Highland Park Dam Mitigation Project

FINAL REPORT

CITY OF TOLEDO in LUCAS COUNTY, OHIO

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Prepared For:

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Patekka Bannister	City of Toledo (Environmental Services)
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Regina Collins	City of Toledo (Environmental Services)
Steve Day	City of Toledo (Engineering Services)
David Derrick	US Army Corps of Engineers
Dennis Garvin	City of Toledo (Forestry)
Jeff Grabarkiewicz	Lucas Soil and Water Conservation District
Matt Horvat*	Toledo Metropolitan Area Council of Governments
Patrick Lawrence	The University of Toledo
Kristina Patterson	Partners for Clean Streams
Scott Sibley	City of Toledo (Engineering Services)

**Team Leader*

Thank you to the Toledo ZooTeens for assisting in the harvesting of vegetation necessary to stabilize the streambanks and keys of this project. To The Nature Conservancy and the Toledo Area Metroparks for allowing us to harvest materials from their property.

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Thank you to those who provided photos and illustrations for this report, including Cherie Blair, Dave Derrick, Scott Dierks, Jeff Grabarkiewicz, Matt Horvat, Katie McKibben, Patrick Lawrence, Kristina Patterson, and Scott High School.

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Highland Park Dam Mitigation Project
Final Report

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1.0 EXECUTIVE SUMMARY

The Highland Park Dam Mitigation Project was commissioned to mitigate the low-head dam on Swan Creek near the South Avenue Bridge, at Highland Park in Toledo, Ohio. The project was funded through a Joyce Foundation Grant to the Partners for Clean Streams (PCS). The project was bid as a design-build contract in August 2007. Construction was completed a year later in August 2008. Although the final design evolved throughout the design and construction process, the overarching goal to improve fish passage over the dam without removing the dam was accomplished.

Highland Park Dam looking upstream before construction.

The objectives of the project, as stated in the Request for Proposals, are outlined below:

A) Restore floodplain function
B) Mitigate the negative effects of a low head dam for aquatic species and public safety
C) Provide an example of how a low head dam can be mitigated onsite without removal
D) Provide a learning experience for officials, dam owners, consultants, academia, etc.
E) Provide safe public access to the creek
F) Improve the aquatic health and water quality

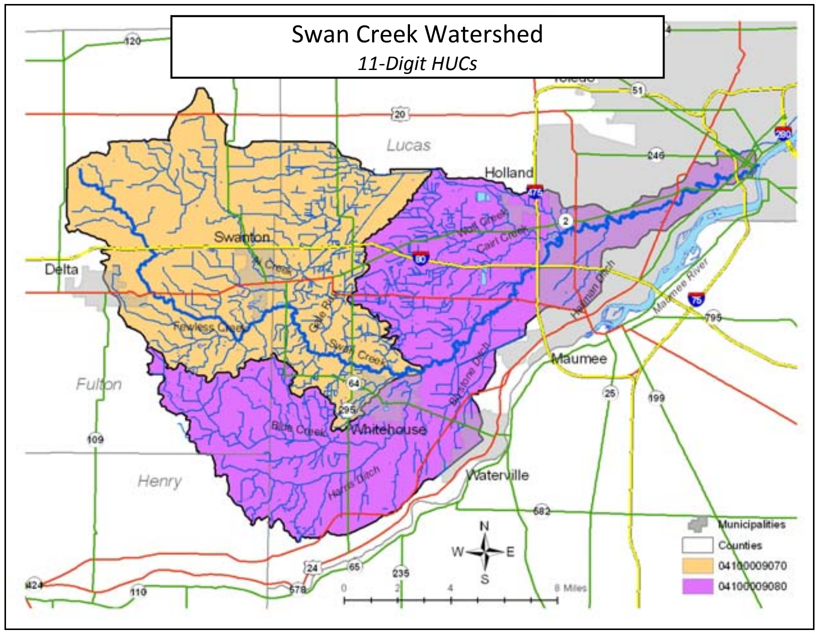
Except for restoring floodplain function, these objectives were met. Due to cost prohibitive and complicated factors, floodplain function was not restored however, two small native plant demonstration areas were established on the west bank of the creek. In-stream construction of the Highland Park Dam Mitigation Project began on August 19, 2008 and was completed on August 28, 2008. Two engineered rock riffles (ERR) were built just downstream of the low-head dam to create “steps” and allow fish passage over the dam during low flow. Approximately 1,900 tons of large stone (18”-30” average diameter) and 600 tons of smaller choke stone (3”-4” average diameter) were used to construct the ERR.

Local plant materials were harvested with the assistance of the Toledo ZooTeens. On August 12-13, 2008, locally native species of willow and dogwood were harvested and then soaked to facilitate growth. The materials were installed throughout the course of construction along the streambank and along the keys for the engineered rock riffles.

An educational workshop was incorporated into this project so that it could serve as a learning tool/model for other areas in similar circumstances. The workshop was held August 25-27, 2008. The workshop included several presentations by team members (PCS, JFNew, US Army Corps of Engineers) as well as hands-on activities including live stake harvesting and planting, and native plant demonstration garden preparation and planting.

2.0 BACKGROUND

2.1 The Watershed



The Swan Creek Watershed is comprised of United States Geological Survey (USGS) Hydrologic Units 04100009 070 and 04100009 080. The drainage area of Swan Creek is 203.9 square miles. Its headwaters rise in Henry, Fulton, and western Lucas counties. Over 200 miles of creeks and ditches drain this watershed. Swan Creek itself is only about 40 miles long. Swan Creek's shallow gradient is similar to the Maumee River with a drop of 2.1 feet per mile (0.04% gradient). The majority of the Swan Creek watershed is located within the Maumee Area of Concern (AOC). The major streams that feed Swan Creek are Ai Creek, Blue Creek, Wolf Creek, and Blystone Ditch.

The Swan Creek watershed can be divided into three major reaches, or parts, based on the dominant stream characteristics within each reach. In the upstream reach from river mile 19 in Monclova Township to the headwaters, or source, the channel is stable, banks are low (15 to 25 feet) with indistinct valleys and floodplains, and the primary land use is agriculture. The middle reach is the area that lies between river miles 19 and 6. Here the creek is actively eroding its channel. The banks are high (35 to 45 feet or more) and unstable and are intermixed with detached floodplains. The major problems in the middle reach are from urbanization, with floodplain filling and destruction of wetland areas.

The Highland Park project site is located in the lower reach of Swan Creek. The lower reach, from river mile 6 (CSX Railroad Bridge) to the mouth in downtown Toledo, is actively silting in its channel. The banks are as high as 35 to 45 feet and are intermixed with floodplain areas. This lower reach is under the seiche effect from the Maumee River and Lake Erie. The level of Lake Erie prevents the lower reach from naturally deepening itself.

The major problem in the lower reach of Swan Creek is extremely poor water quality, due to storm runoff, hydromodification and urban development. This lower reach is neither swimmable nor fishable according to public health standards. Contributing to the pollution are the combined sewer overflows, industrial discharges, storm sewer contamination, and urban storm water runoff which carries fertilizers from lawns and street debris. All of this can and does reach the creek, degrading water quality.

