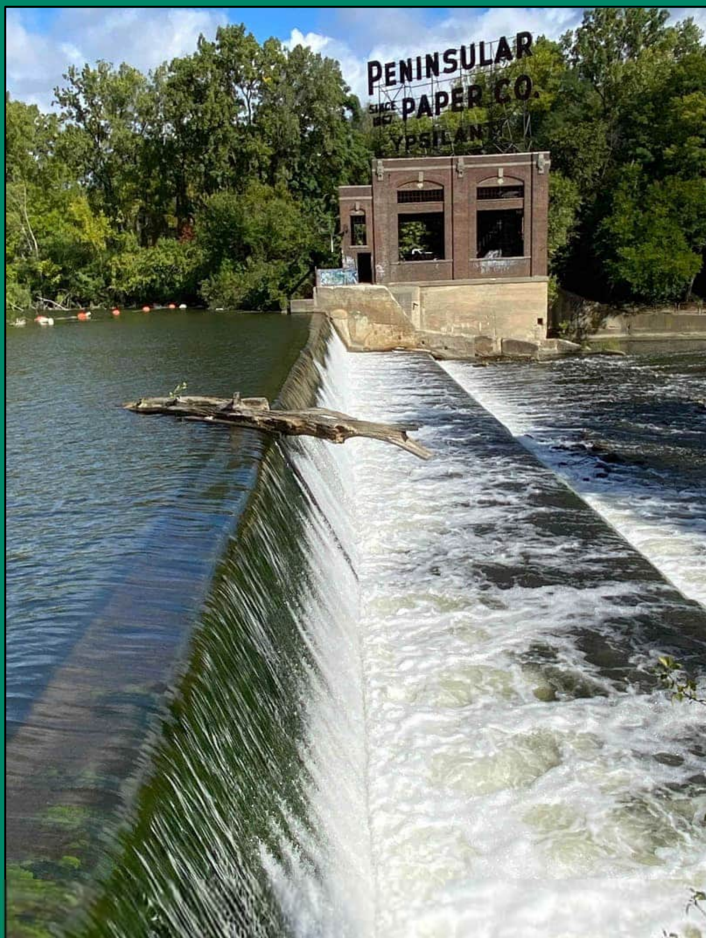

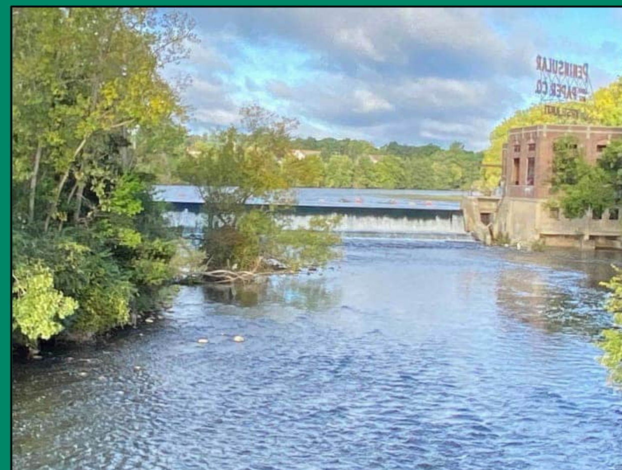
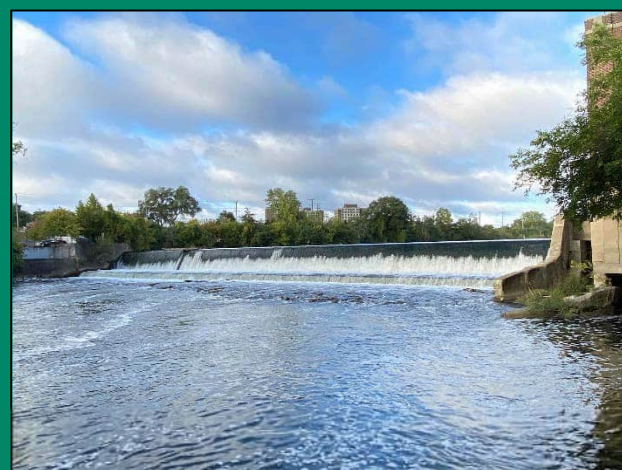

Peninsular Paper Dam Removal

30 Percent Design Basis of Design Report - Draft

City of Ypsilanti and Huron River Watershed Council

Project number: 60689060

Submitted: December 14, 2023

Delivering a better world

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1. Introduction and Purpose

The Peninsular Paper Dam (Pen Dam) is located on the Huron River in Ypsilanti, Washtenaw County, Michigan approximately 550 feet upstream of the Leforge Road bridge (Figure 1). The dam was originally constructed in 1867 to provide hydropower for paper manufacturing; however, the dam no longer generates power, and all electricity-generating equipment has been removed from the powerhouse. The original dam failed in 1918, was rebuilt in 1920 and is currently owned and operated by the City of Ypsilanti.

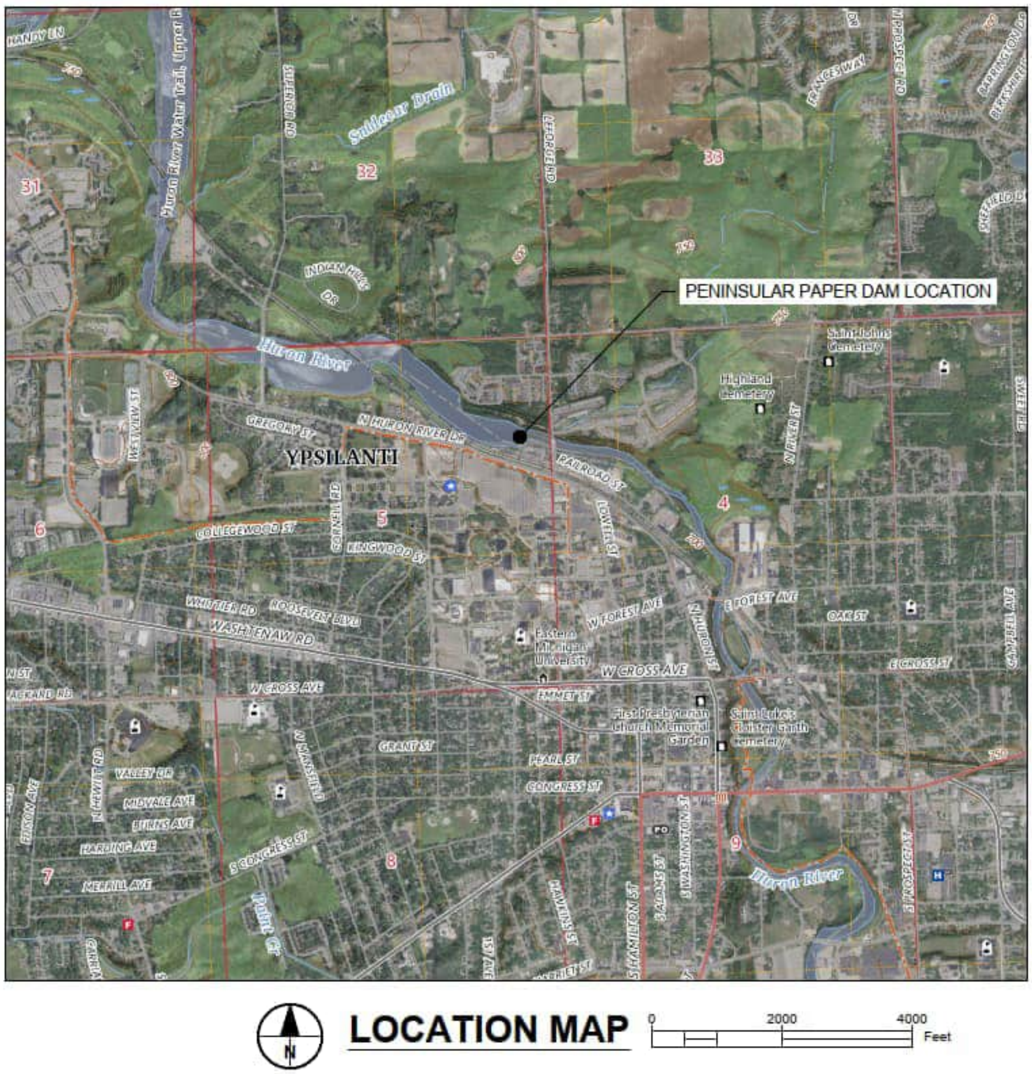


Figure 1. Location Map

The purpose of this report is to document the technical basis of design for the 30 percent Pen Dam removal and Huron River restoration plans. This report includes the presentation of engineering considerations and discussion on major design components and assumptions.

Removal of Pen Dam will provide an opportunity to restore approximately 1.25 miles of the Huron River in the former impoundment, including establishing regular floodplain access, stabilized riverbanks, and planting of native plant species for an overall improvement to the Huron River water quality. The primary goals of this project are to successfully remove the Pen Dam in a controlled manner within minimal downstream transport of impounded sediments, reduce risk associated with dam failure (through removal of the dam), and re-establish natural river processes and ecological health within the former impoundment. The following are project objectives intended to help the project reach its goals:

- Eliminate safety issues involving the existing dam structure and potential dam failure by removing the dam.
- Re-establish connectivity for fish, aquatic organisms, flow, sediment, and recreational users for upstream and downstream areas.
- Establish a stable channel form which will pass flow and sediment delivered from upstream.
- Provide fish passage and riverine habitat within the restored impoundment to the extent project budgets allow.
- Minimize impacts to adjacent landowners, infrastructure, and sensitive slopes within the former impoundment as well as downstream reaches of the Huron River and Ford Lake.
- Create a community amenity for recreation and ecologic health.

An alternatives analysis was completed in Summer 2023 to document alternatives for dam removal and river restoration including a pilot channel alternative, floodplain bench alternatives, and a full restoration alternative. The selection criteria included hydraulic considerations, sediment transport considerations, restoration opportunities, and cost. A final “blended alternative,” which includes aspects of each evaluated alternative was selected as the preferred alternative by the City of Ypsilanti and the Huron River Watershed Council, and includes the following components:

- Full removal of Pen Dam.
- Full restoration of recovered lands in and adjacent to Peninsular Park on lands owned by the City of Ypsilanti.
- Minimal alteration to recovered lands beyond activities included in the floodplain bench alternative between the railroad bridge and Superior Road Bridge.
- Minimal alternation to recovered lands beyond activities included in the pilot channel alternative upstream of the Superior Road Bridge.

2. Previous Studies and Work Completed

The project team has reviewed and/or completed the following information and work as it relates to the demolition of the Pen Dam and associated restoration of the Huron River.

Peninsular Park Management Plan by the HRWC in 2016

The Peninsular Park is an approximately 7-acre parcel owned by the City of Ypsilanti on the north bank of the Huron River. The primary objective of this document was to develop a plan that will improve scenic views, enhance park user safety, improve park facilities to attract more users to enjoy the park and adjacent river, and to enhance the ecological functioning and habitat value of the park.

Peninsular Paper Dam: Dam Removal Assessment and Feasibility Study by Princeton Hydro in September 2018

A dam removal feasibility study was conducted in 2018 to assess three critical issues that affect the feasibility of removing the Pen Dam: sediment quality and quantity, potential infrastructure/utilities impacts, and riverfront land ownership. While the 2018 Feasibility Study does not encompass all tasks required for a comprehensive feasibility assessments, alternatives analyses, engineering designs, permitting, and construction, the study concluded that none of the foregoing critical issues renders dam removal infeasible, but that these critical issues warrant additional consideration and follow-up.

Peninsular Paper Dam Impoundment Draft Restoration Plan by the HRWC in April 2022

This plan is intended to guide the restoration effort in the Pen Dam Impoundment and nearby areas before, during, and after the removal of the Pen Dam. The plan included a summary of data collected and analyses performed by LimnoTech, Inter-Fluve, and AECOM from LimnoTech's *Removal Design and Supporting Analysis of Peninsular Paper Dam Report* submitted to the HRWC in April 2022. The April 2022 LimnoTech report included the following:

- Sediment Sampling and Analysis
  - As a part of the analysis of the impoundment in preparation for the dam removal design, LimnoTech and a subcontractor collected 33 vibracore samples taken in 11 transects in July 2021. The studies conducted on the samples concluded that the quantity of sediment that may be mobilized by dam removal is relatively small compared to the height of the dam and size of the impoundment, and thus does not preclude dam removal. The sediment sampling performed to date meets the requirements of the Michigan Department of Environment, Great Lakes, and Energy (EGLE) Policy and Procedure WRD-048 with sediment sampling that included characterization of the Michigan 10 Metals and PAHs within the impoundment.
- Bathymetric and Depth of Refusal Survey by Inter-Fluve in 2021
  - Bathymetric surveys were conducted by Inter-Fluve in 2021 to understand the submerged shape of the original river channel. Depth to refusal surveys were also completed to estimate the total volume of sediment present in the impoundment and understand where in the impoundment sediment was deposited.
- Geomorphic Assessment
  - Inter-Fluve conducted a geomorphic assessment of the project area and the reach of the Huron River downstream of Pen Dam in 2021. The findings of the assessment are documented in detail in the project team's report summarizing existing conditions and analyses of the project area (LimnoTech et. al, 2022).

Site Reconnaissance

A site visit was conducted by AECOM, Inter-Fluve, and LimnoTech staff on September 27, 2022, to further familiarize the project team with the site. Please see Appendix A for a photo location map and photo log from the September 27, 2022 site visit.

Topographic Survey

Additional data collection was completed including detailed topographic survey of the Pen Dam's spillway, retaining walls, and Powerhouse in November 2022 by AECOM.

Peninsular Paper Dam Removal Alternatives Analysis Report by AECOM, Inter-Fluve, and LimnoTech in June 2023

The AECOM, Inter-Fluve, and LimnoTech project team completed an Alternatives Analysis Report of the Pen Dam removal and Huron River restoration on February 24, 2023. The report contained a flood attenuation study that concluded the removal of the dam will have minimal effect on river conditions downstream of the dam and the conceptual design of four river restoration alternatives including a pilot channel through the impoundment, two floodplain bench alternatives, and a full river restoration alternative. The project team presented the report to the HRWC and City of Ypsilanti on April 6, 2023, and to the Peninsular Paper Dam Restoration Team on June 20, 2023. On August 10, 2023, the project team received recommendations from the HRWC on the restoration option to proceed with, which included aspects from all alternatives presented in the Alternatives Analysis Report. A "blended" restoration option was selected and is described in detail in the *Proposed Restoration Design* section of this report.

3. Existing Project Features

Pen Dam

According to the EGLE Dam Safety Inspection Report of Pen Dam, dated November 29, 2022, the 250-foot-long dam consists of a 232-foot-long principal spillway, an 8-foot-wide auxiliary spillway, and a 40-foot-wide powerhouse, flanked by short earthen embankments at each end. The auxiliary spillway structure consists of a single, 8-foot wide stoplog bay located between the principal spillway and powerhouse structures. The auxiliary spillway currently contains 8-inch by 8-inch square stoplog timbers that allow for dewatering of the impoundment. The dam has a structural height of 21 feet, a hydraulic height of 19.7 feet, and maintains approximately 14 feet of head with 6.5 feet of freeboard, creating a 66-acre impoundment under normal flow conditions. The dam no longer produces power and is a run-of-the-river structure. The dam is currently owned by the City of Ypsilanti. Photos taken during dam construction in 1920 show a gated low-level outlet structure on the river-left side of the spillway at an elevation nearly equal to the bottom of the spillway. Engineering plans dated from 1983 show the low-level outlet replaced with a stoplog structure which is presently in place (Princeton Hydro, 2018). The low-level gate and electricity-generating equipment have been removed from the dam. The dam is classified as a high hazard potential dam by EGLE due to the downstream urbanized conditions along the Huron River. Figure 2 shows a photo of the downstream face of the dam and powerhouse and Figure 3 and Figure 4 show a schematic plan and cross-section of the dam's spillway, respectively.

