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Versailles Lake Dam Decommissioning 30 Percent Basis of Design Report

February 27, 2026

Prepared by:
Stantec Consulting Services Inc.



Versailles Lake Dam Design Phase 1 Basis of Design

Basis of Design report for 30% design of Versailles Lake Dam

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Executive Summary

The Versailles Lake Dam was constructed in 1955-56 on Laughery Creek, a tributary to the Ohio River, in Ripley County, Indiana creating a 230-acre impoundment in Versailles State Park. The Versailles Lake Dam is approximately 56 feet in height and 960 feet in length. A 240-foot-wide concrete ogee spillway makes up a portion of the total dam length. Indiana Department of Natural Resources is looking to address the dam's inadequate discharge capacity and high sedimentation rate in the impoundment which has resulted in loss of recreational value and storage capacity for Versailles Lake. In 2021, Stantec completed a feasibility study for IDNR to assess alternatives to address these problems through either modification of the dam to bring it into safety compliance or decommissioning of the dam. Based on the results of this study, IDNR's preferred approach to addressing the risks associated with the dam is through dam decommissioning. The objective of this report is to present the 30% design approach to lake dewatering and dam demolition and associated field data collection and data analysis that was conducted to inform the proposed design.

During the 30% design phase, a geomorphic assessment of Laughery Creek was performed upstream of the dam's influence to inform design of the re-established channel through the existing reservoir and dam footprint. Sediment samples were taken within Versailles Lake using vibracoring as well as from gravel bars upstream and downstream of Versailles Lake. Sediment data were used to inform sediment transport modeling that was conducted to understand the response of sediment export out of the reservoir following dam removal.

Sediment transport modeling was used to assess differences in reservoir erosion, sediment concentrations downstream of dam, and total sediment deposition downstream of the dam following removal between wet, dry, and median hydrologic scenarios for both full and partial dam removal. Following dam removal, there will be a large peak in downstream sediment concentrations for both the full dam removal and partial dam removal scenarios. After approximately a year for all three hydrologic scenarios, the sediment concentration output begins to reach equilibrium where the amount of sediment coming into the system is equal to the amount of sediment coming out at the dam. For all hydrologic scenarios, modeling results indicate that the channel, both through the reservoir and at the dam crossing, show similar erosional patterns and is able to reach the pre-dam invert elevation at the dam. Although downstream sediment evacuation is higher for the full dam removal than the partial, the difference in sediment mobilization tonnage is relatively small and is not substantial relative to the additional project costs associated with the rock ramp approach.

In 2023, Laughery Creek was proposed for listing as Critical Habitat for the Salamander Mussel from directly below the Versailles Lake Dam to the confluence with the Ohio River (88 FR 57224 57290). Environmental DNA sampling was conducted on Laughery Creek upstream and downstream of Versailles Lake to better understand the distribution of Salamander Mussel and its host species (Mudpuppy) in Laughery Creek. Results indicate that Salamander Mussel populations do not occur within 10.8 river miles downstream of the Versailles Lake Dam. Similarly, Mudpuppy was never detected within 7.4 river miles of the dam.

The 30 percent Versailles Lake Dam decommissioning design assumes full removal of the principal spillway and partial removal of the earthen embankment. The dam decommissioning and associated Laughery



Versailles Lake Dam Design Phase 1 Basis of Design Executive Summary

Creek restoration design will be conducted under two general phases of work. The goal of the first phase of dam removal is to restore Laughery Creek to a free-flowing condition so that the stream can mobilize and transport sediment out of the reservoir footprint. During Phase 1, the concrete ogee spillway will be notched over a period of several weeks allow for controlled dewatering of the reservoir and then subsequently demolished to the proposed extents. During the anticipated 12 to 18-month interim period between Phase 1 and 2, the dewatered lakebed will be temporarily seeded with a cover crop and native grass and sedge seed mix. During Phase 2 of construction, final demolition depth of the principal spillway, abutment walls, footings, and channel lining will be achieved where not completed in Phase 1. Demolition of the energy dissipation pool low-head weir will also be completed at this time. Grading of lakebed sediments will then occur to re-establish a stream valley geometry which will support long-term geomorphic stability. The stream valley will generally follow the historical alignment of the pre-dam channel as approximated by the 1946 USGS topographic map. When final grades are reached, sediments will be stabilized through seeding and installation of native plants.



Acronyms / Abbreviations

Acronym / Abbreviation	Full Name
1D	One dimensional
2D	Two dimensional
ACE	Annual chance exceedance
CEM	Channel evolution model
Cfs	Cubic feet per second
CSGP	Construction Stormwater General Permit
CY	Cubic yard
eDNA	Environmental DNA
EPA	Environmental Protection Agency
FS	Factor of Safety
ft	Feet
ft/s	Feet per second
HEC-RAS	Hydrologic Engineering Center's River Analysis System
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
ILF	In-Lieu Fee
LiDAR	Light Detection and Ranging
LL	Liquid limit
m	Meter
m/s	Meter per second
m ³	Cubic meter
Mg/l	Milligrams per liter
mi ²	Square Miles
mm	Millimeter
mmHg	Millimeters of mercury
NAVD88	North American Vertical Datum of 1988
N-s	Newton second
Pa	Pascal
Park	Versailles State Park
Pcf	Pounds per cubic foot
PMF	Probable Maximum Flood
Psf	Pounds per Square Foot
RCC	Roller compacted concrete



Versailles Lake Dam Design Phase 1 Basis of Design
Acronyms / Abbreviations

SI	International System of Units
USGS	United States Geological Survey
WSE	Water Surface Elevation
WY	Water year



1 Project Background

The Versailles Lake Dam was constructed in 1955-56 on Laughery Creek, a tributary to the Ohio River, creating a 230-acre impoundment in Versailles State Park (the Park), Ripley County, Indiana (

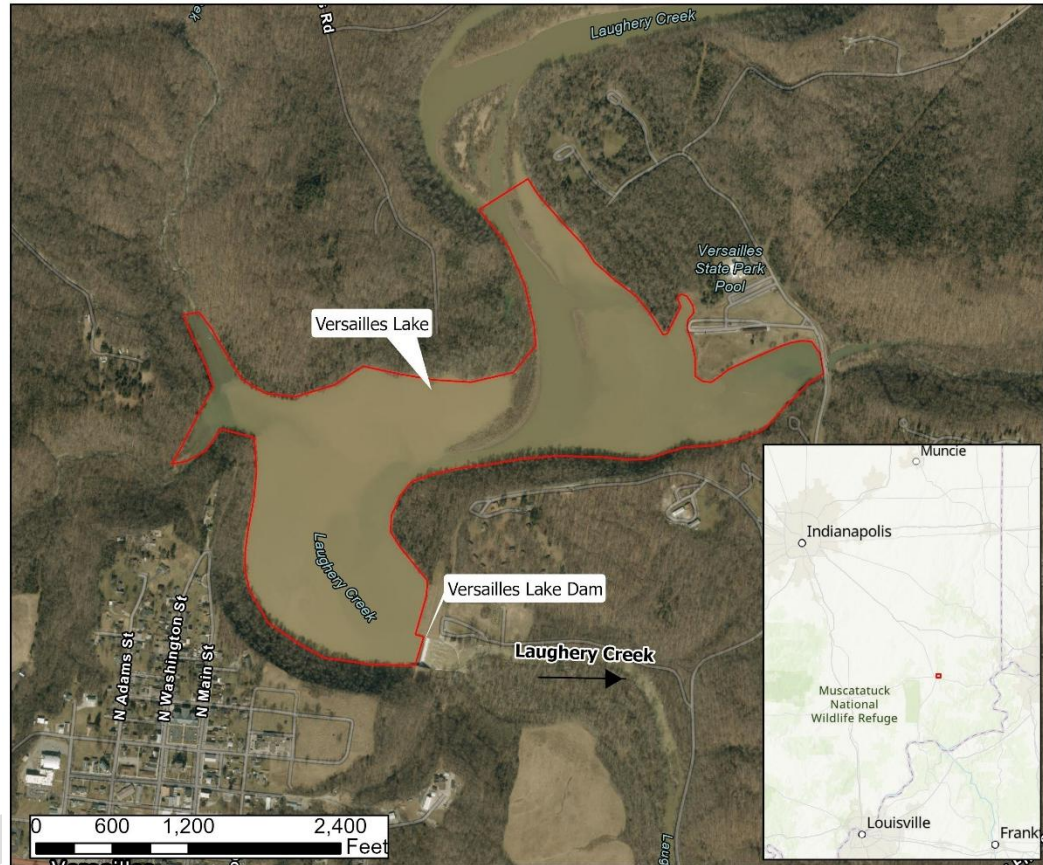


Figure 1). Today, the lake is one of the Park's most prominent attractions. Visitors to Versailles State Park utilize the lake for various recreational opportunities including swimming, boating, and fishing, although the recreational value of the lake has diminished with the accumulation of sediments in the reservoir.

While recent dam safety inspection reports indicate that the dam is in fair condition, Indiana Department of Natural Resources is looking to address current issues with the dam associated with inadequate discharge capacity. The primary driver of project is mitigation of risks to downstream communities and infrastructure associated with the undersized spillway capacity.

Ongoing sedimentation of the lake and noncompliance of the structure with dam safety standards have led the Indiana Department of Natural Resources to evaluate options to upgrade the dam and dredge the lake to both bring the dam into compliance with current dam safety regulations and to restore recreational value to the lake or to decommission the dam.



Figure 1. Project Location

In 2020, IDNR retained the services of Stantec Consulting Services, Inc. (Stantec) to complete a feasibility study on the Versailles Lake Dam to assess options to modify the dam to bring it into compliance or decommission the dam. Based on the results of this study, IDNR's preferred approach to addressing the risks associated with the dam is through dam decommissioning. Details of this study can be found below in Section 1.2. The objective of this report is to summarize the data and analysis conducted during the 30 percent design phase of the Versailles Lake Decommissioning Project and the design approach towards decommissioning the Versailles Lake Dam.

1.1 Project Setting

1.1.1 Versailles Dam Structure

The Versailles Lake Dam was constructed to be 56 feet in height and 960 feet in length. A 240-foot-wide concrete ogee spillway makes up a portion of the total dam length and has a height of approximately 40

feet relative to the downstream channel invert (Figure 2.,



Figure 3) In 1987, the earthen dam embankment was raised 3.5 feet and the vertical abutments of the principal spillway were extended.

The dam is classified by IDNR as a High Hazard structure, meaning failure of the dam is “likely to cause loss of life and serious damage to homes, industrial and commercial buildings, public utilities, major highways, or railroads.” The dam does not have an auxiliary spillway, and the principal spillway is unable to safely pass the Probable Maximum Flood (PMF), a requirement of High Hazard dams.



Figure 2. Versailles Dam Components



Figure 3. Photo of Versailles Lake Dam

1.1.2 Contributing Watershed

The contributing upstream watershed of Laughery Creek at the dam site is approximately 168 square miles (mi²). Two small tributaries enter directly into the lake: Falling Timbers Creek from the east (drainage area of 6 mi²) and Cedar Creek from the west (drainage area of 4.6 mi²). The drainage basin is primarily underlain by limestones and shales (Gray, 1972). Land use in the watershed primarily consists of agricultural and forested lands. Developed areas are limited to less than 10 percent of the watershed.

1.1.3 Sediment Supply and Reservoir Sedimentation

Substantial reservoir sedimentation has decreased the storage capacity and recreational value of Versailles Lake. Several studies have assessed historical sedimentation rates in the reservoir and resulting losses in storage capacity (Stantec 2022 and Renn & Arihood, 1991; Section 1.2).

The USGS has studied suspended sediment loading in Indiana's streams, specifically between 1952 and 1984. The study, published in 1996, also estimated suspended sediment loads for tributary watersheds to USGS gage stations based on watershed characteristics. The report estimated that a mean of 390 tons/mi² per year of suspended sediment was produced by the watershed above the gage on Laughery Creek at Farmer's Rest. If this value is used, an average of approximately 65,520 tons of suspended sediment is a reasonable estimate of the annual suspended sediment load for Laughery Creek at the Versailles Lake Dam.

1.1.4 Ecological Setting and Special Status Species

The project is located in the Eastern Corn Belt Plains Pre- Wisconsinan Drift Plains Ecoregion. The Eastern Corn Belt Plains ecoregion is primarily a rolling till plain with local end moraine. The Wisconsinan Drift Plains Ecoregion is differentiated from the surrounding area by its deeply-leached, acidic, pre-Wisconsinan till and thin loess; widespread areas of nearly flat, very poorly-drained soils with fragipans are also distinctive. Beech forests and elm-ash swamp forests were originally dominant in the area.

An online review was performed using the USFWS Information for Planning and Consultation (IPaC) tool on February 19, 2026 to assess the potential for federally-listed species to occur within the project area.

The assessment returned these species:

- Indiana Bat (*Myotis sodalis*) – Endangered
- Northern Long-eared Bat (*Myotis septentrionalis*) – Endangered
- Tricolored Bat (*Perimyotis subflavus*) – Proposed Endangered
- Salamander Mussel (*Simpsonaias ambigua*) – Proposed Endangered
- Monarch Butterfly (*Danaus Plexippus*) – Proposed Threatened

In 2023, Laughery Creek was proposed for listing as Critical Habitat for the Salamander Mussel (88 FR 57224 57290). The proposed designation extends from directly below the Versailles Lake dam to the confluence with the Ohio River. It is currently proposed as critical habitat (Unit 30) and encompasses ≈ 45 miles of Laughery Creek in Ripley, Dearborn, and Ohio County, Indiana. The population's demographic is unknown (USFWS, 2023), and listing was based on one recent observation record in 2010. The exact

distribution and population status of Salamander Mussel in Laughery Creek is currently unknown. Primary threats to the viability of the Salamander Mussel are identified as degradation of water quality due to contaminants; habitat degradation and loss due to urbanization, agriculture, and the lack of canopy cover and vegetative cover in the riparian buffer; lack of connectivity due to barriers; presence of invasive species; host species vulnerability from the lack of regulation of collection of mudpuppies; and impacts to the hydrologic regime (USFWS, 2023).

No other critical habitat is designated within Laughery Creek, and no federally listed aquatic species are anticipated to be directly impacted from the proposed project activities (USFWS, 2023). Potential impacts to listed bat species from any required tree clearing will be avoided by clearing between October 1 and March 31.

1.2 Previous Studies

The dam and lake have been the subject of multiple studies, and the dam is inspected regularly as part of the IDNR dam safety program. These studies provide a basis for understanding the history of the dam, current dam structural condition, and frame the principal safety and operational concerns surrounding the dam.

1.2.1 Dam Safety Inspection Reports

The dam has been inspected regularly since its construction to confirm compliance with dam safety regulations, identify deficiencies requiring maintenance actions, and recommend corrective actions. Historic dam safety reports through 2018 were reviewed as part of the Feasibility Report. Generally, since the 1987 dam raising, reports indicate that, as stated in the 2018 inspection report, “surficial condition of the dam is Conditionally Poor” (IDNR, 2001 and 2018). While erosion is present due to sheet and concentrated runoff of rainfall, hiker trails, and fisherman trails, there is no indication of movement or recent settlement in the earthen portions of the dam. The visual inspection did not find spalling or cracking in the ogee spillway or associated abutment walls. The lake drain gate is inoperable, presumably due to the sedimentation of the lake.

1.2.2 1991 Sedimentation Study

Since dam construction was completed in 1956, significant sedimentation in Versailles Lake has impacted the storage capacity and surface area of the lake (Renn & Arihood, 1991). Sedimentation volumes and resulting impacts to lake storage capacity between 1956 and 1988 were assessed in a 1991 study conducted by the U.S. Geological Survey (USGS) and the Indiana Department of Natural Resources (IDNR). The 1991 study estimated a sedimentation rate (between 1956 and 1989) of approximately 48,000 cubic yards per year.

1.2.3 2022 Versailles Lake Dam Feasibility Study

The 2022 feasibility study conducted by Stantec included hydrologic modeling to confirm Probably Maximum Flood (PMF) flow, bathymetric and sediment surface grab sampling within the lake footprint,

hydraulic modeling and reservoir routing modeling of the dam, and development of three action alternatives which either brought the dam up to current code standards (able to safely pass the PMF) or decommission the dam. The Versailles Lake Dam Feasibility Study Report (Feasibility Report) was submitted to IDNR in February 2022.

Hydrologic and reservoir routing modeling confirmed that the dam, as configured, is unable to pass the PMF without overtopping of the earthen portions of the dam. The principal spillway is only able to pass approximately 50% of the PMF before overtopping of the earthen dam sections occurs. Overtopping depth would be several feet in a PMF event, leading to a high risk of embankment erosion and failure in such an event.

Bathymetric and sediment data were collected by Stantec to quantify sediment volume, understand changes in sediment deposition depths and patterns relative to historic studies, and test for chemical constituents of concern. The total volume of stored sediment in the reservoir was estimated to be 2.7 million cubic yards (CY), resulting in a decrease in lake storage capacity of 60 percent. The approximate rate of reservoir sedimentation between 1988 and 2021 was estimated to be 38,000 CY per year. The average sediment depth across the reservoir is 9.2 ft (Stantec, 2021). While the lake continues to store fine sediment, the sedimentation rate is slowing as the upper portion of the reservoir is beginning to reach sediment storage capacity. Several point bars and islands have formed within the impoundment as a result of reservoir sedimentation. Chemical analysis of surface grab samples indicate that sediments in the impoundment do not contain concentrations of chemicals of concern that require special handling or containment of the sediment. While the concentration of Barium did exceed the risk based ecological screening value, the concentration was still below background concentrations determined by the Ohio EPA and can be attributed to background geology.