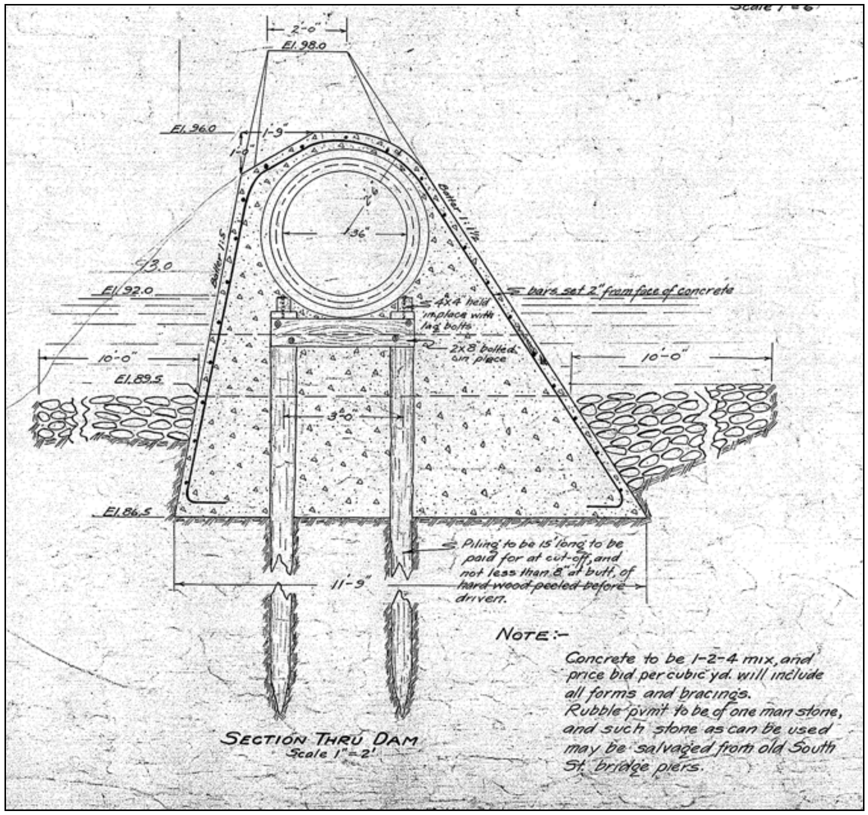
In 2006, Ohio EPA conducted a Total Maximum Daily Load (TMDL) study of the Swan Creek watershed. Samples were collected upstream and downstream of the Highland Park Dam. Data included water chemistry, sediment quality, fish communities and macroinvertebrate communities, as well as riparian habitat quality. The results of this study provide a baseline indication of the health of the stream and the restrictions to fisheries.

Highland Park in Toledo, Ohio and low head dam location

2.2 The Dam

The Highland Park Dam is located on Swan Creek at river mile 4.4, just north (downstream) of the South Avenue Bridge. The low-head dam encases a 36" sewer main. The dam was constructed in circa 1926 specifically for the sewer crossing. Mitigating the impacts of the dam had to be done without removing the dam. A cross-section of the dam and pipe are shown Error! Reference source not found. below. The dam is also believed to be protecting the 3-lane roadway bridge immediately upstream.

Water flowing over the dam created a scour hole immediately downstream of the dam. The combination of the dam height and the scour hole created a barrier to fish passage with a 3 to 4 feet drop in water surface during low stream flow conditions.



Cross-section of original construction plans for Highland Park Dam. (Courtesy of the City of Toledo)

The Highland Park Dam is the furthest downstream dam on the main stem of Swan Creek. It is located within a highly utilized City of Toledo park surrounded by a high density residential area. The successful implementation of the Highland Park Dam Mitigation Project was to restore flow integrity to approximately the lower 11 miles of the main channel.

The Project

The Highland Park Dam Mitigation Project is located in the City of Toledo's Highland Park between the South Avenue bridge and Champion Street bridge, Toledo, Lucas County, Ohio (*Drawing 1 in Attachment A*). The project site is the Highland Park Dam on Swan Creek, a perennial tributary to the Maumee River. Specifically, it is located in Sections 9 and 10 of Township 3 and Range 7 East, of the second principal meridian, on the Toledo (OH, MI) USGS quadrangle.

This project was to effectively eliminate the dam barrier to fish passage and minimizing the safety hazard to fisherman and curious park guests, while improving aquatic and riparian habitat and restoring natural stream function without removing the dam structure. It was also to serve as a demonstration/learning project for others that want to remove low-head dams, but have infrastructure concerns.

The mitigation of the dam involved constructing two large in-stream riffle structures, termed Engineered Rocked Riffles, (ERR), using local quarried stone materials, to ease the elevation change downstream of the dam. The ERR were keyed into the banks using vegetated stone keyways so the structures would not be flanked during high energy events. The ERR were constructed with integrated meandering fish bypass low flow channels. The project also incorporated public access areas so that residents can fish or simply enjoy the stream in a more natural setting; hopefully fostering more concern and care for the natural environment.

Highland Park Dam before construction.

The project evolved during the entire design and construction process. The request for proposals and conceptual design had originally included floodplain re-connection/restoration. The adjacent floodplain was about 2 acres and is already occasionally flooded (several times a year).

A good rule of thumb for any detention facility to have any real hope of mitigating flood impacts or improve water quality is it has to be sized so that it is at least a couple percent of the total contributing area (Wu, et.al., 1996). With approximately 125,000 acres of contributing watershed, there is no cost-effective way that 2 acres (or 0.001% of the watershed area) will have a real impact on either water quantity or quality for Swan Creek. Any significant floodplain enhancements for water quantity or quality control were left out due to budget and time constraints.

2.3 The Team

The Chicago-based Joyce Foundation awarded $5 million in grants to four national and local organizations in a quest to aid the recovery of the 8,316 square mile Maumee watershed, the largest river system in the Great Lakes region. Partners for Clean Streams was proud to be one of the organizations funded through The Joyce Foundation's *Great River – Great Lakes Initiative*.

The Partners for Clean Streams (PCS) was created to assist the Maumee RAP by providing broader funding and project implementation opportunities. Although a new entity was created, the partners, RAP process, and goals for restoration of the Maumee AOC did not change. Together, PCS and the new Maumee RAP Advisory Committee stand as an independent organization to deliver a wide range of programs, projects, and community outreach efforts associated with water quality improvements that have been of long-standing interest to the Maumee RAP community.

Partners for Clean Streams, Inc. is a 501(c)3 non-profit community organization with an interest in supporting local and regional water quality improvements in the metro-Toledo area. They are striving for abundant open space and a high quality natural environment; adequate floodwater storage capacities and flourishing wildlife; stakeholders who take local ownership in their resources; and rivers, streams, and lakes that are clean, clear and safe.

The Highland Park Dam Mitigation Project is one of three projects that are being conducted by PCS through a grant received from The Joyce Foundation. To carry out this project a team of partners, or Project Management Team (PMT), was assembled consisting of representatives from the U.S. Army Corps of Engineers, Ohio EPA, Ohio DNR, City of Toledo, Lucas County, Lucas SWCD, University of Toledo, Toledo Metropolitan Area Council of Governments (TMACOG), and Maumee RAP Advisory Committee. The individual team members are recognized in the Acknowledgements of this report.

The request for proposals for the design-build contract of Highland Park Dam Mitigation Project was released in the end of July 2007. JFNew won the design-build contract for a total amount of $200,000. The JFNew team included engineers and ecologists from JFNew (Ann Arbor, MI), floodplain modeling specialists from TetraTech (Ann Arbor, MI), and landscape architects from Pollock Design Associates (Ann Arbor, MI). JFNew subcontracted with Ecological Restoration (Apollo, PA) for the construction portion of the project.

3.0 DESIGN

3.1 Data Collection and Site Surveys

The JFNew team collected available data from several sources for the Highland Park Dam Mitigation project. The data included site infrastructure details (bridge and dam drawings), topographic maps, soils data, stream and watershed data including the Swan Creek FEMA HEC-2 model and Lucas County flood insurance study (FIS), climatologic data, and digital GIS layers. We also downloaded the historic flow record from the Maumee River USGS gage (station 04193500) at Waterville to compare with flow estimates of Swan Creek.

JFNew conducting an on-site survey during the fall of 2007.

JFNew performed an in-stream cross-section and longitudinal profile survey of about 2,400 feet of Swan Creek in November 2007. The surveyed reach was between the South Avenue Bridge and the Champion Street Bridge. The first cross-section was taken on the upstream side of the South Avenue Bridge (about 50 feet upstream of the dam), and the last cross-section was taken just upstream of the Champion Street Bridge. Cross-sections were spaced approximately 100 to 200 feet apart, with closer spacing between cross-sections at the dam. Cross-sections were taken just upstream and downstream of each of the bridges (including the Highland Park footbridge).

We compiled dimensions of the bridges from field measurements and drawings obtained from the City of Toledo. Although in-stream work was not planned in the downstream portion of the surveyed reach, we included these cross-sections because the Lucas County Flood Insurance Study (FIS) indicates that the Champion Street Bridge plays a role in controlling flood elevations upstream. The survey cross-section locations are shown below.

Surveyed cross-section locations on Swan Creek at Highland Park.