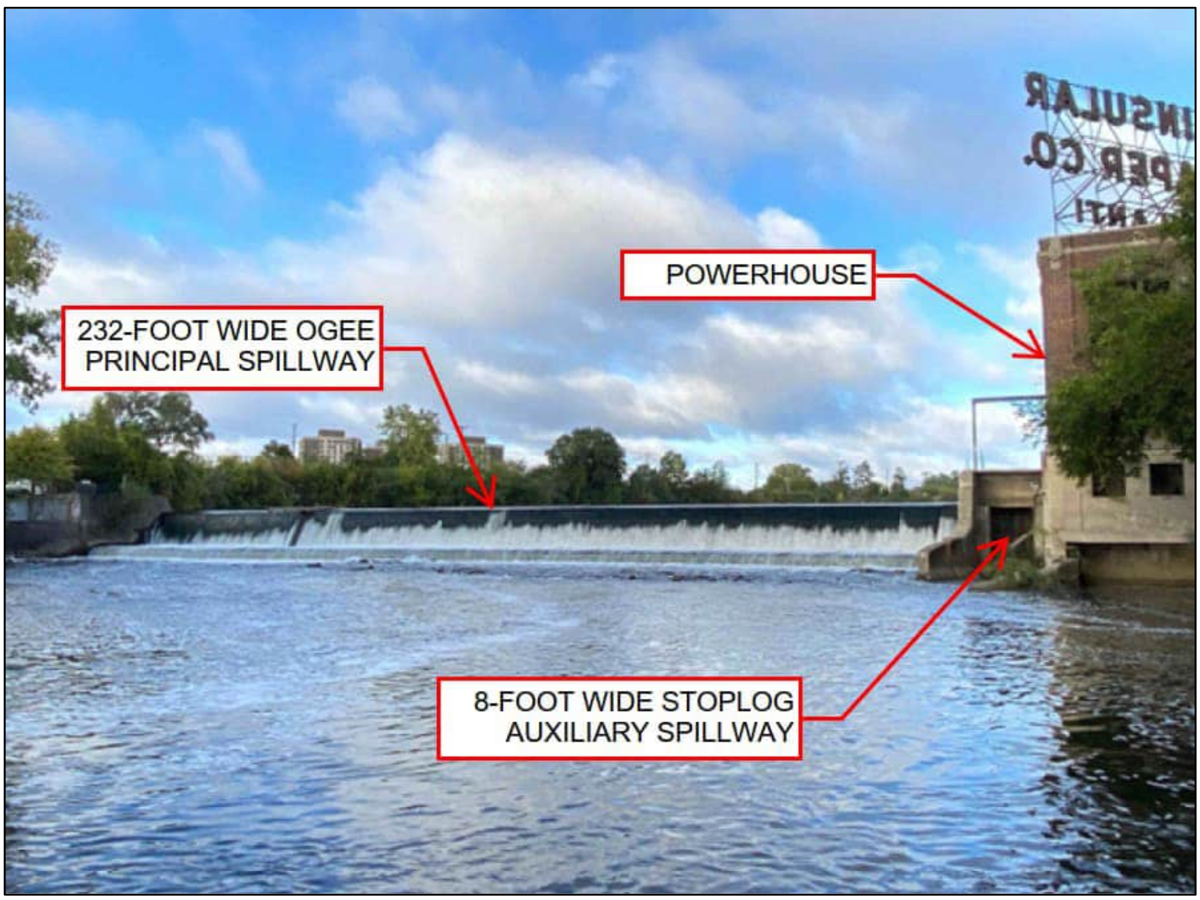
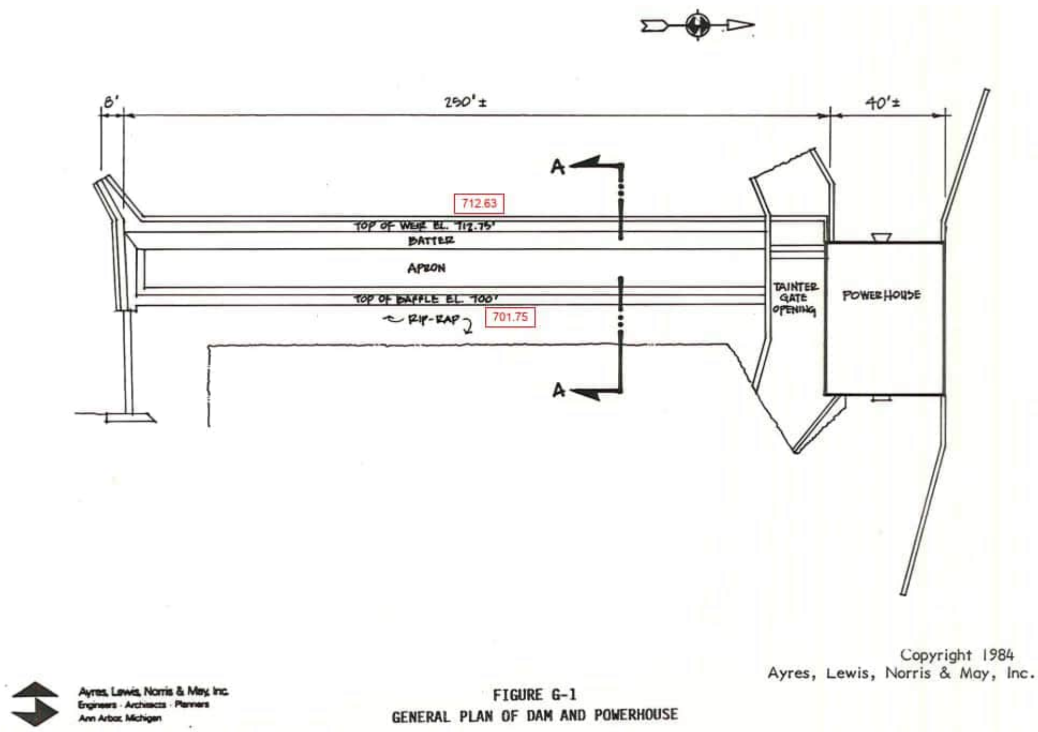


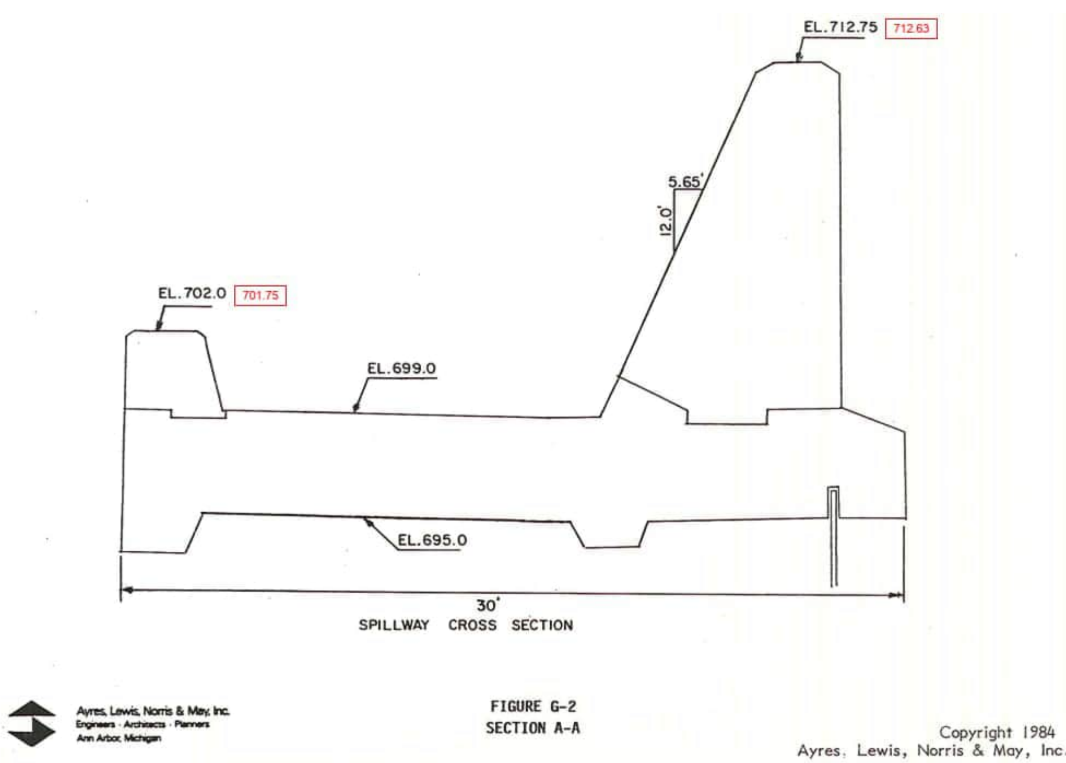
*Photo taken on September 27, 2022.

Figure 2. Photo of downstream face of Pen Dam and Powerhouse.



*Red text shows 2022 surveyed elevations.

Figure 3. Plan view schematic of Pen Dam and Powerhouse.



*Red text shows 2022 surveyed elevations.

Figure 4. Cross-section view schematic of Pen Dam principal spillway.

Pen Dam Impoundment

The Pen Dam Impoundment (Figure 5) extends approximately 1.25 miles upstream from the Pen Dam to just below Superior Dam, and lies within the limits of the City of Ypsilanti in the lower portion of the impoundment, Ypsilanti Township in the central portion, and Superior Township in the upper portion of the impoundment. There are approximately 30 parcels that adjoin the impoundment (Appendix C) and two bridges: the Conrail Railroad Bridge and the Superior Road Bridge. Draining the impoundment is anticipated to expose approximately 100 acres of recovered lands.

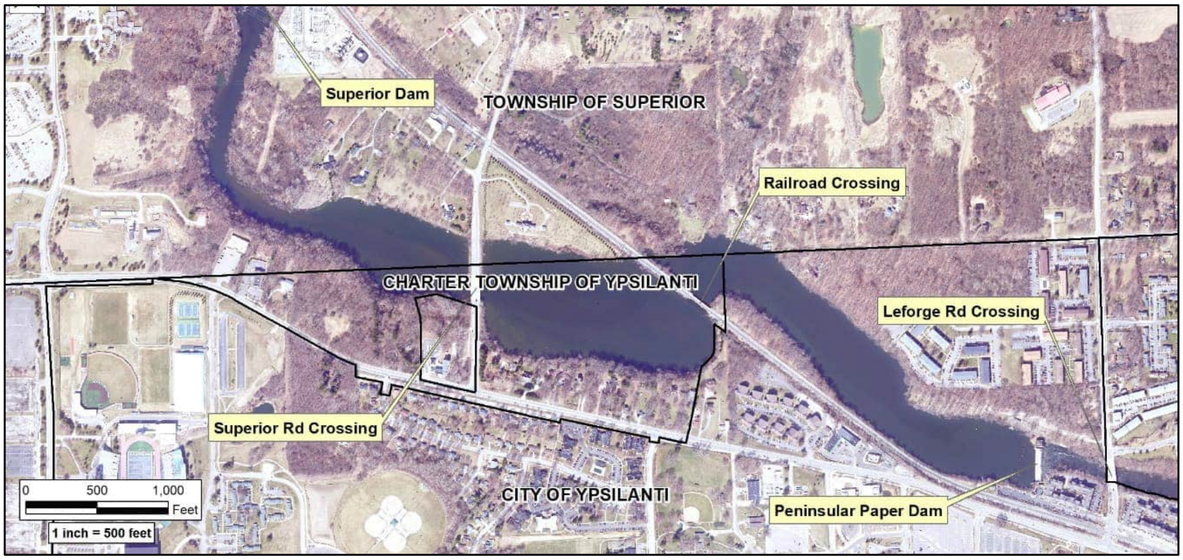


Figure 5. Pen Dam impoundment.

Watershed Geomorphology

At the dam's location, the Huron River has a contributing drainage area of 768 square miles. Four dams obstruct river flows through the Ann Arbor – Ypsilanti urban corridor beginning with the Superior Dam, located 1.5 miles upstream of Pen Dam. Downstream, the Huron River is free-flowing for approximately 2.5 miles before it enters Ford Lake, a large impoundment formed by Ford Dam.

The Huron River's headwaters form in the hummocky terrain of Oakland County, which consist of interlobate moraines and basins formed by the Saginaw and Erie-Huron lobes of the Wisconsinian Glaciation. The river traverses southwest across the interlobate moraines and through lakes before taking a sharp turn to the southeast, where it flows through gravel and sand outwash deposits left by the retreat of the Erie-Huron lobe and lacustrine deposits associated with stages of glacial lakes Maumee, Wittlesey, and Warren (Russell and Leverett, 1907). The reach of the Huron River containing Pen Dam and its impoundment is a naturally confined valley and is relatively steep, with a slope of approximately 5.9 feet per mile, or 0.1%. Floodplain width varies between 200 and 700 feet, is characterized by floodplain forests with steep valley walls. The river channel in the reach downstream of the dam contains sections of plane bed and riffle-run bed morphology dominated by cobble and gravel bed sediments (Figure 6) and is armored due to the presence of upstream dams. Pools in the reach are scarce, and typically are found where the river abuts the valley margins or where large wood jams force scour. Land uses surrounding the Huron River corridor are primarily urbanized including residential and industrial development.

Figure 6. Typical river conditions downstream of Pen Dam.

4. Dam Demolition/Dewatering

A dam demolition/dewatering plan was formulated to determine methods and criteria for impoundment dewatering that will support sediment management plans discussed in Section 7.

4.1 Dam Demolition / Dewatering Plan

A variety of dam demolition/impoundment dewatering scenarios were evaluated to determine methods and criteria for dewatering that will support sediment management plans identified in Section 7. The dewatering plan will be coordinated with the sediment management plan. Active sediment removal will need to occur. Impoundment dewatering will need to be carefully coordinated to facilitate sediment trapping at strategic locations within and downstream of the spillway, while allowing for the upper sediment beds to partially dry for excavation. The preferred method for impoundment dewatering is utilizing a combination of the existing spillway components and incremental dam structure demolition. The dewatering and dam breaching approach will address the need to drawdown the impoundment in a controlled manner, allowing for coordination with upstream sediment removal by the responsible parties. The target dewatering rate of the impoundment is 0.5 feet per day per Part 301 *Inland Lakes and Streams* and 303 *Wetlands Protection* of Michigan's Natural Resources and Environmental Protection Act. The purpose of this target rate is to limit sediment mobilization, reduce risk of impoundment slope failure, and to reduce potential scour of structures and river banks during dewatering.

The impoundment is proposed to be drawn down to the maximum extent possible by incrementally removing the 8-inch by 8-inch stoplog timbers in the 8-foot wide stoplog bay auxiliary spillway while not exceeding a maximum dewatering rate of 0.5 feet per day. As shown in Figure 7, the preliminary HEC-RAS modeling indicate that the river elevation just upstream of the dam can be lowered to approximately elevation 707 with full removal of the stoplogs, leaving approximately 5 feet of water remaining upstream of the dam under typical low-flow conditions (based on the EGLE-provided harmonic mean flow of the Huron River at the Pen Dam of 290 cfs).