The 2022 Feasibility Study assessed three “action” alternative approaches to achieving IDNR’s stated goals as well as assessing likely outcomes of a “no-action” alternative. In the case of the dam decommissioning alternatives, the differentiation between a partial removal option and a full removal option refers only to the extent of *vertical* removal and restoration of the Laughery Creek channel profile. In both cases, the dam does not create a permanent impoundment, but in “partial” removal approaches the channel is raised above its pre-dam profile within the reservoir footprint.

Alternative 0 – No Action

This alternative assumed that no modifications were to be made to the dam and no dredging of sediments in the impoundment occurred. In this alternative, the remaining lake volume would fill with sediment within approximately 20 to 25 years as Laughery Creek established a low gradient, high sinuosity channel and areas adjacent to the newly forming channel became shallow open water or emergent wetlands.

Alternative 1 – Sediment Management and Dam Improvement

This alternative included upgrading the dam through armoring of the earthen embankment with roller compacted concrete (RCC) and targeted dredging of the lake. The RCC armoring would bring the structure into compliance with dam safety standards. Targeted dredging of the lake would partially restore the recreational value of the lake but would require ongoing periodic dredging to maintain the open water acreage and depth in the design.

Alternative 2 – Partial Dam Decommissioning and Stream Valley Restoration

This alternative proposed a hybrid approach to dam removal in which a large rock ramp or boulder rapid structure was installed near the current dam location, the principal spillway and earthen embankments were partially removed, and most reservoir sediments were stabilized in place. This alternative did investigate options to lower the principal spillway elevation such that it could safely pass the PMF, but it was determined that this would not be a feasible approach and a rock ramp option was preferable.

Alternative 3 – Full Dam Decommissioning

This alternative includes removal of the principal spillway and associated structures, removal of all of the southern earthen embankment and partial removal of the northern earthen embankment, and restoration of Laughery Creek to its historic profile. This alternative proposed a multi-stage drawdown approach to incrementally mobilize impounded sediments to be transported downstream by Laughery Creek.

Due to the high capital construction cost, implementation challenges, and necessary ongoing dredging operations associated with dam upgrades required to safely pass the PMF, Alternative 1 was eliminated from further consideration. The advantages of Alternatives 2 and 3 were identified as lower construction costs, less long-term maintenance requirements, elimination of dam safety risks, and improved habitat for riverine fish species. IDNR's preferred approach to mitigating the risks associated with the dam is through dam decommissioning.

1.3 Design Criteria and Project Objectives

In 2025, IDNR contracted with Stantec to complete Phase 1 Design services for the Versailles dam project. The goal of this work is to advance the preferred alternative (Alternative 2) to a 30% stage of design. The scope of services includes additional field data collection, design analysis, and preparation of 30% Design Drawings. Design analysis includes sediment transport modeling to assess the effects of dam decommissioning and subsequent sediment releases from the reservoir on the downstream channel.

Establishment of design criteria and definition of project objectives are a necessary part of design development. These constraints and desired project outcomes provide constraints and targets for the design, providing a clear path for the final product.

The following Design Criteria must be met by project design:

Decommission the Versailles Lake Dam

The project must result in removal of the dam or in a classification of remaining dam structures as non-jurisdictional. Internal IDNR communications have confirmed that both Alternative 2 and Alternative 3 as presented in the Feasibility Report result in a final site condition that would not include a dam structure as defined by the State of Indiana's dam safety regulations.

Manage Reservoir Sediment and Re-Establish Laughery Creek Channel

The project must manage sediment and restore the channel of Laughery Creek through the impoundment footprint in the least environmentally damaging and practicable way. While ongoing evolution of the channel

may occur several years after dam removal, the project must establish an appropriate valley and stabilize remaining sediment.

Allow for and, Where Possible, Enhance Recreational Opportunities

The project design must allow for access and potential future recreation improvements within the former lake footprint. Project design must incorporate either direct elements or allow for future work to create park elements which will enhance the value of the former lake footprint to user recreation.

Permittable Design Approach

The project approach must be permittable at the federal, state, and local levels.

2 Field Data Collection

The following sections describe the field data collected by Stantec during the 30% design phase, including sediment sampling, geomorphic assessment of Laughery Creek, topographic measurements of the project site, and environmental data on threatened and endangered freshwater mussel species. These data were used to inform the design approach and sediment transport modeling.

2.1 Sediment Data Collection

Sediments in Versailles Lake and Laughery Creek were sampled in July and August 2025 to characterize the substrate types within the reservoir as well as upstream and downstream of Versailles Lake (Figure 4). Reservoir sediments were sampled using a vibracore with two subsamples from each core analyzed for grainsize distribution, specific gravity, moisture content, and Atterberg limits. These properties were used to define the erosional properties of the reservoir sediment and inform sediment transport modeling.

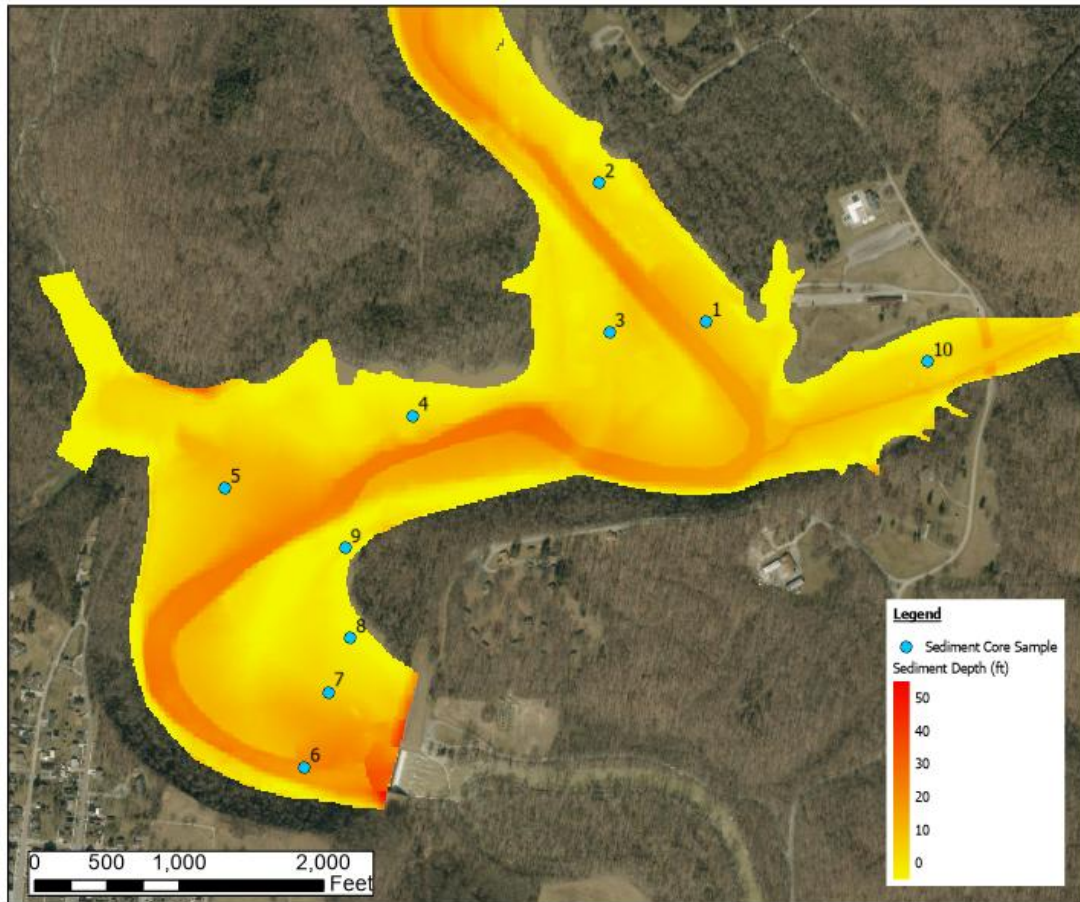


Figure 4. Reservoir sediment core sample location and sediment thickness

Reservoir sediment was dominated by silt and clay with smaller amounts of sand and gravel. The average gradation of reservoir sediment across all core samples was 88 percent silt/clay, 10 percent sand, and 2 percent gravel. The liquid limit (LL) of core samples ranged from 43 to 53 with an average value of 48. These properties are indicative of substrate that is highly erodible and may be readily mobilized following dam removal and subsequent high flow events.

The gradation of riverbed samples in Laughery Creek was characterized by bulk sampling of gravel bars upstream and downstream of Versailles Lake. Riverbed substrates were dominated by gravel and sand with small amounts of cobble. Upstream sediment samples were composed of 59 percent gravel while downstream contained 68 percent gravel. There was slightly more sand upstream of the reservoir (40 percent) than downstream (28 percent). More details of sediment data results can be found in the *Sediment Evaluation at Versailles Lake Dam* report (Appendix A).

2.2 Geomorphic Assessment

A geomorphic assessment of Laughery Creek was completed in August 2025. Results of this assessment are detailed in the *Geomorphic Assessment at Versailles Lake Dam* report (Appendix B). Longitudinal

profile data were collected in three separate mobilizations: a geomorphic assessment upstream of the reservoir influence (August 2025), a bathymetric and topographic survey (April-June 2025), and bathymetric data collection within the lake during a previous phase of dam assessment. Riffle crest elevations documented above and below the reservoir, and the dam were used to estimate a system slope of Laughery Creek. Three cross sections were measured upstream of the dam's influence. Bankfull indicators were difficult to identify in the field. This may be a result of the lack of lateral migration and point bar deposition observed in the field. Bankfull stage was evaluated during desktop review in comparison to the USGS Regional Bankfull-Channel Dimensions of Non-Urban Wadable Stream in Indiana (SIR- 5078). Two active bed riffle pebble counts and a reachwide pebble count were collected upstream of the dam. Additionally, sediment was collected from 5 depositional bars, two upstream of the dam and three downstream. The data collected from this assessment were used to define the planform, velocity, discharge, and competence of Laughery Creek.

The longitudinal profile analysis resulted in an estimated slope of 0.15%. The full profile shows that the reservoir extends approximately 4 miles upstream of the dam during low flow conditions. Excess deposition and a lower system slope are evident for an additional 3,500 feet upstream of reservoir extents, indicating influence from the dam.

Cross sections have a moderate width to depth ratio (25.5-26.7). The stream has access to a floodplain and is slightly entrenched with an entrenchment ratio of between 3.36 and 4.41. The channel is incised, with a bank height ratio of approximately 1.4. Bank erosion upstream of the hydraulic backwater influence of the dam was minimal, but channel widening and/or meandering and subsequent mid-channel deposition was apparent within approximately 3,500 linear feet of the extent of the reservoir at low flow. Field observations did not yield a readily apparent cause for the degree of channel incision measured, but potential causes include vertical degradation of the bed or lateral expansion and subsequent lowering of the bankfull stage.

The D_{50} from the active riffle beds were 37.2 mm and 32.0 mm. The D_{50} for the reachwide pebble count was 29.31 mm leading to a gravel classification. Cobble and small boulder sized substrates are present in Laughery Creek. Exposed banks near the valley edge suggest that this colluvium is weathered limestone bedrock.

The velocity and discharge of the two riffle sections were calculated using Manning's Equation. Cross section data was utilized for the hydraulic radius. Manning's roughness coefficient "n" was estimated at 0.03. Bankfull velocity and discharge were determined to be between 5.1-5.2 ft/s and 2672-2913 cfs respectively.

The competence of Laughery Creek at each riffle cross section was estimated using both the Shields and Colorado Equations. Competence of the stream was approximately 32 mm per Shields Equation and 81 mm per the Colorado Equation. This suggests that greater than 50% of the armor layer of the active bed in the field-measured riffles are mobile at bankfull stage. In each of the five bar samples, when utilizing the Colorado Curve, more than 95% of the particles are mobile at bankfull stage.

After analyzing the profile, dimension, and particle data, Laughery Creek can be described as a C4. Rosgen describes a C4 stream as having gravel channel material, being slightly entrenched, moderate to high width/depth ratio, and moderate to high sinuosity.

2.3 Supplemental Bathymetric and Topographic Data Collection

A bathymetric survey of Versailles Lake was conducted as part of the 2021 feasibility study (Stantec, 2022). Additional bathymetric survey of the riverbed downstream of the dam and reservoir were collected during the 30% design phase to inform dam decommissioning design and sediment transport modeling. Bathymetric measurements were collected using a combination of traditional survey methods and single beam sonar from a boat mounted echosounder. Areas of additional data bathymetric data collection included:

- The stilling basin downstream of the dam;
- Laughery Creek from downstream of the dam to the US-50 crossing; and

Additional topographic data was collected along the dam embankment, spillway, and immediate vicinity of the dam to serve as a basis for estimated material quantities, dam demolition plan, and development of construction drawings.

2.4 Environmental DNA (eDNA) Data Collection

An environmental DNA (eDNA) survey was conducted in Laughery Creek spanning from 7 miles upstream of Versailles State Park to 23 miles downstream. The eDNA sampling was used to characterize the mussel assemblage throughout this stretch of the creek, with a particular emphasis on assessing the presence or probable absence of the proposed federally endangered Salamander Mussel *Simpsonaias ambigua*. This mussel is typically difficult to find, as it can be found wedged under flat rocks and tree roots. A 44.5-mile reach of Laughery Creek in Ripley, Dearborn, and Ohio Counties, Indiana, was proposed as Critical Habitat under the Endangered Species Act. This unit extends from below the dam at Versailles Lake at Versailles (Ripley County, Indiana) downstream to the confluence with the Ohio River at Buffalo (Ohio County, Indiana). In addition to the analysis of mussel assemblage, the eDNA samples were used to assess the presence or probable absence of Mudpuppy *Necturus maculosus*, the obligate host species for Salamander Mussel.

The primary focus of this work was to assess the presence of Salamander Mussel within and downstream of the impoundment of the Versailles Dam (see Appendix C).

- Twelve sampling sites were sampled in the reach downstream of the dam. Samples were collected at readily accessible locations between the dam and the terminus downstream of Friendship, Indiana, which included one site where Salamander Mussel was known to be extant.
- Three sampling sites were collected within the impoundment, and an additional site was sampled ~7 miles upstream of the impoundment.

At each sampling site, four replicate water samples were collected with the exception of site LC08 where three samples were collected prior to a stoppage in work from a thunderstorm. For the eDNA collection, 500-1000mL water samples were collected from near the benthos using a peristaltic pump with a

polypropylene filter holder attached to a painter's pole. The eDNA samples were collected along a transect spanning the width of the river for each replicate sample. Once the first sample was collected, the surveyor took the next sample ~2-3m upstream, and continued sampling in an upstream direction for each replicate. Samples were filtered on a 47-mm-diameter GF/C. On each of the two field collection days, three negative field controls were collected by pouring 500mL of distilled water into a clean Nalgene bottle in the field and filtering it using the same peristaltic pump system used for sample collection. All collection equipment was decontaminated with 10% bleach solution after each day of sampling. The eDNA surveyor wore new sterile nitrile gloves at each site and when handling eDNA equipment.

2.4.1 Results

A total of 20 mussel species were identified from the eDNA sampling in Laughery Creek, which included three species of special concern in Indiana – Pocketbook *Lampsilis ovata*, Kidneyshell *Ptychobranchnus fasciolaris*, and Spike *Eurynia dilatata*. In addition, Salamander Mussel DNA was detected from six total sites, which included all sites sampled between 10.8 – 23 river miles downstream from the Versailles Dam Reservoir (see Appendix C). From the species-specific qPCR test for Mudpuppy, the Salamander Mussel host was detected from three sites. This included two sites overlapping with detections for Salamander Mussel at 21.8 – 23 river miles downstream from the Versailles Dam Reservoir.

The dataset in total suggests that Salamander Mussel populations do not occur within 10.8 river miles of the Versailles Dam Reservoir. Similarly, Mudpuppy was never detected within 7.4 river miles from the Versailles Dam Reservoir. In general, the mussel assemblage shifted from a pool habitat community within and near the reservoir, to that more representative of a riverine mussel assemblage further downstream of the reservoir (see Appendix C).

3 Analysis

3.1 Sediment Transport Modeling

This section describes the development and results of the HEC-RAS one-dimensional (1D) model used to compute hydraulics and sediment transport for the design alternatives. The model was developed using HEC-RAS version 6.6, projected to the geographical coordinate system NAD 1983 StatePlane Indiana East FIPS 1301 (US Feet). The three alternatives considered were partial removal of the dam, full removal of the dam, and no action alternative.

Under No Action conditions, Versailles Lake Dam was simulated as a weir with a spillway elevation of 790.0 ft (NAVD88). For the two dam removal alternatives, it was assumed the dam would be notched at a rate of approximately 0.5 ft/day. For the partial dam removal alternative, 27.5 ft of dam was notched, reducing the dam spillway to an elevation of 762.5 ft (NAVD88). The full removal scenario removes the entire 40-ft tall spillway over a period of approximately 6 weeks, restoring the channel to its historic thalweg and pre-dam invert of 755.0 ft (NAVD88).

3.1.1 Data Development

1.1.1.1 Terrain Development

The model terrain was created using a combination of 2017 LiDAR and bathymetry data collected in 2021 and 2025 within Versailles Lake and Laughery Creek upstream and downstream of the dam. The pre-dam surface was developed using the historic 1946 USGS Quadrangle Map of the project area.