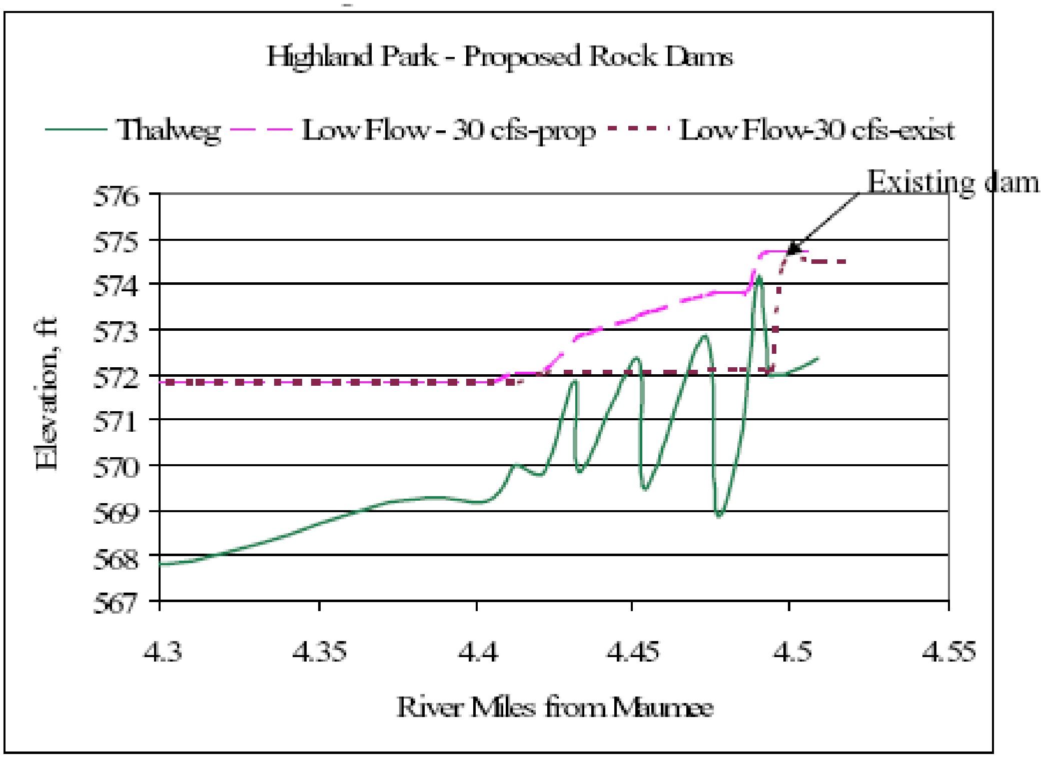
While on-site for the stream survey, JFNew used a velocity meter to measure velocities and flows. We also surveyed site infrastructure including concrete retaining walls and incoming pipes. We looked for high water indicators, such as debris lines, upper limits of bank erosion, changes in bank vegetation, algae lines, water marks on structures, etc. These high water indicators typically identify the ordinary high water (OHW) mark and can be indicative of bankfull flow event. We collected this data as confirmatory evidence of the flow estimation as part of the hydrologic analysis. Lastly, the stream bed material size was also characterized.

A wetland delineation was performed by JFNew on April 4, 2008. One wetland area (approximately 0.2 acres) was found on the west streambank, just upstream of the Highland Park footbridge. This area was partially inundated during the delineation and met all three wetland criteria: vegetation, hydrology and hydric soils. The wetland is dominated by sedge

(*Carex spp*., most FAC, FAC+ or wetter), sycamore (*Platanus occidentalis*, FACW-), and moneywort (*Lysimachia nummularia*, OBL). Positive wetland hydrology was indicated by drainage patterns and soil pit hydrology at 14 inches below the soil surface. The soils displayed a matrix color of 10 YR 4/1 to 14 inches and 10 YR 4/1 with 10 YR 4/4 redoximorphic concentrations to 18 inches with sandy clay and sandy loam textures, respectively. The wetland is likely to be considered jurisdictional by the Corps due to its connection with Swan Creek. See *Wetland Delineation Report in Appendix B* for more details.

3.2 Hydraulic and Hydrologic Modeling

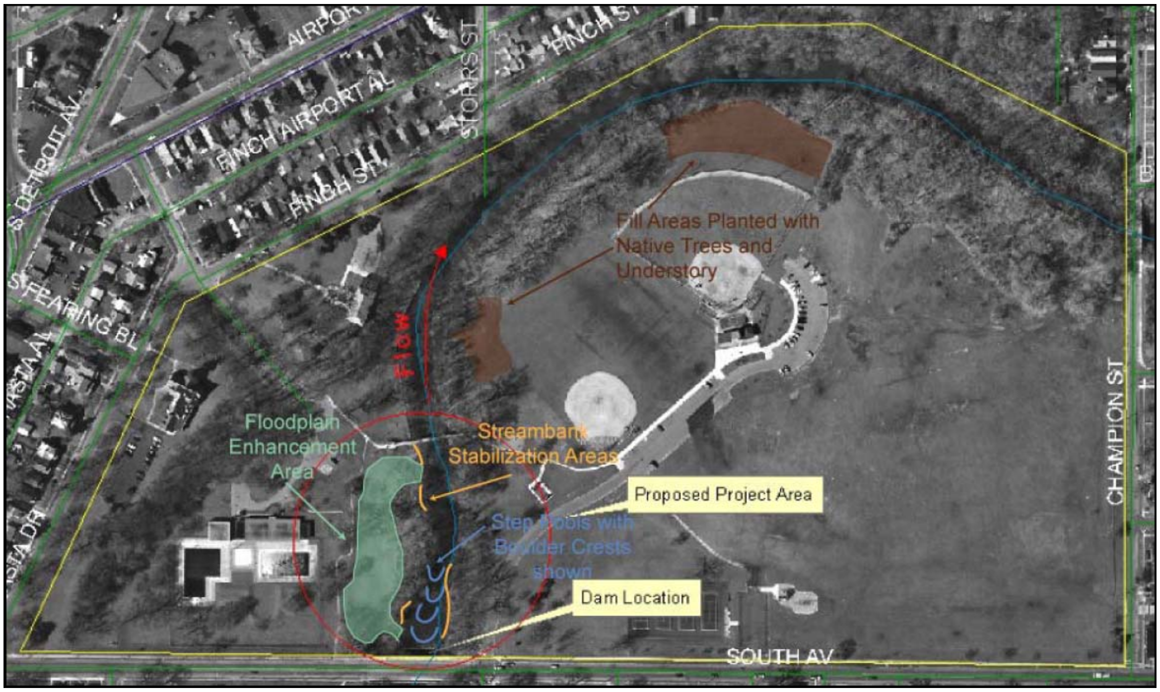
A rigorous hydrologic and hydraulic model evaluation was completed for the study reach of Swan Creek as a part of the Highland Park Dam Mitigation project. The existing HEC-2 model (1972) was obtained from FEMA. Because it arrived in print format only, it had to be re-entered into the HEC-2 program. The surveyed cross-sections were then incorporated into the existing model. Flow data collected during the stream survey work was used to calibrate the existing conditions model to low flow conditions. An early version of the proposed design (4 rock ramp structures) was used in the proposed conditions model. The proposed structures resulted in no significant changes in the flood elevations. See the *Hydraulic Modeling Report in Appendix C* for more details.



3.3 Design Alternatives

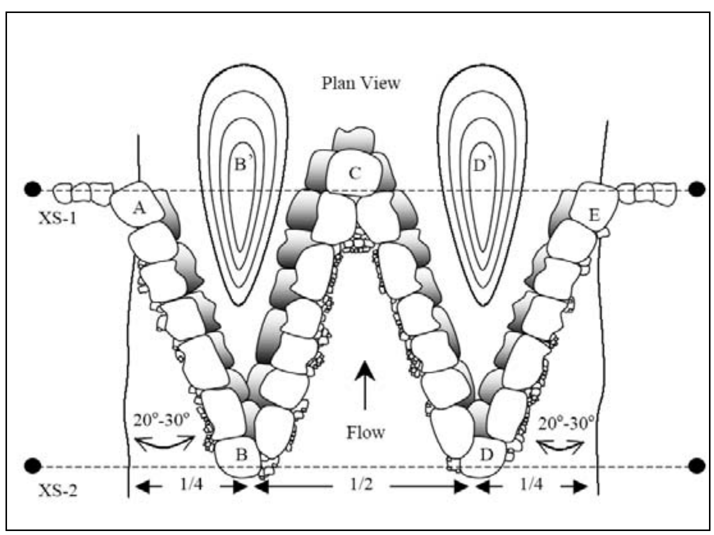
The initial concept of this project envisioned construction of a series of irregularly shaped step-pool drop structures starting from the dam and extending several hundred feet downstream to help ease the drop over the dam. Each step-pool would provide a drop of six to nine inches.

