Pucker Street Dam Removal and River Restoration

DRAFT Design Report

April 7, 2016

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INTRODUCTION

The city of Niles, Michigan, is working with partners, including the Michigan Department of Natural Resources, Pokagon Band of Potawatomi, Southwest Michigan Planning Commission, and others, to restore the Dowagiac River to a free flowing channel by removing the aged Pucker Street Dam. The existing hydroelectric dam was constructed in 1928, but it no longer produces power due to maintenance costs, sedimentation in the reservoir, and damage to its turbines. Structural issues also create safety concerns at the dam and downstream, which prompted the initial investigations into removal. In addition to eliminating Pucker Street Dam's integrity problems, removing the dam will also have important ecological benefits. The dam blocks almost the entire Dowagiac River watershed and all of its tributaries (159 miles of stream) to fish passage from the St. Joseph River and Lake Michigan. Removing the dam would eliminate that barrier and allow for restoration of two miles of high gradient cold water habitat, which is a rare commodity in the region. Overall, restoring the Dowagiac River to free-flowing conditions will elevate the potential of an important regional asset- socially, economically, and environmentally.

The removal of Pucker Street Dam and restoration of the Dowagiac River within the existing impoundment has several goals:

- Eliminate safety issues by removing the dam and surrounding structures.
- Reconnect the upstream and downstream waters.
- Provide a stable channel form that can pass the flow and sediment delivered to it from upstream.
- Minimize impacts downstream of the dam, especially with respect to sediment.
- Provide fish passage through the reconnected and restored reach, including adequate habitat, to the extent that budget allows.
- Minimize impacts to adjacent landowners.
- Create an amenity by improving recreational access

The impounded area has captured sediment since a log dam was built just upstream of the existing structure in 1828, and today approximately 1,000,000 CY of material has filled the impoundment. The volume of stored sands and silts and the length of the impoundment pose some unique restoration challenges. If left to adjust on its own after dam removal, channel recovery could take decades and large volumes of sediment would be evacuated from the impoundment to the detriment of the functioning downstream fishery and adjacent landowners. Actively removing and managing sediment will be costly, especially if habitat improvements are implemented along the excavated channel. The final design will balance budget limitations and the benefits of certain restoration elements.

This document includes descriptions of the existing geomorphic and hydrologic conditions of the study area, and justification of a design that will meet the goals of the project. Due to high cost of sediment removal, the design presented does not incorporate return of the river to the pre-dam channel meanders. Instead, the proposed alignment follows the straighter existing alignment through the impoundment. We expect that over time, the river will continue to evolve within the corridor through processes of erosion and deposition and ultimately reclaim a meandering pattern with deep pools in bends and riffles between the bends. Excavation of floodplain benches is included as an option at this point, depending on final budget, for both safety and to provide ecological benefits associated with floodplain corridors.

GEOMORPHIC PROCESS

Rivers and streams evolve and adjust to efficiently pass the sediment and water delivered to them from upstream. When the energy associated with the flow and channel slope balance the sediment load and bed material size, the channel is considered stable and in equilibrium (Figure 1). Although most natural rivers are resilient, large or consistent changes in flood flows related to climate or management (e.g., dam operations) will likely result in a change in channel dimensions to accommodate the new conditions. Increases in flow or flow energy will lead to erosion and a larger channel, and diminished flows or flow energy will result in deposition and a smaller channel. Similarly, increases in sediment delivery will usually result in sediment deposition within the channel, and a decrease in sediment delivery often results in erosion along the bed and banks (Figure 1).

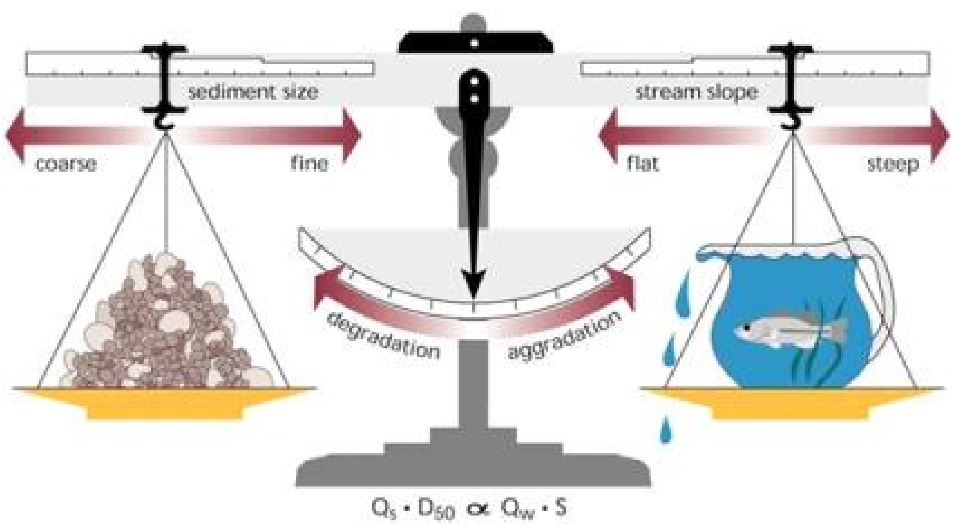

Figure 1. Lane's Balance – Channels in equilibrium balance slope and flow capacity with sediment load and sediment size (from Rosgen, 1996; Lane, 1955).

Dam removal represents a large and fast change compared to natural rates and scales of normal river change. The reservoir, and potentially the upstream main stem channel and tributaries, will respond to the rapid increase in slope at the dam site via channel incision to decrease the slope and attain a new stable position (Schumm *et al.,* 1984; Simon and Rinaldi, 2000; Doyle, et al, 2002). Incising channels follow a general pattern of adjustments through time (Simon and Rinaldi, 2000; Figure 2 and Figure 3), which permits prediction of spatial and temporal trends associated with dam removal (Doyle et al. 2002). Typically, flow released over the sediment stored at the dam face will begin cutting a notch, or nickpoint, as the channel initiates adjusting towards a lower channel gradient (*Stage 1*).

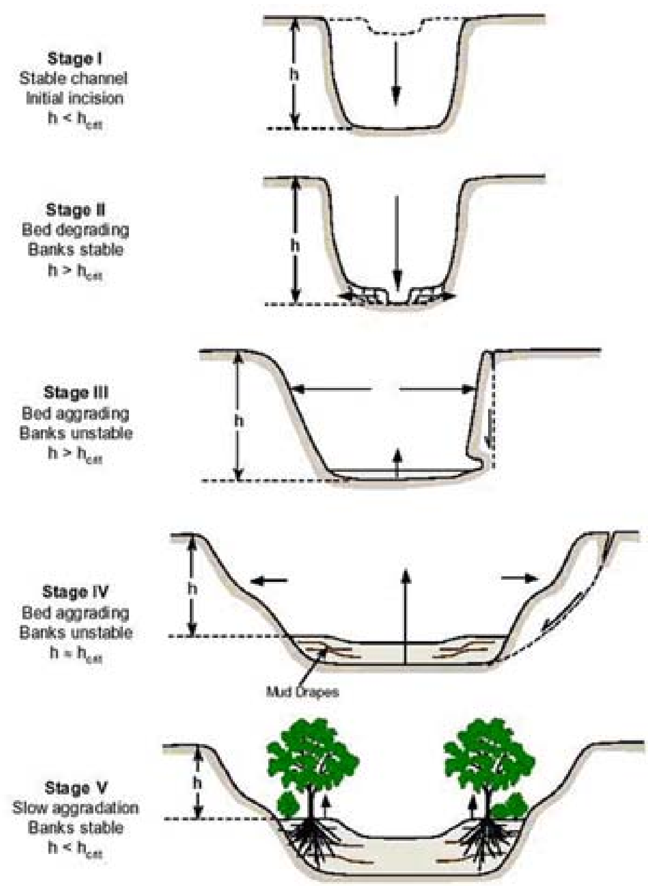

Figure 2. General pattern or stages of channel cross section adjustment over time following a change in downstream base level (Schumm,1984).

Rapid down cutting (i.e., degradation or incision) through the impounded sediment follows as nickpoints migrate upstream, the local gradient flattens, and sediment is evacuated along the incised channel (*Stage 2*). As it progresses downward, incision also frequently results in unstable channel bank heights and slopes, resulting in channel widening as the banks collapse and fall into the river (*Stage 3)*. Meanwhile, newly evacuated upstream sediment begins to deposit along the downstream reaches where incision has already occurred (*Stage 4*). The deposition raises (i.e., aggrades) the channel, which reduces bank heights. Channel widening and erosion become limited to localized areas, such as at the outside of bends and where bar deposits force flow against the banks. Finally, deposition and erosion normalize, vegetation establishes on newly deposited sediment, and a more stable channel form results (*Stage 5*).

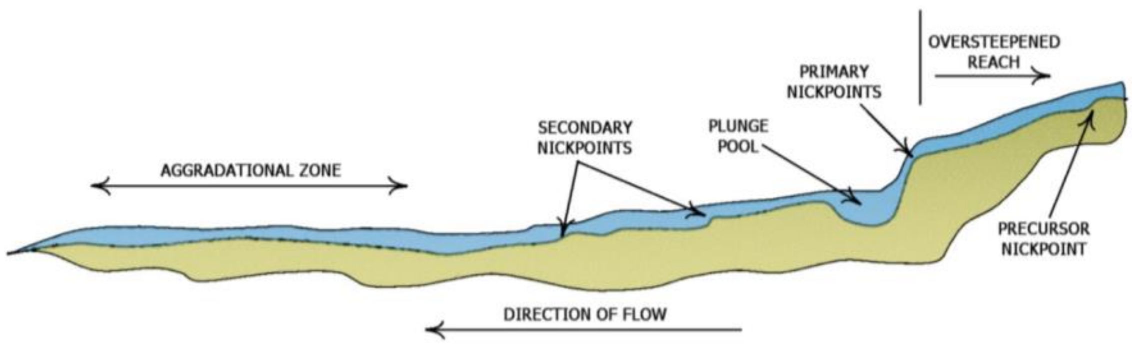

Figure 3. Longitudinal pattern of channel adjustment over time, showing upstream nickpoint migration, which leaves a lower gradient channel downstream level (Schumm,1984).

WATERSHED CONTEXT

The Dowagiac River drains approximately 285 mi² of the southwest corner of Michigan's Lower Peninsula. It originates in Decatur Township, Van Buren County, and terminates approximately 31 miles downstream at its confluence with the St. Joseph River in Berrien County, near the town of Niles, MI. The watershed drains glacial deposits consisting of outwash sand and gravel, coarse-textured till, and finer glacial lake deposits (Kirby and Hampton 1998). The coarse textured materials allow substantial groundwater contributions to the Dowagiac River system. The Dowagiac River and most of its tributaries support a popular coldwater fishery (Wesley and Duffy 2003).

CLIMATE

Berrien County's climate is significantly moderated by westerly winds that are cooled in summer and warmed in winter as they pass over Lake Michigan. Monthly average temperatures vary from 73 degrees F in July to 23 degrees F in January, and a mean annual temperature of 49 degrees F. Mean annual precipitation is approximately 35 inches, which is distributed evenly throughout the year, and generally decreases with distance from the lake.

Total annual precipitation at Dowagiac, MI, is 22 inches. The region gets approximately 70 inches of snow per year. Most of the rainfall and snowmelt water drains to the Dowagiac River and its tributaries as groundwater.

GEOLOGY

Glacial Geology

Michigan was covered by glaciers around 10,000 years ago, and the current landforms, soils, and surface geology are the result of the advance and retreat of the most recent glaciation. The surface geology within the Dowagiac Watershed consists almost entirely of thick glacial sands, silts, and gravels, along with limited post-glacial stream deposits (Figure 4; Kincare, 2010), which have buried the shale bedrock by hundreds of feet. The Michigan Lobe of the Wisconsin Glaciation advanced south, along what is now Lake Michigan, into Illinois and Indiana. The Kalamazoo Moraine and the Valparaiso Moraine, which are large piles of river and delta sand deposited along the edge of the Michigan Lobe during ice retreat, demarcate the east and west side of the watershed near Niles. The moraines mark periods of glacial equilibrium, before melting withdraws the ice front to the next moraine position (Stone et al., 2003; Kincare, 2010; Figure 4).

The Dowagiac River runs along the former Glacial Lake Dowagiac bed between the Kalamazoo and Valparaiso Moraines (Figure 5). The lake formed when ice and sediment blocked spillway outlets to the south (Figure 4). The flat lake bed is expressed in the low gradients of the upper Dowagiac River and the river's associated wetlands upstream of Sumnerville, MI (Figure 6). The glacial lake spillway is largely filled with gravelly, sandy delta deposits from upstream (north) and from the adjacent moraines. These sands and gravels are now the dominant material in the modern channel and floodplain (Stone et al., 2003; Kincare, 2010). They also make up the sandy and loamy soils found in the region (e.g. Ockley/Kalamazoo Loams, Oshtemo Sandy Loam, Cohoctah Sandy Loam). The sands and silts stored behind Pucker Street Dam are derived from these materials.

