Marshall Hydroelectric Project Disposition Study

Analysis of Concepts for Repair or Removal of Marshall Perrin Dam

Prepared for:
City of Marshall

Prepared by:
Stantec Consulting Michigan, Inc.

June 12, 2017

Sign-Off Sheet

Sign Off Sheet

This document entitled Marshall Hydroelectric Project Disposition Study was prepared by Stantec Consulting Michigan Inc. ("Stantec") for the account of the City of Marshall (the "Client"). The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. Any use which a third party makes of this document is the responsibility of such third party.

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Executive Summary

The City of Marshall is working to address items in need of repair at Marshall Perrin Dam. Specifically, prior work identified Potential Failure Modes associated with: 1) internal erosion and piping in the earthen embankment between Perrin No. 1 and 2; and 2) inadequate discharge capacity of Perrin Dams No. 1 and 2 which could lead to overtopping of the Park Embankment and Island Embankment at the Inflow Design Flood (IDF). Stantec was contracted to assess three possible solutions for addressing these problems: 1) repair the dam without drawing down the impoundment; 2) repair the dam by temporarily drawing down the impoundment; and 3) permanently draw down the impoundment and remove the dam. We reviewed regulatory and engineering considerations that could affect implementation of all three alternatives. Concept designs and cost estimates were also developed for the alternatives.

It is estimated that Marshall Perrin Dam is currently storing approximately 1.5 million cubic yards of sediment. Chemical analysis of the sediment has shown that concentrations for some metals and polycyclic aromatic hydrocarbons (PAHs) exceed agency screening criteria. More work will be needed to better understand potential ecological and human health risks posed by the sediments as they relate to project alternatives considered in this report. Our review of site conditions, regulatory considerations, and engineering elements suggest that all three alternatives assessed in this report are feasible. The major difference between them however, is the cost of sediment management. It is estimated that repair of the Island Embankment using a coffer dam will cost a little more than $2,000,000. In contrast, probable construction costs for Repair using Drawdown is $22,000,000 and Dam Removal is between $45,000,000 and $100,000,000.

Abbreviations

DWPC	Residential Drinking Water Protection Criteria
FERC	Federal Energy Regulatory Commission
IDF	Inflow Design Flood
LDB	Left Descending Bank
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
PEC	Probable Effect Concentration
PFM	Potential Failure Mode
PMF	Probable Maximum Flood
RDB	Right Descending Bank
SAP	Sampling and Analysis Plan
STID	Standard Technical Information Document
TEC	Threshold Effect Concentration
TES	Threatened and Endangered Species
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WSE	Water Surface Elevation

1.0 INTRODUCTION

Stantec Consulting Michigan Inc. (Stantec) was commissioned by the City of Marshall to study and report on alternatives for disposition of the Marshall Perrin Dam.

1.1 BACKGROUND

The October, 2012 Part 12D report prepared for the Federal Energy Regulatory Commission (FERC) for the Marshall Hydroelectric Project, completed by Lawson-Fisher Associates, P.C., (Lawson Fisher) identified the following Potential Failure Modes (PMFs) items in need of remediation at the dam:

- Internal erosion and piping in the Island Embankment.
- Inadequate discharge capacity of Perrin Dams No. 1 and 2 leading to overtopping of the Park Embankment and Island Embankment at the Inflow Design Flood (IDF).

The geotechnical report appended to the Part 12D inspection indicates that the stability safety factors of the embankment are unacceptably low due to uncertainties associated with piping. However, it is noted that the stability safety factor was not identified as a separate PFM.

1.2 PURPOSE

In order to address the issues identified with the October, 2012 Part 12D inspection, the City of Marshall has studied three alternatives for remediation. Two of the alternatives are to repair the embankment and improve spillway capacity, and the third alternative is to decommission and remove the dam.

1.3 SCOPE OF WORK AND ALTERNATIVES OVERVIEW

Stantec's scope is to assess the following three alternatives for addressing issues identified with the Part 12D inspection:

1. Repair the dam without drawing down the impoundment. Scenarios under this alternative consist of installing a cofferdam to dewater the embankment and making repairs, or other methods whereby the embankment might be repaired without drawing down the impoundment.
2. Repair the dam by temporarily drawing down the impoundment. The water surface of the impoundment will lowered by diverting the entire river discharge through the powerhouse. The lower water level will facilitate repairs on the embankment.
3. Permanently draw down the impoundment and remove the dam.

1.4 SIGNIFICANT ASSUMPTIONS

Stantec assumes the following for this study:

1. The analysis is based on review of readily available information and information provided by the City of Marshall.

2. The alternatives developed in this study are based on up to date correspondence with regulatory agencies; however, obtaining regulatory approvals is often a complex and iterative process. Therefore, future decisions by agencies may affect scope and cost of proposed alternatives.

3. Stantec's scope does not include a detailed costs/benefit analysis of delicensing alternatives for the project. Potential delicensing, and subsequent changeover to MDEQ regulation, will be discussed only in general terms as pertinent to the respective alternatives.

4. This report provides concept-level cost opinions for general planning purposes. Cost opinions are based on Stantec's professional judgment of typical costs for the items noted. Actual costs are provided by bidding contractors following issuance of detailed construction documents, and are based on multiple factors impacting the bid environment at the time of bid.

2.0 EXISTING CONDITIONS

2.1 PROJECT AREA DESCRIPTION

The Marshall Hydroelectric Project is situated on the Kalamazoo River on the southwest side of the city. The project has two overflow spillways (Perrin No. 1 and Perrin No. 2) and an earthen embankment between the two, known as the Island Embankment. The dam dates back to 1892 when a crib dam and power house were constructed. In 1898, a railroad was built adjacent to the overflow spillways. The railroad is no longer present, but concrete piers adjacent to Perrin No. 2 spillway remain in the impoundment. In the 1920's and 1930's, upgrades to the powerhouse were made and head-gates were added. Diesel generation was added in 1922 and later expanded in the 1930's.

The crib spillways were capped with concrete in the 1920's and 1930's. From 1966 to 1970 concrete repairs and upgrades were made to the spillways, and further concrete repairs were made in 1986, 1990 and 2003-2004.

The Federal Energy Regulatory Commission issued a license order for Project No. 6514-009 on December 22, 2005. The project has an average annual generation of approximately 1,300 megawatt-hours (MWh). The powerhouse contains two operational generating units with an installed capacity of 319 kW. Power generated by the project is integrated into the Michigan South Central Power Agency distribution system. The license is in effect for a 30-year term.

Critical Information

Elevations are based on NAVD 88 datum.

Typical embankment elev. (Island)	902.5'
Embankment crest elev.	900.96'
Perrin No. 1 spillway crest elev.	898.68'
Perrin No. 1 spillway length	213'
Perrin No. 2 spillway crest elev.	898.32'
Perrin No. 2 spillway length	88'
Normal inflow (harmonic mean)	240 CFS
Normal low monthly mean (September)	82 CFS
Normal high monthly mean (April)	460 CFS
1% flood	1,700 CFS
0.5% flood	1,900 CFS
0.2% flood	2,100 CFS
Zero freeboard capacity	3,900 CFS
IDF	5,192 CFS
PMF	13,135 CFS
Normal headwater elev.	898.75' +/- 0.25'
Normal tailwater elev.	885' *
Zero freeboard headwater elev.	900.96'
Zero freeboard tailwater elev.	893' *
IDF Headwater	901.49'
IDF Tailwater	895.5' *
PMF Headwater	903.5'
PMF Tailwater	902' *

Impoundment Size	130 acres	
Normal impoundment depth (at dam)	6' to 12'	
Hydro-plant generation capacity	#1	175 kW
	#2	144 kW (out of service)
	#3	144 kW
Bypass gate	7' 6" wide x 9'8" high; Sill 891.6'	
Hydro-plant flow capacity	1,637 CFS (2 active turbines + bypass gate. Assumes maximum pond elev.)	

*Estimated from tailwater curve.

2.2 EXISTING CONDITIONS OF DAM

Existing conditions of the dam and embankments, based on the findings of the Lawson Fisher Part 12D report (2012) and on field survey done for this report, are shown on the attached drawings. See **Appendix A.1– A.3.**

Appendices A.1 and A.2 comprise an overview of the facility and immediately upstream, showing the Island Embankment, Park and West Embankments, Perrin No. 1 and No. 2 spillways, and powerhouse.

The Park and West embankments represent the low crest conditions that were identified in the Part 12D report. The low embankment crest would result in water overtopping the embankments during high floods. Associated with the low embankment crest issue is the fact that the abutments of the Perrin spillways are too low to direct high flows over the spillway crest.

A significant feature of the Island Embankment is the existing 12" cast iron water main that was built in 1970 through the upstream end embankment. According to drawings provided by the City, the watermain is buried at a 6' depth through the embankment. The City would like to relocate the watermain, but funds may not be available for this in the near future.

In April, 2017, Stantec collected a set of measurements near the dam to augment existing data characterizing sediment volume in the impoundment. This was accomplished by pushing a survey rod into the sediment until the point of refusal. The impoundment bottom topography is indicated on **Appendix A.1 and A.2**. Most of the impoundment appears to have a significant layer of sediment, however there is a relative absence of sediment in the vicinity of Perrin Dam

No. 1 and extending from there downstream to the powerhouse intake. Upstream of Perrin No. 1, the sediment deposits increase as indicated by higher bed elevations.

Appendix A.3 shows a closer view of the Island Embankment and spillways.

Appendix A.4 is a plan view of the entire impoundment with profile.

2.3 SEDIMENT QUALITY

2.3.1 Sediment Volume

In order to estimate sediment volume, it was assumed the impoundment included the open water area up to the point where the river returns to a defined channel, approximately three miles upstream of the dams. The delta at the upstream extent of the impoundment was formed by sediment deposits and is a dynamic feature. Consequently, stored sediment volumes in this location may vary as a function of seasonal stream flow patterns. Some of these deltaic deposits are heavily vegetated and/or isolated from riverine erosional processes and will likely remain in place following a temporary or permanent drawdown of the impoundment. Based on limited preliminary data of sediment depth and location, the impoundment is estimated to be holding approximately 1.5 million cubic yards of sediment (Riser 2016, Stantec unpublished). Figures 1 presents a longitudinal profile of fine sediment storage in the impoundment with the dam on the left side of the graphic and the upstream extent of the impoundment on the right. This profile was derived from soundings collected by Riser (2016) and Stantec (unpublished). Figure 2 illustrates sediment depths as determined by the difference between the top (Sed.Top) and bottom (Sed.Bot) of sediment at individual sounding points along cross sections. The station label for each section corresponds to position on the longitudinal profile (Figure1).

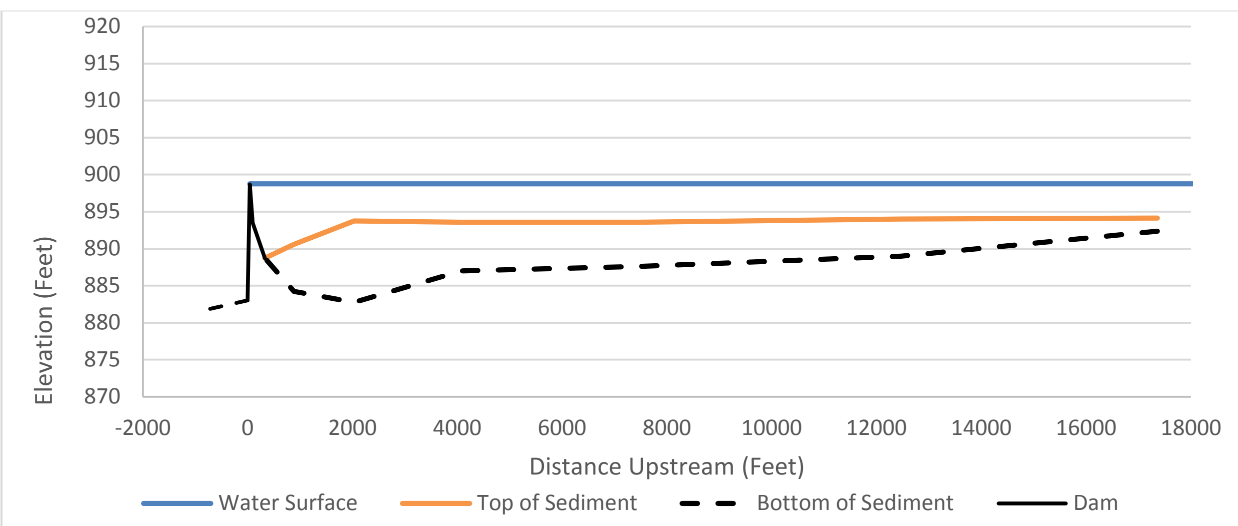

Figure 1. Sediment depth as a function of longitudinal distance upstream of the dam.

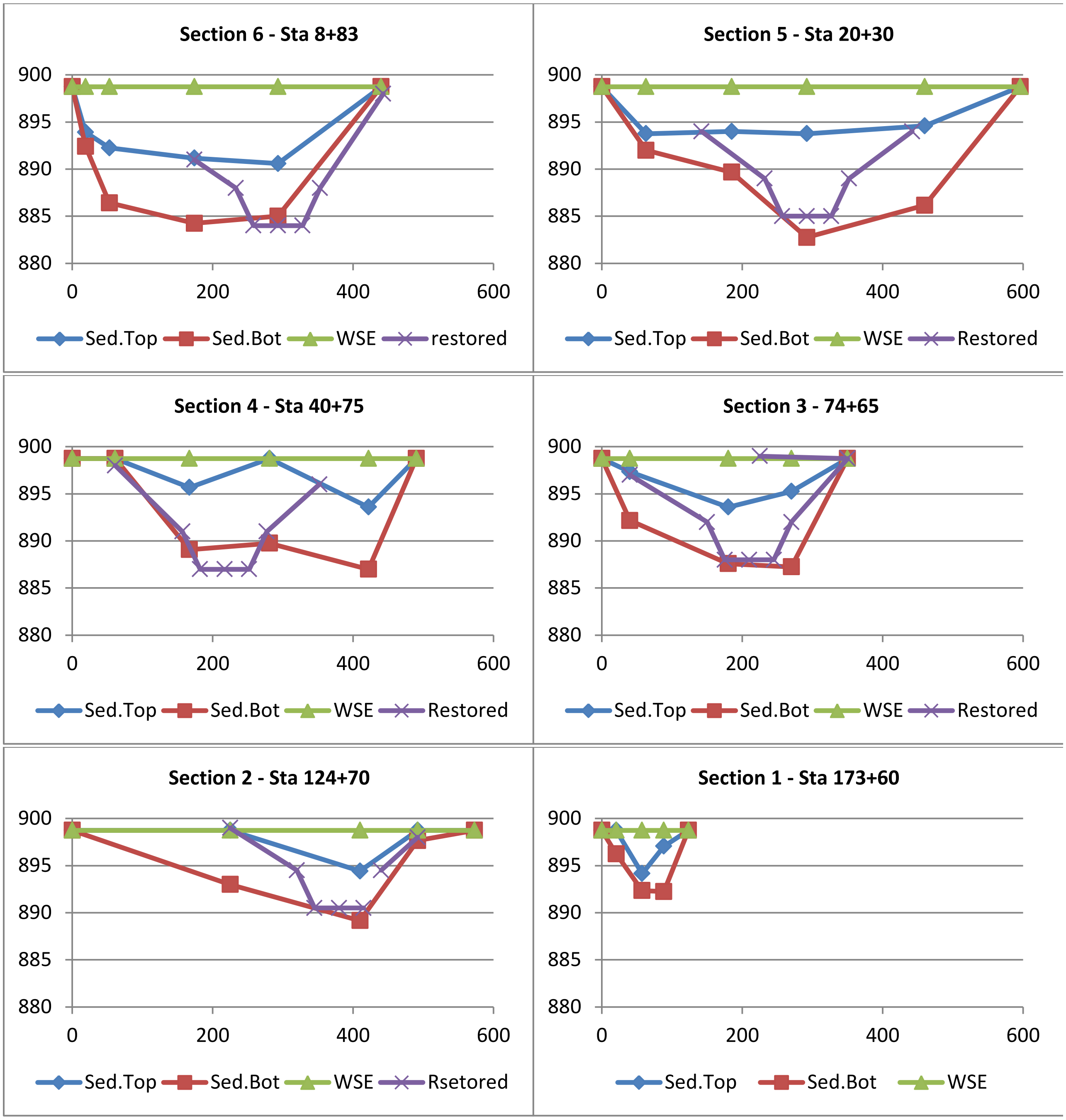

Figure 2. Fine sediment depth at cross sections in the Marshall Perrin Dam impoundment. Restored illustrates the channel alignment following dam removal.

2.3.2 Sediment Chemistry

The Marshall Perrin dam contains substantial sediment accumulation as described above. In such circumstances dams may also trap and store natural and anthropogenic constituents at concentrations that can be harmful to aquatic ecosystems and, in some cases, human health. Existing data sources were used to conduct a screening level assessment of sediment chemistry in the impoundment. Two sources of sediment data from the Marshall Perrin Dam were evaluated to as part of this assessment.

Sediment cores were collected by the Calhoun Conservation District at the request of the City on April 26th, 2016 (Riser 2016). Six sediment cores were collected and analyzed in order to understand potential sediment contaminant levels. Sediment samples were collected as outlined in the MDEQ Operating Procedure for Dredge Sediment Review (MDEQ 2013). Sediment cores varied in (0 to <6 feet) and were homogenized for analysis. All samples were analyzed for total PCBs (Method 608/8082), polycyclic aromatic hydrocarbons (PAHs; Method 625/8270), and the "Michigan 10" metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc).

