1522. https://doi.org/10.1002/nafm.10516

Shiau, J., Watson, J. R., Cramp, R. L., Gordos, M. A., & Franklin, C. E. (2020). Interactions between water depth, velocity and body size on fish swimming performance: Implications for culvert hydrodynamics. *Ecological Engineering*, *156*. https://doi.org/10.1016/j.ecoleng.2020.105987

Sun, J., Galib, S. M., & Lucas, M. C. (2020). Are national barrier inventories fit for stream connectivity restoration needs? A test of two catchments. *Water and Environment Journal*, *34*(S1), 791–803. https://doi.org/10.1111/wej.12578

Torterotot, J.-B., Perrier, C., Bergeron, N. E., & Bernatchez, L. (2014). Influence of Forest Road Culverts and Waterfalls on the Fine-Scale Distribution of Brook Trout Genetic Diversity in a Boreal Watershed. *Transactions of the American Fisheries Society*, *143*(6), 1577–1591. https://doi.org/10.1080/00028487.2014.952449

Service, U. S. F. and W Service. (n.d.). *Fish passage program awards $645,000 - great lakes restoration initiative supports Midwest Partners: U.S. Fish and Wildlife Service Midwest Region*. Official Web page of the U S Fish and Wildlife Service. Retrieved November 30, 2021, from https://www.fws.gov/midwest/news/674.html

U. S. Fish and Wildlife Service. (2013). *Fish passage program awards $645,000 - great lakes restoration initiative supports Midwest Partners: U.S. Fish and Wildlife Service Midwest Region*. Official Web page of the U S Fish and Wildlife Service. Retrieved November 30, 2021, from https://www.fws.gov/midwest/news/674.html

US Geological Survey. (2021). National Hydrography Dataset [Map]. [Reston, Va.] :U.S. Dept. of the Interior, U.S. Geological Survey.

Watson, J. R., Goodrich, H. R., Cramp, R. L., Gordos, M. A., & Franklin, C. E. (2018). Utilising the boundary layer to help restore the connectivity of fish habitats and populations. *Ecological Engineering*, *122*, 286–294. https://doi.org/10.1016/j.ecoleng.2018.08.008

Zielinski, D. P., & Freiburger, C. (2020). Advances in fish passage in the Great Lakes basin. *Journal of Great Lakes Research*. https://doi.org/10.1016/j.jglr.2020.03.008

Appendix A: NPS-IS Plan Review Details

Nine Element Plans Dealing with Fish Passage (No Dams)

East Branch Chagrin:

East Branch Chagrin identifies 1 perched culvert causing fish passage impairment. See below for more details:

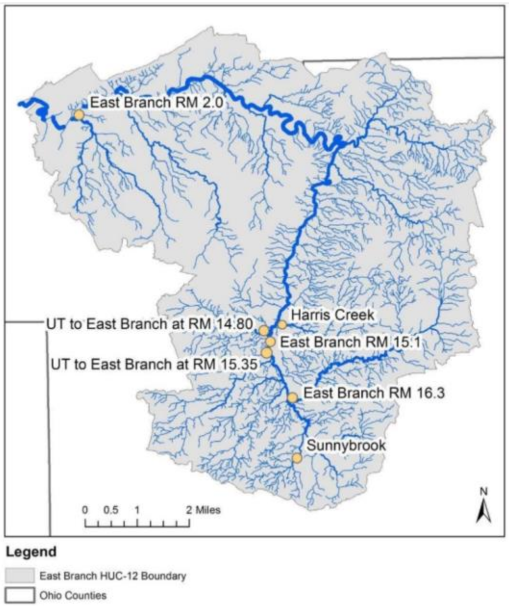


Table 20: Biological conditions of Ohio EPA sampling sites within Critical Area 2 that are impaired by fish barriers. Departures from EWH numerical criteria are highlighted in orange.