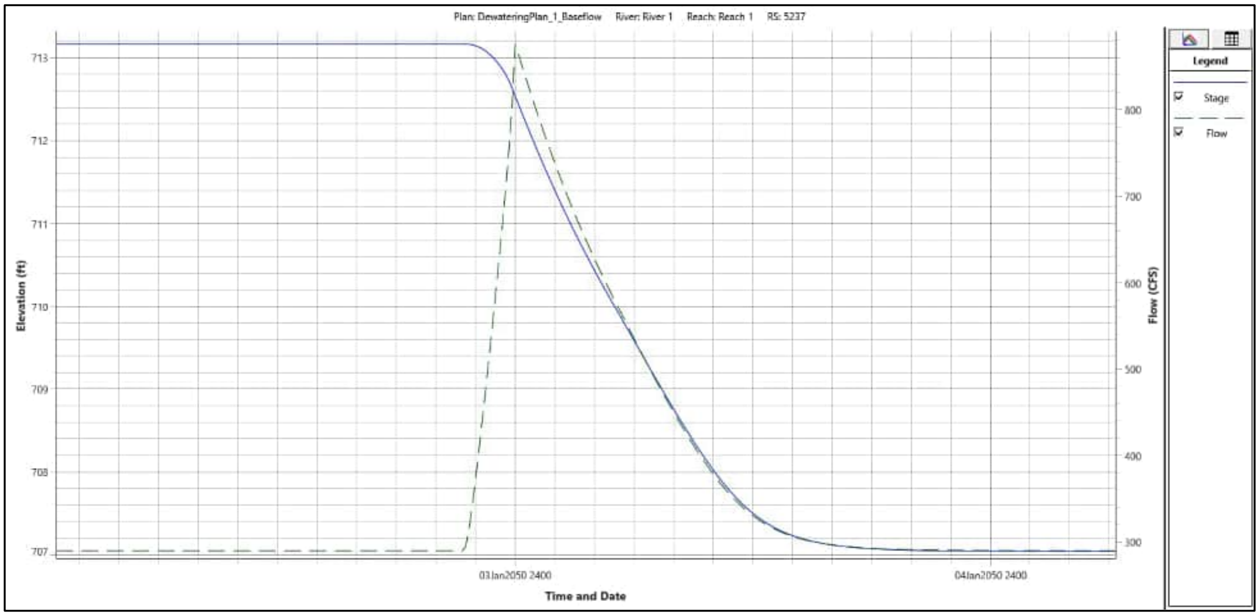


Figure 7. River stage & flow vs. time HEC-RAS results just upstream of Pen Dam with stoplogs fully removed under low-flow conditions (290 cfs).

Preliminary hydraulic modeling indicates that the following stoplog removal schedule, presented in Table 1, yields a drawdown rate not exceeding 0.5 feet per day under typical low-flow conditions (290 cfs). Following this schedule, Figure 8 shows that the river elevation just upstream of the dam can be lowered to approximately elevation 707 within 18 days under typical low-flow river conditions.

Table 1. Stoplog removal schedule for dewatering.

Day	No. of Stoplogs Removed	Day	No. of Stoplogs Removed
0	0	9	22
1	18	10	22
2	18	11	23
3	19	12	23
4	19	13	24
5	20	14	24
6	20	15	25
7	21	16	25
8	21	17	26

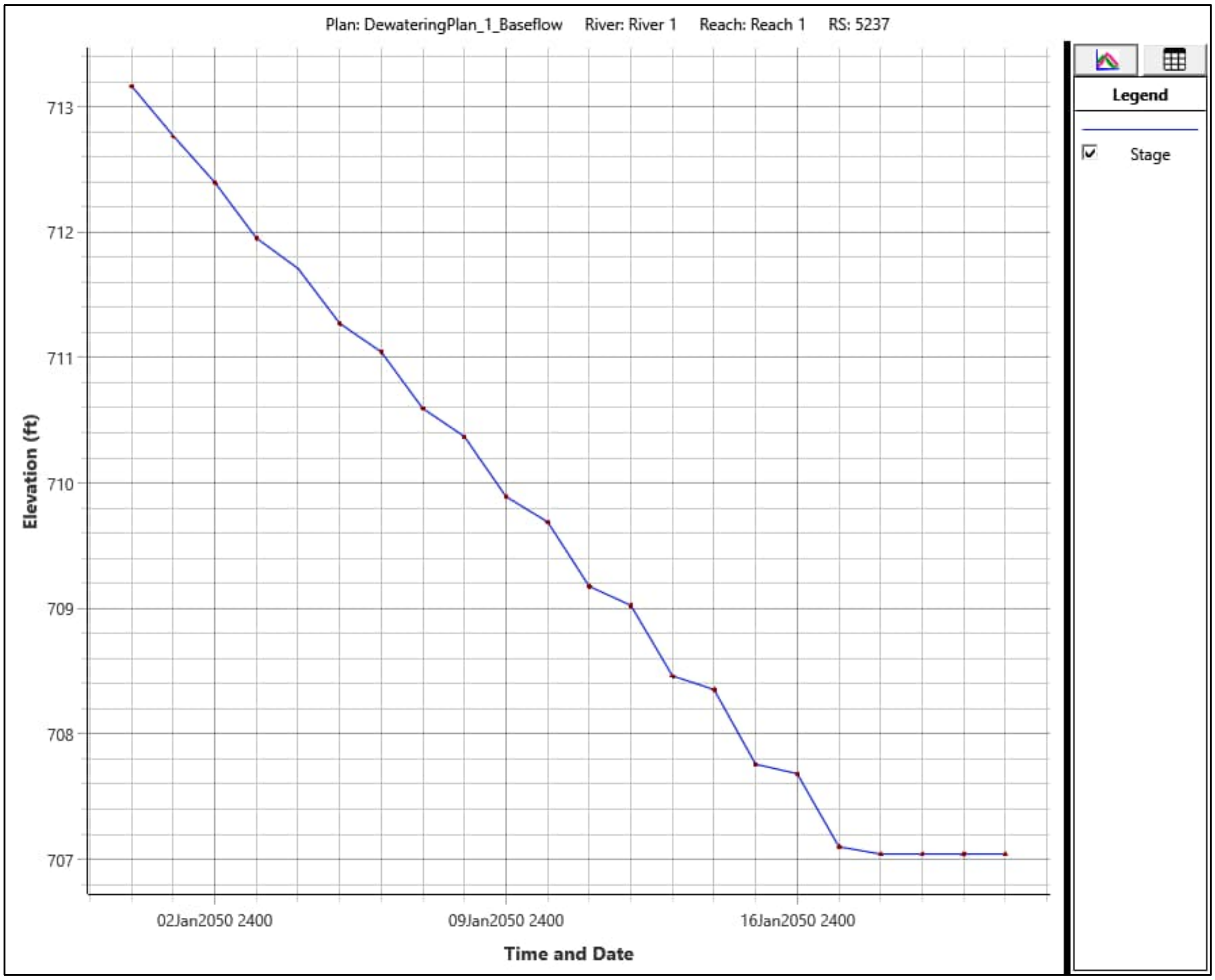


Figure 8. River stage vs. time HEC-RAS results just upstream of Pen Dam with stoplogs removed per schedule shown in Table 1 under low-flow conditions (290 cfs).

The remaining dewatering of the impoundment will occur through the incremental concrete demolition of the 232-foot-long principal spillway. The breaching operation would consist of notching the principal spillway crest to lower the impoundment slowly and carefully at a maximum rate of 0.5 feet per day. The breaching of Pen Dam must be closely coordinated with sediment management and restoration activities as described in the following sections of this report. This would be accomplished by using an excavator-mounted hydraulic jack hammer. The Powerhouse and retaining walls will remain and be protected-in-place by the contractor. Access and staging for dewatering and dam demolition activities will be provided from Peninsular Park. Access within the former impoundment will be temporary and as-needed by the contractor, to move material and equipment where it is needed at the various stages of the project. Structural and geotechnical investigations must be conducted prior to the breaching operation to confirm concrete thickness, structural stability of the spillway and retaining walls, and underlying material characteristics at the location of the dam. The 2022 EGLE Dam Safety Inspection Report of Pen Dam shows a photo of rebar protruding from the spillway (see Figure 9) which could mean that the spillway is structurally reinforced; however, this will need to be further investigated prior to dam removal. Figure 10 shows the conceptual dam demolition/dewatering plan.

Figure 9. Exposed reinforcing steel in auxiliary spillway.

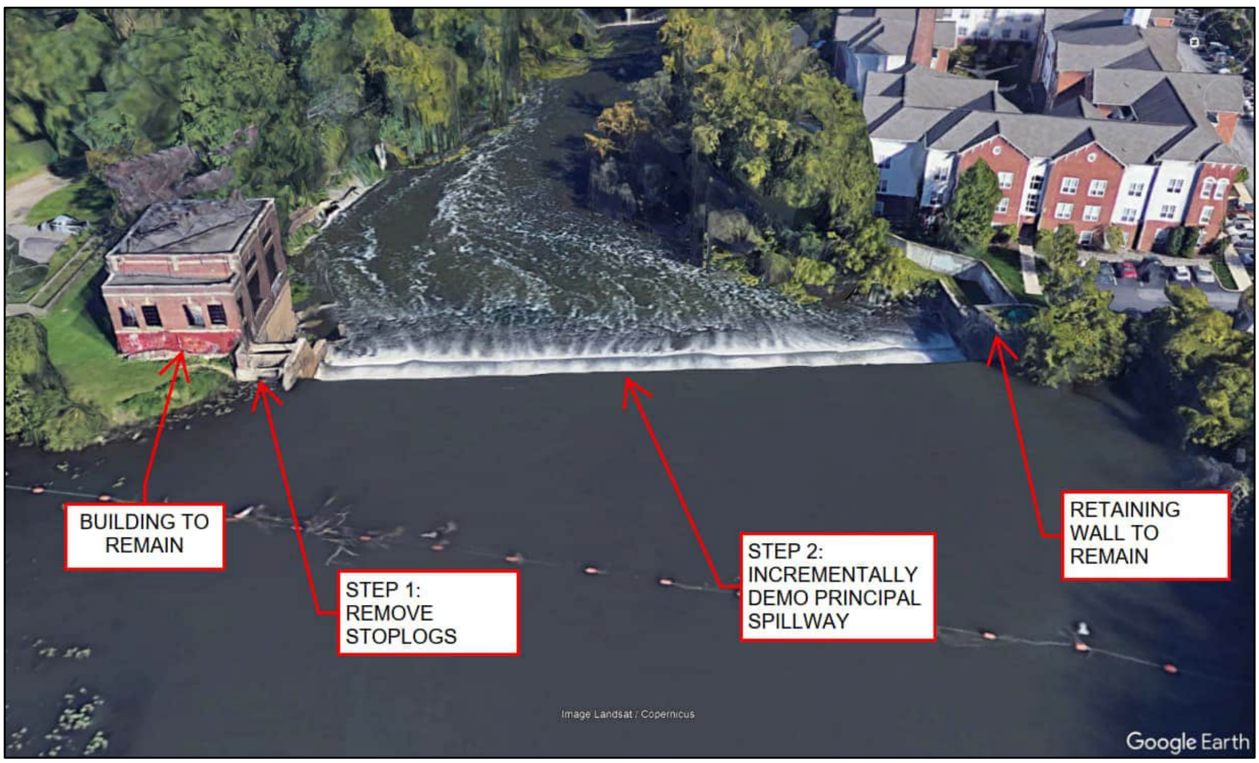
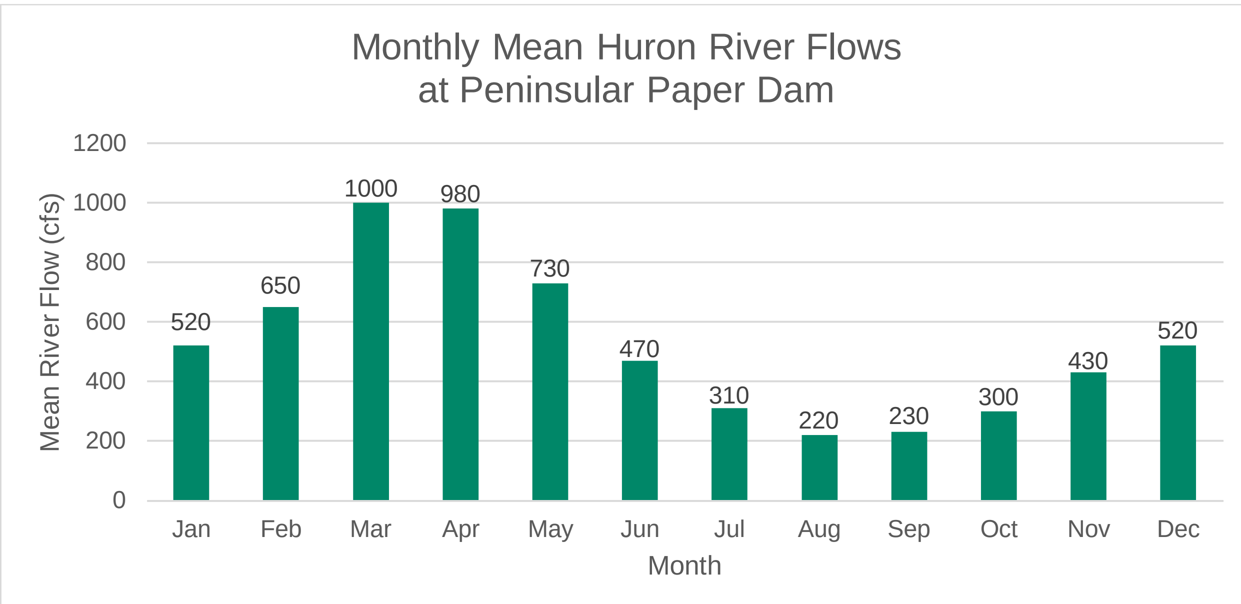


Figure 10. Dam demolition/dewatering plan.

Insufficient data is currently available with regards to the geotechnical characteristics of the existing river bluffs to confidently evaluate the need for an impoundment dewatering rate below the rate of 0.5 ft/day. No geotechnical information (soil borings) or groundwater elevations are available from the adjacent river bluffs to evaluate the implications of the impoundment lowering on the stability of the existing bluffs. The available information is limited to surficial geology maps published by the State of Michigan which indicate that the project area is generally comprised of alluvial soils which is consistent with what would be expected in this riverine environment. Additionally, review of gradation data presented for the sediment samples within the impoundment indicates that cohesionless sand and silty sand soils are present. These alluvial soils are anticipated to be relatively free draining and it is not anticipated that excess pore pressures or undrained conditions will develop in the bluff soils during the dewatering which would lead to bluff instability. Furthermore, the expectation of cohesionless soils in the bluffs would indicate that effective stresses (and stability of the bluff) would be increased by a lowering of the water table. A dewatering rate of 0.5 ft/day is not expected to have an adverse impact on the stability of the bluffs. Soil borings to characterize the bluff soils and canyon stability analyses would be needed to further confirm this assumption.

Dewatering of the impoundment and demolition of the dam is recommended to occur between the months of July and October, as these are the months with the lowest mean river flows as shown in Figure 11; however, discussions with regulatory agencies must be conducted in future design phases of this project to confirm allowable dewatering periods.



*Flows obtained from EGLE on November 10, 2021.

Figure 11. Monthly mean Huron River Flows at Pen Dam.

5. River Restoration Design Analysis

5.1 Impounded Sediment Assessment

In the downstream cell of the impoundment between the dam and the railroad bridge, a distinct pre-dam channel bed is apparent in the refusal surface and bathymetric data (Figure 12), as are areas with thicker deposits of impounded sediments, as well as lower bathymetric elevations. Gravels were encountered near the railroad bridge (Figure 13). Downstream of the railroad bridge, impounded sediment depths in the former channel are less than two feet thick (Figure 14). Along the valley margins, impounded sediments are thicker, ranging between three and ten feet.