The glacial materials associated with the outwash plains and moraines are relatively permeable, allowing precipitation to infiltrate and travel in subsurface pathways through the deposits. The coarse glacial material of the watershed is responsible for storing tremendous volumes of cold groundwater which maintain the Dowagiac River, even in the heat of summer, as a cold water river. Within the study reach, floodplain wetlands have formed along the valley walls where groundwater seeps into the valley. Infiltration also reduces surface runoff in the system, thereby limiting flow fluctuations.

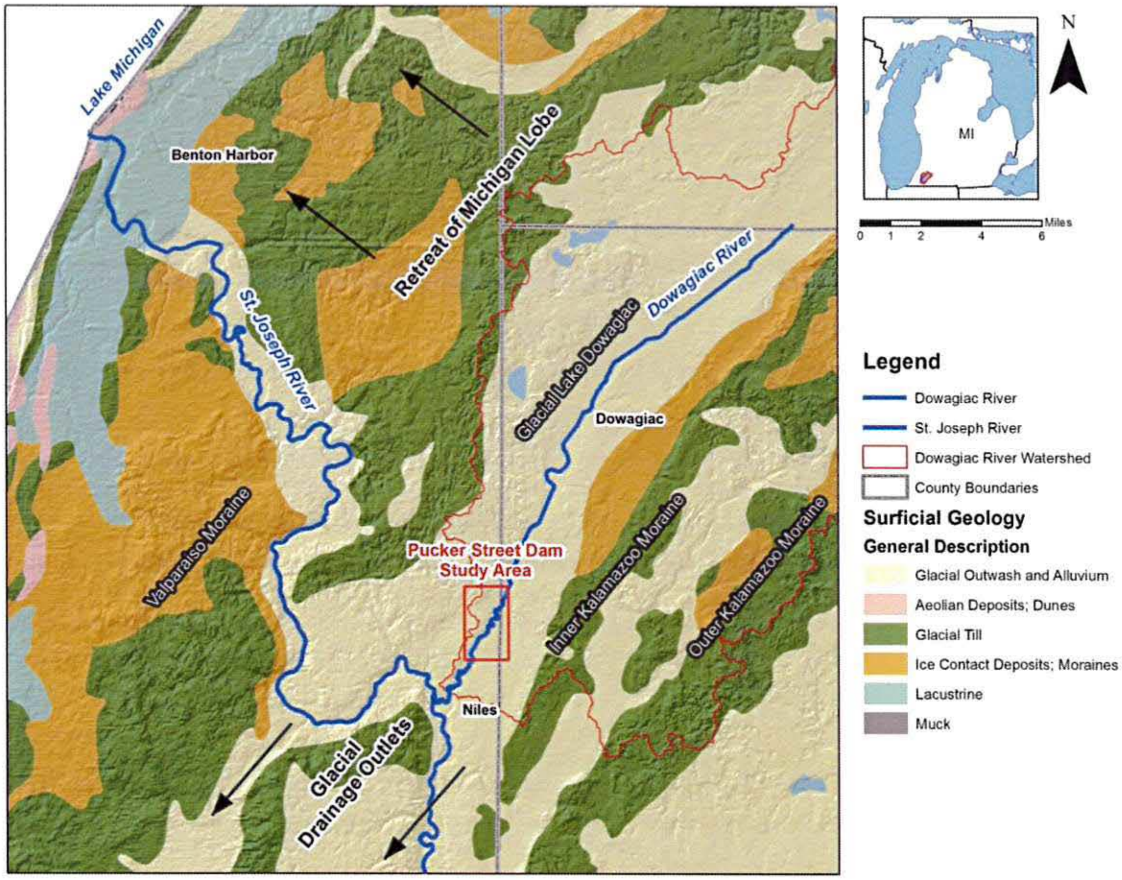

Figure 4. Glacial geology of the region surrounding the Pucker Street Dam project area (red box). The river flows between two end moraines associated with the Michigan Lobe of the Wisconsin continental glaciation. Glacial retreat from the Kalamazoo Moraine system to the Valparaiso Moraine system established a southwest trending meltwater spillway dominated by Glacial Lake Dowagiac. The spillway is largely filled with gravelly, sandy delta deposits from upstream (north) and from the Valparaiso Moraine.

Figure 5. Generalized cross section of the Dowagiac River valley at the upstream end of the project reach. The overall valley is defined by the Valparaiso Moraine to the west (left) and the Kalamazoo Moraine to the east (right).

Before retreating west, ice and sediment along the Valparaiso Moraine directed flow in the St. Joseph River away from its current route to Lake Michigan, sending the water south to the Kankakee River system.. However, once the Michigan Lobe melted back to the west, potholes and kettles (i.e., small ice melt lakes) left behind coalesced and "captured" the St. Joseph River. The flow spilled off to the west, cutting a new route to present day Benton Harbor (Figure 4). Since then, downward shifts in the surface water elevation in Lake Michigan have forced multiple episodes of incision along the lower section of the St. Joseph River. The downstream end of the Dowagiac River also steepened in response to lowered Lake Michigan and St. Joseph River elevations, creating a slope break approximately where Pucker Street Dam sits today – the channel is generally steeper downstream of the dam and less steep upstream of the dam (Figure 6). Survey data suggests the steeper slope extends under the Pucker Street impoundment sediments to near Kinzie Road (See Data Collection Section).

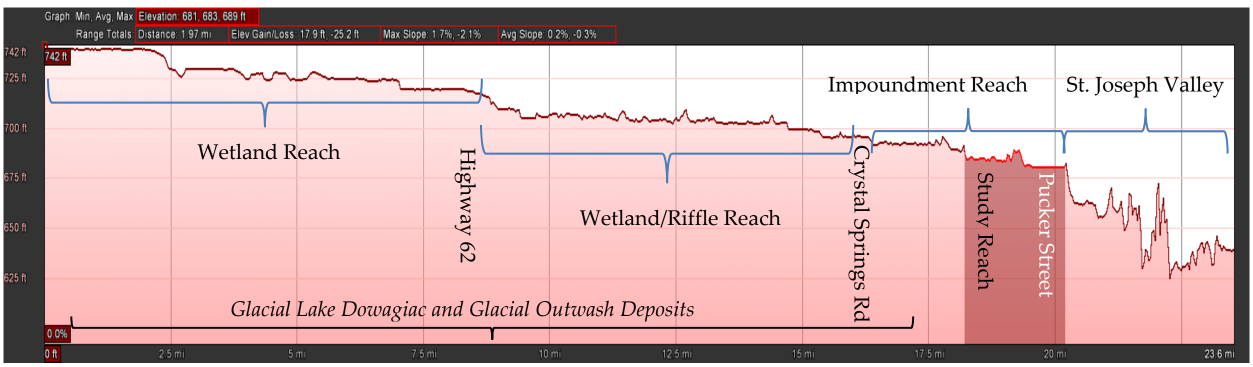

Figure 6. A generalized longitudinal profile of the Dowagiac River.- The project area is highlighted in the profile. Pucker Street Dam sits at a transition from flatter upstream gradient (i.e., lower energy) to steeper gradients (i.e., higher energy) leading into the St. Joseph River Valley.

River Profile

The longitudinal profile of the Dowagiac River presented in Figure 6 is a helpful tool in understanding the energy of the river system, and thus, movement of sediment and water along the channel. The profile provides channel bed elevations from a river's headwaters to its mouth, and the slope of the lines gives a general idea of the relative energy in the system. The steepness of the slope dictates the type of river patterns at various locations along the 31 mile length, with the wetland sections formed in Lake Dowagiac deposits at the headwaters of the river, transitional reaches between wetland and pool/riffle sections in the middle, and finally a steeper channel with coarse cobbles and gravels and riffles characterizing the transition into the St. Joseph River Valley. Beginning in the Dowagiac River headwaters, the flat wetland swamp section is apparent, separated by a few short steeper transitions down to additional flat reaches downstream to Highway 62. As water leaves the upstream wetland area the slope increases slightly and the channel picks up energy. However, the river's slope remains relatively gradual until Crystal Springs Road, where the river steepens again until it hits a series of impoundment deposits. The first impoundment section is just upstream of Kinzie Road, where a former dam blocked the river. This upper impoundment area is followed by the long flat section representing the study reach upstream of the Pucker Street Dam. The steepest section of the Dowagiac River is downstream of Pucker Street Dam, where the channel falls into the St. Joseph River Valley. The channel was steeper through the dam and impoundment prior to construction, and the dam was likely sited to take advantage of the high energy of the river in the section (Figure 6).

Sediment Transport

Based on observations in the upper watershed, the Dowagiac gains sand and finer material from tributaries within the upland wetland reaches, but the sands cannot be transported easily due to the reach's low gradient (i.e., low energy). Once the landscape slope increases, sediment is delivered to the river from tributaries, and to a lesser extent, from erosion along the channel margins. Bed material begins to include more gravels and small cobbles, which form occasional riffles along the channel; however, sand appears to be the dominant bed material along most of the river. Sand moves nearly continuously within the Dowagiac system and is eventually delivered to the impoundment behind the dam. Some gravel is also transported through the system, but currently appears to settle at the upstream end of the study reach, downstream of Kinzie Road, while the smaller sand and fine particles can be carried further downstream into the impoundment.

Flora and Fauna

Vegetation

An interpretation of the General Land Office surveys conducted in the 1800s (Comer and Albert 1997) indicate the historically dominant vegetation type along the Pucker Street section of the Dowagiac River is Beech/Sugar Maple forest with some wet hardwood forests and other wetland types within the floodplain. Today, agriculture dominates the watershed, comprising 55% of the total acreage. The uplands are primarily used for crops, especially corn, but hogs and other livestock are also raised in portions of the watershed. Suburban development also occupies land adjacent to the river and closer to Niles, downstream.

Aquatic Ecology

Aquatic organism sampling has been conducted by the MDEQ and MDNR (2012) within the watershed and tributaries. The following general observations are consistent within the mainstem. Habitat is degraded throughout the Dowagiac River system largely due to historical channelization, dam operations, and land use impacts.

Fish – Fish species above the Pucker Street Dam are consistent with a cold water fishery. Assessments in the mainstem (Wesley and Duffy, 2003) included a total of 37 species, with brown trout, which are stocked by MDNR, being the most numerous species. Although Wesley and Duffy (2003) reported an ample number of species along the river, the authors noted that habitat was lacking. The dam at Pucker Street blocks passage of several fish species including steelhead, chinook salmon, coho salmon, brown trout, white suckers, and walleye to more than 159 miles of main stem and tributary habitat in the Dowagiac River system. Lake Sturgeon ascended the river historically and lake trout were noted to spawn upstream of Niles, MI (Ballard, 1948). The dam also blocks passage of non-native salmon species that are an important component of the regional recreational sport fishery.

Macroinvertebrates – A 2012 survey included documentation of between 22 and 37 macroinvertebrate taxa. Assemblages of mayflies, stoneflies, and caddisflies were present, which is consistent with a cold water system and indicative of good water quality. The Dodd Park site had a river wide high of 37 taxa. The higher values may be a result of recent restoration work completed to expose coarse substrate in an old meander. Given the results from the Dodd Park site, located in the lower part of the river, habitat would appear to be more limiting than water quality in the development of a healthy macroinvertebrate community in Dowagiac River.

WATERSHED HISTORY

Other than the St. Joseph de Miami Missionary, established in 1691, and Fort Saint Joseph, established in 1697, settlement near Niles and within the Dowagiac River watershed began in the late 1820s and rapid settlement followed in the 1830s (Rogers, 1875). The main industry was agriculture and large areas were deforested in the following decades to make way for farms. Clearing the forest and plowing the soil likely increased both the runoff and sediment available for transport through the Dowagiac System.

The Dowagiac River was straightened, lowered, and channelized from Decatur to Sumnerville between 1901 and 1928 to drain the surrounding floodplain swamps and free more land for agriculture. Straightening the river increased the channel slope and the disturbance increased the sediment available for transport. The combination led to an increase in the volume of sediment delivered downstream, where bedload (i.e., sand and gravel) and some finer sediments were trapped behind Pucker Street Dam. The straightened, leveed channel also provides little habitat for fish and other aquatic and riparian fauna.