Year	Station Name	Attainment Status	ALU Designation	River Mile	2003/ 2004 IBI	2003/ 2004 ICI	ICI Narrative	2003/ 2004 QHEI
2004	Harris Creek	Partial	CWH	0.1	38	E	Exceptional	62.5
2004	Trib to EB @ RM 14.80	Partial	CWH	0.1	48	G	Good	63.5
2004	Trib to EB @ RM 15.35	Partial/Full	CWH/EWH	0.2	46 (ns)	VG (ns)	Very Good	72.5

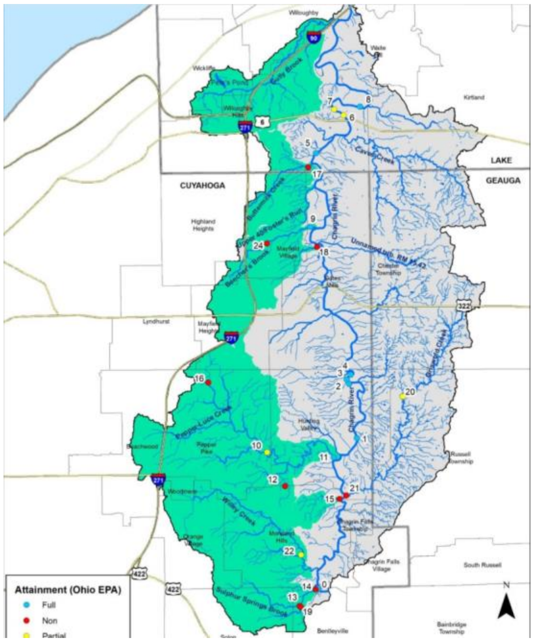
(ns) Indicates nonsignificant departure from biocriteria

An unnamed tributary to East Branch at RM 15.35 is in partial/full attainment of its CWH/EWH designation. Sampling by Ohio EPA in 2003 – 2004 indicated the causes of impairment at this site as habitat alteration, flow alteration, and sedimentation. Nonpoint sources of impairment included a bridge on Sperry Road with a perched culvert that acts as a barrier to fish migration to upstream portions of this stream. Rip-rap was added to this structure in 2006 – 2007.

Figure 36: Unnamed tributary to East Branch at RM 15.35 is impaired by a perched culvert that acts as a fish barrier.

Griswold Creek:

Griswold Creek has identified 1 drop structure on Beecher Brook causing fish passage impairment. See below for more details:



Some of the tributaries in this critical area also have dam structures or other barriers that impede fish migration. At Beecher's Brook near Wilson Mills trailhead, the drop-off structure does not allow for fish to migrate upstream. In addition, near vertical banks contribute to in-stream sedimentation and water quality degradation.

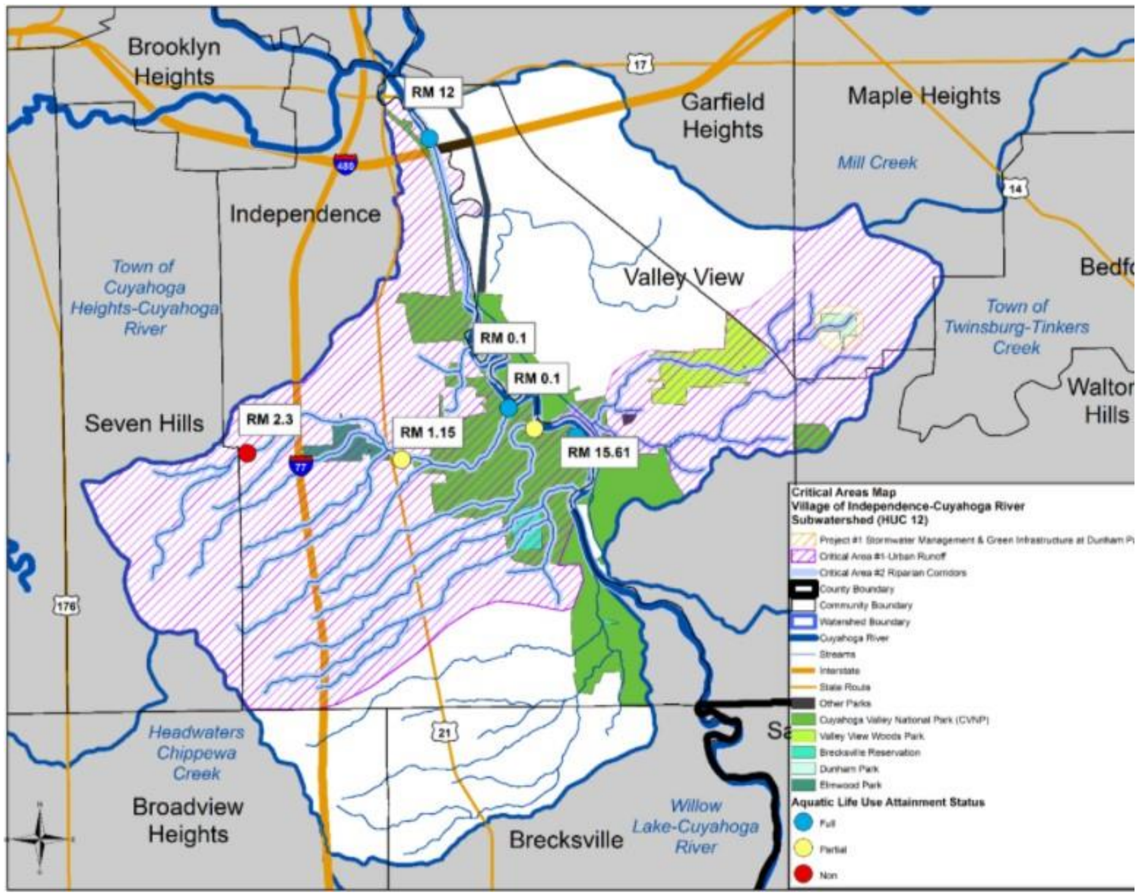
Figure 24: Drop structure acting as fish migration barrier at Beecher's Brook near Wilson Mills trailhead at North Chagrin Reservation