1.1.2.1 Model Domain and Geometry

The model domain extends from approximately 6.0 miles upstream of the dam to approximately 11.0 miles downstream of the dam (Figure 5). The dam is located at approximately station 57883. See Figure 5 for the model extents. Model cross sections were spaced approximately 600 to 750 feet apart. Aerial imagery was used to visually assign roughness (Manning's N) values, using the HEC-RAS user's manual for suggested values based on land cover type. Table 1 provides a summary of Manning's N values used in the model cross sections. The dam was modeled as an inline structure, with an embankment elevation of 809.5 ft and a spillway elevation of 790.0 ft. Dam dimensions and elevations are based on as-built plans and as reported in the feasibility study. Two bridges, downstream of the dam, were modeled: the Historic Busching Covered Bridge and U.S. 50 Highway bridge. Bridge dimensions were approximated based on aerial imagery and terrain data. The 1% annual-chance-exceedance (ACE) event, developed during the feasibility study, was simulated to develop a downstream rating curve boundary condition to be used in the sediment modeling alternatives.

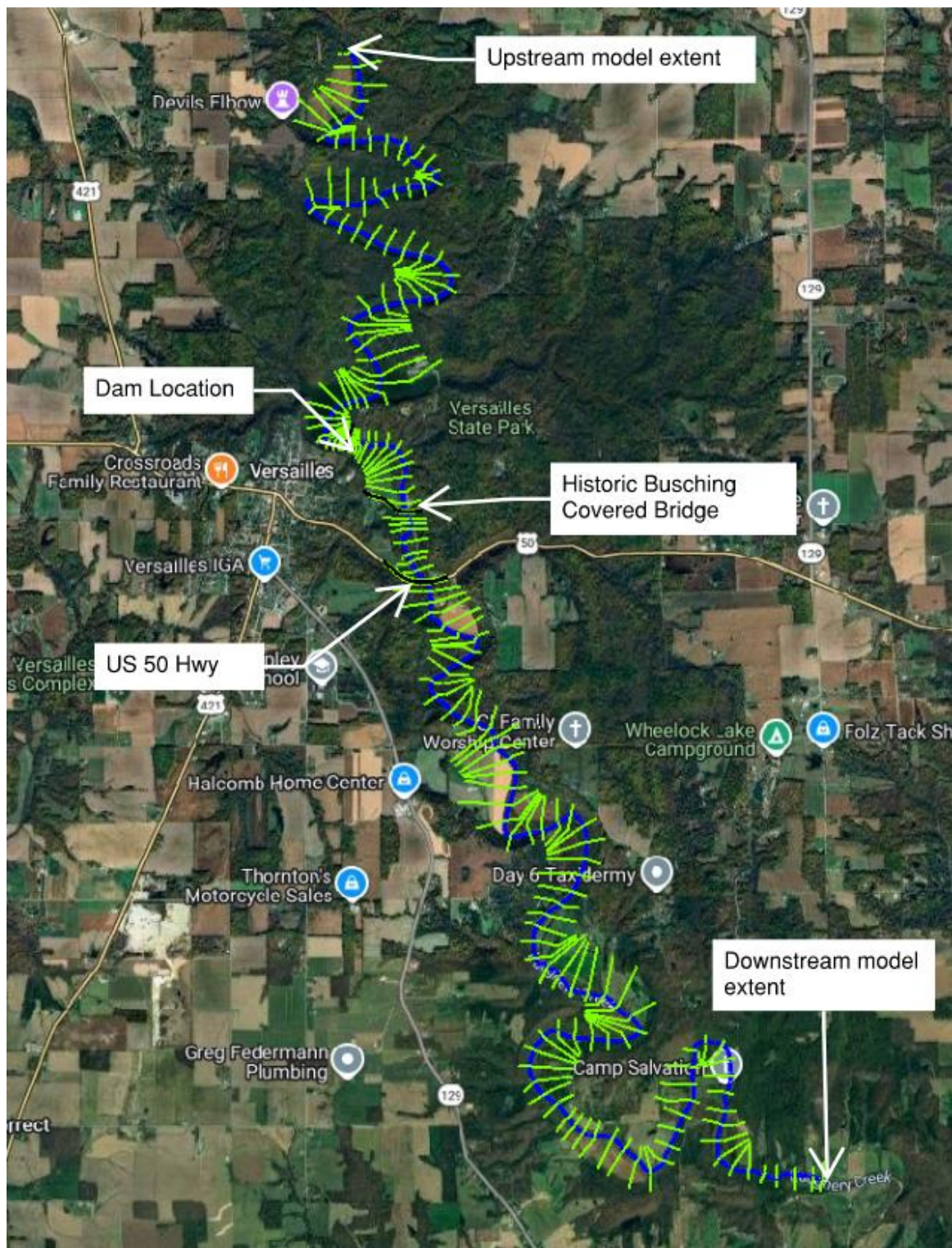


Figure 5. Model Domain

Table 1. Manning's N Values

Land Cover Type	Roughness Value
Trees/Forest	0.12
Open Water (Reservoir)	0.04
Channel	0.035
Field/Pasture	0.03
Developed (Medium Intensity)	0.08
Developed (Open Space)	0.04
Wetland	0.05
Vegetated Islands	0.1

1.1.3.1 Hydrology Development

Since there is no active stream gage on Laughery Creek, flows for the model were determined using the USGS Gage #03369500 Vernon Fork Muscatatuck River at Vernon, Indiana gage. The gage period of record extends from 1939 to present. Daily average flows at this gage with a drainage area of 198 mi² were scaled to match the contributing drainage area upstream of Versailles Lake Dam with a drainage area of 168 mi² (Figure 6). Ten-year hydrologic periods were developed for the sediment transport model simulation that represent the Dry, Median, and Dry Water Year (WY) removal scenario from the gage period of record.

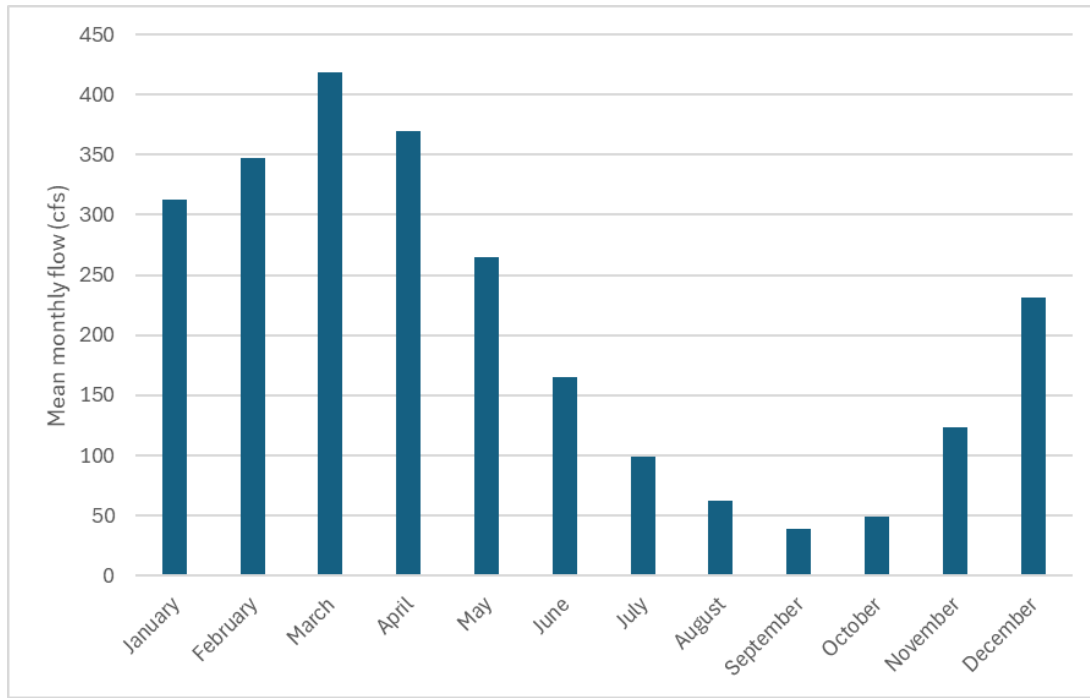


Figure 6. Scaled mean monthly discharge at the USGS Gage #03369500 Vernon Fork Muscatatuck River at Vernon, Indiana (1939-present)

To develop the representative WY scenarios, the mean annual flow was ranked over the period of record and the exceedance probability determined for each year. A Wet year is considered to have a 10% annual exceedance probability (0.9 percentile). The Median year has a 50% annual exceedance probability. The Dry year has a 90% annual exceedance probability (0.1 percentile). The resulting Dry, Median, and Wet water years are shown in Table 2.

Table 2. Water Year Types Classified by Percentile of Mean Annual Flow Measured at USGS Gage #03369500 Vernon Fork Muscatatuck River at Vernon, Indiana

Water Year Type	Exceedance Probability	Representative Water Year	Mean Annual Flow (cfs)
Wet	0.1	2016	293
Median	0.5	2005	207
Dry	0.9	1963	118

The river flows for the 10-yr Dry, Median, and Wet Water Year scenarios are shown in Figure 7, Figure 8, Figure 9. The year that corresponds to the Dry, Median or Wet Year is the first full water year (WY) of the simulation.

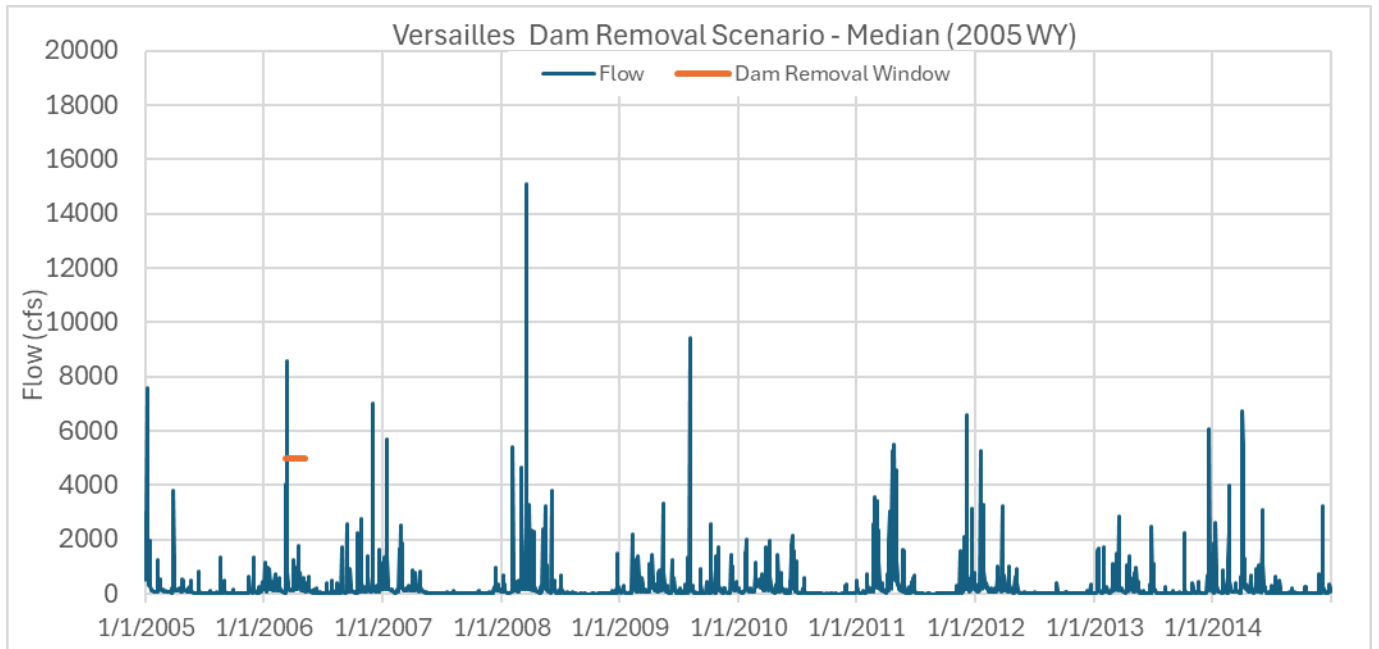


Figure 7. Flow in Laughery Creek for the Median Year, WY 2005

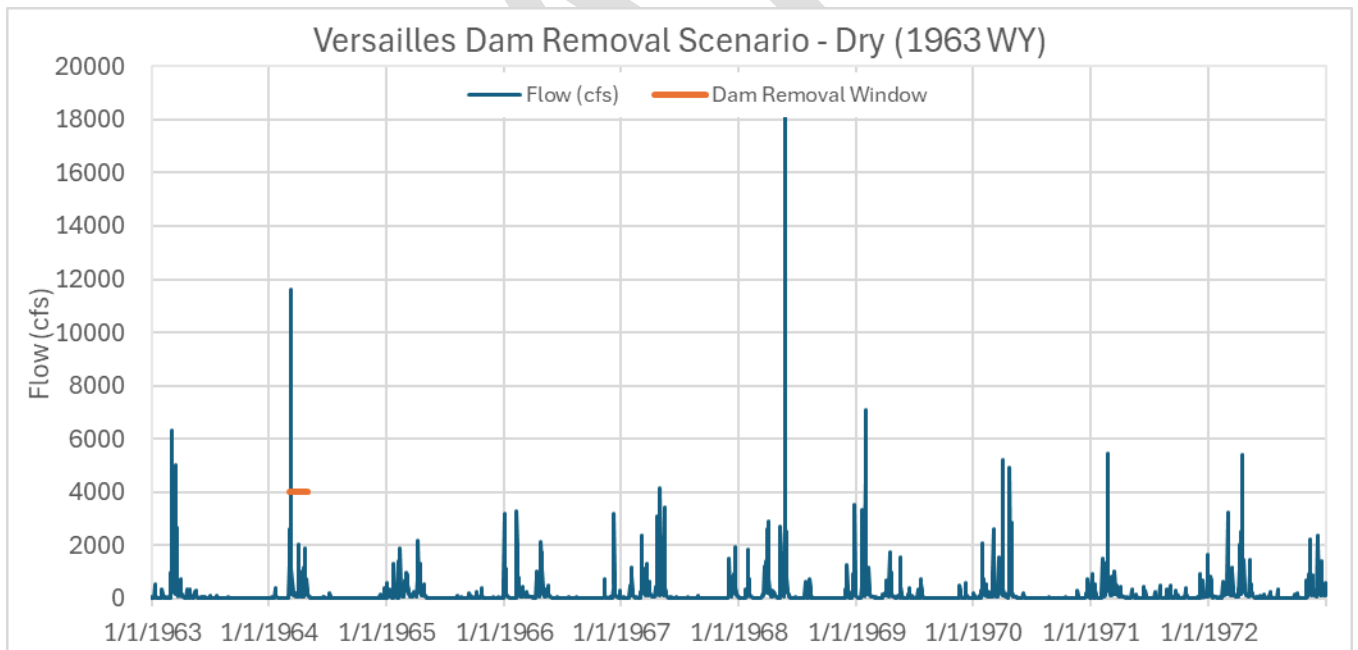


Figure 8. Flow in Laughery Creek for the Dry Year, WY 1963

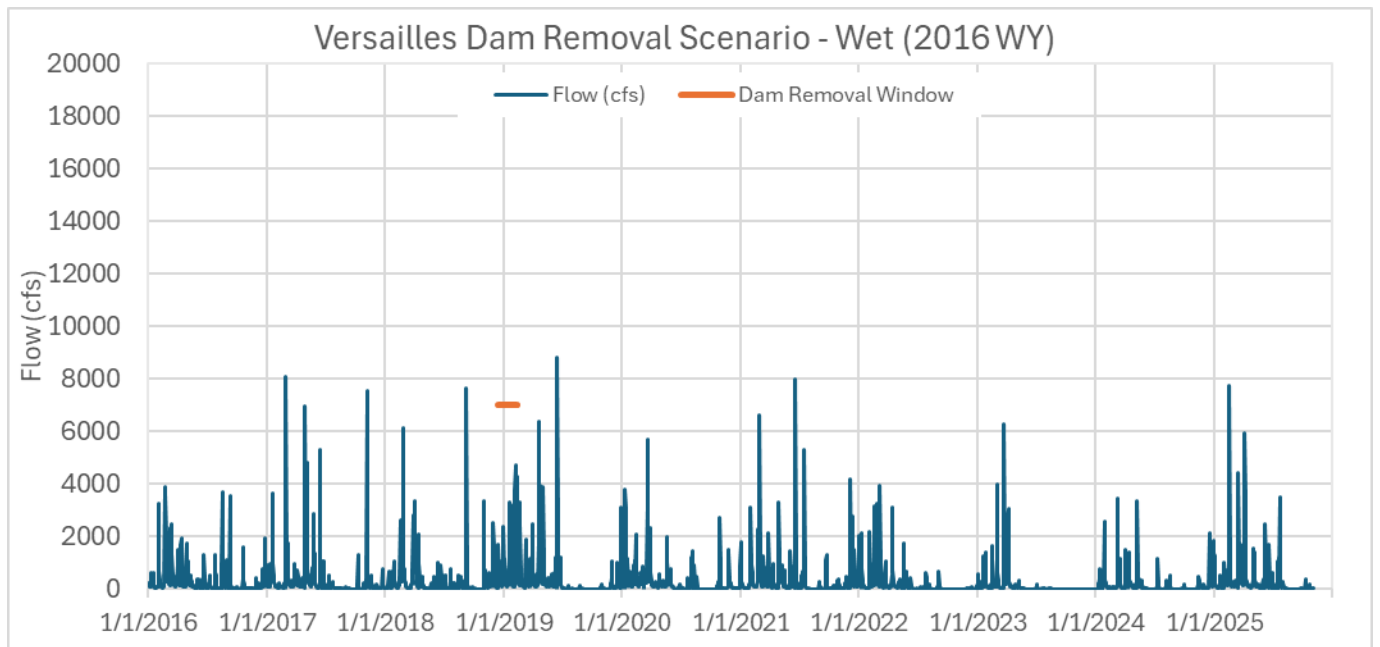


Figure 9. Flow in Laughery Creek for the Wet Year, WY 2016

1.1.4.1 Riverbed Material

The gradation of riverbed material used in the model was defined by bulk sampling of depositional features upstream and downstream of the dam. Riverbed material was dominated by gravel and sand with small amounts of cobble (Table). See Appendix A for more details of riverbed substrate sampling.