Sediment grab samples were collected in 2012 and 2013 as part of the Enbridge Line 6B oil spill response (Enbridge 2014). Six samples were collected from the dam as an upstream reference area. Samples were collected with a Petite Ponar grab sampler from the sediment surface (<0.5 feet). Samples were analyzed for PAHs, but not metals or PCBs.

The screening level assessment of the sediment data included comparison to the following criteria:

- EPA Threshold Effect Concentrations (TECs)[1]
- EPA Probable Effect Concentrations (PECs)[2,3]
- Downstream Surface Sediments (PAHs only)
- Residential Drinking Water Protection Criteria (DWPC)[4]
- Residential Direct Contact Criteria (DCC)[5]

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[1] TEC- A concentration in sediment below which adverse effects are not expected to occur.
[2] PEC-A concentration in sediment above which adverse effects are expected more often than not.
[3] TEC and PAC values from MacDonald et al. 2000, MacDonald et al. 2003, USEPA 2003, USEPA 2015, and Buchman 2008.
[4] MDEQ Soil: Nonresidential Part 201 generic cleanup criteria and screening levels/Part 213 risk-based screening levels
[5] MDEQ Soil: Nonresidential Part 201 generic cleanup criteria and screening levels/Part 213 risk-based screening levels

It is important to note that the USEPA TECs and PECs are consensus based values derived from published literature and, when exceeded, do not necessarily equate to adverse effects. Instead, these values are intended to trigger more definitive sampling and analysis to better understand potential ecological and human health risks.

Appendices B.1, B.2, and B.3 compare the individual sediment sampling results and the arithmetic means against these screening criteria. Sediment samples locations are represented on **Appendix B.4**. The results of this screening are summarized below:

- No PCBs were detected above lab method detection limits (MDLs).
- With the exception of selenium all metals exceeded the TEC.
- The mean sample concentrations of barium, cadmium, chromium, and zinc exceeded the PEC. In addition, lead, silver, and mercury all exceeded PEC in at least one sample.
- Four of the six 2016 samples exceeded TEC for most individual PAHs. Mean 2016 concentrations exceeded TEC for all PAHs, but naphthalene.
- Four of the six 2012/2013 samples also exceeded TEC for most individual PAHs and TEC was exceeded for all mean values.
- With the exception of fluorene and naphthalene all individual mean PAHs exceeded PEC values in the 2016 samples. The same pattern was observed in the 2012/2013 samples[6].
- Most mean PAH concentrations from the 2016 core samples and the 2012/2013 surface samples exceeded both the mean downstream concentrations and the highest levels recorded downstream.
- Arsenic and cadmium exceeded residential DWPC[7].
- Arsenic and benzo(a)pyrene samples exceeded DCC.

The initial sediment samples collected from the impoundment give an indication of contaminant levels, but do not provide enough information for a complete assessment. The Marshall Perrin dam sediments contain elevated concentrations of some contaminants. These sediments will need to be further characterized and managed during the selected remediation to protect ecological and human health. The level of characterization and management will depend on the selected alternative and are further disused in **Section 3.0**. The project will need to work closely with MDEQ during planning, engineering, and design to develop a sampling and analysis plan (SAP) that addresses sampling requirements and applicable standards for the selected alternative. The following data gaps exist:

- The total number of sediment samples collected in 2012, 2013, and 2016, is low compared to the size of the impoundment. Additional samples should be collected based on the remediation alternative. These approaches are further described in **Section 3.0**.
- No sediment toxicity testing was conducted. MDEQ has requested toxicity testing in areas where sediment is expected to mobilize and from the expected sediment surface post dredging. Additional discrete sediment samples should be taken at the target dredge depths and compared to PEC values. If exceedances of PEC occur toxicity testing should also be completed for these sediments.

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[6] Chrysene and dibenz(a,h)anthracene values were not included in the 2012/2013 data.

[7] Analytical data are provided for total chromium only and compared to the cleanup criteria for Cr VI.

- No Synthetic Precipitation Leaching Procedure (SPLP) was conducted on sediment samples. This procedure may be required by MDEQ Remediation & Redevelopment Division (RRD) for surface sediments where DWPC are exceeded. The SPLP analytical data is used to evaluate whether the soil contaminants pose a leaching risk to groundwater resources.

2.4 HYDROLOGIC, HYDRAULIC, AND PHYSICAL PROCESSES

2.4.1 Basin Characteristics

The North and South Branch Kalamazoo Rivers converge near Albion, MI to form the Kalamazoo River, approximately 13 miles upstream of the Marshall Perrin Dam. The Kalamazoo River has a total drainage area of 2,020 miles before it discharges into Lake Michigan, 117 miles downstream of the Marshall Hydroelectric Project. Low hills and sloping uplands characterize the basin. Sandstone bedrock covered by glacial deposits of sand post- glacial alluvium and gravel are typical in this region. Soils around the project area are recorded as dark brown to dark yellowish brown loam soils (FERC 2005).

2.4.2 Streamflow Patterns

USGS Gauge 04103500 in Marshall, Michigan, is located just upstream of South Kalamazoo Avenue. The drainage area at this location is 449 square miles. The gauge is approximately 0.7 miles downstream of Perrin Dam and is ideally located to represent streamflow patterns in the project area. The overall streamflow pattern is one of relative stability with little difference between months (**Figure 3**). Mean daily streamflows were highest in March (494 cfs) and April (488 cfs) and lowest in August (240 cfs) and September (234 cfs). The maximum streamflow for the period of record was observed on March 29, 1950 and totaled 2,050 cfs.

2.5 ECOLOGICAL RESOURCES

2.5.1 Wetland Inventory

The U.S. Fish and Wildlife Service (USFWS) maintain a digital database illustrating the type and extent of wetlands potential present in an area. The data do not represent formal jurisdictional determinations but do suggest a high likelihood that such features are present. The National Wetland Inventory (NWI) data indicate that open water riverine and lake habitat types are located within the project area. The open water impoundment is approximately 140 acres in size. Surrounding the open water habitats are palustrine forested/shrub and emergent wetland types **(Figure 4)**.

Upstream of the dam, along the edge of impoundment (Lake, NWI feature) are lacustrine marsh communities with several emergent and forested/scrub shrub palustrine wetlands. Directly downstream of the embankment and spillways the NWI data show a 3.4-acre palustrine forested feature **(Figure 4)**. Further downstream of the project area, surrounding the more natural river

(Riverine, NWI feature) channel are long floodplain wetland systems, with several palustrine NWI wetlands adjacent to the river.

Within the project area there are 4 identified National Hydrography Dataset (NHD) streams **(Figure 4)**. The far river right (RDB) stream conveys water through the headgates to the power house facility, down the tailrace, until it joins with the main river channel. There are two NHD data indicate that two stream features are present in the overflow channel at each spillway, and threads converge to form a single channel downstream of the Perrin Dam No.2 Tailrace.

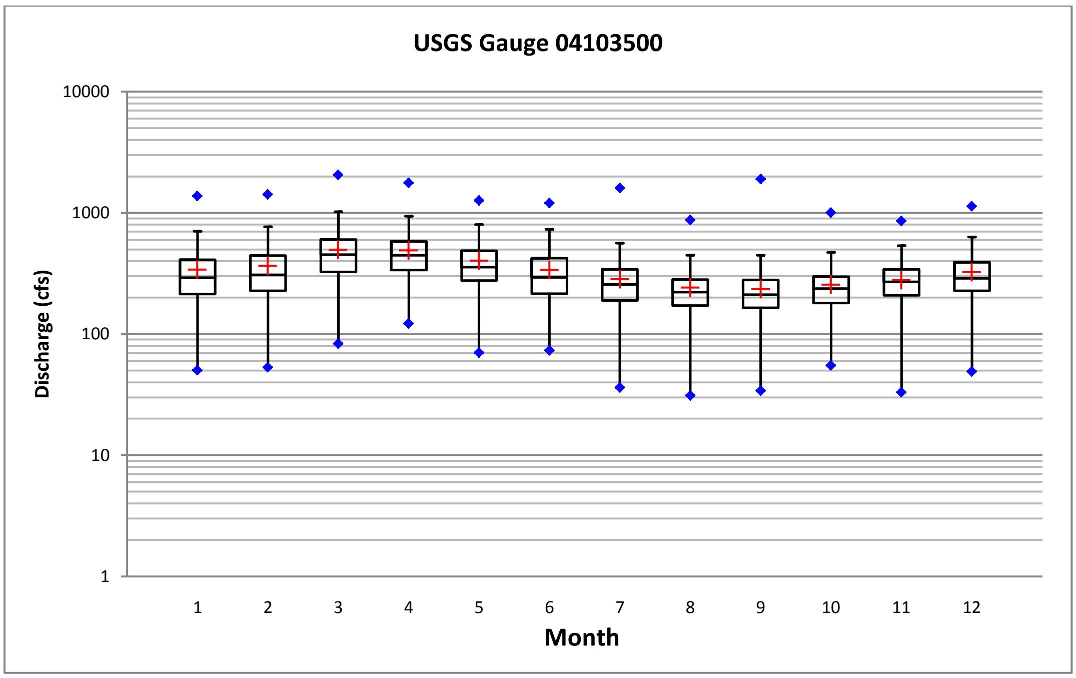

Figure 3. Mean daily discharge by month for the periods between January 1, 1949 and January 31, 1982 and January 1, 2002 and April 5, 2017, at USGS Gauge 04103500 in Marshall, Michigan. Boxes represent the 25th, 50th, and 75th percentile flows. Blue diamonds

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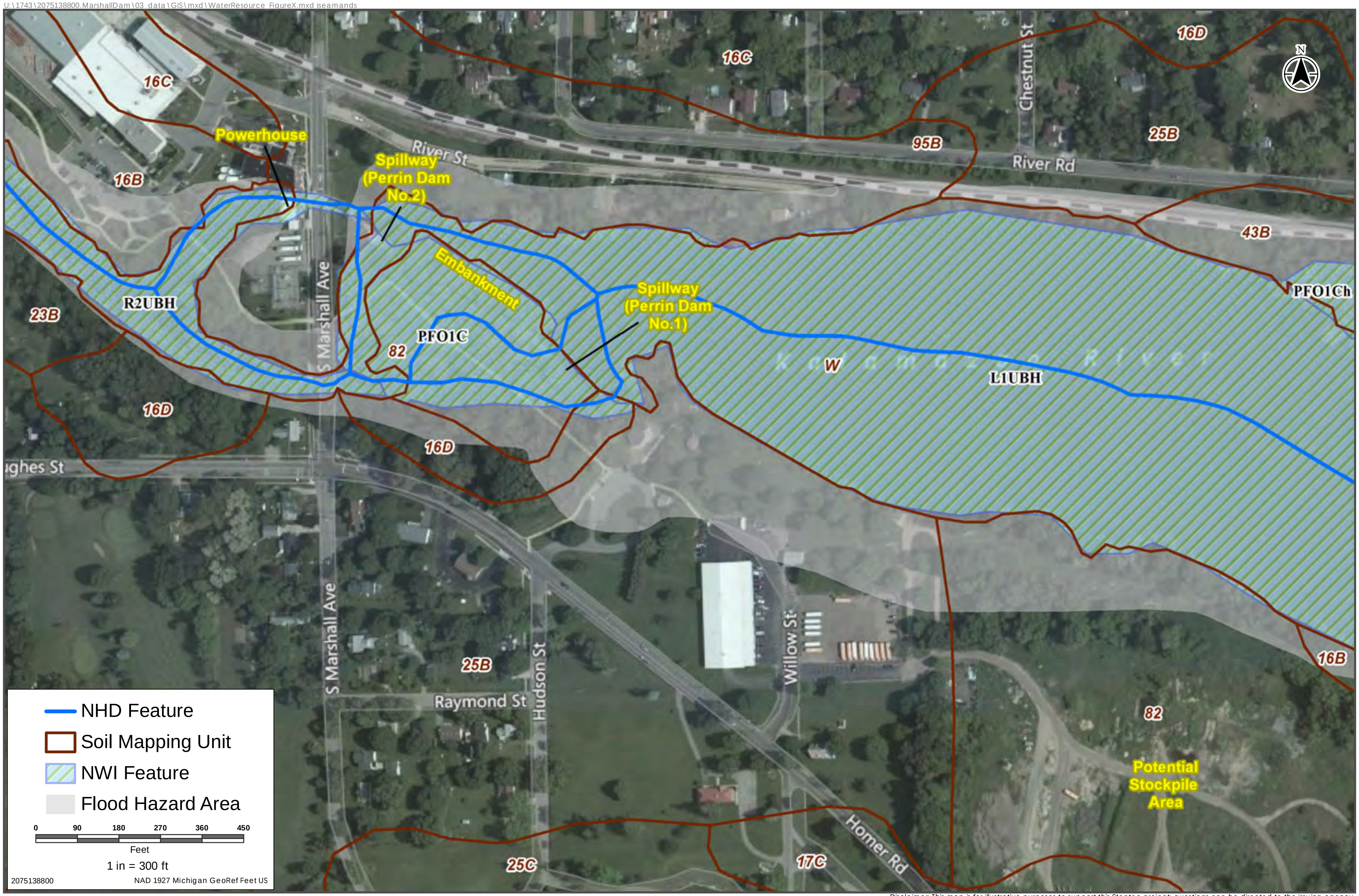

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

NWI = National Wetland Inventory; USFWS
NHD = National Hydrography Dataset; USGS
Bing Arial Imagery
USDA, NRCS SSURGO Mapping Units

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MARSHALL HYDROELECTRIC PROJECT DISPOSITION
CITY OF MARSHALL, MICHIGAN
APRIL 17, 2017

NWI Code Interpreter:
PFO1C = Palustrine Forested Broad-Leaved Deciduous Seasonally Flooded
R2UBH = Riverine Lower Perennial Unconsolidated Bottom Permanently Flooded
L1UBH = Lacustrine Limnetic Unconsolidated Bottom Permanenlty Flooded

Map Unit Symbol:
23B = Hixton loam, 0 to 6 % slope
16B = Oshtemo sandy loam, 0 to 6 % slope
16C = Oshtemo sandy loam, 6 to 12 slope
16D = Oshtemo sandy loam, 12 to 18 % slope
82 = Udipsamments and Udorthents, nearly level to steep
95B = Urban land-Kalamazoo complex, 0 to 6 percent slopes

Water Resource Inventory

Figure 4

2.5.2 Threatened/Endangered Species for Calhoun County

An on-line review (www.fws.gov/midwest/endangered/lists/michigan-cty.html) of federally listed species for Calhoun County, Michigan (accessed April 17, 2017) documented four listed species, as follows:

- Indiana bat (*Myotis sodalis*); Endangered
- Northern long-eared bat (*Myotis septentrionalis*); Threatened
- Copperbelly water snake (*Nerodia erythrogaster neglecta*); Threatened
- Eastern massasauga (*Sistrurus catenatus*); Threatened

The state of Michigan's Official List of Endangered and Threatened Species was accessed on April 17, 2017 at Michigan Department of Natural Resources' (MDNR) homepage. The full special species list for Calhoun county (Michigan Natural Feature Inventory, Michigan State University Extension), current as of 1/31/2017 was accessed at the following URL and is presented in **Appendix C**: http://mnfi.anr.msu.edu/data/cnty_dat.cfm?county=13.

2.6 HUMAN ENVIRONMENT

2.6.1 Land Use/Land Cover

According to the "Landuse circa 1800" a statewide database with vegetation descriptions between 1816 -1856 (prior to settlement), the cover type of much of the Marshall area was "mixed oak savanna" with interspersed "grassland" communities. Currently, agriculture practices dominate the Kalamazoo watershed (04050003) and most of the mixed oak savanna cover type been cleared.

National Land Cover Data (2011) was evaluated within a 5-mile radius of the Perrin Dam 2. When combining Cultivated Crops (corn and soybean) and Hay/Pasture cover types the total cover is over 50%, which is the most dominant cover type within a 5-mile radius of the project site.

The open water category is comprised of the Kalamazoo River and some glacial lakes, Stuart and Cedar Lake. Much of the Developed, Open Space consists of Alwyn Downs Golf Course, Brooks File Airport and Oakridge Cemetery just south of the project. Within the City of Marshall is a mix of residential, industrial, and commercial land occupancy.

Deciduous forests and woody wetlands are located along the main drainages including the Kalamazoo River and Rice Creek.

Table 1. NLCD Project Area Cover Types

Land Cover Type	Percentage	Acres
Barren Land	0.25	124
Cultivated Crops	42.53	21,387
Deciduous Forest	11.95	6,007
Developed, High Intensity	0.44	222
Developed, Low Intensity	4.52	2,273
Developed, Medium Intensity	1.61	811
Developed, Open Space	7.03	3,537
Emergent Herbaceous Wetlands	0.23	115
Evergreen Forest	0.16	83
Hay/Pasture	14.55	7,317
Herbaceuous	0.55	278
Mixed Forest	0.26	130
Open Water	1.73	869
Shrub/Scrub	0.23	113
Woody Wetlands	13.96	7,020
Total	**100**	**50,287**

2.6.2 Historical and Archaeological Resources

The Marshall Project, initially constructed in 1892 and 1893, appears to be the third oldest continuously operating hydroelectric plant in the United States (Commonwealth Cultural Resources Group 2010). The project was deemed eligible for listing under the National Register of Historic Places (NRHP) because of its significant contribution to broad patterns in history (Criterion A) and distinctive characteristics of a type, period, and method of construction (Criterion C). Buildings, structures, and objects eligible for listing included:

- Perrin Dam No. 1 (Contributing structure);
- Perrin Dam No. 2 (Contributing structure);
- Headrace including headgates and trash racks (Contributing structure);
- Hydroelectric Powerhouse and Garage (Contributing building);
- Diesel Plant (Contributing building); and
- Well Houses (Non-contributing buildings).