Station ID	Sample Station Name	River Mile (Drainage Area)	ALU Type	Fish Sample Yr	IBI Score	IBI Desc.	MIwb Score	MIwb Desc.	Bug Sample Year	ICI Score	ICI Desc.	QHEI
9	BEECHERS BROOK (CHAGRIN R. 14.88) UPST. METROPARK ROAD	0.1 (1.28)	Full WWH	2012	42	G	NA			NA		59
24	BEECHERS BROOK @ SOM CENTER RD.	1.2 (0.5)	Non WWH	2016	12	VP	NA		2016	36	G	63.0

Cuyahoga River at the Village of Independence:

The Village of Independence has identified 1 unknown stream modification causing fish passage impairment. See below for more details:

Two (2) known instream barriers to fish passage have been identified in this Critical Area. One (1) of which was identified in the NEORSD's *Cuyahoga River South Stormwater Master Plan* and identified as Major Structure CH00159 (low head dam).



<u>West Creek:</u>

West Creek has identified 2 points of fish passage impairment. See below for more details:

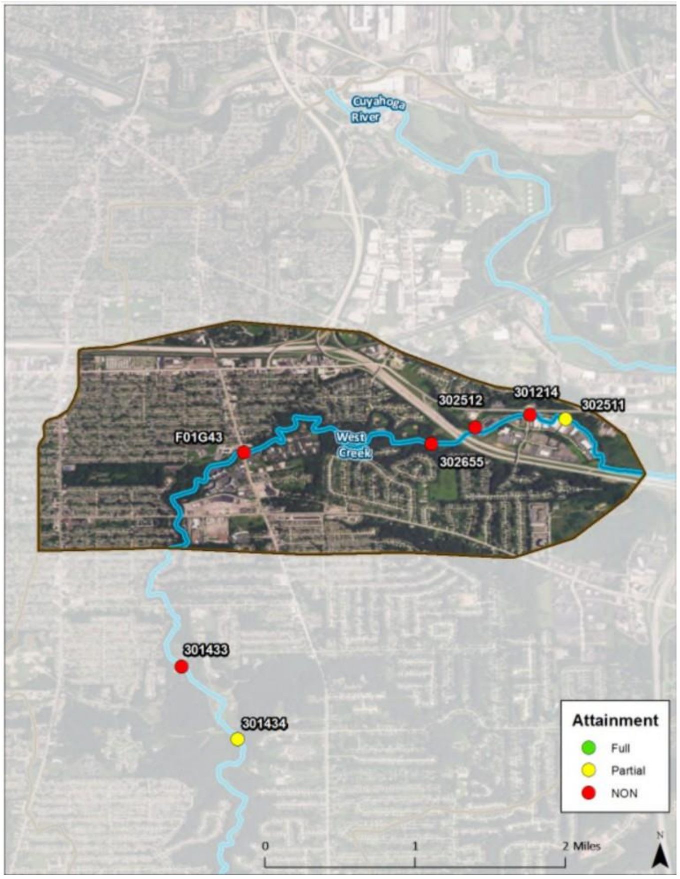


Table 16. Fish community health and habitat data - Critical Area #3

RM	DA	QHEI	Total species	IBI	Predominant species (percent of catch)	Narrative evaluation
3.70	6.3	58.5	4	28	Blacknose dace (75%), Central stoneroller minnow (11%), Creek chub (11%)	Fair
2.10	9.1	73.0	6	28	Blacknose dace (59%), Central stoneroller minnow (32%), Creek chub (8%)	Fair
1.60	9.2	67.0	6	30	Blacknose dace (58%), Central stoneroller minnow (39%), Creek chub (3%)	Fair