Boulders would be placed in a curving alignment with pools two to three feet deep created between each boulder crest. The pools afford fish some refuge as they moved up the steps. These structures would be sized to withstand the 100-year flood event. However, it was felt these would be expensive to build and might not provide deep enough flow over each step to facilitate fish passage.



Initial conceptual design with step pool drop structures.

As we moved into the design process, we next considered the use of W-weirs. A W-weir is one of a suite of stream restoration structures employed in the natural channel design school of stream restoration. The design of the W-weir (W as looking in the downstream direction) was initially developed to resemble bedrock control channels on larger rivers. The objectives of the structures were to provide grade control, enhance fish habitat, and stabilize stream banks. When examined closely, the structures appear "ramp-like" and are designed to dissipate stream energy as the stream moves up the slope as it flows downstream. W-weir design focuses the majority of low flow over a small portion of the ramp,



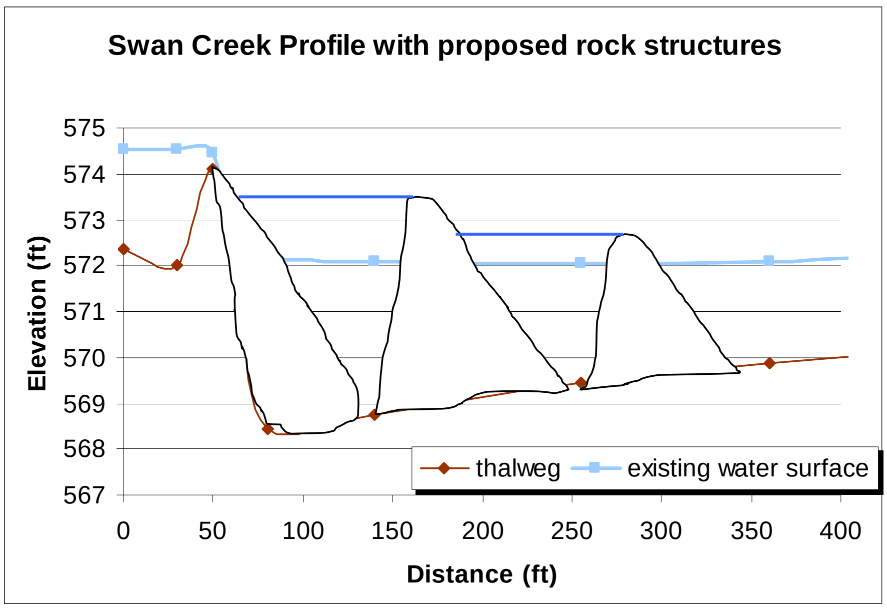
W-weir Plan View (Rosgen, 1996)

compensating for the potential passage problems identified with the step-pool design.

The use of W-weirs for the Highland Park Dam Mitigation project was rejected for several reasons. These included: 1) W-weirs are designed to dissipate energy with a ramp up, which creates an overall larger head drop; 2) W-weirs are not designed to be used in series. A series of W-weirs would be very complicated and time consuming to construct and would be spread over a long stream reach (minimum 200 ft) in order to provide several small elevation drops for fish passage; and 3) Complicated construction with tight slope and angle tolerances.

3.4 Selected Alternative

After the W-weir design was rejected, we investigated the use of a series of engineered rock riffles or rock ramp (ERR) structures. When compared to the W-weirs, the ERR are easier to use in series, much less complicated to construct, and provide fish passage even for species without leaping ability. Initially a series of four rock ramp structures were planned to step down the approximately 18" drop in water surface elevation at low flows. The four structures would extend downstream from the dam to just upstream of the footbridge, necessitating removal of parts of the existing retaining wall to key in the ramps. Because the cost for the amount of rock needed for four structures would take most of the construction budget, the design was changed to three rock ramp structures, each with a 6" -7" drop in water surface elevation.



The ERR structures were designed following the Rock Ramp Design Guidelines (Mooney et. al., 2007) published by the U.S. Department of the Interior's Bureau of Reclamation. The guidelines include several equations used to design the ramps and to size the stone, the stone filter layer, and the low flow channel. Multiple sizing criteria from the manual were used to create a somewhat redundant, but fairly robust design methodology. The stone sizing calculations are based on the 100-year event flow (9,000 cfs), while the low-flow meandering channel sizing is based on a low flow of 40 cfs. The low-flow channel calculations incorporate interstitial flow, depth-based roughness, and velocity to ensure that flow conditions are suitable for fish passage. The rock ramp design will be stable up to the 100-year flood event, and will have sufficient flow in the low flow channel to allow passage of fish with body length greater than 4 inches.

The design process also included consultation with Dave Derrick, a research hydraulic engineer with the U.S Army Corps of Engineers' Coastal and Hydraulics Laboratory in Vicksburg, Mississippi. To ensure that the rock structures would not adversely affect flood elevations, the preliminary design was modeled using HEC-2.

The ERR were designed to have a D_{50} (median size) of 24-inches and with an underlying stone filter with a D_{50} of 2.5 inches. The rock ramps were designed to be keyed into the banks and into the streambed to provide stability during high flows. Each rock ramp was designed to drop the pool water surface elevation by 0.5 feet. The low flow sinuous notch channel was designed to be 0.75 feet deep and 10 to 20 feet wide (notch top width is different for each rock ramp), with one channel on each ramp. These low flow notches are designed to allow warm-water fish with a body length of 4 inches or more to pass during low flow (approximately 40 cubic feet per second).

3.5 Permits

JFNew prepared all necessary permit applications, including a design basis and a plan set sufficient for permitting and construction. The following permits were obtained: U.S. Army Corps of Engineers Nationwide Permit 27 and the City of Toledo Floodplain Hazard Development permit (see *Appendix D* for submitted applications). Because the Ohio EPA has issued Clean Water Act Section 401 Certifications for Nationwide Permits, an individual 401 Water Quality Certification permit from Ohio EPA was not required.

Silt fences (black in foreground) were installed on land and silt curtains (yellow in background) in the water to control sediment leaving the construction site.

An Ohio EPA Storm Water Permit was not necessary because the total construction area to be disturbed was approximately 0.85 acres, less than the 1 acre threshold. Although a permit was not required, storm water controls were used on-site to reduce the amount of sediment that might reach the stream or that might move downstream during construction.

Silt curtains were installed downstream of the second structure.

4.0 CONSTRUCTION

The construction portion of the project was subcontracted through an invitation to bid process. JFNew sent out three bid invitations to local contractors in the Toledo area. Initially, only one bid was received. The quoted price of $210,000 was higher than the design-build portion of the project budget which as $200,000. Per Dave Derrick's (project consultant from USACE) suggestion, JFNew invited Ecological Restoration (based in Apollo, PA) to bid. Their bid came in at $155,000. Although this price was still higher than the original construction budget, it was significantly lower than the first bid. Ecological Restoration's qualifications also demonstrated a significant amount of experience with in-stream work; more than any of the other solicited firms. Ecological Restoration's bid was accepted.

Live mussels prepared for relocation.

4.1 Mussel Relocation

The first of several unplanned modifications to this project came when mussels were identified on-site. This required getting permission from the Ohio Department of Natural Resources (ODNR) and US Fish and Wildlife Service (US FWS) before any construction. Since there was not likely to be federally endangered species at this site, a notification of US FWS was all that was required. Permission from ODNR entailed hiring a state recognized malacologist (mussel expert) to conduct an official survey of the site, relocate any mussels found, and then two years later conduct a follow-up survivability survey of the relocated mussels.

Prior to an official survey being conducted, it was strongly believed that mussels were located at this site, therefore a suitable site for relocation needed to be determined. The best relocation site was determined to be another small dam located upstream of the Highland Park Dam on Swan Creek. Permission was obtained from the property owners with a contract allowing for relocation and future monitoring of the population.

Matt Horvat helped by tagging each mussel for monitoring purposes.