PROJECT SITE

The project site includes the Dowagiac River Valley from about 300 feet downstream of Pucker Street Dam to the Kinzie Road Bridge, approximately 11,000 ft upstream of the dam. Within that reach, the focus is on Pucker Street Dam and its 5,900 ft long impoundment. The Dowagiac Valley width ranges from about 200 feet to 700 feet wide. The wider sections are included in the impoundment area. Suburban homes line the edge of the valley, some within 50 ft of the channel (Figure 7) and, landowners adjacent to the channel often utilize the surface exposed following the 1999 reservoir drawdown. Most of the upland areas, away from the river, are farmed (Figure 11). Except where Pucker Street and the dam cross the river at the downstream end of the reach, all of the floodplain is undeveloped (Figure 11). Three pipes are buried across the channel: an abandoned water line 250 feet downstream of the dam, and two gas lines at Station 4200. The water line is exposed at low flows. The gas line is buried below the existing channel with 3-4 ft of cover when it was located by the TransCanada Pipelines Mid America on 08/25/2015.

Below Kinzie Road, the valley along the *upstream reach* (i.e., upstream of the former impoundment; Figure 11) includes more woodland and narrower valley widths relative to the lower two-thirds of the study area (Figure 8). The channel is relatively sinuous, steep, and gravelly, and large wood is present in the stream. At the downstream end of this section, the channel turns to the west and transitions to the lower gradient, formerly impounded section of the channel.

Figure 7. Houses and yards set within 50 feet of the Dowagiac River impoundment.

Figure 8. Upstream section of Dowagiac River, below Kinzie Road.

The *downstream*, impoundment section (Stations 1150 – 7200) is inset into glacial material, leaving high, steep, wooded, valley walls demarcating the flat floodplain of the former reservoir (Figure 12 and Figure 9). In this lower section, the channel is straighter than upstream, despite the wide flat valley. Cross section surveys along the channel show variable channel widths, ranging from around 70 feet to 100 feet wide at estimated bankfull conditions within the impounded section (Figure 12), and channel depths (i.e., impounded sediment surface to channel bed) varied from around 4 feet to around 8 feet, with an average of approximately 6 feet (see Data Collection section of this report). Wetlands and small side channels are common where groundwater seeps from the adjacent slopes and where side channels were abandoned after the dam was opened in 1999 (Figure 10). Much of the floodplain remains vegetated in native and non-native plants, with occasional thick copses of willows and small stands of cottonwood, ash, and alder (Figure 9 and Figure 10).

Figure 9. Downstream section of Dowagiac River, within the impoundment.

Figure 10. Floodplain wetland along the valley wall within the impoundment reach.

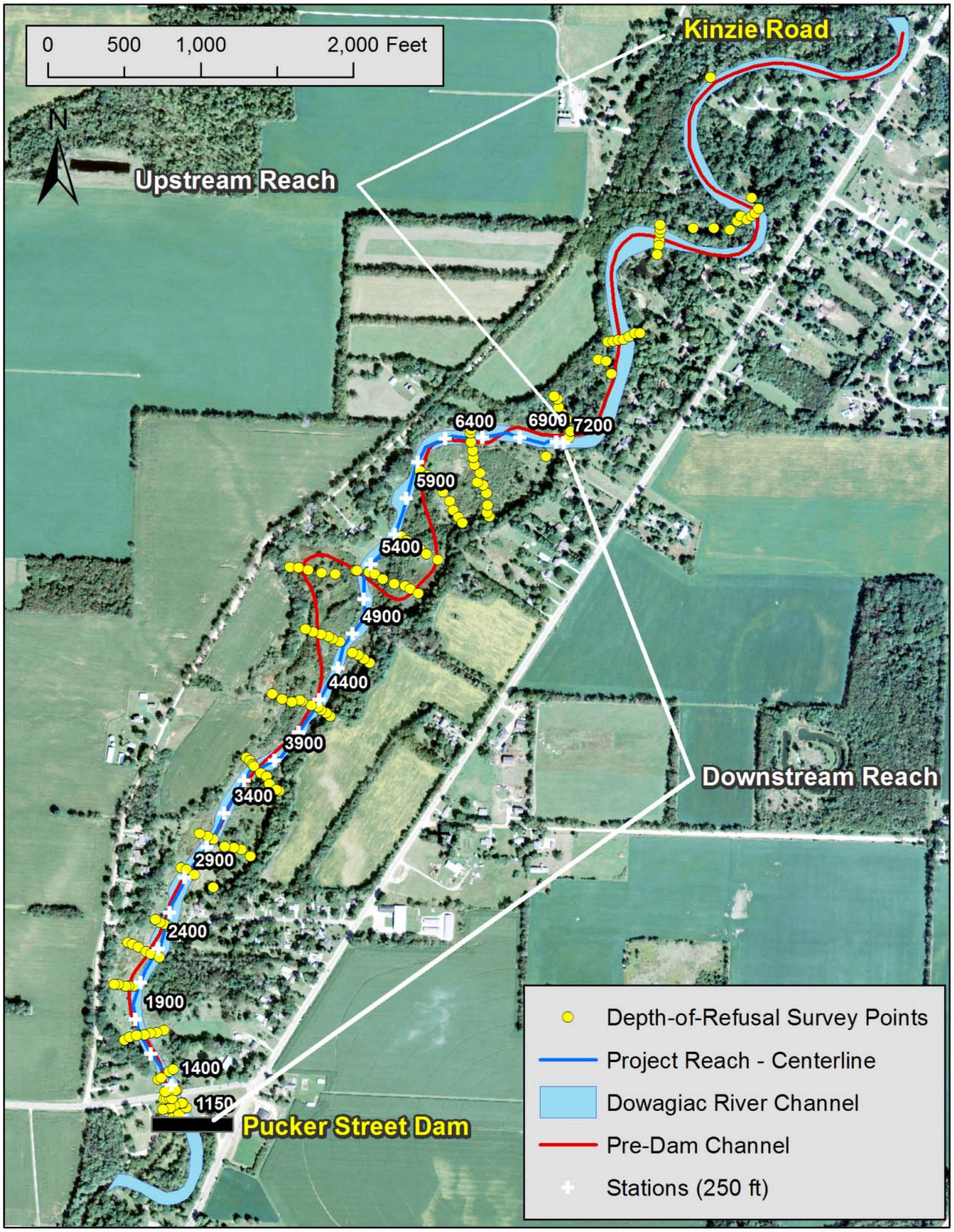

Figure 11. Existing Conditions and Depth of Refusal (DOR) survey points along the study reach of the Dowagiac River.

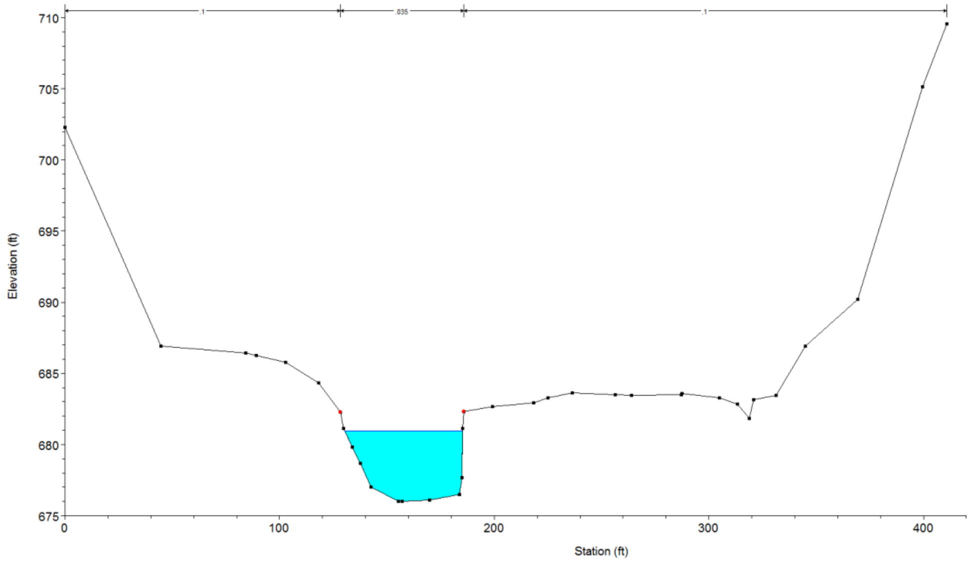

Figure 12. Typical cross-section through the Dowagiac River valley through the impounded reach. The valley generally has a wide flat floodplain between high terrace valley walls. The Dowagiac River is inset into the former impoundment sediments that now form the floodplain.

DAM HISTORY

Pucker Street Dam is located three miles upstream of the Dowagiac River - St. Joseph River confluence. The dam was originally built as a log dam in 1828. The existing, larger concrete hydroelectric structure was constructed 100 feet downstream of the original dam in 1928. Pucker Street Dam is the only mainstem channel barrier that traps sediment within the Dowagiac River system, and by 1940, enough sediment settled behind the dam that the impoundment was dredged (Wesley, 2008). The river likely delivered much of this new sediment after most of its length above the dam was straightened in the 1910s and 1920s. By the 1990s, sediment had filled the impoundment again and suspended silts and sands had damaged the turbines, forcing the city to open the gates and allow run-of-river flow.

The 1938 aerial photographs of the dam impoundment (Figure 13) depict delta formation at the upstream end of the impoundment, indicating continued filling through that time. By 1999, a significant delta had formed over the upper third of the reservoir, leaving low lying vegetated islands and bars of fine material (Figure 13). The wedge of sediment formed despite at least one dredging event (1940) and multiple accidental and maintenance related sediment releases (Wesley, 2008). The reservoir was drawn down in 1999, and the corresponding air photos (Figure 14) show exposed deposition throughout the former pond. Currently, the dam is dormant with three gates permanently left open.

Bedload transport sampling conducted up- and downstream of the dam provided estimates of background base flow transport rates between 3 tons/day and 1 ton/day (Wesley, 2008). An empirical equation produced by the US Army Corps of Engineers (2012) that relates sediment yields to drainage area predicts an average annual rate of transport of 26,300 CY/year (42,600 tons/year) for the Dowagiac River at Pucker Street. The sandy bed load material along the Dowagiac River mobilizes relatively easily, especially if the channel is disturbed, and high flows likely carry large loads of material. Although much of the sediment carried by the river formerly deposited upstream of Pucker Street Dam, now that the reservoir is mostly filled, more sediment likely passes downstream, especially finer material that remains suspended in the flow.

Figure 133. Comparison of the 1999 air photo and 1938 air photo at the Pucker Street Dam impoundment. A sizeable delta formed over the northern (top of 1999 photo) third of the reach.

Figure 144. Sediment exposed within Pucker Street Dam impoundment after the 5 foot draw down event in 1999. Light colored areas adjacent to the channel are exposed reservoir sediment.

DATA COLLECTION

Geomorphic Survey

Initial field reconnaissance along the Dowagiac River occurred in May and July, 2013. Field work included noting general geomorphic characteristics and collecting topographic and depth-of-refusal surveys at transects across the river and along the existing channel alignment. The assessment extended from 2,200 feet downstream of the dam to the Kinzie Road crossing, upstream (Figure 15). Topographic surveying was conducted using rtkGPS (real time kinematic global positioning system), primarily to obtain elevations at 35 cross sections and along the channel for developing a one-dimensional hydraulic model (HECRAS) and a longitudinal profile.

The depth of refusal (DOR) survey was conducted by pushing a rod through accumulated impoundment sediment until a firm layer (e.g., clay or gravel) "refuses" further penetration. DOR surveys allow an initial interpretation of former vertical and horizontal channel position and depth of sediment. Along the Dowagiac River study reach, the DOR survey was difficult due to the fine sediments and large depth of material stored in the impoundment. It was not always clear whether "refusal" occurred in former channel bed deposits, or in former floodplain. Additionally, in some of the wider floodplain areas of the impoundment, such as Station 4500 to 6500, field limitations made it difficult to complete a thorough survey of the reach.

Data collected as part of the DOR and longitudinal profile surveys are plotted in Figure 15. The survey data confirm existing average channel depths (i.e., from bed to impounded sediment surface) of around 6 feet throughout the study reach. Existing channel gradient is 0.0008 ft/ft. The DOR data, however, suggest the valley is filled with sediment up to 18 feet deep at the dam site, and that the channel gradient prior to dam construction was approximately 0.0019 ft/ft, more than double the existing gradient. The DOR rod probed through layers of silt and sand deposited behind the dam. Refusal was often forced by gravel or clay, suggesting that, prior to dam construction, sand was generally passed through the reach or stored in bars and floodplain material, and the channel bed was likely gravel with some sand and clay.