Notes

Objective 1 Remove or bypass two barriers to fish passage

- The West Creek flume is a major barrier that prevents fish passage to most of the West Creek watershed, including the *Normandy* and *East Central Parma* critical areas.
- A trash rack on a tributary to West Creek.

<u>Baker Creek- West Branch Rocky River:</u>

Baker Creek has identified 14 barriers to fish passage, 8 "likely" sites which are planned for removal. The plan does not specify the structure at each location, but does define culverts as a type of structure impeding fish passage in Baker Creek. See below for more details:

The following barrier types are in the Baker Creek-West Branch Rocky River watershed:

Culvert: structures that allow water to flow under a road, railroad, trail, or similar obstruction. An undersized or improperly placed culvert can impede or totally block fish and aquatic species from passing (USFWS).

According to NEORSD there are 14 fish passage barriers within this watershed; eight of which are classified as "Likely" and six that have been classified as "Potential".

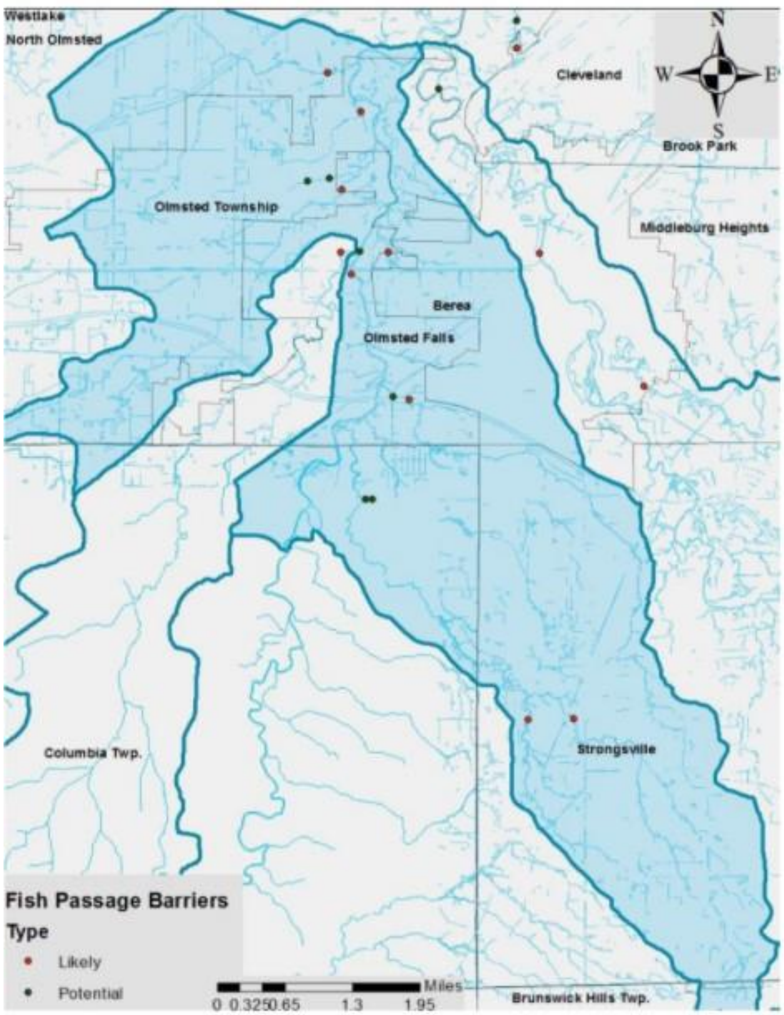


Figure 9: Map of the Baker Creek-West Branch Rocky River watershed indicating fish passage barriers. The red dots indicate "Likely" barriers and the green dots indicate "Potential" barriers.