Table 3. Average gradations of riverbed sediment upstream and downstream of Versailles Lake used in the model

Sediment Size Class	Percentage (%)	
	Upstream Reach	Downstream Reach
Sand	39.5	27.6
Gravel	58.7	68.3
Cobble	1.8	4.1

1.1.5.1 Reservoir Sediment Thickness and Gradations

Reservoir sediment thickness was computed by differencing the current reservoir surface defined by the 2021 bathymetric survey from the pre-dam surface as estimated by the 1946 USGS topographic map (Figure 4).

The average gradation of reservoir sediments was defined by vibracoring sampling within Versailles Lake (Table). See Appendix A for more details of vibracore sampling results.

Table 4. Average gradation of sediment in Versailles Lake used in the model

Diameter (mm)	Percent Finer (%)
0.001	20.1
0.002	26.4
0.004	35.0
0.008	50.2
0.016	68.5
0.032	80.0
0.063	87.8
0.125	92.0
0.25	94.8
0.50	97.0
1	97.2
2	97.4
4	99.3
6	100

1.1.6.1 Cohesive Sediment Transport Properties

Cohesive sediment is generally defined as that with a diameter less than 0.0625 mm. To compute the erosion and deposition of these size fractions HEC-RAS uses the following relationship between shear stress and erosion rate:

$$\epsilon_r = k_d(\tau - \tau_c)$$

where ϵ_r = erosion rate (m/s)

k_d = erodibility coefficient (m³/N-s)

τ = applied bed shear stress (Pa)

τ_c = critical shear stress (Pa)

The parameters k_d and τ_c can vary over a large range of values and there are no standard predictors of its value. A direct test using a jet test device (Al-Madhachi et al. 2013) or the Erosion Function Apparatus (Briaud et al. 2001) are recommended to determine their values. However, for this study, there was no additional sampling performed, and we utilized empirical relationships from Chow (1959) and Temple et al. (1987). The intention of the empirical analysis is to develop the possible range of cohesive sediment parameters.

NRCS (1987) developed the following equations based upon soil type.

MH soils:

$$\tau_c = (1.38 - 0.373e)^2 \begin{cases} (0.0477I_w^2 + 1.43I_w + 10.7) \times 10^{-3}, & 10 \leq I_w \leq 20 \\ 0.058, & 20 \leq I_w \end{cases}$$

ML soils:

$$\tau_c = (1.48 - 0.57e)^2 \begin{cases} (1.07I_w^2 + 7.15I_w + 11.9) \times 10^{-4}, & 10 \leq I_w \leq 20 \\ 0.058, & 20 \leq I_w \end{cases}$$

where

τ_c = critical shear stress (lb/ft²)

I_w = Plastic Index (-)

e = void ratio (-)

Chow (1959) also published estimates of cohesive sediment properties (Figure 10. The chart was updated and given in SI and English units by Akan (2006):

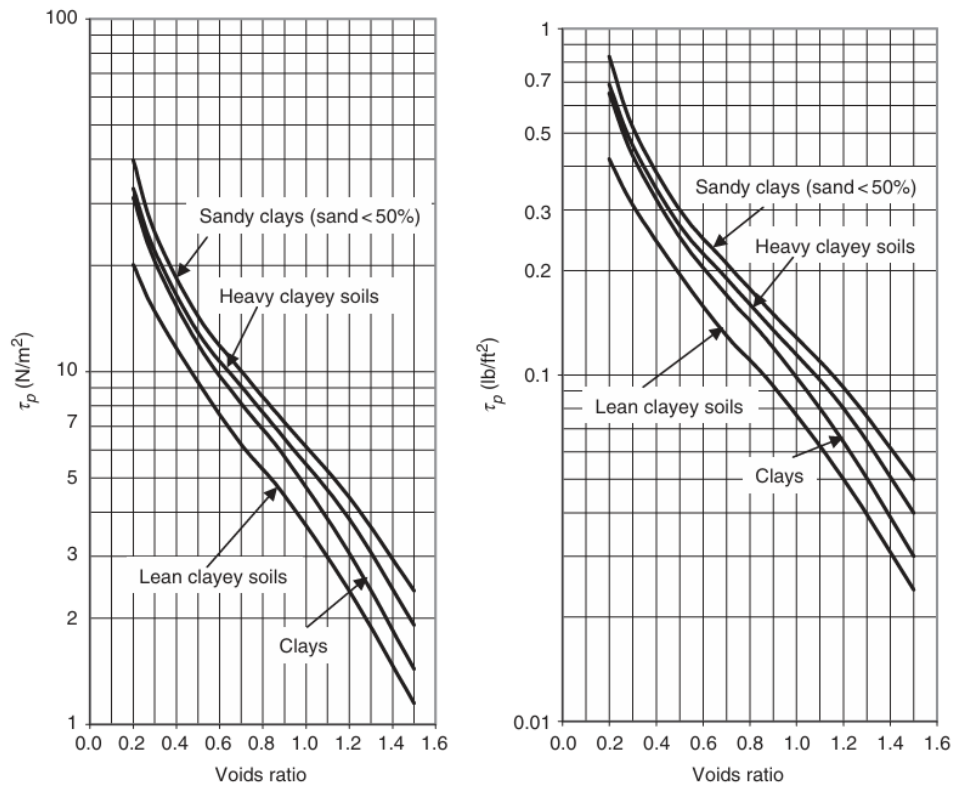


Figure 10. Critical shear stress from Chow (1959)

To compute the erodibility coefficient (k_d), the relationship proposed by Simon et al. (2010) is used, which relates critical shear stress and the erodibility coefficient:

where k_d = erodibility coefficient ($m^3/N/s$)

τ_c = applied bed shear stress (Pa)

To convert the erodibility to the English units used in HEC-RAS, the following relationship is used:

$$k_d\left(\frac{1}{hr}\right) = 3600\gamma(SI)k_d(SI)$$

where $\gamma(SI)$ = unit weight of sediment (N/m^3)

A range of parameter values (Table 5) were used in the simulations to perform a sensitivity analysis on the potential uncertainty in erosion due to uncertainty in the cohesive sediment parameters. The default HEC-RAS cohesive option is to use the selected transport functions for all grain sizes. Simulations were ran using this default, as well as the option to use the Krone/Partheniades for clay and silt size fractions, which is where the parameter values in Table 5 were incorporated to compare resulting channel profiles and sediment concentrations to assess the sensitivity in using the HEC-RAS default cohesive options or assigning the calculated cohesive parameters. No significant differences in resulting erosion and sediment concentrations were observed from the modeling.

Table 5. Empirical Estimation of Critical Shear Stress (τ_c) and Erodibility Coefficient (k_d).

Soil Type in Reservoir	τ_c (lb/ft ²)	k_d (1/hr)
MH Soil	0.039	34
ML Soil	0.022	54

3.1.2 Results

Three design alternatives were modeled: no action, partial dam removal, and full dam removal. For each alternative, the three hydrologic scenarios described in Section 3.1.1.3 were simulated to provide a range of results due to seasonal flow considerations: the dry, wet, and median flow scenarios. For the purpose of

informing the removal design, the results discussed below primarily compare the difference in the reservoir erosion, deposition, and sediment concentrations between the partial and full dam removal simulations.

1.2.1.1 Reservoir Erosion and Deposition

The full dam removal and partial dam removal modeling scenarios were set up to allow erosion down to a specified elevation, as well as an allowable erodible width at each cross section. These elevations and widths were based on the pre-dam terrain, where the cross section representing the dam (Section 57883) was set to an allowable minimum elevation of 754.1 feet, and allowable erodible width of 40 feet, based on the pre-dam invert elevation and thalweg. Figure 11, Figure 12, and Figure 13 show the resulting channel profiles, comparing the full dam removal and partial dam removal for each of the three hydrologic scenarios. Despite the variable hydrologic scenarios and the difference in the full dam removal and partial dam removal final design spillway elevations (pre-dam invert versus the rock ramp elevation of 762.5 feet), the modeling results show that the channel, at and upstream through the reservoir, is able to erode similarly, resulting in a pre-dam invert elevation at the dam. Figure 14 also highlights the similar resulting erosion and invert at the dam cross section between all simulations. As seen in the profiles, similar deposition occurs downstream of the dam for all simulations, which is to be expected due to the sediment output at the dam from removal and the “back up” of sediment due to the downstream bridge constrictions.

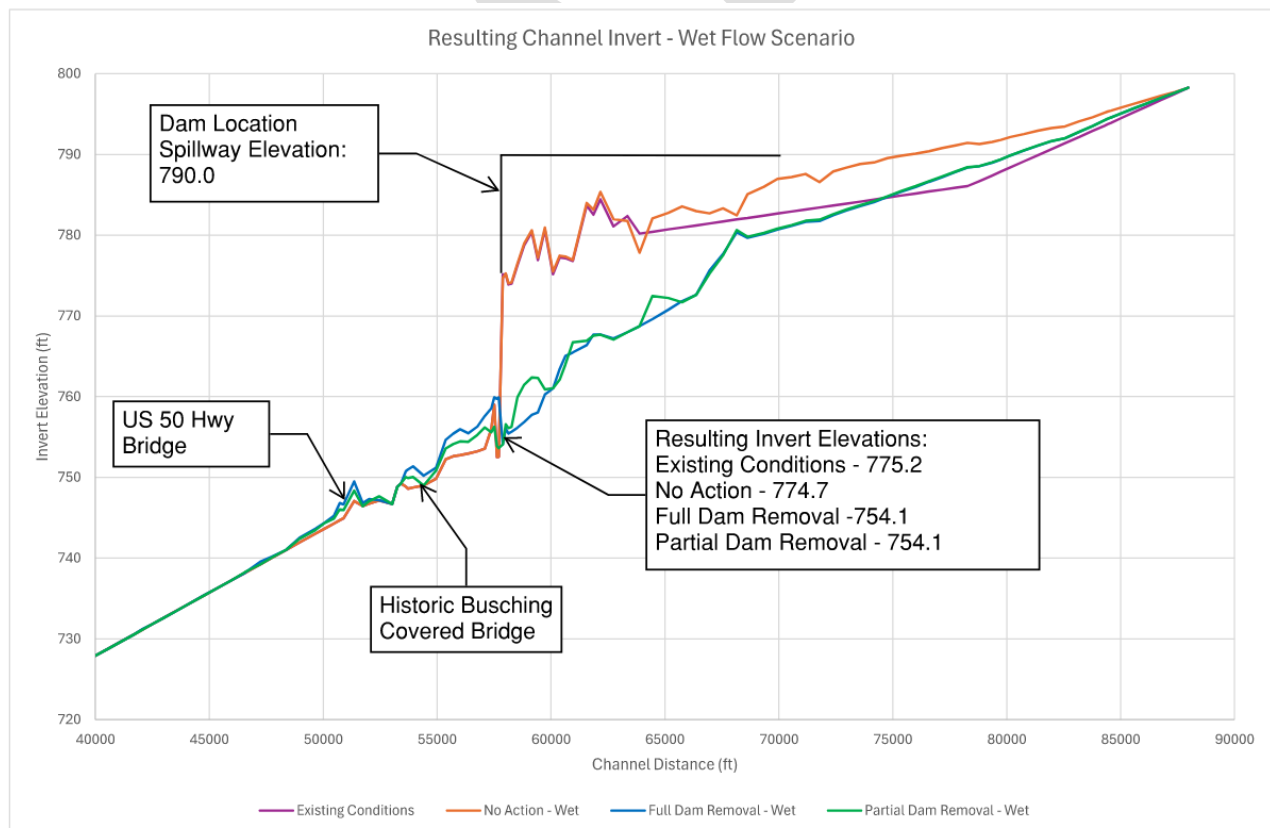


Figure 11. Channel Erosion and Deposition – Wet Flow Scenario – 5 year Simulation

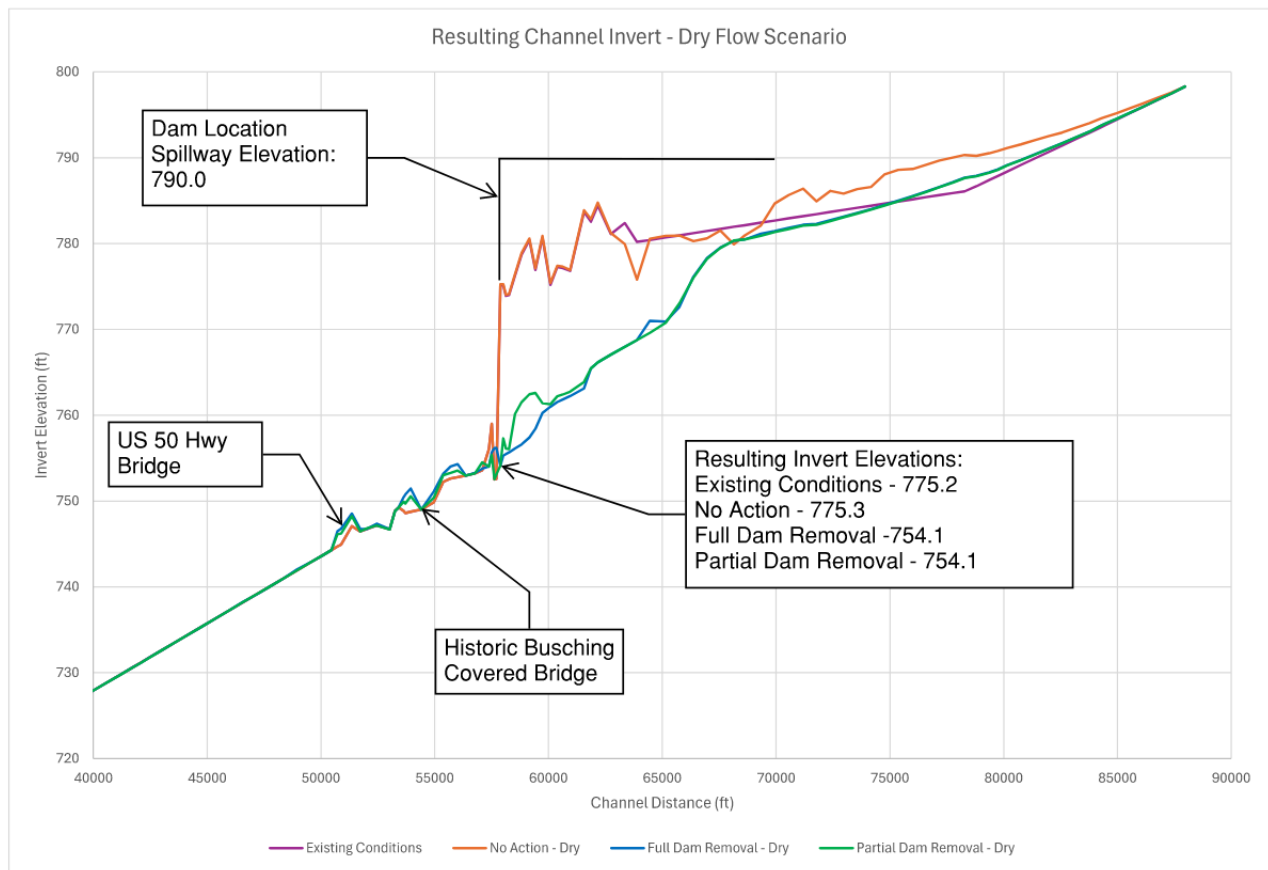


Figure 12. Channel Erosion and Deposition – Dry Flow Scenario – 5 year Simulation