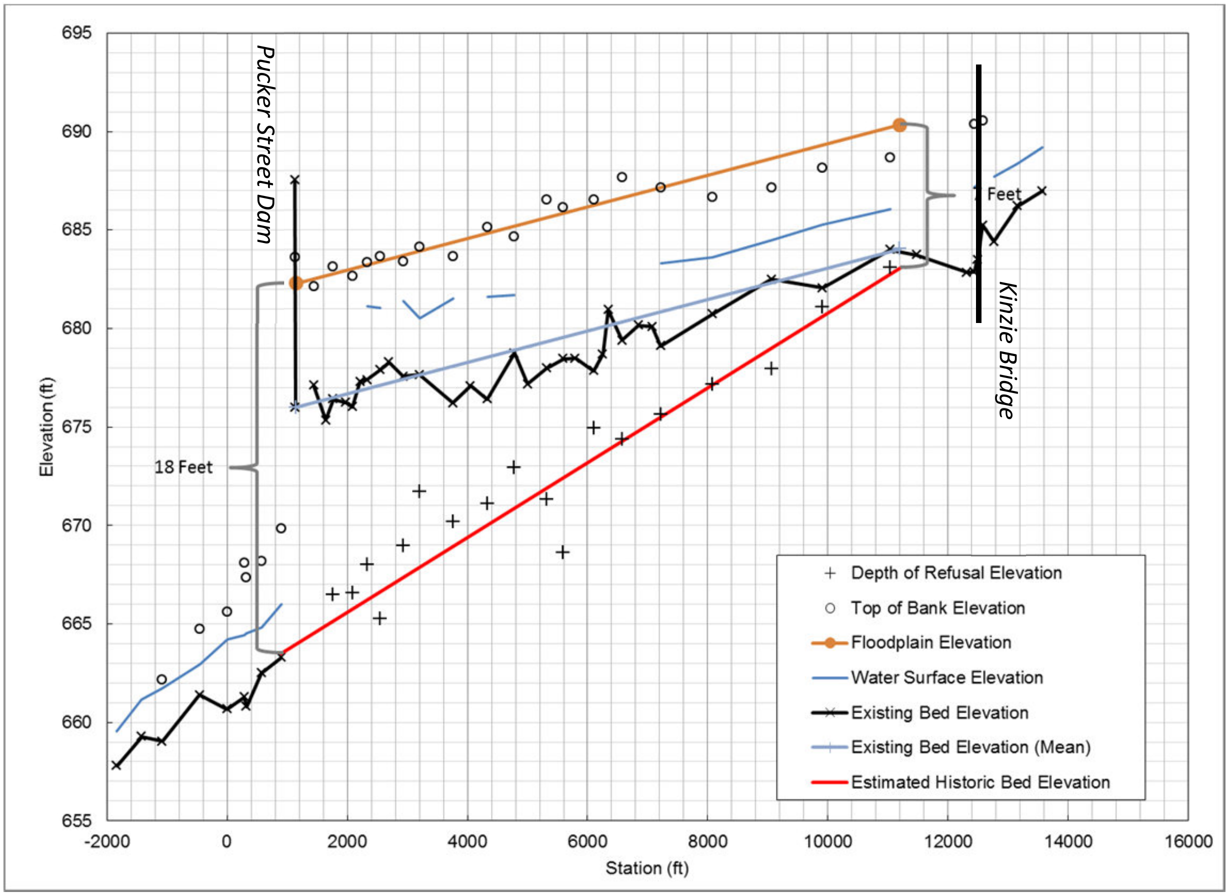

Figure 15. Longitudinal profile of the Dowagiac River from Kinzie Road to Pucker Street Dam (STA 1150). The profile includes expected historical bed elevations based on the DOR survey data, as well as existing bed and floodplain elevations.

SEDIMENT SAMPLING

A total of 42 sediment samples were collected and analyzed for grain size and chemical parameters (PCB's, PNA's, arsenic, cadmium, copper, lead, mercury, nickel, selenium and zinc). A total of 14 transects were conducted, with sediment samples collected from the left, center and right side of the stream when looking downstream. Sediment samples from transects 1 through 9 were collected by Great Lakes Environmental Center (GLEC) using vibracore methods. GLEC could not get their boat past, around or over a large rock in the middle of the stream between transects 9 and 10. Wightman technicians in a small boat using a Russian Peat Borer with stainless steel auger collected the sediment samples from transects 10 through 14. The first transect was 25 feet upstream of the dam, with each successive transect 500 feet upstream.

Results (see appendix for full summary submittal) were submitted to the MDEQ for review and concurrence with our findings. Based on this review it was determined that the dredged sediment is considered clean (inert and suitable for unrestricted upland disposal) and can be used as unrestricted fill material. This material will still need to be permitted for placement in streams or wetlands just like any other fill materials.

Hazardous Material

Sample collection and analysis were performed for three of four hazardous materials investigated within the power house. Investigations were conducted for Asbestos, Lead based paint, PCB's and Mercury. The results of these investigations are that asbestos and lead based paints were detected and will need to be mitigated as part of the power house demolition process. Oils were sampled and tested for PCB's but no PCB's were detected. No items were found that would have contained Mercury so nothing was tested and no report generated.

<u>Asbestos</u> (see full report in the appendix)

Wightman Environmental, Inc. (WEI) conducted a National Emissions Standard for Hazardous Air Pollutant inspection of the power house and dam on 3/18/14 & 4/4/14. The purpose of the inspection was to determine if the referenced structure contained any asbestos containing materials. The dam structure consists of a two-story brick and concrete block structure with associated dam spillways.

During the inspection, bulk samples were randomly collected from any suspected asbestos containing building materials. Category II non-friable asbestos was discovered in electric wire insulation and category I non-friable asbestos in the roofing tar. Since these are non-friable sources of asbestos a licensed asbestos abatement contractor is not required but special procedures and handling per regulations are required.

<u>Lead Based Paint</u> (see full report in the appendix)

Wightman Environmental, Inc. (WEI) performed a lead-based paint inspection for the structure known as the Pucker Street Dam in Niles, Michigan on 3/18/14. Based on that inspection WEI concluded that there is non-intact lead-based paint at the property and lead hazard activities will be required.

The inspection was performed by a Michigan Department of Community Health Certified Lead Inspector and consisted of collecting and testing paint chip samples from 16 painted surfaces within the structure. In conjunction with the paint chip samples a visual surface by surface inspection was also performed. The painted surfaces within the structure were observed to be non-intact at the time of the inspection. Please note not all painted surfaces could be accessed for testing

<u>Polychlorinated Biphenyl (PCB's)</u> (see full report in the appendix)

Wightman Environmental, Inc. (WEI) performed an inspection on 3/18/14 looking for sources of oil to sample for PCBs. Two sources of oil were identified: the large generator and a hydraulic pump. Samples were collected from each source and sent to an independent laboratory for analysis. Both samples were found to be non-detect for PCB's.

ANALYSIS

HYDROLOGY

Base Flows

Base flow is the portion of the river discharge that is groundwater. Surface water runoff when added to base flow, induces flow increases of various magnitudes, including floods. Base flow, although relatively constant, varies in magnitude with precipitation and snow melt within and between years. Groundwater contribution is important to the Dowagiac River, providing a stable source of cold water that provides suitable habitat for cold water species, such as trout. The persistence of vegetation along the banks and the habitat available to different fauna is governed by base low and its seasonal variations.

To investigate base flow in the Dowagiac, a plot of the average daily discharge can be useful. Average daily discharge indicates the average flow on any day of the year in the Dowagiac over the period of record. A plot of this average daily discharge at the Dowagiac River gaging station at Sumnerville (USGS 04101800). is displayed in Figure 16. The seasonality of flow on the Dowagiac River is apparent, with higher flows in the spring, gradually trending lower into summer then increasing in late fall and winter with rainfall and lake effect snow events.

To understand the changes between wet years and dry years in the magnitude of base flow, it is useful to consider the exceedance probability, which is expressed as the percentage of time that a giving flow rate is exceeded. The driest day would have a 100% exceedance flow value, indicating flow has never dropped below this value during the period of record. Base flow during wet years is difficult to interpret as the exceedance values begin to incorporate elements of the flood signature. We used the 10% exceedance value to estimate typical low flows in extremely wet years. The results for the Sumnerville gate were multiplied by the ratio of watershed area at Pucker Street to the watershed at the gage (~1.11) to estimate typical low flow in the study reach (Table 1).

Flood Magnitudes

To estimate flood magnitudes, a Log-Pearson Type III (LP3) probability distribution was fit to the Dowagiac River at Sumnerville, MI, flow gaging station data (USGS gage 04101800; IACWD, 1983). This gage is located 4.5 miles upstream of the project site and has a drainage area of 255 mi^2 compared with 282 mi^2 at the downstream end of the project area. The Sumnerville gage recorded larger floods (>1250 cfs) in 1968, 1985, 1986, 1990, 1993, 1997, 2008, and 2009. The smallest annual peak flow was 629 cfs in 2000 and the largest annual peak was 2300 cfs in 2008 (Figure 17). An additional flow gaging station at State Highway 51 (USGS gage 04101535, installed in 2012) was not utilized for flood magnitude analysis given its short period of record. In general, the high infiltration rates throughout the watershed and subsequent high groundwater supply to the Dowagiac River results in a relatively stable flood hydrology. The range of flood flows is relatively small, with the difference between a frequently occurring peak flow (< 2 year return interval) and an infrequent peak flow (>50 year return interval) less than a factor of 2.

Table 1. Low flow statistics at the Sumnerville gage and at Pucker Street Dam.

% Time Exceeded	Discharge (cfs)	
	Sumnerville Gage	Pucker Street Dam
1	777	859
5	541	598
10	458	506
50	276	305
75	205	227
90	162	179

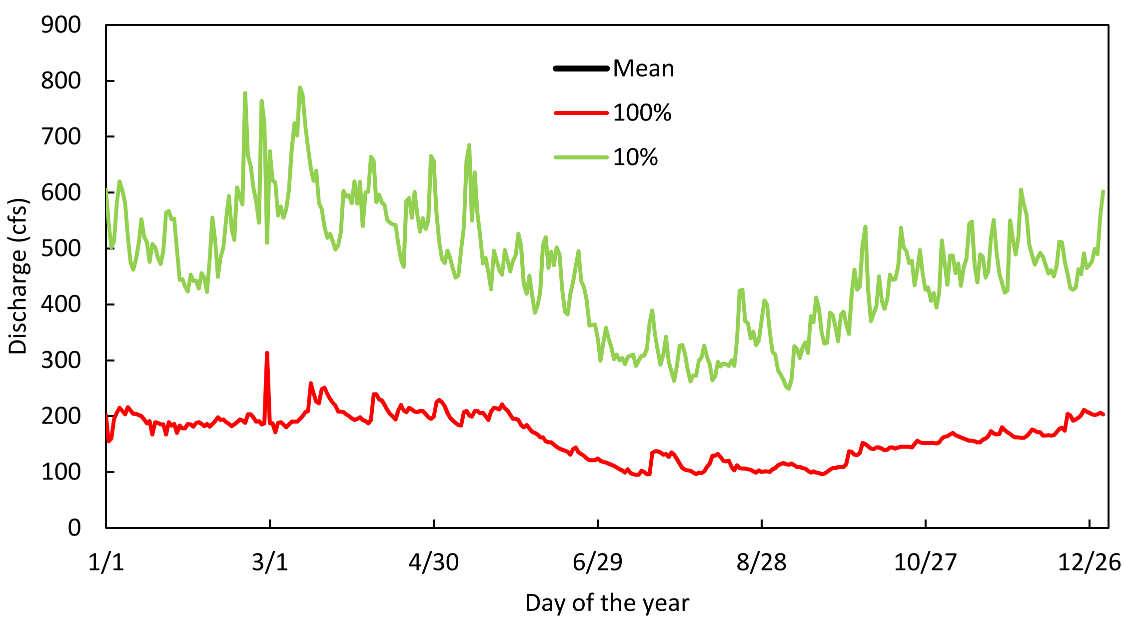

Figure 16. Probability of flows exceeded for each day of the year at the Sumnerville gage. The black line is the average flow magnitude for each day averaged for the gage record since 1980, while the green and red lines relate to flows exceeded 10% and 100% of the time, respectively, for each day of the year.

The gage record at Sumnerville included 52 years of data. Analysis of the annual peak flood plot (Figure 17) suggests peak flood magnitudes have increased over the period of record. Given the importance of flood hydrology to the project, the data was parsed to examine the potential effect of this trend on predicted discharge. Three component sets were analyzed. First, the 1983 through 2013 data set was investigated because it includes inter-decadal climate cycles shown to persist within the Lake Michigan region (Thompson and Baedke, 1997; Hanrahan, 2009; Wang et al., 2012). The second period of analysis focused the data record over the last 11 years. Both study periods included one outlier (2008) which was excluded from the analyses. The IACWD (1983) recommends at least 10 years of data to complete the LP3 analysis.