Some of the powerhouse components were modified and/or replaced beginning in 1910 and in two subsequent construction events. Consequently, it is the architectural/structural elements of the powerhouse that contribute to significance rather than mechanical.

The Island Embankment between Dams No. 1 and 2 was not identified as "contributing" or "non-contributing" resource. A railroad line once ran along this embankment; however, research into whether the embankment was built for use by the railroad or as part of dam construction was inconclusive (Commonwealth Cultural Resources Group 2010). Nor was the tailrace identified as eligible for inclusion in the NRHP. Additional investigation for these structures may be necessary as the project develops.

2.6.3 Recreational Use

The Marshall, Michigan fishing report provides a list of popular places that Anglers fish around Marshall, Michigan (http://www.hookandbullet.com/c/fishing-marshall-mi/). There are three locations located near the vicinity of the project site: Rice Creek, Wilder Creek and Buckhorn Lake. Wilder Creek site is at the confluence with Kalamazoo River, which is within the backwater of the impoundment. Common fish species are bream, bluegill, largemouth bass, perch, northern pike, rainbow trout, catfish, crappie, and brown trout. Motorized boat traffic is not common within the impoundment. Kayaking and canoeing are a common recreational activity downstream of the dam. There is a city park just upstream of Perrin No. 1 dam. The nearest state park, located approximately 20 miles downstream of the project, is the Fort Custer Recreation Area.

3.0 ALTERNATIVES

3.1 NO ACTION

This alternative is included as a baseline for comparison with the repair and removal alternatives. The no action alternative is simply to continue to operate the dam "as is" without addressing the issues as identified in Section 1.1 above.

3.2 REPAIR ISLAND EMBANKMENT – NO DRAWDOWN

This alternative makes needed repairs and modifications on the dam without drawing down the impoundment to achieve dewatering. Areas where work is needed include most notably the Island Embankment, but also the West Embankment, Park Embankment and both the principal (Perrin No. 2) and secondary (Perrin No. 1) spillways. Under this alternative, cofferdams are installed to provide suitably dewatered workspaces so the work can proceed.

Repairs and modifications are intended to address the seepage, structural and flow capacity deficiencies noted in Section 1.1 above. The following sub-sections discuss the repairs in detail and plans illustrating the basic elements of the conceptual design are presented in **Appendix B**.

3.2.1 Recommended Repairs and Modifications

The following repairs and modifications are recommended for the project (Ref. **Appendix D.1 through D.5)**:

- Island Embankment
  - Remove trees and other vegetation.
  - Excavate poor soils from the top and downstream sides, to a level of approximately 4' to 6' below grade. Includes demolishing masonry elements in the embankment (**Appendix D.2**).
  - Install an internal drainage system on the downstream slope (**Appendix D.3**).
  - Backfill with engineered fill material, increasing the crest elevation as required and proving a flatter downstream slope. The modified embankment will be wider as a consequence of the increased elevation and flatter slope.

This alternative assumes that approximately 4' to 6' of removal will be adequate to remove poor soils from the top of the embankment. The downstream slope is assumed to require 2' to 3' removal, plus additional for demolition of the masonry embedded in the side. In addition to facilitating uniform grading on the surface, getting rid of the masonry reduces potential seepage paths and allows for better consolidation of backfill materials.

The rebuilt embankment will include a granular chimney drain to prevent seepage from exiting randomly through the toe, and a weep drain to collect and remove the water from the embankment.

- Perrin No. 1 discharge area (Ref **Appendix D.1**, **D.4,** and **D.5**)
  - Remove and reconstruct a section of boardwalk as required to open a flow channel to the left.
  - Excavate south side of channel (LDB) to move flow in that direction.
  - Add fill near extended toe of Island Embankment to prevent low flow from moving in that direction.

Due to slightly higher final grade, the downstream toe of the rebuilt embankment will extend farther downstream than the existing toe, impinging on the Perrin No. 1 discharge channel on that side. To mitigate detrimental effects of water moving against the toe of the embankment, the primary flow channel will be moved to the south side of the discharge area. The fills along the embankment will be compensated with equal or greater cuts in the same area. Moving the primary channel to the south will require reconstruction of a section of boardwalk with a new bridge crossing to allow flow passage.

- Park Embankment
  - Add fill material to increase crest elevation.

A small amount of fill needs to be added to the Park Embankment to prevent overflowing during the IDF.

- West Embankment/Headrace Wall
  - Place concrete to increase the elevation of the left headrace wall.

To prevent overflow at West Embankment, Stantec suggests increasing the top of concrete elevation of the left headrace wall. Alternately, the earth grade could be increased on the

West Embankment, but doing this would likely require extending the right abutment of Perrin No. 2 spillway.

- Perrin Dam No. 1 and No. 2.
  - Place concrete to increase the elevation of left and right abutment walls.

To fully accommodate the IDF, the abutments of Perrin No. 1 and No. 2 spillways need to be raised by adding reinforced concrete wall sections. In addition, since the grade of the Island Embankment and Park Embankment are being increased, both abutments of Perrin No 1, and the left abutment of Perrin No. 2, need to be extended further downstream.

For all repair scenarios, it is assumed that the 12" watermain through the Island Embankment will remain in place for the duration of construction. However, to minimize interference and risk, Stantec recommends that the watermain be relocated before starting repair work on the dam.

3.2.2 Permanent Sheet Wall

A brief assessment was made of the possibility of permanently installing a wall of tight sheeting in the Island Embankment in order to avoid having to install then remove cofferdam. This option might appear to save costs because the tight sheeting presumably could supply the structural deficiencies of the dam, control seepage and also raise the crest elevation without a lot of added earth work.

A brief review of this alternative, however, suggests that adding permanent sheeting may not preclude seepage due to the fact that when the tight sheeting is driven it is likely to fracture the underlying sandstone in this location, thus possibly opening seepage paths under the toe of the embankment. Also, the marginal safety factor on the stability of the embankment means that slope remediation would still be required because sheeting in this case would rely on the passive earth resistance of the embankment for support. Regardless of seepage and structural issues, good maintenance practice also requires downstream slopes to have a more regular and flatter surface.

Cost savings are not likely to be realized by permanently installing tight sheeting because the sheeting material is expensive and can typically be reused on multiple cofferdam projects before it has to be discarded. Therefore, permanently integrating the sheet piling into the embankment structure means that the material will be purchased by the owner rather than rented.

Installing sheet piling also must contend with the presence of the 12" cast iron watermain in the embankment. In this scenario, working around the watermain is probably possible by employing special methods to seal around the pipe while keeping sheet piles clear. However, a seal of this type would come at an elevated cost. Moreover, the watermain represents a significant construction risk for the following reasons:

- Severing the watermain would deprive a portion of the City of water and expose the main to potential contamination. Currently there is not a way to route around the watermain should it become severed.
- A watermain break near the Island Embankment could lead to a catastrophic washout of the embankment.
- Repairing a watermain break near the Island Embankment would be difficult, time-consuming and costly.

For the above-noted reasons, this option is not recommended.

3.2.3 Staging and Cofferdams

3.2.3.1 Tight Sheeting

Tight sheeting would be installed around the Island Embankment to isolate it from the full pond elevation. Dewatering inside of the cofferdam would only be as low as was required to complete the work. It is estimated that a dewatering elevation of 894', or 5.2' below normal pond elevation, is required to complete repairs on the embankment.

Appendix D.1 shows the proposed location of the cofferdam. Tight sheeting is not a practical choice for crossing the span of the river due to the bracing that is typically required. Constructing a cofferdam near the embankment provides better opportunity for anchoring braces.

Staging is likely to be from the north shore, with barges and/or temporary bridges to access the embankment. It may be practical to drive sheeting on the west (downstream) end of the embankment using a crane situated on the north shore. However, sheeting toward the east end is likely to require employing barges in order to bring a crane close enough to complete the work.

Working around the 12" watermain will be a challenge. Sheet piling would have to be driven fairly close to either side and over top of the watermain without touching the watermain. Once sheeting is in place, the "window" through which the watermain passes would need to be sealed to prevent washing out when the water is lowered. This perhaps could include extending sheeting out around the watermain further off shore and capping the interior of the sheets with tremie concrete. Self-expanding grouts might also be placed under the tremie slab and around the watermain to limit seepage potential. In practice, the method of sealing around the watermain would require engineering efforts on the part of the contractor.

Regardless of the method, working around the 12" watermain with tight sheeting necessarily entails risks as noted above **(Section 3.2.1 Permanent Sheet Wall)**. Even if the watermain is not actually struck by a sheet pile or other equipment, the hammers used to drive sheeting can cause significant vibratory energy in the surrounding earth, resulting in stresses on nearby structures and utilities. Thus, there is potential for construction activities to cause a watermain break even if the pipe is not struck.

It will be important to expose the watermain before beginning work, and to continue monitoring it throughout the entire project so that any seepage or leaks that might occur can be identified immediately and dealt with. The City should have a response procedure in place in the event of a seep event or break. The procedure would include primary emergency responders, utility crews and the contractor. The clear preference would be to relocate the watermain before starting any construction on the embankment.

To avoid working over the watermain, a cofferdam made of sheet piling theoretically could be built across the entire river; however, bracing in this configuration is problematic due to the lack of a horizontal surface behind the cofferdam where supports might be anchored. Bracing down to the river bottom is possible, but this is not a typical installation for sheeting and would therefore tend to drive up the cost. Sheet piling across the river would likely be practical only if the net head difference from upstream to downstream were relatively small and if the underlying soils were adequate to support the cantilever of unbraced sheets.

3.2.3.2 Portable Dam

A portable dam of the type installed by PortaDam may be a viable alternative to traditional sheet piling as noted above (**Section 3.2.3.1 Tight Sheeting**). This system consists of a rigid steel framework covered with flexible sheathing. The portable dam requires little or no embedment into the river bottom or horizontal bracing to a fixed structure, relying rather on hydraulic pressure against the framework to provide sealing and stability.

For the Marshall project, the potential advantages of this system are twofold: 1) the support framework does not require lateral bracing to a fixed earthen structure, thus it is better configured than tight sheeting to be extended across the river channel; and 2) since there no real driving into the bottom, the danger to the existing 12" watermain is minimized.

This cofferdam could be installed either in the same location as is suggested for the tight sheeting (i.e., around the Island Embankment), or directly across the river. In the former case, the system would reduce construction risk to the watermain by avoiding the need to drive embedments around the pipe. However, there might still be a need for additional sealing around the pipe, depending on its depth below the river bottom and the type of substrate in which it is buried.

To further reduce risk to the 12" watermain, the cofferdam could be installed across the river rather than up against the embankment (See **Appendix D.4**). Short of relocating the watermain, installing across the river would provide the least risk to the pipe. However, installing across the river does increase risk is that it requires rerouting the river flow over Perrin Dam No. 1, which is approximately 3" higher than the principal spillway. Thus the river elevation can be expected to increase during construction. Sending water through the discharge area of Perrin No. 1 also interferes with some of the work to be done in that area. It may be possible to stage the work so that excavations and fills on the back of the embankment and in the discharge area are done before or after the cofferdam is installed, but cofferdams may also be required for portions of the work.

In lieu of a PortaDam, a cellular cofferdam could effectively be installed across the river width. This type of cofferdam consists of large cells confined by cofferdam sheeting, and filled with rock or other ballast material. The cells are built together to provide a continuous wall across the river. In effect, a cellular cofferdam is an earth fill contained within steel sheeting. This type of cofferdam is likely to be very expensive and is not considered further in this report.

Coffer damming across the river necessitates that the powerhouse and principal spillway (Perrin No. 2) be dried out and that flow temporarily be diverted over Perrin No. 1 spillway. This adds several complications:

- The hydroplant will have to be shut off with this option. Revenues from generation will be lost.
- Since Perrin No. 1 is higher than the principal spillway (Perrin No. 2) and due to the loss of generation flow, during construction the river elevation upstream of Perrin No. 2 will be approximately 3" higher at normal flows. The differential would be expected to increase during flood events until the water began to spill over the cofferdam. Overall, the higher water surface is likely to result in additional efforts to obtain an MDEQ permit, including doing a hydraulic model of the river to assess river response at various flows.

Discharge flows from Perrin No. 1 will elevate the tailwater at the toe of the Island Embankment, thus potentially requiring short cofferdams along the toe to complete construction work on the embankments and abutment walls.

3.2.4 Regulatory Considerations

3.2.4.1 Sediment Sampling Strategy

The cofferdam alternative has the least amount of potential sediment impact. As described above sediment depths are generally shallow near the spillways and proposed cofferdam. During cofferdam construction and dewatering there is potential for these shallow sediments to be disturbed and to mobilize. Alteration of flow patterns in the vicinity of the cofferdam may also cause some mobilization of sediments upstream of the cofferdam. Dredging is not proposed as part of this option, but best practices for erosion control would be employed during construction including turbidity curtains, silt fences, pumpage filters and other measures.

The project team needs to work closely with MDEQ to develop a SAP specific to sediment impacts associated with this alternative. The SAP will confirm sample numbers and the analytical requirements. For initial project cost estimates, six vibracore samples are proposed to characterize sediments within cofferdam and the vicinity of the dam (within 500 feet). Sediment cores will be homogenized and analyzed for the following parameters (these are minimum requirements):

- 7 Metals (arsenic, cadmium, copper, lead, mercury, selenium, and zinc)
- Polynuclear aromatic hydrocarbons (PAHs)
- Polychlorinated biphenyls (PCBs)

If the results of testing exceed PCB and/or mercury concentrations greater than 1 PPM, or metals data and/or PAH data greater than the PEC screening values MDEQ recommends toxicity testing to confirm sediment toxicity (10-day survival and growth with *Hyalella azteca* and *Chironomus tentans*). The analytical lab can hold the sediment for toxicity sampling pending the results of the screening against PEC criteria.

The sediment sampling strategy for the repair with cofferdam scenario is based on the following assumptions:

- Sediment transport modeling is not needed for this alternative.
- No dredging of sediments will occur.
- Sediment sampling will be limited to the cofferdam and areas within 500 feet of the dam.
- Six vibracore samples will be collected for bulk chemistry. Two samples will include toxicity analysis.
- Excavation from the Island Embankment and the Perrin No. 1 discharge area will be removed from the site. No re-use of excavation spoils is assumed.

3.2.4.2 Wetlands Impacts

The NWI data indicate that wetlands are present in the area immediately below the Island Embankment and Perrin No. 1 . Michigan Department of Environmental Quality (MDEQ) regulates placement of fill in the waters of the U.S., per Parts 301 and 303of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA). Due to fills from expansion of the Island Embankment and cuts for channel rerouting in the Perrin No. 1 discharge area, this alternative would require a permit from DEQ. Wetland mitigation, under Part 303, would be likely be required under this alternative due to anticipated impacts of greater than 1/3 acre.

Anticipated wetland impacts include permanent and temporary to the potential Waters of the U.S. (WUS) resources discussed in **Section 2.5.1**. Temporary impacts would include cofferdam installation and access. Permanent impacts to WUS would be activities associated with repairing embankment including filling and grading to desired contour and slope grade, seepage control system installation, and channel re-routing. Potential impacts to WUS features include discharge (cut/fill) into the 3.4-acre palustrine forested NWI feature as a result of the larger footprint of the repaired earthen embankment. Disposal areas (i.e., City-owned property that is off site from the dam) do not appear to contain wetlands but will need to be assessed prior to embankment improvements. The disposal area would be surveyed for potential wetlands. Other WUS permanent impacts include stream discharge (cut/fill) at the proposed drainage outlet which may result in stream channel relocation and or loss.

Under Section 303, Wetland Protection, MDEQ may provide conditions in the wetland permit to mitigate for impacts to discharge of fill materials that are greater than 1/3 acre. The mitigation ratio for restoration or creation is calculated at 2:1 debit for forested wetland and 1.5:1 debit for other emergent or scrub/shrub. And mitigation in the form of preservation counts for 10:1 acres of mitigation credits. Currently, restoration/creation credit at an approved wetland mitigation bank in the Kalamazoo watershed, Bear Swamp Drain Wetland Mitigation Bank is between $50,000 to $70,000/acre.

Without detailed project design, it is not possible accurately estimate the amount of wetland or stream impacts at this time. If we assume that there are impacts are > 1/3 acre to the mentioned palustrine forested wetland, the replacement ratio is 2 for 1. Mitigation for stream impacts may also be needed if the project results in a reduction of stream length.

3.2.4.3 Threatened and Endangered Species

At this point and time, we assume that site specific surveys for listed taxa as part of this alternative are unnecessary. We assume that routine consultation would be necessary with USFWS, i.e. habitat assessment, concerning the impacts to the federally listed species in section 2.5.2.

Being along a forested riparian corridor, we assume that the wooded habitat located south of the dam could potentially provide summer foraging habitat for TES bat species. We assume that any tree clearing for the proposed project will occur during the seasonal tree clearing period from October 1 to March 31.

Based on the level of disturbance currently existing in the project area and considering the presence of wetland habitat downstream of the dam, we assume that USFWS will concur with an affect determination of “may affect- not likely to adversely affect” for copper belly water snake and eastern massasauga or its habitat and that formal consultation with USFWS is unnecessary.

Stantec anticipates that MDNR staff will require a mussel survey and relocation within the construction footprint, excavation areas, and any area where fill will be placed. This effort will focus on the area surrounding the dams and where the embankment will be regraded.