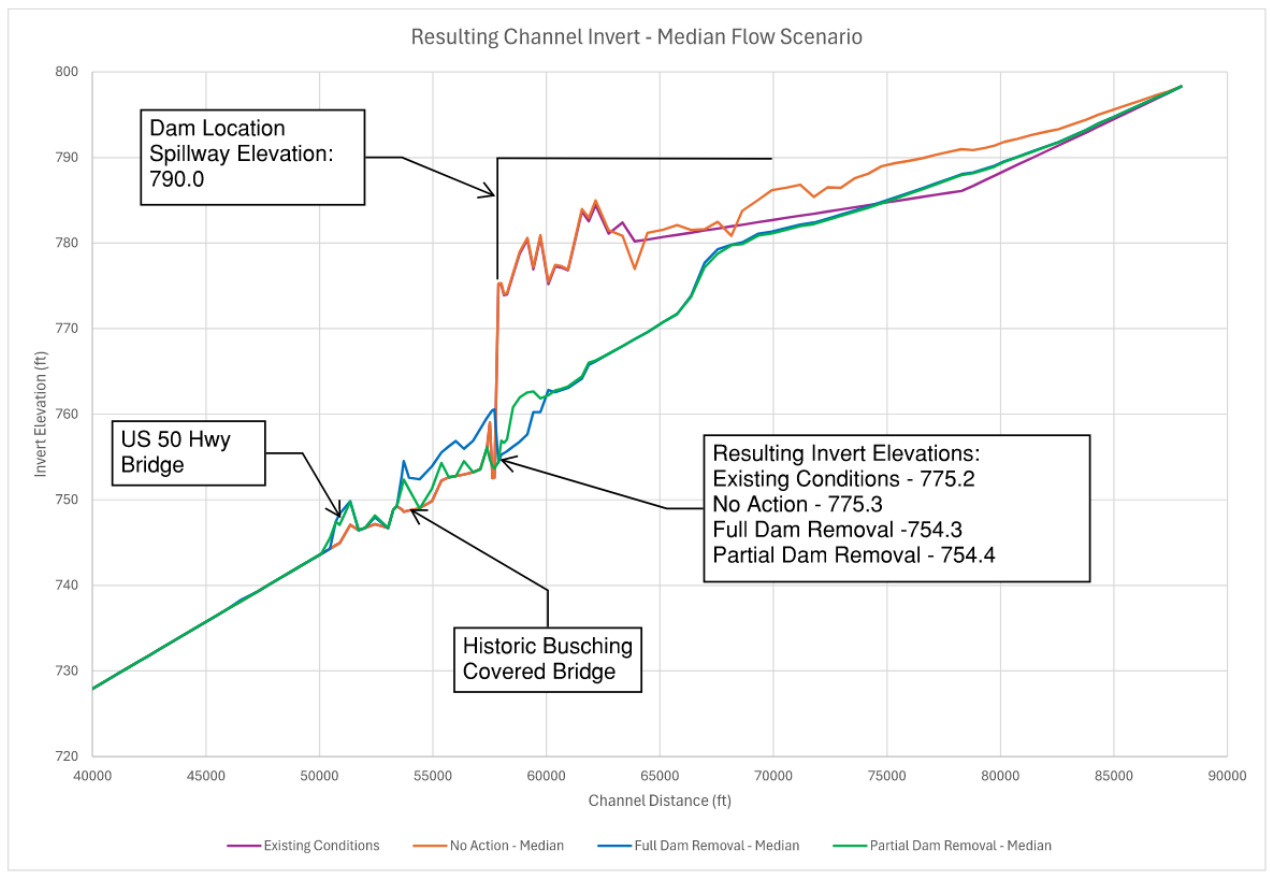


Figure 13. Channel Erosion and Deposition – Median Flow Scenario – 5 year Simulation

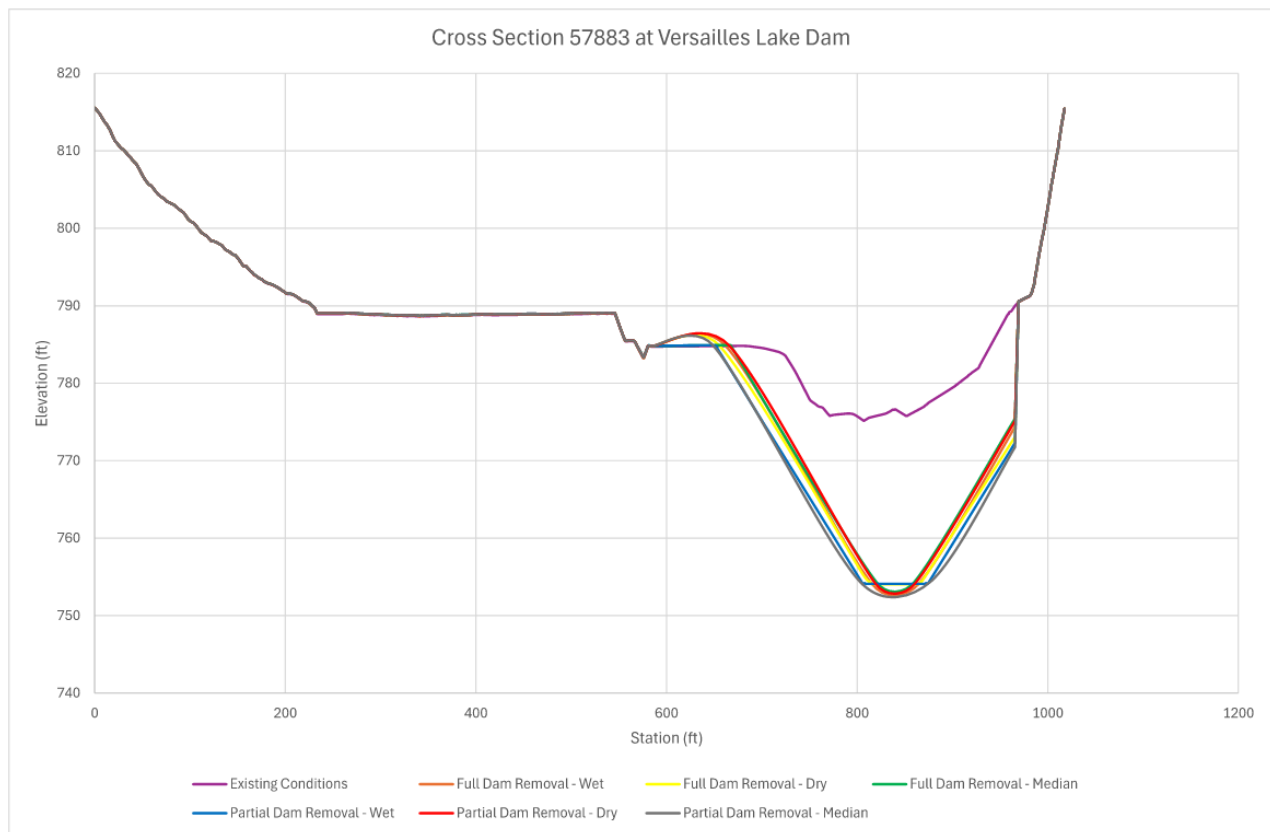


Figure 14. Erosion at the Dam (Cross Section 57883)

1.2.2.1 Sediment Concentrations

For the purpose of informing the removal design, the amount of sediment output downstream of the dam after removal between the full dam removal and partial dam removal scenarios was analyzed. Figure 15, Figure 16, and Figure 17 show the sediment concentrations coming out of the dam versus the sediment coming into the channel from upstream for all three hydrologic scenarios. As seen in the figures below, the amount of sediment coming into the system is higher than the amount of sediment coming out of the dam before the removal window. Once the dam removal occurs, there is a large peak in sediment concentrations, in both the full dam removal and partial dam removal scenarios. After approximately a year for all three hydrologic scenarios, the sediment output begins to reach equilibrium, where the amount of sediment coming into the system is equal to the amount of sediment coming out at the dam. The only significant yet expected difference being that the partial dam removal scenarios show a slightly lesser amount of sediment coming out of the dam. For the sediment transport model simulation to successfully execute, the dam removal window had to occur during peak flows, therefore the day that the dam removal starts is not the same between the three hydrologic modeling events, but the removal duration is the same (60 day removal schedule).

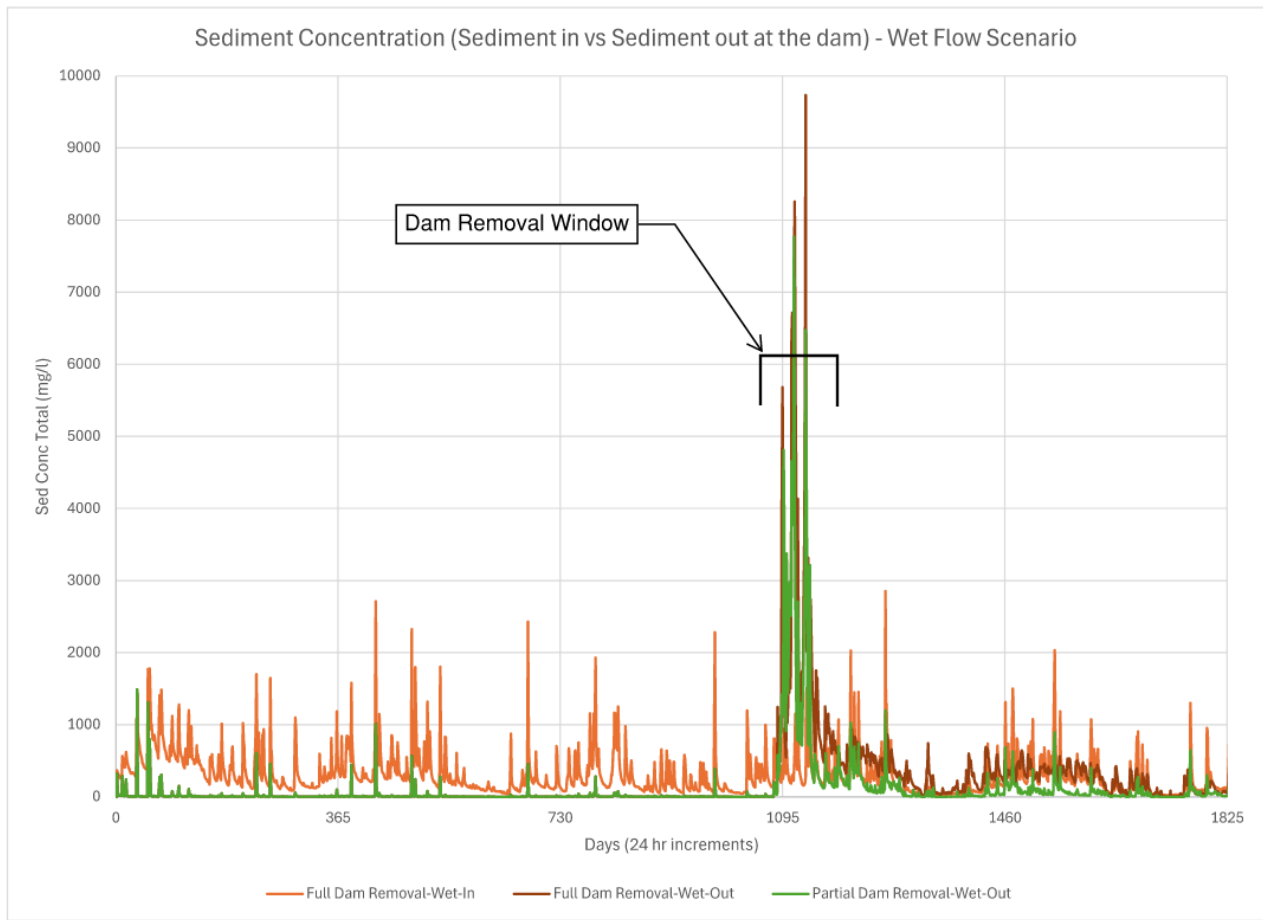


Figure 15. Sediment Concentrations – Wet Flow Scenario

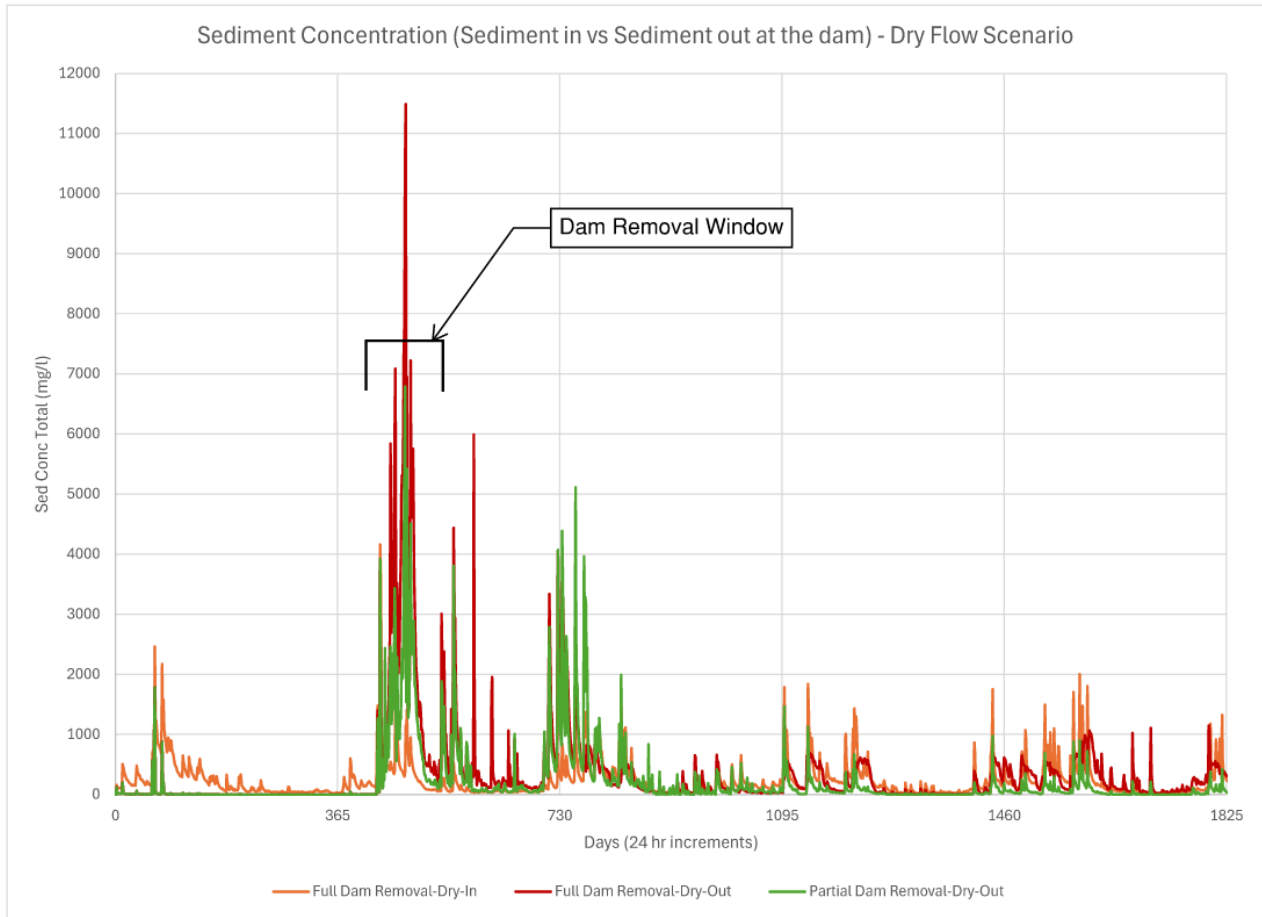


Figure 16. Sediment Concentrations – Dry Flow Scenario

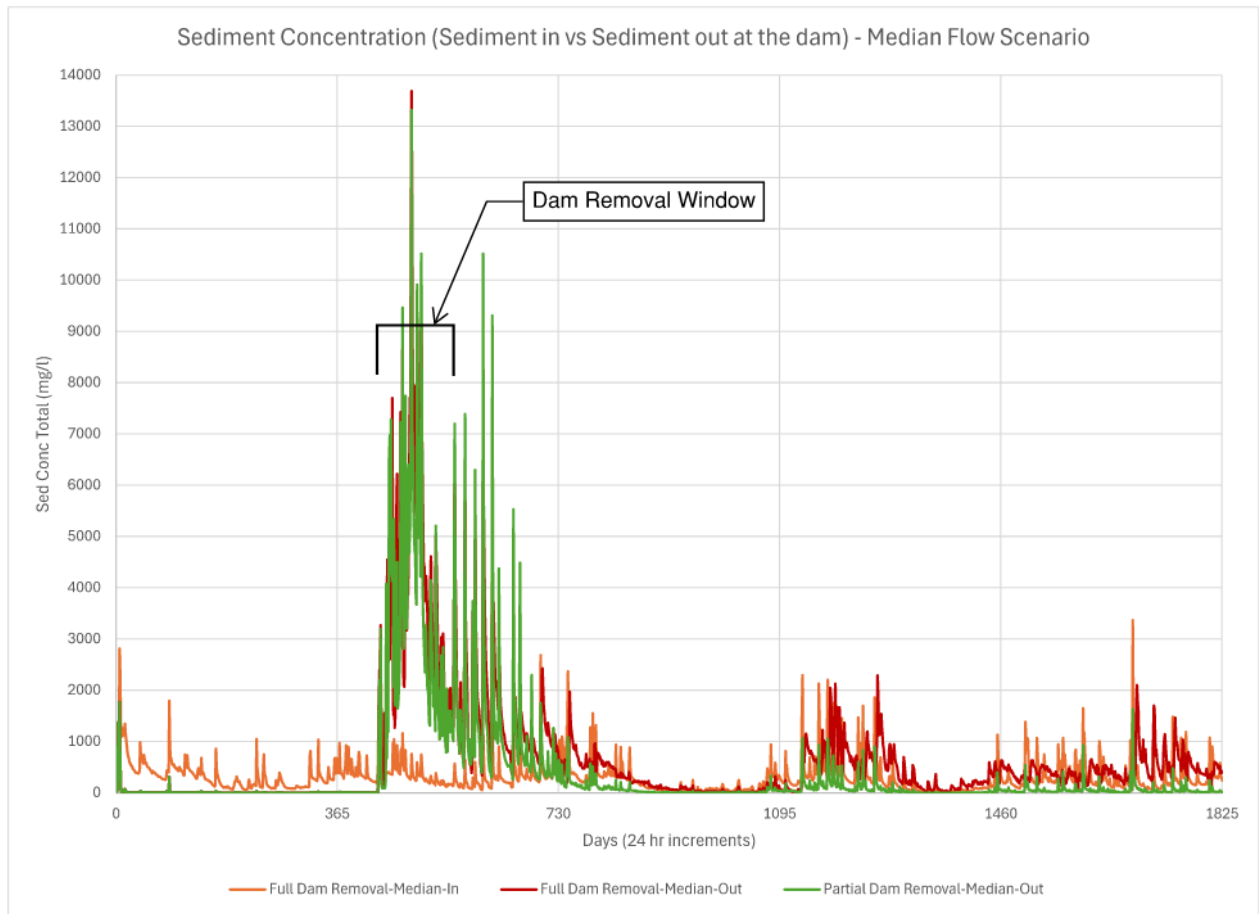


Figure 17. Sediment Concentrations – Median Flow Scenario

1.2.3.1 Total Sediment Deposition

Between all three hydrologic scenarios, the difference in channel erosion and deposition throughout the modeled stream length were comparable, most notably resulting in similar deposition downstream of the dam after removal. Figure 18 compares the channel erosion and deposition between the full dam removal and partial dam removal scenarios, which resulted in a difference of total cumulative mass deposited downstream of approximately 103,000 tons.