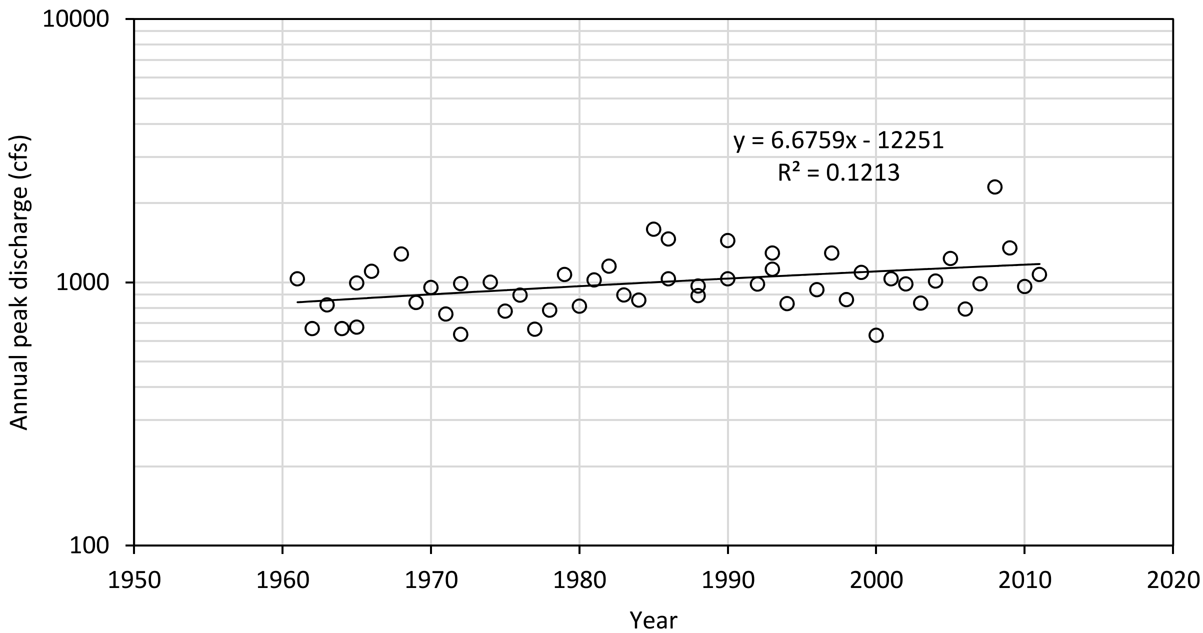

Figure 17. Annual instantaneous peak discharges for the Dowagiac River gaging station at Sumnerville (USGS 04101800). One high outlier was detected in 2008 and removed from the flood quantile estimation procedure. There is a general increase in annual peak flood magnitude.

The application of the LP3 method for determining flood magnitudes required calculating first, second and third moments of logarithms of the annual maximum peak discharges at the USGS Dowagiac River gaging station at Sumnerville (04101800). For the third moment (i.e., skew coefficient), we used a generalized value that combined the gaging record with a regional average value as flood quantiles are relatively sensitive to the value (IACWD, 1983). With the entire gage record data, the skew was 0.085 while the regional average skew was 0.081 (Croskey and Holtschlag, 1983). The similarity between the two values confirms that the Sumnerville gage reflects regional climate and runoff regimes. Combining the two values resulted in a generalized value of 0.083. For the parsed data, the sample skew coefficient was 0.17 and 0.28 for the 30- and 10-year gaging records, respectively. The higher skews indicate larger magnitude floods in recent years.

The flood magnitudes for the 30-year gage record resulted in the largest estimates while the full record had the second highest estimates and the 10-year record had the lowest estimates. We applied the 30-year gaging data for project site as it provided more conservative results by producing higher estimated water surface elevations and larger shear stresses. The final peak discharge values for Pucker Street (Table 3) were derived by multiplying the gage measurements by the ratio of watershed area at Pucker Street to the watershed area at Sumnerville (~1.11).

Table 2. Peak flood magnitude estimates at the USGS gage (04101800) using the full, 30-year, and 10-year data records. The 30-year record predicted the highest discharges and was used to provide a more conservative approach for hydraulic modeling.

Recurrence Interval (years)	Discharge (cfs) for various gaging record lengths		
	Full record	30-year	10-year
1.43	901	911	897
1.5	908	920	914
2	952	1017	991
5	1149	1218	1166
10	1269	1341	1271
25	1314	1488	1394
50	1517	1593	1480
100	1617	1695	1562

Table 3. Predicted flood magnitudes at Pucker Street based on the 30-year Sumnerville Gage data record and the watershed area ratio transformation.

Recurrence Interval (years)	Discharge (cfs)
	Pucker Street Dam
1.43	1008
1.5	1017
2	1125
5	1347
10	1483
25	1646
50	1762
100	1874

CHANNEL FORM AND HYDRAULICS

Channel Planform Alternatives

Figure 18 displays the estimate of the historical planform alignment for initial design purposes. The historical ("pre-dam") alignment includes the channel from just downstream of the dam to the transition point from the upstream section of the study reach to the downstream section where the impoundment began (Station 7200). The historical alignment generally follows the minimum elevations (i.e., deepest points) measured during the DOR survey (Figure 15), especially along the lower end of the reach, from the dam to station 4300. Within this subreach, the inset design channel and the additional slope from the existing surface down to the channel bed will occupy most of the existing valley floor.

At Stations 4400 to 6100, the historical alignment deviates from the existing alignment and features a set of bends that abut the opposing valley walls and traverse the entire valley floor. The similar bends depicted in the 1868 general land survey office (GLO) map offer additional evidence that this is likely the pre-dam alignment (Figure 19). A change in channel planform in this section may have accompanied a possible shift to a lower slope observed at station 3200 in the DOR data (Figure 15), or the bends may have developed due to differences in valley morphology and sediment storage prior to dam construction. Taking advantage of this meandering form would maximize channel length through the reach, increasing the length by approximately 1000 feet. The additional length and sinuosity would provide opportunities for scour hole development and wood recruitment or placement, which would promote habitat improvement. Additionally, the meander bends would reduce overall channel gradient and provide temporary sediment storage on point bars. If these processes are reinstated, they would likely provide more heterogeneous velocities and diverse bathymetry and topography along the meander sequences, thereby creating more complex habitats.

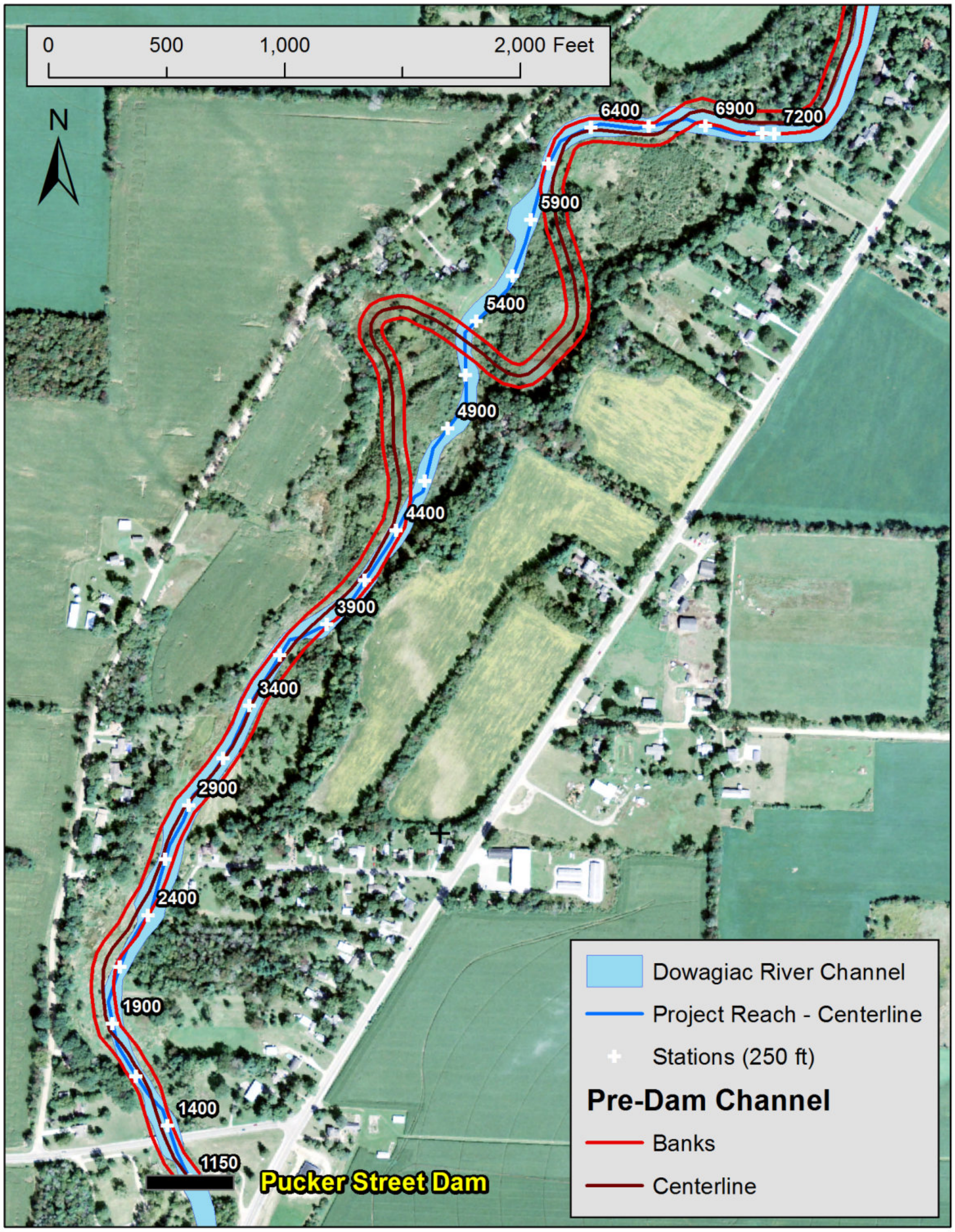

Figure 18. The Dowagiac River pre-dam planform alignment.

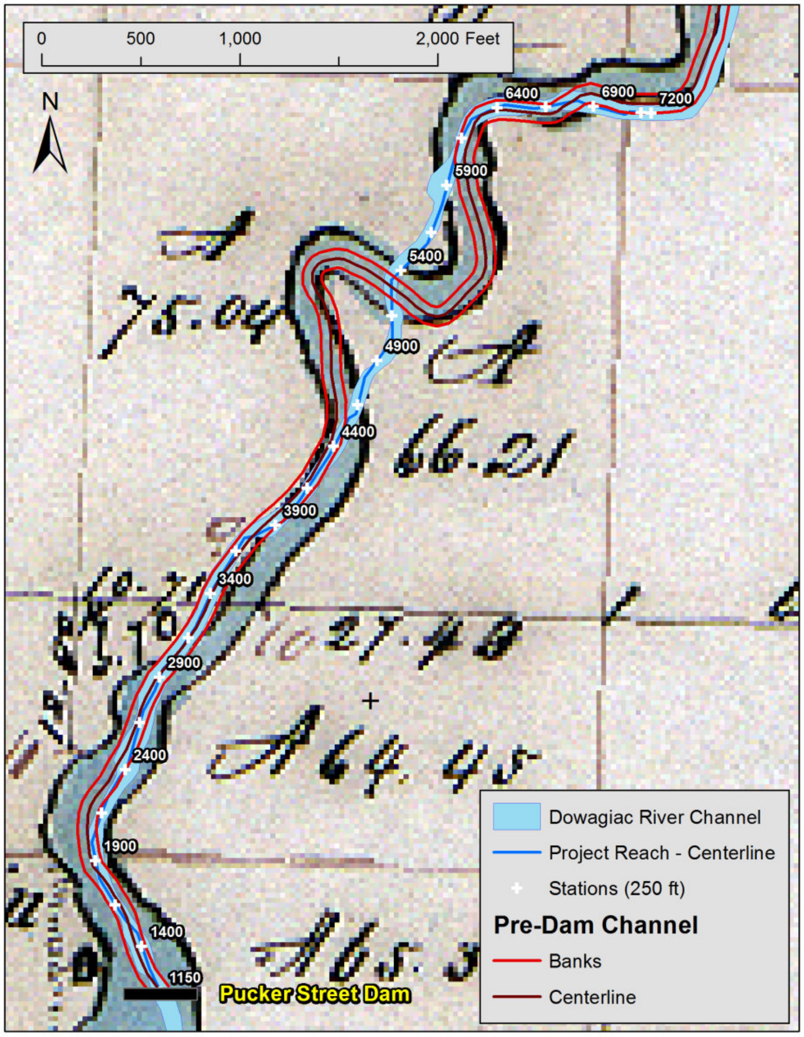

Figure 19. GLO map of the Dowagiac River channel alignment in 1868.