3.2.4.4 Cultural Resources

As discussed, Perrin Dam No. 1 and 2 are contributing elements to the National Register of Historic Places (NRHP)-listed Marshall Hydroelectric Station. However, the earthen embankment and the tailrace are currently unevaluated in terms of their potential NRHP eligibility as contributing elements to the overall resource. Previous research was inconclusive concerning the date of construction for the embankment. Therefore, further assessment may be needed to determine whether or not the embankment is contributing to the overall resource and whether or not the proposed undertaking(s) will result in an adverse effect to the resource. This assessment would focus on materials related to the construction of the embankment.

Once an assessment has been conducted and a recommendation of adverse effects has been made, a Memorandum of Agreement (MOA) would need to be developed between the City of Marshall, the Michigan State Historic Preservation Office (SHPO), and other interested parties. Once and MOA is in place, and the project can move forward, professional Archaeologist will likely need to be on site during work to monitor all ground disturbing activities.

3.2.5 Schedule

From mobilization, this alternative is expected take 8 - 10 months to complete.

3.3 REPAIR ISLAND EMBANKMENT – WITH DRAWDOWN

This alternative draws down the impoundment to achieve dewatering for needed repairs and modifications. Under this alternative, the water surface of the impoundment is lowered approximately 5 feet from normal water surface to allow work to proceed on Island Embankment.

Repairs and modifications are intended to address the seepage, structural and flow capacity deficiencies noted in **Section 1.1** above.

3.3.1 Recommended Repairs and Modifications

Repairs and modifications under this alternative are the same as noted in **Section 3.2.1** above for the cofferdam alternative.

As with the cofferdam alternative, for the drawdown and repair alternative it is assumed that the 12" watermain through the Island Embankment will remain in place for the duration of construction. However, to minimize interference and risk, Stantec recommends that the watermain be relocated before starting repair work on the dam.

3.3.2 Drawdown Scenario

This scenario suggests drawing down the impoundment approximately 5 feet, from the normal elevation of 899.20 to 894.20 (**Appendix E.5**). In order to achieve and sustain a drawdown, all river flow will have to be diverted through the powerhouse. The maximum discharge through the powerhouse, including the two active turbines and bypass gate, is approximately 1,600 CFS. However, this capacity assumes full normal pond elevation. The discharge potential will decrease with decreasing water level. Also, it may be inadvisable to run flow through the turbines during drawdown as the increased sediment and debris load could cause damage to the machinery. Therefore, the "worst case" flow capacity should be based on the bypass gate alone.

The bypass gate is 7' – 6" wide with a sill elevation of 891.6'. Based on this configuration, it is estimated that the flow capacity of the gate alone varies from 450 CFS at maximum pool, to 90

CFS at minimum pool. Comparing gate capacity to the typical flow pattern noted in Section 2.4.2 above, it is apparent that the gate alone will have difficulty maintaining construction pond elevation during most months. Working in August, September and October, the gate should be able to draw down the pond, but it is unlikely that it can maintain the construction elevation though all but the lowest flows. There will be an appreciable chance of re-watering the pond to some extent during rain events. The flow rate can be increased by passing flow through the turbines, but only if the risk of damaging generation machinery is deemed acceptable.

Moving large amounts of water through the powerhouse increases the opportunity for scour damage, both to the upstream and downstream of the structure. Upstream, it appears that the floor of the headrace channel may be unpaved. It is also thought that the floor of the wheel pit itself may be a stony natural material rather than concrete. The bottom perhaps is competent to withstand the higher water velocities associated with increased flow, but this would have to be verified during the detailed design. Added protection may be called for depending on the findings. On the discharge side, there is a relatively sharp drop from the gate sill to the riverbed. While this improves potential flow capacity, it also increases the scour energy of the discharge. This concept therefore suggests adding temporary scour protection at the discharge.

The potential to mobilize and flush sediments with the scenario is high. The impoundment extends approximately 17,000 feet upstream from the dam (Station 170+00 – ref **Appendix A.3_"**Existing Conditions"). The impoundment from approximately station 20+00 to 80+00 would be left with 1 foot or less of water covering the sediment. From station 80+00 to 170+00 the bottom would be largely exposed during construction. Based on the limited data available at this time, exposed areas could total up to 100 acres. Overall, this configuration leaves abundant opportunity for stirring up bottom sediments, head cutting and surface erosion.

In order to mitigate transport of sediment out of the impoundment, pre-dredging a channel is recommended from at least station 80+00 upstream. Channelizing the reach from 20+00 to 80+00 may also be advisable. Best practices should be employed for stabilizing exposed bottomland for the duration of construction. Nevertheless, it is very likely that significant amounts of sediment will be mobilized and flushed downstream. Pre-dredging channels is beneficial, but it will not prevent collapse of embankments or mobilization of sediments.

3.3.3 Regulatory Considerations

3.3.3.1 Sediment Sampling Strategy

The sampling strategy for the drawdown alternative will be very similar to the dam removal alternative **(Section 3.4)**. Due to the shallow depths in the impoundment the drawdown would expose much of the channel and floodplain upstream of the dam.

Sediment sampling associated with the drawdown alternative will require close coordination with multiple MDEQ divisions. Different aspects of the characterization and removal of potentially contaminated sediment fall under the jurisdiction of the RRD, Water Resource Division

(WRD) and Waste Management and Radiological Protection Division (WMRPD). A SAP will need developed in coordination with these divisions. For the purposes of this report assumptions were made on level of sampling effort and characterization. These assumptions will need to be reassessed once a remediation alternative is decided on and the project enters the planning, engineering, and design phases. The number of samples for dredge material sampling is defined in MDEQ Dredge Sediment Review policy and procedure (MDEQ 2013) based on dredge volume. Addition sediment characterization numbers for WRD and RRD will be based on agency coordination and statistical power analysis. Sediment mitigation methods will be dependent on results of testing and volume of sediment mobilized. A project sediment management plan will be developed for agency review and comment following testing.

The sediment sampling strategy for the drawdown alternative is based on the following assumptions:

- Dredging will recreate the channel within the impoundment to minimize sediment transport. An estimated 100,000 cubic yards of sediment will be dredged prior to the drawdown.
- A sediment transport model will be used to identify additional areas of potential sediment erosion.
- Dredged sediments will be removed and disposed of. The preferred disposal option will be dependent on results of further testing to determine whether the sediment is inert and suitable for unrestricted upland disposal or on-site disposal with clean cover and Restrictive Covenant.
- The drawdown period will be limited to 6 months.

3.3.3.1.1 Waste Management and Radiological Protection Division

Sediment testing for the WMRPD is designed to characterize dredged materials for disposal as either solid or hazardous waste, not to define the nature and extent of contamination. The MDEQ Dredge Sediment Review policy and procedure (MDEQ 2013) outlines the sediment testing required for disposal which include:

- A minimum of six discrete samples collected to project depth and analyzed separately for the first 10,000 cubic yards, and one additional sample for each 10,000 cubic yards thereafter must be analyzed for the following parameters (these are minimum requirements):
  - 7 Metals (arsenic, cadmium, copper, lead, mercury, selenium, and zinc)
  - Polynuclear aromatic hydrocarbons (PAHs)
  - Polychlorinated biphenyls (PCBs)
- Samples to be collected from dredge footprint down to dredge depth.
- Typically, each sample will consist of a composited subset of a core taken to full project depth.
- Organic results can be organic carbon normalized.

Based on the MDEQ dredge guidelines it is anticipated 15 samples will be collected to characterize the dredge sediments. Sediment samples will be collected using a vibracore unit to the depth of the proposed dredge.

3.3.3.1.2 Water Resource Division

Sediment testing for the WRD targets surface water protection and sediment quality. Testing for WRD targets newly exposed sediments post dredging, exposed sediments resulting from sediment mobilization and impacts of mobilized sediments. For the dredge areas sediment sampling can be done in conjunction with the RRD vibracore sampling. Discrete samples will be taken from the target dredge depths. If the results of testing exceed PCB and/or mercury concentrations greater than 1 PPM, or metals data and/or PNA data greater than the PEC screening values MDEQ recommends toxicity testing to confirm sediment toxicity (10-day survival and growth with *Hyalella azteca* and *Chironomus tentans*). The analytical lab can hold the sediment for toxicity sampling pending the results of the screening against PEC criteria. Outside the dredge area sampling will also target areas where sediment mobilization is anticipated based on modeling results. Similar to the dredge areas the sediment chemistry will be compared to screening criteria and toxicity testing completed if there are exceedances. Sample numbers and analytical requirements will be based on agency coordination. For the purposes of providing some initial costs for this sampling it is assumed an additional 10 samples will be included for sediment chemistry and 10 samples for sediment toxicity.

3.3.3.1.3 Remediation & Redevelopment Division

Sediments temporarily exposed in floodplain areas during the drawdown period will need to be characterized per Part 201, Environmental Remediation of the Natural Resources and Environmental Protection Act, 1994, PA 451 (NREPA) to evaluate human exposure pathways. This includes potentially mobilized sediments that could be deposited in floodplains below the dam. These pathways include direct contact, ambient and particulate air inhalation, protection of the groundwater/surface water interface (GSI) and protection of groundwater drinking water. Based on recreational site use during the drawdown, it is assumed nonresidential direct contact would be the most applicable screening criteria. If testing results exceed the applicable Part 201 groundwater criterion leachate testing may be required to evaluate the potential impact to groundwater. Sediment sampling for RRD will focus on the nature and extent of contamination and verification of remediation options if required.

Sediment sampling for RRD characterization will target surface sediments outside the dredge channel. Sample numbers and analytical requirements will be based on agency coordination and statistical power analysis. For purposes of providing some initial costs for this sampling it is assumed 40 samples will be collected and the same analytical testing will be performed as the WMRPD testing. The WMRPD dredge sediment testing is assumed to be sufficient to characterize mobilized sediments that may be deposited in floodplains downstream. Although there is a correlation between sediment values and soil criteria the most accurate testing would involve dewatering sediment samples or testing soils after the dam drawdown to account for volatilization and other sediment/soil chemistry changes.

3.3.3.2 Wetland Impacts

Due to the anticipated placement of fill in wetlands below the dam, we assume a permit application and a mitigation plan would be submitted to MDEQ for this alternative as well. Anticipated wetland impacts include permanent and temporary impacts to potential WUS resources discussed in **Section 2.5**. Temporary impacts would include temporary drawdown of lacustrine resource and potential temporary hydrology alteration to upstream wetlands surrounding the impoundment. Proposed permanent impacts to WUS would be the same impacts described in Alternative -2 (Repair Island Embankment-No Drawdown) to the 3.4 acre PFO wetland below the dam.

Prior to the temporary drawdown of the impoundment, the reservoir sediment would be dredged and sediment relocated to a potential on site stock pile area **(Appendix E)**. This activity would be discharge (cut) to WUS, open water feature. This alternative will also result in some sediment release to downstream/ receiving waters. The stockpile area will need to be surveyed for the presence of wetlands prior to the placement (fill) of sediment.

Mitigation debits for wetland and stream channels below the dam, as described for Alternative 2, would apply for this alternative as well. Additional mitigation debits to consider may come from dredging activities, placement of dredge materials. If we assume that mitigation debits would not increase due to temporary hydrology alteration to upstream wetland resources, downstream sediment release, and dredging fill placement, total mitigation would be similar to Alternative 2.

3.3.3.3 Threatened and Endangered Species

This alternative would consider impacts below the dam and would need to consider temporary impacts to wetland habitats above the dam. Assumptions during TES consultation for this alternative would be as follows:

- Habitat for Indiana bat and Northern long-eared bat is present within project footprint;
- Project construction can accommodate seasonal tree cutting restrictions;
- Wetland habitat is present but much of these habitats are disturbed and would not be consider sensitive areas for TES snake species; and
- Despite an increase in WUS impacts due to temporary pool drawdown which would temporarily impact wetland resources surrounding the impoundment, we assume that USFWS would concur with an affect determination of “may affect- not likely to adversely affect” copper belly water snake and eastern massasauga or its habitat.

3.3.3.4 Cultural Resources

It is anticipated that the Section 106 process for this alternative would be very similar to repair of the Island Embankment with a coffer dam. Refer to the text in that section for more details.

3.3.4 Schedule

From mobilization, this alternative is expected take 8 - 12 months to complete. This interval could be extended depending on how project construction falls with respect to various regulatory work windows.

3.4 REMOVE DAM

3.4.1 Description

Removal of one or more portions of the Marshall Perrin Dam would occur in a phased approach. In addition to removing the vertical control structures, the bed of the impoundment would need to be regraded and stabilized to reduce the potential for the export of large amounts of sediment downstream. It is assumed that all operations associated with the dam will have ceased and that no further draw of water would be required by the City. In general, the sequence would include 1) creating staging and access areas, 2) dredging a pilot channel through the proposed river alignment, 3) drawing down the impoundment, 4) removing portions of the dam sections, 5) replacing the water main, 6) re-grading the river and floodplain through the old impoundment, and 7) installing stabilization measures in the river and revegetating the exposed areas.

The goal of river restoration is to create a naturally self-sustaining system where the river and its floodplain have appropriate pattern, dimension and profile to limit scour, erosion and channel migration. A conceptual alignment based on previous designs in the Kalamazoo River was developed for the purposes of analysis and planning (see **Appendix F**). The new alignment begins at the top of the impoundment near the transition from defined channel to open water and attempts to utilize the existing river thalweg (or lowest point) as much as possible to minimize dredging and earthwork, while still maintaining appropriate design parameters. Depictions of the potential restored channel alignment are presented in Figure 2. The alignment passes through the north side of Perrin Dam #1 and turns to the west to pass under the Marshall Avenue bridge. Perrin Dam No. 1 and most of the earthen embankment would be removed to create the new channel and floodplain. Perrin Dam No. 2 may potentially be left in place and the surrounding area graded to reduce safety risks. The existing intake channel and tail-race would be abandoned and filled with excess material removed during demolition and channel construction. Most of the area between the dam(s) and the bridge would be altered to promote a stable channel approaching the bridge (**Appendix F**).

The removal alternative assumes that the existing 12" watermain through the Island Embankment will be relocated.

3.4.1.1 Construction Staging and Access

Access to the work area is somewhat limited due to existing infrastructure, land ownership, and terrain. Access to the dam and surrounding area would likely be set up from two locations: 1) the park on Homer St and 2) directly off of Marshall Avenue. The Homer Road site will allow access to the up and downstream sides of Perrin Dam No. 1. The park would be used as a staging area and restored upon completion of construction. The access from Marshall Avenue would be to Perrin Dam #2 and the river below. Upon drawdown of the impoundment, access to the upstream side of Perrin Dam No. 2 may also be available from the intersection of Marshall Avenue and River Street (**Appendix D**).

Access to the impoundment may be limited based on the ability to obtain entry to private property. On the north side of the impoundment, the railroad closely borders the impoundment, limiting access to only the existing rail crossings to private residences and land. There are currently four existing crossings of the railroad. Access to the impoundment on the south side will be either from the aforementioned City owned parcel, agreements with private landowners, or via the power transmission easement which parallels the river. The easement would offer an ideal haul road for moving equipment and materials. However, this easement terminates prior to the end of the impoundment. Accessing the remainder of the impoundment would be from within the impoundment footprint or via private lands.

Equipment used for this work typically consists of tracked trucks for hauling material, tracked excavators with hydraulic thumbs, tracked equipment with hydraulic hammers for demolishing concrete spillways, bulldozers, wheeled dump trucks

3.4.1.2 Dredging Pilot Channel

Preliminary sediment chemistry data suggest that concentrations of certain pollutants exceed consensus based screening thresholds and the uncontrolled release of sediment downstream may not be a viable option. Dredging a pilot channel will reduce the amount of sediment available to be naturally transported downstream during the drawdown of the impoundment. The pilot channel will also help contain base flows to a defined area, allowing the dewatering of adjacent exposed sediment. As the sediment dries, it can be accessed and moved with a reduced risk of erosion and transport.

Dredging would be accomplished via a floating hydraulic dredge. The pilot channel would be formed along a proposed alignment so that further earthwork during stabilization can be minimized. Dredged sediment would be disposed of outside the ordinary high water in a location approved by regulatory agencies based on its physical and chemical characteristics. Preliminary approximations of hydraulically dredged material range from 60,000 to 160,000 cubic yards (CY). These approximations are based on a very limited amount of bathymetric data and thus are subject to significant change.

The City currently owns a large parcel of land on the south side of the impoundment near the intersection of Homer Rd and Division Dr. The parcel would be accessible directly from the river and via Homer Rd through the western adjacent parcel. If approximately 85% of the parcel area was used for sediment disposal, this parcel could hold most of the dredged sediment. Further analysis of the sediment must be performed to determine the feasibility of disposal on adjacent lands. Specific engineering controls may be needed to contain or stabilize the sediment in place. The other option would be to haul the sediment to an approved landfill location.

3.4.1.3 Impoundment Drawdown and Water Management

Upon completion of dredging, the impoundment would be drawn down to allow work on the dam and impoundment under dry conditions. The impoundment would be drawn down by opening available gates and routing water to the north side of the impoundment. Perrin Dam No. 2 may also be notched to allow the drawdown of water. The drawdown would be at a gradual rate of no more than 0.5 feet per day to minimize the potential for bank instability due to dewatering. This drawdown event would be low enough to work on much of the channel within the old impoundment. As water is routed to Perrin Dam No. 2, Perrin Dam No. 1 will be removed down to grade and channel stabilization work will progress from upstream to downstream. Once work has been completed on Perrin Dam No. 1 and the surrounding area, water can be rerouted to the south permanently.