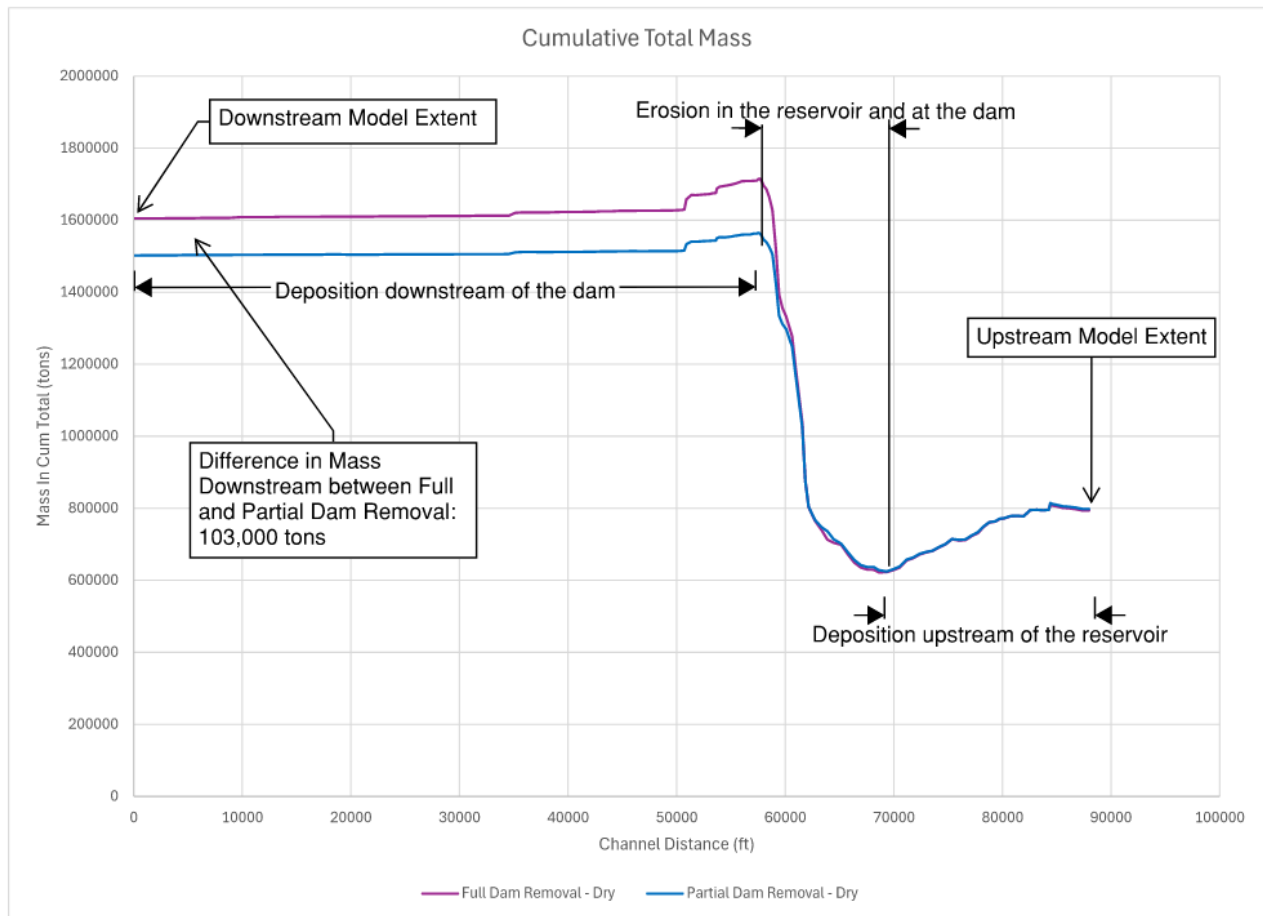


Figure 18. Sediment Erosion and Deposition – Total Mass

1.2.4.1 Water Surface Elevations

The resulting water surface elevations (WSEs) for all simulations, regardless of hydrologic scenario, were comparable. Figure 19 shows the resulting WSEs, comparing existing conditions (no action), full dam removal and partial dam removal scenarios for the median flow scenario. For the no action scenario, the backwater from the reservoir extends upstream to approximate model station 75000. The resulting WSE profiles for the full and partial dam removal are no longer affected by backwater from the dam, the only difference being the minor backwater seen in the partial dam removal scenario from the rock ramp design. WSEs for the removal scenarios are slightly higher downstream of the dam compared to no action, due to the sediment deposition downstream of the dam after removal.

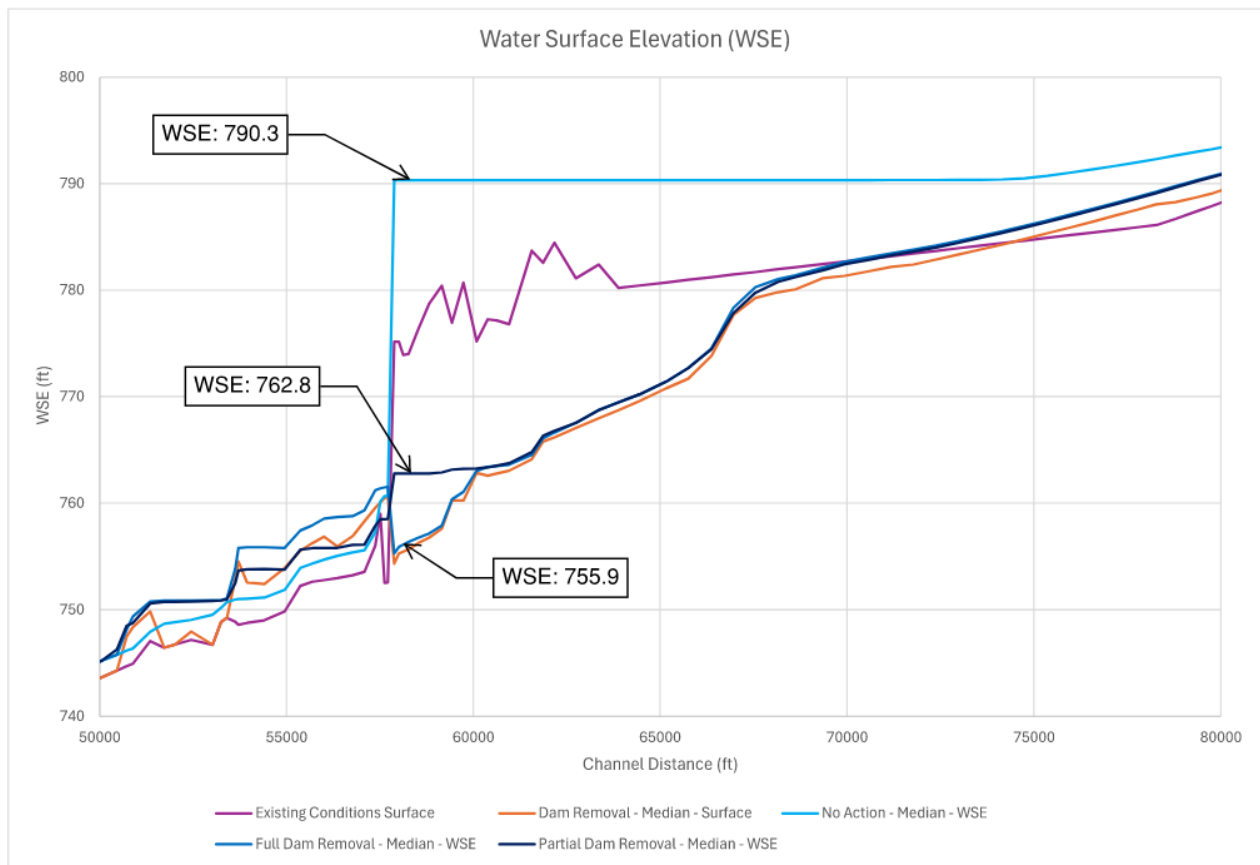


Figure 19. Resulting Water Surface Elevations

3.2 Reservoir Dewatering Design

3.2.1 Structural Analysis

During dewatering of Versailles Lake, the existing ogee-crested spillway will be "notched" (partially cut down). This allows for a controlled release of water until the lake is fully dewatered. Once the lake is drained this leaves the existing abutment walls to support the earthen embankment without counter pressure from the lake pool.

The analysis focused on the stability of the abutment walls during the "worst-case scenario"—defined as the period when the existing spillway is partially cut-down and the walls must support the full pressure of the earthen dam without the counter-pressure of the lake water.

Two primary failure modes were evaluated:

- **Overturning:** The risk of the wall tipping forward due to lateral earth pressure and live load surcharge.

- Sliding: The risk of the wall moving horizontally along its base due to being pushed by the lateral earth pressure.

Per the Indiana Building Code (1807.2.3 and 1610.1), the structure must maintain a minimum Factor of Safety (FS) of 1.5 for both overturning and sliding. The analysis utilized the following design parameters listed in Table 2.

Table 2. Design Parameters used in Structural Analysis

Parameter	Value
Concrete Unit Weight	145 pcf
Soil Unit Weight	130 pcf
Soil Internal Friction Angle (ϕ)	30 degrees
Active Earth Pressure Coefficient (K_a)	0.33
Concrete / Shale Friction Coefficient	0.50
Live Load Surcharge	100 psf
Water Table	No water behind walls once drained

The walls were assessed both as individual segments (based on variations in the foundation thickness) and as a single, unified structure. In all configurations, the results exceeded the required safety threshold of 1.5.

- Individual Segments:
 - Overturning FS: 3.04 to 6.07 (well above the 1.5 requirement)
 - Sliding FS: 1.55 to 2.42 (Exceeds the 1.5 requirement)
- Unified Structure:
 - Sliding FS: 1.79 (Exceeds the 1.5 requirement)

Factor of safety results assessed each abutment segment are presented in Table 3.

Table 3. Factor of Safety Results for Abutment Segments

Abutment Segment	Required Factor of Safety	Overturning Factor of Safety	Sliding Factor of Safety
Segment A	1.5	4.43	1.86
Segment B	1.5	4.17	1.83
Segment C	1.5	4.23	1.87
Segment D	1.5	5.76	2.42
Segment E	1.5	3.64	1.71
Segment F	1.5	3.04	1.55
Segment G	1.5	3.49	1.67
Segment H	1.5	3.58	1.70

Abutment Segment	Required Factor of Safety	Overturning Factor of Safety	Sliding Factor of Safety
Segment I	1.5	3.80	1.75
Segment J	1.5	3.58	1.69
Segment K	1.5	3.49	1.69
Segment L	1.5	3.46	1.69
Segment M	1.5	3.16	1.65
Segment N	1.5	6.07	2.27

3.2.2 Seasonal Considerations

Because management of sediment relies heavily on Laughery Creek to mobilize and transport lower reservoir sediments, the timing of dam notching and demolition should coincide with periods of higher discharge. Generally, gage data from Laughery Creek (USGS #03277000 Laughery Creek at Farmer's Rest, Indiana 1940-1973) and the nearby Vernon Fork Muscatatuck River (USGS Gage #03369500 Vernon Fork Muscatatuck River at Vernon, Indiana, 1939-Current) indicate that average daily flows are highest between January and April.

Sediment releases during warm periods pose elevated risks to aquatic life because higher temperatures both reduce dissolved oxygen solubility and increase biological and microbial oxygen demand. Temperature is the primary determinant of dissolved oxygen levels in United States rivers (Zhi et al., 2023). To minimize the potential for creating temporary hypoxic conditions, associated with sediment release, project activities should be scheduled during winter, when water temperatures are the lowest.

3.2.3 Environmental Considerations

Full or partial dam removal would provide ecological uplift within the current footprint of the lake and for the larger Laughery Creek system through improved sediment transport and restoration of fish/Mudpuppy passage through the current dam footprint. The impoundment currently creates a monotypic pool habitat which cannot support a large diversity of fish species. The fishery would likely shift from a lentic system that supports species like crappie to a lotic one where species like smallmouth bass are targeted. Restoration of the stream through the current impoundment length would likely result in an improved fish community. Riffles would also enhance in-stream aquatic habitat quality.

Furthermore, the eDNA survey found a noticeable shift in the mussel assemblage as sites move downstream from the Versailles Dam Reservoir (Section 2.4.1). Notably, samples collected within the reservoir were comprised of only three common species – *Pyganodon grandis* (Giant Floater), *Utterbackia imbecillis* (Paper Pondshell), and *Quadrula quadrula* (Mapleleaf); whereas samples collected from downstream stretches of Laughery Creek were comprised of greater than 20 mussel species (Appendix C). The mussel assemblage within the impoundment was greatly simplified, likely as a result of pervasive soft sediment and sediment anoxia. Additionally, mussel species known to use darter or minnow fishes as a

host were generally absent from sites near the reservoir, whereas mussel species known to use Freshwater Drum as a host generally had their DNA present within the reach immediately below the reservoir. This change in assemblage further suggests a severe impairment to fish and mussels near the reservoir due to sediment storage.

Based on the results of eDNA sampling on Laughery Creek (Section 2.4.1), Salamander Mussel are the only state-listed/federally proposed aquatic species that is anticipated to occur in close proximity (≈ 10 miles) to the project area. Anticipated impacts on Salamander Mussel can be classified into three primary categories: impacts to the species' obligatory host, the Mudpuppy; impacts to habitat conditions; and direct impacts on individual mussels.

Impacts to downstream aquatic habitat would occur from pulses of sediment delivery into the downstream reach of Laughery Creek as sediment is released from the impoundment. The location and depths of accumulated sediment in Laughery Creek drawdown of the impoundment would depend on many factors, including stream discharge following dam removal. Qualitative assessment of impoundment sediment indicates that most of the sediment is comprised of material finer than sand that would be transported as suspended load during high flow events. This would likely minimize accumulation of sediment shoaling in the downstream reach as base and high flows will continue to flush sediment further downstream. Therefore, impacts on mussel and fish habitat from sediment releases will likely be short term.

A full or partial dam removal is expected to create short-term disruptions to aquatic food webs as stored sediments, organic material, and nutrients are mobilized downstream (Dorobek et al., 2015). Impacts to aquatic life are expected to be variable depending on foraging strategies and the duration of sediment pulses. Specific potential impacts to Mudpuppy and Salamander Mussel are described below.

Mudpuppy Potential Impacts

Host-related impacts are likely to influence reproductive success for the Salamander Mussel, given the species' unique reliance on mudpuppies for the completion of its life cycle. The primary expected impacts to Mudpuppy and fish populations from the proposed action are temporary feeding disruptions due to high turbidity, and stress with the potential for mortality due to sediment mobilization.

The potential for feeding impairment from sediment release depends on the physiological tolerance and life stage of affected organisms and the suspended sediment concentrations generated by the project. Some species are capable of withstanding, or even benefiting from, elevated suspended sediment levels. Impacts to Mudpuppy on feeding are expected to be minimal, because of their use of chemical cues to find food in dark and turbid waterbodies (Bishop, 1943).

Reproductive success may also be reduced through egg burial caused by increased sediment deposition, suspended sediments that disrupt egg metabolism, and suspended sediments that alter essential fish behaviors. Although comprehensive egg-burial studies have been conducted for salmonids and certain estuarine species (Newcombe and Jensen, 1996), comparable studies are lacking for Mudpuppy.

Sediment mobilization into the water column is expected as a result of the proposed dam removal activities. Microbial consumption of mobilized dissolved organic carbon and oxygen is expected to reduce dissolved oxygen levels in Laughery Creek. Under certain environmental conditions, such as elevated water

temperatures or ice cover, these reductions could cause hypoxic events and potentially result in fish mortality (Janice et al., 2013). A 1990 University of Alabama study found that mudpuppies can survive 5–11 days in severe low-oxygen conditions (9–10 mmHg) by switching from gill breathing to lung breathing (Ultsch and Duke, 1989). This adaptation of Mudpuppy may allow for increased survival in temporary hypoxic conditions.

Dam removal is planned for winter when aquatic metabolic demand is low, and dissolved oxygen levels are naturally higher due to the physical properties of water (i.e., higher solubility in cooler temperatures; Zhi et al., 2023). Conducting the work during this period helps reduce the risk of hypoxic conditions associated with elevated suspended sediment concentrations. Partial mitigation of the risks of hypoxia through time-of-year restrictions, is expected to reduce stress and risk of death on fish and Mudpuppy populations downstream of the project area.

Salamander Mussel Habitat/Proposed Critical Habitat Potential Impacts

The entire length of Laughery Creek downstream of the project area to the confluence with the Ohio River (≈ 44.52 miles) is proposed as critical habitat for the Salamander Mussel (Management Unit 30). This accounts for $\approx 2.2\%$ of the entire proposed critical habitat for the species and is one of the 37 management units. The United States Fish and Wildlife Service listed six features that are essential to the conservation of the species in this management unit:

- “degradation of water quality due to contaminants;
- habitat degradation and loss due to urbanization, agriculture, and the lack of canopy cover and vegetative cover in the riparian buffer;
- lack of connectivity due to barriers;
- presence of invasive species;
- host species vulnerability from the lack of regulation of collection of mudpuppies; and
- impacts to the hydrologic regime (USWFS, 2023).”