The middle cell of the impoundment between the railroad bridge and the Superior Road bridge contains impounded sediment depths between two and four feet thick, and the pre-dam channel is more poorly defined than in the downstream reach. Scour beneath the Superior Road bridge and railroad bridge maintains the gravel channel bed near the pre-dam channel elevation. The majority of impounded sediment between Superior Road and the railroad is stored on the left side of the valley (Figure 15), where sediment thickness ranges from two to seven feet. Upstream of Superior Road, impounded sediments are thickest on the margins of the impoundment and range from one to four feet thick. For approximately 1,900 feet downstream of Superior Dam, the river is free-flowing with an armored gravel and cobble bed that does not contain notable amounts of impounded sediments.

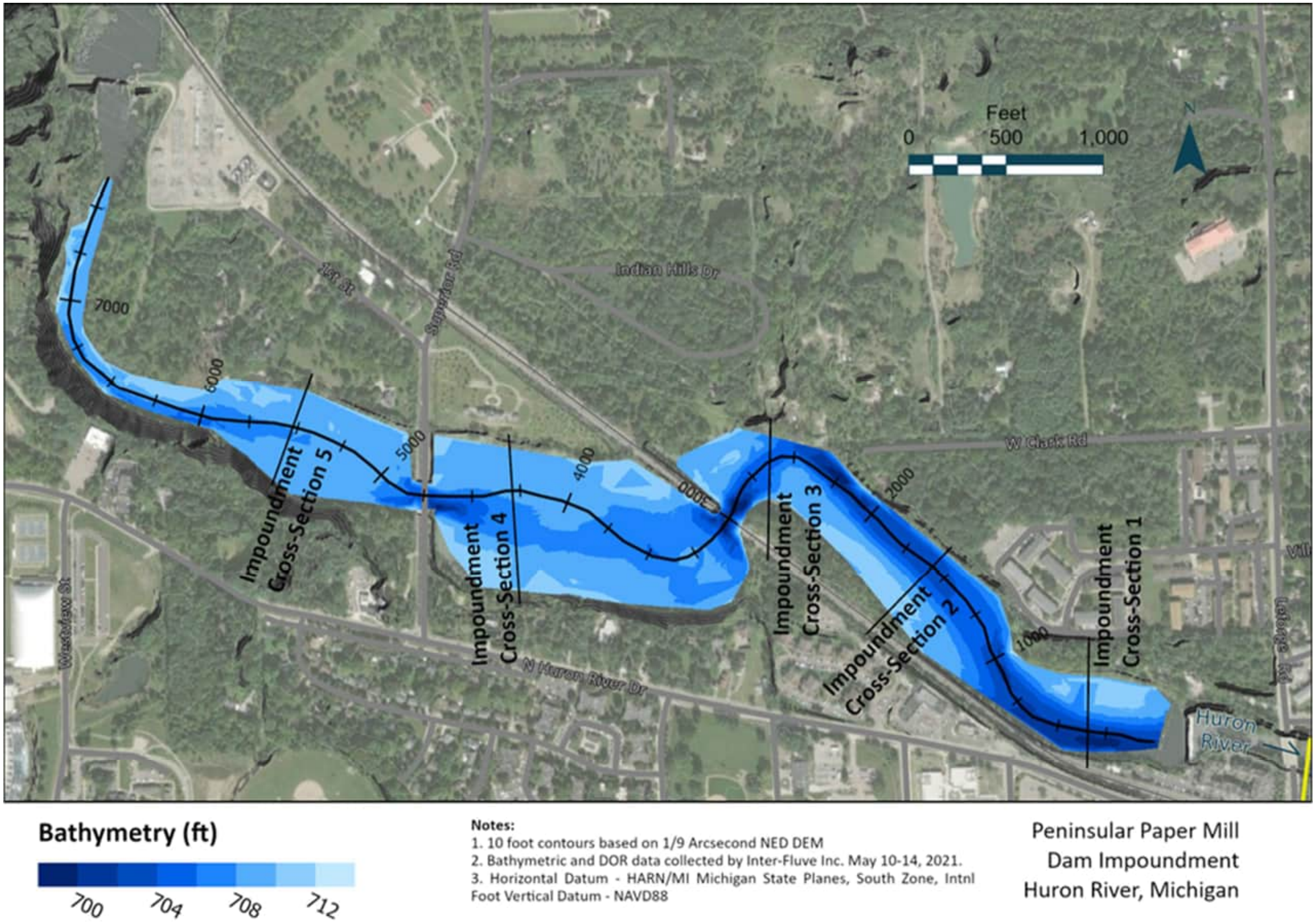


Figure 12. Bathymetry of the Peninsular Paper Dam impoundment.

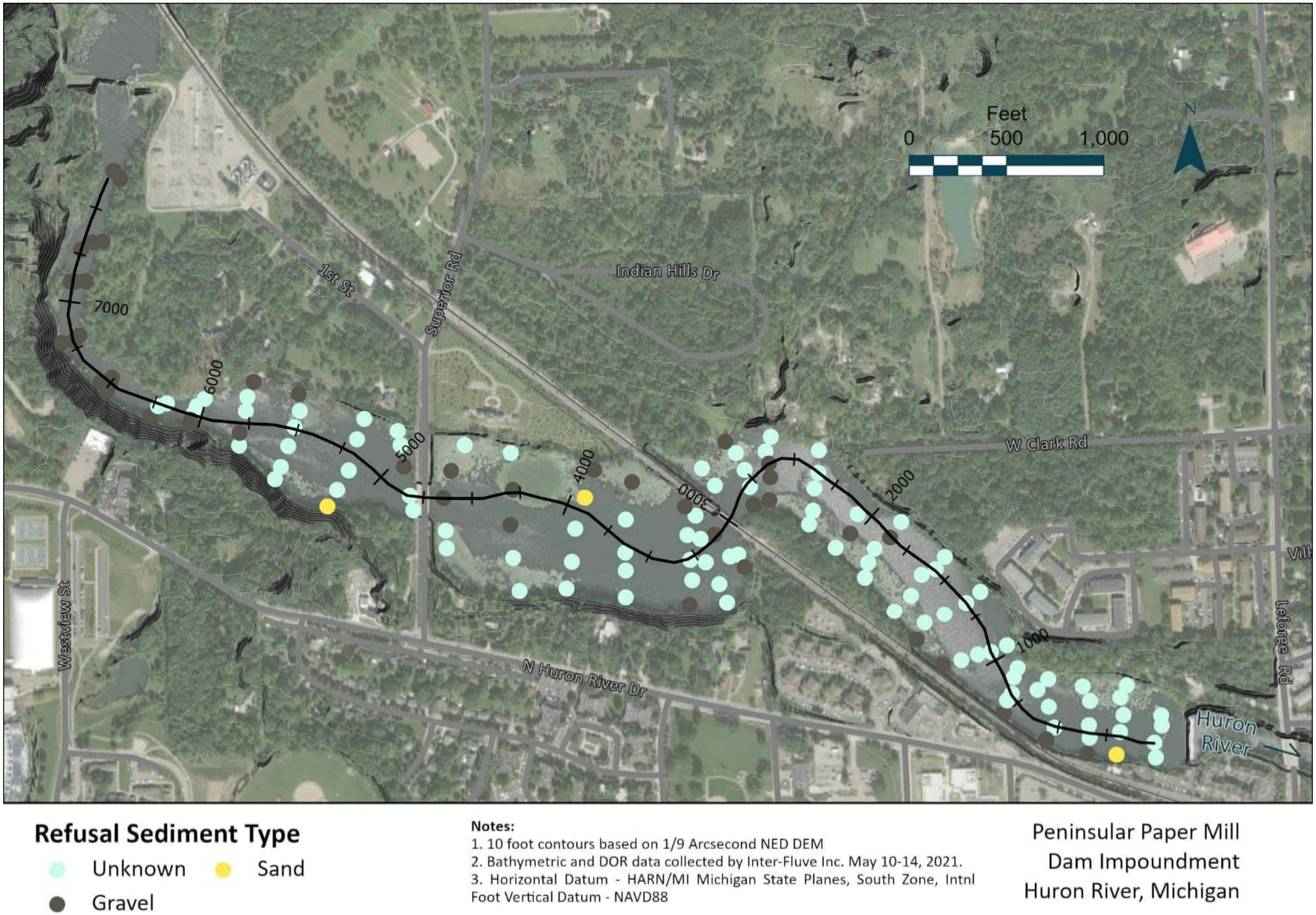


Figure 13. Sediment type encountered at refusal during DOR probing.

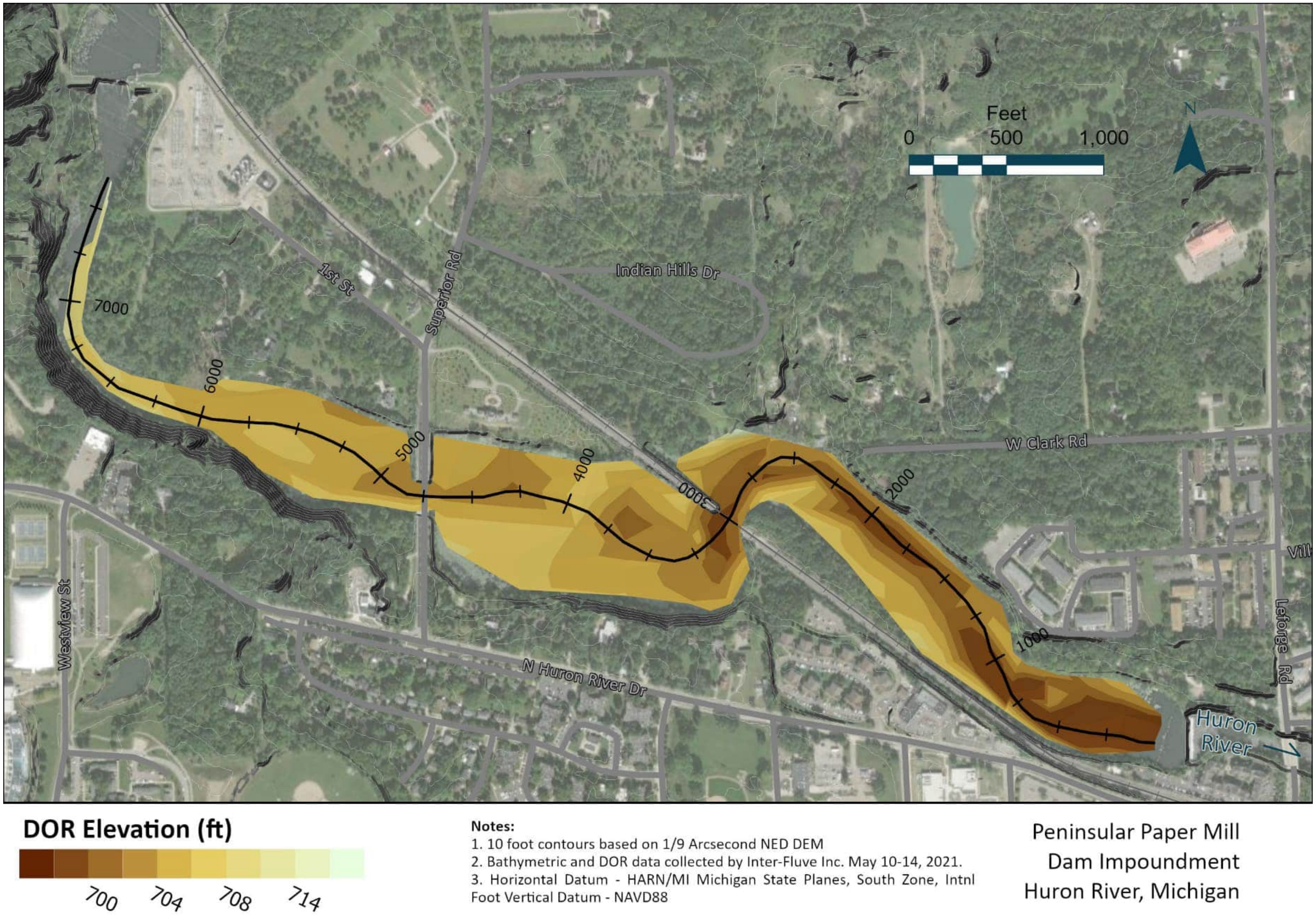
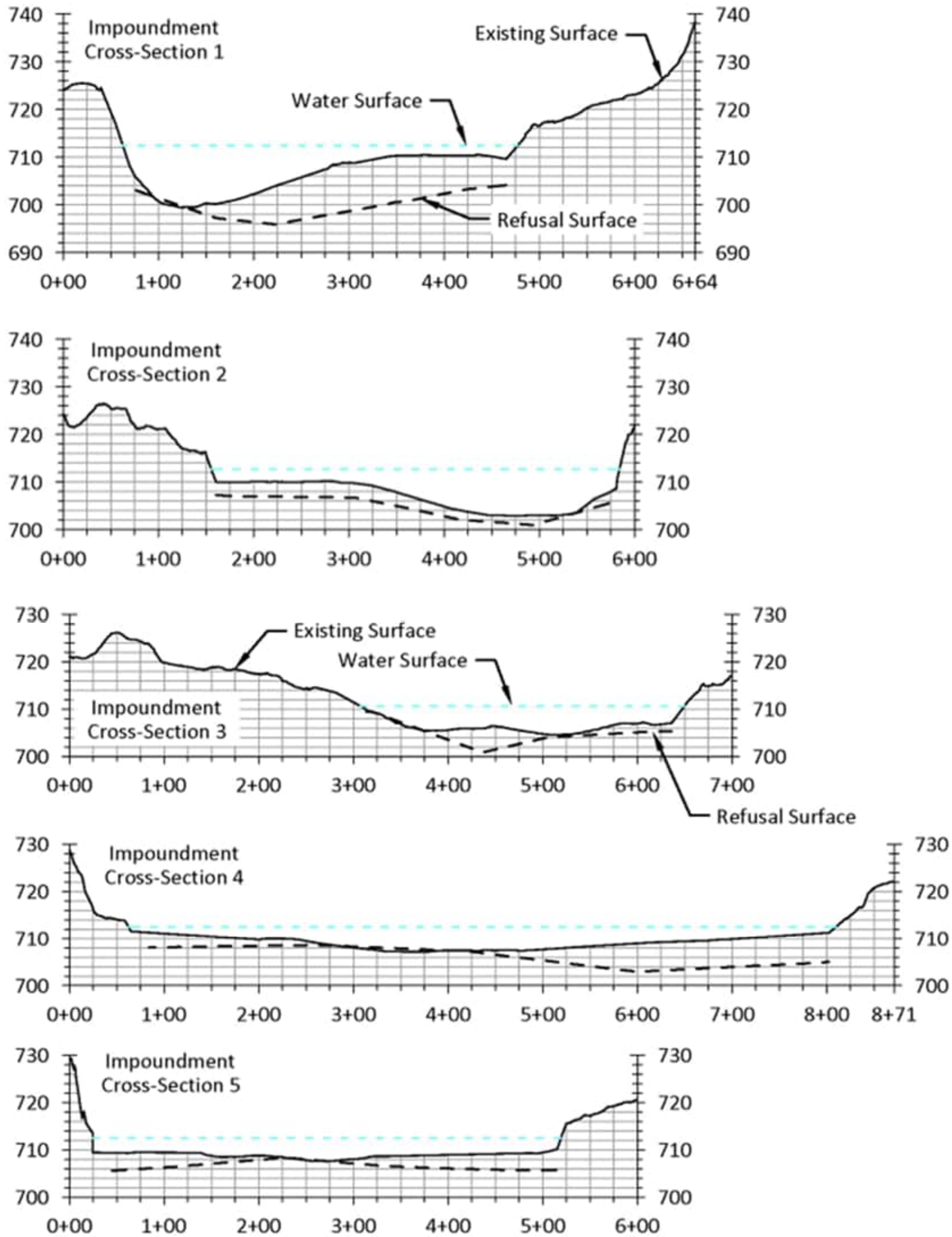


Figure 14. Elevation of the interpreted pre-dam refusal surface.