3.4.1.4 Dam Removal and Sediment Grading

When the impoundment has been drawn down sufficiently, the contractor will access the upstream side of Perrin Dam No. 1 and remove the structure. It is currently assumed the structure would be removed to its entire height. The southern abutment may potentially be left in place depending on stability analysis of the structure and adjacent slope. Further analysis and design is needed to optimize the alignments and grades near the dam(s).

As the dam is removed, work will commence on re-grading the bed of the former impoundment. The remainder of the new river alignment and floodplain will be shaped per design. The river grading will include riffle and pool features necessary to mimic naturally stable conditions. Hydraulic modelling and sediment chemistry analysis will determine if and to what extent mechanically excavated material may be stored on the outer fringes of the old impoundment. Sediment deemed unfit for regrading will be hauled out of the river and disposed of at an approved location. Preliminary approximations of earthwork range from 300,000 to 540,000 CY. However, these numbers may be raised or lowered significantly with more detailed bathymetric data. Costs associated with grading and excavation will likely be higher due to the difficulty of conditions, specialized equipment and difficulty in balancing earthwork.

Based on previous design in the Kalamazoo River, the new channel would most likely be shaped at a depth that is wadable in riffles under baseflow to average hydrologic conditions. Pools would likely not be wadable under any flow-regime. The floodplain grading would likely range from approximately 50 to 150 feet outside of the top of banks. This is highly dependent on hydraulic modeling of flood flows, adjacent morphologic features (eg. Wetland depressions, tributaries, terraces), and sediment characteristics.

3.4.1.5 River and Floodplain Stabilization

As the new river corridor is graded, the bed and banks will be stabilized with bioengineering (e.g. rootwads, live branch layering) and rock riffle grade controls. Based on the limited sediment probe data available, it appears the historic river bed has a relatively gentle slope (less than 0.001 ft/ft). This should preclude the need for large stone or bulky structural controls in the river, however, grade control is still needed due to the small grain size of the existing sediment. The use of natural materials and varying bed facets will promote a self-sustaining stream as well as provide additional forms of habitat for a range of aquatic species. No structures would be used that would prevent floating watercraft from moving up or downstream. However, the new channel may not maintain enough depth for motorized watercraft, especially with outboard motors.

In addition to bioengineering in the channel, the banks and floodplain would be revegetated with native plant species to stabilize the exposed sediments. Vegetation provides the long-term stability of the river banks as their root mass takes hold and prevents channel migration. Vegetation may range from grasses to live stakes to bare root seedlings depending on the need and location. Species are typically chosen based on reference native conditions and by species that tend to grow quickly.

3.4.2 Regulatory Considerations

Due to the permanent impacts to existing WUS, a permit would be necessary from DEQ. This project is a stream restoration project and is anticipated to provide a functional lift for riverine habitats and reestablish wetlands within the restoration area. Therefore, we anticipate that this project alternative would be self-mitigating and not require mitigation from DEQ.

3.4.2.1 Sediment Sampling Strategy

The sampling strategy associated the dam removal alternative is very similar to the drawdown alterative discussed in **Section 3.3**. The same agency coordination, sampling and analytical parameters and assumptions apply. It is assumed most sediment transport would occur shortly after dam removal similar to the drawdown option. The major differences for this alternative are that exposed sediments in floodplain areas would become permanent upland/wetland areas subject to additional erosion and sediment mobilization over time. Additional characterization of sediments remaining following the dam removal in floodplain areas may need to be characterized per Part 201 of NREPA to evaluate human exposure pathways and impacts from exposed soils resulting from regrading of the floodplains.

3.4.2.2 Wetland Impacts

Dam removal would require permanent impacts to any parts of dam infrastructure (e.g. spillways, embankment, head gates etc.) that are below the Ordinary High Water Mark. Other direct impacts would include the potential stream restoration design techniques such as the placement of grade control structures (e.g. constructed riffles).

Prior to potential dam notch and drawdown, the impoundment would be dredged and sediment relocated to a potential on site stock pile area **(Appendix F)**. This activity would be discharge (cut) to WUS. Additionally, the stockpile area will need to be assessed for the presence of wetlands.

Indirect impacts or secondary impacts due to hydrology alteration would occur to the impoundment (conversion from lentic to lotic habitat) open water feature and to some of the upstream wetlands surrounding the impoundment. The restoration area will include a restored stream channel and new wetland development in the former impoundment area.

Currently there are four stream channels directly below the dam. The dam removal would propose to consolidate these into one stream channel.

If we assume that mitigation would not be required for permanent hydrology alteration to upstream wetland resources, downstream sediment release, and dredging fill placement, then this alternative would be considered a self-mitigating/ ecological lift for the Kalamazoo drainage basin. Therefore, under this alternative, mitigation is not anticipated.

3.4.2.3 Threatened and Endangered Species

This alternative would have the following assumptions specific to TES consideration:

- Habitat for Indiana bat and Northern long-eared bat is present within project footprint
- Project construction can accommodate seasonal tree cutting restrictions, tree clearing area would mainly be for temporary access road to reach dam structures
- Wetland habitat is present but much of these habitats are disturbed
- Dam removal would result in permanent loss of wetland habitats surrounding the impoundment
- Despite an increase in permanent impacts from pool drawdown and permanently impacting wetland resources surrounding the impoundment, we assume that USFWS would concur with an affect determination of "may affect- not likely to adversely affect" copper belly water snake and eastern massasauga or its habitat.

It is expected that MDNR staff will require a mussel rescue during the drawdown of the dam. Areas where impacts are expected include, shoreline surrounding the dam pool, the construction footprint and within the small tributaries to the southeast of the dam.

3.4.2.4 Cultural Resources

Demolition of the Perrin Dam No. 1 and No. 2 will result in an adverse effect to a historic resource. Demolition of the earthen embankment and placement of fill in the tailrace may also result in an adverse effect but the status of these features is indeterminate and more research is needed. Once an assessment has been conducted and a recommendation of adverse effects has been made, a Memorandum of Agreement (MOA) would need to be developed between the City of Marshall, the Michigan State Historic Preservation Office (SHPO), and other interested parties. An archaeologist will likely need to be on site during construction to monitor ground disturbing activities. It should be noted, that a wood and metal line shaft, possibly from a waterwheel, lies below Perrin Dam No.2, on the west shore. This feature has not previously been examined or evaluated, and may require additional documentation during monitoring should Dam No. 2 be slated for removal.

3.4.3 Schedule

From mobilization, this alternative is expected take 12 to 18 months to complete. This interval could be extended depending on how project construction falls with respect to various regulatory work windows.

4.0 ALTERNATIVE FEASIBILITY AND COST OPINIONS

4.1 REPAIR ISLAND EMBANKMENT/COFFERDAM

4.1.1 Estimated Cost and Assumptions

We estimate that Repair of the Island Embankment using a cofferdam will cost approximately $2,300,000. This option has several advantages over the other options reviewed in this report. First, the amount of sediment released to the Kalamazoo River downstream of the dam as a result of construction is expected to be lower than options with complete drawdown. Second, repair of the dam in this manner is less expensive than the other alternatives (see subsequent sections) because an extensive and costly sediment management program is avoided. There are, however, several disadvantages that must be considered in this analysis. The design life for this repair is finite and additional repairs will be needed at some point in the future. This option does not address the presence of contaminants in the dam pool nor does it characterize ongoing environmental degradation from the presence of contaminants (if any). It does not eliminate an existing barrier that constrains fish migration. It does not restore aquatic habitat integrity to the portion of the river currently inundated by dam pool.

Table 2. Alternative 1 - Project Costs

STANTEC CONSULTING MICHIGAN - ENGINEER'S OPINION OF PROBABLE COST

Stantec

City of Marshall, Michigan
Perrin Dam Improvements
REPAIR WITH COFFERDAM

Conceptual	X
Preliminary	
Final (As Bid)	

Project Number:	2075138800
Prepared By:	PJM
Checked By:	WCF
Date:	June 12, 2017

	ITEM DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL COST
Work By Contractor					
1	General Conditions & Mobilization	1	LS	$100,000	$100,000
2	Soil Erosion Control Measures	1	LS	$3,000	$3,000
3	Tree + Stump Removal	70	EA	$800	$56,000
4	Earthwork	6100	CY	$15	$91,500
5	Dam Island Access	1	LS	$100,000	$100,000
6	Upstream Cofferdam (steel sheet pile)	8,730	SF	$35	$305,550
7	Sealoff around 12" watermain	1	LS	$50,000	$50,000
8	Downstream Cofferdam (steel sheet pile)	2,000	SF	$35	$70,000
9	Upstream Shore Armoring (Riprap, Stone Filter, Geotextile Fabric	600	SY	$110	$66,000
10	Toe Drain Pipe (8" Diam.), Gravel Jacket	320	LF	$30	$9,600
11	Toe Drain Sand Filter Layer, Geotextile Separator Cover	600	SY	$9	$5,400
13	Re-Route Dam #1 Flow Channel	1100	CY	$40	$44,000
14	Concrete Work (Raise Abutments, Power House Intake Wall	25	CY	$4,000	$100,000
15	Concrete Work (Extend Abutments to downstream)	40	CY	$4,000	$160,000
16	Traffic Control	1	LS	$1,000	$1,000
17	Reconstruct boardwalk	50	LF	$500	$25,000
18	Add bridge to boardwalk	1	LS	$120,000	$120,000
19	Site Restoration	8800	SY	$8	$66,000
20	Sediment Sampling & Monitoring	6	SA	$4,700	$28,200
21	Wetland Mitigation	2	AC	$50,000	$100,000
				CONSTRUCTION ITEM SUBTOTAL	**$1,501,250**
				INSURANCE AND BONDS - 5%	**$75,063**
				CONSTRUCTION CONTINGENCY - 20%	**$300,250**
				ENGINEERING - 10%	**$150,125**
				REGULATORY APPROVALS	**$100,000**
				TOTAL OPINION OF PROBABLE CONSTRUCTION COST	**$2,126,688**

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4.2 REPAIR ISLAND EMBANKMENT/DRAWDOWN

4.2.1 Estimated Cost and Assumptions

The primary advantage of repairing the Island Embankment with drawdown is that needed repairs would be made. The dam pool remains in place which is desirable for some members of the community. The principal disadvantage of this approach is the high cost of the sediment management program which accounts for approximately three-fourths of the total budget (Table 6). The cost is less than the dam removal alternative (see next section) but is substantially higher than repairing the embankment with a coffer dam. Under this alternative the City does not eliminate its commitment to ongoing maintenance of the dam. At some point, the dam will age beyond its design life and additional repairs will be needed. Nor does this method of repair address the presence of a barrier to fish migration or the ongoing impairment of riverine habitat.

Table 3. Alternative 2 - Project Costs

STANTEC CONSULTING MICHIGAN - ENGINEER'S OPINION OF PROBABLE COST

Stantec

City of Marshall, Michigan
Perrin Dam Improvements
REPAIR WITH DRAWDOWN

Conceptual	X
Preliminary	
Final (As Bid)	

Project Number:	2075138800
Prepared By:	PJM
Date:	June 12, 2017

	ITEM DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL COST
Work By Contractor					
1	General Conditions & Mobilization	1	LS	$100,000	$100,000
2	Bathymetry and Survey	1	EA	$40,000	$40,000
3	Dredge/Dewatering/Disposal off site - Mobilization/Demobilization	1	LS	$200,000	$200,000
4	Environmental Controls / Disposal Site	1	LS	$200,000	$200,000
5	Hydraulic Dredging/Dewater/Haul	100,000	CY	$150	$15,000,000
6	Environmental Testing and Monitoring	1	EA	$80,000	$80,000
7	Earthwork	6100	CY	$15	$91,500
8	Dam Island Access	1	LS	$100,000	$100,000
9	Downstream Cofferdam (steel sheet pile)	2,000	SF	$35	$70,000
10	Upstream Shore Armoring (Riprap, Stone Filter, Geotextile Fabric	600	SY	$110	$66,000
11	Toe Drain Pipe (8" Diam.), Gravel Jacket	320	LF	$30	$9,600
12	Toe Drain Sand Filter Layer, Geotextile Separator Cover	600	SY	$9	$5,400
13	Re-Route Dam #1 Flow Channel	1100	CY	$40	$44,000
14	Concrete Work (Raise Abutments, Power House Intake Wall	25	CY	$4,000	$100,000
15	Concrete Work (Extend Abutments to downstream)	40	CY	$4,000	$160,000
16	Traffic Control	1	LS	$1,000	$1,000
17	Reconstruct boardwalk	50	LF	$500	$25,000
18	Add bridge to boardwalk	1	LS	$120,000	$120,000
19	Site Restoration	8800	SY	$8	$66,000
	CONSTRUCTION ITEM SUBTOTAL				**$16,478,500**
	INSURANCE AND BONDS - 5%				**$823,925**
	CONSTRUCTION CONTINGENCY - 20%				**$3,295,700**
	ENGINEERING - 10%				**$1,647,850**
	REGULATORY APPROVALS				**$80,000**
	TOTAL OPINION OF PROBABLE CONSTRUCTION COST				**$22,245,975**

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4.3 REMOVE DAM

4.3.1 Estimated Cost and Assumptions

One major benefit to dam removal and river restoration is the elimination of long-term commitment to ongoing maintenance of a regulated structure. Another benefit is the elimination of a safety hazard to the public. Boaters and adventurous pedestrians are susceptible to major accidents with run-of-the-river dams. Another major benefit is the restoration of fish and float passage and habitat enhancement in the former impoundment. Without the dam, aquatic species may reconnect to isolated assemblages. The impoundment will change from a single, slow-water habitat to multiple habitats capable of supporting an increased variety of native aquatic species. The recently completed removal of the dam in Ceresco downstream serves as an example of the potential changes in the river corridor.

The primary obstacle for removing this dam is the anticipated cost of the associated sediment management program. Unfortunately, the potential risks that contaminated sediments stored by Marshall dam pose to aquatic ecosystems and human health are poorly understood. It is entirely possible that additional testing would demonstrate that dredging and management of contaminated sediment is unnecessary. For the purposes of this analysis we developed costs for two scenarios. The first assumes that dredging is necessary for a pilot channel but that all material would be left onsite. The second assumes that dredging is necessary for a pilot channel but that several hundred thousand cubic yards would be hauled off to an approved disposal facility. Costs for these two scenarios range from $45,000,000 to $100,000,000. Absent sediment management, the dam removal would compare favorably to dam repair in terms of cost.

Another obstacle to dam removal is public perception. With a structure of this age, many people feel a deep connection and will oppose removal. Because of the major earthwork involved in the restoration of the impoundment, the chemistry of the sediment can create difficult and expensive alternatives for its removal. The restoration of the river corridor after dam removal can also be a 'delayed benefit'. Despite the extensive work as part of the project, the natural vegetation and wildlife communities can take time to mature and return to stable conditions.

Table 4. Alternative 3 - Project Costs for Dam Removal (Low End) Assuming Sediment Graded and Left in Place.

STANTEC CONSULTING MICHIGAN - ENGINEER'S OPINION OF PROBABLE COST

City of Marshall, Michigan
Perrin Dam Improvements
DAM REMOVAL AND RIVER RESTORATION - LOW ESTIMATE

Conceptual	X
Preliminary	
Final (As Bid)	

Project Number:	2075138800
Prepared By:	TJT
Checked By:	WCF
Date:	June 12, 2017

	ITEM DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL COST
Work By Contractor					
1	Architectural Cost - Community Aesthetics	1	LS	$100,000	$100,000
2	Bathymetry and Survey	1	EA	$75,000	$75,000
3	Dredge and Dewatering - Mobilization/Demobilization	1	LS	$500,000	$500,000
4	Environmental Controls / Dewatering Site Prep	1	LS	$500,000	$500,000
5	Dredging/Dewater/Recycle	100,000	CY	$110	$11,000,000
6	Environmental Testing and Monitoring	1	EA	$150,000	$150,000
7	Dam Removal and Disposal	1	LS	$650,000	$650,000
8	Restoration Mobilization/Demobilization	1	LS	$1,383,375	$1,383,375
9	Restoration Earthwork (Cut/Fill, Grade, Load, Haul)	500,000	CY	$25	$12,500,000
10	Replace Water Main	1	EA	$750,000	$750,000
11	Constructed Riffles	49,500	TN	$75	$3,712,500
12	Coir Lift with Toe Wood Protection	16,000	LF	$125	$2,000,000
13	Exposed Land Revegetation	80	Acre	$10,000	$800,000
14	Engineering Construction Observation	1	LS	$450,000	$450,000
				CONSTRUCTION ITEM SUBTOTAL	**$34,570,875**
				INSURANCE AND BONDS - 5%	**$1,728,544**
				CONSTRUCTION CONTINGENCY - 20%	**$6,914,175**
				ENGINEERING - 10%	**$2,357,088**
				REGULATORY APPROVALS	**$150,000**
				TOTAL OPINION OF PROBABLE CONSTRUCTION COST	**$45,720,681**

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Table 5. Alternative 3 - Project Costs Project Costs for Dam Removal (High End) Assuming Sediment From Pilot Channel Hauled to an Offsite Disposal Facility.