Full or partial dam removal is likely to permanently improve connectivity, eliminating the largest barrier in the watershed. Water quality will be temporarily degraded from an input of suspended sediments. Sediment aggradation in management unit 30 will be temporary and short-term, because the fine sediment stored in the impoundment is highly mobile. Sediment transported out of the reservoir will continue to mobilize downstream during subsequent high flow events and eventually deposit sediment into the Ohio River. It is unlikely that the interstitial spaces utilized as habitat for the Salamander Mussel and Mudpuppy will be permanently buried. Therefore, there are no anticipated direct impacts to Salamander Mussel habitat within the proposed critical habitat unit.

Salamander Mussel Potential Impacts

The Salamander Mussel is declining primarily due to vulnerabilities in its Mudpuppy host, chemical pollution, sedimentation, altered temperature and flow regimes, habitat fragmentation from structures like dams, competition from numerous invasive species, and impacts from resource extraction activities (U.S. Fish and Wildlife Service 2023). Project activities are anticipated to improve long term habitat connectivity and availability through the removal of a physical barrier limiting Mudpuppy (and thus Salamander Mussel) temporal movements. Potential negative impacts from the action include the potential for physical

disturbance, displacement, or mortality of individual mussels because of temporary in-stream sediment aggradation and water quality degradation.

Full or partial dam removal is likely to cause a short-term, temporary increase in sediment load downstream of the current dam location. Increases in suspended solids can adversely affect freshwater mussels, including Salamander Mussel, by reducing food availability, interfering with filter feeding and respiration, and disrupting key components of the mussel/host fish relationship (Goldsmith et al., 2020). Some studies indicate that freshwater mussels can endure short term environmental stressors by closing their valves and entering a quiescent state (Sheldon and Walker 1989, Haag 2012). A study conducted in 2020 by Goldsmith et al., demonstrated that mussel feeding and fertilization success could be negatively impacted at suspended solids concentrations as low as 8 mg/L. Reproductive failure was reported at suspended solids concentrations of 20 mg/L and respiratory stress was reported to occur at concentrations of \approx 600 mg/L (Goldsmith et al., 2020). The specific impacts on Salamander Mussel feeding and reproduction from high suspended sediment concentrations are unknown but are likely similar to other freshwater mussel species.

Potential Impacts on Water Sources

Dam decommissioning projects in the State of Indiana are subject to Senate Bill 436 (2025) which prohibits IDNR from *“ordering the closure or removal, of the partial closure or removal, of... a dam...if the closure or removal, or the partial closure or removal, of the dam would impact the provision of water utility service to the public or the supply of water to one or more private water wells.”*

Stantec assessed potential impacts to private water sources through a desktop review, based on the assumed dam removal approach presented in this report. Records of 10 potential wells were identified within a 2-mile distance of the lake. Of these, eight were identified as wells and two were only identified as bedrock borings. Five of the wells have depths which only reach the upper, surficial unconsolidated aquifers while three were completed in bedrock. It was not clear whether the two other bedrock borings were finished as wells and confirmation of the status of these borings may be necessary in future design phases. The desktop assessment found that all eight known wells have a low probability of being negatively impacted by dam removal, as designed. Additional field verification may be required to confirm that no negative impacts will result from dam removal, these field investigations will be completed in future design phases. Further details of the desktop well impact assessment are contained in Appendix D.

Versailles Lake historically provided raw water for the Town of Versailles drinking water utility. In 2014, however, the Town changed from a surface water source to a groundwater source of drinking water when it began purchasing water from the Elrod Water Company, Inc. (Hoosier Hills Regional Water District). The raw water intake, pumping infrastructure, and surface water treatment infrastructure formerly associated with Versailles Lake are no longer in use.

The Town of Osgood, Indiana has a raw water intake on Laughery Creek located just upstream of the Highway 350 crossing (according to correspondence from the Town of Osgood and IDNR). The intake is located approximately 10 miles upstream of the Versailles Lake Dam. With the estimated backwater of the dam extending approximately 4 miles upstream, with an additional 3-4,000 linear feet of influence, the Osgood raw water intake is located well upstream of any dam or lake influence is not expected to be impacted by dam removal.

4 Design

The design approach presented in the sections below assumes full removal of the principal spillway and partial removal of the earthen embankment. Following sediment data collection and modeling conducted during the 30% design phase, it was concluded that partial removal of the spillway and construction of a rock ramp would have marginal benefits to downstream sediment management. In addition to having a higher construction cost, construction of a rock ramp raises potential concerns for future channel migration and deposition of coarse substrate at the rock ramp. The 30% design drawings are included in Appendix E. The Versailles Lake Dam decommissioning and associated Laughery Creek restoration design and implementation includes two phases of work. These phases can, generally, be described as:

Phase 1 – Dam Notching and Reservoir Dewatering

The first phase of the project includes a controlled dewatering of the reservoir by notching the concrete ogee spillway section. During this phase of construction, the sequence of spillway notching is designed to optimize sediment mobilization in Laughery Creek. After initial notching to the geometry specified in the 30% Design Drawings, additional dam removal and site stabilization will occur. As described in Section 3, the wing walls of the ogee spillway can support the adjacent dam embankments independently of the ogee spillway section.

After completion of Phase 1 of construction, there will be a period of limited work to allow Laughery Creek to mobilize and transport sediment. This period is referred to as the “interim period” in this report, representing the interim period between Phase 1 and Phase 2 of the project.

Phase 2 – Valley and Stream Restoration

Due to the predicted channel evolution of Laughery Creek during the interim period between reservoir dewatering and active stream restoration, bulk excavation and grading of reservoir sediments is anticipated. The goal of this second phase of work is to establish a geomorphically appropriate valley and stream channel. Because Laughery Creek has an adequate supply of coarse bedload sediments and some degree of channel adjustment is acceptable to IDNR, this phase of work focuses on establishing a “starting point” for channel re-establishment by providing a connected floodplain and a channel slope which approximates the historic Laughery Creek profile.

This phase of work will also incorporate an extensive revegetation program, with the goals of stabilizing remaining reservoir sediments in place and establishing a biodiverse plant community to compliment the existing Park ecosystem. This design does anticipate colonization of the regraded reservoir footprint by species within the seed bank, so the design focuses on rapidly establishing species and improved biodiversity.

4.1 Limits of Work

The design approach relies on natural geomorphic processes to return the site to a balanced state of dynamic equilibrium over time. Active construction work is only proposed in areas where Laughery Creek is unable to re-establish its channel and valley in a reasonable timeframe . Generally, these areas of active

construction work are located in the lower reservoir, where the width of the lake greatly exceeds the width of the natural Laughery Creek channel and establishment of a stable floodplain will require many years of lateral erosion and deposition.

4.1.1 Valley Grading (Bulk Excavation) in the De-watered Reservoir

Valley grading work begins near STA 20+00 (Appendix E, Sheet C-111). This location coincides with a significant narrowing of the current lake, with the width of the impoundment reaching approximately the width of the natural, stable channel observed upstream near STA 15+00. This area also corresponds to the extent of the most highly visible and accessible portion of the lake to park visitors, making it an important area to advance this area towards stability. Valley grading work will continue downstream through the remainder of the lake footprint and towards the dam.

Limiting grading to areas of current open water also limits the potential for direct impacts to wetlands which have formed in areas of deposition. Immediately upstream of the work limits, several small island features or lateral depositional features could contain regulated wetlands.

4.1.2 Dam Demolition and Dam Embankment Excavation

Dam embankment excavation (Appendix E, Sheet C-120) is limited to a width that approximately matches the proposed valley grading upstream in the reservoir footprint. The bottom width of the proposed valley through the dam is approximately 250 feet, completely replacing the width of the principal spillway. This valley bottom width meets the approximate target entrenchment ratio (see Section 4.4.2). The proposed grading removes the entirety of the southern embankment, excavating to the approximate pre-dam valley wall, but leaves most of the northern embankment in place.

The dam structure includes components which were constructed well below the elevation of likely stream scour. The reasons for the depth and extents of these dam features are seepage control (key trenches) and structural integrity of the abutment walls (footings). Dam removal extents, as shown in the drawings (Appendix E, Sheets C-109 and C-110), are intended to allow natural adjustment and evolution of the bed and banks of Laughery Creek while avoiding exposure of remnant concrete portions of the dam. These minimum extents may be exceeded by the construction contractor, depending on their means and methods of dam demolition. Minimum demolition extents were set at 5 feet below the thalweg of the proposed channel for the width of the channel plus a buffer width of 25 feet on either side of the channel. This will allow for some channel adjustment, pool formation, or lateral migration during the first two to three years after dam removal. In areas outside of the channel width and 25-foot lateral buffer, concrete dam components will be removed to a minimum of 3 feet below proposed grade.

The only exception to the minimum removal extents outlined above are the abutment walls and footings along the right (south) edge of the proposed valley cut. Because the 1946 USGS Topographic Quadrangle Map and dam construction drawings show Laughery Creek hugging this edge of the valley before dam construction, the channel has a potential to migrate towards this valley wall over time. Therefore, the footings and principal spillway will be completely removed here to accommodate potential lateral migration or lateral pool scour.

4.2 Dam Demolition and Reservoir Dewatering

Because the project requires two distinct phases of active construction work, the dam demolition plan has also been divided into two scopes of work. The sequence of dam demolition is informed by analyses described in Section 3, drawing on Stantec's understanding of the structural components of the dam and the goal of riverine sediment mobilization.

Due to the size of the bankfull channel identified in the geomorphic assessment (Section 2.2), leaving a "notch" during the interim period between Phases 1 and 2 is feasible, but not desirable. The size of the notch required to avoid backwatering the impoundment during high flows and the potential cost savings of completing most of the concrete structure demolition in a single mobilization, makes demolition of most concrete portions of the dam during Phase 1 a better approach. Only removal of the low-head weir downstream of the stilling basin, the stilling basin bottom, and final grading and bulk excavation of the earthen embankment are reserved for the second demolition scope.

4.2.1 Phase 1 – Dewatering

The goal of the first phase of dam removal is to restore Laughery Creek to a free-flowing condition so that the stream can mobilize and transport sediment out of the reservoir footprint. Outside of that principal objective, the Phase 1 demolition scope and sequence was designed with structural stability and dam safety in mind.

2.1.1.1 Phase 1 Demolition Sequence

The Phase 1 demolition sequence includes four "steps" intended to safely access and demolish the principal spillway.

4.2.1.1.1 Site Preparation

The stilling basin immediately downstream of the dam is currently backwatered by a low-head weir, maintaining a water depth of approximately 5 feet. The weir has previously been flanked around the left (north) abutment and repaired through placement of large concrete blocks. These blocks can be temporarily removed to lower the water surface of the stilling basin by approximately 3.5 feet (estimated from field data collected in 2025). The resulting water depth should allow access by construction equipment to the face of the principal spillway with little or no temporary causeway material placement.

Because notching will need to occur during flows exceeding 100 cfs, safely accessing the concrete spillway will require concentrating most of the flow away from access routes. To accomplish this, Stantec proposes notching of the principal spillway from the right (south) bank. By focusing flows against the right abutment, construction crews can access the remainder of the dam face.

Cutting into the top of principal spillway along the right (south) abutment will likely need to be completed from the top of the south embankment due to the height of the principal spillway. The south embankment is accessible along an unimproved access drive beginning near the former City of Versailles waterworks facility. This access road can also provide a staging area for dam debris, bulk fill, and equipment. The

vertical difference between the top of the earth embankment and the top of the principal concrete spillway is approximately 19.5 feet, requiring a lowering of the south abutment for equipment to reach the spillway crest (figure or plan sheet). This notching effort will create a shallow (3-4-foot deep) notch in the ogee spillway. The intent of this notch is only to focus most of the flow away from the primary access point along the left bank of the stilling basin.

Because this initial preparation and notching will require lowering of the south earthen embankment, it may be necessary to prepare for potential armoring should a high flow event occur before the dam is notched and/or demolished in the next two stages of construction. This emergency preparation will likely take the form of staging of large riprap material near the south embankment for placement on an as-needed basis.

4.2.1.1.2 Dam Notching

The design approach relies heavily on the use of Laughery Creek to mobilize and transport impoundment sediments. To initiate sediment mobilization, lowering the reservoir stage at a relatively rapid rate (up to 1 foot per day) will be necessary. The drawdown rate will be controlled by lowering a section of the concrete spillway to meet the prescribed stages. This notch will be approximately 30-40 feet in width, enough space to allow dewatering to proceed but reasonable for construction equipment given the difficult access required.

4.2.1.1.3 Demolition to Designed Extents

After the notched section of the spillway reaches the pre-dam channel invert, work can begin on removal of the remaining principal spillway, abutment walls, footings, and channel lining to the limits shown in the 30% Design Drawings. While this work could be accomplished during Phase 2, completion of most of the demolition in a single mobilization, as part of Phase 1, will likely lead to overall cost savings and decrease the potential for safety risks associated with leaving partially demolished portions of the dam in place during the interim period between Phase 1 and Phase 2 of construction.

4.2.1.1.4 Temporary Stabilization and Revegetation

During the first three to four months of the interim period between Phase 1 and Phase 2 of construction, temporary measures can be employed to minimize unwanted erosion and begin the restoration process. All temporary fill piles and exposed lakebed sediment will be seeded with a temporary cover crop. Fill piles will be seeded in accordance with the Indiana Department of Environmental Management's (IDEM) Construction Stormwater General Permit (GSCP). It is possible that, even during the spring following Phase 1 of construction, exposed sediment will be difficult to access with large equipment and aerial seeding by drone or helicopter may be required.

While gravel-sized particles constitute a small portion of lower reservoir sediments, these larger bedload particles pose the greatest risk to the stability of downstream reaches of Laughery Creek. To capture bedload (gravel or larger) sediment which may mobilize during the interim period between active construction phases, the concrete blocks at the north end of the still basin low-head weir will be replaced. The stilling basin will act as a sediment trap, capturing bedload sediment that sorts out of the lower

reservoir or which is transported through the lower impoundment from the upstream coarse sediment deposits.

4.2.2 Phase 2 – Final Demolition Extents and Embankment Grading

During Phase 2 of construction, final demolition depth of the principal spillway, abutment walls, footings, and channel lining will be achieved. Demolition of the energy dissipation pool low-head weir will also be completed at this time. The contractor may choose to over-excavate during Phase 1 demolition to achieve the final, minimum removal depth of concrete dam structures and future design development may find that this approach will yield cost savings or other benefits.

Because the design allows for channel adjustment during the first few years of vegetation establishment and bed substrate replenishment, any concrete structures which remain in place must be removed beyond the finished grade. Below the bankfull stage of the final, proposed channel through the dam footprint and for a minimum of 25 feet on either side of the proposed channel, all concrete or other man-made materials will be removed to a minimum of three feet below the thalweg elevation of Laughery Creek. Outside of the channel and adjacent buffer, man-made elements of the dam will be removed to a minimum of three feet below proposed, finished grade.

During Phase 2 of construction, the low-head weir which maintains the stilling basin will also be demolished, returning Laughery Creek to its final profile. Coarse sediment which accumulates within the stilling basin footprint during the interim period between construction phases can be harvested for use in construction of riffles and point bars in the restored Laughery Creek channel.

4.3 Sediment Management

This project represents a unique and difficult sediment management scenario. The combination of a wide lake relative to the channel width of its principal tributary (Laughery Creek) means that riverine transport of impounded sediments can be relied upon for some, but not all, necessary sediment management. As described in Section 3, modeling results suggest that, under the correct flow conditions, the fine-grained sediments in the lower lake can readily be mobilized during drawdown and subsequent high flow events.

The Bureau of Reclamation Subcommittee on Sedimentation's *2017 Dam Removal Analysis Guidelines for Sediment* notes that sediment management approaches can generally be grouped into four categories. This project's approach employs each of the "action" methods described: River Erosion, Mechanical Removal, and Stabilization (SOS, 2017).

4.3.1 Riverine Sediment Erosion

Laughery Creek can be relied upon to mobilize and transport a significant volume of sediment during high flow events in the months and years following initial dam "notching" and reservoir dewatering. The 30% design and associated analyses assessed several facets of riverine sediment management including rate of sediment mobilization, mechanisms of sediment mobilization and associated channel evolution, volume of expected sediment mobilization, and potential downstream impacts (principally periods of high turbidity and

aggradation). Riverine sediment management will be the focus of the first phase of construction, the “dewatering phase”.

The principal mechanism of sediment mobilization by the stream is likely to be vertical degradation of the stream bed, sometimes referred to as downcutting. Stantec’s modeling analysis, described above in Section 3, indicates that this vertical degradation can be expected to reach the approximate historic bed profile of Laughery Creek within two years of dam notching. Once this period of vertical degradation is complete, the rate of sediment mobilization by the creek will decrease as channel evolution moves to a widening phase, eroding the new high, vertical banks through toe scour and lateral migration of the channel. This design proposes a reliance on riverine sediment management through the period of vertical degradation, when Laughery Creek is most effectively transporting impounded sediments, for up to an 18-month period.

4.3.2 Mechanical Sediment Management and Stabilization in Place

Laughery Creek can be relied upon to mobilize and transport a large volume of sediment during high flow events during the interim period between dam notching and impoundment dewatering. Once channel evolution shifts from a process of downcutting to a process of widening, the rate of sediment mobilization will decrease. Due to the relative width of the impoundment compared to the naturally occurring Laughery Creek channel, the stream is unlikely to have the erosive capacity to re-establish a valley geometry which will support long-term geomorphic stability within an acceptable timespan.