Cahoon Creek- Frontal Lake Erie:

Cahoon Creek does not explicitly say the number of barriers to fish passage; the map constructed indicates 5 points of barrier. 3 of those points are dam class level zero which was not defined in the plan. Culverts are mentioned as a barrier for fish passage in this watershed though. See below for more details:

The following barrier types are in the Cahoon Creek – Frontal Lake Erie watershed:

Culvert: structures that allow water to flow under a road, railroad, trail, or similar obstruction. An undersized or improperly placed culvert can impede or totally block fish and aquatic species from passing (USFWS).

Goals	Objectives
1: Raise average QHEI score from 51 to 55* 2: Raise average ICI narratives from Poor/Fair to Good	1: Remove or modify at least two of the passage barriers to allow for fish migration.

This average QHEI pertains to the watershed as a whole

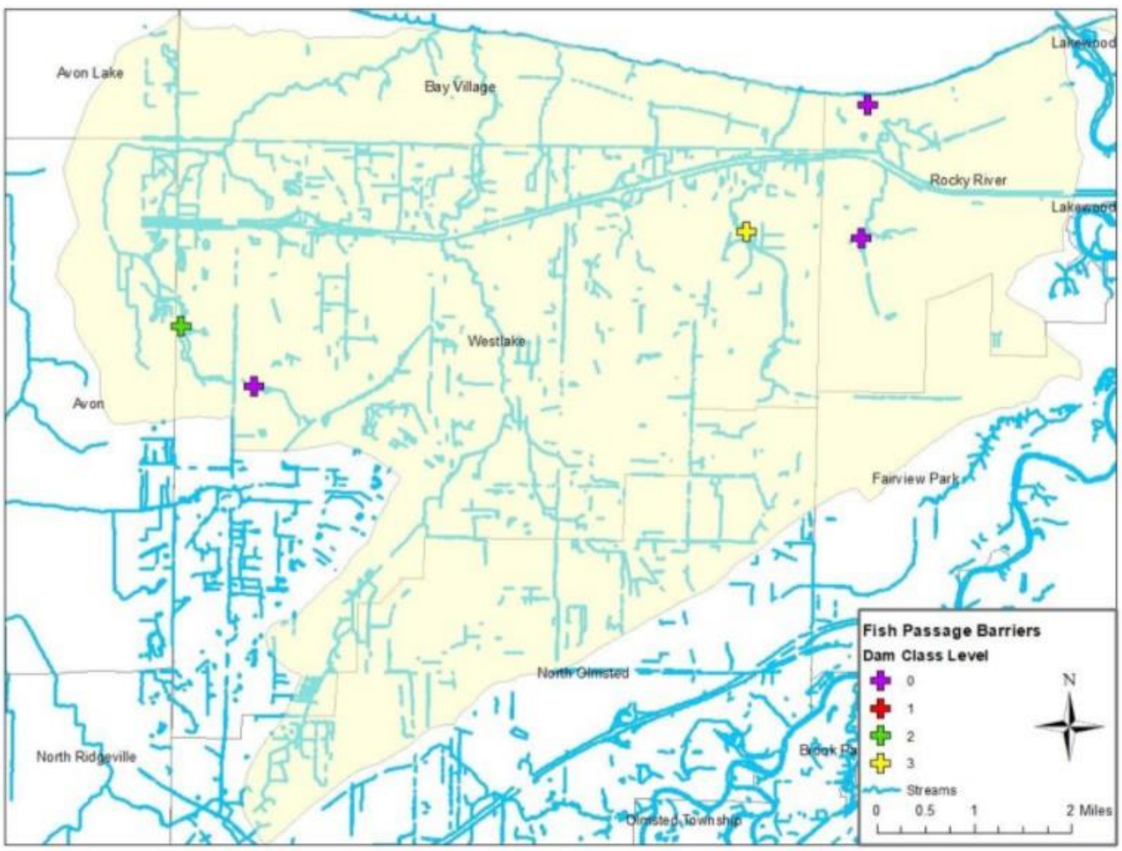


Figure 28: Map of the Cahoon Creek - Frontal Lake Erie Western lobe indicating fish passage barriers. The colored crosses are Critical Area 4.