STANTEC CONSULTING MICHIGAN - ENGINEER'S OPINION OF PROBABLE COST

Stantec

City of Marshall, Michigan
Perrin Dam Improvements
DAM REMOVAL AND RIVER RESTORATION - HIGH ESTIMATE

Conceptual	X
Preliminary	
Final (As Bid)	

Project Number:	2075138800
Prepared By:	TJT
Checked By:	WCF
Date:	June 12, 2017

	ITEM DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL COST
Work By Contractor					
1	Architectural Cost - Community Aesthetics	1	LS	$100,000	$100,000
2	Bathymetry and Survey	1	EA	$75,000	$75,000
3	Dredge/Dewatering/Dispoal off site - Mobilization/Demobilization	1	LS	$500,000	$500,000
4	Environmental Controls / Disposal Site	1	LS	$500,000	$500,000
5	Hydraulic Dredging/Dewater/Haul	100,000	CY	$160	$16,000,000
6	Mechanical Sediment Removal (Cut, Haul, Disposal)	500,000	CY	$100	$50,000,000
7	Environmental Testing and Monitoring	1	EA	$150,000	$150,000
8	Dam Removal and Disposal	1	LS	$650,000	$650,000
9	Restoration Mobilization/Demobilization	1	LS	$594,650	$594,650
10	Restoration Earthwork (Grading/Channel Shaping)	100,000	SY	$3	$300,000
11	Replace Water Main	1	EA	$750,000	$750,000
12	Constructed Riffles	49,500	TN	$110	$5,445,000
13	Coir Lift with Toe Wood Protection	16,000	LF	$75	$1,200,000
14	Exposed Land Revegetation	80	Acre	$10,000	$800,000
15	Engineering Construction Observation	1	LS	$450,000	$450,000
	CONSTRUCTION ITEM SUBTOTAL				**$77,514,650**
	INSURANCE AND BONDS - 5%				**$3,875,733**
	CONSTRUCTION CONTINGENCY - 20%				**$15,502,930**
	ENGINEERING - 10%				**$2,751,465**
	REGULATORY APPROVALS				**$225,000**
	TOTAL OPINION OF PROBABLE CONSTRUCTION COST				**$99,869,778**

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4.4 FUNDING OPPORTUNITIES

Most funding opportunities are focused on dam removal; however, the Dam Management Grant Program can be applied to repair of dams that serve an economic purpose. The removal of the Marshall Dam would provide aquatic organism passage along almost 30 miles of river upstream of the Kalamazoo River "Area of Concern" (a term used by regulatory bodies such as the USEPA to refer to environmentally damaged areas). Additional dam removals proposed as part of the AOC delisting may eventually provide connectivity downstream to the Allegan Dam (which may have a bypass channel some day). Due to this improved connectivity, removing Marshall Dam is likely to be viewed as having significant value to the riverine habitat.

Most grant programs have an annual funding cycle, but some are periodic and new grants are announced every few months. Grants programs often provide less than two months to prepare an application. The availability of grant funding is highly variable based on state and federal budgeting, but opportunities may increase with proposed infrastructure spending. Therefore, pre-application preparation is essential to taking advantage of grants before they become available. This may include coordinating with state and federal agencies, preparing project descriptions, securing cash and in-kind match commitments, and developing options for multi-year phasing.

The best approach is to commit funding for a phased drawdown that can be leveraged with several small to medium-sized grants. The project can be broken down into specific components that may be eligible for different types of funding such as: dam demolition, post-removal river restoration, follow-up habitat enhancements, recreational elements, beneficial use of dredge spoils, stormwater management, erosion control and water quality, public education/involvement, tree planting, invasive plant species control, and wetland restoration.

The following table lists some of the relevant funding sources for planning purposes (**Table 6**). Other sources which are not indicated in Table 6 may also be available. **Table 7** illustrates possible scenarios for funding a project. The amounts shown in the tables below represent potential awards and are presented here as examples to illustrate the implications various funding opportunities. For the Repair alternatives, it was assumed that the Marshall project would satisfy the DMGP requirement of having an economic benefit, however this would have to be evaluated as part of the permit application.

Table 6: Potential Grant Sources

Funding Source	Program	Due	Max. Funding	Comments
MDNR	Dam Management Grant Program (DMGP)	November	All available funding (typically $1-2M)	10% match
NOAA	Open Rivers Initiative	n/a	$3M	Has not been funded since 2011
USFWS	Fish Passage Program	August	Varies (no upper limit)	1:1 match
MDNR	Aquatic Habitat Grant Program (AHGP)	October	All available funding (typically <$1M)	Usually for post-dam removal restoration (10% match)
EPA/USFWS/ NRCS	Various habitat restoration grants	Varies	$50-150K	
MDEQ	Nonpoint Source Grant Program	August	All available funding (typically $2-3M)	Typically funds upland BMPs but may consider in-stream projects benefitting water quality
EPA	Great Lakes Restoration Initiative	varies	Varies (typically $0.5-1M)	Priorities vary
Great Lakes Fishery Trust	Habitat Protection and Restoration	March	<$500K	Typically, $50-250K
U.S. Army Corps	WRDA Continuing Authorities Programs (Sec. 206 Aquatic Ecosystem Restoration)	Before October	$5M	Funding levels vary annually; 35% local cost share; long slow process
Private foundations	Various grants	On-going	<$500K	Can often cover public education and involvement
MDEQ	State Revolving Fund	July	Varies	Low interest 20-30 year loans

Table 7: Potential Funding Scenarios for Dam Removal

Alternative	Cost Opinion	Assumed Funding Breakdown	
		Grant	Match from City
Repair with Cofferdam	$2.2 Million	$200,000	$ 2.0 Million
Repair with Drawdown	$22 Million	$200,000	$22 Million
Remove Dam (LOW)	$45 Million	$1,000,000	$44 Million
Remove Dam (HIGH)	$99 Million	$1,000,000	$98 Million

5.0 CONCLUSIONS

Our review of site conditions, regulatory considerations, and engineering elements suggest that all three alternatives assessed in this report are feasible. The major difference between them however, is the cost of sediment management. It is anticipated that repair of the Island Embankment using a coffer dam will cost a little more than $2,000,000. In contrast probable construction costs for Repair using Drawdown is $22,000,000 and Dam Removal is between $45,000,000 and $100,000,000.

The concept designs in this report are intended for use as a planning level decision tools. At this stage in project development many uncertainties remain. Foremost among these are questions regarding the potential implications of the various sediment management programs that may be needed to execute certain projects. It is still possible that additional analytical work may demonstrate that concern regarding the effect of sediment export on downstream aquatic ecosystems is unsubstantiated. In this case dam removal may be a viable alternative. If the opposite is true the cost of sediment management likely eliminates this alternative from further consideration unless alternate sources of funding can be found. It may be in the City's interest to undertake a complete sediment characterization program in an attempt to definitively answer this question. We currently estimate the cost of such a program is approximately $150,000.

It is important to recognize that contaminants are present along the entire length of the impoundment extending to at least three miles upstream of the City. Given the geographic distribution of these constituents it is reasonable to conclude that the City was not the source of the vast majority of the contaminants (if any). The City simply had the misfortune to own the dam that trapped and collected the contaminants.

Another important factor that should be considered is the fate of the sediments and the associated contaminants under the "No action" scenario. One common misconception of impoundments is that they are one-hundred percent effective as sediment traps. In fact, trapping efficiency is often low for 1) small impoundments; 2) for older impoundments that currently store large volumes of sediment; and 3) impoundments where the dominant grain size supplied by the watershed is small. All of these factors apply to Marshall Perrin dam and it is evident that little storage capacity remains (See Figures 2 and 3). Thus sediments, specifically those that are fine-grained, are currently being transported over the dam although the magnitude of these loads is currently unknown.

6.0 REFERENCES

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APPENDIX A.

Existing Conditions

Stantec

3754 Ranchero Dr.
Ann Arbor, MI 48108
www.stantec.com

Consultants

Legend

Notes
SURVEY DATUM: NAVD88

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name: EXHIBIT A.1 & A.2_TOPOGRAPHIC SURVEY.DWG	PJM	PJM	17.05.04
	Dwn. Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
CITY OF MARSHALL

MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

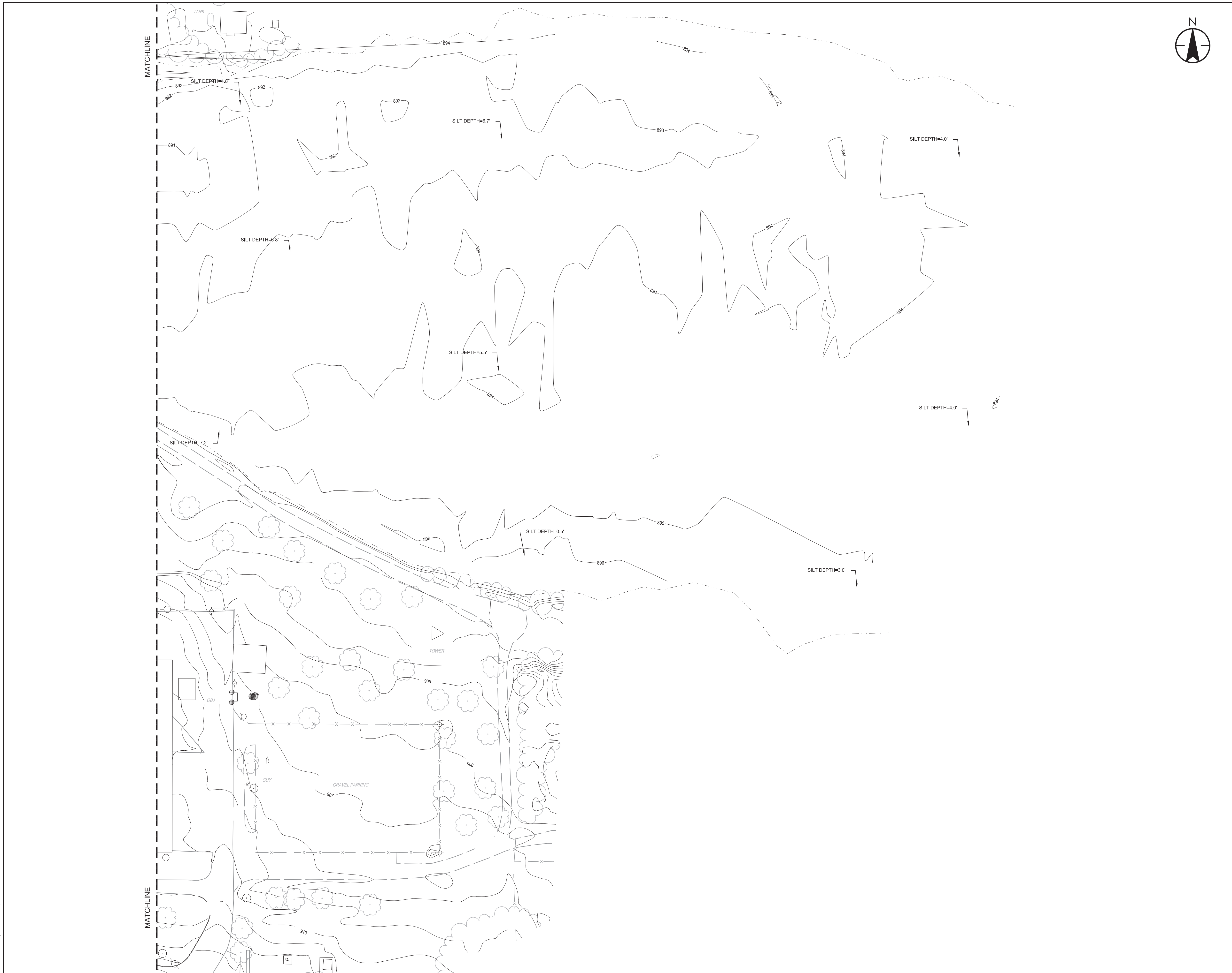
Title
TOPOGRAPHIC SURVEY

Scale: 0 50' 100'

Project No.
2075138800

Drawing No. | Sheet | Revision

Figure A.1



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Notes
SURVEY DATUM: NAVD88

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name: EXHIBIT A.1 & A.2_TOPOGRAPHIC SURVEY.DWG	PJM	PJM	17.05.04
	Dwn. Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
CITY OF MARSHALL

MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

Title
TOPOGRAPHIC SURVEY

0 50' 100'

Project No. 2075138800

Scale

Drawing No. | Sheet | Revision

Figure A.2

Stantec

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Ann Arbor, MI 48108
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Legend

Notes
SURVEY DATUM: NAVD88

Revision | By | Appd. | YY.MM.DD

Issued | By | Appd. | YY.MM.DD

File Name: EXHIBIT A.3_EXISTING CONDITIONS.DWG | PJM Dwn. | PJM Chkd. | PJM Dsgn. | 17.05.04 YY.MM.DD

Permit-Seal

Client/Project
CITY OF MARSHALL

MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

Title
TOPOGRAPHY & EXISTING CONDITIONS

Scale 0 30' 60'

Project No.
2075138800

Drawing No. | Sheet | Revision

Figure A.3

APPENDIX B.

Sediment Chemistry

Table B.1: Marshall Perrin Dam Sediment Comparison to Ecological Screening Benchmarks REVISED: May 9, 2017.

						2016 Perrin Dam Composite Core Sediment Results[1, 2]							2012/2013 Marshall Spill Perrin Dam Surface Sediment Grab						
Analyte	Units	Threshold Effects Concentration (TEC)	Reference	Probable Effects Concentration (PEC)	Reference	Kazoo-Marshall Sample 6	Kazoo-Marshall Sample 5	Kazoo-Marshall Sample 4	Kazoo-Marshall Sample 3	Kazoo-Marshall Sample 2	Kazoo-Marshall Sample 1	Arithmetic Mean[6]	SEKR0000L023	SEKR0000L021	SEKR0000L020	SEKR0000L022	SEKR0000C024	SEKR0000C019	2012/2013 Arithmetic Mean
PCBs																			
PCB-1016 (Aroclor 1016)	µg/kg	NL		NL		<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1221 (Aroclor 1221)	µg/kg	NL		NL		<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1232 (Aroclor 1232)	µg/kg	NL		NL		<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1242 (Aroclor 1242)	µg/kg	NL		NL		<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1248 (Aroclor 1248)	µg/kg	NL		NL		<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1254 (Aroclor 1254)	µg/kg	NL		NL		<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1260 (Aroclor 1260)	µg/kg	NL		NL		<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB, Total	µg/kg	60	a,b	676	a,b	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
Metals																			
Arsenic	mg/kg	9.79	a,b,c	33.00	a,b	10.4	14.8	12.4	16.9	19.7	9.6	14.0	NT	NT	NT	NT	NT	NT	
Barium	mg/kg	20.00	d,e	60.00	d,e	112	128	146	227	197	74.9	147.5	NT	NT	NT	NT	NT	NT	
Cadmium	mg/kg	0.99	a,b,c	4.98	a,b	6.4	11	8.1	23.1	75.3	2.1	21.0	NT	NT	NT	NT	NT	NT	
Chromium	mg/kg	43.40	a,b,c	111.00	a,b	109	209	176	1,210	546	23.4	378.9	NT	NT	NT	NT	NT	NT	
Copper	mg/kg	31.60	a,b,c	149.00	a,b	26.7	33.6	23.9	55.8	82.5	14.7	39.5	NT	NT	NT	NT	NT	NT	
Lead	mg/kg	35.80	a,b,c	128.00	a,b	60.1	73.7	54.6	119	142	43.1	82.1	NT	NT	NT	NT	NT	NT	
Selenium	mg/kg	11.00	e[3]	20.00	e[4]	<3.0	3.0J	<2.7	<2.7	3.3J	<2.0	1.6	NT	NT	NT	NT	NT	NT	
Silver	mg/kg	0.50	a,c	2.20	d	<1.1	<1.1	<0.96	1.3J	2.0J	<0.72	0.9	NT	NT	NT	NT	NT	NT	
Zinc	mg/kg	121.00	a,b,c	459.00	a,b	352	578	425	1,690	1,400	259	784.0	NT	NT	NT	NT	NT	NT	
Mercury	mg/kg	0.18	a,b	1.06	a,b	0.21J	0.34J	0.34J	0.49	1.3	0.73	0.6	NT	NT	NT	NT	NT	NT	
PAHs																			
Anthracene	µg/kg	57.2	a,b,c	845	a,b	899	4,480	<69.6	<70.8	107J	561	1019.5	16	130	139	15.1	5840	2900	1506.7
Benzo(a)anthracene	µg/kg	108	a,b,c	1,050	a,b	1,930	8,520	60.2J	97.4J	401	1,680	2114.8	102	486	565	9.25	12600	6860	3437.0
Benzo(a)pyrene	µg/kg	150	a,b,c	1,450	a,b	2,060	7,650	61.0J	112J	444	1,550	1979.5	107	660	508	9.56	9820	7120	3037.4
Chrysene	µg/kg	166	a,b,c	1,290	a,b	2,290	7,260	<62.0	114J	423	1,450	1928.0							
Dibenz(a,h)anthracene	µg/kg	33	a,b,c	135	f[5]	406	1,070	<49.2	<50.1	64.0J	224	302.3							
Fluoranthene	µg/kg	423	a,b,c	2,230	a,b	4,680	19,700	102J	179	694	3,010	4727.5	212	1380	1680	176	24500	18900	7808.0
Fluorene	µg/kg	77.4	a,b,c	536	a,b	180	1890	<67.1	<68.2	<73.0	121	382.5	6.73	75.2	99.4	7.54	166	749	184.0
Naphthalene	µg/kg	176	a,b,c	561	a,b	73.7J	660J	92.9J	<68.2	84.2J	88.5J	172.2	25.9	174	224	32.2	194	434	180.7
Phenanthrene	µg/kg	204	a,b,c	1,170	a,b	2,420	16,700	80.8J	81.4J	277	1,240	3466.5	68.8	453	666	72.9	13600	6770	3605.1
Pyrene	µg/kg	195	a,b,c	1,520	a,b	3,430	13,000	85.8J	138	516	2,100	3211.6	180	1110	1340	150	18800	15700	6213.3
Percent Moisture (%)						76.4	77.9	75.2	75.6	77.2	65								
Total Organic Carbon	mg/kg					113,000	133,000	102,000	112,000	130,000	87,800		13%	5.14%	5.37%	12%	17%	9.77%	

Shaded values exceed TEC criteria

Shaded values exceed PEC criteria

NL- Not listed

NT- Not tested

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a. MDEQ, 2006. "Remediation and Redevelopment Division Operational Memorandum No. 4. - Attachment 3 – Sediments." August 2, 2006. https://www.michigan.gov/documents/deq/deq-rrd-OpMemo_4Attach3Sediments_250004_7.pdf

b. MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol. 39:20-31.

c. U.S. EPA 2003. Region 5, Ecological Screening Levels for RCRA. https://www3.epa.gov/region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf

d. MacDonald, D.D., C.G. Ingersoll, C. G. Smorong, D. E. Lindskoog, R. A. Sloane, G and T Biernacki. 2003 and T.A. Berger. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters. Prepared for Florida Department of Environmental Protection, Tallahassee, Florida.

e. U.S. EPA. 2015. Supplemental Guidance to ERAGS: Region 4, Ecological Risk Assessment. Originally published November 1995

f. Buchman, M. F. NOAA Quick Screening Reference Tables. NOAA OR&R Report 08-1 Seattle WA, Office of Response and Restoration Division, National Atmospheric and Oceanic Administration (2008): 34 pages

Notes

1. Results with "<" are listed as less than the adjusted method detection limit (MDL)
2. J- Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
3. Ecological screening value (ESV)
4. Refinement screening value (RSV)
5. Listed value is Probable Effects Level (PEL)
6. Non-detects included at half the MDL

Table B.2: Marshall Perrin Dam Sediment Comparison to Downstream Sediments REVISED: May 9, 2017.