During Phase 2 of construction, bulk grading of Laughery Creek’s floodplain will be necessary. The 30% design includes a valley which establishes a minimum entrenchment ratio of 2.2. This valley dimension provides a low, connected floodplain with a width which is appropriate for the C4 channel type identified during the geomorphic assessment (Section 2.2). The proposed valley approximates, but does not exactly, match the pre-dam valley topography of the reservoir footprint.

This proposed valley is generally narrower than the pre-dam valley. This extent is driven by both cost considerations and to ensure that there is adequate space to spoil mechanically graded sediment. The geology and hydrology of southeast Indiana have seen substantial changes throughout its geological history. In many cases, south-flowing streams in southwest Ohio and southeast Indiana either occupy valleys of pre-glacial rivers or have had their upper watersheds truncated by glacial erosion. The morphology of and soils in the Laughery Creek valley within Versailles State Park indicate that this is also the case at the project site. The alluvial valley contains both pre- and post- glacial deposits, suggesting that the current form of Laughery Creek may not have formed the full valley width, but that a pre-glacial stream may have caused this erosion (Indiana University, 1977). A further description of the basis of valley design is included in Section 4.4.2.

After final grades are achieved, the project proposes stabilization of sediments in place through seeding and installation of native plants. Revegetation of the project site, including the reservoir footprint and any remaining sediment, is described in Section 4.5.

4.4 Stream Design

Stantec approached design of the restored Laughery Creek channel in a way that sets a foundation for channel evolution. Sediment and geomorphic field data suggests that Laughery Creek can be relied upon to drive evolution of the proposed stream channel through transport of sand, gravel, and cobble substrates.

Field collected geomorphic data was used to develop a range of dimensional relationships of various planform, cross section, and profile features of Laughery Creek. These relationships provided a range of geometries that form a template for design of the restored Laughery Creek. The observed conditions of stable reaches of Laughery Creek upstream of the dam are applied directly to the channel design.

4.4.1 Profile

Field data collection and analysis associated with this stage of work indicate that a design approach which approximates the historic profile of Laughery Creek within the reservoir footprint provides the best long-term stability and habitat value outcomes.

Field data collection and analysis suggests that the channel slope of Laughery Creek upstream and downstream of the reservoir's influence is consistently approximately 0.15%. The longitudinal profile, when connected between the free-flowing channels upstream and downstream of the reservoir's influence, does not suggest that the pre-dam profile within the reservoir footprint diverged from this wider system slope. In some cases, dam sites can correspond to areas of high gradient within otherwise low-gradient stream systems, but that does not appear to be the case for the Versailles Lake dam.

Targeting the approximate system slope upstream and downstream also decreases the potential for sediment capacity imbalance within the restored reach of Laughery Creek. Sediment capacity of natural channels is highly influenced by slope. While the dimension of stream channels can be designed to account for changes in slope, while maintaining sediment capacity and competence, these potential changes do have limits. Generally, the lower width to depth ratio channel dimensions which could accomplish this will require additional initial bank armoring to maintain the channel shape as part of the initial construction. This approach is both cost prohibitive and higher risk, overall.

Sediment samples taken upstream of the dam indicate that coarse sediment (large gravel and small cobble) constitutes a portion of the active bedload supply of Laughery Creek. Because of this, slope is also a critical consideration for competence of the restored channel. While the project approach uses natural channel evolution processes to do the majority of channel shaping work in the first several years following dam removal and restoration, a large variance from the wider system slope is more likely to create aggradation at slope breaks of the larger particles supplied by Laughery Creek.

Sediment coring and modeling completed as part of this 30% Design scope of services indicate that Laughery Creek can re-establish its historic profile within approximately one year of dam removal or full depth notching. This approach fits within IDNR stated project timeline goals, allowing Phase 2 restoration of the reservoir footprint to begin approximately 12-18 months after completion of Phase 1 dam notching and demolition.

4.4.2 Dimension

The geomorphic assessment described in Section 2.2 included measurement of two stable riffle cross sections and one pool cross section upstream of the backwater influence of the Versailles Lake Dam reservoir. These cross sections provide both an estimate of the bankfull or channel-forming discharge and a direct reference for the size and shape of stable channel which can be expected to form once free flowing conditions and sediment supply rates are returned to the reservoir footprint.

Removal of the dam represents a significant alteration of the hydraulic, sediment regime, and geomorphic processes in the dam footprint. Even without direct intervention, this would initiate a period of channel evolution as the “baseline” of the system dropped vertically and various stages of degradation and aggradation would initiate. The goal of the design, as presented in this report and in the 30% Drawings, is to provide a reasonable starting point for channel evolution. The design assumes a channel evolution process similar to the one displayed in Figure 20, with vertical “downcutting” or degradation initiated during Phase 1 of construction and continuing through the interim period between Phase 1 and Phase 2 of construction. Stantec anticipates that the project site will have completed vertical adjustment and have begun widening (CEM Stage III), with near-vertical banks, at the time of initiation of Phase 2 and mechanical management of sediment. The goal of Phase 2 of design is to utilize mechanical grading of sediment to advance channel evolution through the widening phase and subsequent floodplain re-formation phases (CEM Stages III and IV) and into the final, stable end phase.

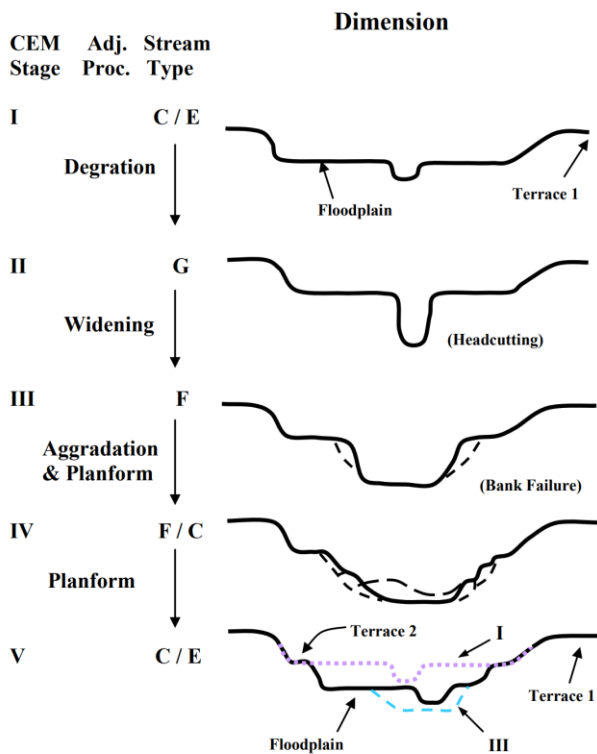


Figure 20 - Channel Evolution Model (Modified from Schumm, 1977 & 1984 and Thorne et al, 1997)

While exact channel dimension can be expected to be both variable and changing, especially as coarse sediment mobilizes and re-establishes natural substrate in the restored channel, the dimensional relationships identified upstream of the project site provide a reasonable starting point for channel restoration.

4.4.3 Pattern

While measurements of the pattern of Laughery Creek were taken upstream of the reservoir influence, this design approach approximates the pre-dam alignment of Laughery Creek rather than proposing a new planform. This design decision was driven by two main factors: the lack of a sinusoidal meander pattern observed upstream of the reservoir influence and the simpler construction logistics of reoccupying the pre-dam channel.

In some cases, low-gradient, alluvial, gravel bed streams form sinusoidal patterns with alternating riffle-pool sequences (Leopold and Wolman, 1957). Pools in these systems generally form as lateral meander pools and generally alternate the side of the channel in which they form as the stream meanders back and forth across its belt width or valley. While Laughery Creek does classify as a low-gradient, gravel dominant, unconfined stream channel type, it does not exhibit the characteristic meander pattern described above. Data and observations from field efforts did not find a definitive reason why this is the case, but the planform of the creek both above and below Versailles Lake does not provide a compelling reason to force a meandering pattern on the restored reach within the reservoir footprint (if the historic stream pattern is available as a template).

Documentation of the approximate pre-dam channel alignment is provided in the 1946 USGS Topographic Quadrangle Map. This topography, representing a condition approximately 10 years before damming of Laughery Creek and filling of Versailles Lake, provides a reasonable template for this design. Because no topographic alteration of the valley (now lake bottom) is apparent in dam construction documents, previous sediment studies, and bathymetry collected as part of the Feasibility Study effort, the bed substrates, stream banks, and floodplains present at the time of dam construction are likely still present. The excavation of fine-grained reservoir sediment will be easier for construction crews, and the risk of encountering debris such as tree roots, stumps, or man-made structures is much lower if channel shaping is focused mainly within the pre-dam stream.

The pattern of the proposed stream channel does divert from the pre-dam planform in a few, strategic locations. These areas of pattern divergence are mostly located in reaches where natural lateral channel migration can be used to complete re-occupation of the pre-dam alignment without creating unnatural vertical valley walls.

Stream reaches near STA 45+00 and between STA 75+00 and 90+00 are both located in areas where the pre-dam alignment appears to have been near the edge of the valley. The geomorphic data collection effort noted several locations where Laughery Creek reached the edge of its valley and, generally, it encountered limestone bedrock. Rather than actively grading the channel and adjacent valley wall, this design approach allows the stream to laterally migrate to the edge of the valley and re-establish the steep bluff valley walls which are shown in the pre-dam 1946 topography.

The stream reach between approximately 35+00 and 42+00 is a single, long bend. While these bends are not uncommon in free-flowing reaches of Laughery Creek, the stable radius of this bend is unknown. The current design “cuts off” the bend, creating a channel section with a higher radius of curvature. This bend may erode to reoccupy its historic alignment, but the proposed geometry provides a potentially more stable form that may transport sediment more efficiently.

4.5 Revegetation

The revegetation plan for the site has a different goal for each of the two Phases. Initially, establishment of vegetation will be important to inhibit the establishment of invasive species. After Phase 2 of work is completed, the establishment of a diverse, native plant community becomes more important.

Temporary Vegetation Cover (Phase 1 and Interim Period)

Establishment of vegetation after reservoir dewatering serves an important role in preventing germination of invasive species which may be present in the reservoir bottom seed bank. Invasive plant species tend to thrive in recently disturbed soils, and vegetation which germinates in the interim period between Phase 1 and Phase 2 of active construction could contribute to the seed bank making long-term control of invasive vegetation at the site more difficult.

The proposed, temporary cover crop will likely need to be aerial broadcast seeded due to the difficult access conditions. The temporary cover crop consists of an annual cereal grain (in this instance, winter wheat – *Triticum aestivum*, and several, native grass/sedge/rush species. The cover crop will germinate quickly, providing initial vegetative cover, while the native species will germinate and establish later in the growing season. The native species mix was chosen for its ability to colonize a spectrum of hydrologic conditions from wetlands to uplands.

Permanent Seeding (Phase 2)

A permanent seed mix which contains a diversity of grasses, sedges, rushes, and forbs will be placed after completion of Phase 2 of construction. This seed mix will be designed to provide long-term stability and a diverse vegetation community. Currently, it is assumed that one seed mix will be sufficient for the entire project area, but depending on future design phases, it may become necessary to specify more than one mix to match the hydrologic conditions of the post-construction site.

4.6 Estimated Implementation Cost

Stantec has prepared an Opinion of Probable Construction Cost (OPCC) and an estimate of costs associated with permitting, design, analysis, and construction phase services to advance the project through final design and implementation. Stantec estimates that professional services and construction costs will be approximately \$15,800,000 and \$18,700,000.

Opinion of Probable Construction Cost

The OPCC was developed using costs from similar projects and accounting for the difficult working conditions within the reservoir footprint. Due to the preliminary level of design, a range of costs (+/- 10%)

were developed for this report. The project, as designed, is estimated to have a construction cost of between \$14.9 million and \$17.8 million in 2026 dollars. The eventual cost of project construction will depend on the year in which construction begins, and changes made during future phases of design.

Design, Permitting, Analysis, and Construction Phase Professional Services

Stantec has prepared an approximate estimate of professional services through completion of the project construction. This cost was driven by the design and analysis needs to develop construction drawings, but also the complexity of the project as relates to permitting and agency coordination. This estimate should be viewed as a conservative budget, assuming a maximum permitting effort. Construction phase services have also been conservatively estimated to cover bidding assistance, availability for addressing contractor questions and field condition required design adjustments.

Stantec estimates that design, permitting, analysis, and construction phase services through the end of project construction will be approximately \$850,000. Permitting, agency coordination, and field investigations related to permitting represent approximately \$350,000 of this total budget and construction phase services represent approximately \$100,000.

5 Recommended Design Analysis and Data Collection as Part of Future Design Phases

While the analyses, field assessments, and design processes described in this BODR are appropriate for a 30% design stage, Stantec recommends further analyses and field data collection to further inform design and potentially identify means of more efficiently implementing the project.

Coarse Sediment Modeling and Channel Evolution Analysis

The 30% design scope included assessment of reservoir sediment response to dam removal but focused heavily on the response of the fine-grained sediments located in the lower reservoir. Further analysis may be required to fully understand the channel evolution process within coarse sediments, or the “delta”, located in the narrower upper reservoir. The design approach assumes that natural adjustment of the deltaic deposits can be expected, but direct intervention through mechanical grading of sediment or installation of in-stream structures is not necessary. This additional analysis will likely take the form of development and iterative modification of a 2D HEC-RAS model.

Stantec is planning to collect additional bathymetric data in the upper reservoir upstream of the proposed work limits but has been delayed due to inclement weather. These additional data will provide further knowledge of the channel geometry upstream of the proposed work limits and, therefore, a better understanding of the coarse sediment load which will migrate through the project area in the first few years after dam removal.

Coarse sediment represents the highest risk to downstream aggradation and increased channel changes/erosion. Aggradation and lateral adjustment pose risks to both biological communities and to existing infrastructure or property. While maintaining the stilling basin below the concrete spillway during the interim period between Phase 1 and Phase 2 of construction will provide a sediment trap by capturing some

of the gravel and sand which may mobilize during construction, it's possible that additional work upstream of the current work limits may be necessary to further "control" movement of coarse sediment through the project site during construction.

Additional Sediment Management Options

While riverine transport and mechanical grading are expected to be sufficient for management of impounded sediments, there may be additional measures which can be taken to decrease the cost of sediment management and site restoration. These measures may also eliminate or decrease the number or magnitude of unknowns still remaining in the project approach.

These additional options may include use of the low-level outlet or hydraulic dredging to periodically release sediment before the initiation of Phase 1 of construction. Assisted sediment evacuation, using placed structures (e.g. rock or wood) or by using construction equipment, immediately after Phase 1 is also an option. Assisted sediment evacuation was used on priority tributary streams during the Klamath Dam Removals in California.

Assessment of Risk to Offsite Infrastructure

Stantec completed a preliminary desktop review of downstream infrastructure which may be impacted (temporarily or permanently) by the removal of the dam. Initial assessment utilized readily available documentation of drinking water infrastructure and aerial imagery only, no field verification or other direct coordination with communities or utility owners was completed at this stage.

Research suggests that no communities downstream of the Versailles Lake Dam source water from Laughery Creek. A desktop assessment completed as part of this scope of services also found that documentation available through public data suggests that private wells are unlikely to be impacted by dam removal. Further design development however, should "... address potential data gaps outreach to property owners, particularly those with properties located within the alluvial flood plain, is recommended. Property owner outreach should include verification of well depth, screen interval, and current usage status.

Lower Laughery Creek is backwatered by the Markland Dam on the Ohio River. This allows the lower creek to be used for recreational boating and has resulted in the development of several marinas and many apparent private docks (Figure 1Figure 21). Fine sediment may accumulate at the margins of the channel near private docks or at the mouth of the two marinas located in lower Laughery Creek. A more detailed assessment of potential impacts or a plan for mitigation of impacts is recommended for future design phases.



Figure 21. Recreational Boating Infrastructure Locations

The Ohio River is an important navigational waterway, and Laughery Creek is considered a Section 10 navigable waterway for its lowest 10.2 miles by the U.S. Army Corps of Engineers. Impacts to both waters, though indirect because of sediment mobilization from the dam removal, should be considered. A review of navigational maps for the Ohio River does not suggest that any fleeting locations are located at or immediately downstream of the mouth of Laughery Creek.

Design Considerations for Future Park Use

This design effort focused entirely on the decommissioning of the dam, management of impounded sediment, and restoration of Laughery Creek's valley and channel. Future use of the reservoir footprint for park amenities was not a consideration of this design effort.

Preliminary Work – Regulatory Approvals

Stantec recommends early coordination with permitting agencies and regulatory decision-makers. These agencies include, but are not limited to, IDEM, USACE, USFWS, the Indiana State Historic Preservation Office, IDNR, and local floodplain administrators. This early coordination will familiarize permitting staff with the project, allow for open lines of communication in advance of permit submission, and allow IDNR and Stantec to seek guidance related to the permit process. This may allow for elimination of unknowns related to the permitting approach as well.

Potential Funding Sources

The project approach, which restores natural flow conditions to Laughery Creek and removes a significant aquatic organism migration barrier, fits well with multiple grant programs. The project may also be able to utilize the State of Indiana's In-Lieu Fee (ILF) Mitigation Program's funding for stream mitigation credits. Reaches of Laughery Creek and its tributaries which are returned to free-flowing conditions through removal of the dam can generate mitigation credits.

Floodplain Impacts

While the dam is a run-of-river structure which was not constructed for flood control purposes, removal of the dam will require floodplain permitting.

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Appendix A Sediment Evaluation Report

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Appendix B Geomorphic Assessment Report

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Appendix C eDNA Survey Report

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Appendix D Versailles Groundwater Well Desktop Assessment

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Appendix E 30% Construction Drawings

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