*Cross section locations correspond to those shown on Figure 12.

Figure 15. Existing top of sediment surface, depth to refusal surface, and water surface cross sections.

5.1.1 Sediment Volume Estimate

The total volume of accumulated sediment was estimated by comparing the surveyed existing bed surface and the refusal surface. Estimates of impounded sediment volumes are shown in (Table 2). A total of approximately 278,000 cubic yards of sediment is impounded in the dam impoundment between the DOR surface and the top of sediment. Of that volume, 127,000 cubic yards, or 45%, is located between the dam and the railroad bridge.

Grain size characteristics were analyzed in sediment cores collected by LimnoTech in 2021 and Princeton Hydro in 2018. Analysis of collected cores indicates the majority of impounded sediment is sand-sized (Table 2). The collected material primarily includes accumulated sediments on top of the pre-dam riverbed and floodplain and does not include coarser alluvial materials comprising the pre-dam channel bed. Upstream reaches of the impoundment contain greater portions of gravels and coarse sand, while downstream reaches contain greater fractions of fine sediments, consistent with models of deposition patterns behind dams.

Table 2: Grain size characteristics of impounded sediments in each cell of the impoundment.

	Accumulated Sediment Volume (CY)	*% Cobble and Coarse Gravel*	*% Fine Gravel*	*% Coarse Sand*	*% Med. Sand*	*% Fine Sand*	*% Silt & Clay*
Upstream Cell	52,000	0.0	8.4	12.5	32.3	36.7	10.3
Middle Cell	99,000	0.0	4.8	14.5	24.7	37.9	17.9
Downstream Cell	127,000	0.0	5.4	12.5	23.8	26.6	31.7

5.2 Sediment Contamination

Sediment testing results were compared against background concentrations of contaminants, human health criteria (Part 201 Cleanup Criteria Requirements for Response Activity for Residential Areas, [EGLE, 2018]), and ecological protection criteria (Consensus-Based Sediment Quality Guidelines (CBSQG) Probable Effect Concentrations (PEC), [MDEQ, 2006; WDNR, 2003]). In general, human health criteria apply to areas which will be future floodplain areas, and ecological protection criteria apply to sediments within future channel areas. Comprehensive results of sediment testing may be found in the appendix to LimnoTech's 2022 report.

The results of the comparison of sediment pollutant levels human health criteria indicate that only two (2) of thirty-three (33) sediment sample locations exceed the criteria for any of the compounds tested (Figure 16). At sampling location D03, the arsenic level measured in the sediment was 23.3 mg/kg, which exceeds the Michigan Soil Survey background concentration threshold of 22.8 mg/kg. At sampling location C02, the PAH compound of benzo(a)pyrene was measured at 2,380 ug/kg, which exceeds the Michigan Background Soil Survey threshold of 2,000 ug/kg. At all other locations, other pollutant analytes were all below background soil levels or below thresholds for protection of public health for direct contact with soils on residential properties.

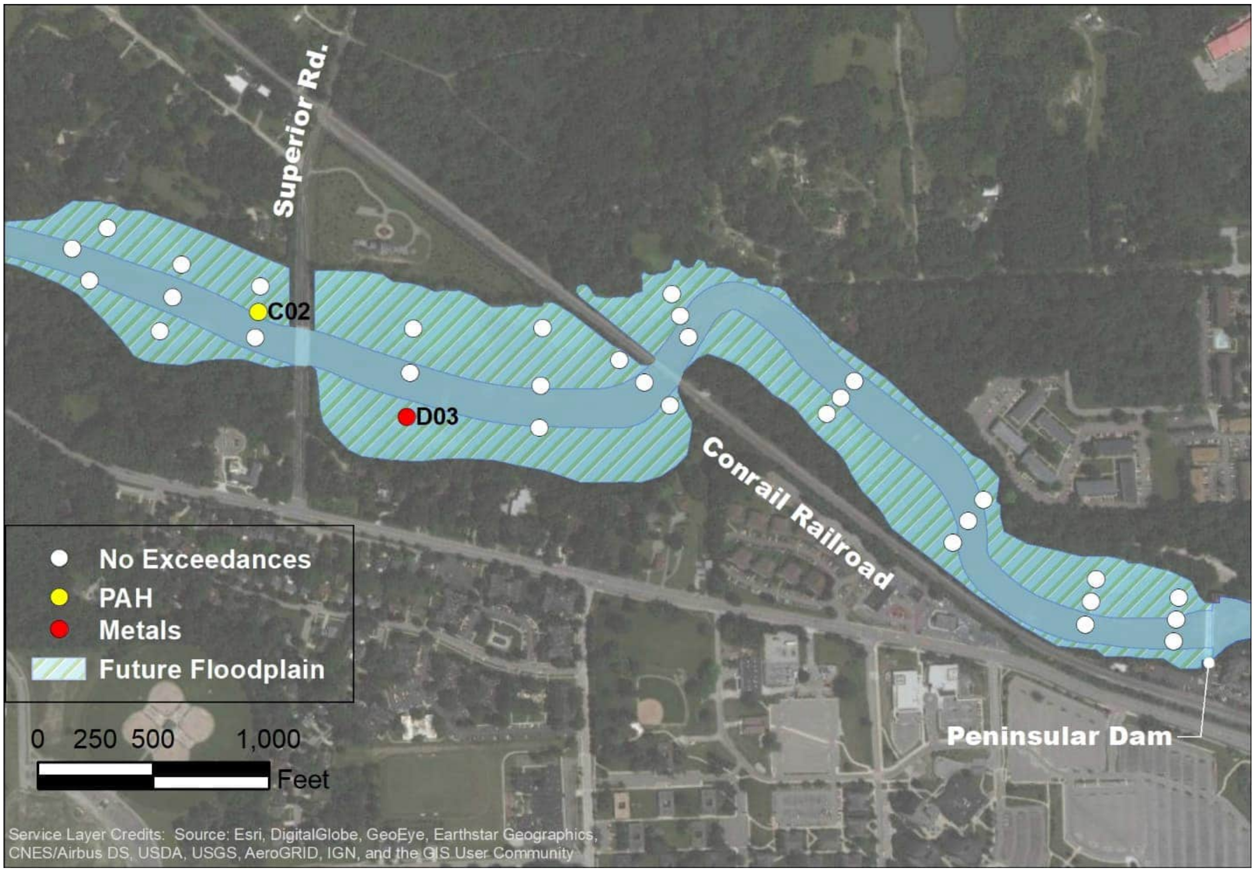


Figure 16. Sediment sampling locations with pollutant levels that exceed Michigan Part 201 residential direct contact values and Michigan background soil survey criteria.

Sediment sampling results indicate that 20 out of the 33 locations sampled had at least one exceedance of the CBSQG PECs (Figure 17). Many of these locations are located in areas that would be future floodplain areas and not the proposed river channel following project implementation. None of the sampled locations exceed the CBSQG PEC criteria for Total PAH, and only three locations were found to have individual PAH compounds that exceed the PEC. The highest levels of PAHs were found at location C02, where seven compounds exceed PEC thresholds and total PAH is 22,310 ug/kg, slightly less than the PEC criteria of 22,800 ug/kg. Sample E02 also had several PAH compounds exceed the PEC criteria. Sample location H02 had a single PAH compound (Dibenzo(a,h)anthracene) exceed the PEC criteria. Metals were found to exceed PEC criteria in 19 locations, and the exceedances at 13 of those locations were for mercury and silver. The exceedances for mercury ranged from 0.49 to 2.5 mg/kg for mercury compared to the PEC criteria of 0.486 mg/kg, and silver exceedances ranged from 2.3 to 8.8 mg/kg compared to the PEC criteria of 2.2 mg/kg. The remaining exceedances were for copper and lead (six locations total).

Contaminated sediment management is discussed on Sections 7 and 8.

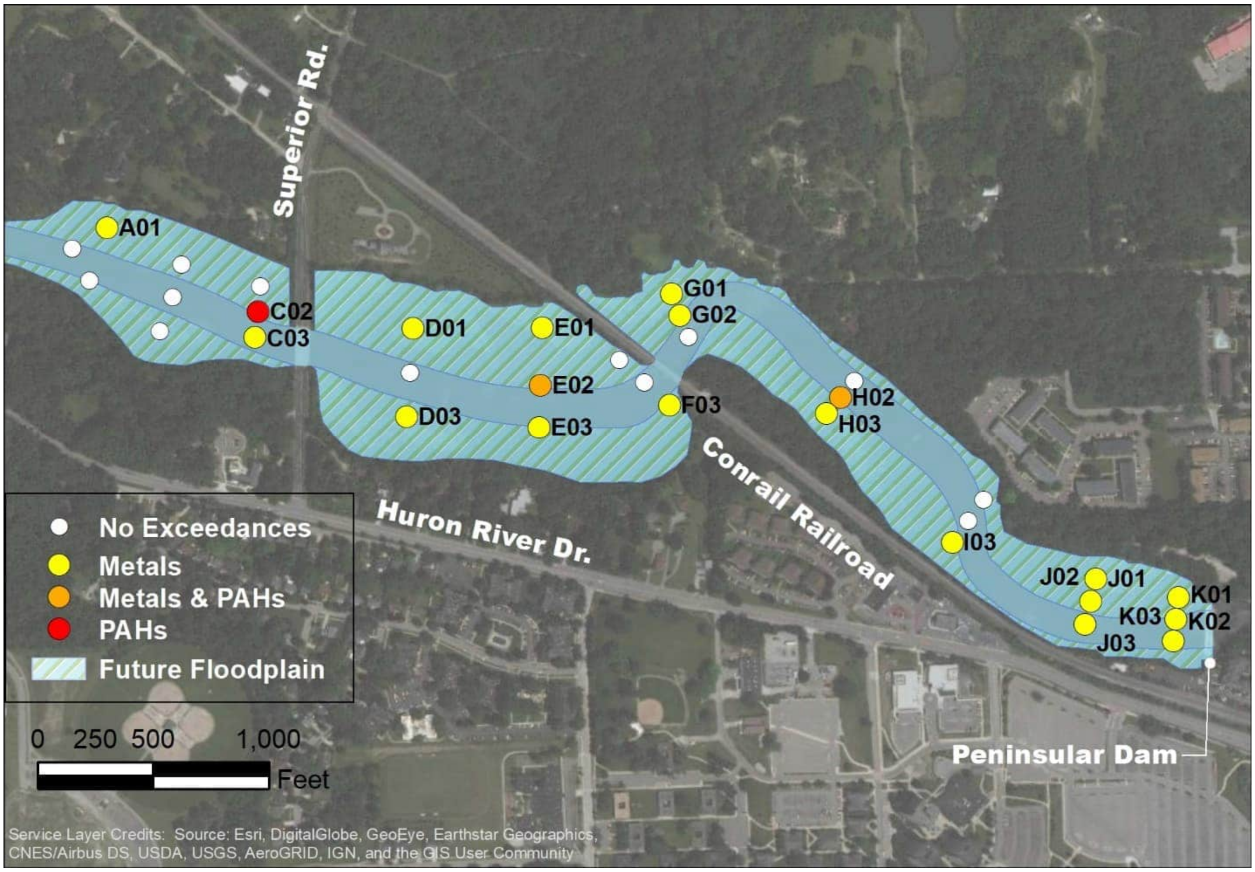


Figure 17. Sediment sampling locations with pollutant levels that exceed the screening level PECs for ecological protection.

5.3 Proposed Channel Planform

The proposed channel alignment was selected to occupy the apparent pre-dam river channel, to accommodate bridge crossings and infrastructure, to reasonably manage excavation volumes, and to promote channel stability over the long-term with minimal bank stabilization. The selected alignment tracks minimum elevations measured during the DOR survey along the deepest part of the modern impoundment bed. The sinuosity of the proposed alignment is 1.14, which compares with a sinuosity of 1.12 in the relatively straight, steep, and confined reach of the Huron River between Leforge Road and East Michigan Avenue.

The proposed alignment ties into the existing channel bed at locations upstream of the limit of impounded sediments and downstream of the dam location. The upstream tie in point is selected to correspond to an armored portion of the channel at the limit of current impoundment, which is located near a potential access point for construction. Downstream, the proposed alignment ties into the existing channel at a location that would permit full demolition of the dam spillway and align flood flow vectors with downstream channel reaches.

5.3.1.1 Channel Cross Section

Channel geometry in downstream analog reaches, together with channel geometry estimates based on regional hydraulic geometry studies, were applied to estimate stable cross-sectional geometry for the Huron River through the project area. Bankfull flow estimates were used to refine final channel dimensions.

Hydraulic geometry equations for Michigan streams (Rachol and Borley-Morse, 2009) provide estimates of channel dimensions at riffles using drainage area as the only independent variable. Relationships developed by Rachol and Borley-Morse are obtained from stable, relatively undisturbed reaches within lower Michigan. The contributing drainage area at the dam is 768 square miles, which is approximately two times larger than the largest gaging station data point used in the study. Results of values for several channel geometry variables are provided in Table 3. Confidence intervals reported by Rachol and Borley-Morse do not include drainage areas larger than approximately 360 square miles. At that upper reporting limit, the upper and lower 95% confidence intervals are approximately +/-20 feet for bankfull width, +/-1 foot for bankfull depth, +/-100 square feet for flow area, and +/-300 cfs for bankfull discharge. Confidence intervals would be expected to increase in range from those reported values along with increased drainage area.

Table 3. Channel geometry values.

Channel Parameter	*Regional Regression Eqn. Value*
Width	152.4 ft
Depth	4.0 ft
Width/Depth	37.8
Flow Area	597.9 ft
Bankfull discharge	2,231 cfs

*Predicted by empirical equations (Rachol and Borley-Morse, 2009).

Channel dimensions were refined further through measurements of channel reaches downstream of the dam obtained during Inter-Fluve's geomorphic assessment, which share characteristics with the project area including geologic inheritance, climate, hydrologic regime, sediment supply, stream gradient, and valley characteristics. This analog reach extends from downstream of the dam to East Michigan Avenue, upstream of the backwater effects of Ford Lake. Mean values and standard deviations of channel dimensions measured at thirteen cross sections in the analog reach are presented in Table 4.

Table 4. Channel dimensions of cross sections.

Channel Parameter	*Average Value*	*Std. Dev.*
Width	137.5 ft	22.0 ft
Depth	4.5 ft	0.5 ft
Width/Depth	31.8	7.9

*Measured in the analog reach downstream of the project area.

To further refine cross-section geometry, the channel was designed to pass an estimated bankfull flow, taken as the bankfull flow value obtained from the regional regression equations of 2,231 cfs. This corresponds to a flow that has a probability of occurrence greater than 50% in any given year and substantially greater than the median spring flow of 840 cfs. Manning's equation was used to calculate ranges of bankfull channel geometry and flow parameters for the selected bankfull flow value (Table 5).

Table 5. Range of channel dimensions based.