		2016 Perrin Dam Composite Core Sediment Results[1, 2]							2012/2013 Marshall Spill Perrin Dam Surface Sediment Grab Results							Downstream Kalamazoo Samples	
Analyte	Units	Kazoo-Marshall Sample 6	Kazoo-Marshall Sample 5	Kazoo-Marshall Sample 4	Kazoo-Marshall Sample 3	Kazoo-Marshall Sample 2	Kazoo-Marshall Sample 1	Arithmetic Mean[3]	SEKR0000 L023	SEKR0000 L021	SEKR0000 L020	SEKR0000 L022	SEKR0000 C024	SEKR0000 C019	2012/2013 Arithmetic Mean	Arithmetic Mean	Maximum Level
PAHs																	
Anthracene	µg/kg	899	4,480	<69.6	<70.8	107J	561	1019.5	16	130	139	15.1	5840	2900	1506.7	141.44	432
Benzo(a)anthracene	µg/kg	1,930	8,520	60.2J	97.4J	401	1,680	2114.8	102	486	565	9.25	12600	6860	3437.0	718.88	1660
Benzo(a)pyrene	µg/kg	2,060	7,650	61.0J	112J	444	1,550	1979.5	107	660	508	9.56	9820	7120	3037.4	838.06	1990
Chrysene	µg/kg	2,290	7,260	<62.0	114J	423	1,450	1928.0									
Dibenz(a,h)anthracene	µg/kg	406	1,070	<49.2	<50.1	64.0J	224	302.3									
Fluoranthene	µg/kg	4,680	19,700	102J	179	694	3,010	4727.5	212	1380	1680	176	24500	18900	7808.0	1712.29	4350
Fluorene	µg/kg	180	1890	<67.1	<68.2	<73.0	121	382.5	6.73	75.2	99.4	7.54	166	749	184.0	47.78	162
Naphthalene	µg/kg	73.7J	660J	92.9J	<68.2	84.2J	88.5J	172.2	25.9	174	224	32.2	194	434	180.7	43.53	98.7
Phenanthrene	µg/kg	2,420	16,700	80.8J	81.4J	277	1,240	3466.5	68.8	453	666	72.9	13600	6770	3605.1	589.22	2050
Pyrene	µg/kg	3,430	13,000	85J	138	516	2,100	3211.5	180	1110	1340	150	18800	15700	6213.3	1569.29	4010
Percent Moisture (%)		76.4	77.9	75.2	75.6	77.2	65										
Total Organic Carbon	mg/kg	113,000	133,000	102,000	112,000	130,000	87,800		13%	5.14%	5.37%	12%	17%	9.77%			

Exceeds ArithMean of downstream sediments

Exceeds highest levels of downstream sediments

Notes

1. Results with "<" are listed as less than the adjusted method detection limit (MDL)
2. J- Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
3. Non-detects included at half the MDL

Table B.3: Marshall Perrin Dam Sediment Comparison to Residential Part 201 Generic Cleanup Criteria and Screening Levels/Part 213 Risk-based Screening Levels.
REVISED: May 9, 2017.

				2016 Perrin Dam Composite Core Sediment Results[1, 2]							2012/2013 Marshall Spill Perrin Dam Surface Sediment Grab Results						
Analyte	**Units**	**Residential Drinking Water Protection Criteria**	**Direct Contact Criteria**	**Kazoo-Marshall Sample 6**	**Kazoo-Marshall Sample 5**	**Kazoo-Marshall Sample 4**	**Kazoo-Marshall Sample 3**	**Kazoo-Marshall Sample 2**	**Kazoo-Marshall Sample 1**	**Arithmetic Mean[6]**	**SEKR0000L023**	**SEKR0000L021**	**SEKR0000L020**	**SEKR0000L022**	**SEKR0000C024**	**SEKR0000C019**	**2012/2013 Arithmetic Mean**
PCBs																	
PCB-1016 (Aroclor 1016)	μg/kg	NL	NL	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1221 (Aroclor 1221)	μg/kg	NL	NL	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1232 (Aroclor 1232)	μg/kg	NL	NL	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1242 (Aroclor 1242)	μg/kg	NL	NL	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1248 (Aroclor 1248)	μg/kg	NL	NL	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1254 (Aroclor 1254)	μg/kg	NL	NL	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB-1260 (Aroclor 1260)	μg/kg	NL	NL	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
PCB, Total	μg/kg	NLL	4000	<106	<113	<101	<102	<110	<71.5		NT	NT	NT	NT	NT	NT	
Metals																	
Arsenic	mg/kg	4.6	7.6	10.4	14.8	12.4	16.9	19.7	9.6	14.0	NT	NT	NT	NT	NT	NT	
Barium	mg/kg	1300	37000	112	128	146	227	197	74.9	147.5	NT	NT	NT	NT	NT	NT	
Cadmium	mg/kg	6	550	6.4	11	8.1	23.1	75.3	2.1	21.0	NT	NT	NT	NT	NT	NT	
Chromium[3]	mg/kg	30	2500	109	209	176	1,210	546	23.4	378.9	NT	NT	NT	NT	NT	NT	
Copper	mg/kg	5800	20000	26.7	33.6	23.9	55.8	82.5	14.7	39.5	NT	NT	NT	NT	NT	NT	
Lead	mg/kg	700	400	60.1	73.7	54.6	119	142	43.1	82.1	NT	NT	NT	NT	NT	NT	
Selenium	mg/kg	4	2600	<3.0	3.0J	<2.7	<2.7	3.3J	<2.0	1.6	NT	NT	NT	NT	NT	NT	
Silver	mg/kg	4.5	250	<1.1	<1.1	<0.96	1.3J	2.0J	<0.72	0.9	NT	NT	NT	NT	NT	NT	
Zinc	mg/kg	47	160000	352	578	425	1,690	1,400	259	784.0	NT	NT	NT	NT	NT	NT	
Mercury	mg/kg	1.7	160	0.21J	0.34J	0.34J	0.49	1.3	0.73	0.6	NT	NT	NT	NT	NT	NT	
PAHs																	
Anthracene	μg/kg	41000	230000000	899	4,480	<69.6	<70.8	107J	561	1019.5	16	130	139	15.1	5840	2900	1506.7
Benzo(a)anthracene	μg/kg	NLL	20000	1,930	8,520	60.2J	97.4J	401	1,680	2114.8	102	486	565	9.25	12600	6860	3437.0
Benzo(a)pyrene	μg/kg	NLL	2000	2,060	7,650	61.0J	112J	444	1,550	1979.5	107	660	508	9.56	9820	7120	3037.4
Chrysene	μg/kg	NLL	2000000	2,290	7,260	<62.0	114J	423	1,450	1928.0							
Dibenzo(a,h)anthracene	μg/kg	NLL	2000	406	1,070	<49.2	<50.1	64.0J	224	302.3							
Fluoranthene	μg/kg	730000	46000000	4,680	19,700	102J	179	694	3,010	4727.5	212	1380	1680	176	24500	18900	7808.0
Fluorene	μg/kg	390000	27000000	180	1890	<67.1	<68.2	<73.0	121	382.5	6.73	75.2	99.4	7.54	166	749	184.0
Naphthalene	μg/kg	35000	16000000	73.7J	660J	92.9J	<68.2	84.2J	88.5J	172.2	25.9	174	224	32.2	194	434	180.7
Phenanthrene	μg/kg	56000	1600000	2,420	16,700	80.8J	81.4J	277	1,240	3466.5	68.8	453	666	72.9	13600	6770	3605.1
Pyrene	μg/kg	480000	29000000	3,430	13,000	85.8J	138	516	2,100	3211.6	180	1110	1340	150	18800	15700	6213.3

Exceeds DW criteria
Exceeds DC criteria
Exceeds both criteria
NLL- hazardous substance is not likely to leach under most soil conditions
NL- Not listed
NT- Not tested

Notes

1. Results with "<" are listed as less than the adjusted method detection limit (MDL)
2. J- Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
3. Analytical data are provided for total chromium only compared to the cleanup criteria for Cr VI.

APPENDIX C.

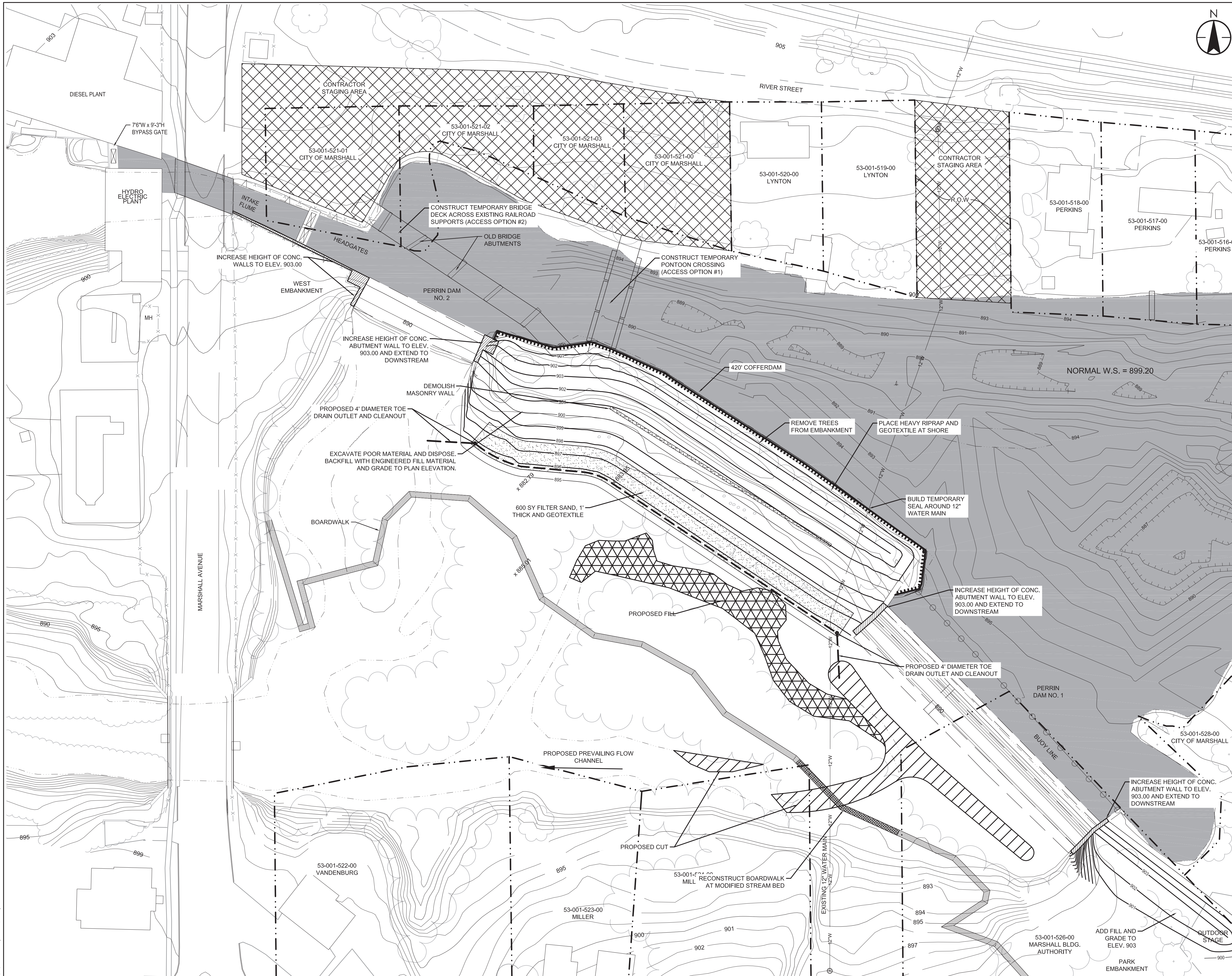
State of Michigan Special Status Species for Calhoun County

Scientific Name	Common Name	Federal Status	State Status	Global Rank	State Rank
Acella haldemani	Spindle lymnaea		SC	G3	SH
Acris blanchardi	Blanchard's cricket frog		T	G5	S2S3
Agrimonia rostellata	Beaked agrimony		T	G5	S2
Alasmidonta marginata	Elktoe		SC	G4	S3?
Alasmidonta viridis	Slippershell		T	G4G5	S2S3
Ammodramus henslowii	Henslow's sparrow		E	G4	S3
Ammodramus savannarum	Grasshopper sparrow	PS	SC	G5	S4
Amorpha canescens	Leadplant		SC	G5	S3
Angelica venenosa	Hairy angelica		SC	G5	S3
Arnoglossum plantagineum	Prairie indian-plantain		SC	G4G5	S3
Baptisia lactea	White or prairie false indigo		SC	G4Q	S3
Brickellia eupatorioides	False boneset	PS	SC	G5	S2
Catinella protracta	A land snail (no common name)		E	G2Q	SNR
Chondestes grammacus	Lark sparrow		X	G5	SNA
Clemmys guttata	Spotted turtle		T	G5	S2
Conioselinum chinense	Hemlock-parsley		SC	G5	SNR
Corydalis flavula	Yellow fumewort		T	G5	S2
Cypripedium candidum	White lady slipper		T	G4	S2
Dichanthelium leibergii	Leiberg's panic grass		T	G4	S2
Dichanthelium microcarpon	Small-fruited panic-grass		SC	GNR	SX
Eleocharis compressa	Flattened spike rush		T	G4	S2
Eleocharis engelmannii	Engelmann's spike rush		SC	G4G5	S2S3
Eleocharis radicans	Spike rush		X	G5	S1
Emydoidea blandingii	Blanding's turtle		SC	G4	S2S3
Erimyzon claviformis	Creek chubsucker		E	G5	S1
Eryngium yuccifolium	Rattlesnake-master or button snakeroot		T	G5	S2
Eupatorium sessilifolium	Upland boneset		T	G5	S1
Falco peregrinus	Peregrine falcon	PS:LE	E	G4	S3
Filipendula rubra	Queen-of-the-prairie		T	G4G5	S2
Fontigens nickliniana	Watercress snail		SC	G5	S2S3
Fraxinus profunda	Pumpkin ash		T	G4	S2
Galearis spectabilis	Showy orchis		T	G5	S2
Geum virginianum	Pale avens		SC	G5	S1S2
Haliaeetus leucocephalus	Bald eagle		SC	G5	S4
Helianthus hirsutus	Whiskered sunflower		SC	G5	S3
Helianthus mollis	Downy sunflower		T	G4G5	S2
Hydrastis canadensis	Goldenseal		T	G3G4	S2
Isotria verticillata	Whorled pogonia		T	G5	S2
Lechea minor	Least pinweed		X	G5	S1
Lepyronia angulifera	Angular spittlebug		SC	G3	S3
Mertensia virginica	Virginia bluebells		E	G5	S1S2
Mesomphix cupreus	Copper button		SC	G5	S1
Moxostoma carinatum	River redhorse		T	G4	S2
Myotis septentrionalis	Northern long-eared bat	LT	SC	G1G2	S1
Myotis sodalis	Indiana bat	LE	E	G2	S1
Nerodia erythrogaster neglecta	Copperbelly water snake	LT	E	G5T3	S1
Notropis anogenus	Pugnose shiner		E	G3	S1S2
Notropis chalybaeus	Ironcolor shiner		X	G4	S1
Notropis texanus	Weed shiner		X	G5	S1
Oecanthus laricis	Tamarack tree cricket		SC	G1G2	S3
Panax quinquefolius	Ginseng		T	G3G4	S2S3
Papaipema beeriana	Blazing star borer		SC	G2G3	S2
Perimyotis subflavus	Eastern pipistrelle		SC	G2G3	S1

Scientific Name	**Common Name**	**Federal Status**	**State Status**	**Global Rank**	**State Rank**
Platanthera ciliaris	Orange- or yellow-fringed orchid		E	G5	S1S2
Platanthera leucophaea	Prairie white-fringed orchid	LT	E	G2G3	S1
Pleurobema sintoxia	Round pigtoe		SC	G4G5	S3
Protonotaria citrea	Prothonotary warbler		SC	G5	S3
Rallus elegans	King rail		E	G4	S2
Setophaga cerulea	Cerulean warbler		T	G4	S3
Setophaga citrina	Hooded warbler		SC	G5	S3
Silene stellata	Starry campion		T	G5	S2
Sistrurus catenatus	Eastern massasauga	LT	SC	G3	S3
Speyeria idalia	Regal fritillary		E	G3	SH
Spiza americana	Dickcissel		SC	G5	S3
Stenelmis douglasensis	Douglas stenelmis riffle beetle		SC	G1G3	S1S2
Terrapene carolina carolina	Eastern box turtle		SC	G5T5	S2S3
Utterbackia imbecillis	Paper pondshell		SC	G5	S2S3
Venustaconcha ellipsiformis	Ellipse		SC	G4	S3
Villosa iris	Rainbow		SC	G5Q	S3
Viola pedatifida	Prairie birdfoot violet		T	G5	S1
Zizania aquatica	Wild rice		T	G5	S2S3

APPENDIX D.