<u>Boston Run:</u>

Boston Run has identified several barriers to fish passage within the watershed, 3 of which are objectives for removal. For what I can interpret 2 of those barriers are dams; the third does not appear to be defined. See below for more details:

Table 12: Critical Area 1 – Aquatic Life Use Monitoring Stations

Sampling Station	Sampling Year	RM	Latitude	Longitude	ALU	IBI Score	ICI Score	QHEI Score
CUYAHOGA R. AT AKRON, 0.5 MI. DST. OLD PORTAGE TRAIL	2008	39.7	41.1386	-81.5528	Full WMH	36 Marginally Good	42 Very Good	81
SAND RUN @ RIVERVIEW RD N OF AKRON	1996	0.2	41.13864	-81.5618	Non WMH	26 Marginally Good	N/A Unsampled	59
SAND RUN UPSTREAM OF SAND RUN PARKWAY FORD (conducted by EMH&T)	2013	0.65	41.1350	-81.5876	N/A	N/A	N/A	61.5
SAND RUN UPSTREAM ADJACENT TO SAND RUN PARKWAY (conducted by EMH&T)	2013	1.4	41.1329	-81.5877	N/A	N/A	N/A	51.5

substrates were extensively embedded. Consequently, the habitat was marginally suited to warmwater habitat faunas. In addition to urban development in the headwaters, about five to seven small low-head dams are also located along the length of the stream. The dams could pose a barrier to fish migration and recolonization and should be evaluated for removal. Fish communities in Sand Run were severely impacted by urban storm water

Sand Run within Sand Run Metro Park has a number of notable barriers to fish passage, as exhibited above in the dam directly upstream of the Mingo Pavilion access road and at the Sand Run Parkway ford. A third notable barrier is downstream at the Cuyahoga Valley Scenic Railroad Bridge. These barriers each