Bottom Width (ft)	*Top Width (ft)*	*Depth (ft)*	*Area (ft^2)*	*Wetted Perimeter (ft)*	*Hydraulic Radius (ft)*	*W/D*	*Shear Stress (lbs/ft^2)*
110	128.5	4.61	550.0	130.6	4.2	27.8	0.51
112	130.3	4.57	553.0	132.4	4.2	28.5	0.51
114	132.1	4.52	556.0	134.2	4.1	29.2	0.50
116	133.9	4.47	559.0	136.0	4.1	29.9	0.50
118	135.7	4.43	561.9	137.8	4.1	30.6	0.49
120	137.5	4.39	564.8	139.6	4.0	31.4	0.49
122	139.4	4.34	567.8	141.4	4.0	32.1	0.49
124	141.2	4.30	570.7	143.2	4.0	32.8	0.48
126	143.1	4.26	573.6	145.1	4.0	33.6	0.48
128	144.9	4.22	576.4	146.9	3.9	34.3	0.48

130	146.7	4.19	579.3	148.7	3.9	35.1	0.47
132	148.6	4.15	582.2	150.6	3.9	35.8	0.47

*Based on Manning's equation evaluation at bankfull flow.

Channel geometry values presented represent a range of interdependent variables which may vary with intrinsic and extrinsic factors such as precipitation, channel bed and bank materials, riparian vegetation, and sediment transport, among others. The downstream analog reach has reached a near equilibrium state under a modified flow and sediment regime in addition to highly urbanized riparian land uses. Based on analog reach values, a channel top width of between 140 and 145 feet and a width to depth ratio of 31-34 appears appropriate for the project area. The project reach has an average gradient of 0.19%. The proposed channel geometry has a channel top width of approximately 143 ft, a depth of 4.3 feet, and a width to depth ratio of 33.6, although actual constructed channel dimensions will vary according to the presence of pre-dam alluvial materials and geomorphic position within the river.

5.4 Two-Dimensional (2D) Hydraulic Analysis

To evaluate hydraulic conditions of the proposed dam removal and impoundment restoration design, Inter-Fluve developed a two-dimensional (2-D) hydraulic model of proposed conditions. The model results are used to characterize post-removal velocities, flow depths, and hydraulic forces, and to design bank and bed stabilization treatments in targeted areas. In future engineering design phases, more detailed grading and engineering analysis will be necessary for the selected alternatives.

5.4.1 Model Development

5.4.1.1 Model Geometry

Two-dimensional hydraulic models were developed in HEC-RAS Version 6.3.1 (USACE, 2022). The model was developed from a digital terrain model (DTM) of the proposed 30% design grading plan developed in AutoCAD Civil 3D. Within the DTM, existing conditions developed from bathymetric survey data and LiDAR data was used as a base surface. Proposed conditions were imposed onto the base surface and include the proposed channel, floodplain benches, pools, and spoils piles. The computational mesh overlain on the DTM includes 30-ft grid cells in floodplain areas with limited topographic and roughness variation, and 10-ft grid cells within the river channel. Breaklines were used to align computational cells with high ground features, bridge piers, and road embankments.

Results of 1-D models developed by AECOM (LimnoTech et al. 2022) for the project indicate that flow will not contact the lower chord of the bridges in the impoundment during floods up to and including the 500-year event under post-restoration conditions. Therefore, the Superior Road and railroad bridge decks were not included in the 2D model domain. The piers of each of bridge were added to the model domain using RAS Mapper's Terrain Modification tool, and grid cells were aligned to each pier. 2D model results indicate the piers are not overtopped during any simulated flood.

5.4.1.2 Model Domain and Boundary Conditions

The model domain's upstream limit extends from 550 feet downstream of Superior Dam to 1-D model river station 1618, located approximately 3,400 feet downstream of Peninsular Paper Dam (Figure 18).

The model's downstream boundary condition is a rating curve selected from 1-D model results at river station 1618. The upstream boundary condition was specified as a stepped flow hydrograph including baseflow (290 cfs), bankfull flow (2,353 cfs), and the peak flood flow design flows.

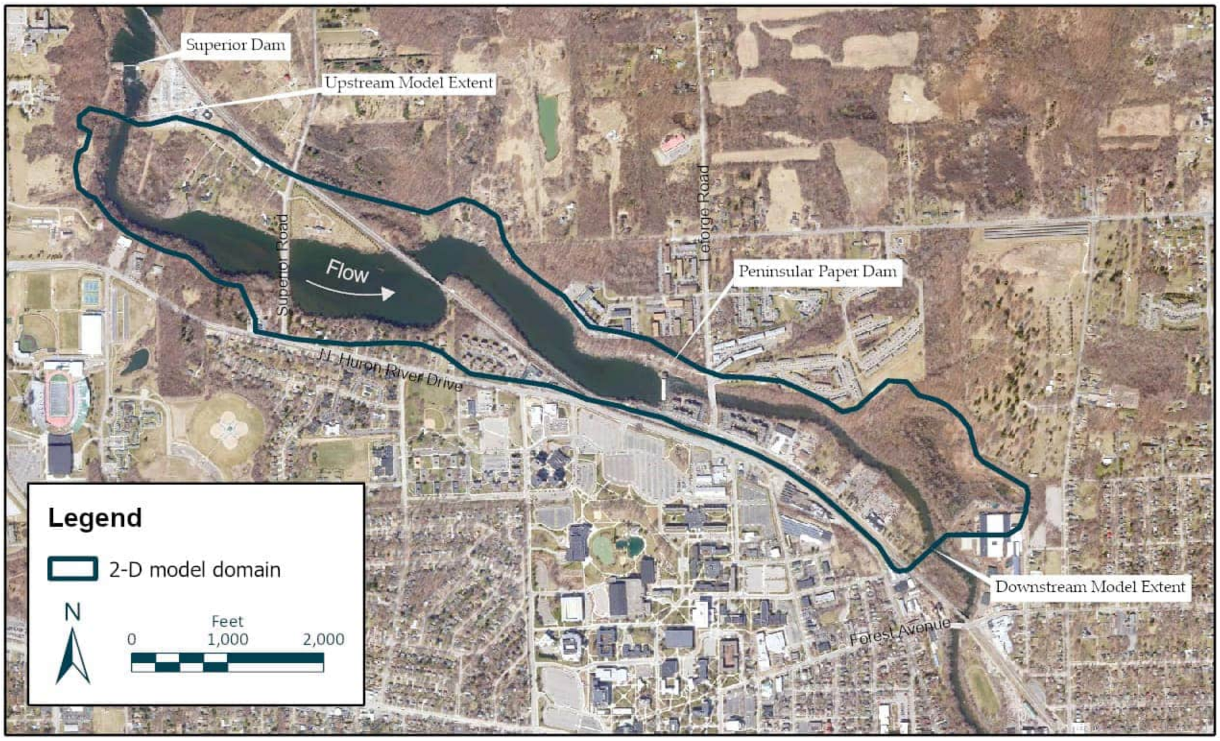


Figure 18. 2D hydraulic model domain used for this study.

5.4.1.3 Hydraulic Roughness

Hydraulic roughness was represented in the computational domain as a spatially varying Manning's n layer with coefficient values based on assessment of existing channel and floodplain conditions downstream of the dam and expected bed, bank, and floodplain conditions within the restored impoundment. Model calibration was not performed because surveyed water elevations do not reflect conditions or higher-magnitude flows represented in the model.

5.4.2 Sediment Transport

Potential transport of sediment during dam demolition, restoration, and following dam removal should be considered within the context of the Huron River's capacity to transport sediment. Sediment transport modeling is useful to characterize reaches as sediment sources, transfer reaches, or sediment sinks. To provide a rough estimate the sediment transport capacity of impounded sediments in downstream reaches, we used the U.S. Forest Service Bedload Assessment for Gravel-Bed Stream (BAGS) software (Pitlick et al., 2009). The Wilcock-Crowe (2003) equation is applicable for noncalibrated bedload sediment transport rate in mixed gravel and sand channels and was developed to simulate the effects of particle hiding and exposure on sediment transport capacity of mixed bed sediments. The result of the BAGS model provides an indication of how much material the downstream reach may be able to transport in a given year for the input discharges but will not reflect actual sediment transport rates without proper calibration using field data. It should be noted also that sediment transport is also event-dependent, and river discharges are unpredictable.

The BAGS model requires input of typical cross section dimensions, roughness, reach-average friction slope, sediment size gradations, and discharges. Cross section dimensions were obtained from Inter-Fluve's 2021 survey of the downstream reach, and friction slope and roughness estimates were obtained from a 1-D hydraulic model developed for the project area by AECOM (LimnoTech et. al, 2022). Sediment gradations of impounded material were averaged based on sediment cores taken during the Feasibility Study and Phase 1 investigations and considered only material larger than 0.5 mm (coarse sand) expected to move as bedload. Annual flow-duration curves data were obtained from USGS gage 04174500 on the Huron River in Ann Arbor, located approximately 6 miles upstream of Pen Dam. Flow data was not transformed to the project area and therefore likely underestimates flow and potential sediment transport for a given event. Only flows up to the 2-year peak flood event were considered.

Bedload sediment transport capacity estimates indicate the reach of the Huron River downstream of Peninsular Paper Dam is capable of transporting +/- 10,000 cubic yards per year of a gradation representative of impounded sand and gravel materials as bedload. Smaller particles which may move as suspended load and coarser existing bed materials are not included in the estimate. The results presented here are not calibrated against actual bedload measurements and represent reach-average conditions. Model estimates may differ from the true sediment transport rate by an order of magnitude or more.

Sediment supply into the impoundment is severely limited by the presence of four dams upstream of the project area. While urban drainages, hillslope processes, and direct runoff may contribute sediment to the impoundment, the magnitudes of sediment entering are expected to be far less than those expected from pre-dam river processes. Any sediment released from the removal of Pen Dam will ultimately be transported through the downstream reach to Ford Lake, where it is expected to deposit on the lake bed.

6. Proposed Restoration Design

Following the alternatives analysis phase of the project, HRWC, in consultation with project partners, identified a preferred "blended" alternative which incorporates distinct features of all the developed alternatives. HRWC's preferred alternative includes varying channel configurations longitudinally through the project.

- *Upstream Cell:* A pilot channel with minimal floodplain restoration/alteration.
- *Middle Cell:* A pilot channel or, where feasible, a floodplain bench, with minimal restoration/alteration work on spoils piles.
- *Downstream Cell:* A floodplain bench alternative within the downstream cell in portions of the river bounded by private property. In areas adjacent to Peninsular Park, channel and floodplain areas should be fully restored.

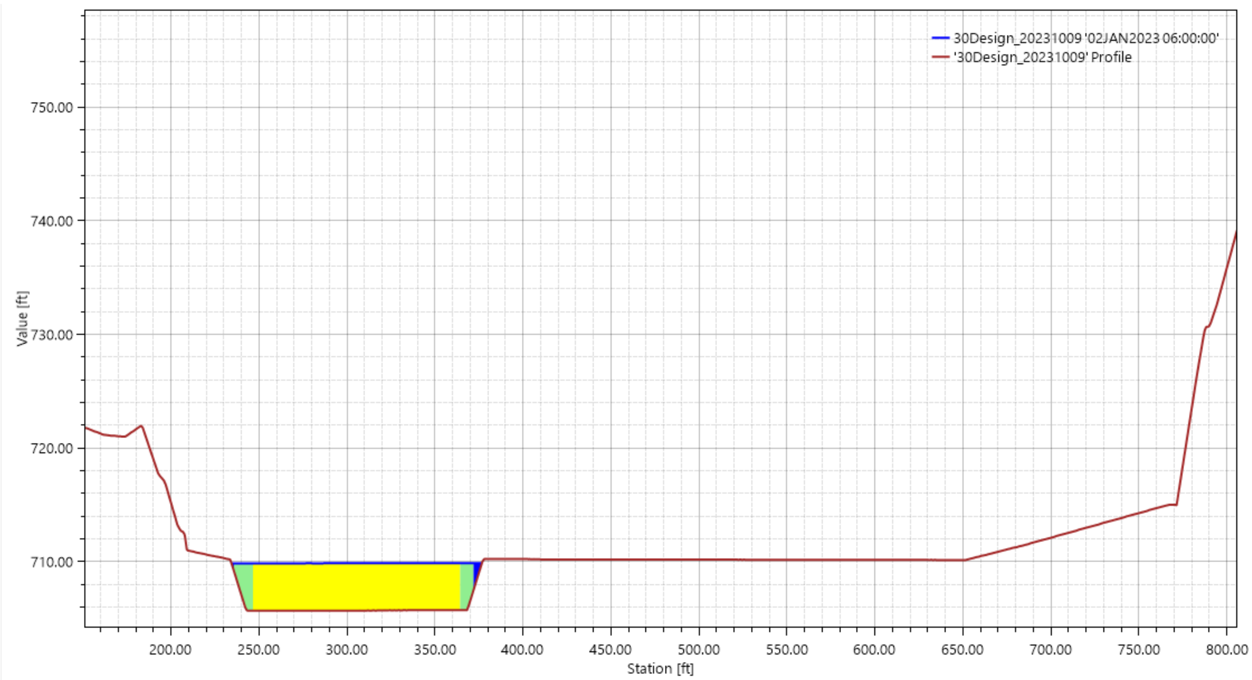
HRWC prefers river restoration techniques consistent with the State of Michigan's Natural River program guidelines. Bank erosion is undesirable in areas adjacent to infrastructure, sensitive bluff slopes, and private property, and special consideration is given to these areas. Additionally, HRWC requested that areas be highlighted where potential future restoration actions may be taken.

Initial design analysis indicated that excavation and grading for a pilot channel alternative in the cell upstream of Superior Road would yield conditions similar to those of a full floodplain restoration. In the middle cell, adjacent infrastructure and private property requires areas of targeted bank and bed stabilization, which is largely incompatible with a pilot channel alternative. Therefore, in the middle cell a floodplain bench with a width of 20 feet per size is included in the 30% project design plans. The same floodplain bench cross section is carried through the downstream cell in the reach upstream of Peninsular Park. Floodplain restoration near the park will result in a broader floodplain more consistent with pre-dam conditions.

6.1.1 Proposed Conditions Hydraulic Model Results

The 2-D hydraulic model results were evaluated to understand hydraulic characteristics of the restored Huron River under design conditions. Water surface elevations, flow depths, velocities, and shear stress were evaluated to understand potential post-restoration geomorphic trajectory within the river and to design stabilized bed and bank treatments.