Concept Plans to Repair Island Embankment - No Drawdown



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Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name: EXHIBIT D.1_COFFERDAM ALT. 1.DWG	BWA	PJM	PJM	17.05.04
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
CITY OF MARSHALL

MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

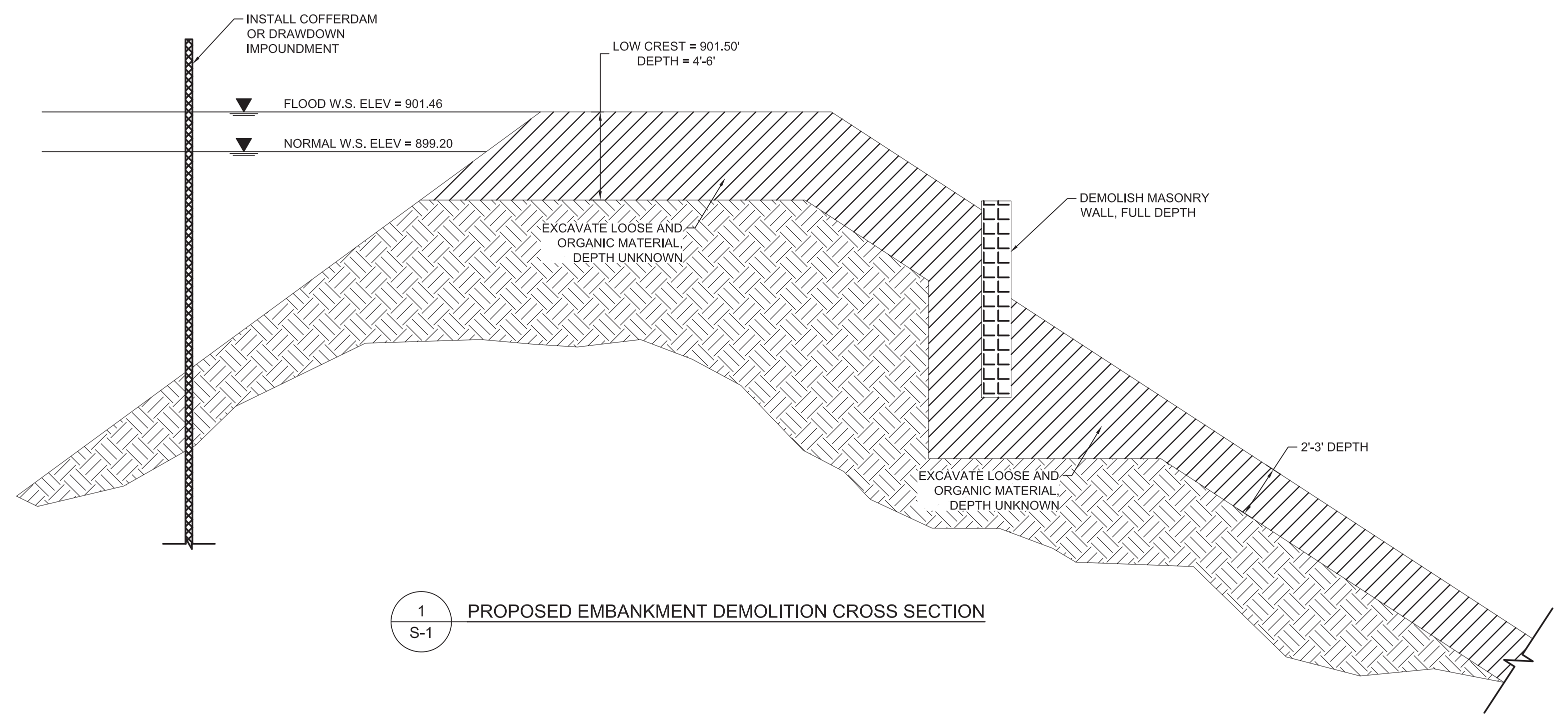
Title
COFFERDAM - ALTERNATIVE 1

Scale: 0 30' 60'

Project No.
2075138800

Drawing No. | Sheet | Revision

Figure D.1



1
S-1
PROPOSED EMBANKMENT DEMOLITION CROSS SECTION

V:\2075\active\2075138800\drawing\Exhibit D.2 & D.3_Embankment Sections.dwg
2017/05/05 4:12 PM By: Bonner, Casey

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File Name: EXHIBIT D.2 & D.3_EMBANKMENT SECTIONS.DWG

Dwn.	Chkd.	Dsgn.	YY.MM.DD
[illegible]	PJM	PJM	17.05.04

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Client/Project

CITY OF MARSHALL

MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

Title

ISLAND EMBANKMENT
CROSS SECTIONS

Project No. 2075138800

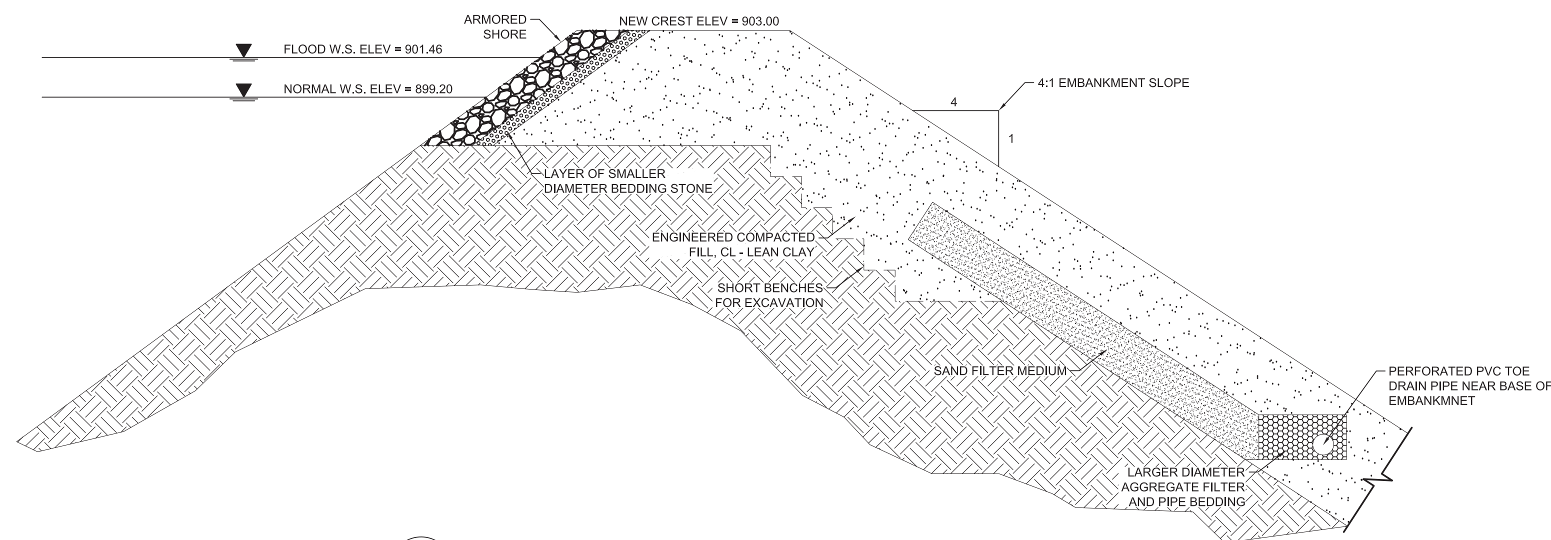
Scale NOT TO SCALE

Drawing No.

Sheet

Revision

Figure D.2



1 / S-2 PROPOSED EMBANKMENT RECONSTRUCTION CROSS SECTION

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MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

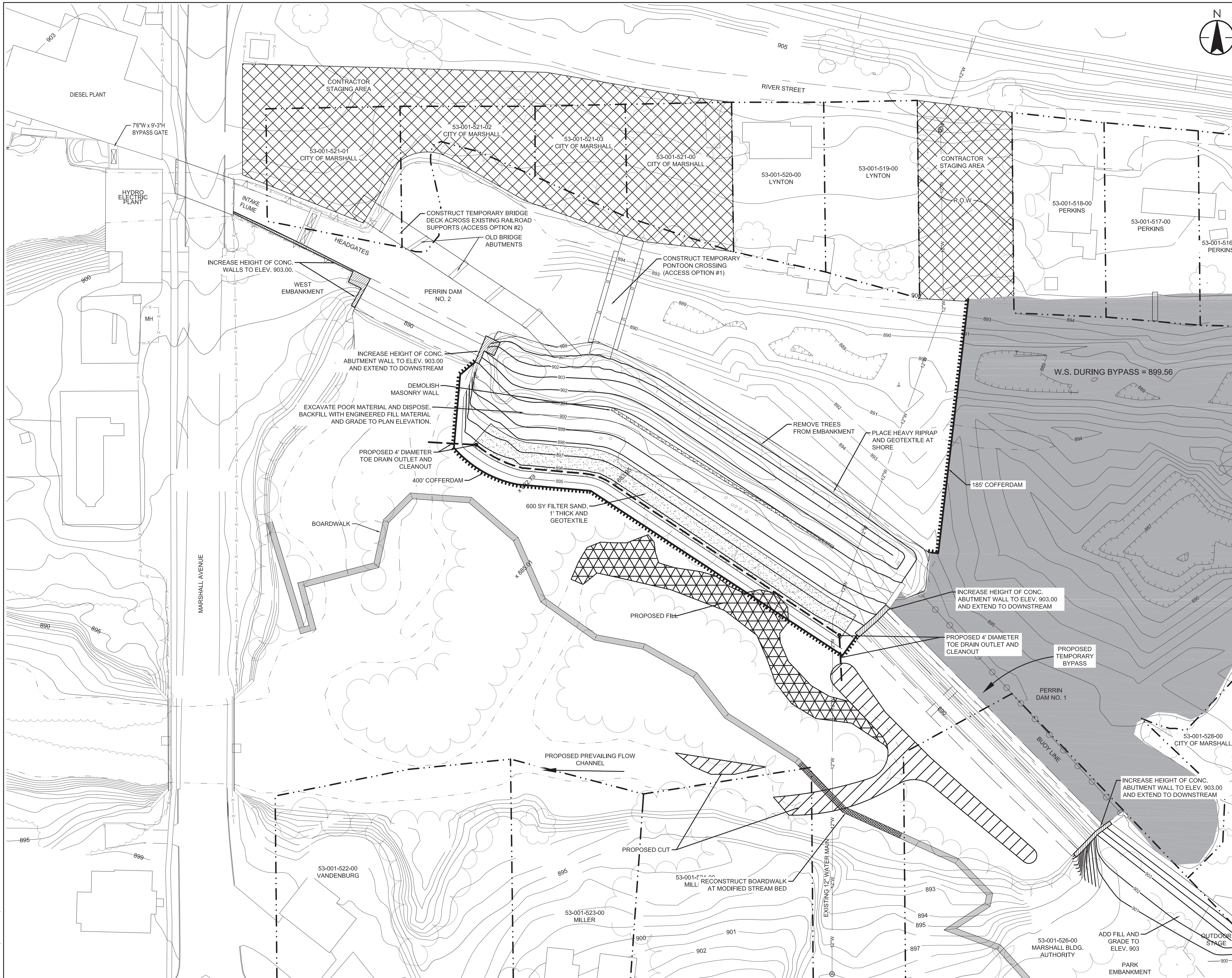
Title

ISLAND EMBANKMENT
CROSS SECTIONS

Project No. 2075138800
Scale NOT TO SCALE

Drawing No. | Sheet | Revision

Figure D.3



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File Name: EXHIBIT D.4_COFFERDAM ALT. 2.DWG	BWA	PJM	PJM	17.05.04
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Client/Project
CITY OF MARSHALL

MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

Title
COFFERDAM - ALTERNATIVE 2

Scale: 0 30' 60'

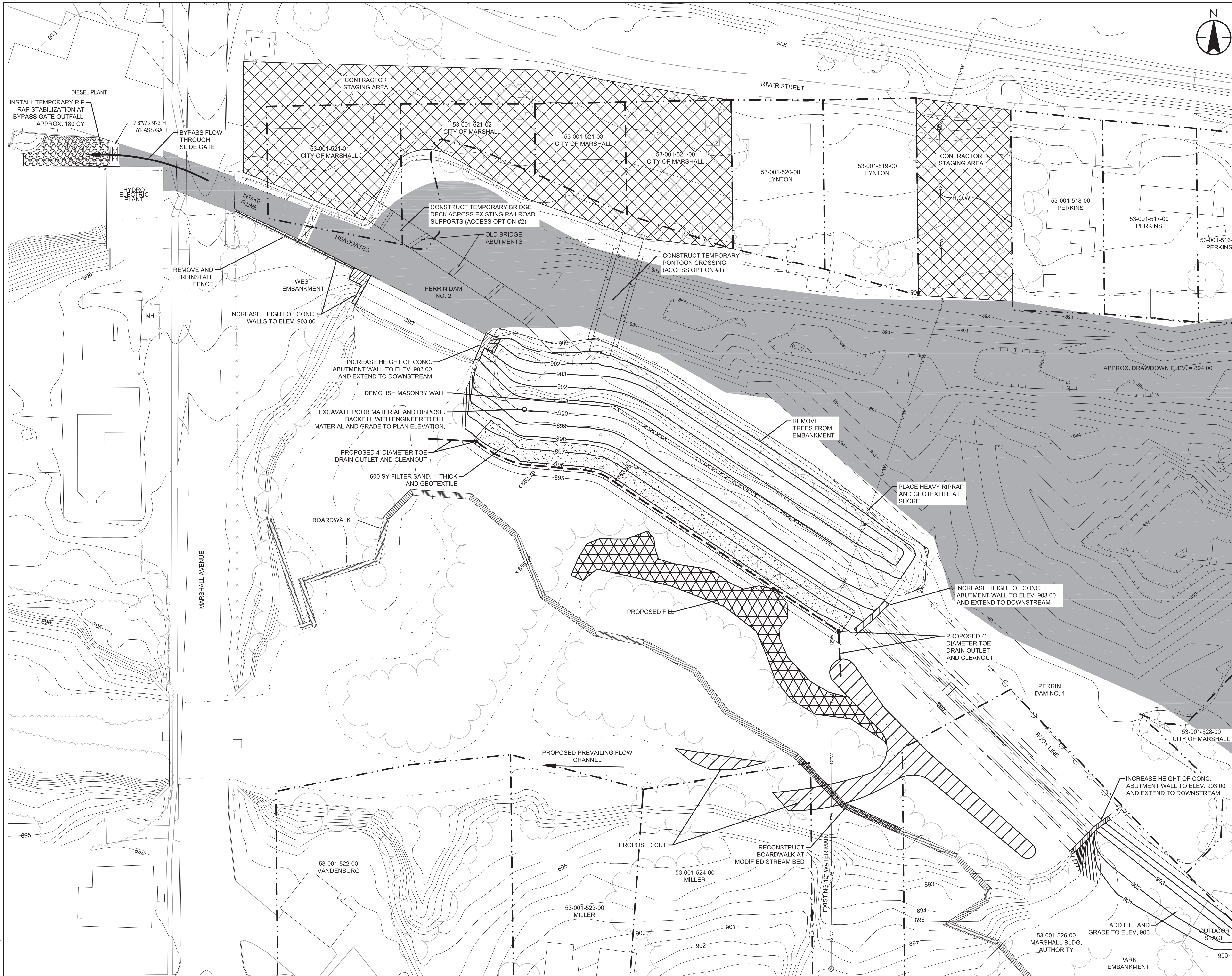
Project No. 2075138800

Drawing No. — Sheet — Revision

Figure D.4

APPENDIX E.

Concept Plans Repair Island Embankment - With Drawdown



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File Name: EXHIBIT B.5_TEMPORARY DRAWDOWN.DWG — Dwn. — Chkd. PJM — Dsgn. PJM — YY.MM.DD 17.05.04

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MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

Title
TEMPORARY DRAWDOWN

0 30' 60'

Project No. 2075138800

Scale

Drawing No. — Sheet — Revision

Figure E.1

APPENDIX F.

Concept Plans to Remove Dam

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File Name: EXHIBIT F.1_DAM REMOVAL.DWG	BWA	PJM	PJM	17.05.04
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Client/Project
CITY OF MARSHALL

MARSHALL HYDROELECTRIC DISPOSITION STUDY

Marshall, Michigan

Title
DAM REMOVAL

Project No. 2075138800
Scale 0 30' 60'

Drawing No. | Sheet | Revision

Figure F.1