On August 10, 2008, Jeff Grabarkiewicz and Phil Mathias conducted survey and translocation activities at the Highland Park Dam site. A total of 69 live unionids were collected and relocated, with six species found live and an additional six species represented by shell only (12 total species). It should be noted that none of the species found were state or federally listed as threatened or endangered.

Species Relocated	Number Live	Min (mm)	Max (mm)
fatmucket (*Lampsilis siliquoidea*)	4	45.6	70.3
white heelsplitter (*Lasmigona c. complanata*)	46	38.9	105.3
fragile papershell (*Leptodea fragilis*)	2	47.7	78.3
pink heelsplitter (*Potamilus alatus*)	12	81.0	122.9
giant floater (*Pyganodon grandis*)	2	68.6	69.4
creeper (*Strophitus undulatus*)	3	53.6	61.9

The live mussels were identified, measured, and tagged with a unique tracking number. Shellfish tags were adhered to both valves using instant KRAZY glue gel. After allowing a short time for the glue to dry, tagged unionids were deposited in mesh bags and placed in Swan Creek until translocation. When survey and tagging activities were complete, all mussels were transported via an aerated cooler to the new site.

Unionids were hand placed at the relocation site using a view-bucket and wetsuit. Photos were taken to document the exact area of translocation and a reference measurement from the dam was recorded. These details will be necessary to evaluate survivorship and health of the relocated mussels with an exhaustive sampling survey that will be conducted approximately two years after relocation. All recovered individuals will be measured with a metric caliper to the nearest tenth of a millimeter. Recovery rates will then be calculated and an analysis of overall health will be assessed by comparing shell lengths at the time of translocation and the time of sampling. Positive growth is generally used as an indicator of health.

4.2 Harvesting

One cost saving effort utilized on this project was the local harvesting of plant materials. By harvesting locally native species we were able to save money on the purchase of plants, install more mature plants, and assist local conservation organizations in maintaining their properties.

Harvesting of live stakes from the Oak Openings Metropark.

The Nature Conservancy provided us access to the Kitty Todd Preserve to harvest plant materials from an area that was to be managed for prairie restoration. The management plan called for the removal of all woody growth and had been mowed about five years ago. The resulting growth in this wet prairie area lead to a relatively thick stand of red-osier dogwood (*Cornus sericia*), button-bush (*Cephalanthus occidentalis*), sandbar and heart-leaved willows (*Salix exigua,* and *S. eriocephala*), and eastern cottonwood (*Populus deltoides*). All plant materials that were harvested were used on the project. Some species (in this case eastern cottonwood) are typically not used as live stakes, but we decided to try them since it was available. The Kitty Todd Preserve site was used for harvesting live stakes with assistance from the Toledo ZooTeens on August 12, 2008 and by the workshop attendees on August 26, 2008.

Matt Horvat bundles live stakes with Toledo ZooTeen assistance.

The Toledo Area Metroparks allowed us to harvest along one of the improved trails in the Oak Openings Metropark with more Toledo ZooTeens volunteers on August 13, 2008. At this site several willows (*Salix discolor, S. exigua,* and *S. eriocephala*), dogwoods (*Cornus racemosa, C. amomum*), eastern cottonwood (*Populus deltoides*) and buttonbush (*Cephalanthus occidentalis*) were again harvested.

When harvesting at each site, the live stakes were cut at the base and hauled to an open area for "processing". Once in the open area the stakes had most of their leaves and any small branches removed with hand pruners. They were cut to a length of approximately 5-7 feet long and placed in bundles of approximately 25-35 stakes. Trimming and cutting to length meets two needs. The stakes are easier to handle when bundling, transporting, and installing, and the reduction of plant mass takes some of the biological stress off of the stake when installed. Over 40 bundles were collected over 2 days with the ZooTeens and 23 bundles were collected by the workshop attendees.

Live stakes were soaked to promote growth.

Immediately after each of the two harvesting events in mid-August, the bundles were taken to a secure stream location and soaked for two weeks. Hydrating the stakes helps to increase their chances of survival and rooting once installed on-site. The project was done in late August, a typical dry time of year, so it was important to do anything to help the stakes survive. The materials harvested by the workshop attendees were also soaked but for a less than one day, as they were installed fairly soon after harvesting. Initial results have been promising, but the next growing season will determine how many and which species showed the best survival.

4.3 In-Stream Structures

Approximately one year prior to the beginning of the project, local stone quarries were contacted. Several site visits were made in an effort to select a source for appropriate stone for the project. It was determined that the Ford Street Quarry operated by Shelley Company was the most appropriate source as it was nearby and could produce the size and quantity of stone this project required. Six hundred tons of choke stone (3"-4"average diameter) and 1900 tons of type A rip-rap stone (18"-30" average diameter) was specifically produced for use by this project. We found it is important to set up a supply for any material needed for a project since this size of stone is typically not produced on a daily basis. Most of the local quarries crush their stone into gravel for use on traditional road and construction projects. How the large stone will be trucked also needs to be considered as well, since most trucks have aluminum beds and cannot handle large stone. Trucks with steel bodied beds are needed to transport the large material.

Actual construction began during the week of August 18, 2008 with site preparation. It was necessary to remove three trees (Crabapple (*Malus sp*.), Elderberry (*Sanbucus canadensis*), and Catalpa (*Catalpa speciosa*). The trees had to be removed to construct the temporary haul roads and access points for the project to allow equipment and materials to reach the creek. Federal laws involving US Fish and Wildlife Service came into play due to the potential disruption of Indiana Bat habitat. Once it was determined that there would be no detrimental impact, the trees were allowed to be removed.

An early load of large stone being delivered.

Several loads of fines and gravel were first delivered to create the temporary haul roads leading from the parking lot to the two access points for rock ramp construction. The haul roads were later reshaped to be walking paths between the sidewalk and the river. As rock arrived from the quarry, it was dumped in the channel from the west bank. The excavator, in this case a Komatsu PC200, was used to distribute the material across the stream.

It quickly became evident that it was going to take much more stone than originally estimated to build each structure. This is when another unplanned modification occurred. The team decided that two structures should be built instead of three, each structure with a 9" drop in water surface elevation, rather than the three structures with 6" drops. The second structure would be placed slightly downstream from the original location of the middle structure. It was moved as far downstream as possible without interfering with an existing storm sewer pipe protruding from the east bank.

Heavy equipment was used to move the rock across the stream and to compact it.

As more stone was delivered and dumped, the excavator worked from west to east distributing the stone to create the rock ramps. There is typically a bedding layer of smaller stone placed in the truck along with the armor stone to prevent punctures in the truck bed during loading and unloading. This bedding layer of unsorted smaller material was incorporated into the ramp as construction preceded helping to lock the material in place. The excavator worked to

Rocks were dumped on the west bank and pushed across to form the second structure.

compact and lock-in the stone as it worked. Materials were hammered with the bucket when necessary or just driven over during construction pressing the material well into the bed of the stream. The upstream structure was tied in to an existing concrete wall on the west bank and feathered into the undercut on the eastern bank. A constructed key for the rock ramp was not necessary as the dam was already serving that purpose.

The second downstream structure was created in much the same way. Material was placed from west to east; however more substantial keys were constructed. The soil in the bank was removed creating a notch that extended from slightly below the streambed to approximately 20 feet landward and about 10 feet wide. The key trench was backfilled with some of the larger pieces of the Type A Armor stone and compacted as it was placed. Native soil was also placed in with the stone to fill any voids created. During this process live stakes were also installed on the downstream side of the key reaching to the full depth of the key trench.

The large stone of the ramps were choked with smaller choke stone/gravel (5" diameter average). Placing and working this gravel into the voids of the larger stone helped to lock the stone together to prevent movement during storm events and also to slow infiltration of water through the structures during low water. The effects of the choke stone were easy to see as more water flowed over the structure instead of through it throughout the choking process.

During construction, it was decided that two low-flow channels would be constructed on each rock ramp rather than the planned single channel. This would allow for a "backup" channel if one were to become closed off with debris. The widths and depths of the channels were adjusted in the field (with the help of a few quick calculations) to try to maintain a velocity in each of the twin low-flow channels that would still allow passage of larger than 4" long fish.