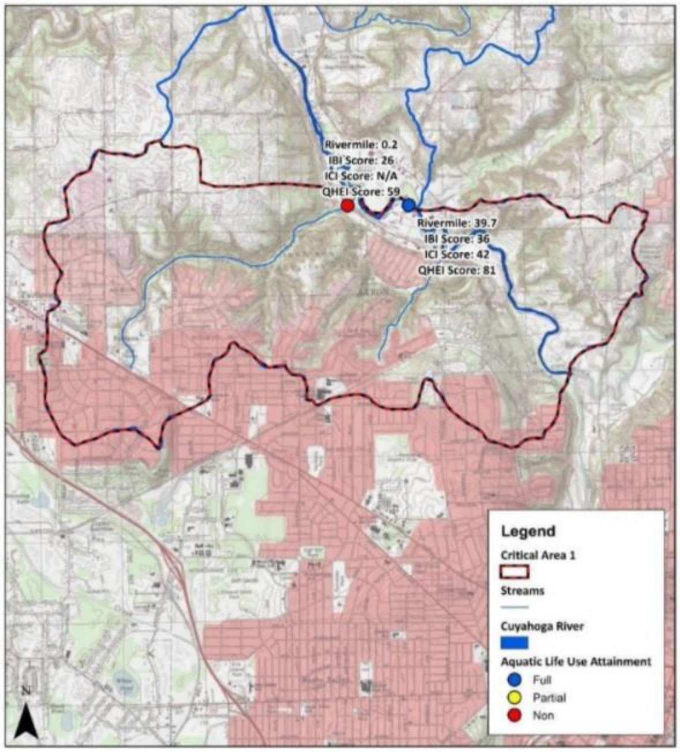


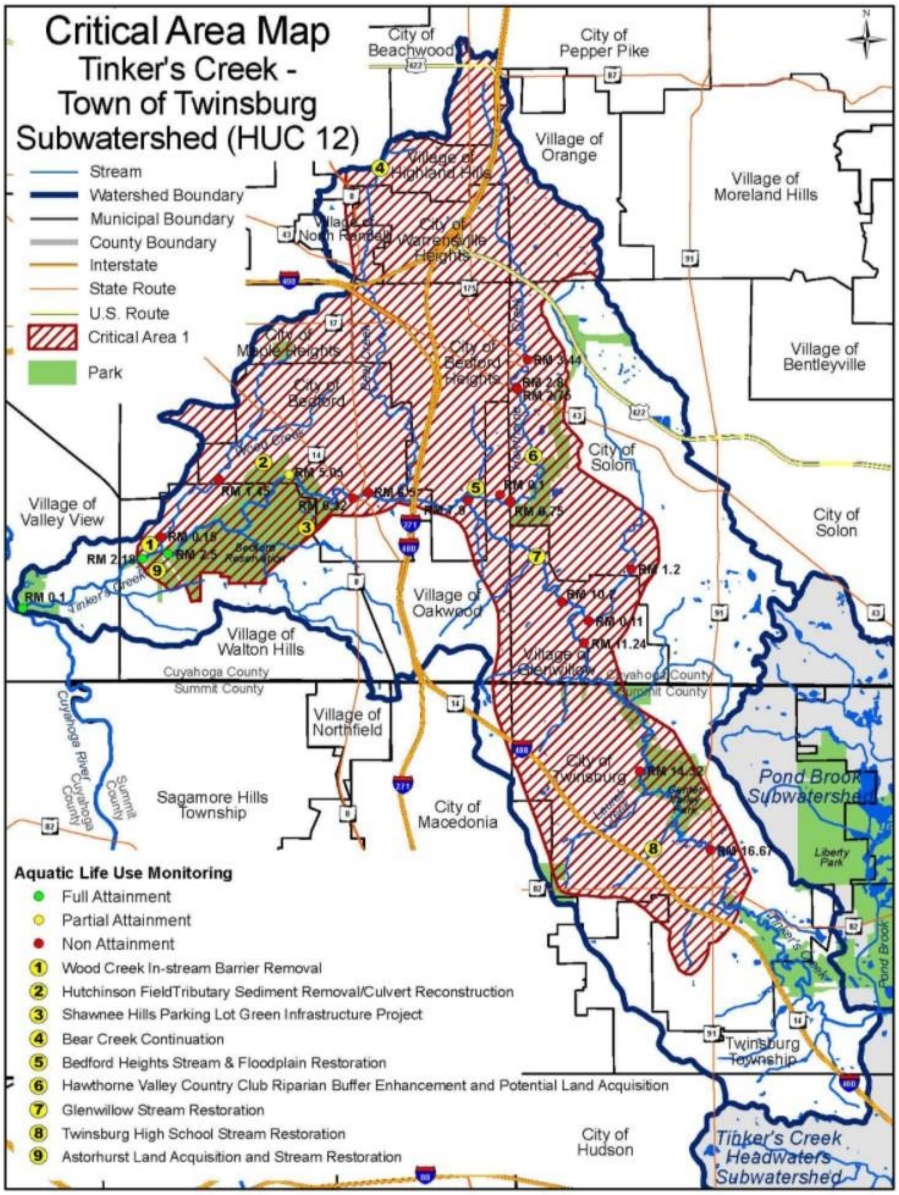
Figure 15: Critical Area 1 - Aquatic Life Use Monitoring Stations

Tinker's Creek:

Tinker's Creek has identified 2 in-stream barriers to fish passage. See below for more details:

Objective 4: Restore Tinker's Creek tributaries by modifying in-stream habitat for fish passage.

- Remove 2 in-stream barriers.



Big Creek:

Big Creek has identified 3 barriers to fish passage. See below for more details:

Objective 1 Remove or bypass three barriers to fish passage

- The Big Creek drop structure is a major barrier that prevents fish passage to most of the Big Creek watershed, including the *West Branch*, *Lower East Branch and Stickney Creek*, and *Upper East Branch* critical areas.
- Two- and three-barrel culverts just downstream of the CM Zoo parking lot along with the long sections of Big Creek culverted under the Zoo are barriers to fish passage.

Table 11. Fish community health and habitat data - Critical Area #2

RM	DA	QHEI	Total species	MIwb	IBI	Predominant species (percent of catch)	Narrative evaluation
0.23	37.1	69.5	14-19	7.6	27	sand shiner (16-19%), common emerald shiner (13-19%)	Fair

Figure 15. Critical Area #1: *Main Stem Big Creek*.

NPSIS plans Reviewed for Dams and Fish Passage structures.