The remaining pre-dam channel alignment, above the bends, extends to Station 7200 where the channel transitions from the formerly ponded area to the upstream reach characterized by a narrower, forested floodplain and more gravelly bed. No work is anticipated in this subreach. The river at this location was likely impacted by Pucker Street Dam, and has adjusted since the 1999 drawdown. Following dam removal, continued adjustments will likely be smaller in comparison and limited to coarsening bed material and a slight decrease in water surface elevation.

A second option considered for the project channel alignment is to leave the river in its existing configuration. After dam removal, the channel along both the historical and existing alignments will be similar between the dam and Station 4500. Upstream of Station 4500, the existing channel planform does not follow the DOR elevations and mapped meander bends, leaving a straighter and steeper channel than the proposed historical alignment. Using the existing channel alignment reduces opportunities to improve overall channel and riparian habitat and limits the dam removal's impact on ecological restoration, at least in the short term; however, it also reduces costs, both in excavation and sediment management. Because we anticipate a budget that will not be sufficient to fully excavate the pre-dam meanders, leaving the river in the existing alignment is the project partners' preferred option.

Proposed Channel Cross Section

A number of methods were applied to estimate stable cross-sectional geometry for the Dowagiac River through the project reach, including using reference reaches as guides to channel sizing, estimating widths and depths based on regional hydraulic geometry studies, and using bankfull flow estimates to refine the final dimensions.

Hydraulic geometry equations for Michigan streams (Rachol and Borley-Morse, 2009) provide estimates of channel dimensions using drainage area as the only independent variable. The drainage area at the dam is 282 square miles and at the upstream end of the project area, Kinzie Road, the drainage area is 281 square miles. The equations were used to develop values for several channel geometry variables (Table 5).

Table 5. Channel geometry predicted by empirical equations from Rachol and Borley-Morse (2009).

Channel Parameter	*Predicted by geometry equations*
Width	98.0 ft
Depth	3.1 ft
Width/Depth ratio	31.9
Bankfull discharge	861 cfs

Channel dimensions were further defined by observing channel reaches downstream from the dam and just upstream from the impounded area. The downstream reach is steeper and has been impacted by a lack of sediment supply below the dam; therefore, below the dam, the channel has larger grain sizes, greater channel width, and shallower channel depth. The channel upstream of the historic impounded area likely provides a slightly better reference reach as sediment is still being supplied from upstream. Results from the reference reach analysis are provided in Table 6.

Table 6. Channel dimensions observed at reference reaches along the Dowagiac River upstream and downstream of the project reach.

Downstream Reference Reach	
Average Width	110 ft
Average Depth	3.7 ft
Average Width:Depth	30
Upstream Reference Reach	
Average Width	88 ft
Average Depth	4.2 ft
Average Width:Depth	21

To refine the proposed cross-section geometry, the channel was designed to pass an estimated bankfull flow. The bankfull discharge was predicted using the estimated annual flood quantiles at the Sumnerville stream gage and then transferring the data downstream by the ratio of drainage area. The 1.5 year annual recurrence interval flood, approximately 1015 cfs, was used as a first prediction of bankfull discharge (see Hydrology Section). The bankfull discharge was then routed through a trapezoidal channel using Manning's equation.

$Q = (1.49AR^{2/3}S^{1/2})/n$

Where A = channel area

R = hydraulic radius (A/Wetted Perimeter)

S = slope = 0.0024 ft/ft based on DOR data representing historic bed elevations but existing channel alignment

N = roughness = 0.038 based on existing bed material and Strickler's equation.

A range of potential channel geometries were calculated based on fitting depths and bottom widths to the estimated bankfull flow of 1015 cfs (Table 7).

Based on the channel geometry analyses summarized previously, a channel top width between 90 and 100 ft appears appropriate as it is narrower than the sediment starved downstream reach and wider than the upstream reach that has a slightly lower slope. Further, a width to depth ratio (W:D) of 31 was chosen as it was close to the downstream reach and the hydraulic geometry results. The upstream reference reach did not factor into the W:D decision as some legacy effects from the dam likely elevate bankfull depths relative to "natural" conditions.. Applying 2:1 side slopes and the W:D ratio and bankfull channel width requirements to the suite of bankfull channel dimensions results in an 82 ft wide channel bed width, a 94 ft top width, and a depth of 3.0 ft.

Table 7. Range of channel dimensions based on fitting depths and bottom widths to the estimated bankfull flow.

Bottom Width Feet	*Top Width Feet*	*Depth feet*	*Area ft^2*	*Wetted Perimeter feet*	*Hydraulic Radius feet*	*W/D*	*Shear Stress lbs/ft^2*
70	83.3	3.32	254.2	84.8	3.00	25.1	0.45
72	85.1	3.26	256.3	86.6	2.96	26.1	0.44
74	86.9	3.21	258.4	88.4	2.92	27.0	0.44
76	88.7	3.16	260.5	90.1	2.89	28.0	0.43
78	90.5	3.12	262.5	91.9	2.86	29.0	0.43
80	92.3	3.07	264.6	93.7	2.82	30.0	0.42
82	94.1	3.03	266.6	95.5	2.79	31.1	0.42
84	95.9	2.99	268.6	97.4	2.76	32.1	0.41
86	97.8	2.94	270.6	99.2	2.73	33.2	0.41
88	99.6	2.91	272.6	101.0	2.70	34.3	0.40
90	101.5	2.87	274.5	102.8	2.67	35.4	0.40

Floodplain Width Analysis

The proposed *bankfull* dimensions described above only define a channel that passes the 1.5 year recurrence interval flood, not the entire channel that will be excavated through the existing impoundment materials, either naturally or mechanically. Figure 15 indicates that bank heights, when extended from the proposed bed elevation to the existing sediment surface, will range from 18 feet at the dam to around 10 feet at the upstream end of the proposed alignment. With 2H:1V bank slopes and large bank heights, the resulting channel will hold flows well over the 100 year return interval flow (Figure 20). The channel may seem somewhat canyon-like, and the existing floodplain surface will be abandoned and revert to an upland condition in most areas. This situation makes establishing riparian vegetation and in-channel habitat difficult. Additionally, flood flows confined by the high banks will likely force widening within the narrow channel area, ultimately leading to natural development of an inset floodplain as sediment erodes laterally in the reach. This additional eroded sediment will be delivered downstream in the process. The excavation volume for this channel configuration along the existing alignment, with no floodplain bench construction, is about 203,000 CY. A similar amount, at least, would be expected to evacuate naturally over time if no channel excavation is conducted.

In situations where channels are actively cut into relatively deep sediments, floodplain benches provide a number of advantages. Spreading flood water laterally over the bench decreases energy within the channel, and during floods, the wider overall channel will store more water, attenuating downstream flooding and increasing groundwater-surface water interactions. The bench also presents an area for vegetation recruitment and establishment. The vegetation cover provides natural resistance to the erosive forces of water along the bench surface and along the banks. The floodplain bench can also be used to create off-channel habitat and flood refugia. For instance, where groundwater elevations are high, pocket wetlands can be fostered by excavating low spots (i.e., scrapes) in the bench.

In the case of a 20 foot bench, the lower surface would extend 20 feet from the top of the design channel before starting up the slope to the top of the impounded sediment (Figure 21). Benches should not be constructed where they will impact adjacent structures, or where the channel abuts the valley wall. Finally, the benches are often wider on the inside of bends to replicate point bars. Excavating 20 foot benches along the entire existing alignment will add about 102,000 CY to the excavation quantity, bringing the total excavation to approximately 305,000 CY of sediment. Depending on final budget, the project partners may elect to excavate a floodplain along only a portion of the channel to reduce sediment volumes. Excavation volumes would increase to 115,000 CY and 430,000 CY for floodplain and total excavation, respectively, if project partners chose to pursue restoration of the pre-dam alignment.

During the concept phase analysis, general channel and floodplain geometries were combined with flow duration and peak flow statistics to develop a, steady-state hydraulic model using the U.S. Army Corps of Engineers' HEC-RAS program. The analysis was based on restoring the channel to the pre-dam alignment, therefore the slope is slightly flatter (0.0019) than the proposed condition slope of 0.0024. However, the general patterns are expected to be similar so the analysis conducted is presented here.

The program is one-dimensional; therefore, there is no direct modeling of multi-dimensional hydraulic effects of cross section shape changes, bends, and other two- and three-dimensional aspects of flow. The hydraulic model calculates channel and floodplain water velocities, depths, and shear stresses for various input flows (developed above in Table 3). Models were set up for general existing conditions, and proposed trapezoidal channel conditions to begin understanding post removal hydraulics of the channel. The proposed conditions included a "no floodplain" scenario, in which the channel geometry continued at a 2H:1V slope from the channel bottom up to the existing impoundment surface (Figure 20), a 20 ft floodplain bench width (40 ft total floodplain width; Figure 21), and a 50 ft floodplain bench width (100 ft total floodplain width). The model was constructed only for this evaluation and has not been developed within the calibrated model of the river.

The model allowed comparison of water surface depths, velocities and shear stresses for multiple floods (Table 4), for the three described floodplain scenarios. At the 10YR return interval flood, channel depth decreases by 0.1 ft when adding 20 ft floodplain or 50 ft benches to the cross section. At the 100 yr return interval flood, the depth decreases by 0.2 ft for 20 ft benches and 0.3 ft for 50 ft benches. This translates into small differences in energy dissipation, as seen in the change in shear stress. Comparing the shear stress in the project site during a 100-yr return period flood to the "no floodplain" condition, the addition of 20 ft floodplain benches offers insignificant relief of 0.02 lbs/ft^2, and 50 ft benches lower shear stress by just 0.03 lbs/ft^2.

Based on this analysis, floodplain benches in the project would appear to function largely for ecological value and safety, rather than as a conveyance for flood energy. However, the need to develop vegetation as a resisting element to channel migration is a critical stabilization component along the river corridor that will be limited without a bench. Given these findings, we propose including a 20 ft (average) bench on each side of the river wherever possible given budget limitations. If budget precludes incorporation of benches for the entire length of the river, we propose including them at the downstream end and continuing up as far as budget allows.

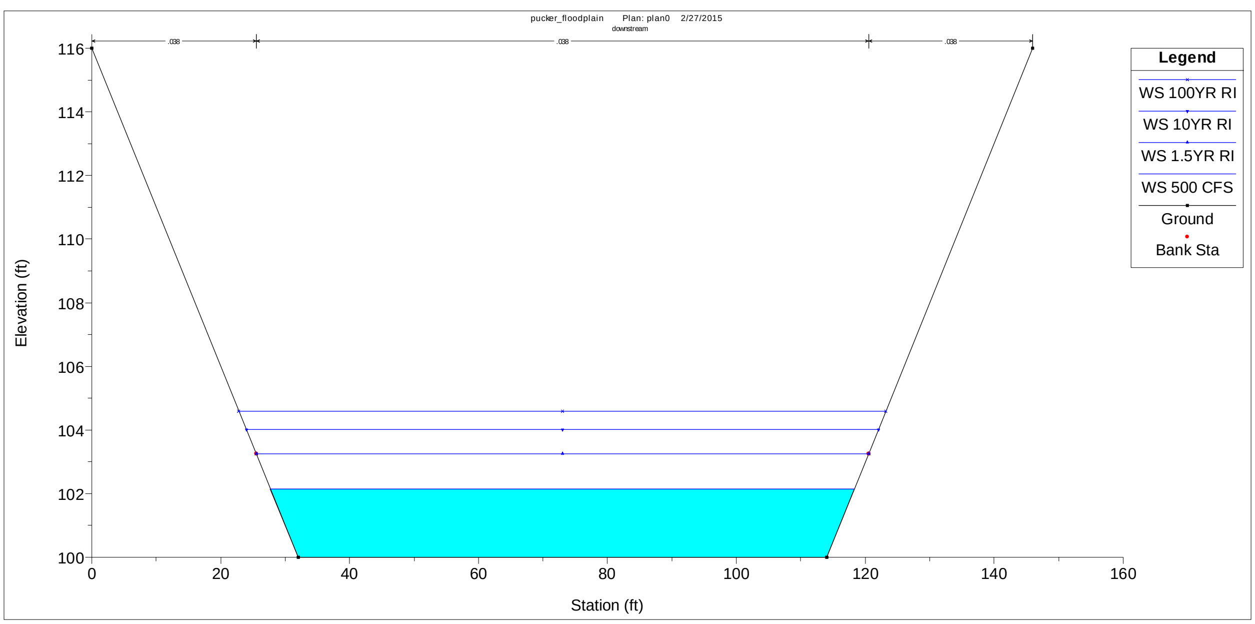

Figure 20. Floodplain cross section based on a 16 foot excavation depth and 2:1 slopes and no floodplain bench. 500 cfs represents an average flow for the study reach.