The live stakes that were previously harvested and soaked were incorporated into the project along the waterline near the structures during construction, as well as any accessible areas on the bank between the two structures. The live stakes were installed into the keys before they were backfilled. The key areas were also planted with a mixture of native seed and covered with a jute erosion control material.

4.4 Storm Water Drainage Pipe

Another unplanned issue arose during the early stages of the in-stream construction. A submerged storm water outfall was located on the western retaining wall of the dam. This pipe was overlooked during design as it was partially blocked by a sediment bar that had formed in

Unknown discharge entering Swan Creek through submerged storm pipe.

front of it. During the first day of construction, the City of Toledo investigated the submerged storm sewer line, and potential illicit discharge, set in the western retaining wall of the dam. The City of Toledo Dept of Public Utilities was called to investigate whether a break or a cross-connection was causing the discharge.

Concurrently, a sinkhole was found in the wooded area to the west of the stream. The City of Toledo found that a broken sewer line had caused the sink hole and it had no connection to the storm sewer line discovered previously. The broken sewer line was repaired immediately and the sinkhole filled.

In order to avoid covering the storm water pipe outlet in the dam wing wall with the rock ramp, a manhole structure and pipe were connected to the outlet. A second pipe was extended from the manhole that would outlet to the stream. The rock ramp was then constructed around the manhole and over the pipe.

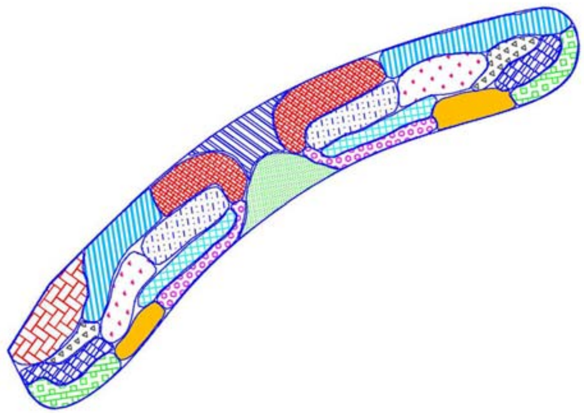
New manhole and storm sewer pipe being connected to an existing storm sewer in the dam's west retaining wall.

4.5 Native Gardens

In addition to the in-stream work, native plant demonstration gardens were planted on the west floodplain. Although the original plan called for one large garden area, it was split into two smaller gardens due to site constraints, including the inability to cut down a tree that may provide Indiana bat habitat and a sinkhole that was caused by a broken sewer pipe in the nearby wooded area.

The turf grass on the native plant garden sites was scraped off with the excavator. Approximately 10 cubic yards of compost was mixed into the top 6"-8" of soil to prepare the planting bed. Volunteers from the workshop spread mulch over the surface of the two planting gardens, and then laid erosion control blanket over the area, keying it into trenches on the perimeter of each garden. Over the course of two days, native plant plugs were installed through the blanket and were watered. After planting was finished, additional mulch was scattered over top of the erosion control blanket for improved aesthetics and to serve as a deterrent to keep vandals from seeing and therefore pulling the blanket up.

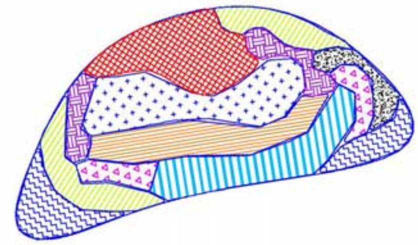
Native plant plugs being planted in the large native garden.



Large Planting Area - West

PLANTING LEGEND

Botanical Name	Common Name	# Plugs
Asclepias tuberosa	Butterfly Milkweed	76
Asclepias syriaca	Common Milkweed	76
Aster oolentangiensis	Sky-Blue Aster	114
Aster levis	Smooth Blue Aster	76
Baptisia lactea	White Wild Indigo	76
Coreopsis lanceolata	Sand Coreopsis	76
Echinacea purpurea	Purple Coneflower	76
Helianthus occidentalis	Western Sunflower	38
Parthenium integrifolium	Wild Quinine	76
Ratibida pinnata	Yellow Coneflower	76
Schizachyrium scoparium	Little Bluestem	76
Solidago speciosa	Showy Goldenrod	76
Verbena stricta	Hoary Vervain	114



Small Planting Area - East

PLANTING LEGEND

Botanical Name	Common Name	# Plugs
Coreopsis tripteris	Tall Coreopsis	114
Elymus canadensis	Canada Wild Rye	114
Panicum virgatum	Switch Grass	114
Penstemon digitalis	Foxglove Beard Tongue	76
Rudbeckia hirta	Black-eyed Susan	76
Schizachyrium scoparium	Little Bluestem	76
Solidago rigida	Stiff Goldenrod	76
Sorghastrum nutans	Indian Grass	114
Veronioncastrum virginicum	Culver's Root	76

Approximately 1800 plugs of twenty species were planted in the two gardens. The plants that were installed are listed with the diagrams above.

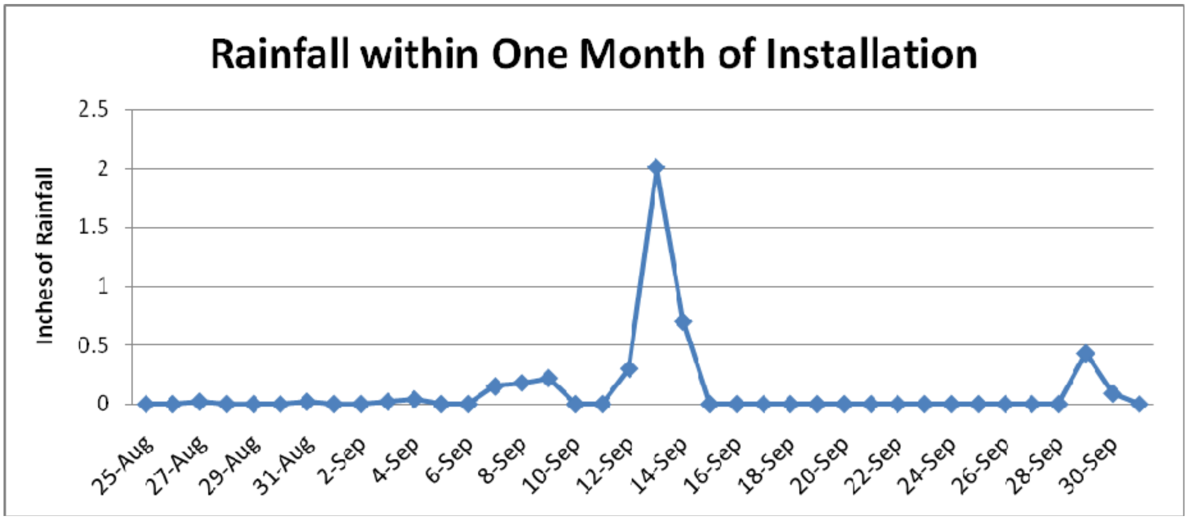
5.0 POST-CONSTRUCTION

5.1 Site Visits

The summer of 2008 in Northwest Ohio started out wet, but it did not take long for drought conditions to develop during the peak of the growing season. Between mid-July and mid-September, the area recorded less than 2 inches of rainfall and was officially considered in a moderate drought. Toledo had received only 44% of normal precipitation (2.64 inches observed vs. 6.03 inches normal). These conditions were very helpful when it came to constructing this project; however, things would quickly change as the remnants of Hurricanes Gustav and Ike made their way into the Midwest.

Wood, leaves, and debris caught in the upstream structure, but they did not affect the movement of water through the low flow channels.

It was expected that the structures would have an opportunity to “settle” before being challenged by Mother Nature. However, within a month of completion there were two smaller and one significant rain event that challenged the structures. The largest was only two weeks after construction. A “drought-buster” rainfall fell on September 13 and Toledo recorded 2.01 inches of rain that day. There was enough rainfall across the area to replenish ground water and nearly remove the drought status.



The structures were tested, but they held and performed as designed. Some wood and debris was caught by the structures, but it did not damage or reduced their function. The debris has since moved downstream naturally without intervention or clearing.

Numerous site visits have been made since construction was completed. Samples of these visits are shown below.