Dam Removal		
Watershed number	Watershed name	Plan title
041100040607	Red Creek-Grand River	Red Creek-Grand RIver HUC-12: 041100040607 Nine-Element Nonpoint Implementation Strategic Plan (NPS-IS Plan)
041100020304	City of Akron - Cuyahoga River	Nonpoint Source Implementation Strategy Plan for City of Akron-Little Cuyahoga River HUC-12
041000010308	Sibley Creek-Ottawa River	Sibley Creek-Ottawa River HUC 12: 041000010308 Nonpoint Source Implentation Strategic Plan
041000080205	Blanchard River- City of Findlay	Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS) Blanchard River: City of Findlay Riverside Park- Blanchard River Watershed (041000080205)
041100020402	Yellow Creek-Summit Co.	Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS) Cuyahoga River: Yellow Creek (041100020402) Version 1.0
041100020601	Mill Creek--Cuyahoga River	Mill Creek Cuyahoga River sub-watershed (HUC 12) 041100020601 Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS Plan)
041100030504	Doan Brook	Doan Brook-Frontal Lake Erie (041100030504) Nonpoint Source Pollution Implementation Strategy (NPS-IS)
041100040606	Big Creek--Lower Grand	Big Creek HUC-12: 041100040606 Nine-Element Nonpoint source Implementation Strategy (NPS-IS)
Creating Fish Passage Structures		
Watershed number	Watershed name	Plan title
041000100603	Lower Toussaint River	Lower Toussaint Creek HUC-12 Habitat Restoration Plan (HRP) and Nonpoint Source Implmentation Strategic Plan (NPS-IS plan)
041000100701	Turtle Creek	Turtle Creek-Frontal Lake Erie HUC-12 Habitat Restoration Plan (HRP) and Nonpoint Source Implementation Strategic Plan (NPS-IS plan)
041000100702	Crane Creek	Crane Creek-Frontal Lake Erie HUC-12 Habitat Restoration Plan (HRP) and Nonpoint Source Implementation Strategic Plan (NPS-IS plan)

Appendix A References:

Chagrin River Watershed Partners, Inc. (2019a, August 14). *Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS Plan) Chagrin River: East Branch Chagrin River HUC-12 (04110003–04-01)*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Approved%209-Element%20Plans/East%20Branch%E2%80%94Chagrin%20River%20_Ver1.2_8-14-2019.pdf

Chagrin River Watershed Partners, Inc. (2019b, August 14). *Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS Plan) Chagrin River: Griswold Creek-Chagrin River HUC-12 (04110003–04-02)*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Approved%209-Element%20Plans/Griswold%20Creek%E2%80%94Chagrin%20River_Ver1.3_8-14-2019.pdf

Chagrin Valley Engineering, LTD. (2017, August 8). *Tinker's Creek 04110002 05 04 Town of Twinsburg (HUC 12) Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS Plan)*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Approved%209-Element%20Plans/TinkersCreekTwinsburgV1_0.pdf

Chagrin Valley Engineering, LTD & West Creek Conservancy. (2020, May 21). *Village of Independence-Cuyahoga River (HUC 12) 04110002 06 02 Nine-Element Nonpoint Source Implementation Strategic Plan (NPS-IS Plan)*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Village%20of%20Independence_Cuyahoga%20River_Ver1.0_5-21-2020.pdf

Cuyahoga Soil & Water Conservation District & Chagrin River Watershed Partners, Inc. (2020, January 13). *Cahoon Creek-Frontal Lake Erie (HUC-12: 04110001 02 04) Nine-Element Nonpoint Source Implementation Strategy Plan (NPS-IS)*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Approved%209-Element%20Plans/Cahoon%20Creek-FLE_Ver1.1_1-13-2020.pdf

Cuyahoga Soil & Water Conservation District & Rocky River Watershed Council. (2019, December 27). *Baker Creek-West Branch Rocky River (HUC-12: 04110001 01 08) Nine-Element Nonpoint Source Implementation Strategy Plan (NPS-IS)*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Approved%209-Element%20Plans/Baker%20Creek-WB_RockyR_Ver1.0_12-27-2019.pdf

Summit Metro Parks & Summit Ecological Consulting. (2020, February 21). *Boston Run - Cuyahoga River Watershed (HUC 041100020405) Nine-Element Nonpoint Source Implementation Strategic Plan*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Approved%209-Element%20Plans/BostonRun_Ver1.0_2-21-2020.pdf

Tetra Tech, Inc. & West Creek Conservancy. (2017, June 9). *West Creek Nonpoint Source Implementation Strategy*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Approved%209-Element%20Plans/WestCreekV1_0.pdf

Tetra Tech, Inc., Big Creek Connects, & West Creek Conservancy. (2020, April 14). *Big Creek Nonpoint Source Implementation Strategy*. Ohio Environmental Protection Agency. Retrieved November 23, 2021, from https://epa.ohio.gov/Portals/35/nps/Big%20Creek_Ver1.1_4-14-2020.pdf