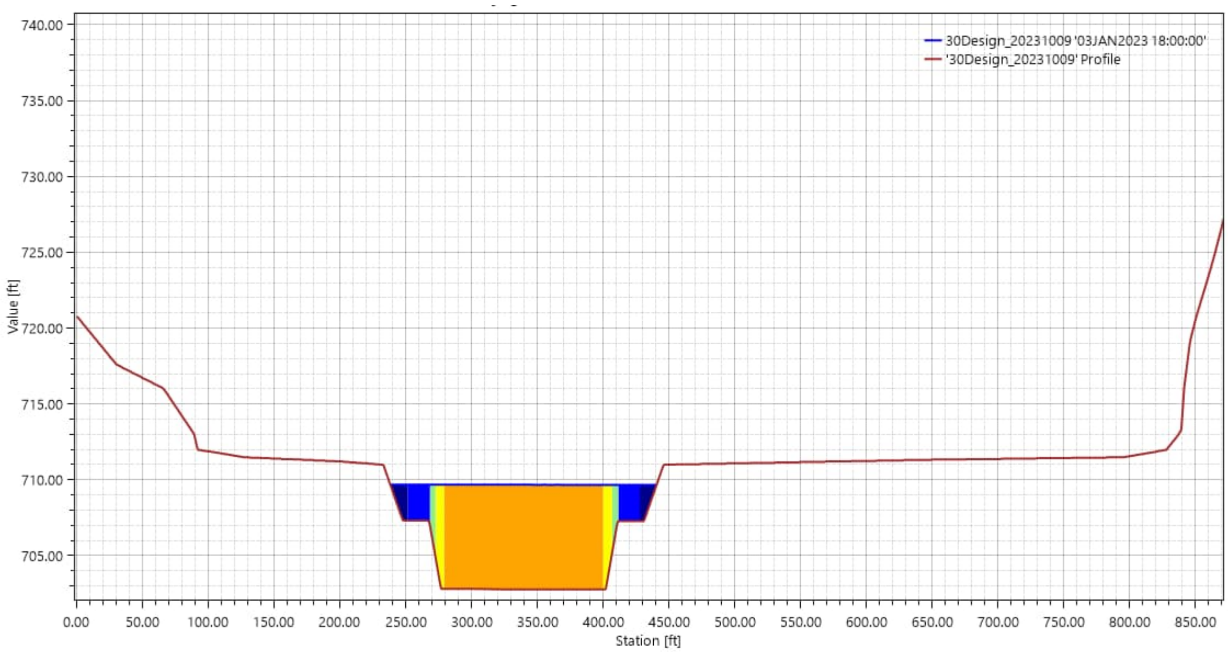
Within the upstream cell of the impoundment (i.e., upstream of Superior Road), river flows will be confined to the channel for flows less than 2,353 cfs, or the assumed bankfull discharge. Above this discharge, flow will access floodplain areas. During the bankfull flow event, model results indicate flow velocities within the channel will range between 3.2 and 4.6 ft/s and shear stresses will be as high as 0.65 psf, capable of mobilizing very coarse gravels. During large flood events, flow velocities within the channel area expected to exceed 7 ft/s upstream of Superior Road and may result in some erosion and scour along banks not stabilized with large wood or stone. Vegetation established on streambanks will serve to reduce the extent and degree of bank erosion during floods. The Superior Road embankment and bridge obstruct the floodplain and constrict overbank flows during flood events. During flood events exceeding the 5-year event, water surface gradients over proposed floodplain areas have a mean gradient of 0.18% and flow velocities on floodplains exceed 2 ft/s. To reduce the risk of avulsion in newly constructed floodplain areas, hydraulic roughness elements such as planted native woody vegetation, grasses, and large woody debris are included in the project design.



*Flow velocity is depicted with the colormap within the wetted portion of the channel for bankfull flow conditions (2,353 cfs).

Figure 19. Cross section of the proposed channel and floodplain upstream of Superior Road.

The middle cell of the impoundment between Superior Road and the railroad bridge will feature floodplain benches 20 feet wide and spoils piles located within the impoundment footprint. The hydraulic model indicates that river flow will begin to overtop channel banks and spill onto floodplain bench areas at river flows exceeding 3,300 cfs, or approximately the 2-year recurrence interval flood event. During the bankfull flow condition, model results show in-channel a range of in-channel velocity of 3.2 to 4.5 ft/s and maximum modeled shear stress of 0.60 psf, and flows would be capable of mobilizing very coarse gravels. Flood flow velocities in the channel are greater than during bankfull conditions, indicating that the floodplain benches do little to attenuate floods, and rather their benefit is primarily in regard to creating floodplain habitats. The bend immediately upstream of the railroad bridge poses a potential avulsion pathway the project designs include floodplain large wood for hydraulic roughness. Woody and non-woody native vegetation should be planted along this bend to increase root zone stability and hydraulic roughness.

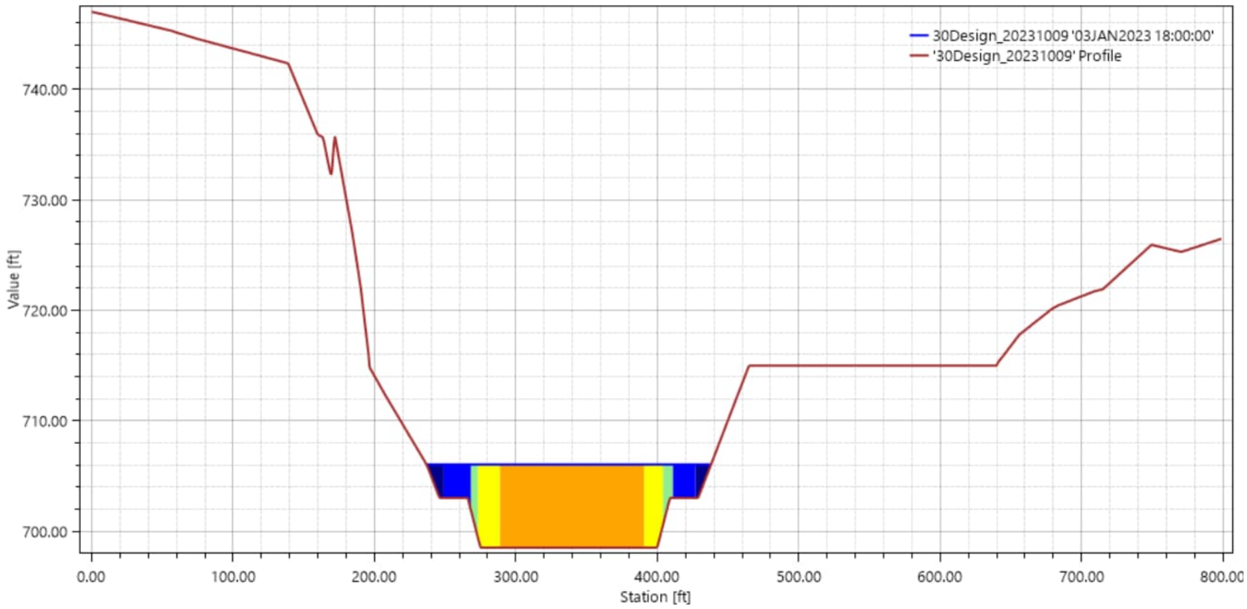


*Flow velocity is depicted with the colormap within the wetted portion of the channel and excavated floodplain.

Figure 20. Cross section of the proposed channel and floodplain in the middle cell of the impoundment near Sta. 46+00 for the 10-year peak flood event (5,600 cfs).

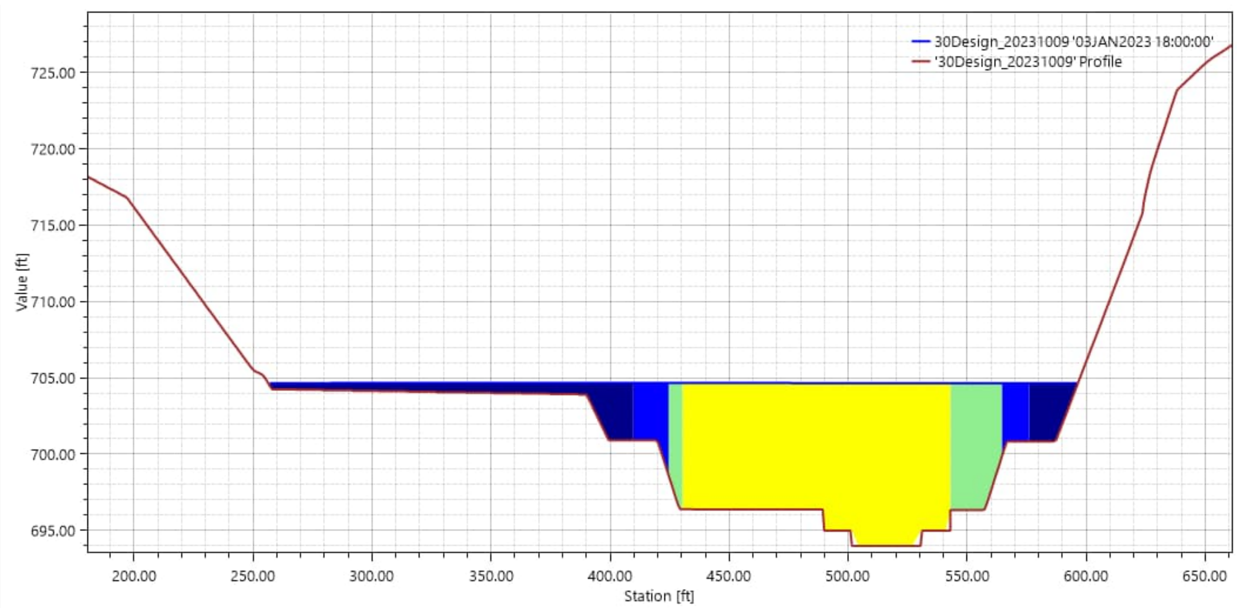
The downstream cell of the impoundment between the railroad bridge and Pen Dam features a relatively narrow, confined valley compared to upstream areas and is similar to reaches of the Huron River downstream of Pen Dam. Excavated channel sediments placed in spoils piles will further confine the valley cross-section. Within the upstream portion of this cell, floodplain benches 20 feet in width will flank either side of the channel. During average bankfull conditions (2,353 cfs), model results show ranges of flow velocities and shear stresses are broadly similar to upstream cells, and flow would be competent to mobilize very coarse gravels. The constriction posed by the remaining former mill building adjacent to the dam and the narrow valley cross section at the dam's location will backwater the downstream-most reach of this cell and inundate floodplain bench and floodplain areas near Peninsular Park during the bankfull flow and low-magnitude flood flows. The excavated floodplain near Peninsular Park is expected to attenuate flow velocity within the channel during large floods by approximately 1.0 to 1.5 ft/s compared to upstream areas.

In sections of the downstream cell containing floodplain benches and spoils piles, large-magnitude flood events will be entirely confined to channel and floodplain areas and will not inundate spoils pile areas. During the 10-year event and greater magnitude floods, flow velocities within the channel will exceed 5.0 ft/s and will be competent to erode and scour unarmored banks in the reach. Native vegetation will act to reduce erosion during these flood events. Flow depth during the 100-year flood event exceeds 10 feet.



*Flow velocity is depicted with the colormap within the wetted portion of the channel and excavated floodplain.

Figure 21. Cross section of proposed channel and floodplain grading in the downstream cell of the impoundment upstream of Peninsular Park near Sta. 23+00 during the 10-year peak flood event (5,600 cfs).



*Flow velocity is depicted with the colormap within the wetted portion of the channel and excavated floodplain.

Figure 22. Cross section of the proposed channel and floodplain in the downstream cell of the impoundment near Peninsular Park and the dam's location for the 10-year peak flood event (5,600 cfs).

6.1.2 Stream Stabilization

Following removal of the dam and restoration, many portions of the restored Huron River will have mobile boundaries, meaning they will be allowed to migrate naturally over time. Erosion and deposition can be expected in the restored channel and floodplain. Localized bank and bed stabilization is required to meet project objectives of protecting infrastructure, sensitive slopes, and private property. Critical bank areas requiring stabilization are shown on the 30% design drawings and are located on banks along outside bends upstream and downstream of the Superior Road and railroad bridge crossings, in addition to along the railroad embankment upstream of the dam. Two forms of bank stabilization are proposed: large wood cribwalls and stone toe banks. Cribwalls will consist of a stable configuration of large wood placed from the estimated scour depth to the above the average baseflow water surface, with bioengineered banks on the upper slopes. Banks with stone toes include rounded stone on the lower part of the banks, into which large wood will be integrated at regular intervals. Rounded stone gradations would have a median grain size of 18 inches based on moment stability analysis methods (Julien, 2010). Upper portions of the banks will be constructed using bioengineering techniques and temporary, biodegradable coir erosion control fabrics. After the fabrics degrade, native riparian vegetation will provide bank stability.

Bed stabilization in the form of riffle construction is proposed at the location of the dam and may be necessary within the middle and downstream cells to provide grade control and limit vertical channel adjustment in the period following restoration. Riffles in the middle and downstream cells may not need to be constructed if channel excavation exposes competent riffles in the pre-dam riverbed in the locations near proposed riffles. Riffles will be constructed out of imported rounded stone with a median grain diameter of 6 inches, which is expected to be immobile over the full range of design flows up to and including the 100-year flood event. Floodplain cutoff sections are included at the upstream ends of riffles to reduce the risk of bank erosion and flanking at riffles. Floodplain cutoffs include buried riffle material mixed with select fill within the floodplain bench section.

6.1.1 Superior Road Bridge and Railroad Bridge Stabilization

Based on preliminary results of the scour analysis and impoundment restoration, the depth of predicted scour is near the bottom of the pier foundations for the Superior Road Bridge based on as-built drawings thus requiring scour mitigation measures. The depth of the piles for the Railroad Bridge are unknown due to the lack of available information on the bridge foundation; however, it is expected that this bridge will also require scour mitigation measures. Please refer to LimnoTech's *Supporting Analysis of the Peninsular Paper Dam Removal Report* submitted to the HRWC in March 2022 for more information and discussion regarding the scour mitigation assessment at the Superior Rd and railroad bridges in the impoundment.

The preliminary hydraulic modeling and analysis indicate scour mitigation may include the placement of up to a 30-inch-thick riprap apron with a median rock size of 18-inches extending 25 feet from the toe of the bridge abutments and piers. Additional protection such as constructing flow deflectors to redirect flow from bridge foundations to further reduce potential erosion may also be considered. Additional structural and geotechnical data collection and evaluation of the bridges will be required in the future design phase to determine the appropriate countermeasures.

6.2 Excavation and Spoils Management

The extent of excavation involved to restore the pre-dam channel and floodplain is a key component of restoration plans and is estimated to be the greatest cost element of the project. Sediment excavation volume and disposal location not only correspond directly to project cost but have significant implications for the geomorphic and ecological trajectory of the Huron River and its floodplain in the years following dam removal and impoundment restoration. During construction, care should be taken to limit channel excavation to the former channel bed and to not remove coarse pre-dam channel bed gravels and cobbles.

Excavation volumes at the 30% design stage reflect average channel cross section and gradients and include floodplain grading. The extents and elevations of spoil piles on the floodplain were designed such that excavated sediments would be placed in spoils piles in the same cell. This assumption is made because of the anticipated difficulty of crossing Superior Road and the railroad with haul trucks during construction. Hydraulic dredging may be used to move sediment from downstream cells to upstream cells. Experienced contractors may be able to provide valuable insight into relative costs, site access, and management of dredged material during the project's final design phase.

Spoils piles were also designed to meet HRWC preferences regarding aesthetics of upland areas (i.e., minimal alteration, grading, or vegetation restoration) and to balance cut/fill to within 1% of the estimated excavation volume. In future design phases, spoils piles could be shaped to provide a more naturalized appearance and, where possible, create wider floodplain areas.

Floodplain restoration near Peninsular Park will require additional floodplain excavation. Floodplain excavation in this location occupies an area that would otherwise be used as a spoils pile. Given the downstream position of the floodplain restoration area relative to spoils piles and physical limitations on the size of spoils piles, excavated sediments from the reach near Peninsular Park will likely need to be hauled to an offsite disposal location. This location has not been identified at the current design stage but should be identified during the final design phase of the project. Nearby agricultural fields or developments may be willing to receive large volumes of clean sediment. Impacts to roads along the haul route may result from heavy truck traffic.

6.3 Habitat Restoration

The overall project goal is to restore the Huron River within the Pen Dam impoundment to a free-flowing channel with sediment and flow continuity both longitudinally along the stream profile and laterally between channel and floodplain. Mechanical removal of sediment from the pre-dam channel will provide immediate benefits to species living in the Huron River corridor. However, habitat restoration outcomes of the restored Huron River are fundamentally constrained by existing infrastructure and project budget, including the fate of excavated spoils and areas where armored banks are required to protect sensitive areas. The project’s 30% designs include habitat improvements within the scope of the preferred restoration alternative as outlined by HRWC. As the project moves forward to the final design stage, habitat elements may be scaled up or down to meet project goals and budget needs.