Pre-Construction *(low flow conditions)*

Upstream site looking west

Downstream site from upstream

September 5 *(7 days after install) (low flow conditions)*

Upstream structure looking west

Downstream structure from upstream

September 13 *(15 days after install) (high flow conditions)*

Upstream structure looking west

Downstream structure from upstream

September 18 *(18 days after install) (coming down from high flow conditions)*

PHOTO NOT AVAILABLE

Upstream structure looking west

Downstream structure from upstream

November 5 *(10 weeks after install) (leaves, debris and moderate flow conditions)*

Upstream structure looking west

Downstream structure from upstream

January 27, 2009 *(21 weeks after install) (low flow, ice and snow conditions)*

Upstream structure looking west

Downstream structure from upstream

5.2 Early Results

The early results of this project are very promising. As illustrated above, the structures have held up to flood conditions, woody debris and leaves, as well as snow and ice. The preliminary results from the live stakes are also looking good. Within two weeks there were stakes with new leaves on them. The local harvesting of plants and soaking to facilitate growth seems to have worked. We will need at least one growing season to see if the stakes have actually rooted and established themselves.

A cottonwood stake 2 weeks after planting.

Willow stakes 2 weeks after planting.

Some early evaluations of conditions in the stream are also available because of some local high school students. Students involved in the Student Watershed Watch (SWW) (a program sponsored by the Toledo Metropolitan Area Council of Governments) collected samples at our project site. The SWW is a program that involves upper elementary, junior high and high school students in a two-phase educational program that includes water quality sampling and analysis, as well as the public reporting of results. The program provides an opportunity for hundreds of students each year to participate in real life scientific investigations and problem solving.

In 2008 the SWW program was expanded to work with The University of Toledo Lake Erie Center (UT LEC). The UT LEC works to links the environmental science learning community by linking graduate student watershed research projects with the SWW program. Their projects center on the environmental study of urbanized and agricultural habitats to

Students are filmed by local media while sampling at Highland Park.

investigate multiple stressors and major ecological community change. Graduate students work to exchange their knowledge and research experience through high school classroom and field exercises.

Students scuff the bottom to "kick-up" macro-invertebrates for collection.

Six weeks after the construction was completed on the Highland Park Dam Mitigation Project, Jahnine Blosser's class at Scott High School, in conjunction with UT doctoral student Todd Crail, collected samples to compare the macroinvertebrate community on two riffles: 1) the new upstream riffle structure (former dam site), and 2) an existing riffle (downstream of the footbridge) that existed before construction.

The students measured the quality of water at each riffle in a series of physical and chemical tests, and sampled macroinvertebrates as a biological index. In the new upstream riffle they scuffed their feet upstream of a benthic seine for one minute and found two orders of macroinvertebrates. This gave them a Steam Quality Measurement (SQM) score of 4 (Poor). In the existing downstream riffle they repeated the method and found six orders of macroinvertebrates. This gave us an SQM score of 17 (Good).

Macroinvertebrates found on the Existing Riffle	
Common Name	**Order**
Cranefly larva	Diptera
Dragonfly larva	Odonata
Clam/mussel	Bivalva
Midge larva	Diptera
Isopod/Sowbug	Isopoda
Gilled snail	Gastropoda
Caddisfly larva	Trichoptera
Leech	Class Hirudinea

Macroinvertebrates found on the New Riffle	
Common Name	**Order**
Midge larva	Diptera
Caddisfly larva	Trichoptera

The students also made note of the fish that were collected in the seines. They found 13 species in 5 families shown in the table below.

Common Name	Family	Species
Emerald shiner	Cyprinidae	*Notropis atherinoides*
Spottail shiner	Cyprinidae	*Notropis hudsonius*
Bluntnose minnow	Cyprinidae	*Pimephales notatus*
White sucker	Catostomidae	*Catostomus commersonii*
Pumpkinseed sunfish	Centrachidae	*Lepomis gibbosus*
Orangespot sunfish	Centrachidae	*Lepomis humilus*
Bluegill sunfish	Centrachidae	*Lepomis macrochirus*
Largemouth bass	Centrachidae	*Micropterus salmoides*
Greenside darter	Percidae	*Etheostoma blennoides*
Johnny darter	Percidae	*Etheostoma nigrum*
Yellow perch	Percidae	*Perca flavescens*
Logperch darter	Percidae	*Percina caprodes*
Round goby	Gobidae	*Apollonia melanostoma*

At the conclusion of the testing, water quality results were the same for both riffles. However, they did not find as many macroinvertebrates in the upstream riffle (new) as the downstream riffle (old). The students hypothesized that the difference in the macroinvertebrate scores was related to the age of the riffles, not water quality.

Scott High School students conducting water quality tests.

They found it surprising that any macroinvertebrates were found on the new riffle, since it was only six weeks old. This may show that downstream drift of larva may be important to colonization for some species. These students intend to sample this site at least one more time during the 2008-09 school year.

The Ohio EPA sampled up and downstream of the dam site in 2006 as a part of the Total Maximum Daily Load (TMDL) sampling program. They plan to re-sample the site with electro-fishing and macroinvertebrate surveys both upstream and downstream of the dam (at the same locations assessed in 2006). These surveys have not yet been scheduled, but are likely to occur in the summer of 2010. This should allow adequate time for system recovery before a formal re-assessment of the site is done.

6.0 WORKSHOP

6.1 Description

An educational workshop was incorporated into Highland Park Dam Mitigation project so that it could serve as a learning tool/model for other areas with similar situations. The workshop was held August 25-27, 2008. A total of 24 workshop attendees came from as far away as Manitoba, Canada and South Dakota. Nearly half of the attendees were from outside the Toledo area.

The workshop included several presentations by Project Management Team (PMT) members (PCS, JFNew, USACE) as well as hands-on activities including live stake harvesting and planting, and native plant garden preparation and planting. The presentations included primers on hydrology and fluvial geomorphology, as well as stream restoration methodologies and case studies from dam removals and rock riffle installations.

Dave Hails, Ecological Restoration Inc, explains the construction that is occurring on site to the workshop attendees.

Workshop attendees harvest live stakes to plant at the Highland Park Dam site.

The workshop also included site visits to both the Highland Park Dam site and the Ottawa Hills/ Secor Road Dam site. The Ottawa Hills/Secor Road Dam project was another recent dam decommissioning project conducted by TMACOG with funding through US EPA's Clean Water Act 319(h) Nonpoint Source Program. These two sites demonstrated two different options for low-head dam restoration: removal versus mitigation. The Ottawa Hills/Secor Road Dam was removed in November 2007. The concrete from the dam was crushed in place to fill the scour hole and create a riffle. Streambank stabilization and enhancement efforts on this site occurred concurrently with the Highland Park Dam project construction, so that workshop attendees could experience two different approaches to a stream restoration.

Dave Derrick, US Army Corps of Engineers, explains rock sizing to attendees.

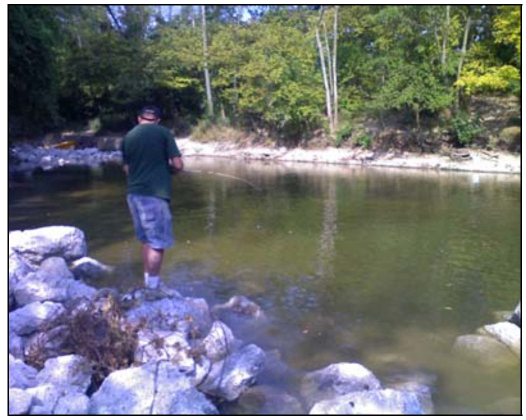
7.0 PUBLIC FEEDBACK AND INFORMATION

7.1 Local Communication and Media Coverage

A couple months prior to construction, Matt Horvat, as Project Leader, attended the Highland Heights Neighborhood meeting on June 12, 2008. Attendees at the meeting were locals from the area. Matt shared with them the focus of The Joyce Foundation's *Great River – Great Lakes Initiative*, the grant given to PCS and the specifics on the Highland Park Dam Mitigation Project.

The group talked about how many kids play in the creek in the area and the safety risks and concerns because of the dam. They also mentioned that there are a lot of people that fish in the area. Matt discussed the project and explained that the dam could not be removed because it encases a major sanitary sewer line.

The group talked about how this project would remove of the safety hazard of the low head dam. Matt provided details of the project including how the rock ramps would be built, where they materials would be placed, and the benefits of the project were discussed. He explained that the project would including creating several natural-looking rock ramp structures across the creek to ease the transition of water elevation from the dam to downstream levels. The group was quite happy with the project as explained, and that anyone actually cared enough to do environmental work in their neighborhood.