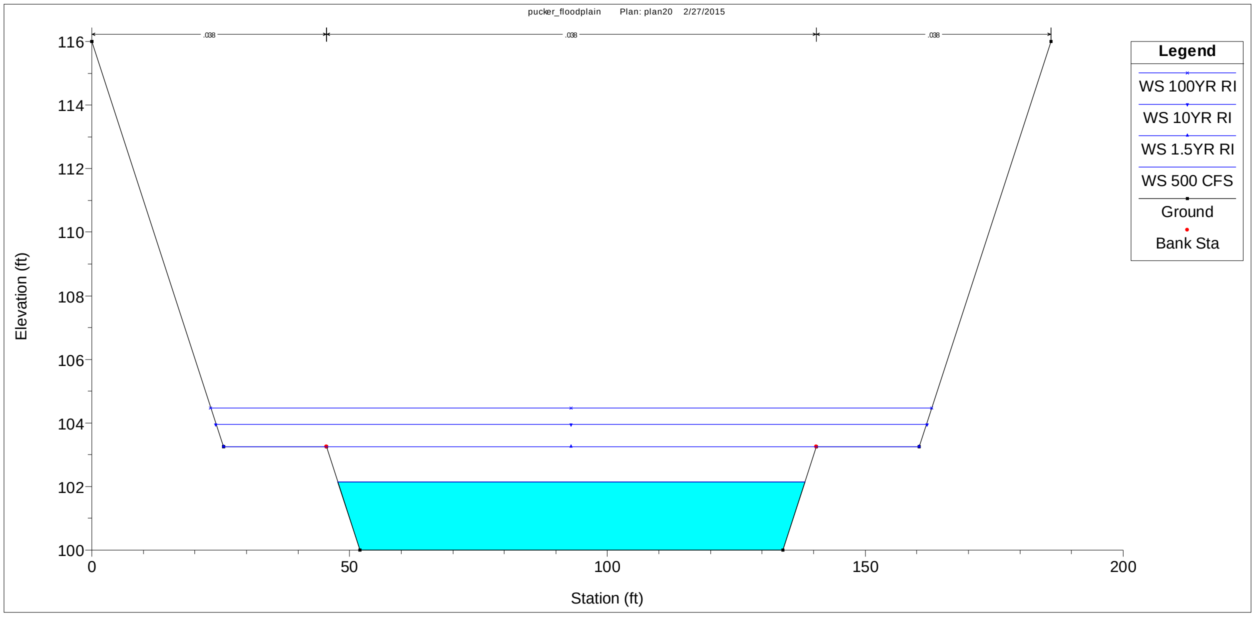

Figure 21. Floodplain cross section based on a 16 foot excavation depth and 2:1 slopes, and 20 foot floodplain benches. 500 cfs represents an average flow for the study reach.

Table 4. Changes in channel dimensions with varying flows and floodplain bench widths. 500 cfs represents an average flow for the study reach.

Flood	*Discharge (cfs)*	*Floodplain Width (ft)*	*Flow Area (sq ft)*	*Top Width (ft)*	*Max Depth (ft)*	*Shear Channel (lb/sq ft)*	*Shear Floodplain (lb/sq ft)*	*Velocity (ft/s)*	*Slope (ft/ft)*
500 CFS	505	50	185.3	90.6	2.2	0.24	0.00	2.7	0.0019
500 CFS	505	20	185.3	90.6	2.2	0.24	0.00	2.7	0.0019
500 CFS	505	0	185.3	90.6	2.2	0.24	0.00	2.7	0.0019
1.5YR RI	1015	50	287.9	195.0	3.3	0.35	0.00	3.5	0.0019
1.5YR RI	1015	20	287.7	135.0	3.3	0.35	0.00	3.5	0.0019
1.5YR RI	1015	0	287.6	95.0	3.3	0.35	0.00	3.5	0.0019
10YR RI	1483	50	414.4	197.6	3.9	0.43	0.08	4.0	0.0019
10YR RI	1483	20	384.9	137.9	4.0	0.44	0.08	4.1	0.0019
10YR RI	1483	0	362.2	98.1	4.0	0.44	0.04	4.1	0.0019
100YR RI	1874	50	499.0	199.3	4.3	0.48	0.12	4.3	0.0019
100YR RI	1874	20	454.2	139.9	4.5	0.50	0.13	4.4	0.0019
100YR RI	1874	0	418.5	100.4	4.6	0.51	0.07	4.5	0.0019

SEDIMENT MANAGEMENT

1999 Drawdown

An initial drawdown and passive sediment release occurred at Pucker Street Dam in May 1999 when the gates were permanently opened (Wesley, 2008). Water levels were dropped 5 feet and a slug of sediment was released into the river below the dam. A week after the drawdown, turbidity increased and remained high for about three weeks while the river cut downward to a new, lower channel elevation through the impoundment. Formerly flooded sediments in the impoundment were exposed after the first week of the draw down. By August 1999, the turbidity within and downstream of the impoundment was the same and appeared to be back to normal levels for the river. A wave of sandy bedload material was noted in the downstream channel in June following the drawdown. The sand moved as a coherent slug, increasing in thickness, by up to 18 inches, and then decreasing again at subsequent downstream monitoring stations as it spread and progressed towards the St. Joseph River. By July 21, 1999, sand was clearing from steeper sections (e.g., riffles) in the reach downstream of the dam but persisted in the lower velocity runs and pools. A year after the drawdown, sand had mostly evacuated in areas immediately below the dam, and continued to progress downstream (Wesley, 2008).

After the initial sediment slug was released, a sediment trap was constructed between the dam and Pucker Street to capture material prior to entering the reach below the dam. Approximately 35 tons/day of sand was caught by the 110 ft long, 70 ft wide and 12 ft deep sediment trap over the first few months after installation. The trap required monthly dredging, but it is not clear if dredging was scheduled, or if the trap filled on a monthly basis. If the trap filled before scheduled dredging, additional material would have passed downstream. Sediment delivery from above Pucker Street Bridge remained high through the fall of 1999, but decreased to about 5 tons/day in spring, 2000. The trap was maintained until September 2002 when bedload estimates at the dam were equivalent to background estimates (about 1 ton/day). Overall, the sediment trap was cleaned 14 times, removing approximately 48,000 cubic yards of sand at a total cost of approximately $50,000. Three years after the draw down the river channel had stabilized considerably in the former impoundment. Continued bank erosion during high flows periodically added sediment to the system. The river below the dam recovered to near pre-draw down conditions. Riffle and run substrates returned to gravel and cobble, and the pools deepened. However, sand that was not there prior to draw down persisted along the margins of the river. Based on the channel dimensions established after the drawdown (Wesley, 2008), roughly 100,000 CY of sediment was estimated as the release from the impoundment between 1999 and 2002. Although no measurements were made, up to half of the material could have passed downstream of the dam (Wesley, personal communication).

Active versus Passive Sediment Management

Passive restoration of a stream entails removing the major impediment to natural river function, in this case a dam, to natural river function and allowing the river to restore itself over time. The advantage to this approach is the low cost, as it requires little work in the impoundment to control sediment or foster more natural channel characteristics. Low cost comes at the expense of time, as the river will evolve through a lengthy process of erosion and migration that may require decades to centuries to arrive at the restored condition. It can also have a negative short term impact on downstream reaches as large volumes of sediment may be delivered below the dam.

Active restoration entails not only removing the impediment to natural function, but also using mechanical means to create a stable channel form with higher ecological function. The advantage to this approach is that the time scale for recovery is shortened, and short term impacts are reduced, particularly those impacts associated with transport of sediment below the impoundment. This advantage is offset by the significant capital expense of the project.

Passive Sediment Management

Under a passive sediment management scenario, the dam is breached or removed with little or no sediment management. The channel within the impoundment is allowed to freely adjust its slope and form via incision, widening, and meandering (Figure 2 and Figure 3); and the resulting eroded sediment is allowed to flush downstream unimpeded. These adjustments will continue until the channel develops a form consistent with the flows and sediment regime imposed on it.

If passive management is utilized and the Dowagiac River follows general post-dam removal patterns of incision within the impoundment (Figure 2), adjustment through the reservoir materials will likely generate steep, unvegetated slopes left behind as the channel cuts away sediment to return to a more natural bed level. The river bed occupied after incision will likely have elevations similar to the bed prior to building the dam. These elevations are estimated by the DOR data along the channel (Figure 15). The banks will be roughly 10 to 18 feet high within the former impoundment (Figure 15), and will likely be too steep and unstable to establish vegetation. With no vegetation for long term stabilization, the channel will likely widen over time and form a new floodplain inset into the impoundment sediments. The exact nature of sediment transport and downstream depositional patterns associated with this sediment evacuation is difficult to predict accurately. The speed at which this process progresses will be governed by the magnitude and frequency of high flows that act on the channel following dam removal.

Active Sediment Management

The anticipated general pattern of channel evolution after a dam removal can be used to organize sediment stabilization efforts within the former impoundment. The evolutionary process (Figure 2) can be accelerated, and downstream sediment impacts can be reduced. Under an active sediment management scenario, sands and silts in the impoundment would be mechanically removed down to the pre-dam channel bed elevation and channel width. This represents the volume of material most likely to mobilize downstream following removal of the dam.

Because the 1999 drawdown produced a significant sediment slug, and because there are fishery, recreational, and infrastructure considerations downstream, active sediment management is desired for the Pucker Street Dam project. The initial incision that would be expected under a passive management scenario can be mimicked by excavating the channel to the proposed bed elevations, which are based on the DOR survey (Figure 15). The bank slopes from the channel bed to the existing sediment surface should not be steeper than 2H:1V. The excavation allows reaching a relatively stable endpoint quickly while controlling the release of sediment. In this alternative, the channel will be aligned to match the historical channel location. Due to the depth and extent of the sediment stored behind Pucker Street Dam, active sediment removal will require large scale cut and fill.

Sediment Volumes

The Pucker Street Dam impoundment stores roughly 1,026,000 CY of sand and silt. This value does not include coarser gravel material stored along the channel upstream of the impoundment to Kinzie Road, which could amount to an additional 43,300 CY. This coarser material is best left in the river as substrate. Only sediment associated with establishing a new river channel and floodplain must be managed. Sediment outside of this corridor can be left in place. An estimated 203,000 CY of sediment will need to be excavated to achieve the “no floodplain” scenario along the existing alignment. If moved to the historic alignment, approximately 315,000 CY would need to be excavated for the “no floodplain” scenario. Similar amounts of material would be expected to evacuate from the impoundment if the channel only progressed to *Stage 3* (Figure 2) under a passive sediment management scenario (i.e., no floodplain development). Adding an average 20 foot bench to both sides of the channel (i.e., 40 foot floodplain) increases the amount of required digging by 102,000 CY for the proposed alignment and 115,000 CY for the existing alignment.

It is important to understand that the channel will continue to evolve over time. Particularly during the first few years after dam removal, before vegetation becomes well established, channel banks will be susceptible to erosion. We are not proposing stabilizing the banks of the excavated channel with erosion control fabric or stone because the cost of running those treatments along the full length of the excavated river would be prohibitive. Leaving a sediment trap in the lower impoundment may help reduce the amount of eroded material from traveling downstream.

Contamination

Results (see appendix for full summary submittal) were submitted to the MDEQ for review and concurrence with our findings. Based on this review it was determined that the dredged sediment is considered clean (inert and suitable for unrestricted upland disposal) and can be used as unrestricted fill material.

The results show that only concentrations of arsenic, selenium and zinc in some samples exceed the statewide default background levels however the Upper Confidence Limits (UCL) for arsenic and zinc are below the accepted state background levels for this area. Although the UCL for selenium at 480 parts per billion (ppb) exceeded the default background limit of 410 ppb this is still a low enough concentration to not exceed the part 201 (environmental remediation) criteria.

Pipeline Crossing

Two Transcanada/ANR natural gas pipelines cross the Dowagiac River at Station 4200. The pipes consist of a 24 inch diameter line and a 22 inch diameter line running parallel to each other. Both are buried below the channel, and a 2015 inspection indicated a minimum cover of 3.9 ft over the 22 inch pipe and 3.1 ft over the 24 inch pipe. Depth-of-refusal probing in this section of river suggests the pre-dam channel bed is likely 5 to 7 feet below the existing bed (Figure 15), which indicates the pipes were buried in post-dam reservoir sediment. If the channel is allowed to passively achieve its pre-dam bed elevations, the pipes will eventually be exposed and elevated above the bed. This would be an unacceptable condition that risks both the integrity of the pipes, particularly given the likelihood of debris accumulating on them to an unpredictable degree, and risks the safety of recreational users. The pipes will be relocated at a sufficient depth below the expected grade of the pre-dam channel. Project partners are currently planning to proceed with pipeline reconfiguration and are discussing solutions with Transcanada/ANR.