Removal of the dam and excavation of accumulated sediments from the proposed river channel will result in increased complexity of depths, velocities, substrates, vegetation, and other elements, which in turn will produce a variety of habitat types in the river corridor. Portions of the bed and banks will be stabilized with rock, large wood, and bioengineering treatments to protect infrastructure against bed incision and bank erosion, such as near bridges that cross the impoundment. Habitat elements included in the project’s 30% designs include constructed geomorphic features (pools, riffles, and depositional features), boulders with pocket water pools, mobile-boundary banks, large wood placement, and impoundment revegetation with diverse assemblages of woody and non-woody plants. Proposed habitat improvements such as revegetation, large wood structures, and boulders also serve channel stabilization functions by increasing roughness, reducing flow energy, and armoring surfaces.

6.3.1 Riffles, Pools, and Bars

Riffles are proposed in three areas to control grade and create coarse-substrate habitat for mussels and macroinvertebrates. Riffles will be constructed by excavating the existing channel bed to subgrade and backfilling with layers riffle material (Figure 23). Riffles are designed to permit passage for native fish and recreational paddlers. The specified gradation of riffle material features a median grain size that is predicted to be immobile over the full range of flows up to and including the 500-year peak flood event. Native material excavated from the river channel or undisturbed native bed material may be used to construct riffles.

Pools are constructed by excavating sediment and casting the spoils on the opposite bank in the form of a depositional bar. This approach helps to maintain channel hydraulic stresses that prevent pools from filling with fine sediment. Logs and rootfans included within cribwalls constructed along pool sections will induce local scour, provide boundary roughness, and stabilize banks.

*Photo taken 8 years after dam removal.

Figure 23. Example of a constructed riffle on the Mill River in MA.

6.3.2 Boulders

Large boulders in the 2- to 4-foot diameter range can provide adult holding cover habitat in steeper reaches. Pocket water pools downstream of boulders provide feeding stations and holding water, creating fishing opportunities. Boulders will be integrated into riffles to provide hydraulic bed roughness and velocity refugia for fish. The density and quantity of boulders may be scaled to the project's budget.

6.3.3 Large Wood

Large-diameter wood is proposed to protect banks from erosion, provide overhead cover and visual separation for fish, local scour in pools, flood refugia, reptile and amphibian basking areas, and perches and nesting habitat for birds. In the project's 30% designs, large wood is focused on banks to provide stability and increased in-stream habitat, and in targeted locations on floodplains to provide hydraulic roughness during overbank flows. Bank applications of large wood include discrete engineered log jams in the downstream cell to deflect flow vectors away from sensitive bank areas. Cribwalls are also included to provide bank stabilization and habitat benefits along critical outside bends Large wood must be designed with paddlers in mind to avoid trapping and pinning boaters. Ballasting requirements and stability against overturning and sliding were assessed using national U.S. Bureau of Reclamation and U.S. Army Corps of Engineers standards. Log piles and earthen backfill are proposed for ballasting cribwalls and bank large wood structures. Floodplain large wood structures will rely on piles for ballast.

6.3.4 Riparian Revegetation

Once the drawdown and construction activities are completed, the floodplain area and spoils piles will be seeded and planted to encourage native plant establishment and discourage invasion by non-native plants. In bioengineering applications, planting is critical to bind soils in the root zone, minimize soil water pore pressure, and provide resistance to erosion. Detailed planting and seeding plans are not included in the current phase of the design but are indicated in general terms in the project design drawings. The type of vegetation communities that are established in floodplain and spoils areas will depend primarily on the frequency and duration of inundation during floods. Spoils piles will feature less flood tolerant, and upland plant communities. Floodplain and near-bank areas will require native, flood-tolerant, vegetation suited to the anticipated degree of inundation and proximity to flowing water. Per HRWC's direction, cost estimates were prepared assuming only seeding in spoils piles adjoining private parcels, with the exception of bioengineered banks along riffles and stabilized banks, which will include planting of native riparian woody vegetation for stability. More extensive and diverse assemblages of native vegetation planting may be pursued in the areas surrounding Peninsular Park.

6.3.5 Potential Future Restoration Work

HRWC requested a list of additional potential restoration options which may be pursued within the former impoundment following the completion of restoration work. The goal of the existing 30% restoration designs is to establish a stable, free flowing river with only minimal vegetative restoration effort in the reach upstream of the railroad bridge. Potential future restoration options include:

- Placing additional large wood within pools or along the banks of the Huron River to improve in-stream habitat conditions by inducing localized scour, deposition, and habitat heterogeneity.
- Placing large wood structures on floodplain surfaces to create additional hydraulic roughness as needed.
- Additional select excavation of spoils to produce larger floodplain areas. These areas could include fine grading to introduce floodplain microtopography or vernal pool habitat in floodplain areas.
- Planting native riparian trees and shrubs in floodplain areas to establish *shrub-scrub* or *floodplain forest* vegetative communities.
- Planting native trees and shrubs on spoils piles and transitional slopes to establish *upland forest* vegetative communities.
- Reseeding spoils pile areas with diverse seed mixes of native forbs and grasses to establish pollinator habitat.
- Paddler access points, recreational trails, etc.
- Invasives species management.

7. Proposed Sediment Management

7.1 Sediment Management Strategy

The proposed dam removal and river restoration project will employ an active sediment management approach to reduce the amount of sediment transported downstream. Impounded sediments will be excavated from historic channel and floodplain areas and placed in spoils piles, where they are less likely to mobilize. A relatively small amount of sediment may be hauled offsite to a yet-to-be determined approved offsite location. An active sediment strategy was selected by HRWC because the quantity of impounded sediment greatly exceeds the transport capacity of downstream reaches of the Huron River. The selected management strategy and the proposed project designs are intended to minimize the amount of sediment released downstream during construction and in the years following the restoration project.

Sediments in the upstream and middle cells primarily contain coarse to fine sand deposits. During drawdown, these deposits will most likely dry out quickly, and active excavation using heavy equipment can likely begin shortly after drawdown. There will likely be areas where layers of organic material or silt deposits retain moisture, and those areas will need to be accessed using haul roads, mats, or amphibious equipment. Impoundment areas dominated by fine sediment may require alternative strategies such as suction dredging or drying and temporary seeding to facilitate mechanical removal. Uncertainties in the depth of refusal and sediment coring data are a result of the methods and resolution of sampling; design plans and specifications have been developed to be adaptable in both planform and elevation such that field indicators such as historic channel bed, floodplain soils, and tree stumps can be used to guide excavation.

Please refer to Appendix D for the preliminary Pen Dam Removal Sediment Management Plan.

7.1.1 Contaminated Sediment Management

Concentrations of PAHs and metals were found to exceed Michigan Part 201 thresholds at samples CO2 and DO3. Sediments containing these materials are deposited above the pre-dam channel and floodplain surface. Materials excavated within a 50-foot radius of these sample locations will be excavated, stockpiled and handled separately from other excavated materials, placed within spoils piles, and capped with a minimum of one foot of clean fill material sourced from elsewhere in the project.

Concentrations of contaminants were found to exceed CBSQG probable effect concentrations for benthic organisms in 20 locations. Where these locations are within the proposed channel and floodplain excavation limits, excavated sediments will be placed in the spoils piles shown on the 30% design drawings. Spoils piles will be seeded and/or planted with native vegetation following construction.

Coordination with regulatory agencies needs to be completed to confirm the proposed sediment management approach.

7.1.2 Sediment Traps

Temporary sediment traps are included in project’s 30% design and are intended to limit the amount of coarse sediment transported downstream of active work areas during dam drawdown and dewatering phases of construction. Sediment traps may be constructed out of sand and gravel filled bulk bags or similar materials and will be removed as channel excavation is completed upstream of each trap. Proposed locations of sediment traps are upstream of Superior Road and railroad bridges, as well as near the dam. The traps will be operational during the period of time construction is occurring upstream. Dam demolition and drawdown activities will be sequenced to maintain marginally backwatered conditions at the upstream operational trap location to encourage deposition. Sediment removal will occur daily, or as needed to maintain sediment trap operation.

Estimates of sediment mobility during drawdown were made using the 1-D hydraulic model considering known sediment grain size characteristics and possible dam configurations at 2-foot water surface intervals during staged drawdown. Model results indicate that as drawdown begins, baseflow, bankfull, and small-magnitude flood flow conditions will be competent to mobilize fine gravel and smaller grains. As drawdown and channel excavation progresses, and a more defined channel results, the same flow ranges may be competent to transport gravel-sized material in excavated portions of the channel outside of backwatered areas. Sediment traps are sized to capture bedload materials (sand and gravel) under marginally backwatered conditions. The precise rates of sediment transport during drawdown and channel excavation are highly uncertain because variables including flow magnitude, surface bed sediment composition, water depth, local flow velocity, rate of excavation, and channel size, may change simultaneously. Frequent sediment trap excavation is anticipated in the early stages of drawdown, and the need to clean traps may diminish over the duration of the project.

7.1.3 Long-Term Sediment Transport

Sediment management for the removal of Peninsular Paper Dam will require mechanical removal of sediment from the river channel. In the absence of mechanical removal, a channel would evolve along an anticipated trend over two phases (Collins et al., 2017). Initially, sediment is eroded from the channel in a ‘process-driven’ phase as a result of base level lowering and increase in the energy gradient, incising the channel until a stable channel slope and cross-section are formed (Pearson et al., 2011). Following the 'process-driven' phase, channel evolution enters a 'event-driven' phase in which larger flood events contribute to the majority of sediment transport (Collins et al., 2017).

Excavation of the channel and floodplain replicates the 'process-driven' step of channel erosion, and thus any post-construction erosion will follow an 'event-driven' trajectory. Sediment eroded during flood events will migrate downstream toward Ford Lake in pulses. Ultimately, the amount of sediment released from the restored impoundment will depend on the degree of bank treatment during restoration, establishment of vegetation along the channel banks, and precipitation and flood events in the months and years following construction.

7.1.4 Sediment Fate Analysis

The 1-D hydraulic model developed for the project was used to assess channel competence for materials that may potentially be released downstream during dewatering and demolition or after restoration is complete. Model results indicate that the proposed dam removal will not reduce the ability of downstream portions of the Huron River to mobilize particles and will continue to mobilize gravel and sand-sized materials under baseflow conditions. This analysis suggests that the rate of sediment transport out of the restored impoundment will be less than the potential sediment transport capacity of the downstream reach, and the reach will remain supply-limited over the long term. Thus, any released impounded sediments are likely to transport through free-flowing portions of river before ultimately being deposited in Ford Lake. Coarse sediment may be temporarily stored within depositional areas of the downstream reach such as point bars and pool bottoms and remobilized during periods of high flow.

The Alternatives Analysis Report prepared by the project team in 2023 analyzed potential depths of sediment deposition in downstream reaches of the Huron River and Ford Lake. That analysis found that even extremely large sediment pulses of ~6,000 to 30,000 CY evacuating the restored impoundment in a single year would result in approximately 0.5 to 3.1 inches of deposition in the Huron River and 0.1 inches in Ford Lake. Due to the presence of upstream dams, the restored impoundment will represent the primary sediment source for the restored reach.

8. Water Quality Implications of Dam Removal

Removal of Pen Dam will restore the natural flow of the river through the reach that is currently impounded. The increase in the flow velocity is expected to increase the dissolved oxygen in the river reach by both increasing the water velocity and allowing for additional entrainment, as well as lower the temperature of the water which will allow for additional oxygen to remain in in solution. The decreased surface area of the impounded water and increased velocity will decrease the solar radiation absorbed by the river through the impoundment reach, resulting in lower temperatures. Further, restoration of the floodplain may include additional shade along the banks that can further reduce solar radiation and decrease the water temperature.

The proposed design of the river channel includes three large riffles that cover over 90,000 square feet. These riffles increase the turbulence and encourage additional oxygen entrainment. In addition, the proposed design includes several large woody habitat structures and shoreline stabilization with wood cribwalls and bioengineering. These are critical supplies of carbon to the aquatic ecosystem that support the natural cycling of nutrients in the system.

In the restored river channel, sediment and phosphorus will be transported with the flows as they would through a natural system. The natural movement of bedload during higher flows will help to promote downstream channel stability, as a natural supply of sediment can help to reduce streambank erosion in systems where the flow of sediment from the watershed is interrupted. One key element in the full removal design of the channel will be to ensure that the channel is stable for the flows that will be encountered, as well as ensuring that the restored stream accesses the floodplain during high flows, which will allow for sediment and phosphorus to be deposited. Robust native vegetation on a floodplain bench can help to slow velocities in the overbank areas, promoting deposition, and allowing for vegetation uptake of deposited nutrients.

The existing sediment contained in the Pen Dam impoundment can release phosphorus sorbed to the sediment into the overlying water column, particularly under anoxic conditions on the bottom of the impoundment. With portions of the impoundment being relatively shallow, higher temperatures and high algae and plant productivity and respiration can contribute to low oxygen conditions during the summer. The release of phosphorus from internal loads would typically occur during the summer months, and the phosphorus from these loads would be readily available for biological uptake that could contribute to downstream nuisance algae blooms in Ford Lake. Restoring the natural flow through the system will reduce the potential for release of phosphorus from the sediment during periods of low dissolved oxygen.

The removal and/or capping of sediment that has been found with contaminants above the Predicted Effects Concentrations for supporting aquatic life will reduce the potential for environmental exposure of those contaminants.

9. Construction Sequence

The construction sequence for the Pen Dam removal and Huron River restoration was drafted to provide for the safest drawdown of the impoundment as possible while accommodating flexibility in water level control for sediment management purposes. The following is the anticipated construction sequence:

1. Mobilize and setup staging and access to various work areas and the dam site.
2. Install temporary soil erosion/pollution prevention systems prior to earth moving activities and construction of access roads. Add/modify fencing, as needed, to provide a secure site. Install construction access roads as needed for access to work areas including the spillway location and upstream restoration areas. Install staging areas for equipment parking and storage of materials.
3. Prior to all in-river earthwork activities, install turbidity curtains and sediment traps downstream of work areas to provide adequate protection of the riverine environment in the demolition areas.
4. Begin lowering the impoundment via the stoplog auxiliary spillway at a rate not exceeding 0.5 feet per day. The drawdown operation must occur in conjunction with sediment removal and remediation upstream of the dam. Use of the existing stoplogs will allow the contractor to slow dewatering as needed to prevent uncontrolled sediment transport.
5. Incrementally demolish the Pen Dam spillway to allow a maximum rate of 0.5 feet per day. Continue to coordinate dam demolition with sediment management and river restoration work.
6. Complete excavation, grading, and stockpiling of material as shown on plans.
7. Install large wood habitat structures, bank and bed stabilization features, and additional erosion protection improvements.
8. Finish grading site, revegetation, and demobilize.

10. Cost Estimate

An Engineer’s Opinion of Probable Construction Cost (EOPCC) for the proposed design is included in Appendix F. The EOPCC is prepared to a Class 3 estimate per American Association of Cost Estimators (AACE) standards and includes a cost range of -20% to +20% to reflect the uncertainty associated with the current level of design, and a 30% project contingency to reflect the uncertainty in the bidding environment and economic factors. The current EOPCC for the project is $9,991,700, plus a 30% contingency of $2,997,510, for a total of $12,989,210. Cost estimates are made in 2023 U.S. Dollars.

The current design phase has identified the overall channel planform and profile, bank stabilization features, and sediment management approach for the impoundment restoration portion of the project, but project elements such as the quantity of large wood placed for habitat or channel/floodplain stability and amount of sediment disposed of offsite may be adjusted in future design phases to meet project goals. Additionally, features such as additional site plantings, recreational access points, and discrete habitat features are not included in the current designs but can be included if requested by project partners.

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