Local fisherman couldn't wait until the project was complete to try their luck from the new structures.

This positive response from the neighbors was again shown throughout the two weeks that construction activities were occurring. Several local residents and fishermen stopped by the site and showed excitement in what was going on. Many people asked questions about the project and its goals. A few people were skeptical, however most showed appreciation that something was being done to improve the stream and their immediate environment. A couple of residents even pitched in to help plant and water the native plants.

Some of the comments from neighbors who visited the site include:
Mike Berry was excited to see the project. He said, "It's about time. I've fished here all my life." He caught a steelhead and northern pike under the bridge, bluegill, catfish and white bass and largemouth bass. "I think the walleye may come up here and spawn."

Rich Young and Mike Spyehalski said, ". . . white bass and walleye never used to come here and now they do but the only fish we have seen come over the dam are the white suckers. Now everything can make it."

Several newspaper articles and television stories were run regarding this project, before the construction, as well as during and after. Three of the four local television station ran stories during the two weeks of construction. Local NBS affiliate, WNWO-TV Channel 24, actually did on-site filming during construction to air in their evening newscast. WTOL-TV (CBS-Channel 11) filmed Scott High School when they were on-site collecting samples for the Student Watershed Watch.

Toledo Blade Columnist, Steve Pollick, canoed Swan Creek with PCS in late June 2008. He was able to see first-hand conditions of the creek. He came out to visit the Highland Park Dam site after construction. Based on his observations, on October 7, 2008 he published an article titled *Division of Wildlife to Stock Rainbow Trout in Local Waters,* that included information on the Highland Park Dam Mitigation project. The article read, *". . . anglers who are wondering about the impact of a fish-ladder, dam-mitigation project done in August at Highland Park might heed observations by angler John Jokinen. He landed a smallmouth bass there on a recent trip and watched another angler catch, of all things, a yellow perch. 'It was something different,' Jokinen said of the perch. 'I haven't seen that in a while down there.' Other anglers have watched steelhead threading their way upstream above the old dam."*

7.2 Results Sharing and Presentations

The dissemination of information related to this project is very important to The Joyce Foundation and the Partners for Clean Streams. Several Project Management Team members, as well as PCS, have taken or plan to take opportunities to share information about the Highland Park Dam Mitigation Project. These are highlighted below by organization.

Scott Dierks presenting at the Dam Mitigation Workshop.

Scott Dierks from JFNew made a pre-construction presentation regarding this project at the American Ecological Engineering Society (AEES) Conference in Blacksburg, Virginia (June 11-14, 2008). He also did a poster presentation at the Stewardship Network Conference - The Science, Practice and Art of Restoring Native Ecosystems in East Lansing, Michigan (January 23-24, 2008).

Dave Derrick presents on a stream restoration project.

Since the construction of the project Dave Derrick, Research Hydraulic Engineer with the US Army Corps of Engineers, has incorporated this project into his stream restoration presentations. Dave presents this lecture to 500 to 800 people each year. He has also posted it as a stand-alone case study PowerPoint presentation on his FTP site, which is accessed by fellow professionals several hundred times a year. Dave plans to come back to Toledo for a follow-up workshop during the summer of 2009, where the Highland Park Dam Mitigation Project will be highlighted.

After submitting an abstract for consideration, Patekka Bannister with the City of Toledo Division of Environmental Services was selected to make a presentation at the Ohio Storm Water Conference on May 14-15, 2009 in Mason, Ohio.

This Highland Park Dam Mitigation Project has been included with the rest of PCS's Joyce Foundation funded projects in at least 5 presentations that Kristina Patterson, Executive Director, gave to community groups in 2008. It was also featured at the Partners for Clean Streams Annual General meeting in December 2008. The Partners for Clean Streams will be sharing detailed information on all three of its Joyce Foundation projects; along with the other Joyce Foundation funded projects, at the International Association of Great Lakes Researchers Conference in May 18-22, 2009. The PCS also intends to present this project at other local and regional conferences throughout 2009.

8.0 CONCLUSION

8.1 Lessons Learned

This project almost succeeded in completely meeting the original objectives for the original budget. The objectives for this project were met with the exception of restoring floodplain function. However, the actual project costs of the design-build contract were $227,000, which exceeded the original budget by more than 10%. The Project Management Team believes this is mostly due to the actual construction costs exceeding the original budget. In fact, without the assistance of a very experienced construction contractor, actual construction costs would likely have been even higher.

A number of lessons were learned during this project. They include:

- An experienced stream restoration contractor can help lower construction costs, can provide critical, realistic appraisal of design and construction methods and is particularly important if the project is the "first of its kind" for the region.

- This kind of project lends itself well to the design-build process, particularly for providing flexibility during construction.

- Establish formal, explicit chain of command for field changes. Having multiple designers on site during construction is not always a straightforward benefit.

- Be careful when planning construction access points – dead trees can be as valuable as live trees. For instance, the Indiana Bat (an endangered, federally protected animal) prefers dead and dying trees for habitat.

- Investigate the location of existing infrastructure very carefully (redundant searches, run down every detail). Never assume anyone else will do it for you.

- Spend time and money up front with very detailed site surveys.

- Plan carefully for stone volume – include voids, include "sinkage" factor, include irregularities of surface to be filled. Stone needed on this project exceeded original engineering estimates by over 50%.

- The project team did not necessarily need to estimate flow through ramp. By choking large stone with small stone, and any excavated fill, flow through ramp stone interstices can be minimized up front.

- If silt/turbidity curtain is needed for entirely crossing a river, plan for a long lead time for acquiring. Proper curtains are mostly custom-made. Neither silt curtain, nor turbidity curtains are actually made to traverse a river, perpendicular to flow, to contain suspended sediment.

- If there is a Flood Insurance Study, you need to procure the existing floodplain model and provide ample time in planning to acquire that model. The existing model on this project had to be found by the USACE by going through old microfiche files.

- Be flexible, but do not work outside of original work limits without careful investigation.

- Make contact with the local regulatory agencies. By meeting on-site with the local representatives that have input on your permit, you may be able to avoid complications and/or delays in receiving your permit(s).

8.2 Next Steps

This project seems to have been a success, but that does not mean this site is done. Other peripheral projects were identified when JFNew was on-site surveying for this project in the fall of 2007. These opportunities along with several other issues could be addressed in future projects, including: more stream bank stabilization plantings, native garden enhancement, public access improvement, and educational signage.

Possible site for access improvement project.

Follow-up sampling will be needed to determine the environmental success of improving the water quality attainment of this site. The Ohio EPA plans to re-sample the site with electro-fishing and macroinvertebrate surveys both upstream and downstream of the dam (at the same locations assessed in 2006). These surveys have not yet been scheduled, but are likely to occur in the summer of 2010. This should allow adequate time for system recovery before a formal re-assessment of the site.

The mussels that were relocated by the project also must be sampled to evaluate survivorship and health of the relocated mussels. This will include an exhaustive sampling survey that will be conducted approximately two years after relocation. All recovered individuals will be measured with a metric caliper to the nearest tenth of a millimeter. Recovery rates will then be calculated and an analysis of overall health will be assessed by comparing shell lengths at the time of translocation and the time of sampling. Positive growth is generally used as an indicator of health.

9.0 REFERENCES

Mooney, DM, CL Holmquist-Johnson, and S Broderick. 2007. Rock Ramp Design Guidelines. Reclamation: Managing Water in the West. U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center.

Rosgen, D. Applied River Morphology, 1996. Wildland Hydrology, Pagosa Springs, Colorado.

Wu, J.S., Holman, R.E., and Dorney, J.R., 1996. Systematic Evaluation of Pollutant Removal by Urban Wet Detention Ponds. Journal of Environmental Engineering, vol. 122 (11), 983-988.

National Weather Service, www.weather.gov, information downloaded 1/15/09, http://www.weather.gov/climate/index.php?wfo=cle

National Weather Service, www.weather.gov, information downloaded 1/15/09, http://www.erh.noaa.gov/cle/wx_events/2008/2008end.php

Scott High School, Student Watershed Watch project presentation and poster board. November 2008.

APPENDICES

(Provided in electronic format on enclosed companion CD)