Access / Locations for Spoils

Due to the confined valley within the project area, access and excavated sediment disposal requires careful consideration. Access can be achieved at the dam site, at the city-owned parcel near station 6400, and with the necessary permission, might be possible at some of the privately owned properties along the valley.

A number of opportunities exist for disposing the excavated sands from the valley. Spoils from the sediment trap during the 1999 drawdown were placed next to the dam site, and there appears to be additional room for storage within the city-owned park. Material could also be placed in the existing floodplain area not impacted by the proposed in-channel work. The most inexpensive approach is to keep material on-site. Based on analysis of sediment volumes and available area for disposal within the existing impoundment, former raceway, and city park, we anticipate keeping all material on site.

We are working with project partners to finalize access locations.

HABITAT RESTORATION

Habitat potential for the project lies largely within two realms, the in-channel habitat and the floodplain habitat. The overall goal for any habitat project is to increase the complexity of depths, flow velocities, vegetation, and other elements, which in turn increases the type and abundance of species that utilize such areas.

Floodplain Habitat

The existing floodplain has developed on the impounded sediment surface exposed after the 1999 drawdown. It includes floodplain wetlands, remnant side channels, and microtopography, although it may be somewhat disconnected from the channel in some sections. Following removal, this surface will dry considerably and vegetation may shift to comprise more upland species. Constructing inset floodplains during excavation (i.e., 20 ft bench) will allow for the addition of planned topographic variation such as shallow wetland scrapes and shallow deposits of fill to augment the existing topographic variation. Excavation of a floodplain bench will also foster vegetation development, which is important for habitat and erosion resistance. Under a "no floodplain bench" scenario, floodplain benches will develop over time as sediment is eroded and deposited along the channel margins and vegetation naturally proliferates. In general, channel banks will be self-forming through the project area, but development of stable banks may be slower and will result in sediment migration to the downstream reach under a passive or "no floodplain bench" scenario.

In-Channel Habitat

Wood

Habitat within the newly excavated channel will be augmented by the construction of wood complexes and single log pieces. Analogs of these exist within the current channel, both upstream and downstream of the project reach (Figure 22). A complex of large wood provides important habitat for adult and young of the year fish. In-channel wood also induces scour and deposition within the channel, creating bed variability and habitat heterogeneity. Installation of large wood remains an option in the proposed design and will be dependent on the final budget and contractor bid prices. If installation of large wood is completed as part of this project, wood will not span the channel, and will be compatible with paddler use of the river. Placed wood may require periodic maintenance to ensure captured debris from upstream does not completely block the channel.

Figure 22. Examples of single log and wood accumulations along the Dowagiac River.

Pool and Riffle Habitat

Bed forms (e.g., pools, riffles, runs, etc.) associated with the pre-dam channel are currently buried by fine sediment trapped by the dam. Dam removal will uncover many of these features, thus, reestablishing a more heterogeneous channel form. The DOR survey indicated the historic bed in the project reach contained gravels as well as sand. These gravels, and possibly coarser material, will be exposed along the project reach following removal, and will also be delivered to the project reach from upstream. Reactivating the natural transport of these materials will maintain the exhumed bed features, and reestablish river function and process.

Pools will develop in two places within the project reach: 1) on the outside of meander bends and 2) in association with local scour from obstructions (e.g., wood) encountered in the channel. Pools on meander bends often develop in concert with point bar sediment deposited on the inside of a bend. Point bars are not common above the dam along the Dowagiac River largely because the channel was straightened. Field observations of point bar development upstream of the project site (Figure 23) provide examples of this process. Given that we are not reestablishing the pre-dam meanders, bend scour will be initially limited. However, as the stream evolves and creates new meander bends, we expect these features to develop.

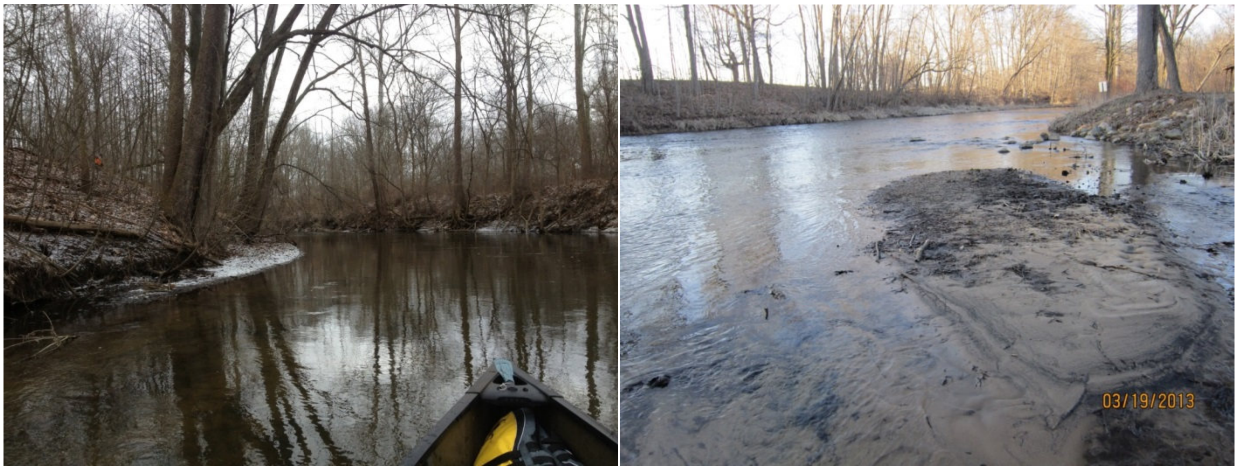

Figure 23: Bends in the Dowagiac River upstream of the study area exhibit weak point bar formation with a coincident deeper pool on the outside of the bend.

Proposed Changes at Pucker Street Dam

The dam and the area around it pose additional constraints and opportunities for the project. First, channel position will be maintained under the Pucker Street Bridge and through the dam site. The concrete wall along the east bank at the dam (Figure 24) will likely be left in place, but it will be hidden and the vertical drop will be eliminated by creating a stone toe with fabric encapsulated lifts on top. The upper portion of the slope will be vegetated with native plants that will not require mowing. On the west side of the river, the bank will be shifted to the east enough to accommodate the material placed along the eastern wall while maintaining the conveyance capacity of the upstream reach. The bank will slope up to the existing ground surface at the island to create a natural bank that allows for access to the water by both people and wildlife. Both banks will tie into the existing topography within a few hundred feet downstream of the dam.

Some of the material excavated from the impoundment will be used to fill the upstream raceway adjacent to the dam. The raceway is currently spanned by a foot bridge which will be replaced by a wider land bridge created from fill material. The lower end of the raceway may be left open for additional backwater habitat or perhaps to accommodate recreational access.

Figure 24. Concrete wall along the east bank below Pucker Street Dam.

DEMOLITION AND DEWATERING

Prior to the start of demolition, dredging of the area behind the dam will be performed to create a sediment basin during the drawdown of the river. Demolition will start with the powerhouse and the removal of the hazardous materials and equipment followed by the structure above the main floor elevation. To accommodate a possible flood flow during construction the overflow spillway will be removed to the current water level.

Once this is complete a sheeting and king pile cofferdam will be installed to isolate the west portion of the spillway consisting of the first three bays including the one that has been sealed that the office room sits above. The upstream portion will be isolated first and then the downstream portion. The cofferdam will then be partially dewatered to allow bracing and rakers to be added as the hydraulic pressure increases. Once the bracing is in place the cofferdam will be fully dewatered and the spillway demolished down to the concrete apron elevation of approximately 663.41 feet. Simultaneously split bulkhead style gates will be installed in the cofferdam.

When everything is ready the sheeting in front of the gates will be removed and the gates gradually opened drawing down the river in a controlled manner to the approximate tailwater elevation of 666 feet. The intent is to use a split bulkhead where the upper bulkhead can be gradually lifted to allow the water surface to fall to the elevation of the lower bulkhead. After the top bulkhead is removed, the bottom bulkhead will be gradually lifted until water surfaces reach the final drawdown level. Once the new river level is established, the cofferdam structure shall be removed, the bridge pier support work will occur, and the concrete apron removed. The remaining spillway will then be isolated and removed.

The final portion of the demolition will be to remove the remaining portion of the powerhouse structure and any additional structural removal needed to reshape and restore the channel from the bridge to the downstream end of the project.

CONCEPT LEVEL COSTS

The concept level engineer's opinion of probable construction costs indicates the project will cost approximately $3.4M, including alternative items aimed at improving in-channel habitat. Just under half of the estimated costs are associated with excavating and disposing of the impoundment sediment. Powerhouse demolition and dam disposal accounts for $1M of the estimate.

60% - Engineer's Opinion of Probable Construction Costs				
BASE BID				
Description	**Unit**	**Quantity**	**Unit Price**	**Subtotal**
Mobilization and Controls	LS	1	$118,000	$118,000
DAM REMOVAL	**Unit**	**Quantity**	**Unit Price**	**Subtotal**
Powerhouse Demolition and Dam Disposal	LS	1	$956,000	$956,000
Bridge Stabilization	LS	1	$100,000	$100,000
BANK STABILIZATION	**Unit**	**Quantity**	**Unit Price**	**Subtotal**
Bank Stabilization (East Wall) - Rock	CY	240	$75	$18,000
Bank Stabilization (East Wall) - FES Lifts	FF	750	$40	$30,000
Channel Excavation (West Bank)	CY	1200	$6	$7,200
Steep Slope Hydroseed	AC	2.0	$2,500	$5,000
SEDIMENT MANAGEMENT AND RESTORATION	**Unit**	**Quantity**	**Unit Price**	**Subtotal**
Excavate Sediment within Channel (reuse within former impoundment area)	CY	203000	$6	$1,218,000
Install and Maintain Sediment Traps	EA	4	$5,000	$20,000
ALTERNATE BID ITEMS (PENDING FINAL BUDGET)	**Unit**	**Quantity**	**Unit Price**	**Subtotal**
Floodplain Excavation (up to 102,000)	CY	30000	$6	$180,000
Large Wood for In-Channel Habitat (up to 300)	EA	100	$450	$45,000
In- Channel Dig and Pitch (Operator and Excavator) (upto 15)	DAY	0	$2,000	$0
Seed (floodplain mix) Floodplain Corridor (upto 15)	AC	8.0	$2,000	$16,000
			Sub Total base bid items	**$2,472,200.00**
			Sub Total IFI alternate items	**$241,000.00**
			Contingency (15%)	**$406,980.00**
			Construction Oversight	**$300,000.00**
			Total	**$3,420,180.00**

SUMMARY

The removal of Pucker Street Dam presents significant opportunities and challenges. Challenges include the size of the Dowagiac River, the interaction with the Pucker Street Bridge, and the volume and depth of material stored within the impoundment. Removing the dam provides an opportunity for restoring a unique high gradient, cold water habitat for both the Dowagiac River system, and all of southern Michigan.

Construction funding will dictate the extent of active restoration elements that can be included within the project. At a minimum, removal of the dams and proper management of sediment will be priorities. Other desired elements of the project can be enacted later if and when funds are available. Budget constraints, short term sediment management concerns, and other factors limit the project partners' ability to fully restore the pre-dam river. A compromise solution that allows fish passage, habitat enhancement within the channel, partial floodplain excavation, at a significantly lower cost, is proposed. This proposed solution entails excavating a channel along the existing alignment that has partially cut through the impoundment sediment. In the long term, natural processes will allow the river to fully re-establish geomorphic and biologic health.

A primary goal of the project is to limit the impact of downstream sediment transport, a concern developed from stakeholder experience with the 1999 drawdown. Active sediment management represents the best means to accomplish this goal. Sediment will be managed using active approaches to the greatest extent practical, although minor incidental sediment release should be expected. Significant turbidity will persist while active construction in the channel is occurring, but will be limited following conclusion of construction. Excavation and sediment management will include construction and operation of at least one sediment trap. Excavated material will be reused within the existing impoundment footprint.

A floodplain will be excavated to the extent that budget allows beginning in the lower impoundment near the existing dam site. In areas of active excavation, seeding is expected to promote quick establishment of vegetation. Woody species such as trees and shrubs are not included but may be added if final budget allows.

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APPENDIX

Wightman Environmental, Inc. Sediment Regulatory Summary

Wightman Environmental, Inc. Asbestos Inspection Report

Wightman Environmental, Inc. Lead Base Paint Report

Wightman Environmental, Inc. PCB Report